UPDATED TMDL PROGRESS REPORT

Pajaro River Basin:

River Basin Setting, Water Quality Standards, Preliminary Water Quality Data Analysis, & Preliminary Source Analysis

Updated TMDL Progress Report

to support

Development of Total Maximum Daily Loads

For Nutrients in Streams of the Pajaro River Basin

December 2014

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Updated TMDL Progress Report

December 2014

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1 PREFACE

The purpose of this updated progress report is to present information on the river basin setting, water quality standards, preliminary nutrient water quality data analysis and preliminary nutrient source analysis for streams of the Pajaro River basin. Central Coast Regional Water Quality Control Board (Central Coast Water Board) staff developed this information to support the development of nutrient total maximum daily loads (TMDLs) for streams of the river basin. Data and information in this document are a draft work in progress, and thus information and narrative contained herein are subject to revision or change.

2 INTRODUCTION

Section 303(d) of the federal Clean Water Act requires every state to evaluate its waterbodies, and maintain a list of waters that are considered "impaired" either because the water exceeds water quality standards or does not achieve its designated use. For each water on the Central Coast's "303(d) Impaired Waters List", the Central Coast Water Board must develop and implement a plan to reduce pollutants so that the waterbody is no longer impaired and can be de-listed. Section 303(d) of the Clean Water Act states:

> *Each State shall establish for the waters identified in paragraph (1)(A) of this subsection, and in accordance with the priority ranking, the total maximum daily load for those pollutants which the Administrator identifies under section 1314(a)(2) of this title as suitable for such calculation. Such load shall be established at a level necessary to implement the applicable water quality standards with seasonal variations and a margin of safety that takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality.*

The State complies with this requirement by periodically assessing the conditions of the rivers, lakes and bays and identifying them as "impaired" if they do not meet water quality standards. These waters, and the pollutant or condition causing the impairment, are placed on the 303(d) List of Impaired Waters referred to hereafter as the "303(d) List". In addition to creating this list of waterbodies not meeting water quality standards, the Clean Water Act mandates each state to develop TMDLs for each waterbody listed. Simply put, TMDLs are strategies or plans to address and rectify impaired waters identified on 303(d) list. The Central Coast Water Board is the agency responsible for developing TMDLs and programs of implementation for waterbodies identified as not meeting water quality objectives pursuant to Clean Water Act Section 303(d) and in accordance with the Porter-Cologne Water Quality Control Act §13242.

2.1 Pollutants Addressed & Their Environmental Impacts

The pollutants addressed in this TMDL are nitrate, low dissolved oxygen, and chlorophyll *a*. In addition, to protect waters from biostimulatory substances, orthophosphate is included as a pollutant. Nitrate pollution of both surface waters and groundwater has long been recognized as a problem in parts of the Pajaro River basin. While nitrogen fertilizer inputs are essential for maintaining the economic viability of agriculture worldwide, elevated levels of nitrate can degrade municipal and domestic water supply, groundwater, and also can impair freshwater aquatic habitat. Some streams in the Pajaro River basin frequently have exceeded the water quality objective for nitrate in drinking water. The streams therefore do not support designated drinking water supply (MUN) beneficial uses and may be impaired for designated groundwater recharge (GWR) beneficial uses[1]. The Water Quality Control Plan for the Central Coastal Region – 2011 version (Basin Plan) explicitly requires that the designated GWR beneficial use of streams be maintained, in part, to protect the water quality of the underlying

[1] "Beneficial uses" is a regulatory term which refers to the legally-protected current, potential, or future designated uses of the waterbody. The Water Board is required by law to protect all designated beneficial uses.

groundwater resources[2]. It is widely recognized by scientists and resource professionals that there is a critical need to continue to improve best management practices to reduce nitrogen releases to the environment from human activities, while maintaining the economic viability of farming operations (for example, see Shaffer and Delgado, 2002).

Regarding nitrate-related health concerns, it has been well-established that infants less than six months old who are fed formula made with water containing nitrate in excess of the U.S. Environmental Protection Agency (USEPA) safe drinking water standard (i.e., 10 milligrams of nitrate as N per liter) are at risk of becoming seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue baby syndrome, also known as methemoglobinemia.[3] High nitrate levels may also affect the oxygen-carrying ability of the blood of pregnant women[4]. There is some evidence to suggest that exposure to nitrate in drinking water is associated with adverse reproductive outcomes such as intrauterine growth retardations and various birth defects such as anencephaly; however, the evidence is inconsistent (Manassaram et al., 2006). Additionally, some public health concerns have been raised about the linkage between nitrate and cancer. Some peer-reviewed epidemiological studies have suggested elevated nitrate in drinking water may be associated with elevated cancer risk (for example, Ward et al. 2010); however currently there is no strong evidence linking higher risk of cancer in humans to elevated nitrate in drinking water. Further research is recommended by scientists to confirm or refute the linkage between nitrates in drinking water supply and cancer.

Another water quality impairment addressed in this TMDL that is associated with nutrients is biostimulation. Biostimulation can result in eutrophication of the waterbody. While nutrients - specifically nitrogen and phosphorus – are essential for plant growth, and are ubiquitous in the environment, they are considered pollutants when they occur at levels that have adverse impacts on water quality; for example, when they cause toxicity or eutrophication. Eutrophication is the excessive and undesirable growth of algae and aquatic plants that may be caused by excessive levels of nutrients. Eutrophication effects typically occur at somewhat lower nutrient concentrations than toxic effects. Either of these modes of water quality impairment can affect the entire aquatic food web, from algae and other microscopic organisms, through benthic macroinvertebrates (principally aquatic insect larvae), through fish, to the mammals and birds at the top of the food web.

In addition to detrimental impacts to aquatic habitat, algal blooms resulting from biostimulation may also constitute a potential health risk and public nuisance to humans, their pets, and to livestock. The majority of freshwater harmful algal blooms reported in the United States and worldwide is due to one group of algae, cyanobacteria (blue-green algae), although other groups of algae can be harmful (Worcester and Taberski, 2012). Possible health effects of exposure to blue-green algae blooms and their toxins can include rashes, skin and eye irritation, allergic reactions, gastrointestinal upset, and other effects[5]. At high levels, exposure can result serious illness or death. These effects are not theoretical; worldwide animal poisonings and adverse human health effects have been reported by the World Health Organization (WHO, 1999). The California Department of Public Health and various County Health Departments have documented cases of dog die-offs throughout the state and the nation due to blue-green algae. Dogs can die when their owners allow them to swim or wade in waterbodies with algal blooms. Dogs are also attracted to fermenting mats of cyanobacteria near shorelines of waterbodies (Carmichael, 2011). Dogs reportedly die due to ingestion associated with licking algae and associated toxins from their coats. Additionally, according to recent findings, algal toxins have been implicated in the deaths of central California southern sea otters (Miller et al., 2010). Currently, there reportedly have been no confirmations of human deaths in the U.S. from exposure to algal toxins, however many people have become ill from exposure, and acute human poisoning is a distinct risk (Dr. Wayne Carmichael of the Wright State University-Department of Biological Sciences, as reported in NBC News, 2009).

[2] See Basin Plan, Chapter 2 Beneficial Use Definitions, page II-19
[3] USEPA: http://water.epa.gov/drink/contaminants/basicinformation/nitrate.cfm
[4] California Department of Public Health www.cdph.ca.gov/certlic/drinkingwater/Pages/Nitrate.aspx
[5] California Department of Public Health website, http://www.cdph.ca.gov

Also noteworthy is that TMDL development intended to address nitrate pollution risks to human health and address degradation of aquatic habitat is consistent with the Central Coast Water Board's highest identified priorities. The Central Coast Water Board's two highest priority areas[6] (listed in priority order) are presented below:

> Central Coast Water Board Top Two Priorities (July 2012)
>
> 1) "Preventing and Correcting Threats to Human Health"
>   - ✓ *Nitrate contamination is by far the most widespread threat to human health in the central coast region*
> 2) "Preventing and Correcting Degradation of Aquatic Habitat"
>   - ✓ *"Including requirements for aquatic habitat protection in Total Maximum Daily Load Orders"*

The USEPA recently reported that nitrogen and phosphorus pollution, and the associated degradation of drinking and environmental water quality, has the potential to become one of the costliest and most challenging environmental problems the nation faces[7]. Over half of the nation's streams, including some steams in the Pajaro River basin, have medium to high levels of nitrogen and phosphorus. According to USEPA, nitrate drinking water standard violations have doubled nationwide in eight years, and algal blooms, resulting from the biostimulatory effects of nutrients, are steadily on the rise nationwide; related toxins have potentially serious health and ecological effects[8]. Water quality monitoring in the Pajaro River basin has widely demonstrated that water resources in the river basin have locally been substantially impacted by nitrate. Placeholder text: Biostimulation of surface waters in the Pajaro River basin are documented in this report; these water quality impairments may also be contributing to localized, episodic adverse downstream impacts to ecologically sensitive coastal and estuarine areas of the Monterey Bay National Marine Sanctuary, as demonstrated by marine researchers and the peer-reviewed scientific literature (refer to report Section 3.13).

2.2 Updating & Replacement of the 2005 Pajaro River Nitrate TMDL

Upon approval by the Office of Administration Law, these TMDLs supersede and replace the TMDL *entitled "Pajaro River and Llagas Creek Total Maximum Daily Load for Nitrate"* which was approved by Resolution No. R3-2005-0131 on December 2, 2005 by California Regional Water Quality Control Board Central Coast Region, and subsequently approved by the U.S. Environmental Protection Agency on October 13, 2006. The 2005 Pajaro River nitrate TMDL addressed only nitrate surface water impairments for the drinking water supply beneficial use (MUN); the current TMDLs will update and supersede the 2005 nitrate TMDL by addressing nutrient-related impairments to all relevant designated beneficial uses of streams in the Pajaro River basin.

2.3 A Note on Spatial Datasets & Scientific Certainty

Central Coast Water Board staff endeavored to use the best available spatial datasets from reputable scientific and public agency sources to render and assess physical, hydrologic, and biologic conditions in the TMDL project area. Spatial data of these types are routinely used in TMDL development and watershed studies nationwide. Where appropriate, staff endeavored to clearly label spatial data and literature-derived values as estimates in this TMDL progress report, and identify source data and any assumptions. It is important to recognize that the nature of public agency data and digital spatial data provide snapshots of conditions at the time the data was compiled, or are regionally-scaled and are not intended to always faithfully and accurately render all local, real-time, or site-specific conditions. When

[6] See Staff Report (agenda item 3) for the July 11, 2012 Water Board meeting.

[7] USEPA: Memorandum from Acting Assistant Administrator Nancy K. Stoner. March 16, 2011. Subject: "Working in Partnership with States to Address Phosphorus and Nitrogen Pollution through Use of a Framework for State Nutrient Reductions".

[8] *Ibid*

reviewing TMDLs, the USEPA will recognize these types of datasets as estimates, approximations, and scoping assessments. As appropriate, closer assessments of site specific conditions and higher resolution information about localized pollution problems would be conducted during TMDL implementation.

Also noteworthy is that while science is one cornerstone of the TMDL program, a search for full scientific certainty and a resolution of all uncertainties is not contemplated or required in TMDLs adopted in accordance with the Clean Water Act, and pursuant to U.S. Environmental Agency (USEPA) guidance. Staff endeavored to identify uncertainties in the TMDL, and reduce uncertainties where possible on the basis of available data. It should be recognized that from the water quality risk management perspective, scientific certainty is balanced by decision makers against the necessities of addressing risk management. Conceptually, this issue is highlighted by reporting from the U.S. National Research Council as shown below:

> *"**Scientific uncertainty is a reality within all water quality programs, including the TMDL program that cannot be entirely eliminated.** The states and EPA should move forward with decision-making and implementation of the TMDL program in the face of this uncertainty while making substantial efforts to reduce uncertainty. Securing designated uses is limited not only by a focus on administrative rather than water quality outcomes in the TMDL process, but also by unreasonable expectations for predictive certainty among regulators, affected sources, and stakeholders… Although science should be one cornerstone of the program, an unwarranted search for scientific certainty is detrimental to the water quality management needs of the nation. Recognition of uncertainty and creative ways to make decisions under such uncertainty should be built into water quality management policy."*
>
> *From: National Academy of Sciences – National Research Council (2001)*
>
> *Report issued pursuant to a request from the U.S. Congress to assess the scientific basis of the TMDL program: National Research Council, 2001. "Assessing the TMDL Approach to Water Quality Management – Committee to Assess the Scientific Basis of the Total Maximum Daily Load Approach to Water Pollution Reduction, Water Science and Technology Board"*
>
> *(Emphasis not added – emphasis as published in the original National Research Council report)*

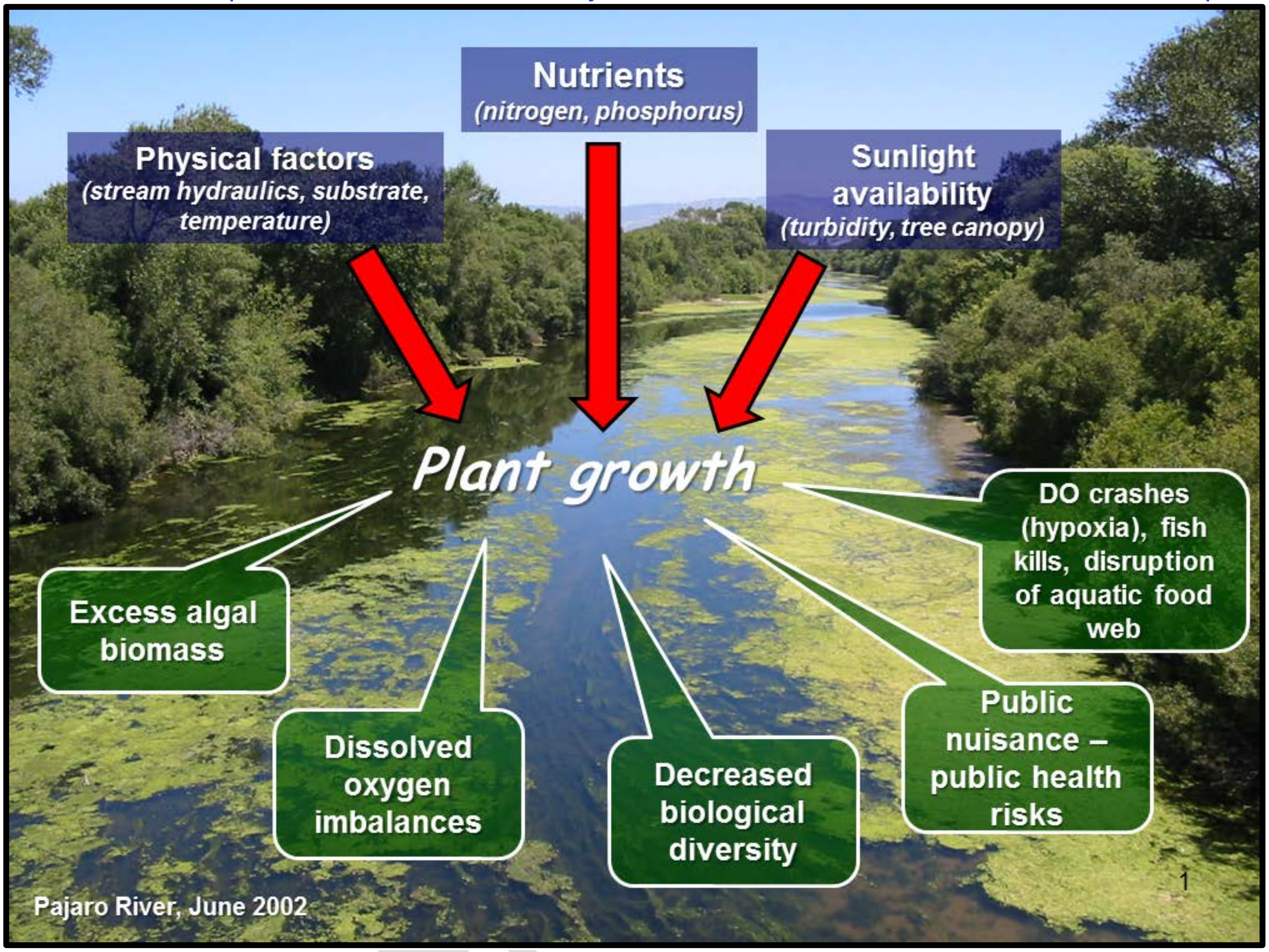
3 RIVER BASIN SETTING

3.1 Informational Background

This section of this report presents substantial amounts of information on the river basin setting for this TMDL project. Understanding and assessing variation in river basin characteristics is important to the development of water quality criteria for nutrients. Human activities can result in discharge of nutrients (specifically nitrogen and phosphorus) to waterbodies, but nutrients are also naturally present and ubiquitous in the environment.

It is important to recognize that documenting high nitrogen and phosphorus concentrations is not sufficient in and of itself to demonstrate a risk of eutrophication. Research has demonstrated the shortcomings of using ambient nutrient concentrations within a waterbody alone to predict eutrophication, particularly in streams (Tetra Tech, 2006). Tetra Tech (2006) notes that except in extreme cases, nutrients alone do not impair beneficial uses. Rather, they cause indirect impacts through algal growth, low dissolved oxygen, etc., that impair uses. These impacts are associated with nutrients, but result from a combination of nutrients interacting with other physical and biological factors. Other factors that can combine with nutrient enrichment to contribute to biostimulatory effects include light availability (shading and tree canopy), stream hydraulics, geomorphology, geology, and other physical and biological attributes (see Figure 3-1).

Figure 3-1. Biostimulation (excessive aquatic plant growth) can result from a combination of contributing factors – the consequences of biostimulation may include a cascade of adverse environmental impacts.



As such, nutrient criteria need to be developed to account for natural variation existing at the regional and/or watershed-scale. To reiterate: nutrient water column concentration data by itself is generally not sufficient to evaluate biostimulatory conditions and develop numeric nutrient criteria. Waterbodies in the TMDL project area have substantial variation in stream hydraulics, stream morphology, tree canopy and other factors. Accordingly, this section of the TMDL progress report presents information on relevant physical and biological watershed characteristics for the TMDL project area that can potentially be important to consider with regard to development of nutrient criteria.

Therefore, staff endeavored to characterize the river basin as fully as possible both to assist in development of defensible nutrient water quality criteria (where needed) and to assess natural inputs of nutrients in the watershed. The information and data on watershed conditions are presented in this section of the project report.

3.2 TMDL Project Area & Watershed Delineation

The geographic scope of this TMDL project[9] encompasses approximately 1,300 square miles of the Pajaro River basin located in parts of Santa Clara, Santa Cruz, San Benito, and Monterey counties (see Figure 3-2). The Pajaro River mainstem begins just west of San Felipe Lake (also called Upper Soda Lake) approximately 5 miles east-southeast of the city of Gilroy. From there, the Pajaro River flows west

[9] In the context of this report, the terms "TMDL project area" and "Pajaro River Basin" are used interchangeably and refer to the same geographic area.

for 30 miles through south Santa Clara Valley, through the Chittenden Gap, past the city of Watsonville, and ultimately forming an estuary/lagoon system at the river mouth at the coastal confluence with Monterey Bay. A sand bar forms across the mouth of the Pajaro River in many years, and thus direct discharge into Monterey Bay occurs only episodically when the sand bar is breached. Major tributaries of the Pajaro River include the San Benito River, Pacheco Creek, Llagas Creek, Uvas Creek, Watsonville Slough, and Corralitos Creek.

The human population of the Pajaro River basin is approximately 233,000 people, with an average of 3.22 people per housing unit according to 2010 Census Bureau data. Figure 3-3 presents an illustration of the spatial variation in the density of human population in the river basin. Agriculture, including livestock grazing lands and cultivated cropland, is the current dominant human land use in the river basin. Urbanized land use comprises 4% of the river basin's land area. Undeveloped lands, including grassland, shrubland and forest also comprise substantial parts of the upland reaches of the river basin within an ecosystem characterized locally by oak woodland, annual grasslands, montane hardwood, and coastal scrub (source: National Land Cover Dataset, 2006; Calif. Dept. of Forestry and Fire Protection, 1977).

Figure 3-2. TMDL Project area – the Pajaro River basin.

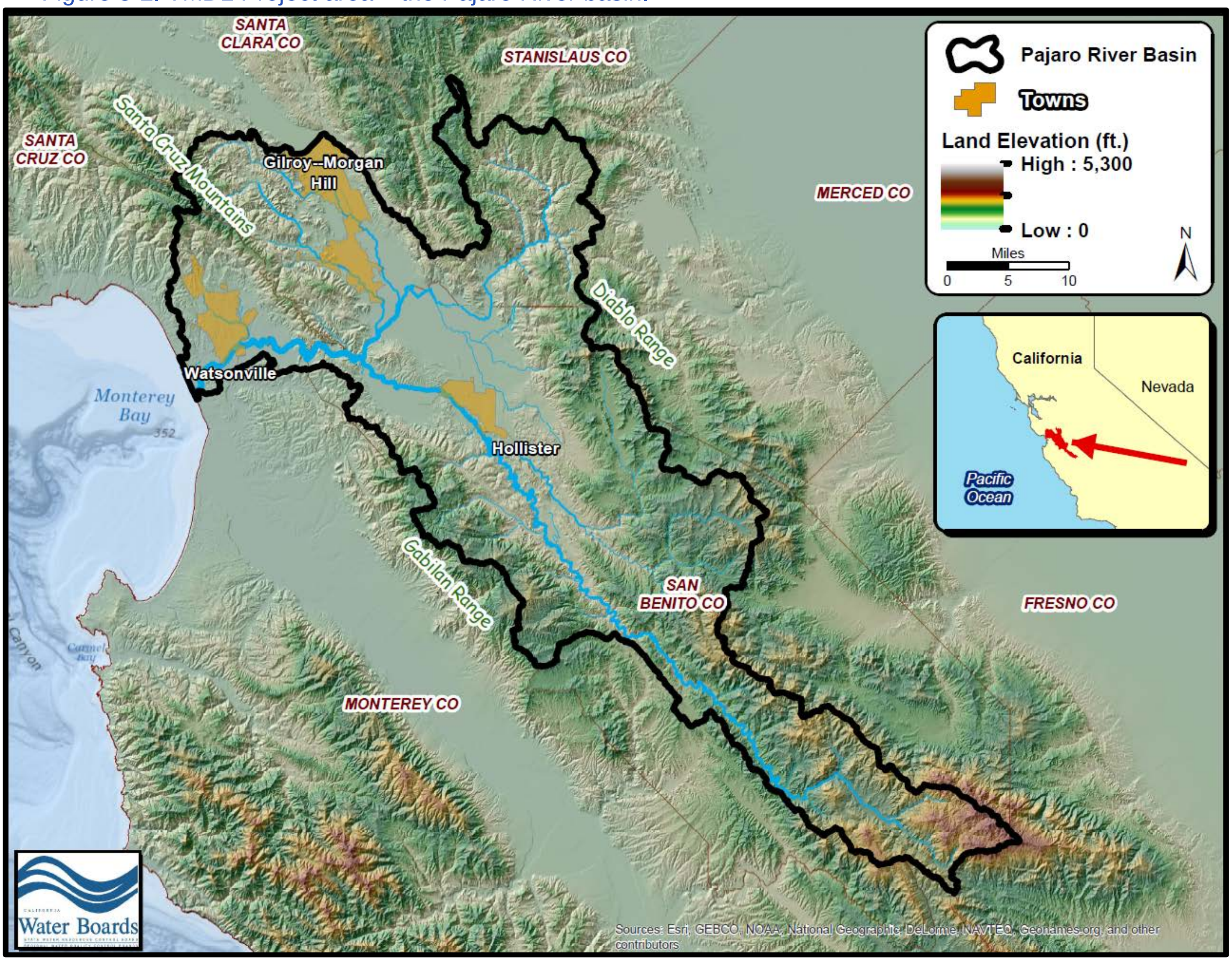
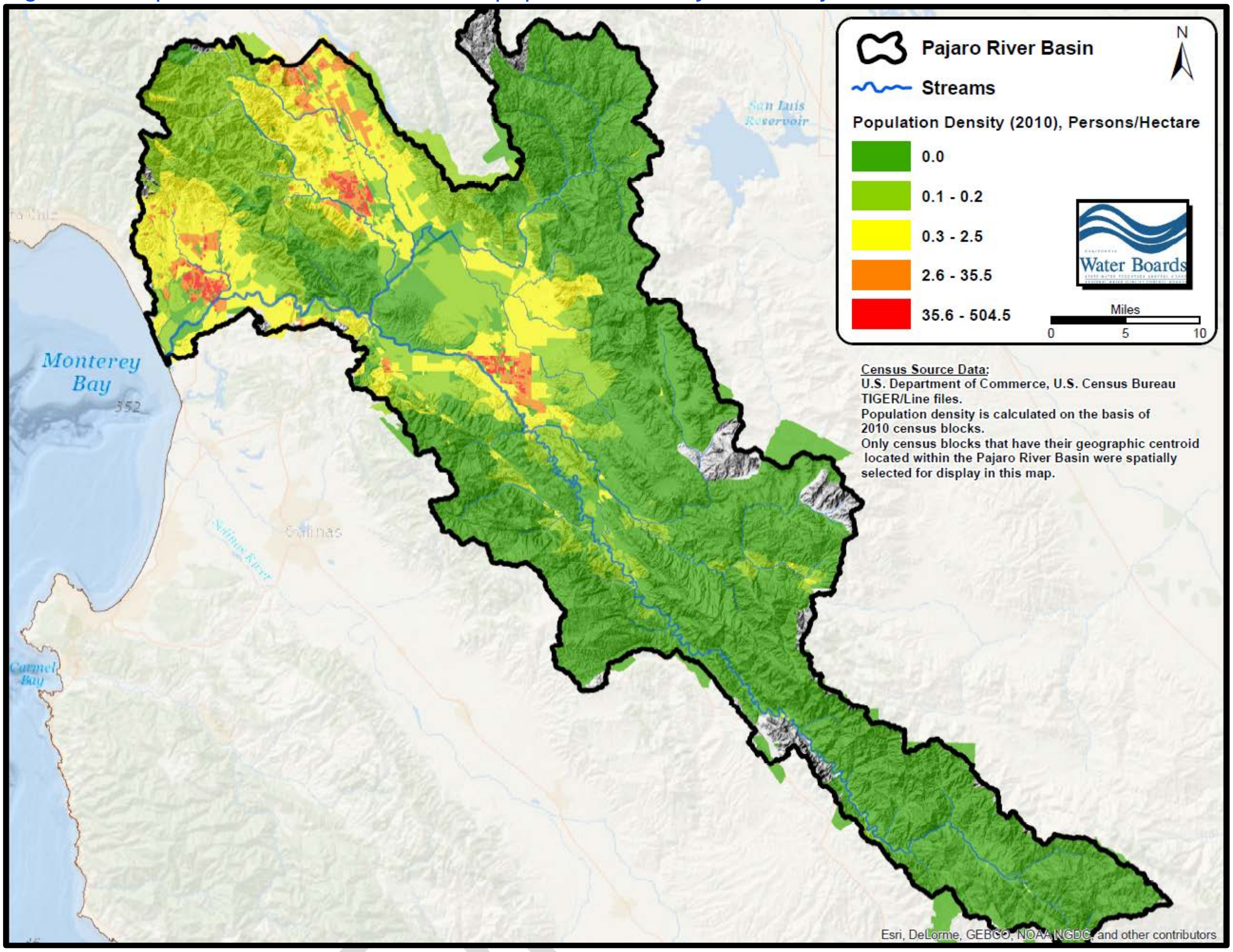


Figure 3-3. Spaital variation in the human population density in the Pajaro River basin.



ESRI™ ArcMap® 10.1 was used to create watershed layers for the TMDL project area. Drainage boundaries of the TMDL project area can be delineated on the basis of the Watershed Boundary Dataset[10], which contain digital hydrologic unit boundary layers organized on the basis of Hydrologic Unit Codes. Hydrologic Unit Codes (HUCs) were developed by the United States Geological Survey to identify all the drainage basins of the United States.

Watersheds range in all sizes, depending on how the drainage area of interest is spatially defined, if drainage areas are nested, and on the nature and focus of a particular hydrologic study. Watersheds can be characterized by a hierarchy as presented in Table 3-1.

Table 3-1. Watershed heirachy used in this TMDL project[A].

Hydrologic Unit	**Drainage Area mi^2 (approx.)**	**Example(s)**	**Spatial Data Reference (USGS Hydrologic Unit Code shapefiles)**
Basin	$\geq$ 1,000	Pajaro River basin	Watershed Boundary Dataset HUC-8 shapefiles

[10] The Watershed Boundary Dataset (WBD) is developed by federal agencies and national associations. WBD contains watershed boundaries that define the areal extent of surface water drainage to a downstream outlet. WBD watershed boundaries are determined solely upon science-based principles, not favoring any administrative boundaries.

Hydrologic Unit	Drainage Area mi^2 (approx.)	Example(s)	Spatial Data Reference (USGS Hydrologic Unit Code shapefiles)
Subbasin	> 250 to < 1,000	San Benito River Subbasin	2 or 3 HUC-10s [B] *(spatial dissolve)*
Watershed	~ 100 to ~ 250	Llagas Creek Watershed	Watershed Boundary Dataset HUC-10 shapefiles
Subwatershed	> 10 to < 100	Salsipuedes Creek Subwatershed	Watershed Boundary Dataset HUC-12 shapefiles
Catchment	~ 1 to < 10	Beach Road Ditch Catchment Tar Springs Creek Catchment	National Hydrography Dataset catchment shapefiles

[A] Based on adaptation from Jonathan Brant, PhD, and Gerald J. Kauffman, MPA, PE (2011) Water Resources and Environmental Depth Reference Manual for the Civil Professional Engineer Exam.
[B] This is approximately equivalent to "Hydrologic Area" in the CalWater 2.2 watershed convention, and is developed here to allow for distinct drainage areas that are smaller than a river basin, but larger than a United States Geological Survey (USGS) HUC-10 watershed.

The Pajaro River basin is delineated at the HUC-8 hydrologic unit scale (HUC 18060002). Individual watersheds at the HUC-10 hydrologic unit scale that are nested within the Pajaro River basin were delineated by digitally clipping HUC-10 watershed shapefiles using the Pajaro River basin shapefile as a mask. Based on HUC delineations, there are three distinct subbasins nested within the Pajaro River basin: the 1) Pajaro River Subbasin[11]; the 2) San Benito River Subbasin[12]; and the 3) Pacheco Creek Subbasin[13] (see Figure 3-4).

There are eight distinct watersheds, delineated at the HUC-10 scale, located within these three subbasins, as shown in Figure 3-4.

A total of 36 subwatersheds, delineated at the HUC-12 scale are nested with the Pajaro River basin (subwatersheds are shown in Figure 3-5).

A summary of the Pajaro River basin's watershed hierarchy is presented in Table 3-2.

[11] In the CalWater 2.2 watershed convention, this area corresponds approximately to the Watsonville, Santa Cruz Mountains, and South Santa Clara Valley hydrologic areas.

[12] In the CalWater 2.2 watershed convention, this area corresponds to the San Benito River hydrologic area.

[13] In the CalWater 2.2 watershed convention, this area corresponds approximately to the Pacheco-Santa Ana Creek hydrologic area.

Figure 3-4. Subbasins and watersheds nested within the Pajaro River basin.

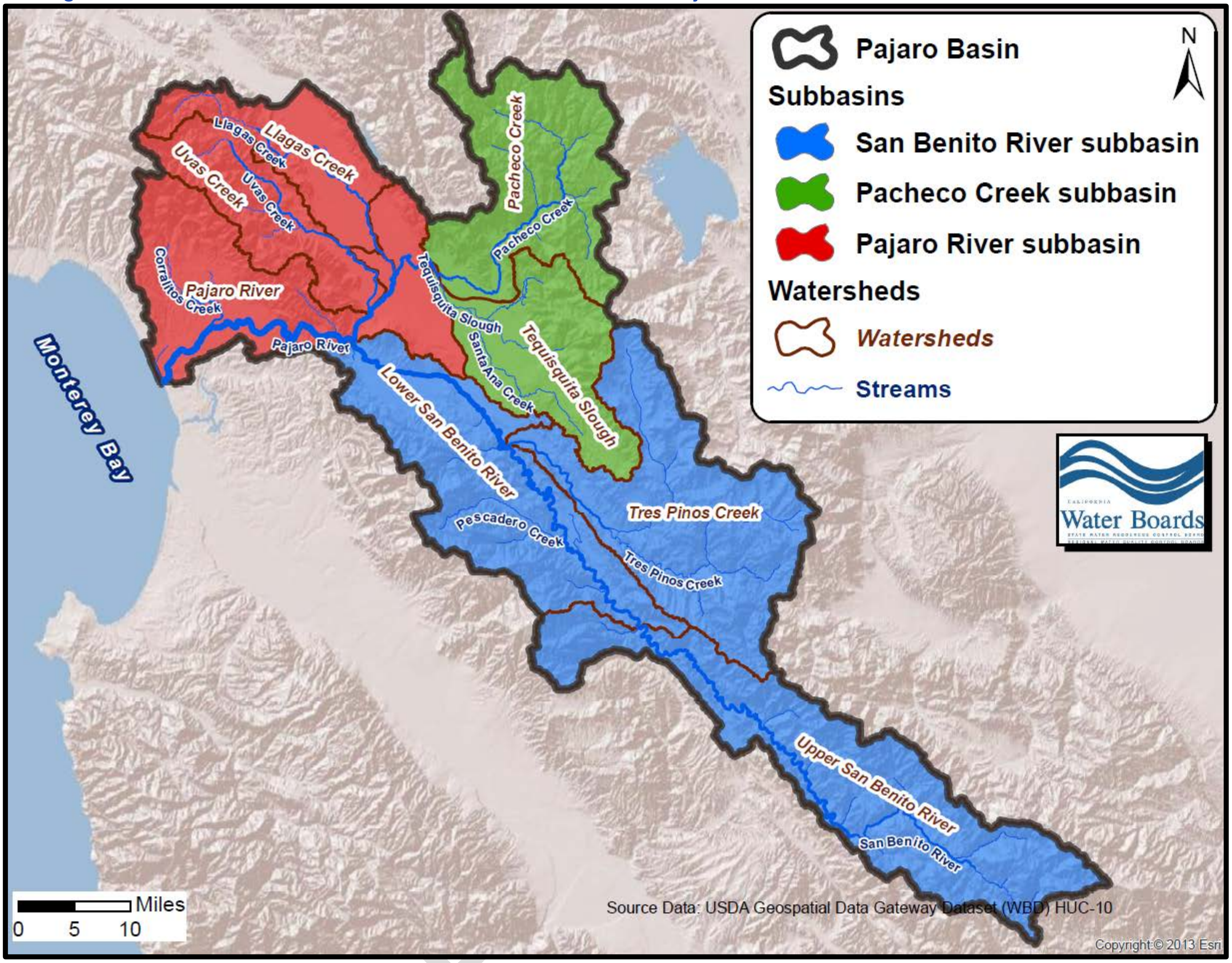


Table 3-2. TMDL watershed hierarchy (basins, subbasins, watersheds, and subwatersheds).

Name	Hydrologic Scale	Data Source (HUC)	Drainage Area (square miles)
Pajaro River basin	**Basin**	WBD 8-digit Hydrologic Unit Code *HUC # 18060004*	1,300.6
Pajaro River Subbasin[A]	**Subbasin** *within the Pajaro River basin*	Spatial dissolve on WBD 10-digit Hydrologic Unit Codes *1806000203* *1806000204* *1806000208*	355.6
San Benito River Subbasin[B]	**Subbasin** *within the Pajaro River basin*	Spatial dissolve on WBD 10-digit Hydrologic Unit Codes *1806000205* *1806000206* *1806000207*	660.8
Pacheco Creek Subbasin[C]	**Subbasin** *within the Pajaro River basin*	Spatial dissolve on WBD 10-digit Hydrologic Unit Codes *1806000201* *1806000202*	284.2

Name	Hydrologic Scale	Data Source (HUC)	Drainage Area (square miles)
Llagas Creek Watershed	**Watershed** *within the Pajaro River Subbasin*	WBD 10-digit Hydrologic Unit Code *HUC # 1806000203*	84.6
Pajaro River Watershed	**Watershed** *within the Pajaro River Subbasin*	WBD 10-digit Hydrologic Unit Code *HUC # 1806000208*	184.3
Uvas Creek Watershed	**Watershed** *within the Pajaro River Subbasin*	WBD 10-digit Hydrologic Unit Code *HUC # 1806000204*	86.7
Lower San Benito River Watershed	**Watershed** *within the San Benito River Subbasin*	WBD 10-digit Hydrologic Unit Code *HUC # 1806000207*	198.2
Upper San Benito River Watershed	**Watershed** *within the San Benito River Subbasin*	WBD 10-digit Hydrologic Unit Code *HUC # 1806000205*	243.2
Tres Pinos Creek Watershed	**Watershed** *within the San Benito River Subbasin*	WBD 10-digit Hydrologic Unit Code *HUC # 1806000206*	219.4
Pacheco Creek Watershed	**Watershed** *within the Pacheco Creek Subbasin*	WBD 10-digit Hydrologic Unit Code *HUC # 1806000202*	167.9
Tequisquita Slough Watershed	**Watershed** *within the Pacheco Creek Subbasin*	WBD 10-digit Hydrologic Unit Code *HUC # 1806000201*	116.3
Subwatersheds of the Pajaro River basin	**Subwatersheds**	WBD 12-digit Hydrologic Unit Codes See Figure 3-5 and Table 3-3 for subwatershed information	

[A] *In the CalWater 2.2 watershed convention, this subbasin corresponds approximately to the Watsonville, Santa Cruz Mountains, and South Santa Clara Valley hydrologic areas.*

[B] *In the CalWater 2.2 watershed convention, this subbasin corresponds to the San Benito River hydrologic area.*

[C] *In the CalWater 2.2 watershed convention, this subbasin corresponds to the Pacheco-Santa Ana Creek hydrologic area.*

Within each HUC-10 watershed, higher resolution subwatershed delineation of project area stream reaches and associated drainage areas were delineated on the basis of HUC-12 shapefiles. According to the Watershed Boundary Dataset's HUC-12 delineations, there are 36 distinct subwatersheds within the Pajaro River basin. Figure 3-5 illustrates the individual subwatersheds developed for the TMDL project area. Table 3-3 tabulates the names and the areal sizes of the subwatersheds. It should be noted that at high-resolution spatial scales (e.g., individual parcels), site-specific engineering, such as man-made water conveyance structures or grading, can result in parcel-scale drainage that runs counter to topographic elevation direction. Thus, the lower spatial resolution drainage patterns of watersheds and subwatershed delineations may not necessarily represent hydrologic drainage patterns at localized parcel and catchment scales.

Figure 3-5. Map of subwatersheds (HUC-12 delineations) with numeric identifiers located within the Pajaro River Basin. The subwatershed names with their associated numeric identifiers are tabulated in Table 3-3.

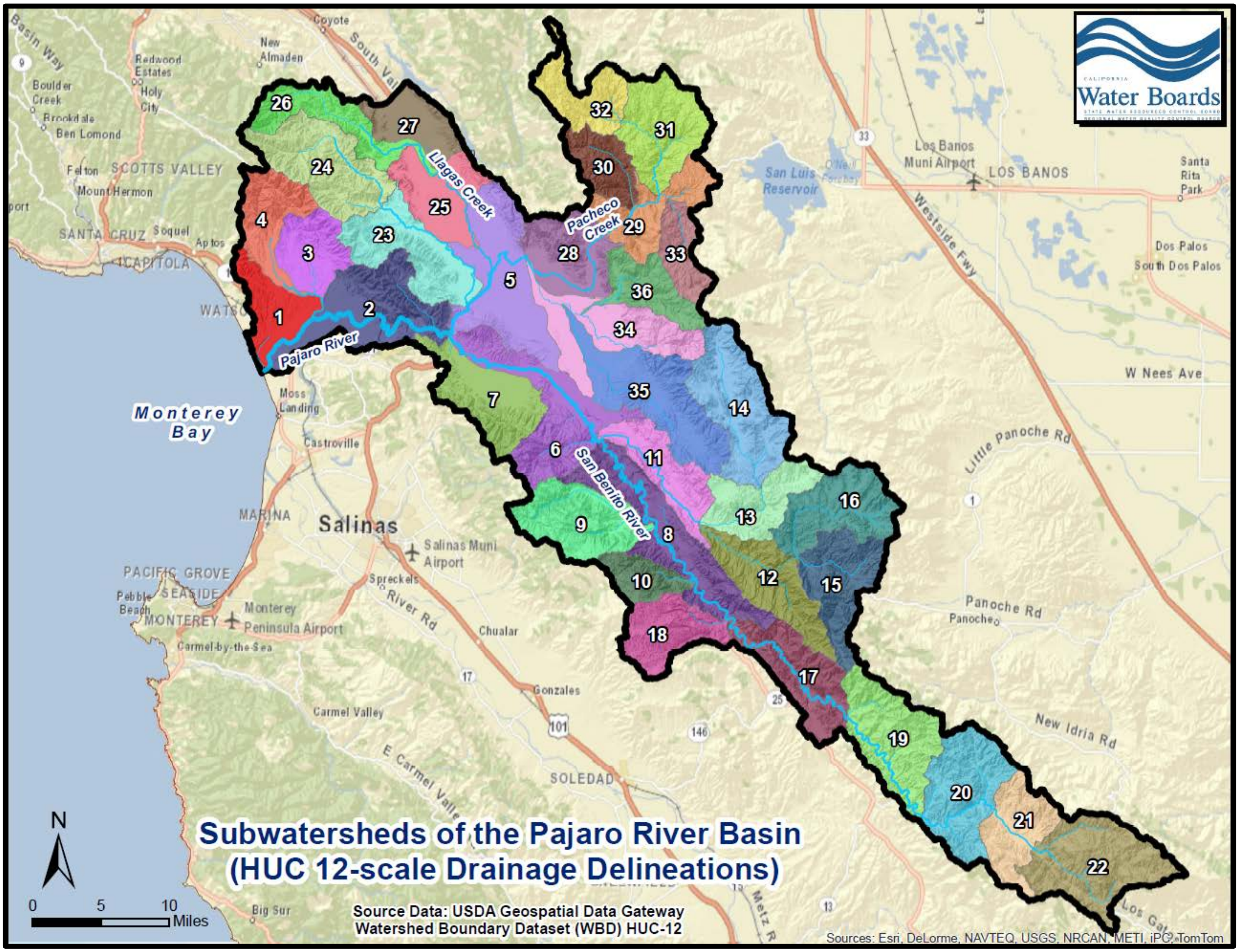


Table 3-3. Tabular summary of Pajaro River Basin subwatersheds as shown in Figure 3-5.

Subwatershed Numeric ID	Subwatershed (HUC 12) Name	U.S. Acres	Square Miles	Major Hydrologic Modification(s) [A]	The subwatershed is located within this watershed (HUC 10)
1	Watsonville Slough	15,551	24.3	Levee	Pajaro River Watershed
2	Lower Pajaro River	33,285	52.0	Levee	Pajaro River Watershed
3	Salsipuedes Creek	15,881	24.8	Levee	Pajaro River Watershed
4	Corralitos Creek	17,789	27.8	Levee	Pajaro River Watershed
5	Upper Pajaro River	35,467	55.4	Levee	Pajaro River Watershed
6	Bird Creek-San Benito River	32,742	51.2	No Modifications	Lower San Benito River Watershed
7	San Juan Canyon	24,415	38.1	No Modifications	Lower San Benito River Watershed
8	Paicines Reservoir-San Benito River	33,976	53.1	No Modifications	Lower San Benito River Watershed
9	Pescadero Creek	25,665	40.1	No Modifications	Lower San Benito River Watershed
10	Stone Creek	10,060	15.7	No Modifications	Lower San Benito River Watershed
11	Lower Tres Pinos Creek	17,851	27.9	Pipe Diversion	Tres Pinos Creek Watershed

Subwatershed Numeric ID	Subwatershed (HUC 12) Name	U.S. Acres	Square Miles	Major Hydrologic Modification(s) [A]	The subwatershed is located within this watershed (HUC 10)
12	Middle Tres Pinos Creek	22,997	35.9	Pipe Diversion	Tres Pinos Creek Watershed
13	Los Muertos Creek	18,928	29.6	Pipe Diversion	Tres Pinos Creek Watershed
14	Quien Sabe Creek	32,669	51.0	No Modifications	Tres Pinos Creek Watershed
15	Upper Tres Pinos Creek	23,240	36.3	Pipe Diversion	Tres Pinos Creek Watershed
16	Las Aguilas Creek	24,730	38.6	Pipe Diversion	Tres Pinos Creek Watershed
17	Sulphur Creek-San Benito River	24,174	37.8	No Modifications	Upper San Benito River Watershed
18	Willow Creek	18,585	29.0	No Modifications	Upper San Benito River Watershed
19	Rock Springs Creek-San Benito River	29,781	46.5	No Modifications	Upper San Benito River Watershed
20	James Creek-San Benito River	28,740	44.9	No Modifications	Upper San Benito River Watershed
21	Hernandez Reservoir-San Benito River	19,512	30.5	No Modifications	Upper San Benito River Watershed
22	Clear Creek-San Benito River	34,843	54.4	No Modifications	Upper San Benito River Watershed
23	Lower Uvas Creek	25,690	40.1	No Modifications	Uvas Creek Watershed
24	Upper Uvas Creek	29,823	46.6	No Modifications	Uvas Creek Watershed
25	Lower Llagas Creek	20,007	31.3	Levee	Llagas Creek Watershed
26	Upper Llagas Creek	18,737	29.3	Levee	Llagas Creek Watershed
27	Little Llagas Creek	15,392	24.1	Levee	Llagas Creek Watershed
28	Lower Pacheco Creek	21,986	34.4	Reservoir, General Canal	Pacheco Creek Watershed
29	Upper Pacheco Creek	18,334	28.6	Reservoir, General Canal	Pacheco Creek Watershed
30	Cedar Creek	12,766	19.9	No Modifications	Pacheco Creek Watershed
31	Lower North Fork Pacheco Creek	25,771	40.3	No Modifications	Pacheco Creek Watershed
32	Upper North Fork Pacheco Creek	17,079	26.7	No Modifications	Pacheco Creek Watershed
33	South Fork Pacheco Creek	11,518	18.0	No Modifications	Pacheco Creek Watershed
34	Tequisquita Slough	25,964	40.6	General Canal	Tequisquita Slough Watershed
35	Santa Ana Creek	33,717	52.7	No Modifications	Tequisquita Slough Watershed
36	Arroyo De Las Viboras	14,742	23.0	General Canal	Tequisquita Slough Watershed
Total		832,406	1,300.6		

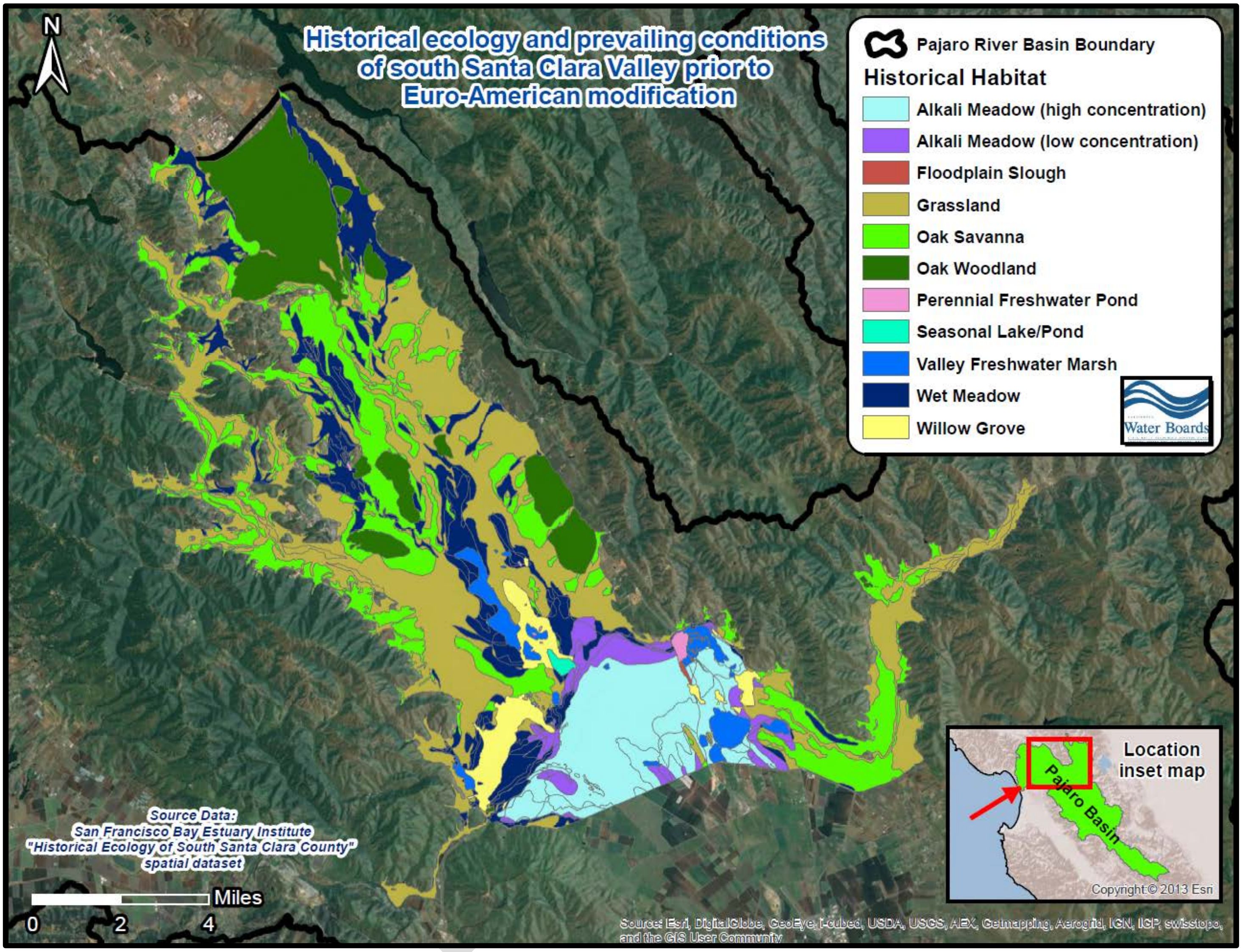
[A] This column identifies any type of man-made modification(s) to natural overland flow that alters the location of the hydrologic unit boundary for a HUC-12 subwatershed, on the basis of attribute data provided with the Watershed Boundary Dataset.

3.3 Land Use & Land Cover

Land use conditions play an important role in pollutant loading to water resources in any given watershed, thus evaluating land use and land cover is an important part of TMDL development. Historical land cover conditions in parts of the Pajaro River basin (south Santa Clara Valley), prior to Euro-American modification, are available as spatial datasets from the San Francisco Bay Estuary Institute[14] (see Figure 3-6). These datasets provide some insight into what land cover conditions were in historical lowland ecosystems of the Pajaro River basin prior to substantial human modification. The lowlands associated with the Santa Clara Valley in historic times were characterized predominantly by grasslands, oak savannah, oak woodlands, freshwater marshes, wet meadows, and alkali meadows. Also worth noting, 1917-vintage topographic maps of the southern Santa Clara Valley indicate there were still substantial areas of freshwater marshes in the vicinity of Gilroy and the lower Llagas Creek area at that time (U.S. Geological Survey, 1917a and 1917b).

[14] Source data – Robin Grossinger, San Francisco Estuary Institute. Title: *South Santa Clara Valley Historical Landscape*. This database contains several feature classes representing a reconstruction of the historical landscape and prevailing conditions of south Santa Clara Valley prior to Euro-American modification. This dataset integrates many sources of data describing the historical features of south Santa Clara Valley. Extensive supporting information, including bibliographic references and research methods, can be found in the south Santa Clara Valley report. Online linkage: http://gis.sfei.org/geofetch/catalog/search/search.page

Figure 3-6. Historical ecology and landscape conditions of the southern Santa Clara Valley prior to Euro-American modification.



Modern land use and land cover in the project area can be evaluated from digital data provided by the California Department of Conservation Farmland Mapping and Monitoring Program. The Farmland Mapping and Monitoring Program maps are updated every two years with the use of aerial photographs, a computer mapping system, public review, and field reconnaissance. For this TMDL progress report, the 2010 Farmland Mapping and Monitoring Program mapping data was used. Table 3-4 presents the Farmland Mapping and Monitoring land use–land cover categories as defined by the Department of Conservation.

Table 3-4. Land use-land cover categories used in this Progress Report and as defined by the California Dept. of Conservation Farmland Mapping and Monitoring Program.

Land Use / Land Cover	Description (with alphabetic code) as defined by Farmland Mapping and Monitoring Program [A]
Farmland	*The aggregate category "Farmland" used in this TMDL progress report includes several categories defined by the Farmland Mapping and Monitoring Program, as shown below:* Prime Farmland (P): Irrigated land with the best combination of physical and chemical features able to sustain long-term production of agricultural crops. This land has the soil quality, growing season, and moisture supply needed to produce sustained high yields. Land must have been used for production of irrigated crops at some time during the four years prior to the mapping date. Farmland of Statewide Importance (S): Irrigated land similar to Prime Farmland that has a good combination of physical and chemical characteristics for the production of agricultural crops. This land has minor shortcomings, such as greater slopes or less ability to store soil moisture than Prime Farmland. Land must have been used for production of irrigated crops at some time during the four years prior to the mapping date. Unique Farmland (U): Lesser quality soils used for the production of the state's leading agricultural crops. This land is usually irrigated, but may include non-irrigated orchards or vineyards as found in some climatic zones in California. Land must have been cropped at some time during the four years prior to the mapping date. Farmland of Local Importance (L)
Urban and Built-up Land	Urban and Built-Up Land (D): Urban and Built-Up land is occupied by structures with a building density of at least 1 unit to 1.5 acres, or approximately 6 structures to a 10-acre parcel. Common examples include residential, industrial, commercial, institutional facilities, cemeteries, airports, golf courses, sanitary landfills, sewage treatment, and water control structures.
Grazing Land	Grazing Land (G): Land on which the existing vegetation is suited to the grazing of livestock. This category is used only in California and was developed in cooperation with the California Cattlemen's Association, University of California Cooperative Extension, and other groups interested in the extent of grazing activities. The minimum mapping unit for Grazing Land is 40 acres.
Other Land (Woodland, Undeveloped, or Restricted)	Other Land (X): Land which does not meet the criteria of any other category. Typical uses include low-density rural development, heavily forested land, mined land, or government land with restrictions on use.
Open Water	Water (W): Water areas with an extent of at least 40 acres.

[A] *Land use-Land cover dataset: California Department of Conservation Farmland Mapping and Monitoring Program (2010)*

Figure 3-7 illustrates land use and land cover in the Pajaro River basin. As one would expect, agricultural lands, and developed or urbanized lands generally comprise the majority of the lowlands areas within the river basin. Upland areas are typically characterized chiefly by grasslands, woodlands, and natural areas.

Figure 3-7. Land use – land cover of the Pajaro River basin (year 2010).

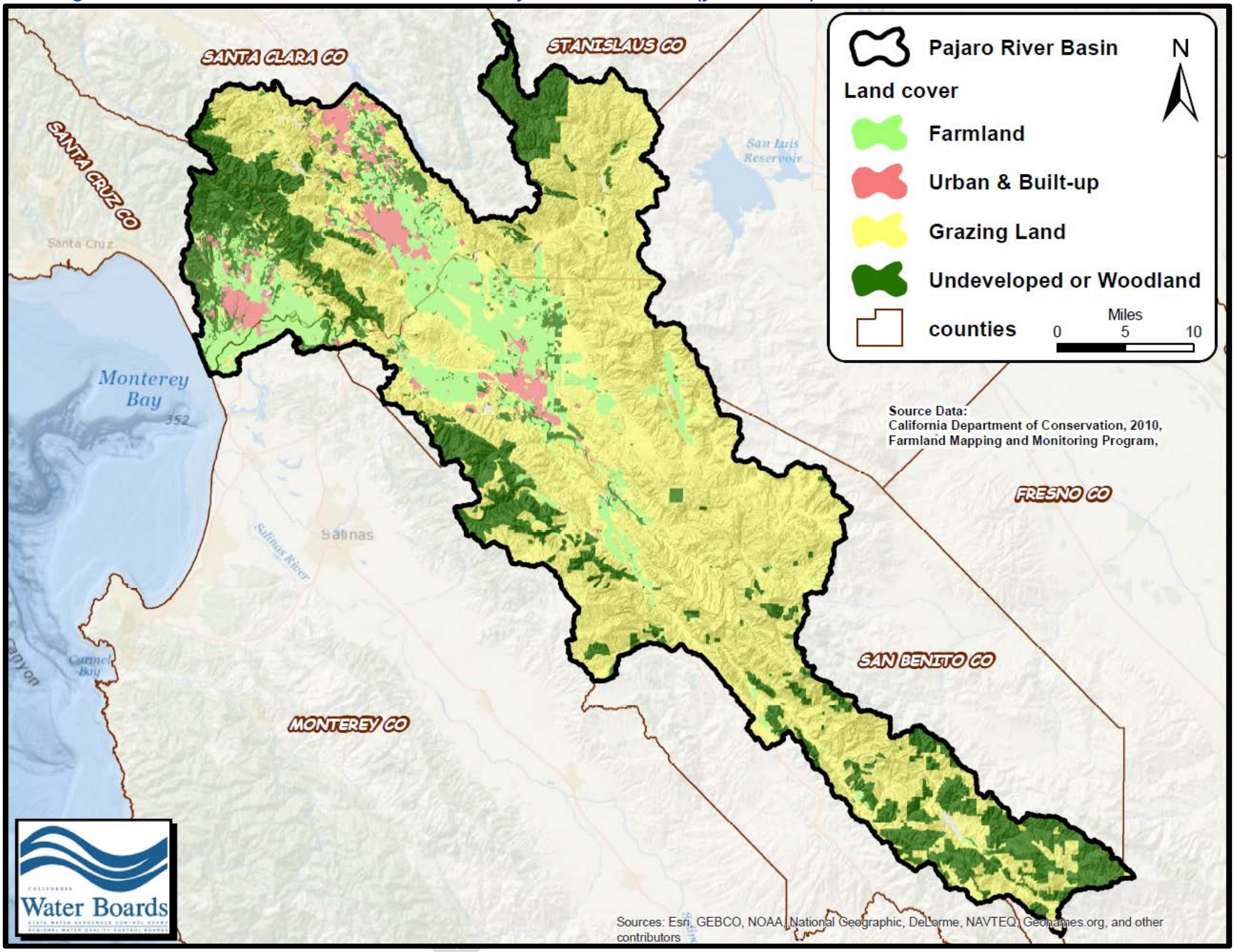


Table 3-5 tabulates the distribution of land cover in the Pajaro River basin. The river basin as a whole is largely comprised of grazing lands, woodlands and undeveloped areas. Agricultural lands and urban lands are concentrated in the lowland areas of south Santa Clara Valley, and the Pajaro Valley. The overwhelming majority of identified stream water quality impairments are associated with stream reaches in these lowland areas.

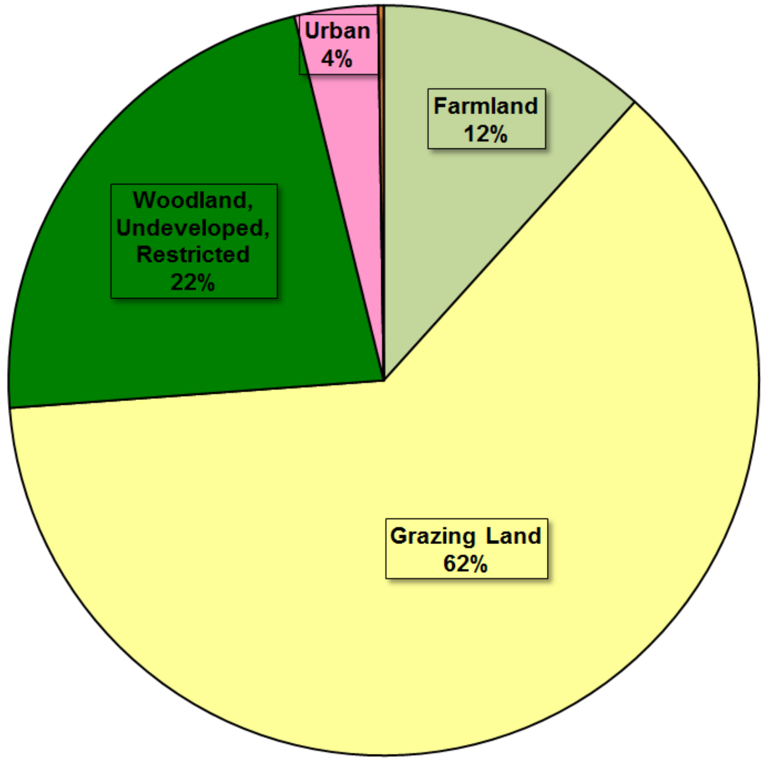
Table 3-6 presents the distribution of land cover at a higher spatial resolution; the table tabulates land cover estimates for all the subwatersheds nested within the Pajaro River basin.

Table 3-7 presents the distribution of land cover in selected drainages of particular interest at the catchment hydrologic scale (i.e., drainages less than 10 square miles in size).

Table 3-5. Tabulation of estimated land use/land cover in the Pajaro River basin (year 2010).

River Basin Land Cover (Year 2010)[A,B]	U.S. Acres
Urban and Built-Up Land	29,945
Farmland	97,114
Grazing Land	517,322
Other Land (Woodland, Undeveloped, or Restricted)	185,867
Open Water	1,964
Vacant or Disturbed Land [C]	12
Total	832,225

River Basin Land Cover Pie Chart



[A] Source: Calif. Dept. of Conservation, Farmland Mapping and Monitoring Program (2010)

[B] The total acreage in this table is negligibly smaller (by less than 200 acres) than the size of the Pajaro River basin total drainage area previously reported in Section 3.2 of this report. This is due to very small differences between the Farmland Mapping and Monitoring Program dataset that is reported by county (and thus delineated on the basis of county boundaries) and the Watershed Boundary Dataset that is report by drainage area. The areal extents of these two datasets are slightly different in some areas of the Pajaro River basin. It should be noted that these difference amount to 181 acres total which is insignificant compared to the total size of the Pajaro River basin of over 832,000 acres.

[C] This land cover category is only used and reported by Fresno County in the 2010 Farmland Mapping and Monitoring Program dataset; there is a tiny sliver of Fresno County that overlaps the Pajaro River basin in the upper San Benito River Subbasin area. Other counties in the Pajaro River basin do not use or report this land cover category.

Table 3-6. Estimated land cover (year 2010)[A] tabulated by subwatershed (units = U.S. acres).

Subwatershed Name (HUC-12 drainage scale)	Farmland	Urban & Built Up	Woodland, Undeveloped, or Restricted	Grazing Lands	Open Water	Vacant or Disturbed Land	Total
Watsonville Slough	5,049	4,178	5,952	292	0	N.A.	15,472
Lower Pajaro River	11,321	963	9,321	11,680	0	N.A.	33,285
Salsipuedes Creek	4,019	1,342	7,993	2,344	183	N.A.	15,881
Corralitos Creek	2,594	1,108	13,909	178	0	N.A.	17,789
Upper Pajaro River	19,596	1,313	1,070	13,487	0	N.A.	35,466
Bird Creek-San Benito River	3,779	3,034	8,424	17,505	0	N.A.	32,742
San Juan Canyon	6,136	927	5,774	11,360	218	N.A.	24,415
Paicines Reservoir-San Benito River	4,354	16	2,610	26,909	87	N.A.	33,976
Pescadero Creek	672	87	11,420	13,486	0	N.A.	25,665
Stone Creek	5	0	1,922	8,133	0	N.A.	10,060
Lower Tres Pinos Creek	2,179	231	1,468	13,973	0	N.A.	17,850
Middle Tres Pinos Creek	19	0	508	22,470	0	N.A.	22,997
Los Muertos Creek	42	0	710	18176	0	N.A.	18,928

Subwatershed Name (HUC-12 drainage scale)	Farmland	Urban & Built Up	Woodland, Undeveloped, or Restricted	Grazing Lands	Open Water	Vacant or Disturbed Land	Total
Quien Sabe Creek	3,172	0	116	29268	105	N.A.	32,662
Upper Tres Pinos Creek	81	0	2,243	20,916	0	N.A.	23,240
Las Aguilas Creek	0	0	220	24,509	0	N.A.	24,730
Sulphur Creek-San Benito River	461	0	2,802	20911	0	N.A.	24,174
Willow Creek	41	0	2,583	15,962	0	N.A.	18,585
Rock Springs Creek-San Benito River	303	0	6,397	23,080	0	N.A.	29,781
James Creek-San Benito River	10	0	12,401	16,330	0	N.A.	28,740
Hernandez Reservoir-San Benito River	178	0	9,888	8,821	625	N.A.	19,512
Clear Creek-San Benito River	0	0	21,625	13,205	0	12	34,843
Lower Uvas Creek	4,142	1,602	6,269	13,677	0	N.A.	25,690
Upper Uvas Creek	316	201	13,491	15,576	238	N.A.	29,823
Lower Llagas Creek	5,378	5,442	4,467	4,721		N.A.	20,007
Upper Llagas Creek	505	1,232	2,713	14,056	231	N.A.	18,737
Little Llagas Creek	2,216	5,257	2,636	5,284	0	N.A.	15,392
Lower Pacheco Creek	4,172	192	1,717	15,796	109	N.A.	21,986
Upper Pacheco Creek	0	0	222	18,094	0	N.A.	18,316
Cedar Creek	0	0	4,876	7890	0	N.A.	12,766
Lower North Fork Pacheco Creek	0	0	688	24,891	167	N.A.	25,746
Upper North Fork Pacheco Creek	0	0	15,667	1,372	0	N.A.	17,040
South Fork Pacheco Creek	0	0	10	11,497	0	N.A.	11,507
Tequisquita Slough	8,966	1,966	2,393	12,638	0	N.A.	25,964
Santa Ana Creek	7,084	853	1,177	24,603	0	N.A.	33,717
Arroyo De Las Viboras	327	0	184	14,229	0	N.A.	14,740

[A] Land use-Land cover dataset: California Department of Conservation Farmland Mapping and Monitoring Program (2010)
N.A. = not applicable, this land cover category is specific to Fresno County.

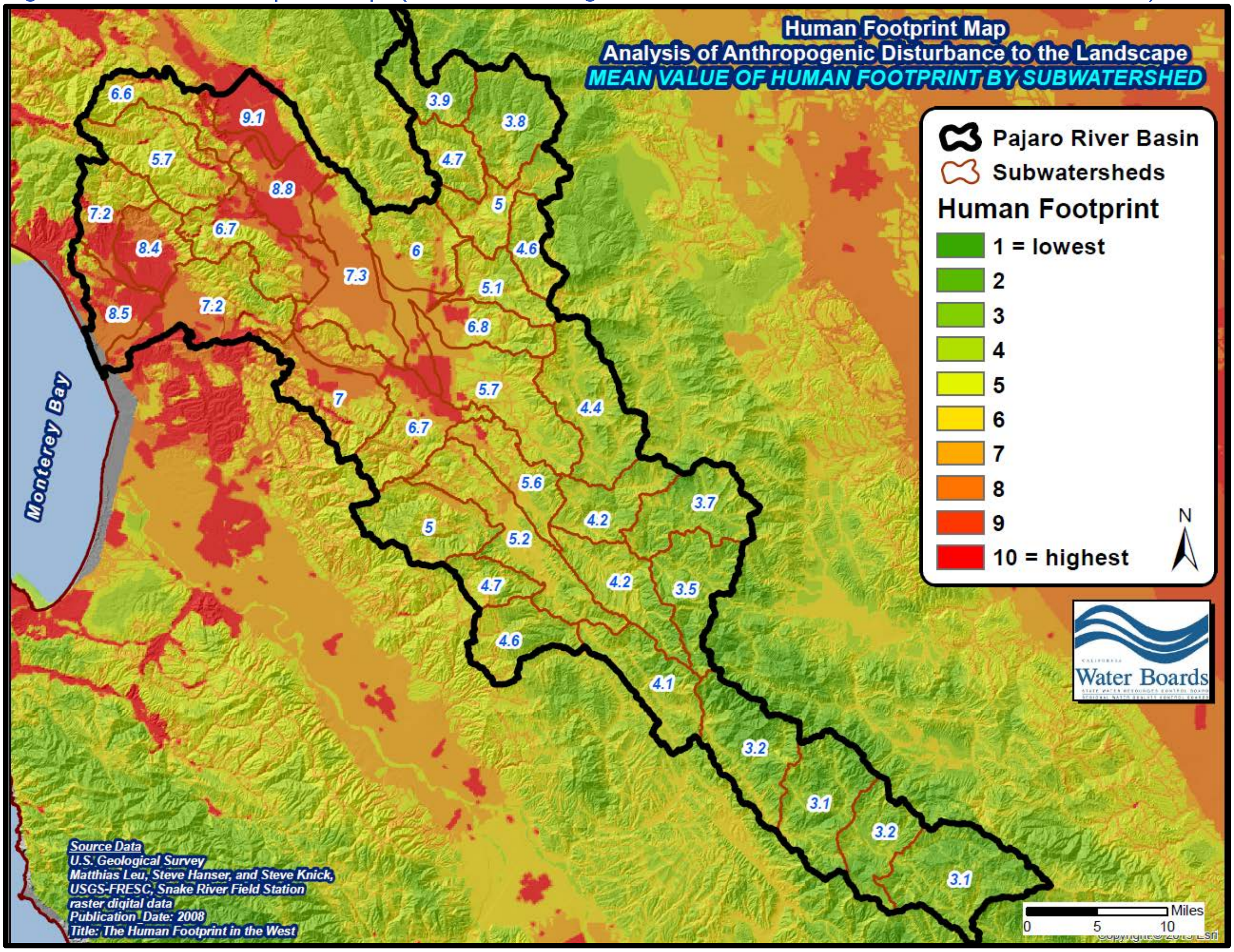
Table 3-7. Estimated land cover of catchment-size drainages of particular interest (units = U.S. acres).

Catchment	this catchment occurs within this subwatershed [A]	Farmland	Urban & Built Up	Woodland, Undeveloped, or Restricted	Grazing Lands	Total
McGowan Ditch [B]	Lower Pajaro River Subwatershed	1,634	258	662	0	2,554
Miller Canal [C]	Upper Pajaro River Subwatershed	3,112	67	75	277	3,531
Beach Road Ditch [D]	Watsonville Slough Subwatershed	1,675	0	0	0	1,675
Watsonville Slough [D]	Watsonville Slough Subwatershed	1,498	1,684	156	0	3,338
Struve Slough [D]	Watsonville Slough Subwatershed	2,051	1,487	376	0	3,914
Galligan Slough [D]	Watsonville Slough Subwatershed	716	1,433	409	205	2,763
Hanson Slough [D]	Watsonville Slough Subwatershed	200	100	401	301	1.002
Harkins Slough [D]	Watsonville Slough Subwatershed	819	3,385	1,510	1,669	7,383

[A] Refer to Figure 3-5 and Table 3-6 in this report to view subwatershed location and information.
[B] Source: Table 2 in Smalling and Orlando, 2011.
[C] As delineated by Central Coast Water Board staff on the basis of the National Elevation Dataset 30 meter digital elevation model (source: U.S. Geological Survey, EROS Data Center 1999) and an associated flow accumulation grid and stream link raster network developed with the Esri® ArcMap™ 10.1 Spatial Analyst Hydrology Tool. Estimated land cover is based on the Farmland Mapping and Monitoring dataset (2010).
[D] Source: Table 3-1 in Swanson Hydrology & Geomorphology, et. al., 2003.

Human disturbance to the landscape varies spatially across any given river basin. In the context of TMDL development, it is important to be aware of this variation. The establishment of water quality "reference conditions" also relies on knowledge about the magnitude of human disturbance to the landscapes of a river basin (see report section 3.6). The degree of human disturbance to the landscape can be quantified with data available from the U.S. Geological Survey[15]. Figure 3-8 presents the "human footprint" in the Pajaro River basin. Human footprint is a measure of human disturbance to the landscape. Human footprint values range from one (pristine conditions) to 10 (extremely modified by humans). In general, lowland and valley areas of river basins typically have the highest human footprint, whereas upland areas of the river basin unsurprisingly will have a lower human footprint. For example, human footprint values range from about 3 to 4 in lightly impacted subwatersheds of the Upper San Benito Subbasin and the Upper Pacheco Creek Subbasin. In contrast, human footprint values range from about 7 to 9 in highly modified subwatersheds of the Santa Clara Valley and Watsonville coastal plain. Table 3-8 presents a tabulation of the ranges and averages of human footprint values by individual subwatersheds, and thus illustrates the degree to which subwatershed landscapes of the Pajaro River basin are modified by human activities.

Figure 3-8. Human footprint map (refer back to Figure 3-5 and Table 3-3 for subwatershed names).



[15] "The Human Footprint in the West" is a geospatial dataset originated by Matthias Leu, Steve Hanser, and Steve Knick, U.S. Geological Survey, Snake River Field Station. Leu, Nahser and Knick developed the map of the human footprint for the western United States from an analysis of 14 landscape structure and anthropogenic features: Online linkage: http://sagemap.wr.usgs.gov/HumanFootprint.aspx

Table 3-8. Tabulation of human footprint values by subwatershed on the basis of map data shown previously in Figure 3-8 (human footprint value of 2 = landscape is undisturbed or near pristine conditions, value of 10 = landscape is extremely modified by humans).

Subwatershed[A]	Human Footprint (minimum)	Human Footprint (maximum)	**Human Footprint (average)**		**Subwatershed**[A]	Human Footprint (minimum)	Human Footprint (maximum)	**Human Footprint (average)**
Clear Creek-San Benito River	2	5	**3.1**		Santa Ana Creek	3	10	**5.7**
Hernandez Reservoir-San Benito River	2	5	**3.2**		Tequisquita Slough	4	10	**6.8**
James Creek-San Benito River	2	6	**3.1**		Watsonville Slough	4	10	**8.5**
Rock Springs Creek-San Benito River	2	6	**3.2**		Lower Pajaro River	4	10	**7.2**
Sulphur Creek-San Benito River	2	6	**4.1**		Arroyo De Las Viboras	4	10	**5.1**
Willow Creek	3	10	**4.6**		Salsipuedes Creek	5	10	**8.4**
Stone Creek	3	7	**4.7**		Lower Pacheco Creek	4	10	**6.0**
Upper Tres Pinos Creek	2	5	**3.5**		South Fork Pacheco Creek	3	7	**4.6**
Middle Tres Pinos Creek	2	6	**4.2**		Lower Uvas Creek	4	10	**6.7**
Pescadero Creek	3	7	**5.0**		Upper Pajaro River	4	10	**7.3**
Las Aguilas Creek	2	6	**3.7**		Corralitos Creek	4	10	**7.2**
Los Muertos Creek	2	6	**4.2**		Upper Pacheco Creek	3	7	**5.0**
Paicines Reservoir-San Benito River	3	10	**5.2**		Lower Llagas Creek	4	10	**8.8**
Lower Tres Pinos Creek	3	10	**5.6**		Cedar Creek	3	7	**4.7**
San Juan Canyon	4	10	**7.0**		Upper Uvas Creek	4	10	**5.7**
Bird Creek-San Benito River	4	10	**6.7**		Little Llagas Creek	4	10	**9.1**
Quien Sabe Creek	3	7	**4.4**		Upper Llagas Creek	5	10	**6.6**

[A] Refer back to Figure 3-5 and Table 3-3 for a map and tabulation of subwatersheds within the Pajaro River basin.

3.4 Hydrology

Assessing the hydrology of a watershed is an important step in evaluating the magnitude and nature of nutrient transport and loading in waterbodies. The entire drainage area contributing to flow in the Pajaro River basin encompasses over 1,300 square miles (refer back to Figure 3-2). Figure 3-9 illustrates some regional hydrographic features and hydrologic characteristics within the Pajaro River basin.

Due to highly variable climatic, hydrologic, anthropogenic, and geomorphic influences within the river basin, stream flows in various stream reaches can range spatially from perennial or sustained flow, to infrequent seasonal or intermittent flows – refer again to Figure 3-9 for illustrations of these variations.

Table 3-9 presents flow statistics for select stream reaches in the Pajaro River basin on the basis of U.S. Geological Survey stream gages.

Figure 3-9. Generalized hydrography of the Pajaro River basin: major streams, generalized hydrologic flow conditions, major lakes, estuaries, reported cold water springs and reported geothermal springs.

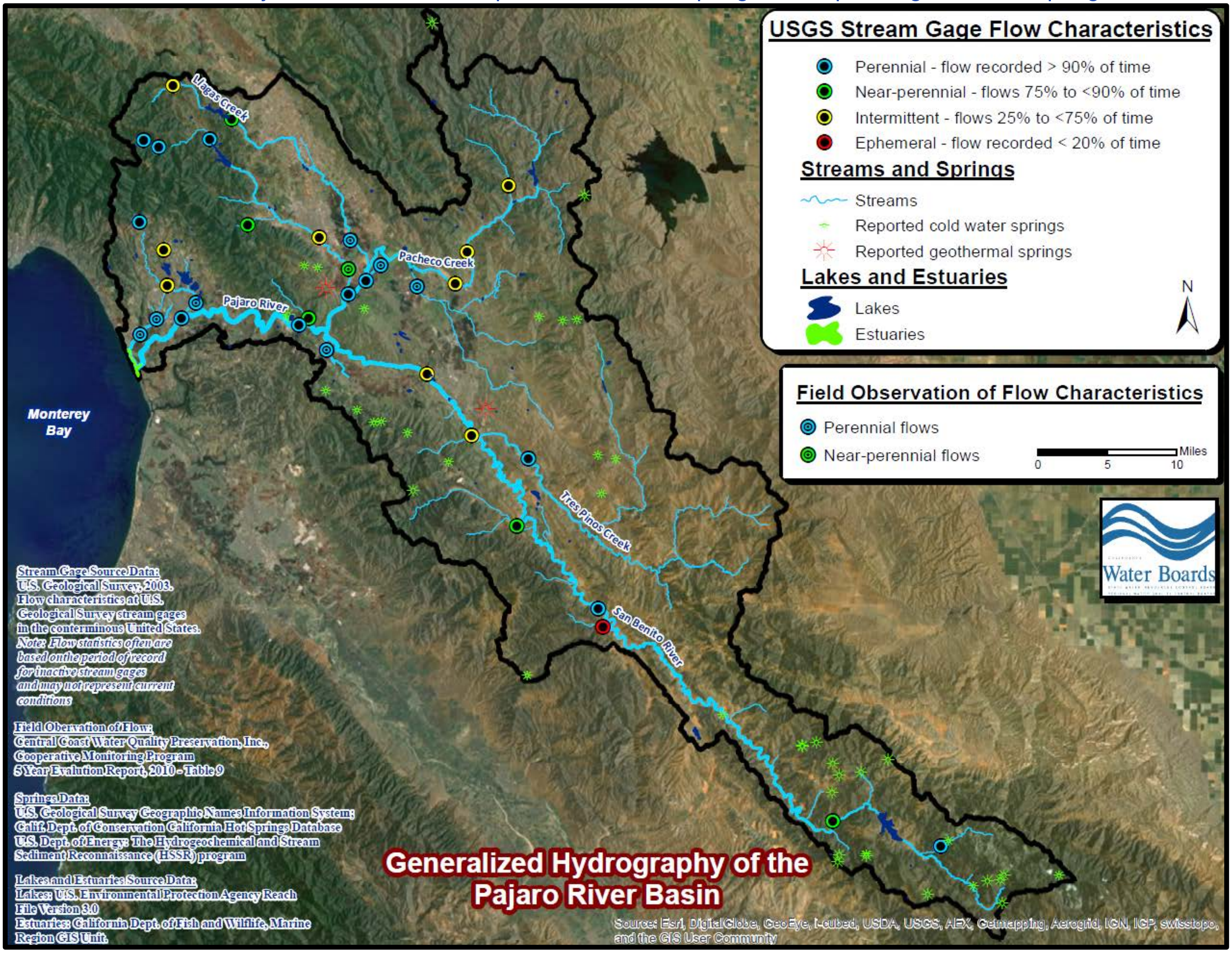


Table 3-9. Flow statistics from U.S. Geological Survey stream gages in the Pajaro River basin. Flow units = cubic feet per sec.; drainage area units = sq. miles; BFI = base flow index.

Station No.	Station Name	Period of Record	Ave. Flow	MIN	P10	P25	P50	P75	P90	P95	P99	Max Flow	BFI	Drain Area
11152900	Cedar C Nr Bell Station Ca	1961-1982	4.4	0.0	0.0	0.0	0.0	0.6	4.2	16.0	92.0	832	0.176	13
11153000	Pacheco C Nr Dunneville Ca	1939-1982	34.5	0.0	0.0	0.0	2.0	8.9	38.0	124.0	698.2	7730	0.198	146
11153470	Llagas C Ab Chesbro Res Nr Morgan Hill Ca	1971-1982	9.6	0.0	0.0	0.0	0.6	5.3	22.0	46.0	153.6	508	0.37	10
11153500	Llagas C Nr Morgan Hill Ca	1951-1971	15.5	0.0	0.0	1.1	4.1	16.0	33.0	48.0	178.1	1230	0.603	20
11153700	Pajaro R Nr Gilroy Ca	1959-1982	60.2	0.0	0.5	2.1	5.3	13.0	67.0	245.8	1220.0	11700	0.307	399
11154100	Bodfish C Nr Gilroy Ca	1959-1982	3.8	0.0	0.0	0.1	0.4	1.8	7.0	16.0	63.0	505	0.331	7
11154200	Uvas C Nr Gilroy Ca	1959-1992	38.5	0.0	0.0	0.0	0.0	6.4	61.0	180.2	746.2	6520	0.154	71
11154700	Clear C Nr Idria Ca	1993-2000	5.5	0.1	0.5	1.0	1.9	5.1	14.0	22.0	45.0	464	0.726	14
11156000	San Benito R Bl M C Nr Hernandez Ca	1949-1963	12.4	0.0	0.0	0.8	1.7	4.8	24.0	79.0	160.3	754	0.402	108
11156450	Willow C Trib Nr San Benito Ca	1964-1969	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	12	0.018	1
11156700	Pescadero C Nr Paicines Ca	1959-1970	1.6	0.0	0.0	0.2	0.6	1.5	2.5	3.8	21.0	160	0.674	38
11157500	Tres Pinos C Nr Tres Pinos Ca	1940-2000	18.2	0.0	0.5	1.2	3.0	6.5	18.0	50.0	290.8	9000	0.431	208
11158500	San Benito R Nr Hollister Ca	1949-1983	37.3	0.0	0.0	0.0	2.5	18.0	40.0	97.0	715.0	8390	0.253	586
11158600	San Benito R A Hwy 156 Nr Hollister Ca	1970-2000	42.5	0.0	0.0	0.0	1.8	11.0	41.0	173.0	800.0	19800	0.289	607
11158900	Pescadero C Nr Chittenden Ca	1970-1981	3.0	0.0	0.0	0.1	0.3	1.5	5.8	14.0	52.0	191	0.38	10
11159150	Corralitos C Nr Corralitos Ca	1957-1972	8.6	0.0	0.1	0.1	0.5	4.1	18.0	41.0	134.0	997	0.232	11
11159200	Corralitos C A Freedom Ca	1956-2000	16.9	0.0	0.0	0.0	0.4	5.5	35.0	81.0	301.8	2290	0.181	28
11159500	Pajaro R A Watsonville Ca	1911-1973	93.8	0.0	0.1	1.0	5.4	26.0	70.0	368.2	2100.4	6570	0.53	1272
11153900	Uvas C Ab Uvas Res Nr Morgan Hill Ca	1961-1982	28.1	0.0	0.3	0.8	2.7	14.0	50.0	116.0	475.6	3390	0.313	21
11156500	San Benito R Nr Willow Creek School Ca	1939-2000	28.1	0.0	0.2	0.5	3.9	24.0	58.0	93.0	382.4	5000	0.471	249
11159000	Pajaro R A Chittenden Ca	1939-2000	173.1	0.0	1.2	4.3	12.0	39.0	270.0	777.5	3420.0	21700	0.344	1186

Data source: U.S. Geological Survey, 2003. *Flow characteristics at U.S. Geological Survey stream gages in the conterminous United States.* Open File Report 03-146.
P = percentiles, for example the P10 attribute is the 10th percentile of daily streamflow values for the period of record.

Staff developed visual representations of flow variation in the Pajaro River basin in Figure 3-10 and Figure 3-11. Figure 3-10 illustrates mean annual flow estimates within the project area, based on U.S. Geological Survey flow gage data and resolution National Hydrography Dataset Plus (NHDplus)[16], estimates of mean annual flow[17].

[16] NHDPlus Version 1.0 (2005) was created by the USEPA and the U.S. Geological Survey and is an integrated suite of application-ready geospatial data sets that incorporate many of the features of the National Hydrography Dataset (NHD) and the National Elevation Dataset (NED). NHDPlus includes a stream network (based on the 1:100,000-scale NHD), networking, naming, and "value-added attributes" (VAA's). NHDPlus also includes elevation-derived catchments (drainage areas) produced using drainage enforcement techniques.

[17] U.S. Geological Survey gages provide measured daily flow records (online linkage: http://ca.water.U.S. Geological Survey.gov/). NHDPlus provides modeled mean annual flow estimates; staff used values for the attribute “MAFlowU”. MAFlowU are based on the Unit Runoff Method (UROM), which was developed for the National Water Pollution Control Assessment Model (NWPCAM) (Research Triangle Institute, 2001). Values in “MAFlowU” are based on methods from Vogel et al., 1999. NHDplus uses two flow estimation procedures, both developed by using the Hydro-Climatic Data Network (HCDN) of gages. These gages are usually not affected by human activities, such as major reservoirs, intakes, and irrigation withdrawals; thus, the mean annual flow estimates are most representative of “natural” flow conditions. These estimation methods used the HCDN gages because each method is developed for use at large scales; such as Hydrologic Regions. It was beyond the scope and capabilities of both methods to determine the human-induced effects at this scale.

Figure 3-10. Estimated mean annual discharge in streams of the northern Pajaro River basin on the basis of stream gage data and NHDplus flow estimates; units=cubic feet/sec,.

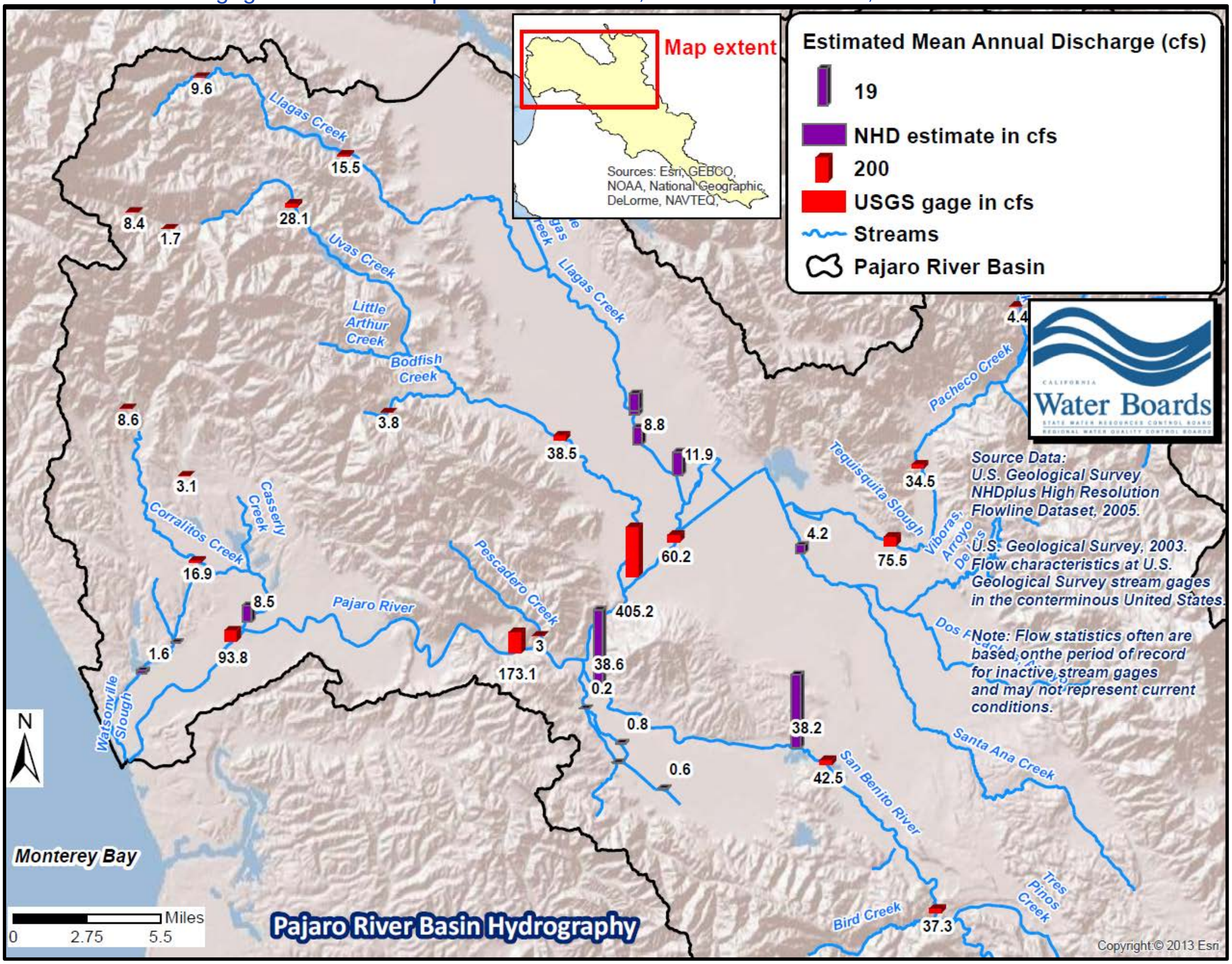
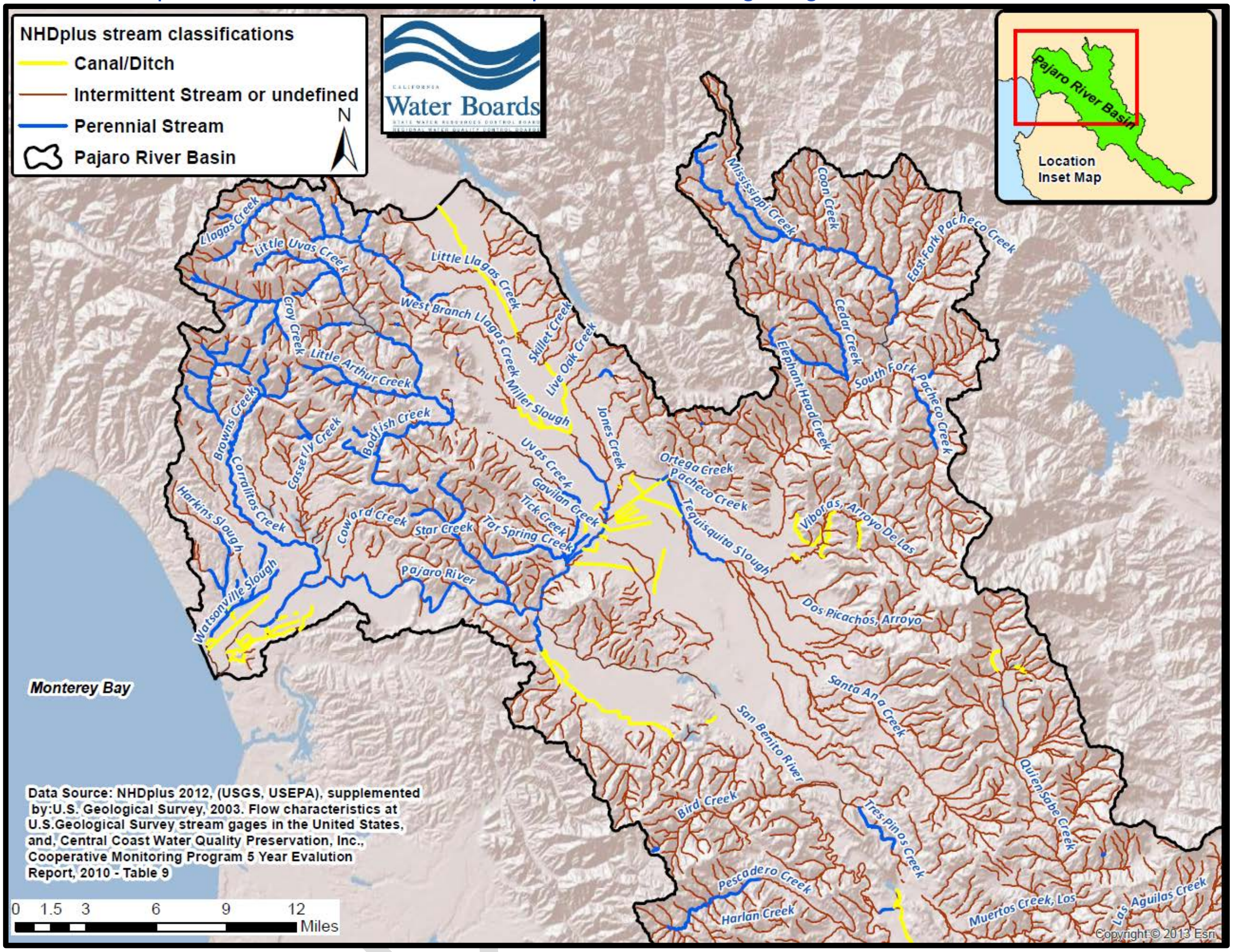


Figure 3-11 illustrates the estimated hydrographic stream channel classifications in the project area. The source of these hydrographic stream classification attributes is the U.S. Geological Survey's high resolution NHDplus supplemented by field observation of flow patterns. It should be noted that the NHDplus stream channel classifications carry no formal regulatory status, and have not necessarily been field-checked. In the NHDplus metadata these are described as "value-added" geospatial attributes created to supplement the NHDFlowline shapefiles.

Figure 3-11. Generalized stream classifications in the northern and central Pajaro River basin on the basis of NHDplus flow line attributes and Cooperative Monitoring Program field observations.



Riparian characteristics are often considered in nutrient TMDL development, because riparian cover, canopy shading, and riparian health can play a role in the nature and risk of nutrient pollution of water resources. Stream riparian landscape characteristics have been published as digital datasets by the USEPA's Landscape Ecology Branch[18]. Figure 3-12, Figure 3-13, and Figure 3-14 present estimated percentage of stream length that is adjacent to various land cover categories (i.e., cropland, urban, and natural land).

Table 3-10 tabulates weighted averages of the digital riparian landscape characteristics shown in the aforementioned figures. Significant proportions of lowland stream reaches of the Pajaro Valley and southern Santa Clara Valley are located adjacent to croplands and developed urban/residential areas. In contrast, stream reaches of the San Benito River Subbasin are largely adjacent to natural landscapes.

[18] The EMAP-West (Environmental Mapping and Assessment Program-West) metrics, developed by the USEPA's Landscape Ecology Branch, were generated with an ArcView extension called ATtILA (Analytical Tools Interface for Landscape Assessments). The wemap3k_atmetrics dataset contains metric information from four metric groups; landscape characteristics, riparian characteristics, human stresses and physical characteristics. Derived from the National Land Cover Dataset, DEM, DEM slope, roads, census block groups and streams datasets used in the ATtILA processing.

Figure 3-12. Estimated percentage of stream reach length which is adjacent to cropland.

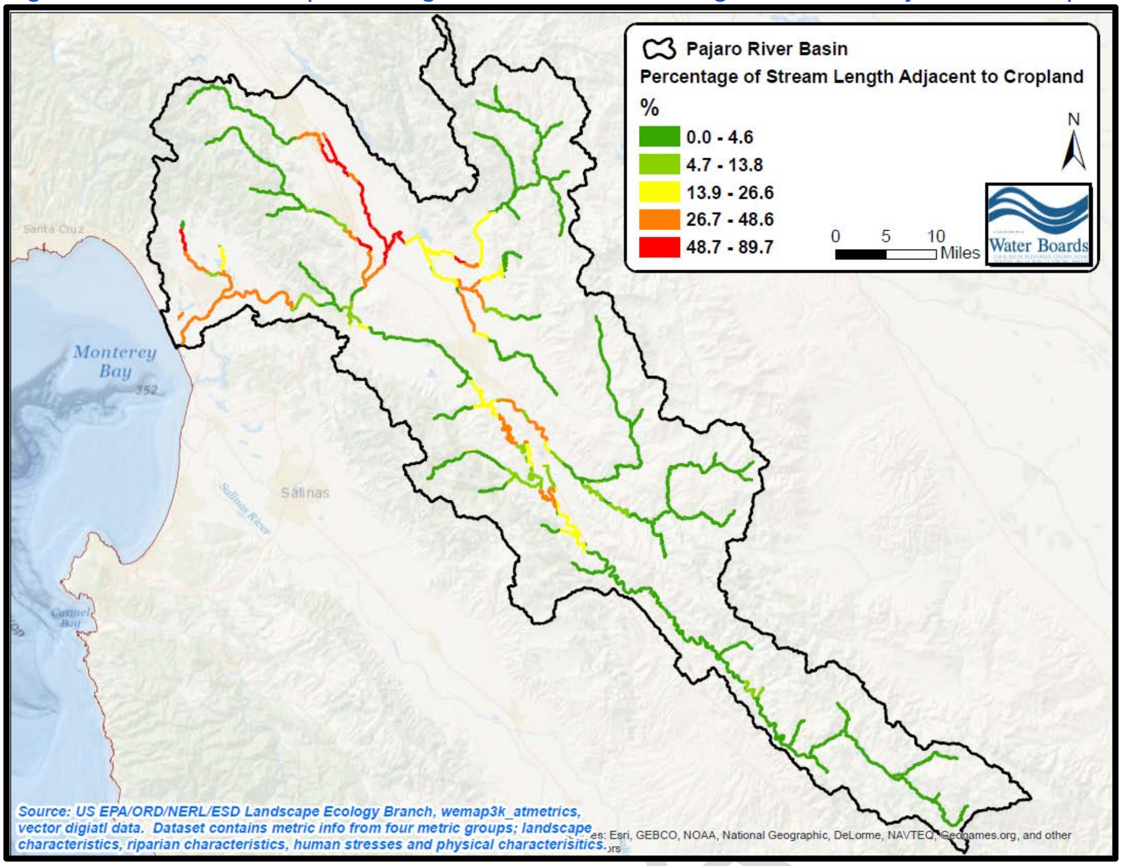


Figure 3-13. Estimated percentage of stream reach length which is adjacent to urban land.

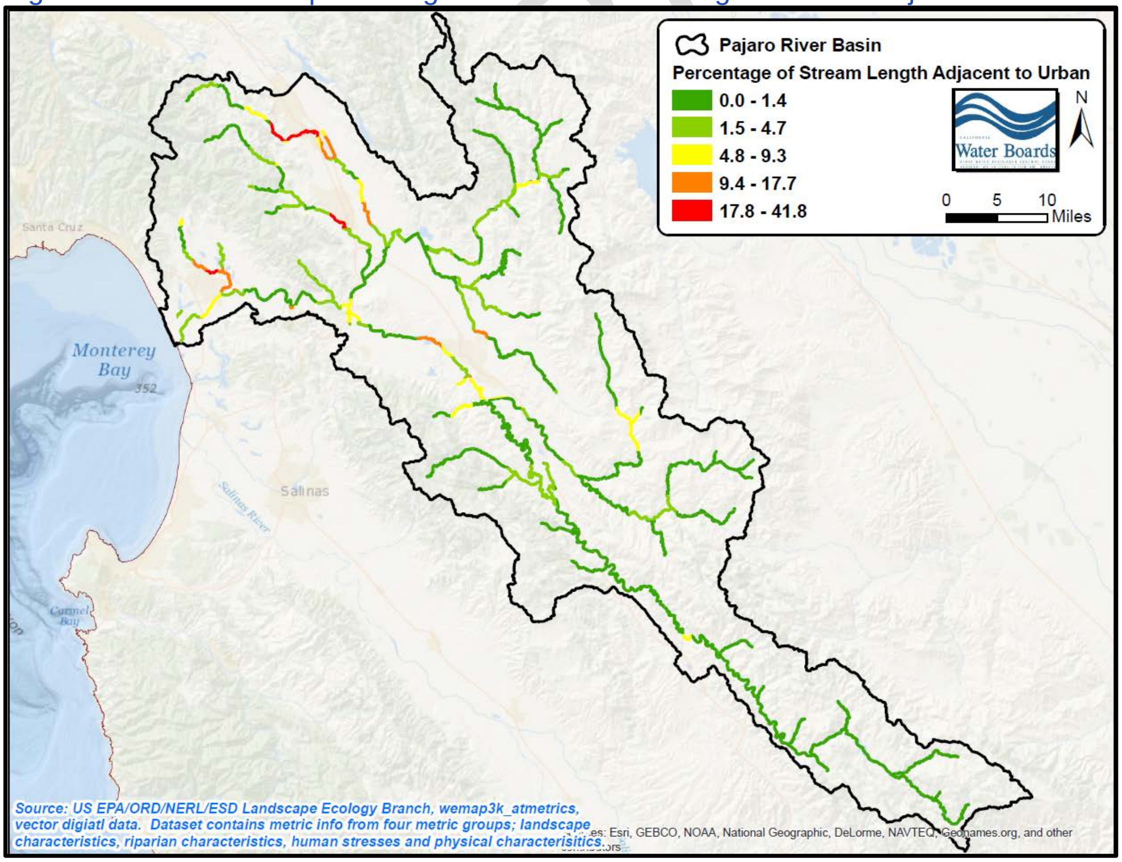


Figure 3-14. Estimated percentage of stream reach length which is adjacent to all natural land.

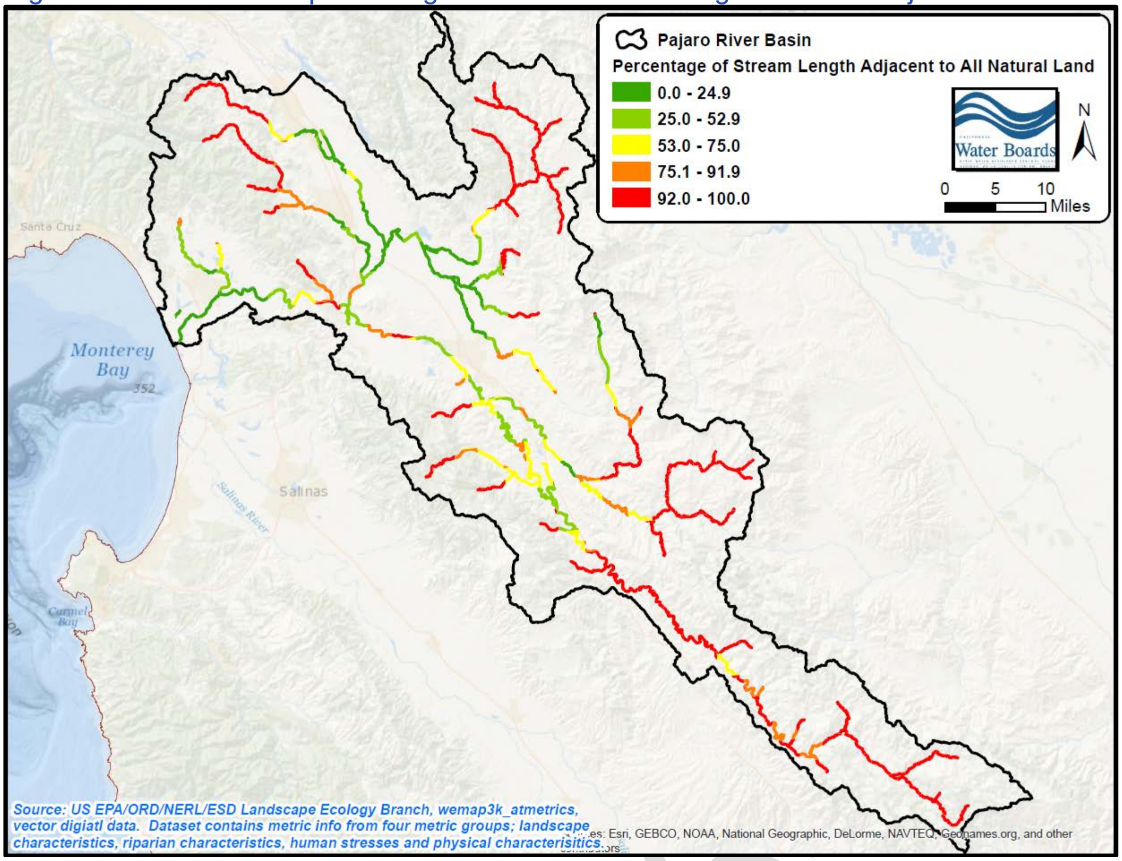


Table 3-10. Weighted percentages of select land cover categories occurring within a 100 meter buffer of higher order streams (source data: EMAP-West[19]).

	Land Cover Proportions[A]: Percentages of Land Cover Categories within 100 meter Buffer of Higher Order Streams[B, C]		
Hydrologic Area[D]	Weighted % of land within 100 m stream buffer that is CROPLAND	Weighted % of land within 100 m stream buffer that is URBAN	Weighted % of land within 100 m stream buffer that is ALL NATURAL land cover
Pajaro River Basin	**12.6**	**2.6**	**73.2**
Pajaro River Subbasin	**30.0**	**7.4**	**52.7**
Pacheco Creek Subbasin	**11.8**	**1.4**	**67.0**
San Benito River Subbasin	**4.6**	**0.9**	**85.4**

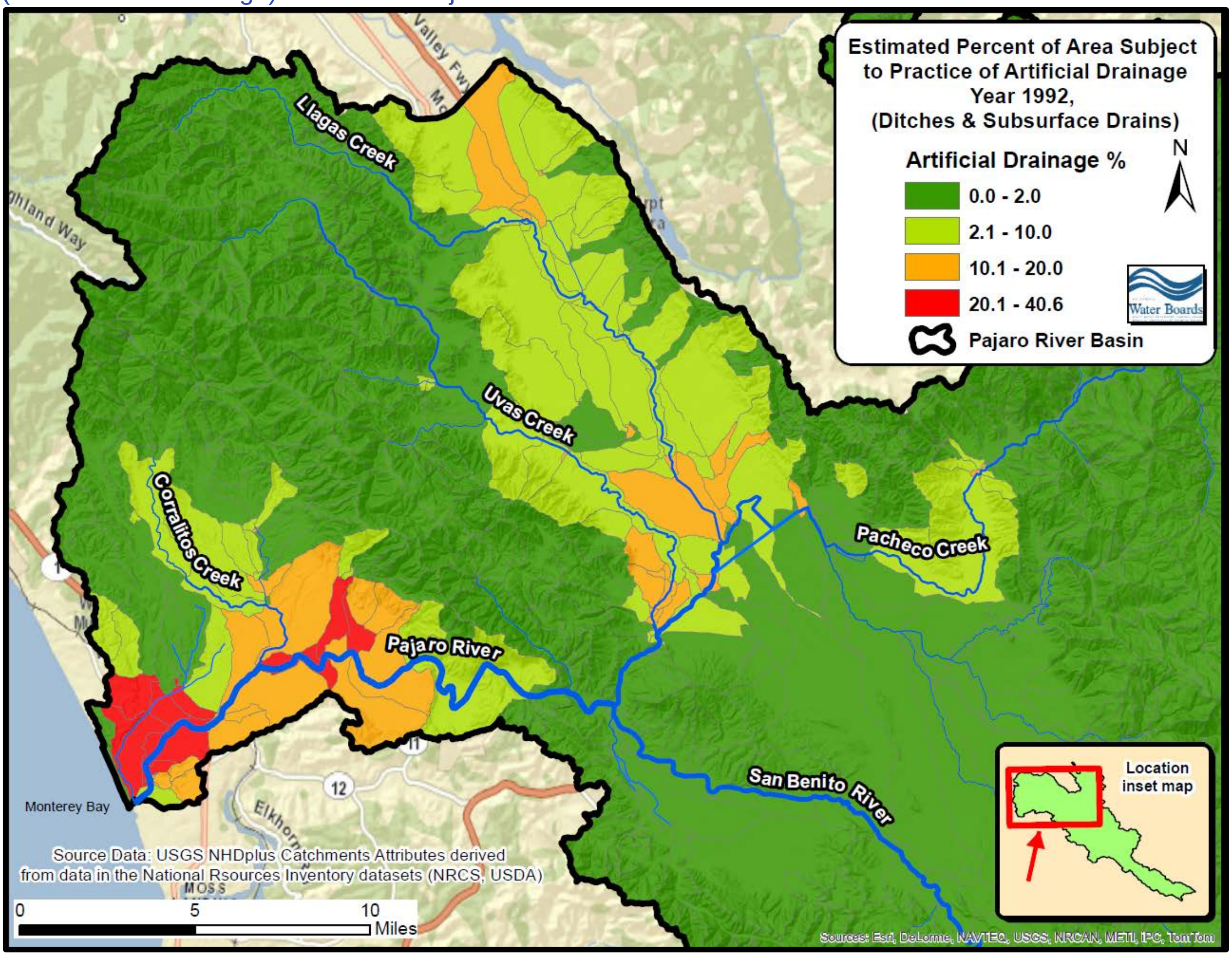
[A] *Source Data: EMAP-West Landscape Metrics, USEPA – Landscape Ecology Branch.*
[B] *Does not include Strahler first-order head water stream reaches.*
[C] *Cropland, Urban, and All Natural land categories do not sum to 100% for a given hydrologic area because grasslands, wetlands, and shrubland were not included in this land cover tabulation.*
[D] *Refer back to Figure 3-4 for a map showing location of the subbasins within the Pajaro River Basin.*

Agricultural watersheds are often characterized by a significant amount of artificial drainage. Staff was cognizant of this fact during the development of this TMDL. Artificial drainage, such as agricultural runoff, can be an important contributor to flows in some waterbodies of the Pajaro River basin. In

[19] *Ibid*

watersheds dominated by agriculture, artificial drainage systems can act as efficient conveyance systems which rapidly transport excess water from agricultural soils. Consequently artificial drainage can considerably increase the amount of nutrients exported from agricultural fields to waterways (Strock et al., 2007). Figure 3-15 illustrates the estimated percentage of land area that is subject to the practice of artificial drainage, such as ditches and tile drains. The estimations are from U.S. Geological Survey NHDplus catchment attribute datasets. They are intended for informational value only and are based on data derived by the National Resource Inventory conducted by the NRCS for the year 1992[20], which is the best available dataset to estimate artificial drainage. Thus, this dataset is presumed to represent a plausible gross regional approximation of the current percentage of land area subject to artificial drainage practices[21]. The data indicates that artificial drainage is most intensive in the lowermost areas of the Pajaro River basin (i.e., Pajaro Valley) as well as in localized areas around the Llagas Creek, and lower Uvas Creek watersheds.

Figure 3-15. 1992 vintage estimate of percentage of land area subject to artificial drainage practices (ditches & tile drainage) in northern Pajaro River basin.



[20] This tabular dataset was created by the U.S. Geological Survey and represents the estimated area of artificial drainage for the year 1992 and irrigation types for the year 1997 compiled for every catchment of NHDPlus for the conterminous United States. The source datasets were derived from tabular National Resource Inventory (NRI) datasets created by the National Resources Conservation Service. Artificial drainage is defined as subsurface drains and ditches.

[21] It should be noted that the information is this figure should be considered very qualitative and substantial changes at local scales may have occurred since 1992.

3.5 Geomorphology

Pajaro River basin geomorphology was considered in the development of nutrient numeric water quality targets. Because eutrophication is generally assumed to be limited to slow-moving waters in low gradient streams, lakes, ponds, estuaries and bays, a review of project area geomorphology provides insight into where higher risk of biostimulatory effects are to be expected.

In high gradient streams (steep slopes), the residence time of nutrients may be too short to allow nutrient assimilation by primary producers and so impacts on water quality may be minimal. As reported in Tetra Tech (2006), Dodds et al. (2002) reported a negative correlation of benthic chlorophyll a to gradient. Also, high gradient streams in steeper terrains keep water aerated diminishing the potential for anoxic zones (USEPA, 2001). USEPA reports that headwater systems in temperate zones usually have been found to be limited by phosphorus, thus it is generally assumed that eutrophication effects are expected in downstream ecosystems.

As such, the nutrient concentration that results in impairment in a high-gradient, shaded stream may be much different from the one that results in impairment in a low-gradient, unshaded stream (Tetra Tech, 2006). However, it is important to note that it is generally presumed that excess nutrients in head water reaches will ultimately end up in a receiving body of water where the nutrient concentrations and total load may degrade the water resource.

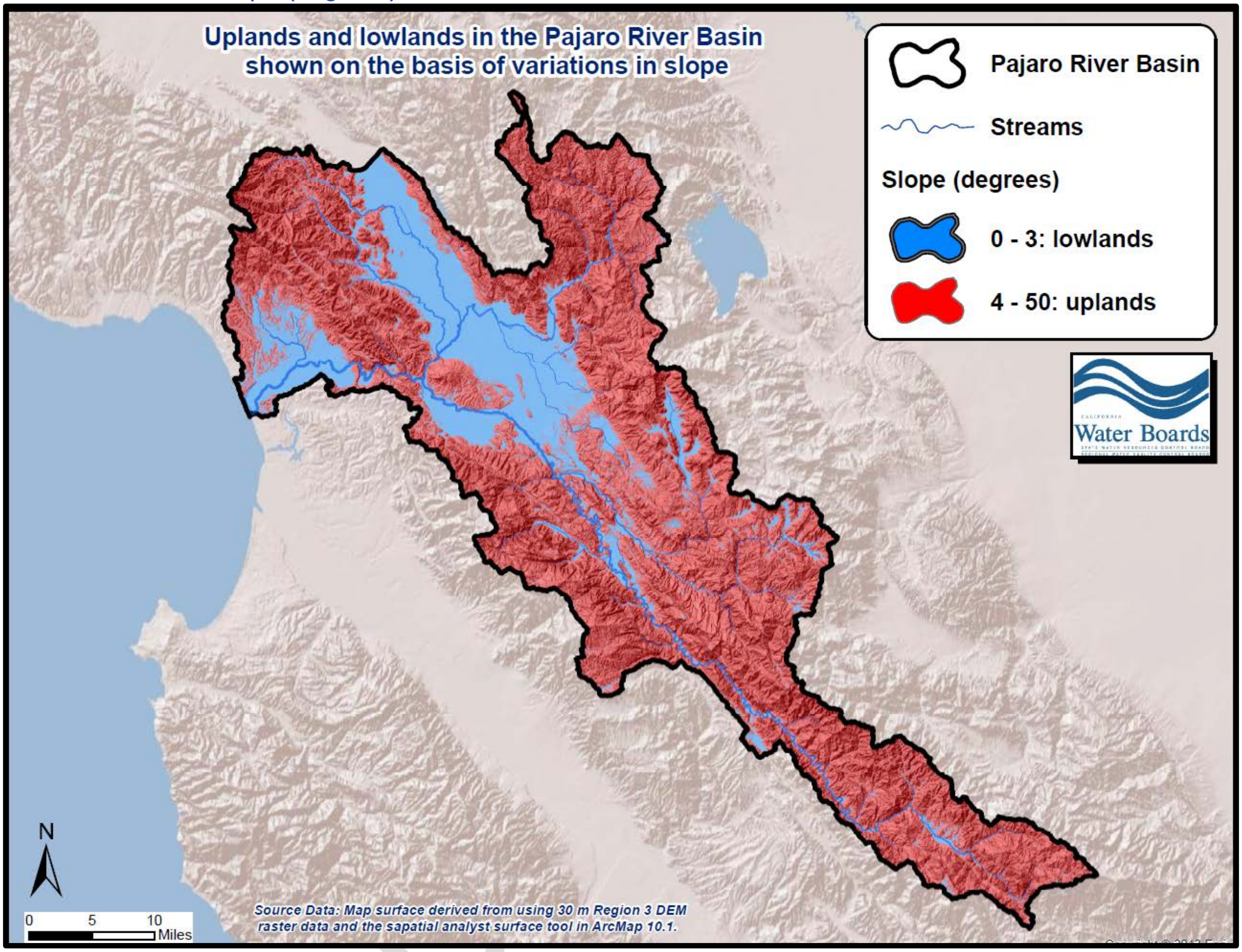
An additional reason for assessing geomorphic conditions in the watershed is that geomorphic conditions can potentially be used in grouping streams into categories, consistent with nutrient water quality target development guidance from USEPA.

Further, California central coast researchers have reported a linkage between geomorphology and biostimulatory impairments in the Pajaro River basin:

> "*Sections of the Pajaro River watershed have been listed by the State of California as impaired for nutrient and sediment violations under the Clean Water Act ……**The best evidence linking elevated nutrient concentrations to algae growth was shown when the stream physiography, geomorphology, and water chemistry were incorporated into the survey and analysis**."*****
>
> ********emphasis added***
>
> *From: University of California, Santa Cruz (2009). Final Report: Long-Term, High Resolution Nutrient and Sediment Monitoring and Characterizing In-stream Primary Production. Proposition 40 Agricultural Water Quality Grant Program (Project Lead: Dr. Marc Los Huertos).*

Figure 3-16 broadly illustrates the distribution of lowlands and uplands in the Pajaro River basin, on the basis of variations in slope as derived from a 30 meter digital elevation model.

Figure 3-16. Map showing distribution of lowlands and uplands in the Pajaro River basin on the basis of variations in land slope (degrees).



Generalized geomorphic landscape provinces of the Pajaro River basin are presented in Figure 3-17. Landscapes of the northern parts of the river basin include the coastal Monterey Bay Plains and Terraces[22] and the inland, intermontane Santa Clara Valley. These lowlands are characterized by gently sloping to nearly level floodplains, alluvial fans, and stream terraces. These lowlands are dissected by a series of northwest-southeast trending upland features including the Santa Cruz Mountains, the Leeward Hills, and the Western Diablo Range. Landscapes of the southern parts of the Pajaro River basin are dominantly characterized by uplands of the Gabilan and Diablo ranges.

[22] Locally, this geomorphic landscape area is generally known as the "Pajaro Valley"

Figure 3-17. Physiographic landscapes of the Pajaro River basin on the basis of Level IV ecoregions.

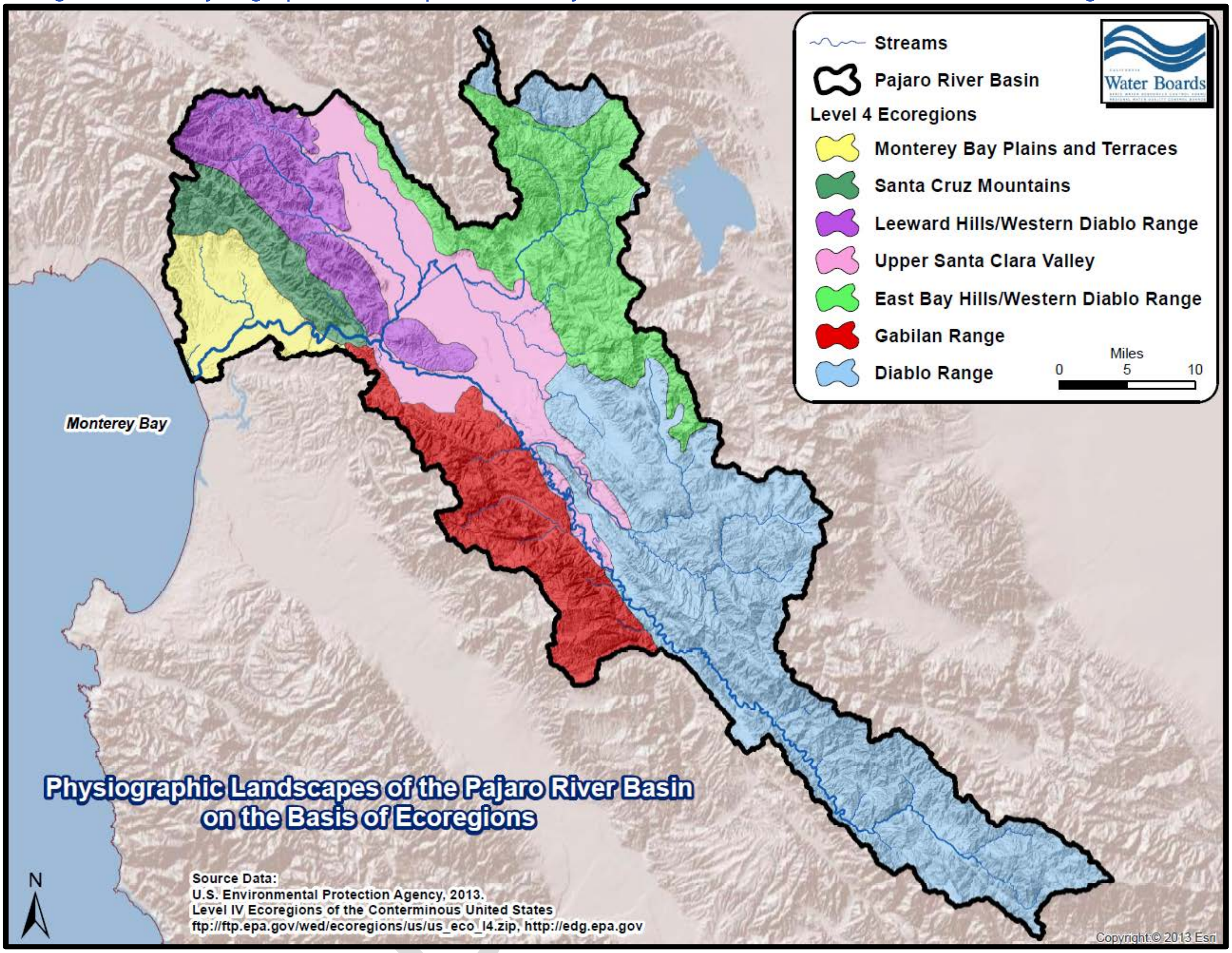
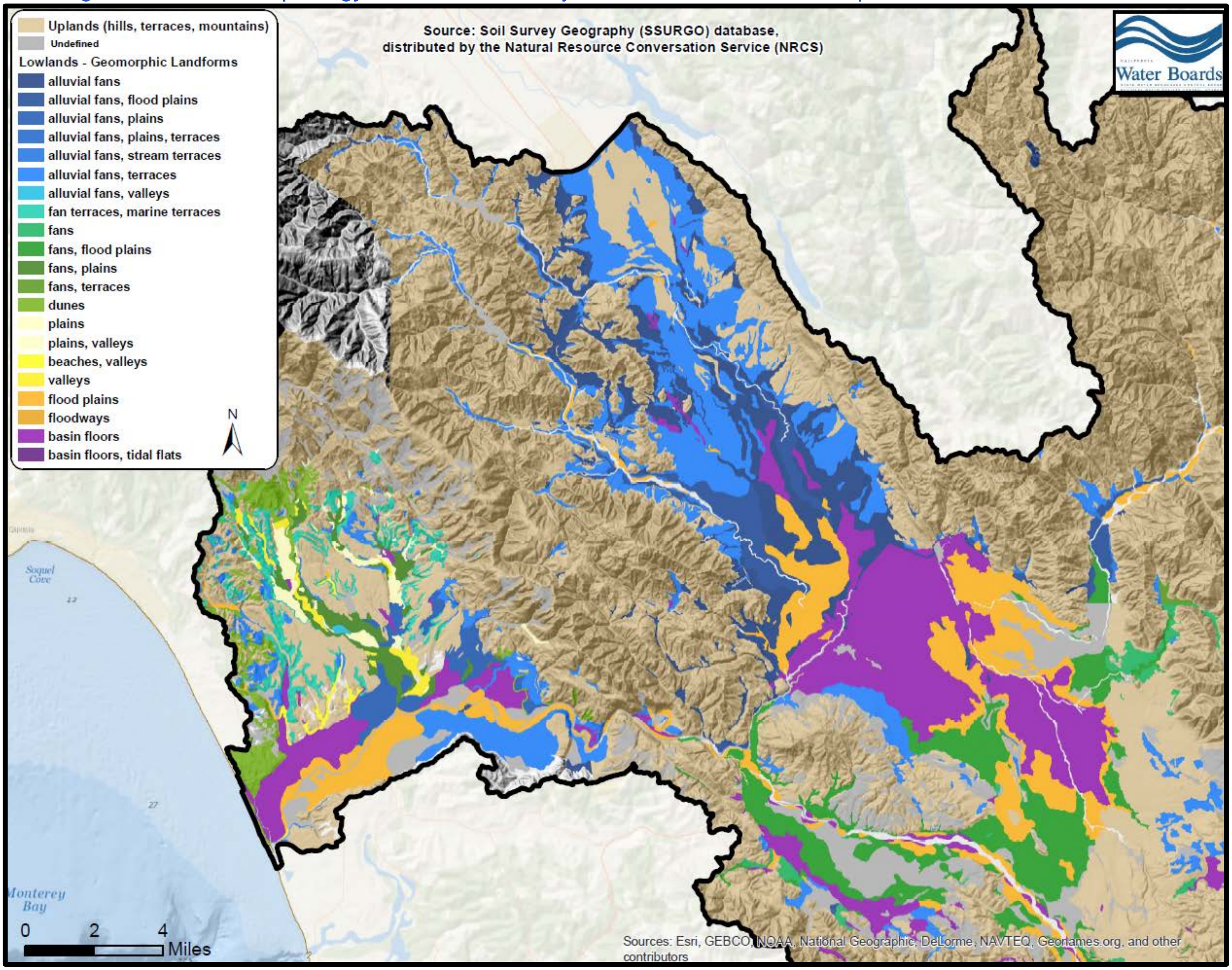


Figure 3-18 illustrates geomorphic landscape descriptions of the Pajaro River basin; these geomorphic descriptions are available from U.S. Department of Agriculture National Resources Conservation Service (NRCS) Soil Survey Geographic (SSURGO) Database. Low gradient areas such as basin floors, flood plains, sloughs, and alluvial valleys are physiographic areas that are likely to be at higher risk of summertime algal growth and excessive algal biomass in surface waterbodies, relative to higher gradient, higher canopy, and non-perennial flow upland areas.

Figure 3-18. Geomorphology of the northern Pajaro River basin, with an emphasis on lowland landforms.



3.6 Nutrient Ecoregions & Reference Conditions

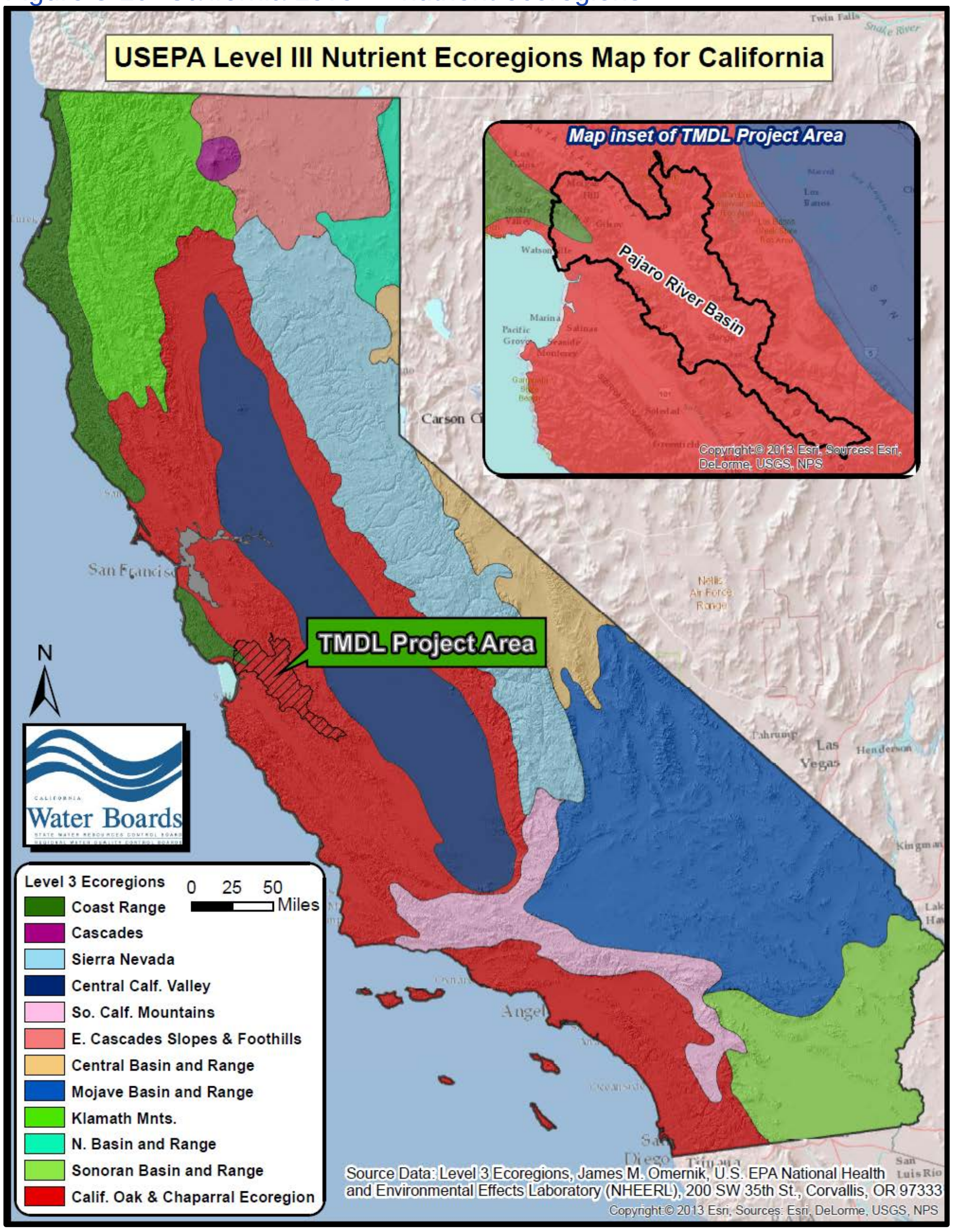
Nutrient ecoregions are USEPA designations for subregions of the United States that denote areas with ecosystems that are generally similar (e.g., physiography, climate, geology, soils, land use, hydrology). The Pajaro River basin is located largely in Ecoregion III subecoregion 6 – Southern and Central California Chaparral and Oak Woodlands[23] (see Figure 3-19). The primary distinguishing characteristic of this ecoregion is its Mediterranean climate of hot dry summers and cool moist winters, and associated vegetative cover comprising mainly chaparral and oak woodlands; grasslands occur in some lower elevations and patches of pine are found at higher elevations. Most of the California Chaparral and Oak Woodlands ecoregion consists of open low mountains or foothills, but there are areas of irregular plains in the south and near the border of the adjacent Central California Valley ecoregion. A small portion of the Pajaro River basin (approximately 40 square miles of the Santa Cruz Mountains) is located in Ecoregion II subecoregion 1 – Coast Range[24] (see Figure 3-19). The primary distinguishing

[23] Also referred to throughout this report more concisely as “Nutrient subecoregion 6”.
[24] Also referred to more concisely as “Nutrient subecoregion 1.”

characteristic of this subecoregion is its highly productive, rain-drenched coniferous forests that cover the low mountains of the Coast Range. Sitka spruce and coastal redwood forests originally dominated the fog-shrouded coast, while a mosaic of western red cedar, western hemlock, and Douglas-fir blanketed inland areas. Today Douglas-fir plantations are prevalent on the intensively logged and managed landscape.

Ecoregional natural variation illustrates that a single, uniform regulatory numeric nutrient water quality target is not appropriate at the national or state-level scale. At the larger geographic scales, natural ambient nutrient concentrations and associated biostimulatory risks in surface waters are highly variable due to variations in vegetation, hydrology, climate, geology and other natural factors. As such, it is important to consider natural variability of nutrient concentrations locally at smaller geographic scales (e.g., the ecoregional, watershed, or subwatershed-scales). Therefore, note that some subsequent elements or sections of this Project Report will reference nutrient water quality conditions in Ecoregion III subecoregion 6 (i.e., Calif. Oak and Chaparral subecoregion).

Figure 3-19. California Level III nutrient ecoregions.



➢ *USEPA Ecoregional Nutrient Numeric Criteria*

In 2000, the USEPA published ambient numeric criteria to support the development of State nutrient criteria in rivers and streams of Nutrient Ecoregion II and III. Narrative from the 2000 USEPA guidance is reproduced below (emphasis added):

> (The 2000 report) presents EPA's nutrient criteria for **Rivers and Streams in Nutrient Ecoregion II and III.** These criteria provide EPA's recommendations to States and authorized Tribes for use in establishing their water quality standards consistent with section 303(c) of CWA [Clean Water Act]. Under section 303(c) of the CWA, States and authorized Tribes have the primary responsibility for adopting water quality standards as State or Tribal law or regulation. The standards must contain scientifically defensible water quality criteria that are protective of designated uses. **EPA's recommended section 304(a) criteria are not laws or regulations** – they are guidance that States and Tribes may use as a starting point for the criteria for their water quality standards.
>
> In developing these criteria recommendations, EPA followed a process which included, to the extent they were readily available, the following elements critical to criterion derivation:
>
> **Historical and recent nutrient data in Nutrient Ecoregion II & III:** Data sets from Legacy STORET, NASQAN, NAWQA and EPA Region10 were used to assess nutrient conditions from 1990 to 1998.
>
> **Reference sites/reference conditions in Nutrient Ecoregion II & III:** Reference conditions presented are based on 25th percentiles of all nutrient data including a comparison of reference condition for the aggregate ecoregion versus the subecoregions. States and Tribes are urged to determine their own reference sites for rivers and streams within the ecoregion at different geographic scales and to **compare** them to EPA's reference conditions.
>
> The intent of developing ecoregional nutrient criteria is to represent conditions of surface waters that are minimally impacted by human activities and thus protect against the adverse effects of nutrient over enrichment from cultural eutrophication. EPA's recommended process for developing such criteria includes physical classification of waterbodies, determination of current reference conditions, evaluation of historical data and other information (such as published literature), use of models to simulate physical and ecological processes or determine empirical relationships among causal and response variables (if necessary), expert judgment, and evaluation of downstream effects. To the extent allowed by the information available, EPA has used elements of this process to produce the information contained in this document. **The values for both causal (total nitrogen, total phosphorus) and biological and physical response (chlorophyll *a*, turbidity) variables <u>represent a set of starting points</u> for States and Tribes to use in establishing their own criteria in standards to protect uses.** The values presented in this document generally represent nutrient levels that protect against the adverse effects of nutrient over enrichment and are based on information available to the Agency at the time of this publication. However, States and Tribes should critically evaluate this information in light of the specific designated uses that need to be protected.
>
> *-from: Ambient Water Quality Criteria Recommendations – River and Streams in Nutrient Ecoregion III, USEPA December 2000.*

USEPA's Technical Guidance Manual for Developing Nutrient Criteria for Rivers and Streams (USEPA, 2000a) describes two ways of establishing a reference condition. USEPA proposed that the 25th percentiles of all nutrient water quality data could be assumed to represent unimpacted reference conditions for each aggregate ecoregion, and also provided a comparison of reference condition for the aggregate ecoregion versus the subecoregions.

USEPA characterized 25th percentile values of a population of water quality data as criteria recommendations that could be used to protect waters against nutrient over-enrichment (USEPA, 2000a). However, USEPA also cautioned that States and Tribes may "need to identify with greater precision the nutrient levels that protect aquatic life and recreational uses. USEPA also proposed that the 75th percentiles of all nutrient data of reference stream(s) could be assumed to represent unimpacted reference conditions for each aggregate ecoregion, and also provided a comparison of reference condition for the aggregate ecoregion versus the subecoregions. USEPA (U.S. Environmental Protection Agency) defines a reference stream as follows:

"A reference stream is a least impacted waterbody within an ecoregion that can be monitored to establish a baseline to which other waters can be compared. Reference streams are not necessarily pristine or undisturbed by humans."

For reference, USEPA's 25th percentiles (representing unimpacted reference conditions) for the California Oak and Chaparral subecoregion (i.e., nutrient subecoregion 6) are presented in Table 3-11. Percentiles for Coastal Range subecoregion (i.e., nutrient subecoregion 1) are presented in Table 3-12.

Table 3-11. USEPA Reference conditions for Level III subecoregion 6 streams.

Parameter	25th Percentiles based on all seasons data for the decade
Total Nitrogen (TN) – mg/L	0.52
Total Phosphorus (TP) – mg/L	0.03
Chlorophyll *a* – µg/L	2.4
Turbidity - NTU	1.9

Table 3-12 . USEPA Reference conditions for Level III subecoregion 1 streams.

Parameter	25th Percentiles based on all seasons data for the decade
Total Nitrogen (TN) – mg/L	0.14
Total Phosphorus (TP) – mg/L	0.010
Chlorophyll *a* – µg/L	1.53
Turbidity - NTU	1.08

It should be re-emphasized that the above ecoregional criteria are not regulatory standards, and USEPA in fact considers them "starting points" developed on the basis of data available at the time. USEPA has recognized that States need to evaluate these values critically, and assess the need to develop nutrient targets appropriate to different geographic scales and at higher spatial resolution.

- ***Historical Nitrate Concentrations in California Alluvial Valley Rivers***

Development of nutrient water quality criteria could consider variations between lowland ecosystems and upland ecosystems. Often, reference background nitrate water quality conditions are heavily weighted towards undisturbed or lightly-disturbed tributary reaches located in headwater or upland reaches of a river basin. This is because most valley floor areas of California have been developed for agricultural or residential land uses, and thus are not representative of undisturbed systems.

Nutrient criteria development guidance published by the State of California notes that nutrient water quality targets established for main stem river or alluvial valley stream reaches should not be lower than concentrations found in undisturbed tributary reaches or background conditions in the river basin (TetraTech, 2006). Also noteworthy, a scientific peer reviewer has previously stated to Central Coast Water Board staff that headwater and lightly-disturbed tributary reaches may not be fully representative of lowland ecosystems (Buetel, 2012). Alluvial river valleys in California, and indeed throughout the world, tend to be highly modified by human activities, because they are generally ideal locations for agriculture, commerce, and human populations. Thus, there can be uncertainty about what ambient, undisturbed, natural background nutrient water quality should be expected in an alluvial valley river.

Table 3-13 presents historical nitrate water quality data from alluvial valley stream reaches in California from sampling conducted in the years 1907 to 1908[25]. The years 1907-08 represents a time when

[25] It is important to recognize that analytical techniques and analytical precision for water sampling have changed over the last century, so the historical 1907-08 nitrate water quality data should be considered informational and anecdotal only, and should not be considered a definitive representation of undisturbed, ambient alluvial valley river conditions.

human impacts to surface waters in California rivers undoubtedly tended to be significantly less than today. Thus these century-old, vintage nitrate concentration data may be a close proxy to natural or lightly-impacted nitrate concentrations that may be expected in alluvial valley rivers of California. Note that, on average, alluvial valley river waters in 1907-08 contained 0.31 mg/L nitrate as N, with 90 percent of the samples collected having concentrations under 0.45 mg/L. In contrast, recent data indicate that wadeable streams in undisturbed upland and headwater reaches of California (see Table 3-14) collectively tend to have marginally lower nitrate as N concentrations – a mean nitrate as N concentration of 0.15 mg/L, and 90% of the samples having concentrations below 0.23 mg/L nitrate as N[26]. Thus, while data from the historical alluvial valley river waters, and the upland tributary stream waters are both generally quite low in nitrate, it is worth noting that the 1907-08 vintage water quality data from alluvial valley rivers tend to have nitrate concentrations noticeably higher than the sampled upland tributary streams – around 0.31 mg/L vs 0.15 mg/L nitrate as N on average, respectively. Figure 3-20 illustrates the aforementioned information in map-view.

To further probe possible differences between the historical alluvial valley river data and the upland tributary data, a two-sample Wilcoxon Rank Sum Test[27] of the two datasets (i.e., the historical alluvial valley river nitrate data and the upland tributary nitrate data) using R[28] indicates that the alluvial valley river waters are generally higher in nitrate as N concentration (median = 0.181 mg/L) than nitrate as N in waters from the upland tributary streams (median = 0.068 mg/L). Further, the differences in the nitrate concentrations between the two datasets is highly statistically significant (P-value < 2.2e-16)[29] indicating a very small probability of observing this difference by random chance. Practically speaking, this suggests that nitrate concentrations observed in waters of historical alluvial valley rivers of central and southern California are generally higher than nitrate concentrations observed in wadeable streams of headwater and upland tributary reaches of California. While understanding that there are uncertainties in comparing two datasets of substantially different vintages, this constitutes at least a circumstantial line of evidence that ambient waters of alluvial valley rivers are generally higher in nitrate concentration than ambient waters of upland tributary stream reaches in California.

Based on staff's knowledge of state water quality data, it is extremely unlikely that an alluvial valley floor stream could be expected to achieve a water quality condition of 0.11 mg/L nitrate as N, commensurate with the observed undisturbed headwater wadeable stream average condition from Table 3-14[30]. Indeed, as noted previously, headwater and lightly-disturbed tributary reaches may not be fully representative of lowland ecosystems (Buetel, 2012). Further, in contrast to headwater stream reaches, alluvial valley floors are typically characterized by thick, well-developed, and extensive soil profiles, and researchers have stated that waterbodies can be expected to interact with soil nitrogen (for example, Moran et al., 2011).

On the basis of the aforementioned information, in the development of nutrient water quality criteria for alluvial valley rivers and streams, it may be important to ensure that the numeric criteria not be unduly weighted or biased by nutrient water quality data from upland, tributary stream reaches.

[26] On the basis of data collected by the State Water Resources Control Board, Surface Water Ambient Monitoring Program, Reference Conditions Management Plan to Support Biological Assessment of California's Wadeable Streams.

[27] Also widely known as the Mann-Whitney test.

[28] R Core Team (2013). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org

[29] By convention, P-values are considered to indicate statistical significance when the P-value < 0.05.

[30] It is important to recognize that nitrogen in aqueous systems exists in many forms other than the nitrate molecule. Hypothetically, in headwater upland reaches, stream nutrients could exist more preferentially in the form of organic matter such as woody debris, and leaf drop (personal communication, Karen Worcester, senior environmental scientist, Central Coast Water Board).

Table 3-13. Numerical summary of early 20th century (1907-1908) river nitrate (as N) water quality from alluvial valley floor river reaches in central and southern California.

River - Sampling Location	Dates sampled	Arithmetic Mean	Min	25th %	50th % (median)	75th %	90th %	Max	No. of Samples
Ventura River at Ventura	Dec. 1907 – Dec. 1908	0.17	0.02	0.07	0.14	0.17	0.27	1.36	35
Salinas River at Paso Robles	Dec. 1907 – Dec. 1908	0.17	0.04	0.09	0.14	0.23	0.30	0.41	30
Salinas River at Spreckels	April 1908 – August 1908	0.26	0.23	0.24	0.26	0.28	0.29	0.29	2
San Antonio River above Bradley	Dec. 1907 – Dec. 1908	0.24	trace	0.16	0.25	0.32	0.40	0.45	37
San Gabriel River near Azusa	Dec. 1907 – Dec. 1908	0.28	0.02	0.07	0.16	0.23	0.40	3.84	32
San Joaquin River at Lathrop	Dec. 1907 – Dec. 1908	0.25	0.08	0.16	0.23	0.32	0.43	0.54	34
Estrella River near San Miguel	Dec. 1907 – Dec. 1908	0.20	trace	0.10	0.16	0.25	0.35	0.90	37
Mojave River at Victorville	March 17, 1908	0.08	0.08	0.08	0.08	0.08	0.08	0.08	1
Nacimiento River near San Miguel	Jan. 1908 – Dec. 1908	0.99	0.05	0.32	0.45	0.88	1.79	9.04	34
Sacramento River above Sacramento	Dec. 1907 – Dec. 1908	0.15	0.02	0.09	0.12	0.20	0.24	0.36	34
Numerical composite summary for all river sampling events	Dec. 1907 to March 1908	0.31	trace	0.1	0.18	0.29	0.45	9.04	276

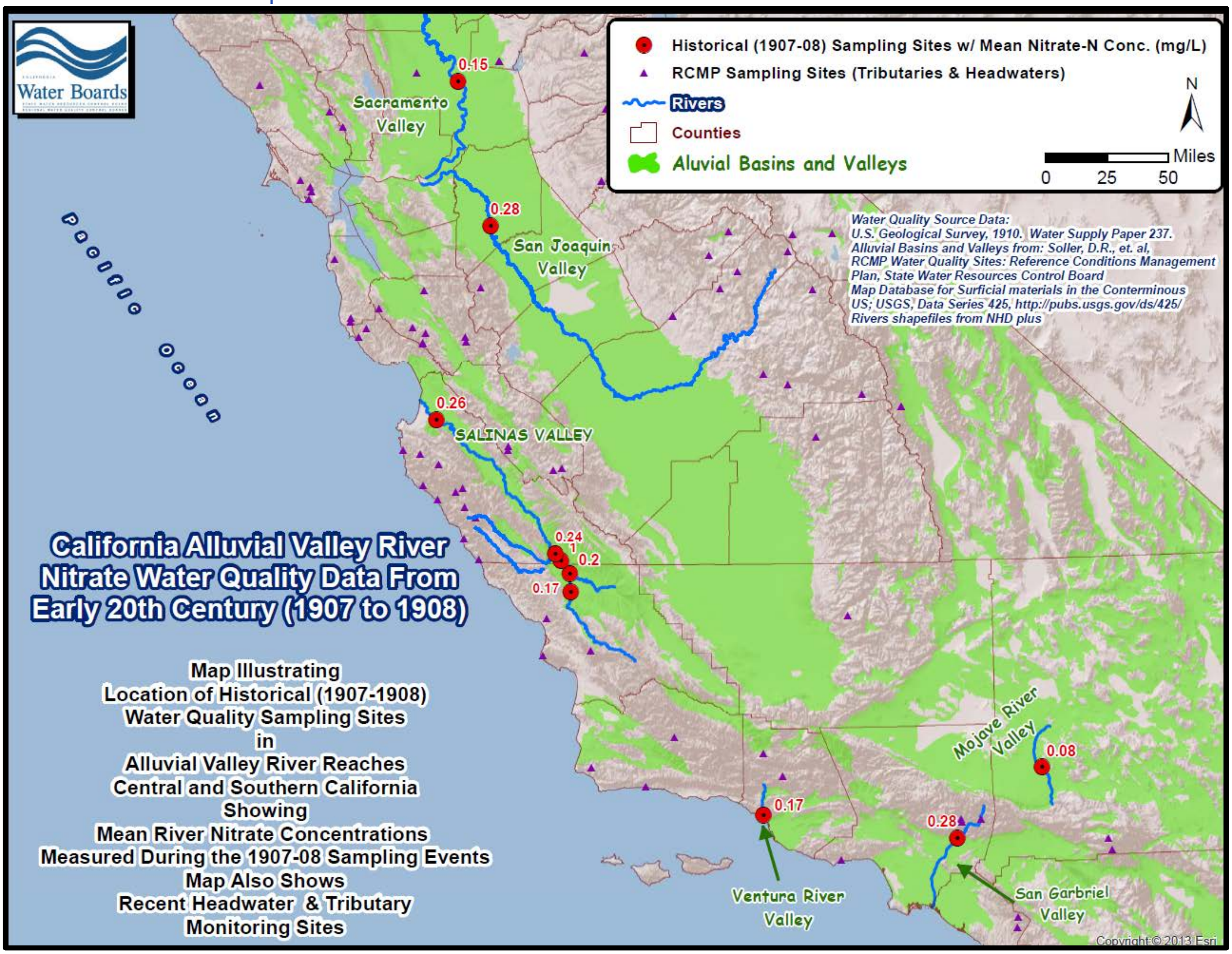
Data source: U.S. Geological Survey, 1910. Water Supply Paper 237, The Quality of the Surface Waters of California. Note: In the 1910 report, nitrate is reported as the nitrate molecule; in this table staff converted the reported nitrate values to elemental nitrogen equivalent (nitrate as N).

Table 3-14. Numerical summary of nitrate (as N) water quality from wadeable streams in upland and tributary reaches of California .

Stream Types	Sampling locations	Dates sampled	Number of samples	Nitrate as N statistical summary for all samples	
Wadeable streams in upland & headwater reaches	108 upland & headwater streams throughout California	May 2008 – Sept. 2010	108	mean	0.15 mg/L
				min	<0.01 mg/L
				25%	0.022 mg/L
				50%	0.068 mg/L
				75%	0.013 mg/L
				90%	0.23 mg/L
				max	6.5 mg/L

Data source: RCMP – State Water Resources Control Board, Surface Water Ambient Monitoring Program, Reference Conditions Management Plan (RCMP) to Support Biological Assessment of California's Wadeable Streams

Figure 3-20. Map illustrating early 20th century (1907–1908) river nitrate (as N) water quality in central and southern California alluvial valley river reaches on the basis of data previously presented in Table 3-13. The locations of upland tributary and headwater stream monitoring sites from Table 3-14 are also annotated on the map.



One way to establish plausible reference conditions appropriate for stream reaches of the Pajaro River basin, is to apply the US Environmental Protection Agency (USEPA) reference stream methodology (75th percentile approach, as described previously) for water quality data from natural or lightly-disturbed headwater and tributary reaches in and around the Pajaro River basin (see Figure 3-21) for map of reference conditions monitoring sites). It should be noted that these sites are most directly representative of uplands, since most remaining undisturbed or lightly-disturbed areas of California's central coast region are associated with upland ecosystems. USEPA chose the 75th percentile since this percentile is likely associated with minimally impacted conditions and will be protective of designated uses. For informational purposes, staff also calculated the 90th percentiles of nitrogen and phosphorus compounds concentrations in these reaches to assess plausible "high-end" concentrations of these constituents which might be expected in lightly-disturbed areas. A tabular summary of the reference monitoring sites are presented in Table 3-15 and numerical summaries of the water quality data from these sites are presented in Table 3-16. It can be concluded from these data that nitrate as N and total nitrogen background surface water quality represented by these sites are generally less than 1 mg/L nitrate as N; orthophosphate is generally less than 0.1 mg/L. It is noteworthy that streams of the Santa

Cruz Mountains and Monterey Plains ecoregion locally (Pescadero Creek) have anomalously elevated total phosphorus and orthophosphate concentrations. Staff hypothesizes that the presence of phosphatic rocks and phosphatic sediments associated locally with Miocene marine strata may be a contributor to elevated levels of phosphorus in Pescadero Creek waters (see report Section 3.10).

Figure 3-21. Human footprint map and ecoregional stream water quality reference monitoring sites which are plausibly representative of natural background or lightly-disturbed conditions in upland reaches. Reference conditions stream water quality monitoring sites here are grouped on the basis of Level IV ecoregions, refer back to Section X and Figure Y for a map of level IV ecoregions.

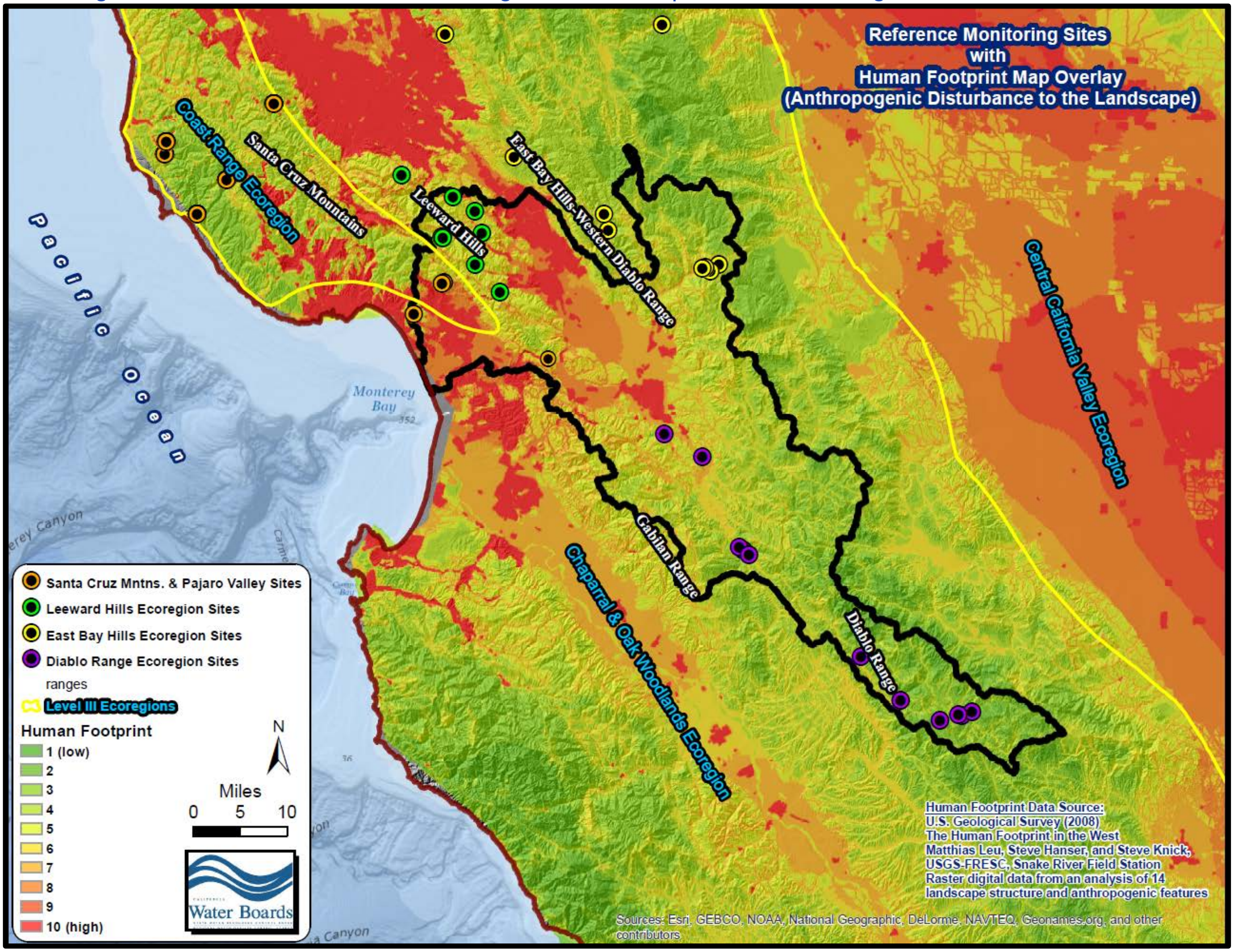


Table 3-15. Level IV ecoregional water quality reference conditions monitoring sites in lightly disturbed reaches in and around the Pajaro River basin. Map view of monitoring sites shown in Figure 3-21.

Level IV Ecoregion(s)[A] refer back to Figure 3-21 for geographic reference for monitoring sites and refer to Figure 3-17 for map of Level IV ecoregions.	**Reference Conditions Monitoring Sites**
Santa Cruz Mountains and Monterey Bay Plains and Terraces (Pajaro Valley upland reaches)	San Pedro Creek upstream footbridge
	Little Butano Creek @ Butano State Park
	Upper Stevens Creek
	Sempervirens Creek above Hwy 236

Level IV Ecoregion(s)[A] refer back to Figure 3-21 for geographic reference for monitoring sites and refer to Figure 3-17 for map of Level IV ecoregions.	**Reference Conditions Monitoring Sites**
	Butano Creek @ Girl Scout Camp
	Waddell Creek ~1.8mi above Hwy 1
	Browns Creek at Browns Valley Road
	Browns Creek at Browns Rd and Caudill
	Harkins Slough at White Road
	Pescadero Creek NE of Chittendon at RR Tracks
Leeward Hills and Upper Santa Clara Valley (westside upland reaches)	Llagas Creek above Chesbro Reservoir
	Llagas Creek above Baldy Ryan Canyon. Creek
	Swanson Creek above Uvas Creek
	Uvas Creek above Swanson Canyon Creek
	Little Arthur Creek ~1mi west of Redwood Retreat Rd.
	Blackhawk Canyon Tributary To Bodfish Creek
	Uvas Creek above Uvas Reservoir
	Uvas Creek at Canyon County Park
	Guadalupe Creek above Res
East Bay Hills / Western Diablo Ranges (including the Pacheco Creek Subbasin)	Coyote Creek Hunting Hollows
	Del Puerto Creek
	Upper Penitencia Creek Upper Alum Rock Park
	Coyote Creek ~1.4 mi below Big Canyon.
	Pacheco Creek ~1.3 mi Above South Fork
	Pacheco Creek South Fork 1.1 mi SE/Pacheco Ln
	Pacheco Creek South Fork near Pacheco Lake
	Pacheco Creek just below North Fork Confluence
	Coyote Creek below confluence of West Fork
	Las Animas Creek Below San Felipe Creek
Diablo Range (San Benito River Subbasin)	San Benito River Bridge 1.9 mi downstream of Willow Creek
	Tres Pinos Creek at Southside Rd
	San Benito River below Hernandez Reservoir
	San Benito River 0.4 mi below Willow Creek
	Tres Pinos Creek At Hwy. 25
	Clear Creek
	Laguna Creek
	San Benito River at Willow Creek School

[A] Refer back to Figure 3-17

Table 3-16. Numerical summaries of water quality data from reference conditions monitoring sites.

Level IV Ecoregion [A]	**Parameter** [B, C]	**Dates sampled**	**Arithmetic Mean**	**Min**	**25th %**	**50th % (median)**	**75th %**	**90th %**	**Max**	**No. of Samples**
Santa Cruz Mountains and Monterey Bay Plains and Terraces (Pajaro Valley upland reaches)	Nitrate as N	Dec. 1997-Dec. 2013	0.346	0.006	0.113	0.113	0.226	0.57	9.72	134
	Total Nitrogen	June 2009-June 2010	0.094	0.0402	0.0491	0.0802	0.104	0.158	0.213	6
	Orthophosphate as P	Dec. 1997-June 2013	0.131	0.018	0.05	0.066	0.135	0.293	1.09	60
	Total Phosphorus	Dec. 1997-June 2010	1.04	0.037	0.058	0.067	1.1	3.44	4.8	9
	Dissolved Oxygen	Dec. 1970-June 2010	8.94	6.9	8.4	8.8	9.35	10	12	46

Level IV Ecoregion [A]	Parameter [B, C]	Dates sampled	Arithmetic Mean	Min	25th %	50th % (median)	75th %	90th %	Max	No. of Samples
	pH	Dec. 1997-June 2010	7.52	6.95	7.5	7.5	7.5	8	8.4	46
	Chlorophyll *a*	June 2009-June 2010	10.4	3.84	7.71	9.53	14.1	16	16.6	6
Leeward Hills and Upper Santa Clara Valley (westside upland reaches)	Nitrate as N	Feb. 1998-July 2010	0.103	0.005	0.02	0.032	0.12	0.26	0.504	17
	Total Nitrogen	June 2001-July 2010	0.129	0.07	0.078	0.118	0.157	0.195	0.221	5
	Orthophosphate as P	Feb. 1998-July 2010	0.013	0.002	0.007	0.013	0.016	0.02	0.024	17
	Total Phosphorus	Oct. 1975-July 2010	0.036	0.004	0.0124	0.03	0.0358	0.085	0.13	16
	Dissolved Oxygen	Feb. 1998-July 2010	8.94	6.73	8.19	9.5	9.62	10.16	10.87	20
	pH	Feb. 1998-July 2010	7.95	7.53	7.77	7.92	8.09	8.22	8.61	16
	Chlorophyll *a*	Feb. 1998-June 2001	1.4	0.01	0.25	0.87	1	1.8	9.1	12
East Bay Hills / Western Diablo Ranges (including the Pacheco Creek Subbasin)	Nitrate as N	Mar1987-June 2010	0.09	0.003	0.006	0.031	0.07	0.2	0.44	8
	Total Nitrogen	Mar1987-June 2010	0.21	0.01	0.089	0.13	0.4	0.42	0.43	5
	Orthophosphate as P	Mar1987-June 2010	0.035	0.006	0.013	0.026	0.036	0.07	0.1	6
	Total Phosphorus	Feb. 1974-June 2010	0.020	0.002	0.008	0.017	0.032	0.036	0.049	11
	Dissolved Oxygen	Feb. 1974-June 2010	10.28	5.72	9.6	10.5	11.2	11.82	13	29
	pH	Mar1987-June 2010	7.98	7.21	7.85	7.96	8.28	8.37	8.53	8
	Chlorophyll *a*		No data for water column chlorophyll							
Diablo Range (San Benito River Subbasin)	Nitrate as N	Dec. 1997-Dec. 2011	0.23	0.003	0.021	0.028	0.17	0.82	1.85	109
	Total Nitrogen	July 1994-Dec. 2011	0.53	0.1	0.1	0.23	0.43	0.99	3.9	43
	Orthophosphate as P	July 1994-Dec. 2011	0.026	0.003	0.005	0.01	0.019	0.086	0.18	58
	Total Phosphorus	July 1994-Dec. 2011	0.38	0.003	0.016	0.04	0.12	0.53	6.6	55
	Dissolved Oxygen	Jan. 1953-Dec. 2011	9.79	3.99	8.71	9.7	10.8	11.6	16.9	352
	pH	Jan. 1998-Dec. 2011	8.46	7.57	8.37	8.48	8.58	8.64	9.5	156
	Chlorophyll *a*	Feb. 1998-Dec. 2011	3.2	0	0.88	1.37	3.99	6.31	27.4	49

[A] Refer back to Figure 3-17

[B] Units: all parameters reported in mg/L except chlorophyll *a* = micrograms/L and pH = – [log H+].

[C] Water quality data sources: see TMDL Report Section 5.2 and supplementary data from the State Water Resources Control Board, Surface Water Ambient Monitoring Program – Perennial Stream Survey & the Statewide Reference Condition Management Plan.

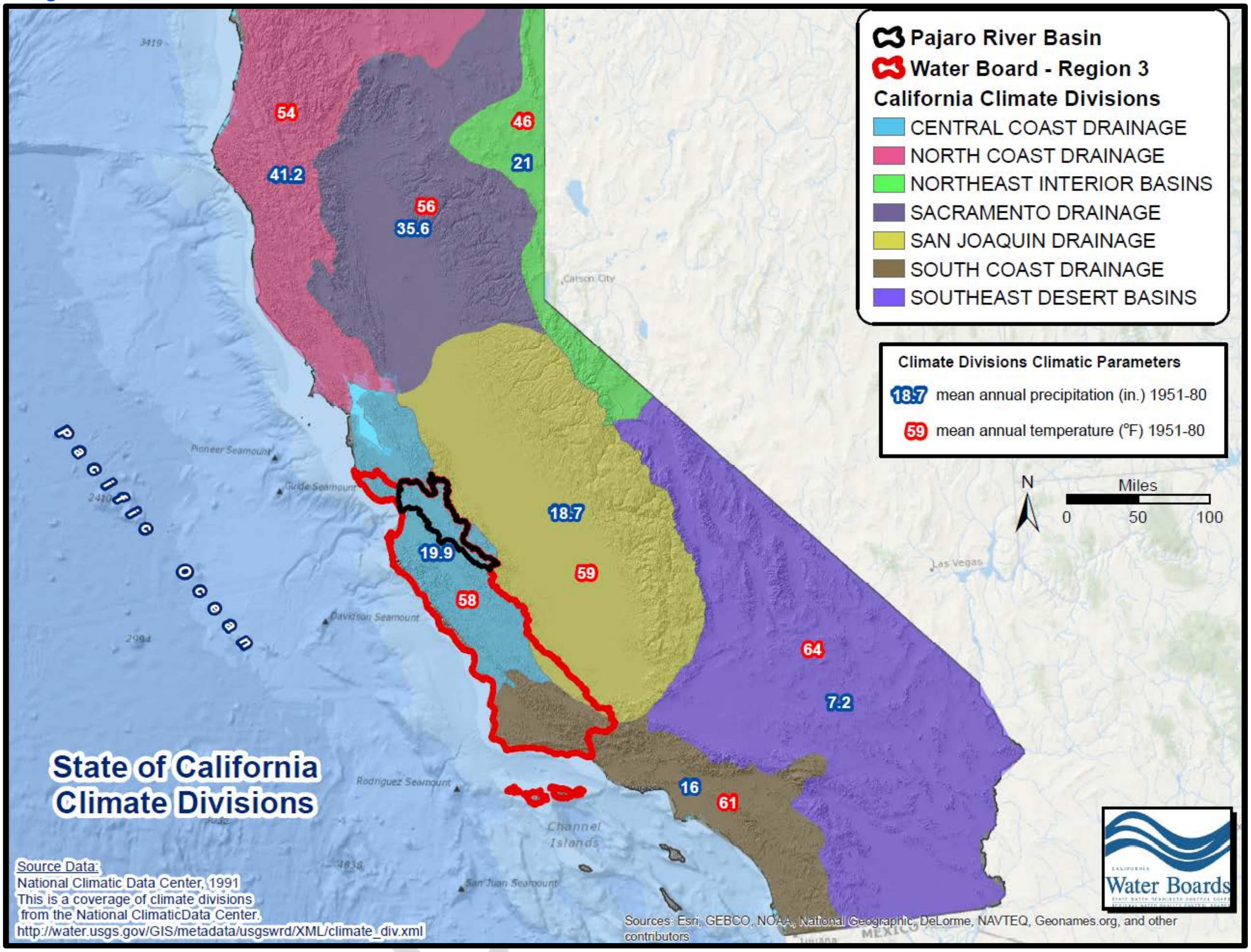
3.7 Climate & Atmospheric Deposition

Precipitation is often considered in the development of TMDLs. Having good estimates of precipitation in the Pajaro River basin is a necessary input parameter of the U.S. Environmental Protection Agency's STEPL source analysis spreadsheet tool staff used for source assessment (see Section 6.1). Further, staff compiled information on atmospheric deposition because atmospheric deposition of nitrogen may be important to consider as a nutrient source loading category.

➢ *Precipitation & Climatic Parameters*

The Pajaro River basin is located in the Central Coast Drainage Climate Division, as defined by the National Climatic Data Center (see Figure 3-22). .

Figure 3-22. California's climate divisions from the National Climatic Data Center.



Precipitation rain gage data in the Pajaro River basin is available from the National Oceanographic and Atmospheric Administration - Western Regional Climate Center (http://www.wrcc.dri.edu). The Pajaro River basin has a Mediterranean climate, with the vast majority of precipitation falling between November and April (see Table 3-17).

Table 3-17. Project Area rain gage precipitation records.

Station	Elevation (ft)	Climatic Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Watsonville Waterworks[A] (1938-2013)	95	Average Precipitation (inches)	4.52	3.89	3.02	1.52	0.49	0.14	0.04	0.05	0.30	0.99	2.39	4.18	**21.52**
Gilroy[A] (1906-2013)	194	Average Precipitation (inches)	4.70	3.74	3.24	1.40	0.39	0.10	0.05	0.05	0.32	0.90	2.21	3.72	**20.83**
Morgan Hill[A] (1948-2013)	375	Average Precipitation (inches)	4.83	4.72	3.21	1.50	0.29	0.00	0.03	0.00	0.04	0.95	2.39	3.70	**21.68**
Hollister 2[A] (1948-2013)	275	Average Precipitation (inches)	2.78	2.75	2.15	1.01	0.35	0.06	0.03	0.05	0.29	0.70	1.62	2.06	**13.86**

Station	Elevation (ft)	Climatic Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Pacines 5W[A] **(1948-2011)**	905	Average Precipitation (inches)	3.26	2.82	2.41	1.20	0.34	0.05	0.04	0.04	0.24	0.62	1.86	2.83	**15.71**
Corralitos (COR) [B]	450	Average Precipitation (inches)	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	**27.05**
Burrell Station (BRL) [B, C]	1,850	Average Precipitation (inches)	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	**42.60**

A: Western U.S. COOP weather station (Source: NOAA Western Regional Climate Center)
B: Calif. Dept. of Forestry weather station – data published in the California Natural Resources Agency CERES database
C: Located in Soquel Creek watershed of Santa Cruz mountains, 3.5 miles west of Pajaro Basin watershed boundary.
NR = not reported

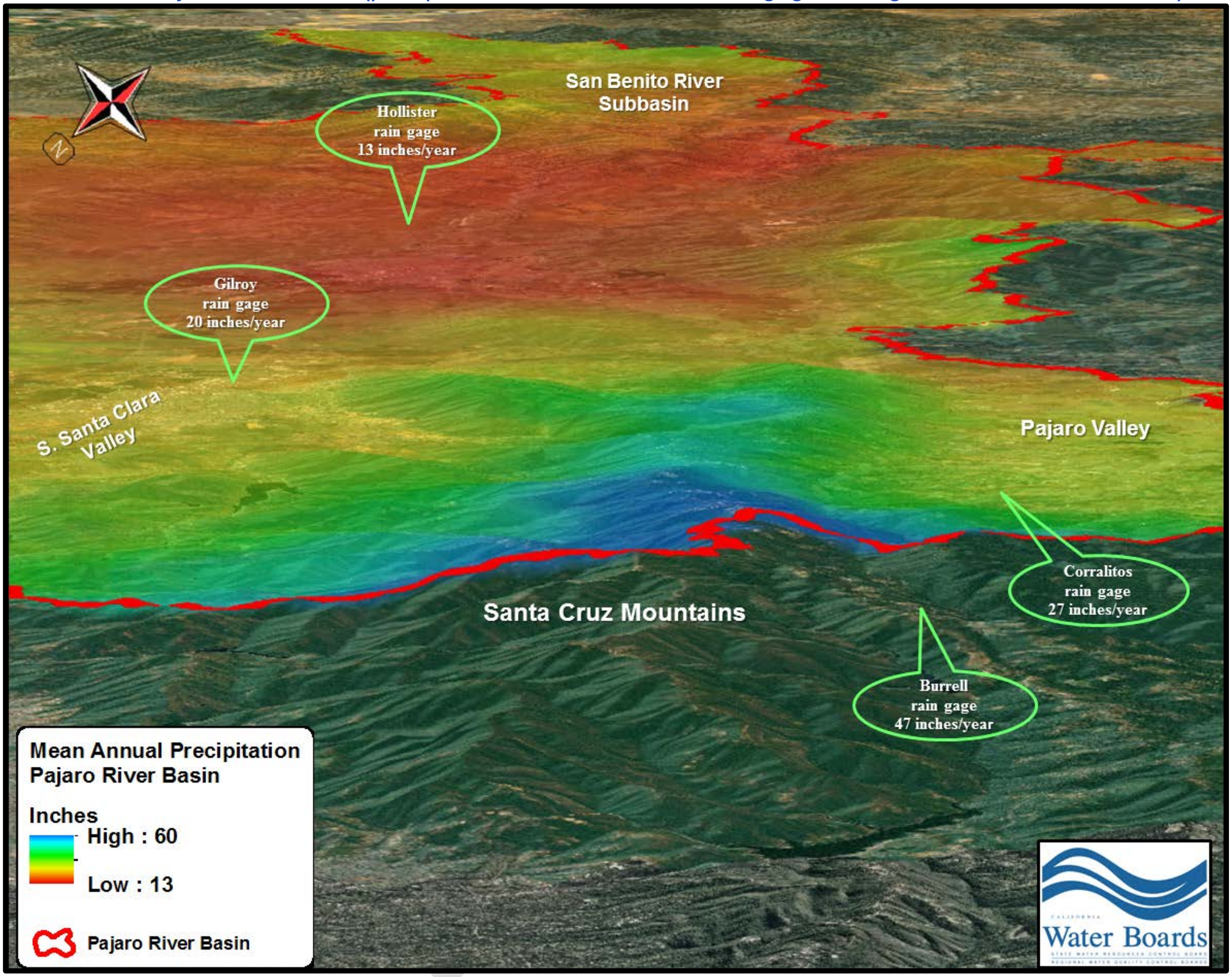
It is important to recognize that rainfall gauging stations have limited spatial distribution, and that gauging stations tend to be located in lower elevations where people live. Consequently, these locations can bias estimates of regional rainfall towards climatic conditions at lower elevations. The topography of the California central coast region however, can result in significant orographic enhancement of rainfall (i.e., enhancement of rainfall due to topographic relief and mountainous terrain – for example, refer back to the higher-elevation Burrell Station rain gauge station shown previously in Table 3-17).

Note that elevations in the Pajaro Basin range from sea level to over 3,000 feet above mean sea level. Topography, elevation, and atmospheric circulation patterns can have pronounced effects on regional precipitation patterns. For example, the coastal Santa Cruz mountains create a substantial orographic effect as moist marine air is lifted, cooled, and condenses passing over the mountains. A noteworthy example is illustrated by rain gage records from March 12-17, 2012 when a couple of remote rain gages in the Santa Cruz mountains near Ben Lomond and Boulder Creek received between 16 and 20 inches of rain over those five days. Meanwhile, during those same five days in San Jose (only 25 miles to the northeast on the downslope, leeward side of the Santa Cruz mountains), only two-thirds of an inch (0.66 inches) of rain fell[31].

Figure 3-23 is an illustration of the orographic effect of the Santa Cruz Mountains. Clearly, it is not appropriate to treat rainfall as a relatively uniform spatial attribute of the Pajaro River basin.

[31] National Weather Service, San Francisco Bay Area, Public Information Statement dated April 11, 2012 and entitled “March 2012 Regional Climate Summary”.

Figure 3-23. Illustration of orographic effects in the Pajaro River basin – oblique view looking southeast across the Pajaro River basin (precipitation source data from rain gages and gridded PRISM estimates)

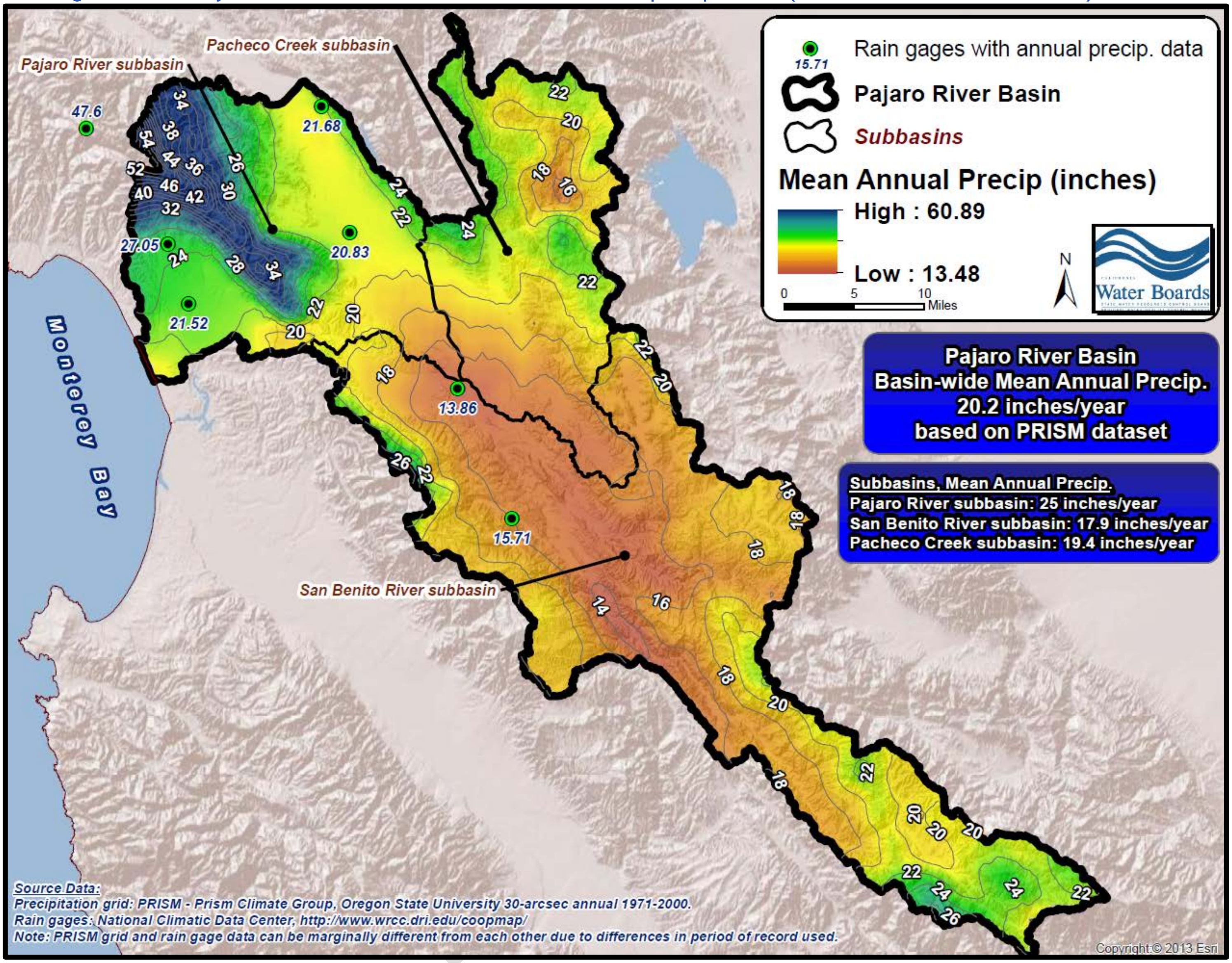


Therefore, due to climatic spatial variability, mean annual precipitation estimates for the Pajaro River basin may be assessed using the Parameter-elevation Regressions on Independent Slopes Model (PRISM)[32]. PRISM is a climate mapping system that accounts for orographic climatic effects and is widely used in watershed studies and TMDL projects to make projections of precipitation into rural or mountainous areas where rain gage data is often absent, or sparse. PRISM is also the U.S. Department of Agriculture's official climatological dataset and PRSIM is used by the U.S. National Weather Service to spatially interpolate rainfall frequency estimates. An isohyetal map for estimated mean annual precipitation in the TMDL project area, with overlays of the hydrologic subbasin boundaries, is presented in Figure 3-24. The precipitation range estimates shown in Figure 3-1 comport reasonably well with regional precipitation range estimates reported by the County of Santa Clara[33].

[32] The PRISM dataset was developed by researchers at Oregon State University, and uses point measurements of precipitation, temperature, and other climatic factors to produce continuous, digital grid estimates of climatic parameters. The dataset incorporates a digital elevation model, and expert knowledge of climatic variation, including rain shadows, coastal effects, and orographic effects. Online linkage: http://www.prism.oregonstate.edu/

[33] The *2007 Drainage Manual* published by the County of Santa Clara states: *"Mean annual precipitation ranges from 10 inches in the inland valley areas to 56 inches at the top of the Santa Cruz Mountains."*

Figure 3-24. Pajaro River basin estimated mean annual precipitation (1971-2000, source: PRISM).



Due to spatial variation in rainfall, it is prudent to develop not only a basin-wide estimate of mean annual rainfall, but also estimates of mean annual rainfall at the smaller subbasin scale. For example, it is clear that regional precipitation patterns and intensity in the Pajaro River Subbasin are different than in the San Benito River Subbasin. Consequently, based on the statistical summaries as calculated by ArcMap® 10.1 for digitally clipped PRISM rainfall grids, average precipitation estimates in the in the TMDL project area can be summarized as follows (see Table 3-18):

Table 3-18. Mean annual precipitation estimates within the Pajaro River basin.

Hydrologic Area	Estimated mean annual precipitation, accounting for orographic effects *(period of record 1971-2000)*
Pajaro River Basin (basin-wide)	20.2 inches/year
Pajaro River Subbasin	25 inches/year
Pacheco Creek Subbasin	19.4 inches/year
San Benito River Subbasin	17.9 inches/year

Further, PRISM precipitation grids allow for rainfall estimates at higher resolution spatial scales. Table 3-19 presents estimates of mean annual precipitation in subwatersheds in the Pajaro River basin.

Table 3-19. Estimated mean annual precipitation[A] within subwatersheds of the Pajaro River basin.

Subwatershed Name[B]	**Mean Annual Precipitation** (Inches) 1971-2000		**Subwatershed Name**[B]	**Mean Annual Precipitation** (Inches) 1971-2000
Clear Creek-San Benito River	22.2		Tequisquita Slough	17.8
Hernandez Reservoir-San Benito River	21.3		Watsonville Slough	23.1
James Creek-San Benito River	20.0		Lower Pajaro River	23.2
Rock Springs Creek-San Benito River	18.4		Arroyo De Las Viboras	20.2
Sulphur Creek-San Benito River	16.0		Salsipuedes Creek	26.2
Willow Creek	17.6		Lower Pacheco Creek	21.5
Stone Creek	17.9		South Fork Pacheco Creek	21.6
Upper Tres Pinos Creek	18.2		Lower Uvas Creek	24.4
Middle Tres Pinos Creek	16.4		Upper Pajaro River	19.4
Pescadero Creek	17.8		Corralitos Creek	32.5
Las Aguilas Creek	18.0		Upper Pacheco Creek	20.3
Los Muertos Creek	16.1		Lower Llagas Creek	21.0
Paicines Reservoir-San Benito River	15.2		Cedar Creek	21.2
Lower Tres Pinos Creek	14.8		Upper Uvas Creek	32.7
San Juan Canyon	19.5		Little Llagas Creek	21.2
Bird Creek-San Benito River	17.0		Upper Llagas Creek	28.8
Quien Sabe Creek	17.2		Lower North Fork Pacheco Creek	20.0
Santa Ana Creek	15.7		Upper North Fork Pacheco Creek	21.3

[A] Source data: PRISM Climate Group, Oregon State University, 30-arcsec annual precipitation grid, 1971-2000. PRISM precipitation zonal statistics were extracted for subwatersheds using the ArcMap 10.1™ Spatial Analyst extension.
[B] Refer back to Figure 3-5 and Table 3-3 for a map and tabulation of subwatersheds within the Pajaro River basin.

Noteworthy is that staff's estimate of a Pajaro River basin-wide mean of 20.2 inches of mean annual precipitation comports reasonably well with an estimate developed by consulting engineers − in 2001 Raines, Mellon and Carella, Inc. estimated a Pajaro basin-wide average annual rainfall of approximately 19 inches (Raines, Mellon and Carella, Inc., 2001).

Since development of nutrient numeric water quality targets are intended to take into account regional physical, hydrologic, and climatic variation, staff also considered additional climatic parameters for the Pajaro River basin. Figure 3-25 illustrates estimates for mean annual potential evapotranspiration[34] (PET) and aridity indices[35] (AI) in the river basin. PET and AI are climatic parameters used to characterize degree of aridity or humidity at regional scales. Potential evapotranspiration (PET) rates in the Pajaro River basin average 1,317 millimeters per year, with a range of 1,101 to 1,526 millimeters/year. PET is lower in the Pajaro Valley and Santa Cruz Mountains, and is marginally higher in the Pacheco Creek and San Benito River subbasins (refer to Figure 3-25). Pajaro River basin aridity index (AI) values average 0.37, with a range of 0.255 to 0.778.

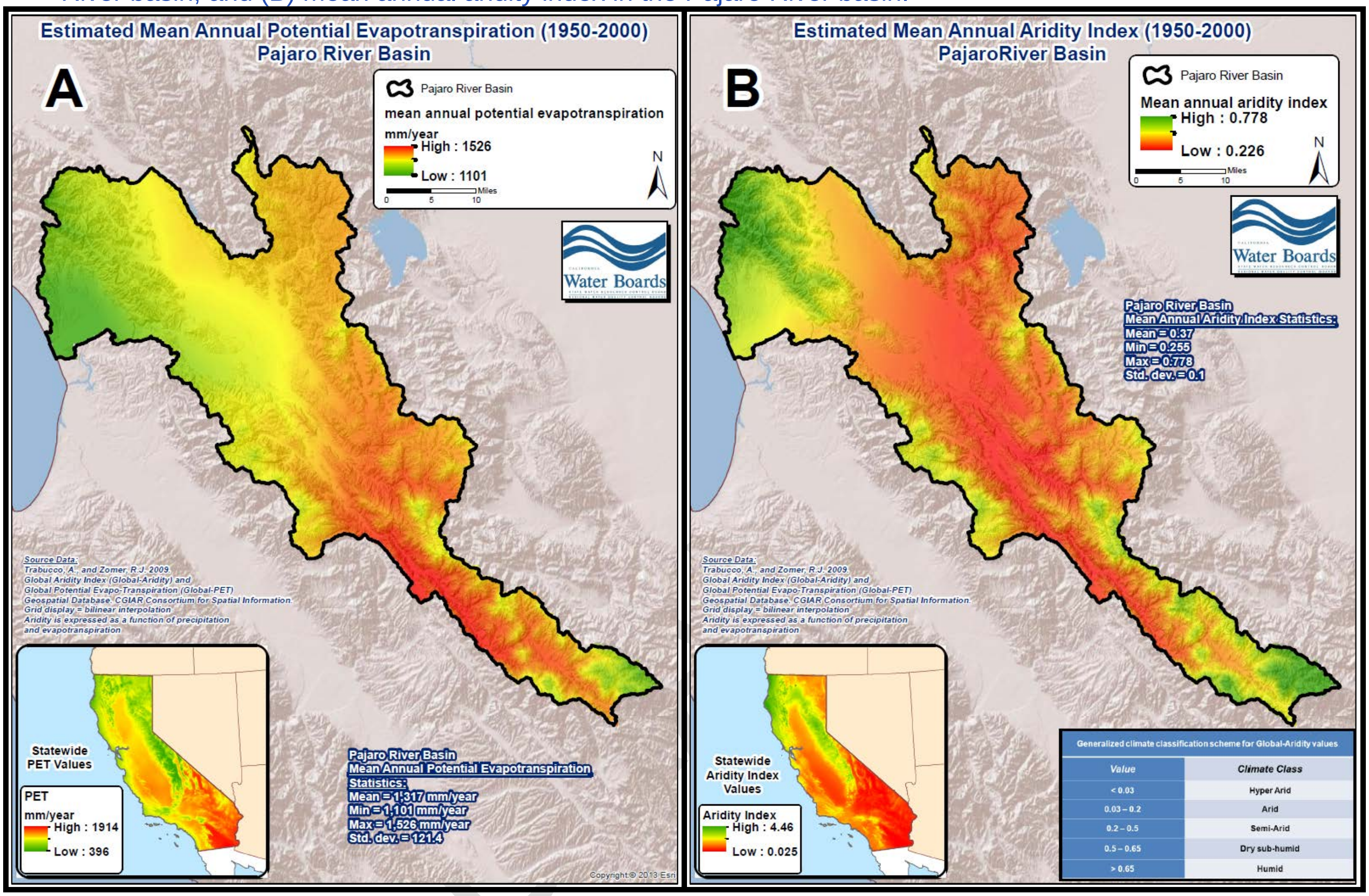
Practically speaking, the AI data show that most of the Pajaro River basin would be characterized by a semi-arid climate on the basis of aridity index values – however, the Santa Cruz mountains portion of the river basin is characterized by a dry sub-humid to humid climate (refer to Figure 3-25). Noteworthy is that while there is some climatic variability in the Pajaro River basin on the basis of PET and AI, the

[34] Potential evapotranspiration is the amount of water that would be removed from the surface if the amount of water present were not a limiting factor. In other words, the potential evapotranspiration over the Sahara desert is very large because the amount of evaporation that *could* take place there is huge. However, because there isn't any water there to be evaporated the evapotranspiration that actually takes place is quite small.

[35] Aridity is expressed as a generalized function of precipitation and potential evapotranspiration. Lower aridity index (AI) values indicate increasingly arid conditions; by convention AI values from 0 to 0.5 indicate hyper-arid, to arid, to semi-arid conditions, whereas AI values greater than 0.5 indicate sub-humid to humid climatic conditions.

magnitude and scale of the variation is not as large and substantial as variation observed at the statewide scale, or even at the scale of the central coast region (refer to Figure 3-25).

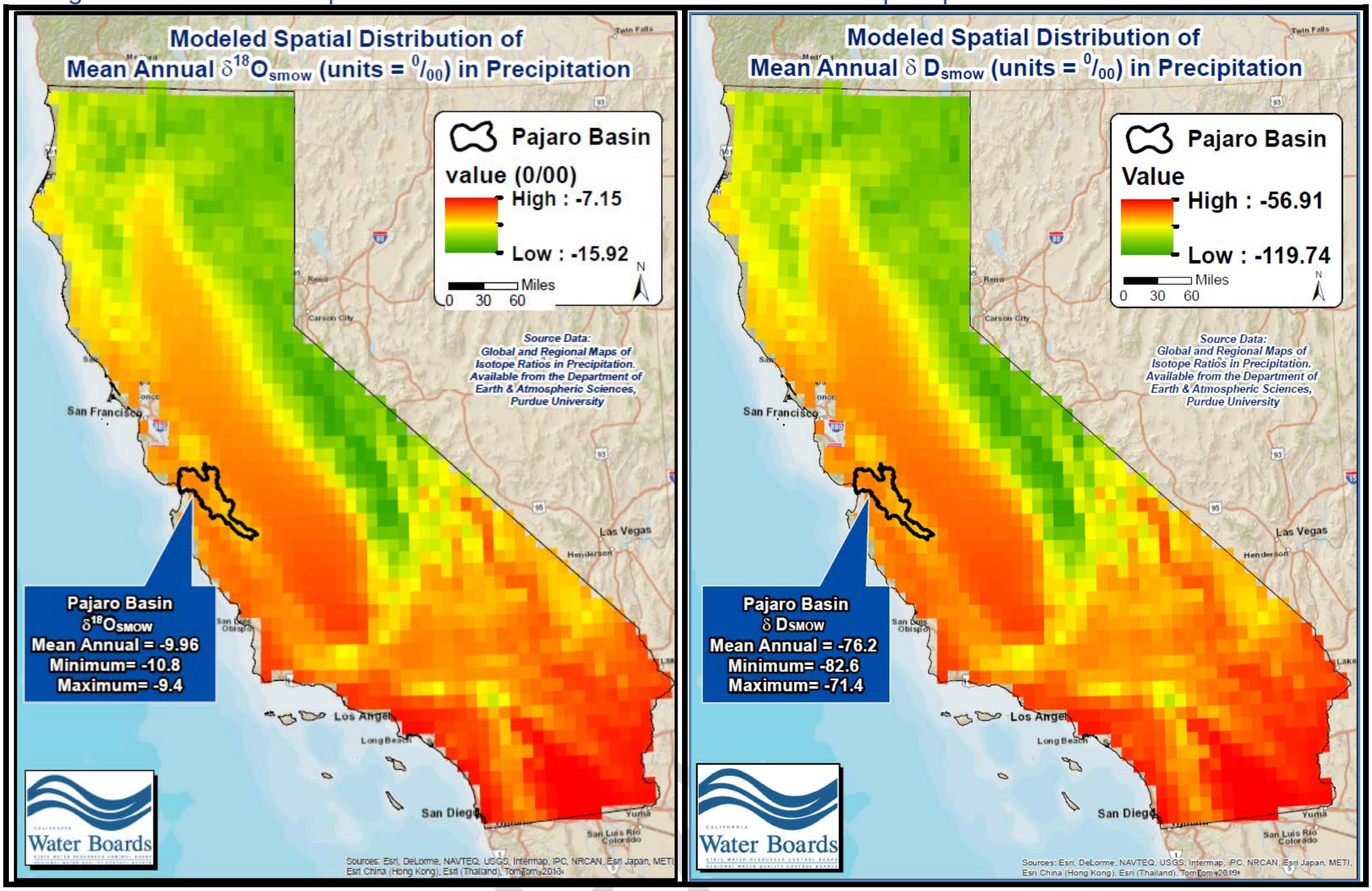
Figure 3-25. Climatic parameters: (A) estimated mean annual potential evapotranspiration in the Pajaro River basin; and (B) mean annual aridity index in the Pajaro River basin.



Staff also compiled information on precipitation isotopes. Isotopes in groundwater, in surface water, and in precipitation are used to give insight into the movement and distribution process of waters within the hydrologic cycle. A growing number of hydrologic studies rely on water isotope tracers to determine the geospatial origin and transport of water, geological, or biological materials. Isotopes commonly used in these types of investigations include the heavy stable isotopes of the water molecule: deuterium (D) and oxygen-18 (^{18}O), and others. Figure 3-26 presents the modeled spatial distribution of $\delta^{18}O_{smow}$ and δD_{smow} ratios in California precipitation, on the basis of data developed by the Purdue University Department of Earth and Atmospheric Sciences[36].

[36] Global and Regional Maps of Isotope Ratios in Precipitation. Department of Earth & Atmospheric Sciences, Purdue University, West Lafayette, Indiana. Online linkage: http://wateriso.eas.purdue.edu/waterisotopes/index.html

Figure 3-26. Modeled spatial distribution of $\delta^{18}O$ and δD in California precipitation.



Based on the modeled spatial distribution of isotope ratios, Table 3-20 presents summaries of the mean and range of isotope ratios in the Pajaro River basin and in the state of California.

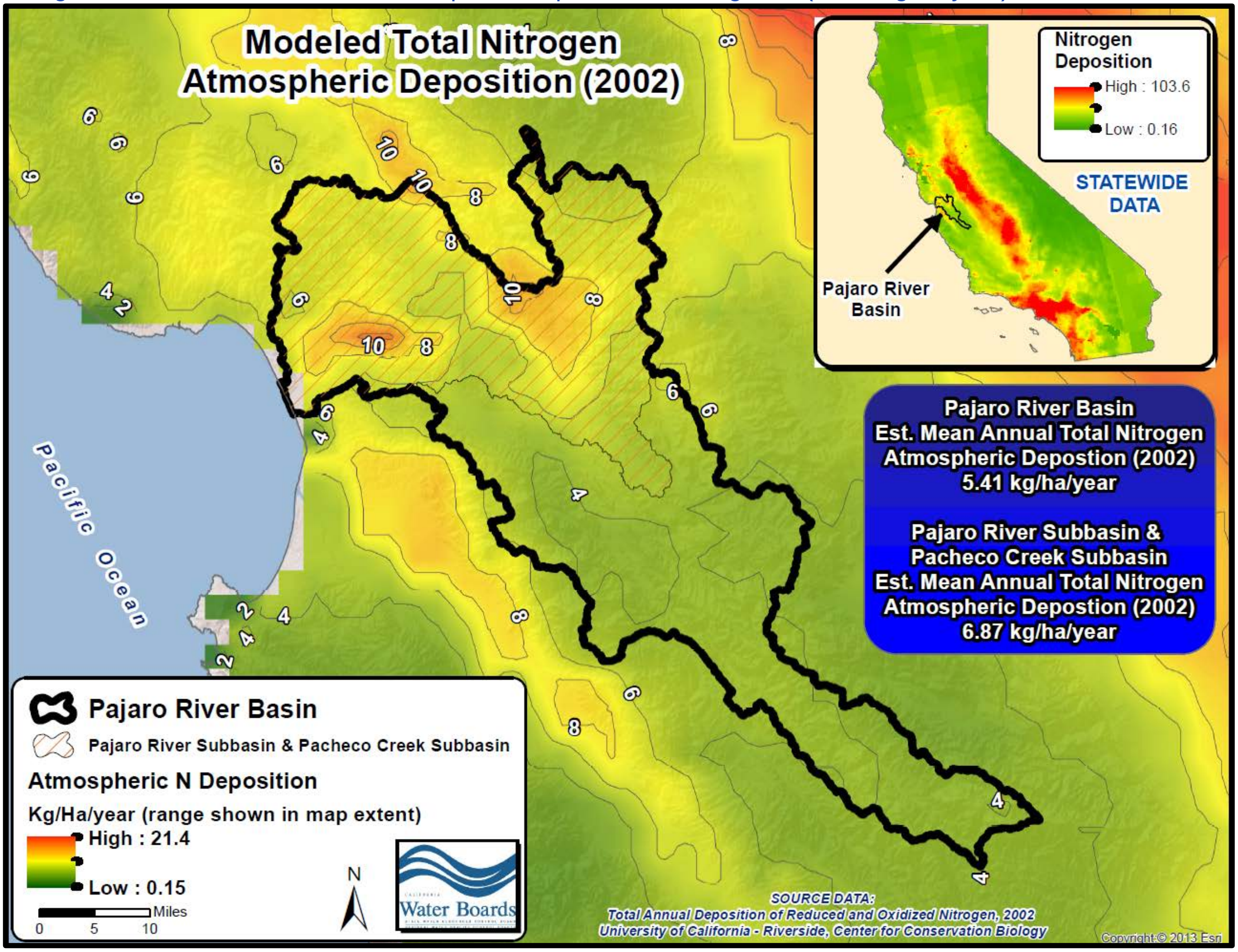
Table 3-20. Summary table showing annual mean and range of isotope ratios in precipitation.

Geographic Location	Mean Annual $\delta^{18}O_{smow}$	Range $\delta^{18}O_{smow}$	Mean Annual δD_{smow}	Range δD_{smow}
Pajaro River Basin (basin-wide)	–9.96	–10.8 to –9.4	–76.2	–82.6 to –71.4
California (state-wide)	–10.7	–15.9 to –7.2	–82.5	–119.7 to –56.9

- ***Atmospheric Deposition of Nitrogen***

Input of nutrients in rainfall can locally be a significant source of loading in any given watershed. Because nitrogen can exist as a gaseous phase (while phosphorus cannot), nitrogen is more prone to atmospheric transport and deposition. It is important to recognize however that atmospheric deposition of nutrients is typically more significant in lakes and reservoirs, than in creeks or streams (USEPA, 1999). This is because the surface area of a stream is typically small compared to the area of a reservoir or a watershed. Additionally, it should be recognized that atmospheric deposition of nitrogen compounds is most prevalent downwind of large urban areas, near point sources of combustion (like coal burning power plants), or in mixed urban/agricultural areas characterized by substantial vehicular combustion contributions to local air quality (Westbrook and Edinger-Marshall, 2014). Figure 3-27 presents estimated total atmospheric deposition for the year 2002 in California and in the Pajaro River basin on the basis of a deposition model developed by the University of California-Riverside Center for Conservation Biology[37].

Figure 3-27. Estimated annual atmospheric deposition of nitrogen-N (units=kg/ha/year).



Based on the University of California-Riverside model, atmospheric deposition to total nitrogen in the Pajaro River basin can be characterized as follows:

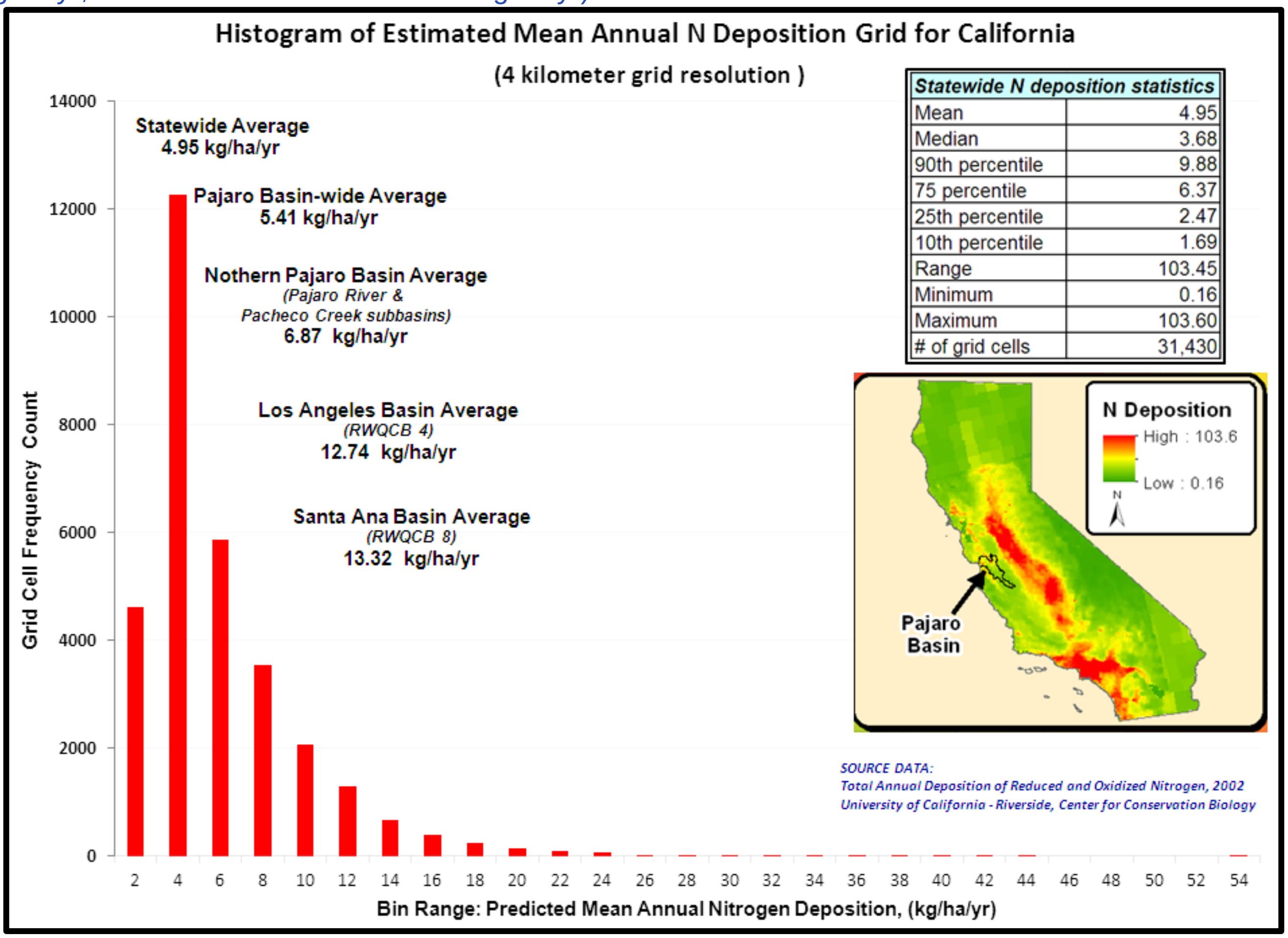
Estimated average basin-wide annual atmospheric of total nitrogen for the *Pajaro River Basin:*
5.41 kg/hectare per year
Estimated average annual atmospheric of total nitrogen in the *Pajaro River and Pacheco Creek subbasins:*
6.97 kg/hectare per year

Figure 3-28 illustrates a histogram of the gridded atmospheric total nitrogen deposition model, and summary average deposition estimates for various regions of the state. Based on summary statistics of the gridded nitrogen deposition data, the 25th percentile is 2.5 kg/ha and the median is 3.7 kg/ha – these

[37] Tonnesen, G., Z. Wang, M. Omary, and C. J. Chien. 2007. University of California-Riverside. Assessment of Nitrogen Deposition: Modeling and Habitat Assessment. California Energy Commission, PIER Energy-Related Environmental Research. CEC-500-2006-032.

values presumably could represent a plausible range for lightly-impacted or natural ambient conditions in California. Estimated atmospheric deposition of nitrogen in the Pajaro Basin (5.41 kg/ha) is marginally higher than the aforementioned ambient condition; however deposition in the river basin is substantially lower than in highly developed areas of southern California such as the Los Angeles Basin and the Santa Ana Basin (see Figure 3-28).

Figure 3-28. Histogram of variation in estimated statewide mean annual atmospheric nitrogen (N) deposition (2002) based on UC-Riverside gridded spatial model of N-deposition rates. Note that average N atmospheric deposition in the Pajaro River basin (5.41 kg/ha/yr) is substantially less than areas of the state characterized by high average rates of N atmospheric deposition (e.g., Los Angeles Basin = 12.74 kg/ha/yr, and Santa Ana Basin = 13.32 kg/ha/yr)



3.8 Vegetation & Riparian Tree Canopy

Nutrient-related impacts and biostimulation may often occur in areas where the river is wide, water is shallow, and tree canopy is open and light is readily available. As such, having estimates of variations in tree canopy cover are important to consider in the development of numeric nutrient criteria.

An additional reason for developing plausible canopy distribution data for this TMDL project is that nutrient water quality target development tools staff used require input estimates for riparian canopy as a parameter influencing sunlight availability, and thus affecting algal photosynthesis.

With regard to general vegetation categories in the Pajaro River basin, upland ecosystems of the Santa Cruz Mountains and Gabilan Range ecoregions[38] tend to be characterized primarily by coast live oak

[38] Refer back to Figure 3-17 for a map showing Level IV ecoregions of the Pajaro River Basin.

woodland, and subsidiary canyon live oak and montane hardwood, on the basis of CALVEG77[39] spatial data. In contrast, upland ecosystems of the Diablo Range and Western Diablo Range ecoregions tend to be characterized by blue oak woodland, with subsidiary amounts of coast live oak in lower Pacheco Creek Subbasin, and Coulter Pine hardwood in the uppermost San Benito River Subbasin. Lowland ecosystems of the Pajaro River basin have been highly modified by agriculture and urbanization, but with some subsidiary lightly-impacted areas of coastal scrub/sumac and annual grassland.

➢ *Nitrogen-fixing Plants & Water Quality*

There is some evidence of an association between nitrogen-fixing vegetation and groundwaters which are naturally enriched in nitrate in semi-arid regions, based on research conducted in West Africa. Most plants rely on the introduction of nitrogen to the soil to be able to use it. Nitrogen-fixing plants are able to utilize nitrogen gas from the atmosphere due to specialized bacteria in the roots of these plants. These bacteria are able to convert inert atmospheric nitrogen into bioavailable compounds of nitrogen. The bioavailable nitrogen is thus added to the soils and stored in the roots of the plant (Rhoades, 2014). Edmunds and Gay (1997) identified high nitrate concentrations in shallow groundwaters (average 11 mg/L NO_3-N) beneath the root zones of natural or introduced nitrogen-fixing leguminous vegetation in northern Senegal. Favreau et al. (2003) found high nitrate concentration shallow groundwaters in southwest Niger in areas where fertilizers or latrine and animal wastes were not plausible sources. Favreau et al. (2003) concluded that the high nitrate in groundwaters was related to soil nitrogen and land clearance, which promoted the leaching of soil nitrogen to the unconfined aquifer.

Based on the aforementioned information and as a matter of due diligence, it is relevant to compile information on native, nitrogen-fixing vegetation reported to exist in the Pajaro River basin on the basis of information available from the U.S. Department of Agriculture. Table 3-21 presents a tabulation of native, nitrogen-fixing plants in the Pajaro River basin that are reported to have medium to high nitrogen fixing efficiency (> 85 lbs. N/acre).

Table 3-21. Native, nitrogen-fixing plants reported to exist in Santa Cruz and Santa Clara counties and classified as “high” nitrogen fixers (>160 lbs. N/acre) or “medium” nitrogen fixers (85–160 lbs. N/acre).

Scientific Name	Common Name(s)	Group	Family	Nitrogen Fixation Efficiency
Alnus rubra	Red Alder (Pacific Coast Alder, Western Alder)	Dicot	Betulaceae	High
Astragalus lentiginosus	Freckled milkvetch	Dicot	Fabaceae	Medium
Ceanothus velutinus	snowbrush ceanothus	Dicot	Rhamnaceae	Medium
Lathyrus littoralis	Silky beach pea	Dicot	Fabaceae	Medium
Lupinus arboreus	Yellow bush lupine	Dicot	Fabaceae	Medium
Robinia pseudoacacia	Black locust	Dicot	Fabaceae	Medium
Trifolium wormskioldii	Cows clover (perennial clover, marsh clover)	Dicot	Fabaceae	Medium

Data source: U.S. Department of Agriculture – Natural Resources Conservation Service Plants Database, online linkage http://plants.usda.gov/adv_search.html

It should be recognized that the native, nitrogen-fixing plants in Table 3-21 are not ubiquitous or pervasive in the Pajaro River basin – see the personal communication below:

> *“In my many treks around Santa Cruz/Santa Clara Counties for forestry field trips, the listed herbaceous and woody plants were not found to be widespread.”*
>
> *–Elaine Sahl, environmental scientist, California Central Coast Water Board staff, personal communication by email, 10/2/2014*

Therefore, these nitrogen-fixing plants would not be expected to significantly contribute to the widespread nitrogen enrichment observed in shallow groundwaters and surface waters of the river basin.

[39] CALVEG77 is a U.S. Forest Service spatial dataset of vegetation throughout California based on mapping done between 1979 and 1981 by U.S. Forest Service ecologists.

➢ *Riparian Tree Canopy & Shading Estimates*

Figure 3-29 and Figure 3-30 presents riparian spatial data which illustrates that, in general, higher amounts (%) of riparian cover are often expected in upland ecosystems of the Pajaro River basin (for example, in the upland stream reaches in the Santa Cruz Mountains); in contrast valley floor and lowland stream reaches (i.e., southern Santa Clara valley) are often characterized by lower amounts (%) of riparian cover. Tree canopy and shading can vary from zero percent, particularly along coastal sloughs and water conveyance structures, to significantly higher in other types of waterbodies (see Figure 3-29 and Figure 3-30).

Figure 3-29. Percent tree canopy in the Pajaro River basin and vicinity.

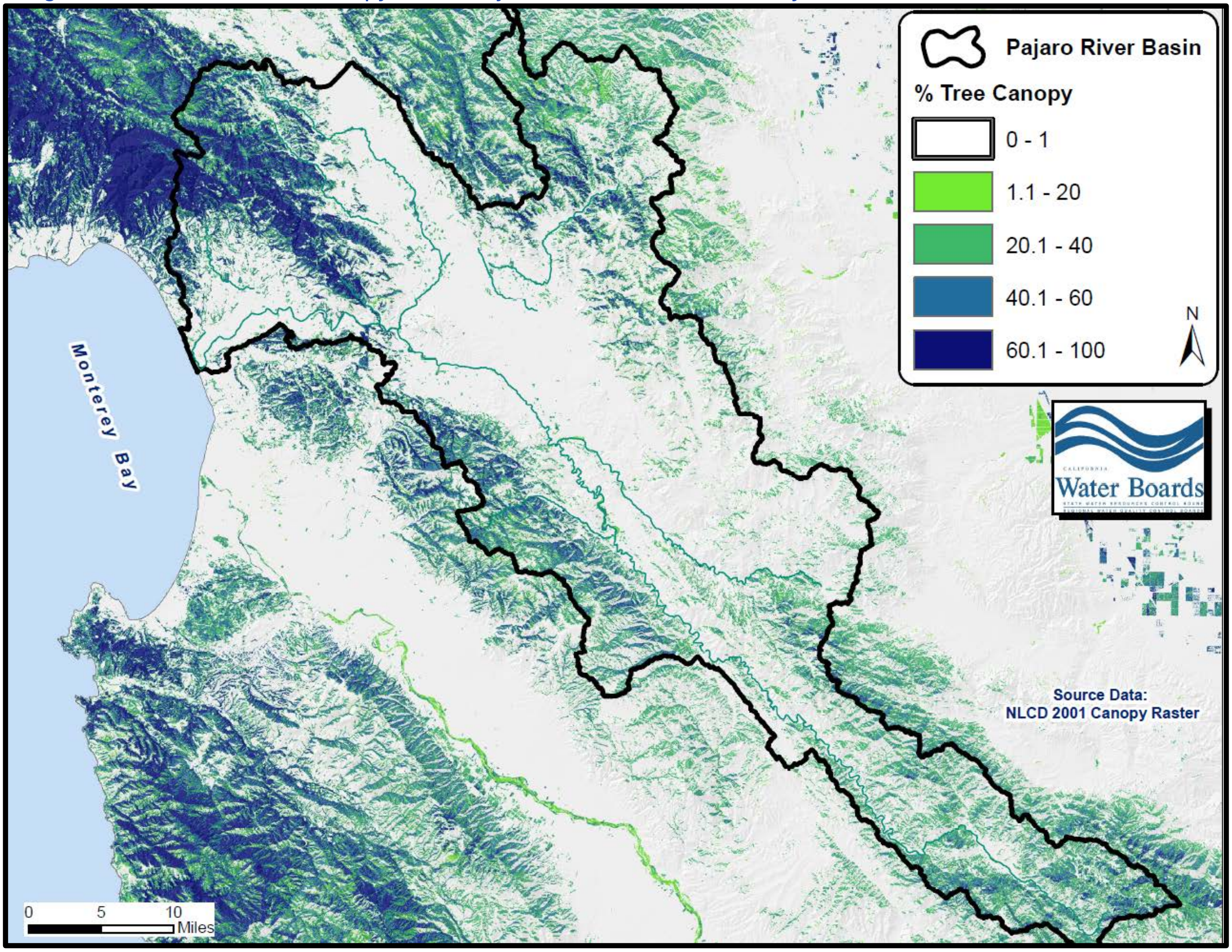
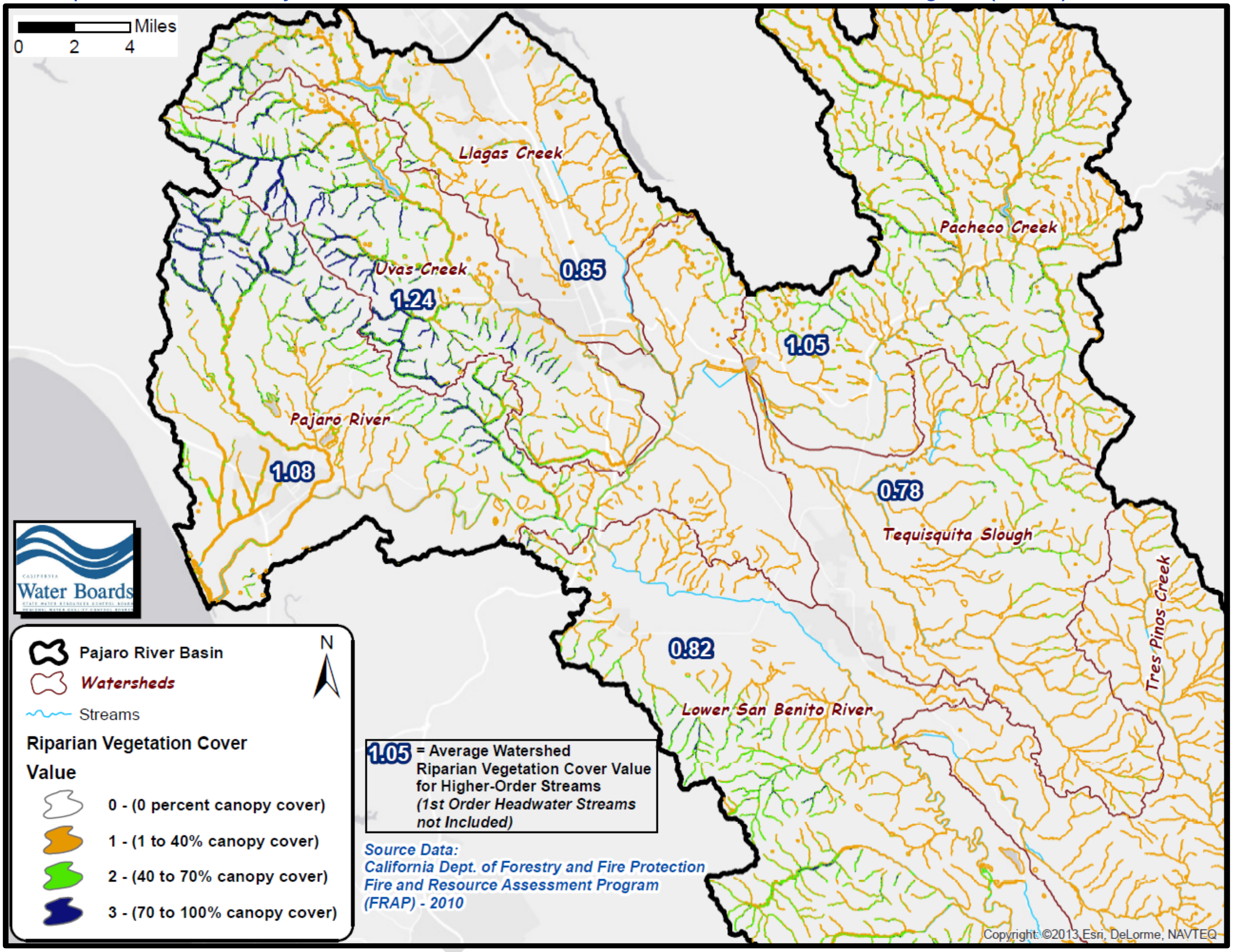
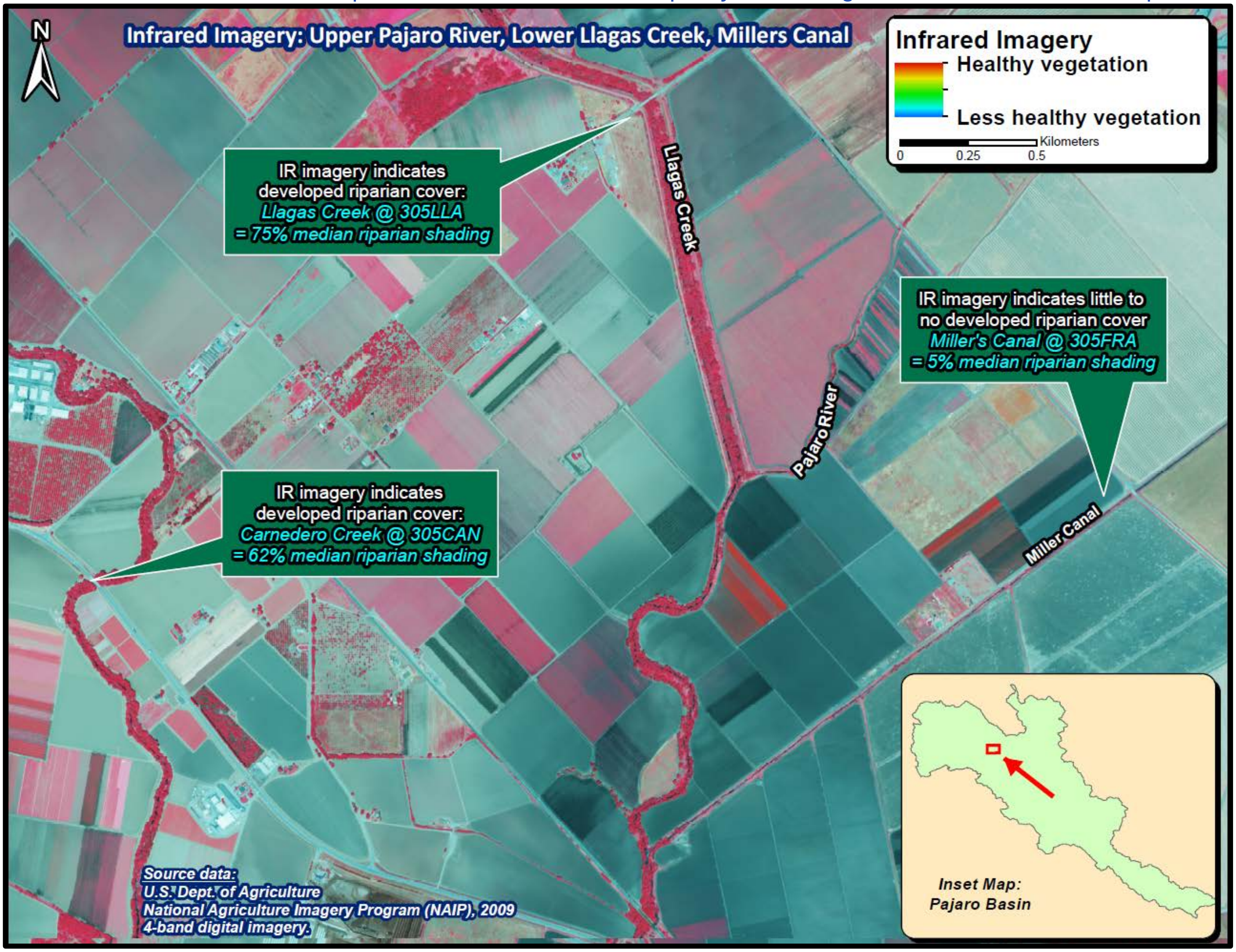


Figure 3-30. Estimated riparian vegetation canopy cover percentages, based on 2010 California Department of Forestry and Fire Protection's Fire and Resource Assessment Program (FRAP).



Other methods are available to staff to assess the spatial distribution of riparian vegetative cover. One such methodology is infrared (IR) spectral analysis. IR imagery is available from the National Agricultural Imagery Program, a program which collects and processes IR aerial photography. The usefulness of this IR analysis in aerial imagery is based on the fact that most objects exhibit a negligible IR reflectance, but actively growing plants exhibit a high IR reflectance and stressed plants (either from disease or drought) exhibit a reduction in their IR reflectance. Figure 3-31 illustrates variations in riparian canopy cover in reaches of the upper Pajaro River, lower Llagas Creek, and Miller's canal.

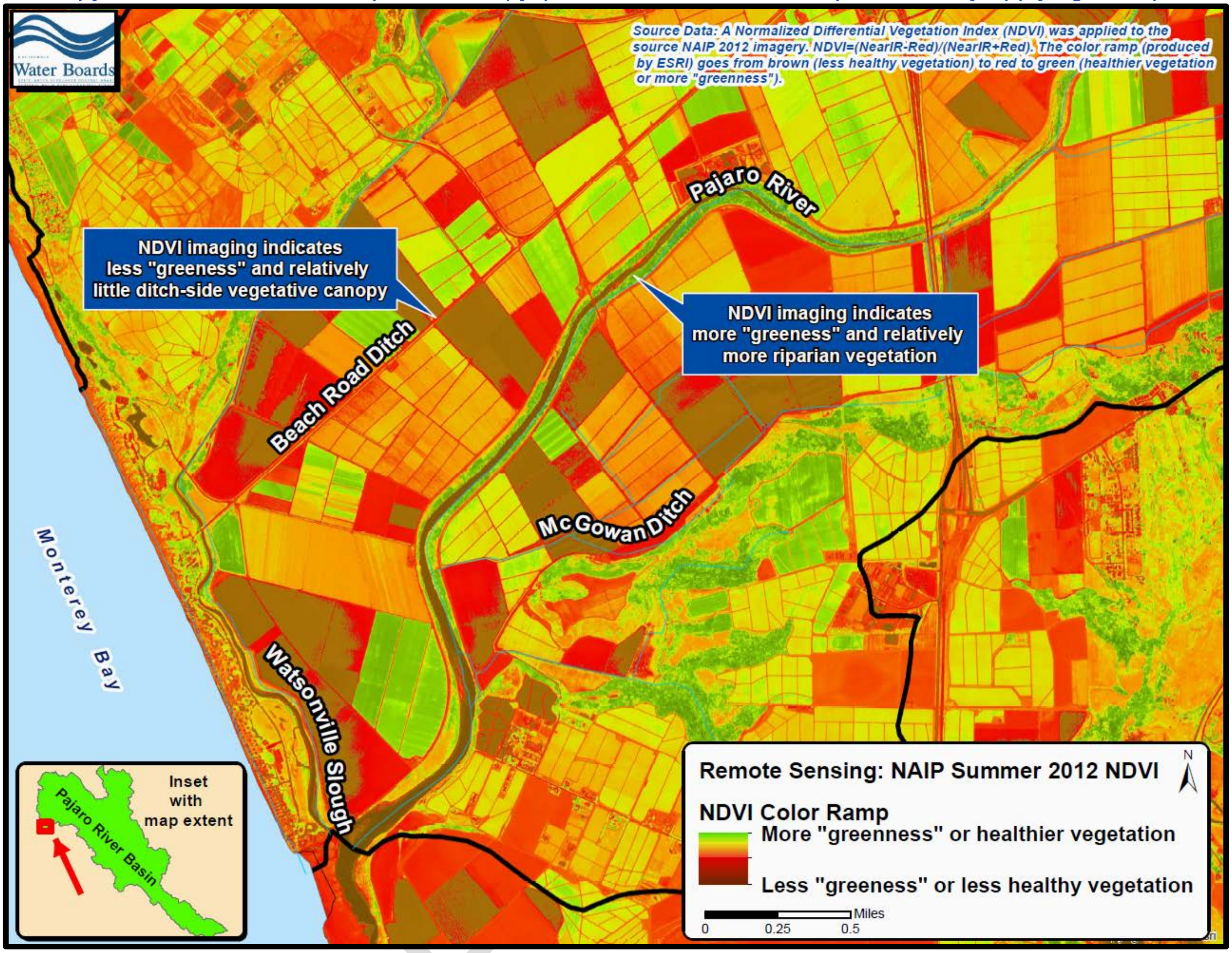
Figure 3-31. Infrared spectral image (year 2009) of upper Pajaro River, lower Llagas Creek, and Miller's canal area, illustrating variations in riparian vegetative density with supplementary information about visual field observations of riparian cover at select water quality monitoring sites annotated on the map.



Normalized Differential Vegetation Index (NDVI) is an imaging methodology in which the infrared and the red band are processed to provide a measurement of the density of plant growth. The NDVI process creates an image dataset that mainly represents greenery. NDVI imagery has been produced by the California Department of Fish and Wildlife[40]. Figure 3-32 illustrates a Summer 2012 NDVI image of the lowermost Pajaro River basin near Watsonville and the confluence with Monterey Bay. The NDVI color ramp goes from brown (less healthy vegetation, or bare soil) to red to green (healthier vegetation or more “greenness”).

[40] California Dept. of Fish and Wildlife. Map Services. Online linkage: http://www.dfg.ca.gov/biogeodata/gis/map_services.asp

Figure 3-32. Lower Pajaro River area, NDVI image illustrating stream reaches with little to no riparian canopy, and areas with more riparian canopy (NAIP summer 2012 data presented by applying NDVI).



As noted previously, estimates of stream shading and stream canopy cover are necessary as input for nutrient water quality criteria development tools used by Central Coast Water Board staff in this TMDL project, and thus it is worth looking at multiple lines of evidence and different datasets regarding riparian canopy. Sunlight penetration and photosynthesis play key roles in the scope of aquatic plant and algae growth in waterbodies. Estimates of percentage canopy cover, and of stream riparian corridor shading are available from raster datasets developed by the Multi-Resolution Land Characteristics Consortium[41] for the National Land Cover Dataset, and also from field reporting by the Central Coast Ambient Monitoring Program[42]. These two sources have different strengths. The Central Coast Ambient Monitoring Program reporting constitutes *direct field observation* of shading at a specific stream monitoring location. The National Land Cover Dataset constitutes a *remote-sensing* dataset, and while not based on direct field observations, it provides more extensive spatial estimates of canopy (compared to site-specific observation) based on imagery processing. It is presumed that the National Land Cover

[41] The Multi-Resolution Land Characteristics (MRLC) consortium is a group of federal agencies who coordinate and generate consistent and relevant land cover information at the national scale for a wide variety of environmental, land management, and modeling applications. Online linkage http://www.mrlc.gov/index.php

[42] The Central Coast Ambient Monitoring Program (CCAMP) is the Central Coast Regional Water Quality Control Board's regionally scaled water quality monitoring and assessment program. Online linkage: http://www.ccamp.org/

Dataset's remote-sensing estimates of percentage canopy constitute a plausible surrogate for percent canopy shading along riparian corridors. To derive the riparian estimates, 60 meter buffers around representative stream reaches were created digitally in ArcMap 10.1™. These buffers were used as masks to digitally clip the National Land Cover Dataset canopy raster data to the riparian stream corridors. ArcMap 10.1™ can calculate statistics of a user-defined raster, such as the stream buffer-clipped rasters delineated by staff. Therefore, the stream-buffer clipped canopy data were used to derive estimates of the mean amount of canopy cover in the riparian corridors at the stream reach-scale.

Table 3-22 presents the field observations of canopy cover at specific monitoring sites based on the Central Coast Ambient Monitoring Program field reporting.

Figure 3-33 presents a visual illustration of the digital stream buffers used to clip the National Land Cover Dataset canopy raster, while Table 3-23 tabulates the canopy statistics associated with these stream corridor buffers.

Also worth noting, as shown previously in Figure 3-30, riparian canopy cover ranges from one to 40% in most alluvial valley stream reaches, while riparian cover in upland stream reaches of the Santa Cruz, Gabilan, and Western Diablo ranges are often in the range of 40 to 70%, on the basis of California Department of Forestry and Fire Protection digital data. Thus, riparian canopy estimates for streams of the Pajaro River basin from three different data sources used here are generally in broad agreement and comport reasonably well with each other.

In general, it can be concluded that valley floor and lowland ecosystem stream reaches have canopy shading of around 25% or less, while stream reaches in upland ecosystems or headwater reaches tend to have higher canopy shading, on the order of 50% or more. It should be recognized that lowland streams tend to be broader and wider than upland streams, generally allowing for more sunlight penetration to the stream channel. Human modification of lowland ecosystems can also locally play a role in the nature and extent of riparian canopy cover.

Table 3-22. Numerical summaries of riparian corridor shading (units = %) in streams of the Pajaro River basin on the basis of field observation[A].

Stream Monitoring Site	Mean	Std. Dev	0%	25%	50 %	75 %	100 %	Number of Observations
Carnadero Creek at private property access	55.9	21.1	20	36.2	62.5	70	90	26
Corralitos Creek at Brown Valley Road	28.3	23.6	5	10	20	35	85	21
Furlong Creek at Fraiser Lake Road	38.7	28.9	5	15	30	60	90	27
Harkins Slough at Harkins Slough Road	3.6	3.2	1	1	2	5	10	14
Llagas Creek at Bloomfield Avenue	65.9	23.1	12	50	75	80	98	29
Llagas Creek at Buena Vista Avenue	50.0	NA	50	50	50	50	50	1
Llagas Creek at Chesbro Reservoir	1.0	NA	1	1	1	1	1	1
Llagas Creek at Holsclaw below Leavesley Road	25.0	NA	25	25	25	25	25	1
Llagas Creek at Leavesley Road	9.9	11.1	0	1.25	5	17.5	30	10
Llagas Creek at Luchessa Avenue-Southside Drive	25.0	NA	25	25	25	25	25	1
Llagas Creek at Monterey Road	0.0	NA	0	0	0	0	0	1
Llagas Creek at Oak Glen Avenue	100.0	NA	100	100	100	100	100	1
Millers Canal at Frazier Lake Road	9.7	10.7	0	1.5	5	17.5	40	27
Pacheco Creek at San Felipe Road	48.9	25.5	10	30	47.5	75	90	28
Pajaro River at Betabel Road	26.2	17.9	5	15	22.5	31.2	75	28
Pajaro River at Chittenden Gap	32.0	21.7	5	15	30	35	100	28
Pajaro River at Murphys Crossing	18.0	8.6	2	15	15	25	35	28
Pajaro River at Porter	15.4	11.6	1	7.75	15	20	50	34
Pajaro River at Thurwatcher Road	10.2	14.2	1	5	5	10	95	115

Stream Monitoring Site	Mean	Std. Dev	0%	25%	50 %	75 %	100 %	Number of Observations
Pescadero Creek NE of Chittendon at RR tracks	60.0	NA	60	60	60	60	60	1
Salsipuedes Creek at Hwy 129 downstream of Corralitos Creek	22.6	26.8	0	1.75	15	31.2	95	28
San Benito at Y Road	47.3	22.5	10	32.5	47.5	67.5	80	28
San Benito River Bridge downstream Willow Creek	11.6	17.3	0	1	2	15	70	26
San Juan Creek at Anzar	12.5	18.6	0	0.5	5	15	80	27
Struve Slough at Lee Road	36.6	25.7	3	20	35	40	90	13
Tequisquita Slough at Shore Road	0.0	NA	0	0	0	0	0	1
Tres Pinos Creek at Southside Road	4.4	4.9	0	1	2	5	15	16
Uvas Creek at Bloomfield Avenue	33.5	22.7	0	17.5	25	47.5	80	19
Watsonville Slough upstream Harkins Slough	77.8	28.0	5	68.75	95	98.2	100	20

[A] Source Data: Central Coast Ambient Monitoring Program, 1997-2012 field observation data.

Figure 3-33. Map of percent tree canopy closure and illustration of 60 meter stream buffers used to estimate riparian corridor canopy. The riparian canopy esimates are tabulated below in Table 3-23.

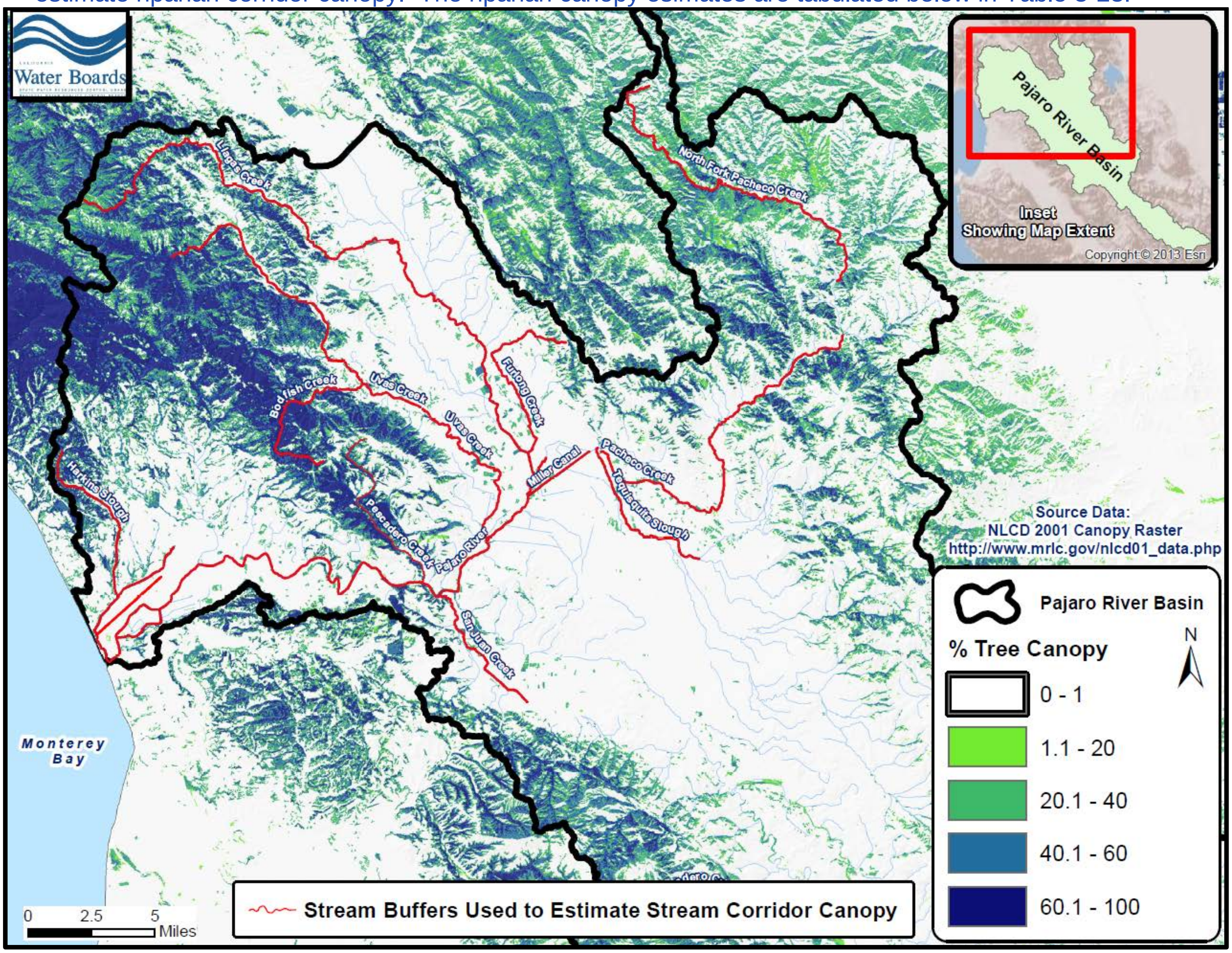


Table 3-23. Numerical summaries of estimated percent tree canopy closure in select stream corridors (60 meter buffer proximity to stream) of the Pajaro River basin on the basis of Landsat satellite imagery analysis available from the National Land Cover Dataset (2001). Units = %

Stream Reach	**Mean Percent Canopy**	**Minimum Percent Canopy**	**Maximum Percent Canopy**	**Level IV Ecoregion(s)[A]**
Beach Road Ditch	0.3	0	38	Monterey Bay Plains and Terraces
Bodfish Creek	53.9	0	91	Santa Cruz Mountains & Leeward Hills
Furlong Creek	7.3	0	79	Upper Santa Clara Valley
Upper Llagas Creek *from headwaters downstream to confluence with Little Llagas Creek near Hwy. 101*	26.2	0	87	Leeward Hills
Lower Llagas Creek *from confluence of Little Llagas Creek downstream to confluence with the Pajaro River.*	7.9	0	60	Upper Santa Clara Valley
McGowan Ditch	6	0	81	Monterey Bay Plains and Terraces
Miller Canal	1.6	0	50	Upper Santa Clara Valley
Pacheco Creek, main stem	10.2	0	76	Western Diablo Range & Upper Santa Clara Valley
Pacheco Creek, North Fork	19.4	0	83	Western Diablo Range
Pajaro River *entire reach, from Santa Clara Valley to Pacific Ocean*	21.9	0	86	Upper Santa Clara Valley & Monterey Bay Plains and Terraces
Pescadero Creek (Santa Cruz County)	53.2	0	89	Santa Cruz Mountains
San Juan Creek	7	0	81	Upper Santa Clara Valley
Tequisquita Slough	1.8	0	53	Upper Santa Clara Valley
Uvas/Carnadero Creek *excluding the first and second Strahler Order headwater reach*	21	0	85	Leeward Hills & Upper Santa Clara Valley
Watsonville Slough and Harkins Slough	10.2	0	82	Monterey Bay Plains and Terraces

[A] Source data: Level IV Ecoregions of the Conterminous United States, 2013. U.S. Environmental Protection Agency Office of Research and Development - National Health and Environmental Effects Research Laboratory.

3.9 Groundwater

TMDLs do not directly address pollution of groundwater by controllable sources. However, shallow groundwater baseflow pollutant inputs to streams, and groundwater recharge designated beneficial uses[43] of streams may be considered in the context of TMDL development. Groundwaters and surface waters are not closed systems that act independently from each other; it is well known that groundwater discharge to surface waters can be a source of nutrients or salts to any given surface waterbody. The physical interconnectedness of surface waters and groundwater is widely recognized by scientific agencies, researchers, and resource professionals, as highlighted below:

[43] See Section 4.1.2 of this report.

"Traditionally, management of water resources has focused on surface water or ground water as separate entities….Nearly all surface-water features (streams, lakes reservoirs, wetlands, and estuaries) interact with groundwater. Pollution of surface water can cause degradation of ground-water quality and conversely pollution of ground water can degrade surface water. Thus, effective land and water management requires a clear understanding of the linkages between ground water and surface water as it applies to any given hydrologic setting."

From: U.S. Geological Survey, 1998. Circular 1139: "Groundwater and Surface Water – A Single Resource"

"While ground water and surface water are often treated as separate systems, they are in reality highly interdependent components of the hydrologic cycle. Subsurface interactions with surface waters occur in a variety of ways. Therefore, the potential pollutant contributions from ground water to surface waters should be investigated when developing TMDLs."

From: U.S. Environmental Protection Agency, Guidance for Water Quality-Based Decisions: The TMDL Process – Appendix B. EPA 440/4-91-001.

"Although surface water and groundwater appear to be two distinct sources of water, they are not. Surface water and groundwater are basically one singular source of water connected physically in the hydrologic cycle…Effective management requires consideration of both water sources as one resource."

From: California Department of Water Resources: Relationship between Groundwater and Surface Water http://www.water.ca.gov/groundwater/groundwater_basics/gw_sw_interaction.cfm.

"Surface water and ground water are increasingly viewed as a single resource within linked reservoirs. The movement of water from streams to aquifers and from aquifers to streams influences both the quantity and quality of available water within both reservoirs"

From: C. Ruehl, A. Fisher, C. Hatch, M. Los Huertos, G. Stemler, and C. Shennan (2006), *Differential gauging and tracer tests resolve seepage fluxes in a strongly-losing stream.* Journal of Hydrology, volume 330, pp. 235-248.

"It's a myth that groundwater is separate from surface water and also a myth that it's difficult to legally integrate the two….California's groundwater and surface water are often closely interconnected and sometimes managed jointly."

From: Buzz Thompson, Professor of Natural Resources Law, Stanford University Law School, quoted in *Managing California's Groundwater*, by Gary Pitzer in Western Water January/February 2014, *and* from Public Policy Institute of California, *California Water Myths*, www.ppic.org.

The reporting shown above recognizes the potential for polluted streams to degrade underlying groundwater. In addition, it is likewise widely recognized by local resource professionals that subsurface infiltration of river waters can affect, alter, or degrade the water quality and/or water supply of an underlying groundwater resource, as highlighted below:

"The distinguishing feature of the (Pajaro River Valley) East Area is that ***its groundwater is recharged primarily from the Pajaro River****…Boron originates from geological sources, generally in the San Benito watershed… Related to this recharge, wells in this area produce mixed-ion or sodium-carbonate water, with virtually every well in the East Area having a boron concentration exceeding 0.2 mg/L****. This local boron concentration is a water-quality fingerprint of recharge (sic) Pajaro River waters*."***

From: Pajaro Valley Water Management Agency, Draft Environmental Impact Report for the Basin Management Plan Update, October 2013.

"Category 2 is recent or young groundwater…The TDS range for this category is 300-1,100 mg/L ***depending on the source of the recharging water* (Pajaro River, Corralitos and Carneros Creek****, precipitation, and applied water). The best quality groundwater in this basin…is outside the spheres of influence of the seawater intrusion* ***and the plume of poor quality water associated with Pajaro River infiltration*."***

From: California Department of Water Resources, California's Groundwater Bulletin 118, Pajaro Valley Groundwater Basin.

*"Groundwater quality within…the Pajaro Valley is influenced by factors related to hydrology, geochemistry, well construction, groundwater pumping, and land use….**Nitrate contamination has been identified as a problem** in areas of high residential septic tank density and **in some areas that are recharged by the Pajaro River*.***

From: Pajaro Valley Water Management Agency, 2012 Basin Management Plan Update, January 2013 draft.

*"Runoff from watersheds tributary to the Llagas groundwater basin have very limited direct use for irrigation and domestic purposes in the San Martin area, but it **constitutes a major source of water available to replenish the groundwater basin by direct or controlled percolation" *.***

From: Brown and Caldwell Geotechnical Consultants, County of Santa Clara San Martin Area Water Quality Study, Phase 1 Report, January 1981.

** all emphasis shown in above text boxes added by Central Coast Water Board staff*

To highlight the importance of the nexus between surface waters and groundwaters, it is worth noting that a water budget hydrologic model reported by the Pajaro Valley Water Management Agency indicates that stream flow infiltration into the subsurface accounts for 30% of all water inputs into Pajaro Valley groundwater basin aquifers[44].

The range of information discussed above is illustrated conceptually in Figure 3-34.

Figure 3-34. Streams are intimately connected to the groundwater system.

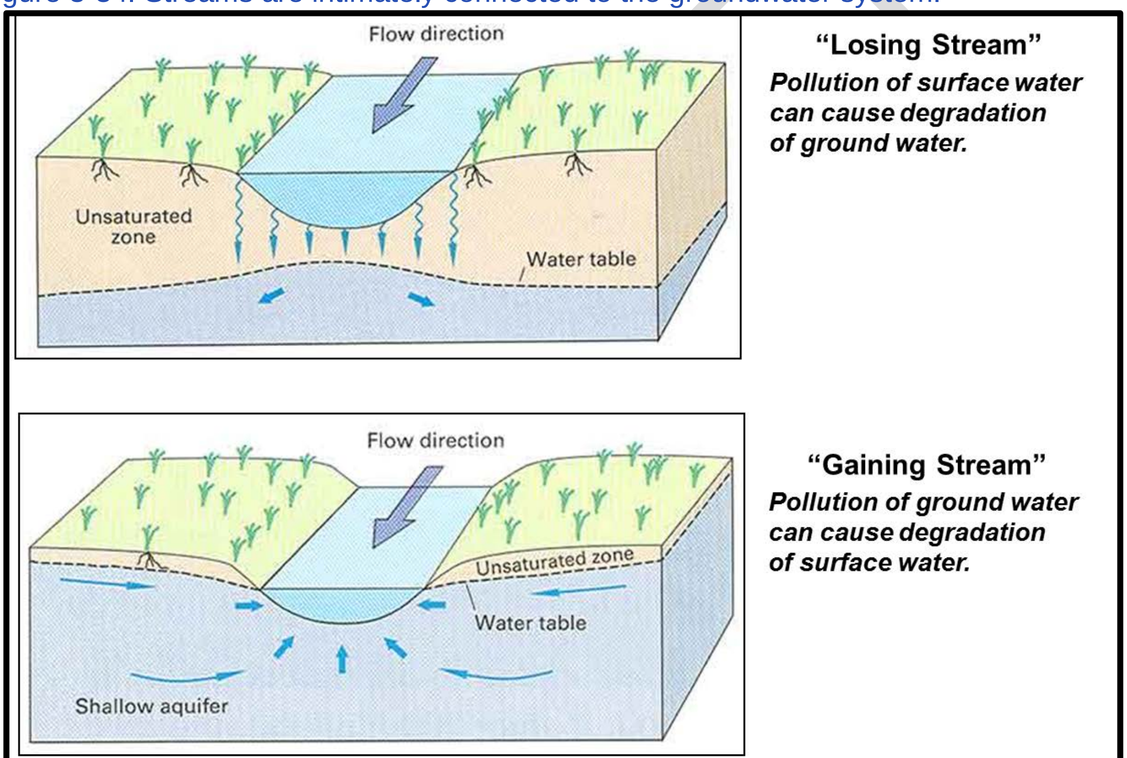


Figure credits: U.S. Geological Survey Circular 1139 , Groundwater and Surface Water A Single Resource (1998)

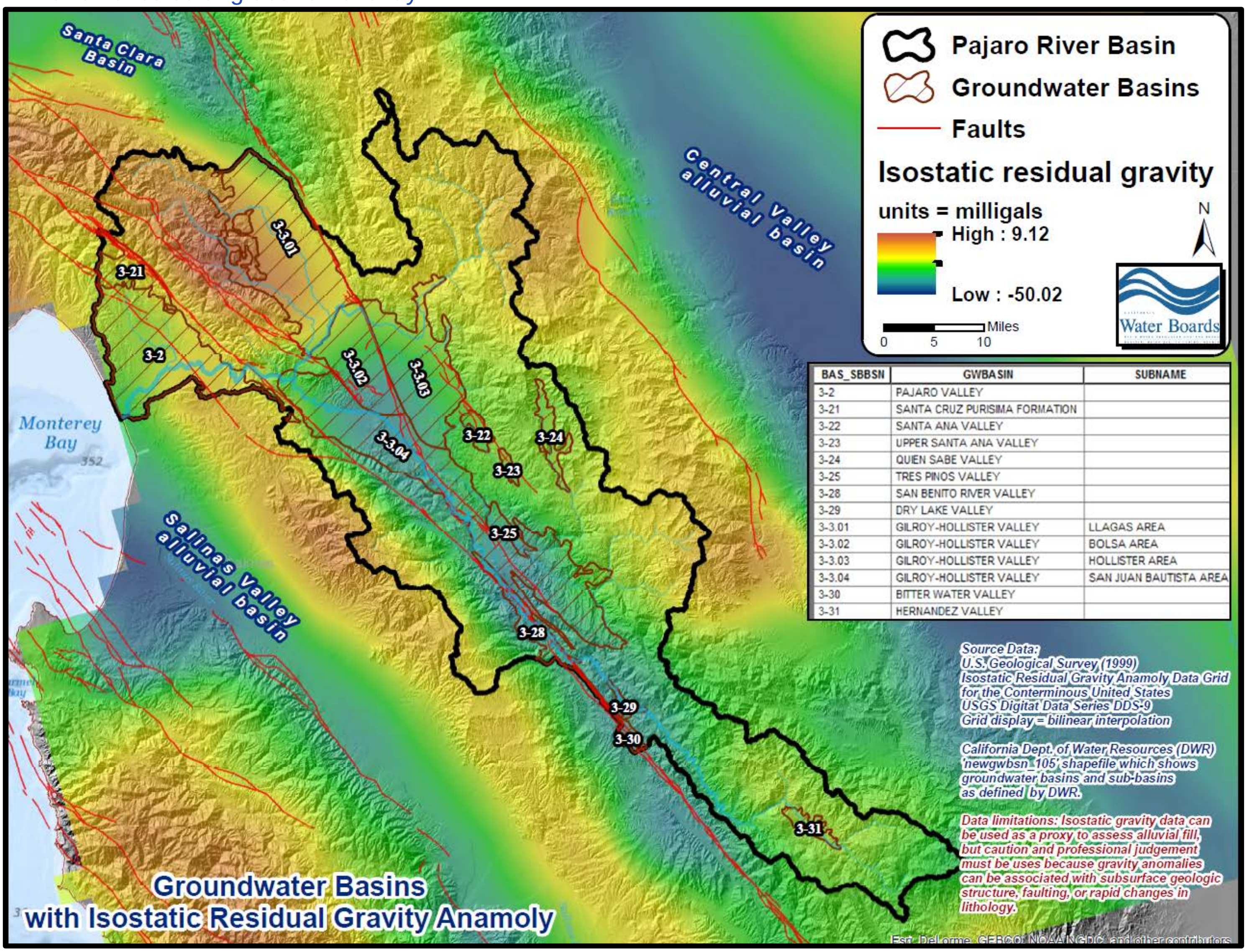
Based on the aforementioned concepts and information, it is relevant to consider the nexus between groundwaters and surface water in this TMDL project. In addition, groundwater information is needed for the pollutant source characterization spreadsheet model used in this TMDL project.

[44] Pajaro Valley Water Management Agency, Annual Simulated Water Budget. Inputs – 16,000 acre feet stream recharge + 35,000 acre feet from precipitation and applied water + 2,000 acre feet from subsurface inflow. Online linkage: http://www.pvwma.dst.ca.us/hydrology/hydrologic-modeling.php

➢ *Groundwater Basins & Groundwater Recharge Areas*

As with any watershed study, it is worth being cognizant of the distribution of alluvial groundwater basins located within the Pajaro River basin. Alluvial groundwater basins in and around the Pajaro River basin, with an isostatic residual gravity anomalies overlay[45], are presented in Figure 3-35. Note that groundwater basins are three-dimensional in architecture, and gravity data can thus give some insight into the shape and distribution of alluvial basins. A number of groundwater basins and groundwater subbasins underlie the Pajaro River basin; hydrologic communication between these groundwater basins are limited to an extent by faulting and geologic structure, as illustrated in Figure 3-35.

Figure 3-35. Groundwater basins in the Pajaro River basin with regional isostatic residual gravity anomalies color gradation overlay.



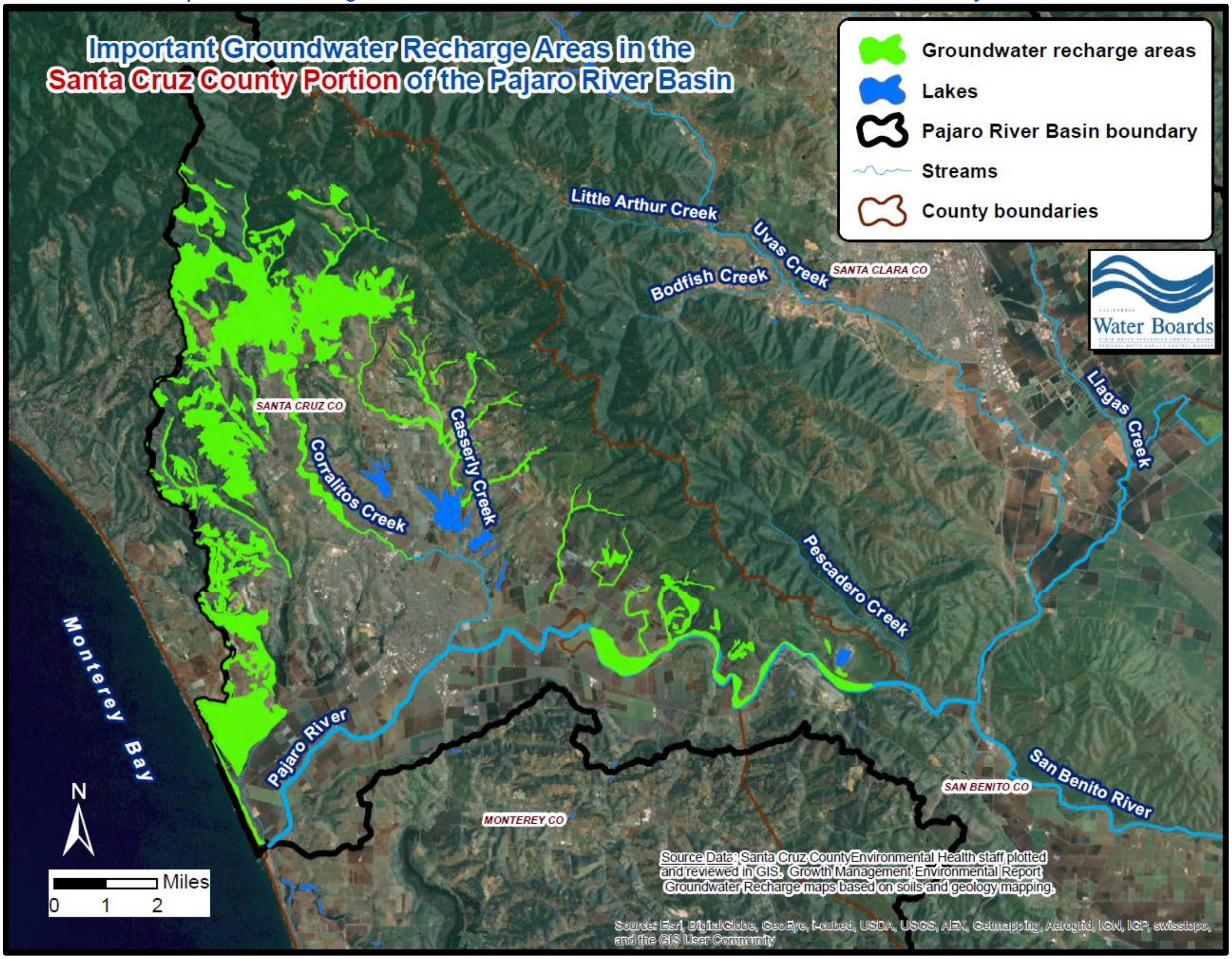
BAS_SBBSN	GWBASIN	SUBNAME
3-2	PAJARO VALLEY	
3-21	SANTA CRUZ PURISIMA FORMATION	
3-22	SANTA ANA VALLEY	
3-23	UPPER SANTA ANA VALLEY	
3-24	QUIEN SABE VALLEY	
3-25	TRES PINOS VALLEY	
3-28	SAN BENITO RIVER VALLEY	
3-29	DRY LAKE VALLEY	
3-3.01	GILROY-HOLLISTER VALLEY	LLAGAS AREA
3-3.02	GILROY-HOLLISTER VALLEY	BOLSA AREA
3-3.03	GILROY-HOLLISTER VALLEY	HOLLISTER AREA
3-3.04	GILROY-HOLLISTER VALLEY	SAN JUAN BAUTISTA AREA
3-30	BITTER WATER VALLEY	
3-31	HERNANDEZ VALLEY	

The County of Santa Cruz Department of Environmental Health Service has published spatial data highlighting areas which are particularly important for groundwater recharge in the Santa Cruz County

[45] Isostatic residual gravity anomaly data are a geophysical attribute that represents density contrasts, and can be used as a proxy to assess the presence and the depth or thickness of alluvial fill. Caution and professional judgment must be used, because gravity anomalies can also be associated with subsurface geologic structure, faults, and rapid changes in lithology (rock types). Isostatic residual gravity data source: U.S. Geological Survey (1999), *Isostatic residual gravity anomaly data grid for the conterminous U.S.*

portion of the Pajaro River basin[46], which are presented in Figure 3-36. On the basis of these data, It is worth noting that some reaches of the Pajaro River are considered a particularly important source of groundwater recharge. It should also be noted that groundwater recharge (GWR) is a designated beneficial of many streams and rivers in the Pajaro River basin and elsewhere in the central coast region (refer to report Section 4.1.2).

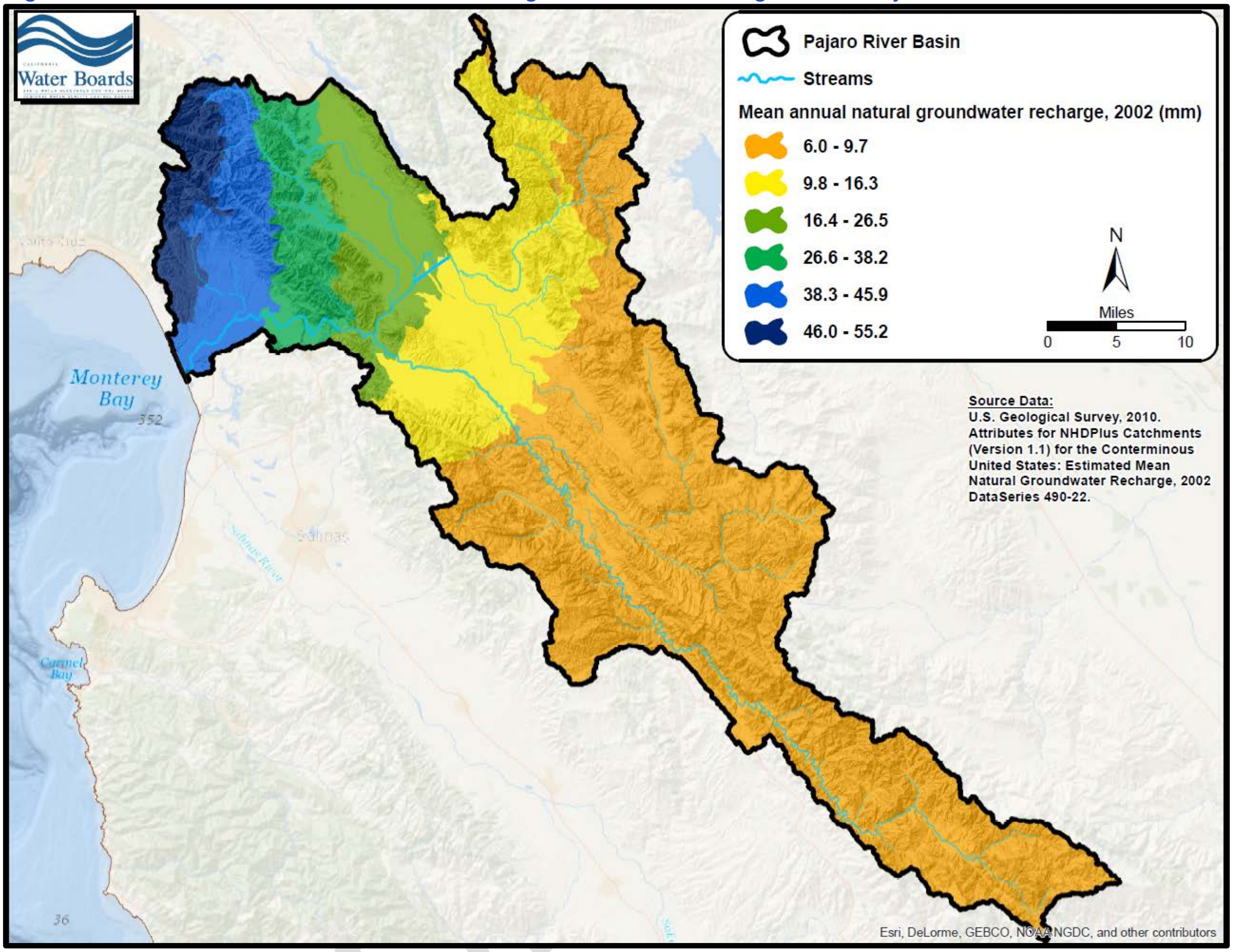
Figure 3-36. Important groundwater recharge areas of the Santa Cruz County portion of the Pajaro River basin. Note important recharge areas associated with some inland reaches of the Pajaro River.



Further, the U.S. Geological Survey has published estimates of mean annual natural groundwater recharge; Figure 3-37 illustrates the groundwater recharge estimates for the Pajaro River basin. Unsurprisingly, the Pajaro Valley, Santa Cruz Mountains, and Leeward Hills receive the greatest amount of natural groundwater recharge based on local climatic conditions (refer back to Section 3.7) and hydrologic conditions (refer back to Section 3.4). These areas of the river basin also have the greatest density of stream reaches characterized by perennial or near-perennial flows (refer back to Figure 3-9 and Figure 3-11), which are, in part, a hydrologic response to higher inputs of groundwater which manifests as stream baseflow.

[46] County of Santa Cruz Department of Environmental Health Service. GIS Layer Number = 36/ Original Mapping Source: Growth Management Environmental Report Groundwater Recharge Maps based on soils and geology mapping.

Figure 3-37. Estimated mean annual natural groundwater recharge in the Pajaro River basin.



➢ *Shallow Groundwater & Hydraulic Connectivity with Surface Waters*

An additional reason for developing groundwater data for this TMDL project is that many nutrient loading models (e.g., STEPL, refer to Section 6.1) require data input for shallow groundwater nutrient concentrations to allow for baseflow load estimates to surface waters. Shallow groundwater zones and perched groundwater, which can contribute to stream flows, are known to exist in the Pajaro River basin:

> *"… stream flow in lower Pacheco Creek (from Highway 156 and downstream) was **the result of perched groundwater resurfacing***, which maintained surface flows to San Felipe Lake".*
>
> *"**Perched groundwater*** from Lower Llagas Creek **sustains*** the portion of the Pajaro River between Llagas Creek and Miller Canal."*
>
> *From: Casagrande (2011). Aquatic Species and Habitat Assessment of the Upper Pajaro River Basin, Santa Clara and San Benito Counties, California: Summer 2011.*
>
> ***** *emphasis added by Central Coast Water Board staff*

Los Huertos et al. (2001) also reported the presence of a laterally continuous, nitrogen-saturated shallow groundwater table in the lower Pajaro Valley which locally interacts with surface water flows:

> *"…results suggest this area of the lower Pajaro River Valley contains a **shallow water table*** that is N saturated. Based on the locations sampled to date this water table extends at least several square kilometers."*
>
> *From: Los Huertos et al (2001). Land Use and Stream Nitrogen Concentrations in Agricultural Watersheds Along the Central Coast of California. The Scientific World Journal (1):615-622.*
>
> ***** *emphasis added by Central Coast Water Board staff*

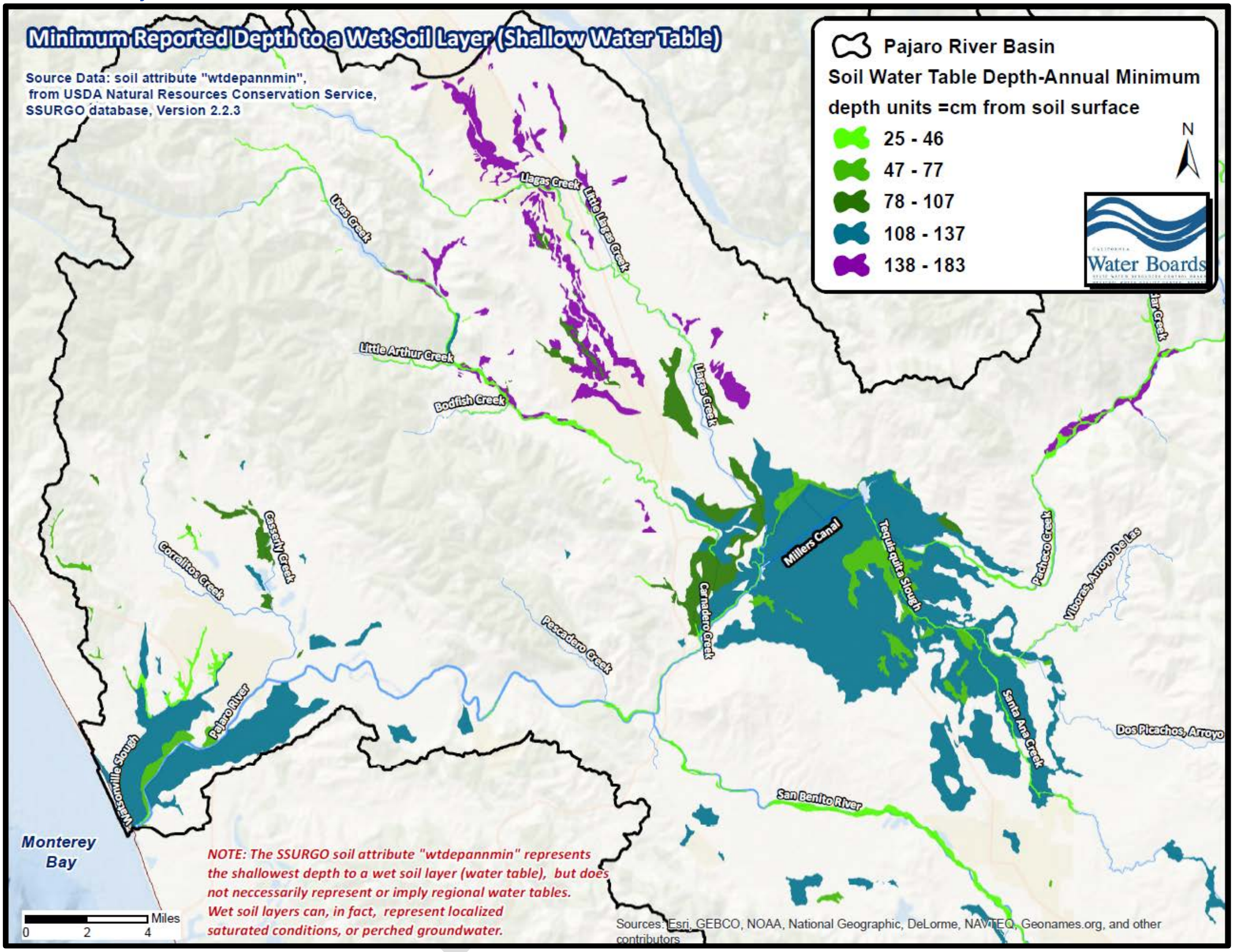
Similarly, Central Coast Water Board staff report that Llagas Creek in the lower part of the South Santa Clara Valley is a gaining stream, indicating that shallow or perched groundwater inputs can contribute to streamflow in the these reaches of the creek (personal communication Dean Thomas engineering geologist Central Coast Water Board, January 24, 2014). Locally, groundwater has been observed at less than 2 feet below ground surface in the lower Llagas Creek area (personal communication Monica Barricarte, water resources control engineer, Central Coast Water Board, October 7, 2014). Further, groundwater inputs to streamflow in upper Uvas Creek and Swanson Creek are suggested by the presence groundwater-associated amphipods of the genus *Stygobromus* (Herbst et al., 2014).

Also worth noting, some parts of the lower Pajaro River Valley near Watsonville contain shallow (~two feet below ground surface) clay hardpan layers, and thus these subsurface conditions *can cause perched groundwater horizons and horizontal flow of shallow perched groundwater* (personal communication Richard Casale, District Conservationist, U.S. Dept. of Agriculture Natural Resources Conservation Service, July 22, 2014). This type of shallow groundwater lateral flow therefore has the potential to result in hydraulic communication locally with surface waterbodies.

Shallow groundwater or perched groundwater zones can provide base flows to streams and can locally be a major source of surface water flows during the dry season. The water stored in wetland and riparian areas can also contribute base flow to a stream during times of the year when surface water would otherwise cease to flow (DWR 2003). Therefore, dissolved nitrate in groundwater can be important nitrate sources during dry periods or low flow periods. Therefore, it is relevant to consider the scope and importance of shallow groundwater and base flow contributions to stream reaches in the Pajaro River basin. Figure 3-38 illustrates the minimum reported depth (centimeters) to a wet soil layer (shallow groundwater) in northern parts of the Pajaro River basin, based on soils data available from the U.S. Department of Agriculture Natural Resource Conservation Service. These reported data do not represent or imply all possible or known locations of shallow or perched groundwater, but do constitute best available spatial data for the distribution of occurences of shallow groundwater. In the Pajaro River basin, these shallow groundwater horizons are typically associated with lowland areas in the Pajaro Valley, the Santa Clara Valley, and locally within the riparian corridors of many stream reaches.

The interactions between groundwater and surface water can vary even at the stream reach scale. For example, a 3-mile section of the lower Pajaro River between the Rogge Lane Bridge and downstream to Murphy Crossing is generally known to be a "losing" reach, where river water infiltrates through the stream substrate and recharges the underlying groundwater (Hatch, et al., 2010). However, even within this discrete 3-mile reach there are exceptions to this trend; researchers have documented a pool-riffle sequence in this section of the Pajaro River where groundwater flows *into* the river contributing to stream flow, and thus this particular segment of the river is a "gaining" reach (Hatch, et al., 2010).

Figure 3-38. Minimum reported depth (cm) to a wet soil layer (shallow groundwater) in the northern parts of the Pajaro River basin.



With regard to the hydraulic connection of streams and groundwater systems, it is important to recognize the significance of the fluvial morphology of streams. Streams, rivers, creeks, and ditches are incised vertically into the alluvial floodplain (see Figure 3-39, Figure 3-40, and Figure 3-41). Stream elevation cross section profiles reported for the Pajaro and San Benito Rivers and for Llagas Creek indicate that these streams are vertically incised into the surrounding flood plains by depths ranging from 8 to 30 feet, as measured from the flood plain elevation to the stream channel bottom (ESA PWA, 2013; Raines, Meltion & Carella, Inc. 2001(b); and Raines, Meltion & Carella, Inc. 2005). Thus, shallow groundwater zones observed in wells on the surrounding alluvial flood plains can be intersected or penetrated locally by incised stream channels. Consequently, in areas characterized by shallow groundwater zones, the groundwater may locally flow into the incised creek, ditch, or river channels, thus contributing – in part – to total stream flow. This stream reach hydrologic condition is often referred to as a "gaining" stream reach (refer back to Figure 3-34).

Figure 3-39. Photo of Pajaro River channel bottom and channel bank.

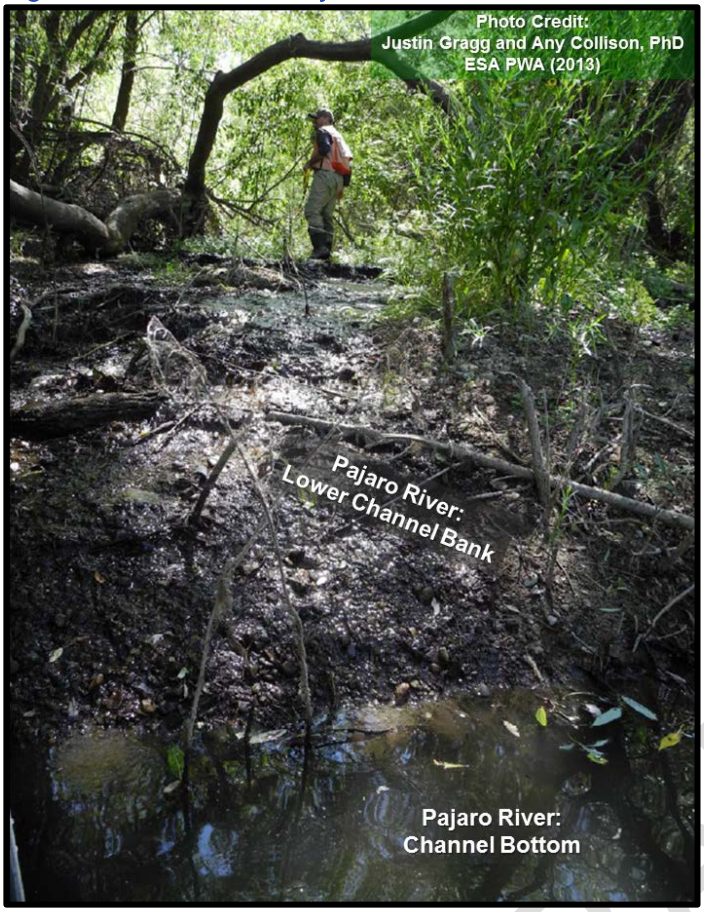
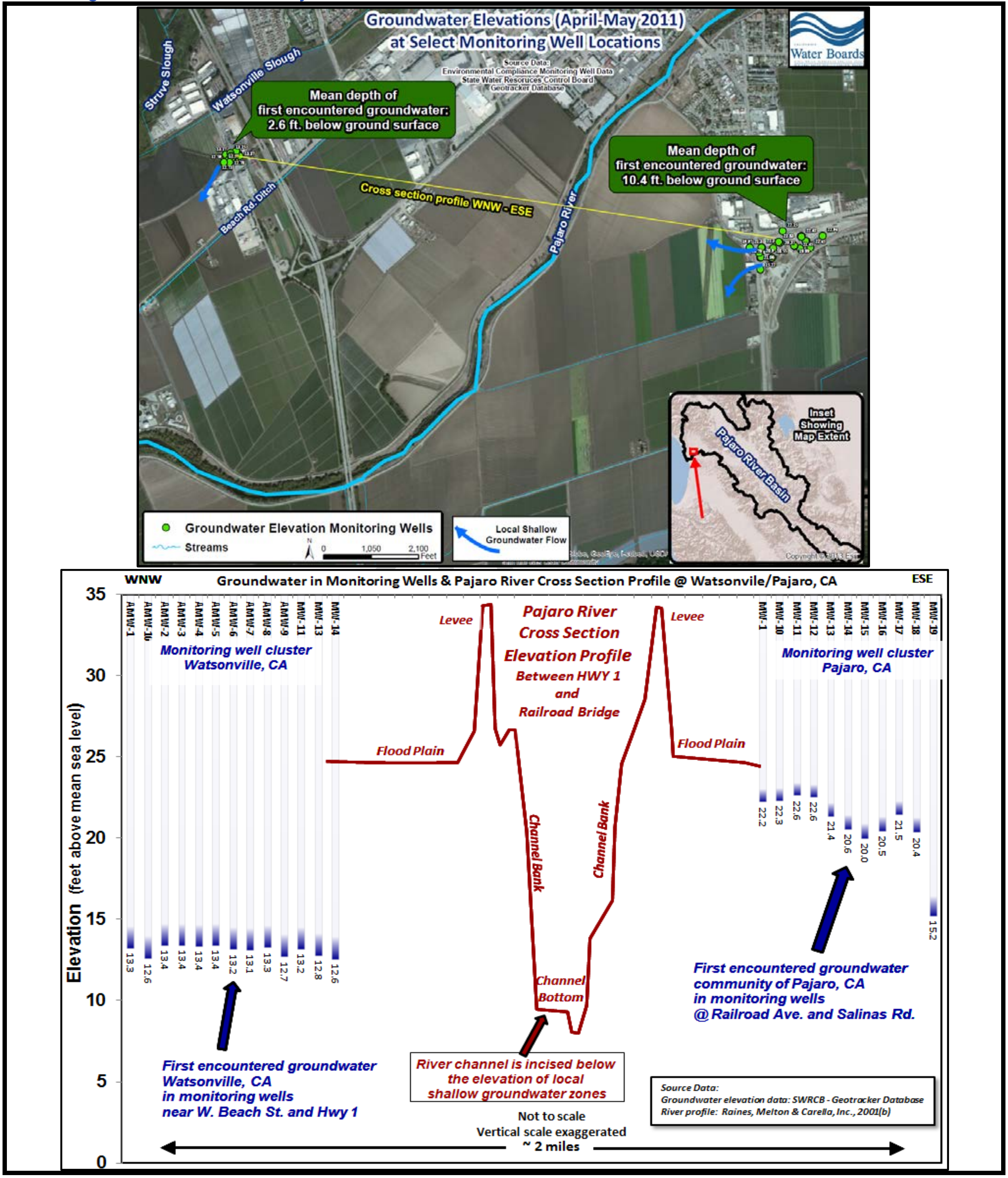


Figure 3-40. Photo of Miller Canal channel bottom and channel bank.

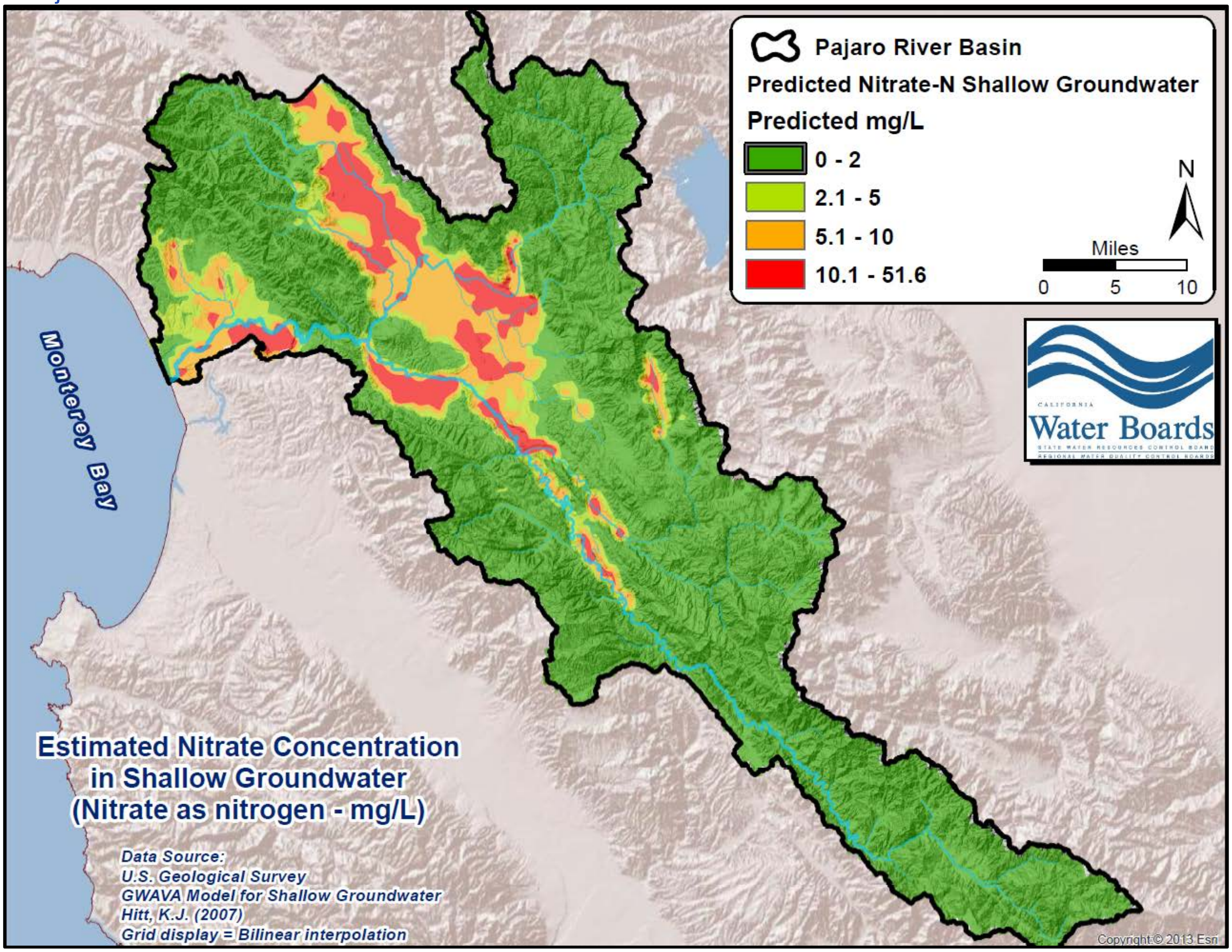
Figure 3-41. Map and associated cross section elevation profile, lower Pajaro River basin near Watsonville. The cross section profile illustrates that the Pajaro River channel is vertically incised below the elevation of local shallow groundwater tables observed in monitoring wells, thus indicating that shallow groundwater can locally flow into the stream channel and contribute to stream flow.



➢ *Estimated N Concentrations in Shallow Groundwater*

As previously noted, stream baseflow resulting from these shallow water-bearing hydrogeologic zones can contribute to nutrient loading to streams. Figure 3-42 illustrates the estimated nitrate as nitrogen concentration in project area shallow, recently-recharged groundwater (data source: U.S. Geological Survey GWAVA model[47]). Shallow, recently recharged groundwater is defined by the U.S. Geological Survey in the GWAVA dataset as groundwaters less than 15 meters below ground surface.

Figure 3-42. Predicted nitrate as nitrogen concentrations in shallow, recently-recharged groundwater, Pajaro River basin.



Nitrate groundwater concentrations are not uniform throughout the project area, and to a significant extent are related to land use/land cover. Pollutant source assessment tools used by staff (see Section 6) require inputs of nitrate concentrations in shallow groundwater for specific land use categories. Therefore, it is necessary to develop plausible estimates of nitrate concentrations in shallow groundwaters of the Pajaro River basin. Paired land use/groundwater nitrate as N concentration estimates are presented in Figure 3-43 and in Table 3-24.

[47] The GWAVA dataset represents predicted nitrate concentration in shallow, recently recharged groundwater in the conterminous United States, and was generated by a national nonlinear regression model based on 14 input parameters. Online linkage: http://water.U.S. Geological Survey.gov/GIS/metadata/U.S. Geological Surveywrd/XML/gwava-s_out.xml

The agricultural, alluvial valley floor basin has substantially higher predicted nitrate concentrations than predicted nitrate in the alluvial fill and fractured bedrock groundwaters of upland and rangeland areas.

Figure 3-43. Estimated nitrate as N concentrations and averages in shallow groundwaters of 1) the alluvial basin floor areas; and 2) the upland regions of the Pajaro River basin.

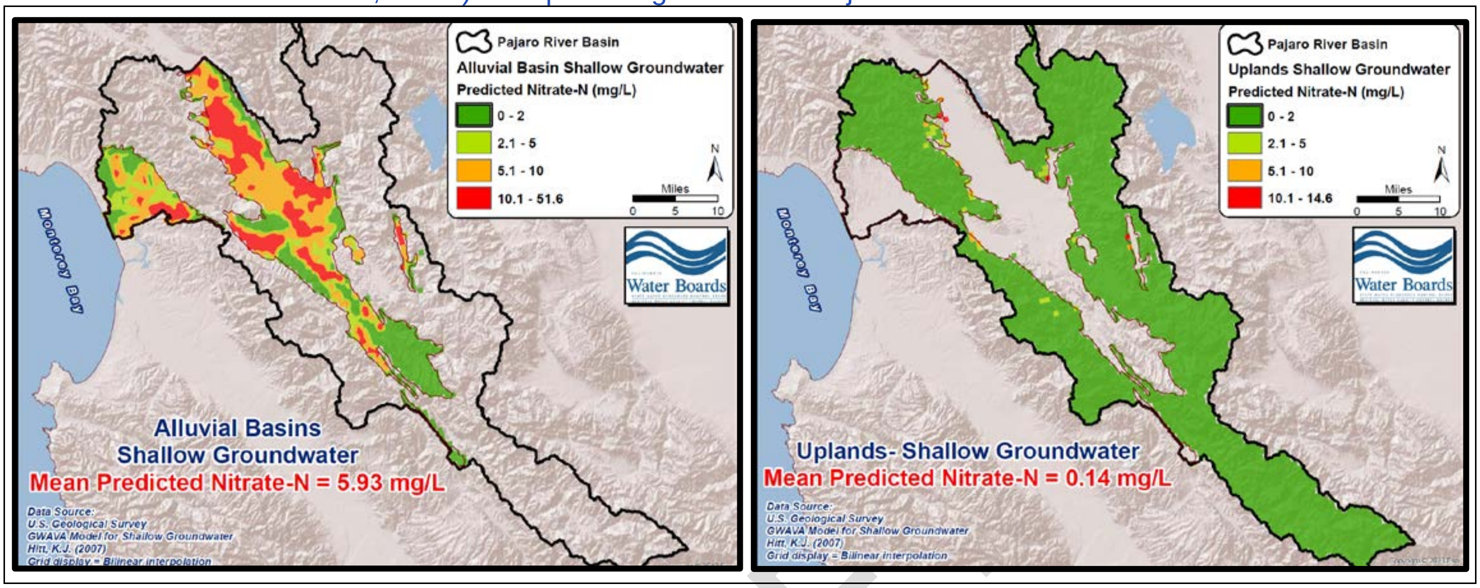


Table 3-24. Measured nitrate as N concentrations and average measures of nitrate as N in shallow groundwaters beneath U.S. urbanized areas (table – source NAWQA studies 1991-1998).

Shallow Ground Water Concentrations in the United States - USGS National Nutrients Synthesis Project

*NO3 + NH4 - Summary Statistics of the **Median Values** Reported for the Suite of Samples From Each Study Area*

Land Use	Number of Observations	Min	25th percentile	Mean	Mean	Median	75th percentile	90th percentile	Max	Ave. % of Times Samples Exceeded Nitrate MCL
Agriculture	1228	0.09	0.47	3.89	3.89	2.82	6.35	9.25	13.02	19.5
Urban	633	0.12	0.72	1.80	1.80	1.56	2.62	3.92	5.37	2.6
Undeveloped Land	81	0.09	0.11	0.25	0.25	0.15	0.37	0.50	0.59	0.0

Data from: USGS (U.S. Geological Survey). 2000. National statistical analysis of nutrient concentrations in ground water, compiled Bernard T. Nolan.

Since nitrogen occurs naturally in the environment, it is also important to recognize that nitrate-impacted groundwater has both a natural, ambient background load, and a load attributable to human activities. Natural, background nitrate concentrations in groundwater in the alluvial valley floor reaches[48] of the Pajaro River basin can be approximated using data obtained by Moran et al., (2011) in an agricultural valley basin area located in the Salinas Valley of central Monterey County. Using isotopic data, Moran et al. (2011) found that precipitation-derived ambient nitrate from observed wells in agricultural areas adjacent to the Arroyo Seco River were always at concentrations less than 4 mg/L, with a mean for all the observed ambient groundwater samples calculated as 1.21 mg/L nitrate as N[49,50]. Staff uses this

[48] It should be noted that ambient, background groundwater nitrate in alluvial valley basins with thick soil profiles may be different (possibly higher) than background nitrate found in bedrock aquifers and alluvial fill of many upland areas. Moran et al. (2011) indicate that rainwater which percolates through alluvial valley soil profiles would interact with soil nitrogen during infiltration and recharge.

[49] The estimate that natural, background nitrate in alluvial valley groundwater is approximately an order of magnitude lower than anthropogenic nitrate in groundwater underlying agricultural areas is consistent with the Salinas Valley and Tulare Lake basin study of the University of California-Davis (2012). In this University of California-Davis study the authors reported that "natural nitrate is a comparatively unimportant source of groundwater N".

value (1.21 mg/L) as a plausible estimate of background nitrate as nitrogen in groundwaters of the Pajaro River basin. Worth noting is that this estimated alluvial valley groundwater background nitrate as N concentration (1.21 mg/L) comports quite well with estimates of background nitrate concentrations reported by the U.S. Geological Survey – as illustrated below – thus providing some additional confidence in staff's estimate:

> *"In general, we use **1 mg/L*** (nitrate-N) as a national background level (see http://water.usgs.gov/nawqa/nutrients/pubs/circ1350/). Note that this is a nationally derived value and that regional background levels can vary."*
>
> *− B.T. (Tom) Nolan, Hydrologist, U.S. Geological Survey, personal communication 12/19/2012 in an email exchange with Central Coast Water Board staff regarding background levels of nitrate-N in groundwater.*
>
> ***emphasis added by Central Coast Water Board staff.*

> *"Nitrate (as N) concentrations in samples from background sites generally were **less than 2 mg/L** for groundwater."*
>
> *− Mueller and Helsel, 1996. "Nutrients in the Nation's Waters: Too Much of a Good Thing?" U.S. Geological Survey Circular 1136.*
>
> ***emphasis added by Central Coast Water Board staff.*

While groundwater research from basins elsewhere in the world are not necessarily directly relevant to groundwater of the Pajaro River basin, it is worth noting that natural background nitrate levels in groundwater in semi-arid regions of China and in Australia comport quite well with the background estimates provided above – thus adding some assurance that these ranges of background nitrate concentrations in groundwater (generally less than 2 mg/L nitrate as N) are frequently observed around the world:

> *"In the (semi)arid northern China, the median values of nitrate baseline for the three large regions (Tarim river basin, TRB; Loess Plateau of China, LPC; North China Plain, NCP) range from 2 to 9 mg/L nitrate as NO_3" [or **0.45 to 2.0 mg/L*** in the nitrate as nitrogen reporting convention]"*
>
> *− Huang, T. et al. 2013. Nitrate in groundwater and the unsaturated zone in (semi)arid northern China: baseline factors controlling transport and fate. Environmental Earth Sciences, Vol. 70, Issue 1, pp. 145-156.*
>
> ***** *emphasis and unit conversion parenthetical note added by Central Coast Water Board staff.*

> *"Background nitrate concentrations in groundwater across Australia are in the order of **less than 2 mg/L NO_3 (as N)***."*
>
> *Bolger, P. and M. Stevens. 1999. Land and Water Resources Research and Development Corporation (LWRRDC). Contamination of Australian Groundwater Systems with Nitrate. LWRRDC Occasional Paper 03/99.*
>
> ***emphasis added by Central Coast Water Board staff.*

Another line of evidence to assess background concentrations of nitrate in groundwater can be developed with tritium data[51]. Tritium is a geochemical tracer which has been used to identify relative

[50] Moran et al. (2011) report nitrate as NO3; however staff chose to report this value as nitrate-N herein, because in staff's judgment and based on the body of scientific literature presented herein, it is plausible that any alluvial valley groundwater less than about 5 mg/L nitrate-NO3 could be representative of ambient background conditions, or conditions that have no significant human impacts. Further, staff endeavors to develop biostimulatory targets that would not be infeasible to achieve because of plausible background conditions.

[51] Tritium, a radioactive isotope of hydrogen, is measured and used to indicate differences in the relative age of groundwaters. Elevated levels of tritium were introduced into the atmosphere by nuclear weapons testing between 1952 and 1980. Therefore groundwaters with relatively high levels of tritium indicate recharge of atmospheric meteoric waters after 1952. By convention, groundwaters with less than 0.8 TU represent groundwaters which were recharged before 1952 (see U.S. Geological Survey, 2007).

groundwater ages. By convention (U.S. Geological Survey 2007), relative groundwater ages are identified on the basis of the following tritium concentration ranges (tritium units[52]):

1. Less than about 0.8 tritium units – generally represents premodern groundwater (groundwater recharged prior to 1952);
2. About 0.8 to about four tritium units – generally represents a mixture of premodern groundwater (recharged prior to 1952) and recent groundwater (recharged after 1952); and
3. Greater than four tritium units – represents groundwater substantially comprised of recently recharged groundwater (recharged after 1952).

Staff used paired tritium–nitrate groundwater data available from the U.S. Geological Survey to estimate nitrate concentration ranges in various types of groundwaters in California – these numerical summaries are presented in Table 3-25.

Table 3-25. Numerical summaries of nitrate as N concentrations in various types of groundwaters in California (nitrate as N units = mg/L). Groundwater types are differentiated on the basis of tritium concentrations. See Figure 3-44 for a map of the sampling sites.

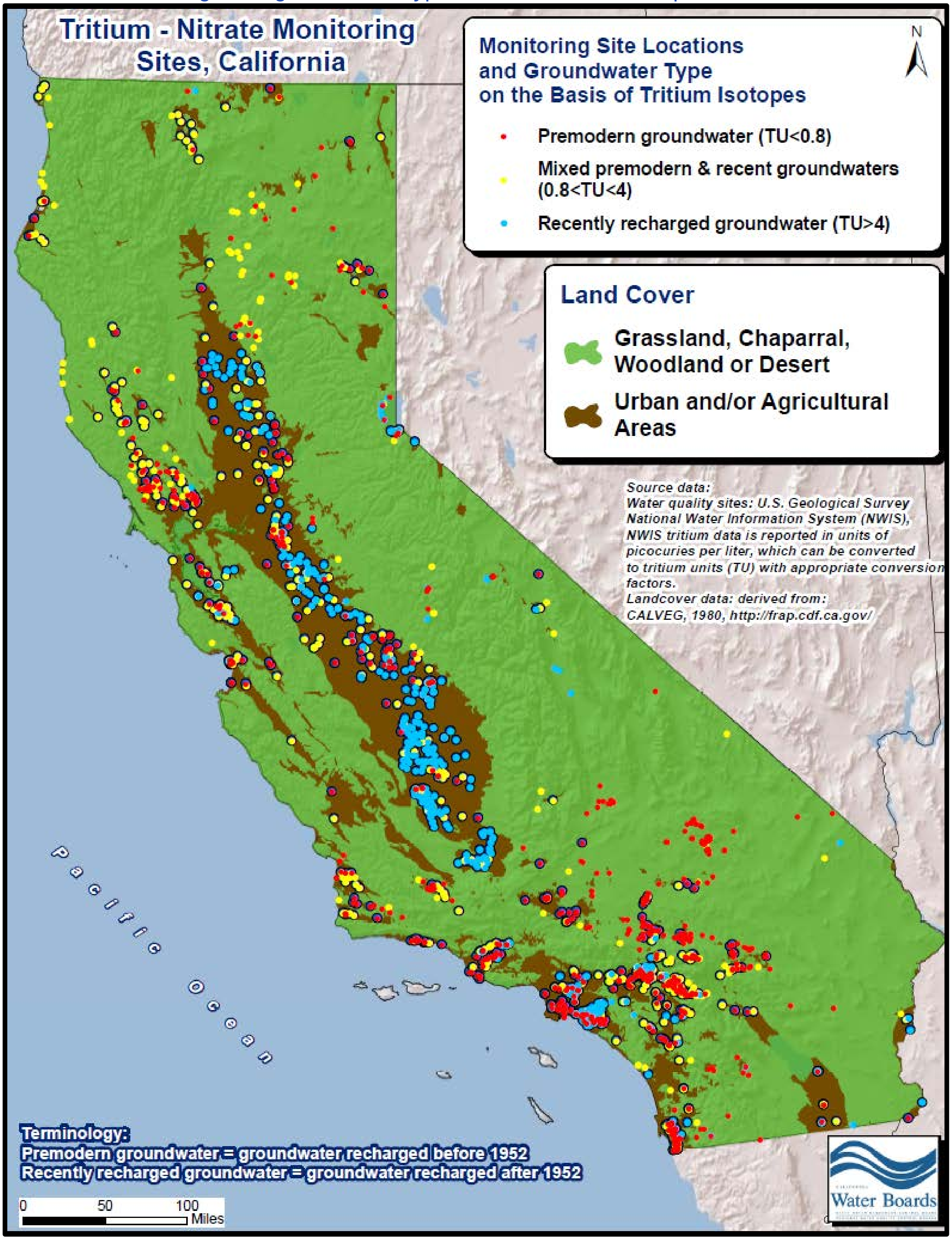
Groundwater Type ***(on the basis of tritium concentrations)***	**Sample Dates**	**Arithmetic Mean**	**Min**	**25th %**	**50th % (median)**	**75th %**	**90th %**	**Max**	**No. of Samples**
Premodern groundwater[A] *(recharged before 1952)*	March 1984 – Aug. 2012	2	0.02	0.06	0.64	2.5	5.35	45.3	873
Mixed premodern groundwater and recently recharged groundwater	Apr. 1988 – Aug. 2012	4.54	0.02	0.35	1.98	5.37	11.04	77.3	657
Mostly recently recharged groundwater *(comprised mostly of water recharged after 1952)*	Sept. 1981 – Apr. 2012	7.26	0.002	0.46	2.72	8.25	18.12	185	487

Source Data: U.S. Geological Survey, National Water Information System, online linkage: http://waterdata.usgs.gov/nwis
[A] Some samples collected in recent years could potentially represent very recently recharged groundwater, since groundwater recharged within the last decade may be indistinguishable from pre-1952 era groundwater on the basis of tritium data – see report narrative.

Figure 3-44 illustrates the sampling locations for the paired tritium-nitrate groundwater samples, and suggests reasonably good spatial representation across the state. “Premodern” groundwaters (groundwater recharged prior to 1952, and thus less likely to have been influenced by human activities) generally have the lowest nitrate as N concentration ranges (median = 0.64 mg/L, mean = 2 mg/L). The nitrate as N concentrations of these “premodern” groundwaters plausibly represent natural background conditions, and the median and mean nitrate as N concentrations observed comport reasonably well with the estimates of natural background groundwater nitrate as N reported in the scientific literature noted previously. In contrast, recently recharged groundwater (which are more likely to be influenced by human activities) have generally higher nitrate as N concentrations (median = 2.72 mg/L, mean = 7.28 mg/L) – see Table 3-25 – consistent with the presumption of a greater human influence on recently recharged groundwaters.

[52] 1 tritium unit (TU) is equal to 3.22 picocuries per liter. See U.S. Geological Survey conversion factors, online linkage: http://pubs.usgs.gov/sir/2010/5229/section.html

Figure 3-44. Groundwater monitoring sites in California which have paired nitrate-tritium water quality data (source U.S. Geological Survey, National Water Information System) and color-coded to illustrate estimated relative age and groundwater type based on tritium isotope concentrations.



It should be noted that the half-life of tritium is relatively short (12.32 years)[53], and since atmospheric nuclear testing ended by 1980, atmospheric levels of tritium began to return to pre-atomic testing, natural background levels around the mid–1990s. Therefore, the utility of tritium as a geochemical tracer of relative groundwater ages is approaching an expiration date. Modern precipitation increasingly becomes indistinguishable from precipitation from the pre-atomic testing era on the basis of tritium data alone.

Nonetheless, tritium as a tracer of atomic testing-era precipitation and recharge dating will remain useful for the next several decades (Eastoe, et al. 2011). Indeed, tritium is still being used in recent studies of groundwater age (U.S. Geological Survey 2007, U.S. Geological Survey 2011). Noteworthy, is that the paired tritium-nitrate California data staff assessed came from a wide range of sampling dates going back to the early 1980s, providing reasonably good temporal variation, Further, a non-parametric Wilcoxon rank sum test[54] using R[55] of premodern California groundwaters and recently recharged California groundwaters indicates that these two groups of groundwaters are highly statistically significantly different from each other (P value = 2.2e-16)[56], indicating a very small probability of observing this difference by random chance.

Also highlighting the differences between these groundwater types, Table 3-26 illustrates that approximately 21 percent of recently recharged California groundwaters exceed the nitrate human health water quality standard of 10 mg/L (nitrate as N), compared to only approximately 3% of groundwater samples from the premodern category. This is due to the fact that groundwaters recharged after 1952 are more likely to be influenced by human activities and land use practices.

Table 3-26. Percent of samples that exceed, or are less than, the nitrate human health water quality standard (MCL) in different groundwater types in California.

	% of Samples Exceeding Nitrate MCL*	% of Samples Less Than Nitrate MCL*	No. of Samples
Mostly Recently Recharged Groundwater	20.7%	79.3%	487
Mixture of Premodern & Recent Groundwater	11.6%	88.4%	657
Mostly Premodern Groundwater	3.2%	96.8%	873

* MCL = maximum contaminant level – the human health water quality standard (10 mg/L nitrate as nitrogen)

Recapping, multiple lines of evidence assessed above, including groundwater studies in the nearby Salinas Valley, personal communication and reporting from the U.S. Geological Survey, scientific literature, and tritium isotope data indicate that natural background concentrations of nitrate as N in groundwaters of the Pajaro River basin could be expected to be in the range 1 to 2 mg/L. Staff is using the aforementioned Moran et al., 2011 study, as a quantification of average natural background nitrate as N in alluvial basin groundwaters of the Pajaro River basin. This value thus represents the average, expected ambient concentration of nitrate as N in unimpacted shallow groundwaters underlying the alluvial valley floor areas.

In addition to a natural background nitrate load, groundwaters locally have nitrate loads attributable to human influence. Thus, the information and data presented previously (refer back to Figure 3-43 and Table 3-24) also provides insight into expected average concentrations of nitrate as N in shallow groundwaters underlying agricultural areas, urbanized areas, rangelands and woodlands of the river basin.

The text box below summarizes staff's conclusions drawn from this information.

[53] Tritium naturally decays to a non-radioactive isotope of helium (^{3}He). http://en.wikipedia.org/wiki/Tritium

[54] Also widely known as the Mann-Whitney test.

[55] R Core Team (2013). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org

[56] By convention, P-values are considered to indicate statistical significance when the P-value < 0.05.

Based on the aforementioned information, estimated average shallow groundwater nitrate (nitrate as N) in the Pajaro River basin can be summarized as follows:

- **ALLUVIAL VALLEY AMBIENT BACKGROUND:** *Ambient natural background nitrate as N concentration that would be expected in unimpacted shallow groundwater underlying the alluvial valley floor:*
  - **1.21 mg/L** (see preceding discussion on background nitrate)
- **AGRICULTURAL AREAS:** *Average, shallow groundwater nitrate as N concentration expected to underlie agricultural areas of the Pajaro River Basin:*
  - **5.93 mg/L** (refer back to Figure 3-43)
- **URBAN AREAS:** *Average, shallow groundwater nitrate as N concentration attributable to urban influence that would be expected to underlie urban areas of the Pajaro River Basin:*
  - **1.8 mg/L**[57]
- **WOODLAND, RANGELAND, UPLAND REACHES:** *Average, shallow groundwater nitrate as N concentration that would be expected in bedrock aquifers and alluvial fill underlying woodland and rangeland in upland ecosystems of the Pajaro River Basin:*
  - **0.14 mg/L** (refer back to Figure 3-43)

➢ *Estimated P Concentrations in Shallow Groundwater*

Phosphorus typically does not leach to groundwater from land use activities in substantial amounts because phosphorus readily binds to sediment and is not as mobile in the environment as nitrate. Nonetheless, phosphorus is found in groundwaters generally as a result of the leaching of subsurface geologic materials.

Figure 3-45 and Table 3-27 present observed phosphorus concentrations in groundwaters and spring waters of the Pajaro River basin. Thus, our estimate of average phosphorus as P concentrations in groundwaters of the Pajaro River basin is as follows:

On the basis of National Geochemical Dataset water quality data, a plausible estimate of average groundwater phosphorus concentration within the river basin can be identified from the geometric mean of the available data, which is: **0.04 mg/L** phosphorus as P.

[57] Average of national median values, refer back to table in Table 3-24

Figure 3-45. Observed phosphorus concentrations in groundwaters of the Pajaro River Basin on the basis of National Geochemical Database datasets.

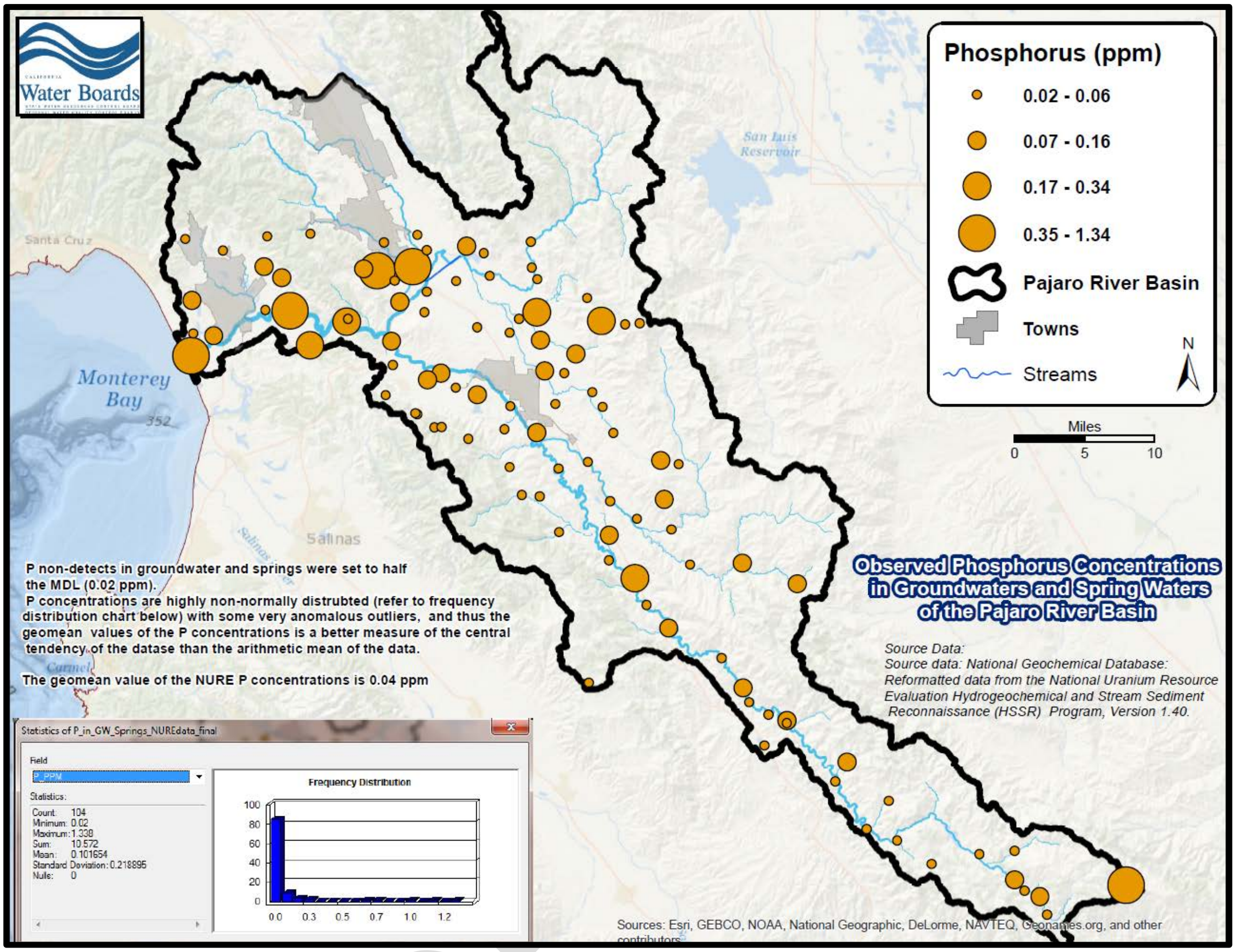


Table 3-27. Observed concentrations of phosphorus in groundwaters and spring waters of the Pajaro River Basin (units = mg/L) on the basis of National Geochemical Database datasets.

Groundwater Constituent	Sampling Dates	Geometric Mean	Min	50th % (median)	75th %	90th %	Max	No. of Samples
Observed phosphorus as P concentrations in groundwaters of the Pajaro River Basin[A]	Jan.to Feb. 1980	0.04	0.02	0.02	0.08	0.16	1.34	104

[A] Source data: National Geochemical Database: Reformatted data from the National Uranium Resource Evaluation Hydrogeochemical and Stream Sediment Reconnaissance (HSSR) Program, Version 1.40. Begun in 1975 and ending in 1980, the HSSR program was initiated by a consortium of federal agencies and included planned systematic sampling of sediments, groundwater, and surface water over the conterminous United States.

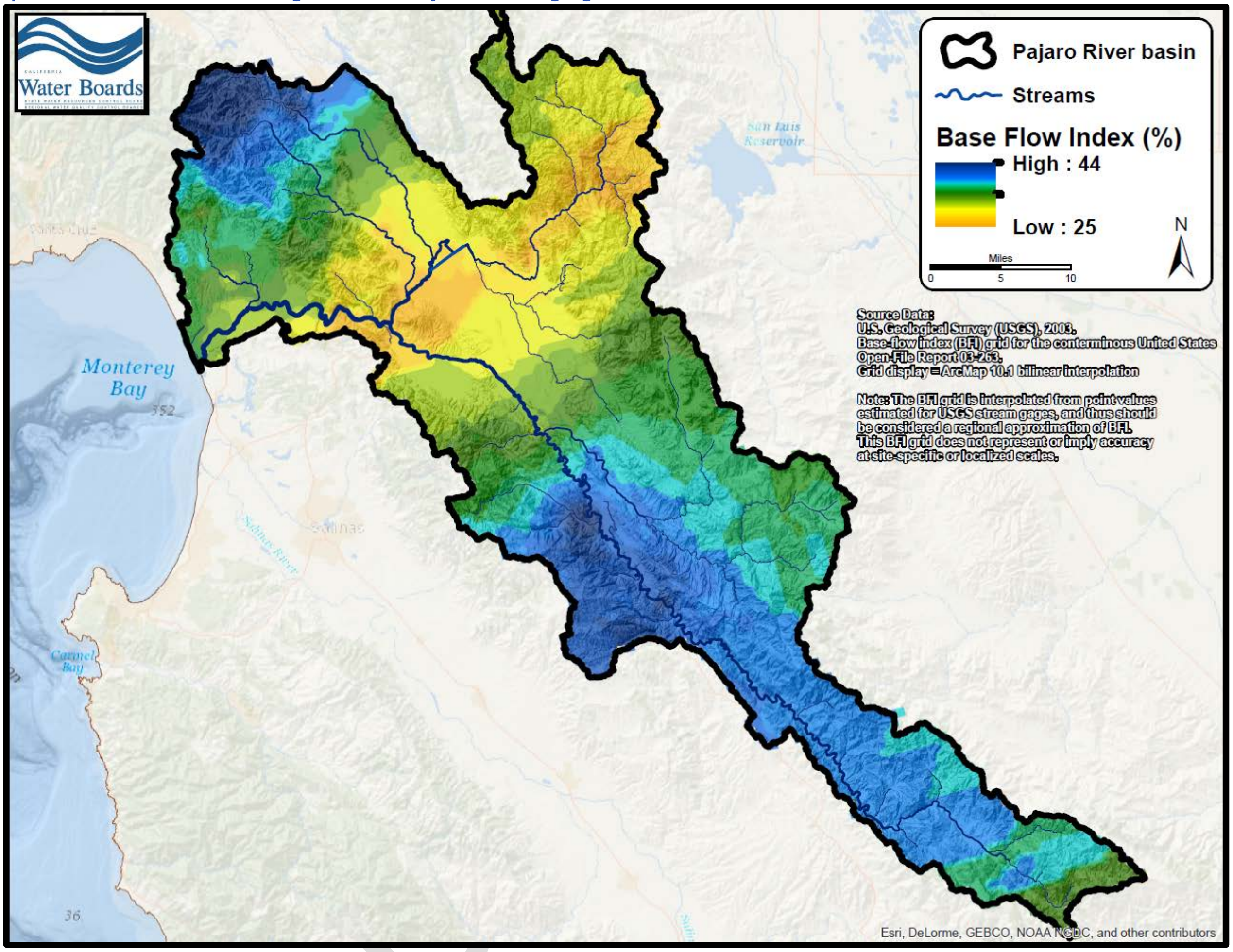
➢ *Base Flow Indices*

As noted previously, groundwater inputs to streamflow as baseflow is a hydrologic process that varies in magnitude and importance based on numerous physical, climatic, geomorphic, geologic, and characteristics. Figure 3-46 illustrates regional estimates and spatial variation of base flow[58] (measured as base flow indices) in the Pajaro River Basin. This map should be considered a coarse, gross regional approximation of base flow indices mathematically interpolated between stream gages; there will be substantial variation in the magnitude of base flow at localized and site-specific scales. It can be concluded that shallow groundwater locally is an important hydrologic process contributing to total stream flow, locally in the Pajaro River Basin. Where groundwater is a significant contributor to total

[58] Baseflow is the component of stream flow that can be attributed to groundwater discharge into streams.

stream flow, pollution present in shallow groundwater has the potential to locally degrade surface water (refer back to Figure 3-34).

Figure 3-46. Estimated regional average base flow indices in the Pajaro River Basin, on the basis of interpolation of U.S. Geological Survey stream gage data.



- ***Heterogeneity of Subsurface Alluvial Depositional Systems***

Because groundwater exists in three-dimensional space it is relevant to be cognizant of potential spatial variation in groundwater-bearing zones. It is well known that due to the depositional nature of fluvial depositional systems[59], the subsurface stratigraphic architecture of alluvial basins are highly heterogeneous both laterally and vertically (see Figure 3-47, Figure 3-48 and Figure 3-49 for conceptual examples). Thus, perched or shallow groundwater systems[60] and groundwater flow will preferentially occur in shallow, laterally discontinuous permeable[61] zones (sands and gravel), In fluvial deposits, these discontinuous permeable sand and gravel zones constitute the channel belt facies[62] of the depositional system, and generally nest within or interfinger with fine-grained aquitard strata (silts and clays) of the floodplain and overbank facies.

[59] "Fluvial" is a term used in physical geography and geology to refer to the processes associated with rivers and streams including the sedimentary deposits and landforms created by them. Sedimentary material deposited by rivers and streams is commonly referred to as alluvium or alluvial deposits.

[60] "Perched groundwater" refers to shallow zones of saturation, typically in shallow, subsurface sands and gravels, which exist vertically above the main zone of saturation.

[61] Permeability is a measure of a soil or rock's ability to transmit fluid.

[62] Facies (sometimes also called "lithofacies") – An assemblage of sediment types deposited in a specific depositional environment (aka, tidal flats, alluvial flood plains, river channel belt, river deltas, shallow offshore marine environments, etc).

Figure 3-47. Generalized block model of a fluvial depositional system (figure credit: Utrecht University, Department of Physical Geography).

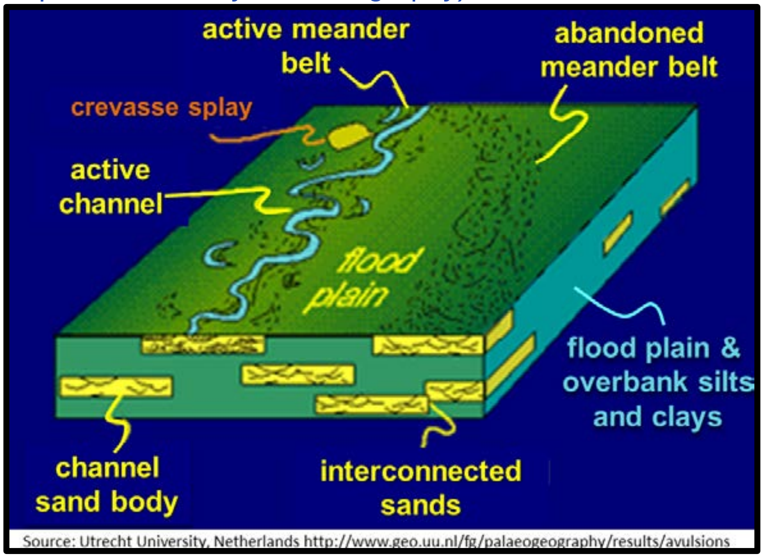


Figure 3-48. Seismic block model of alluvial deposits in the shallow subsurface of the San Joaquin Valley, illustrating heterogeneity in subsurface hydraulic properties (figure credit: Hyndman et al., 2000).

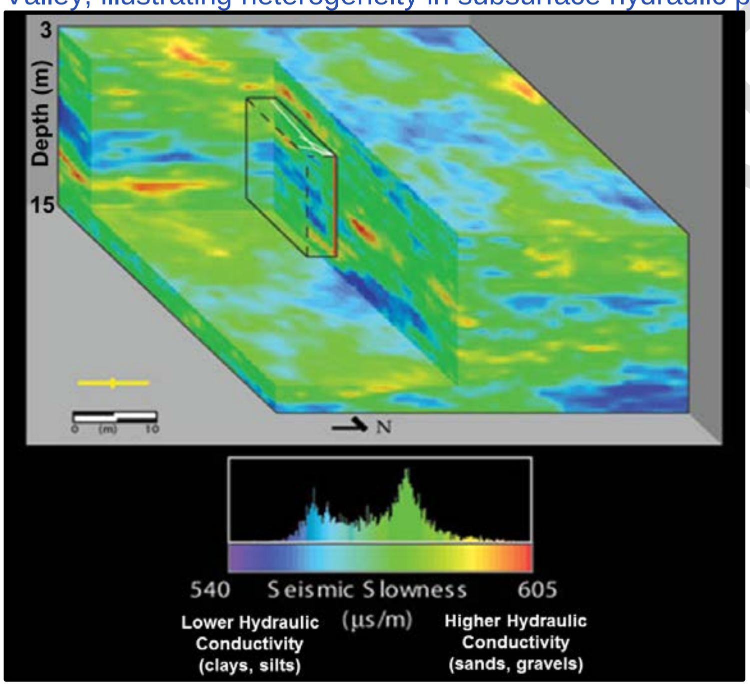
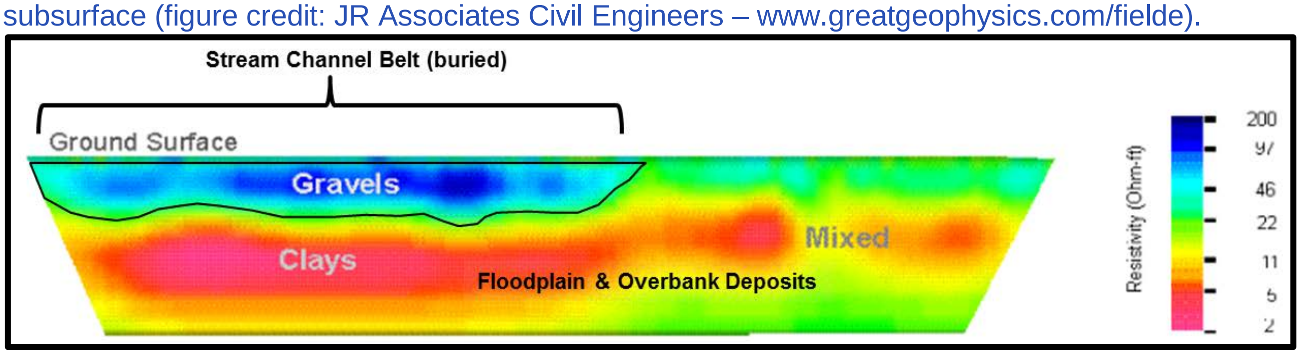
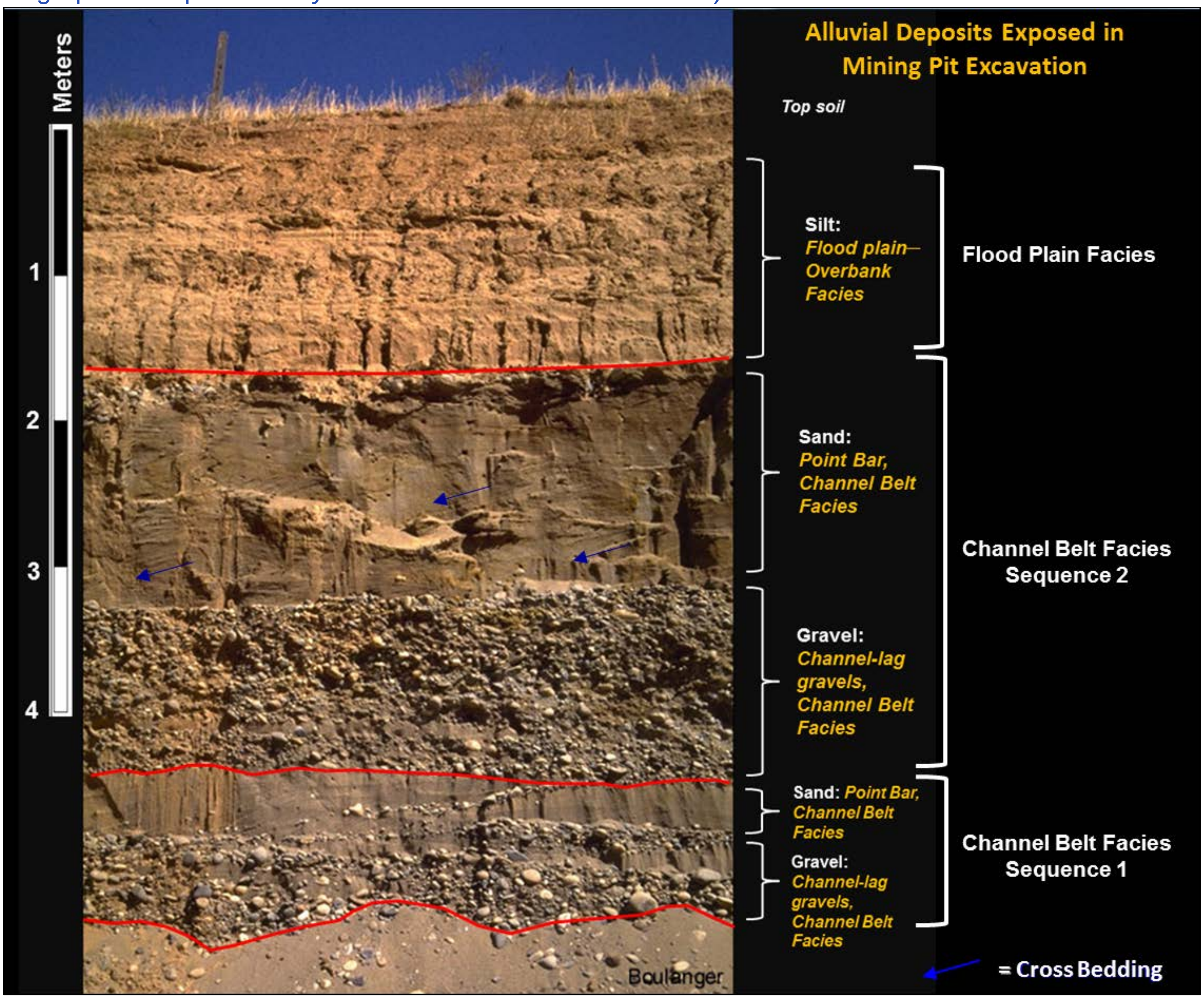


Figure 3-49. Electrical resistivity profile of buried stream channel belt & floodplain deposits in the shallow subsurface (figure credit: JR Associates Civil Engineers – www.greatgeophysics.com/fielde).



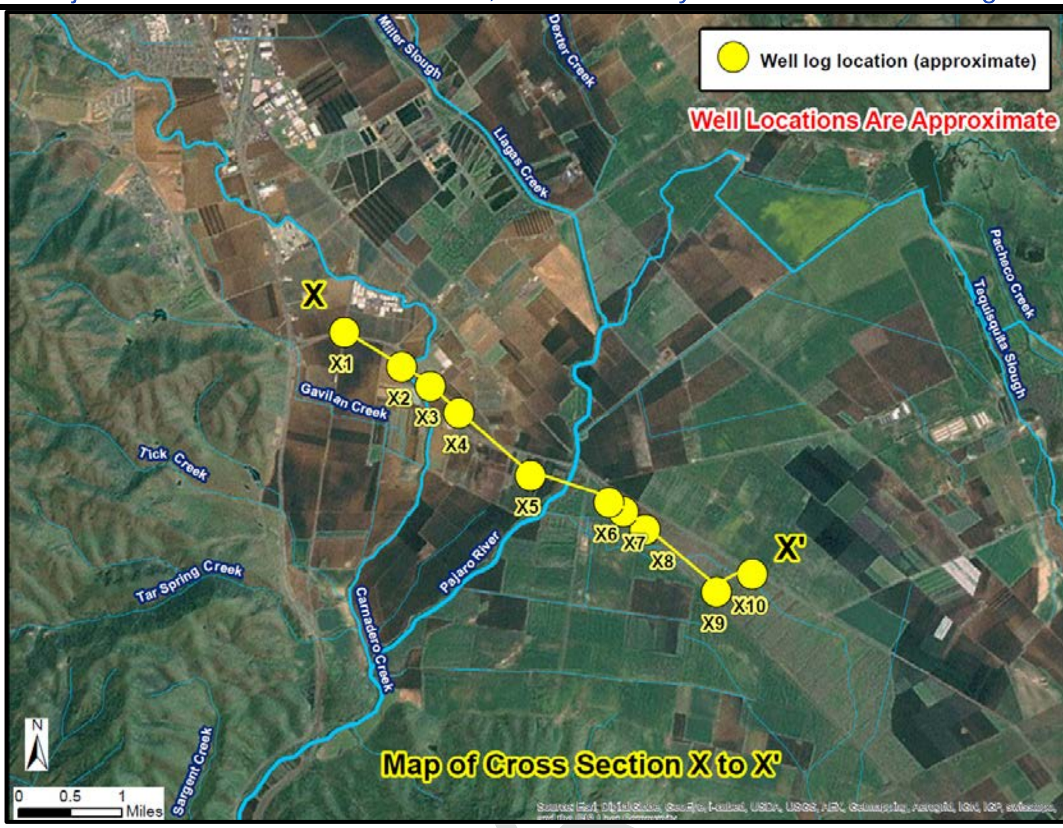
In valley floor areas characterized by low-permeability surficial soils and sediments, it might be assumed that conditions are not present favoring lateral groundwater flows in the shallow most subsurface (e.g., less than five meters depth below ground surface). However, due to the lateral and vertical heterogeneity of fluvial depositional systems, low-permeability surficial clays and silts can locally be underlain by high-permeability river gravels and sands present in the shallow subsurface (see Figure 3-50), which potentially promote shallow, lateral groundwater flow, perched groundwater horizons, and hydraulic communication with nearby streams given appropriate hydrogeologic conditions.

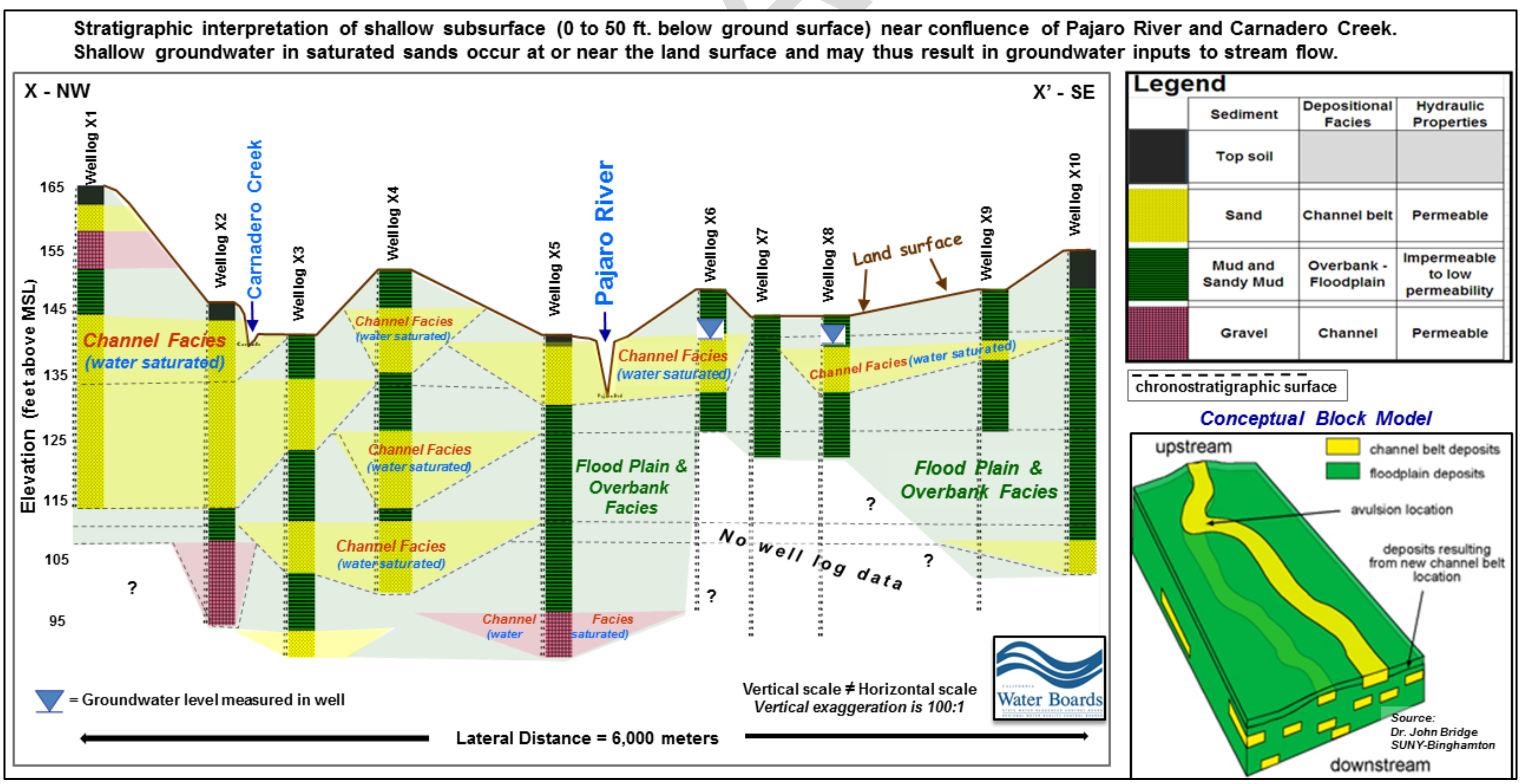
Figure 3-50. Excavation exposing Sacramento Valley alluvial sedimentary deposits. This exposure illustrates a one to two meter thick surficial flood plain silt, underlain by high-permeability river channel sands and gravels present in the shallow subsurface (photo courtesy of Dr. Ross W. Boulanger – stratigraphic interpretation by Central Coast Water Board staff).



Indeed, Figure 3-51 illustrates that shallow, laterally-discontinuous high permeability facies (channel belt sands and gravels) locally occur at very shallow depths (five to 20 feet below ground surface) in the basin floor reaches of the southern Santa Clara Valley. These shallow, discontinuous permeable strata would be expected to be potential zones for perched groundwater horizons, and conduits for shallow groundwater flow and baseflow contributions to streams. Indeed, as shown in Figure 3-51, groundwater elevation measurements and lithofacies indicate that shallow groundwater in permeable sand bodies present in the shallow subsurface underlying valley floor areas can locally be in direct hydraulic communication with waters in the Pajaro River channel.

Figure 3-51. Map and stratigraphic interpretation of shallow subsurface (cross section X – X') near confluence of Pajaro River and Carnadero Creek, south of Gilroy on the basis of well log data.



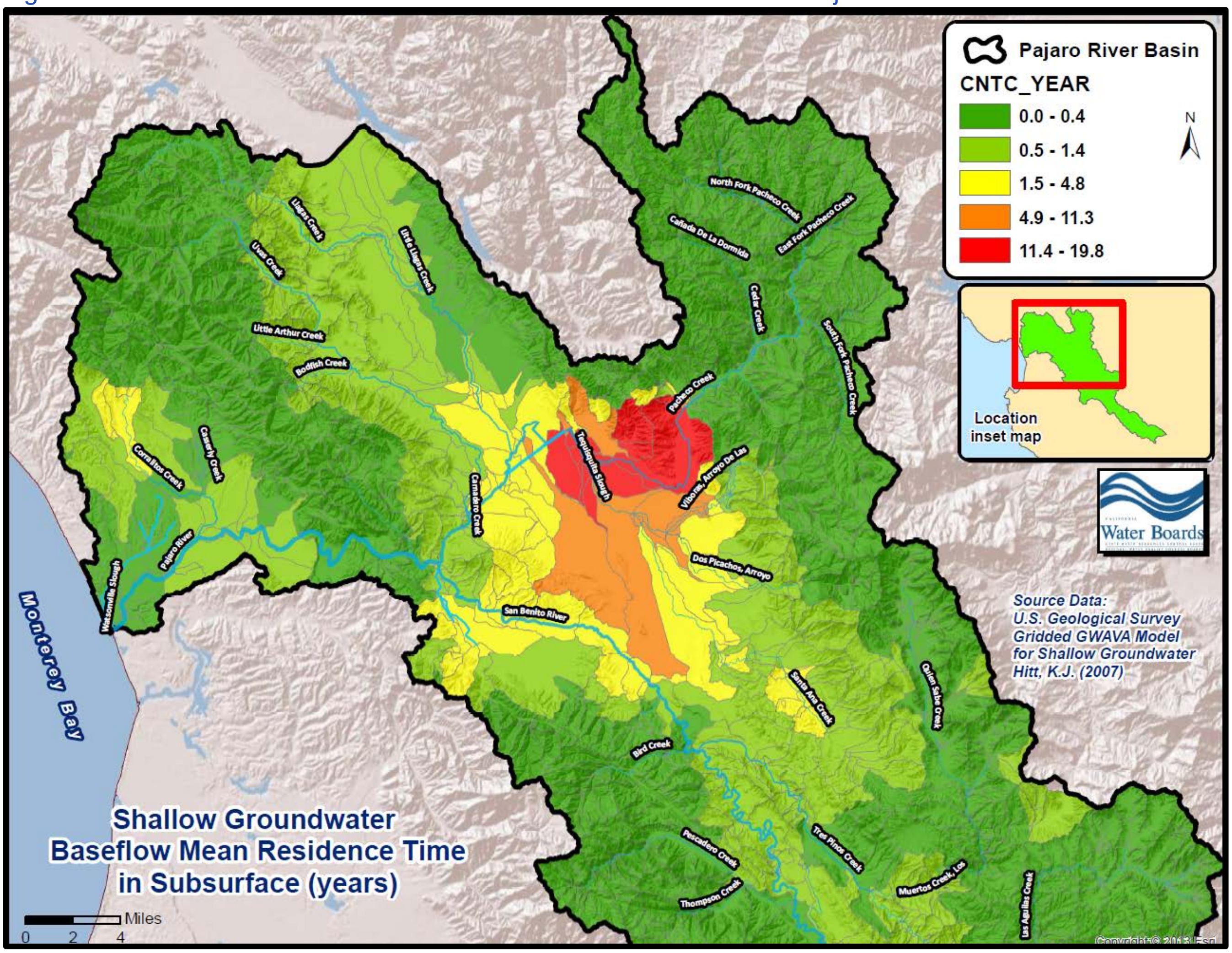


Interpreted from well log data available from the State Water Resources Control Board's GAMA Geotracker database.

➢ Residence Time of Baseflow in the Shallow Subsurface

Finally, it may be important to consider the possibility of existing legacy pollution of shallow groundwater, and the residence time in the subsurface before the groundwater is expressed as baseflow. Legacy pollution (associated with long-residence times in groundwater) may be unrelated to current land use practices, and could potentially be a result of land use practices that occurred many years ago. From an implementation perspective, it could be important to consider whether nitrate pollutant loads in shallow groundwater may express themselves as creek base flow relatively rapidly; or alternatively whether the subsurface residence time of baseflow is on the order of years to decades. Figure 3-52 illustrates estimated mean groundwater baseflow residence time in the subsurface[63] on the basis of NHD catchments. It should be noted that "contact time", as defined by the U.S. Geological Survey (U.S. Geological Survey) metadata for this dataset represents an "average" amount of time groundwater is in the subsurface before being expressed as stream baseflow.

Figure 3-52. Estimated baseflow mean contact time in the northern Pajaro River Basin.



Collectively, the U.S. Geological Survey baseflow contact time estimates suggest that nitrate pollution of shallow groundwater, and nutrient loads associated with ambient baseflow to streams in some alluvial basin floor reaches of the southern Santa Clara Valley may locally be partially attributable to legacy pollution.

[63] Data source: Attributes for NHDplus Catchments, Contact Time, 2002. This dataset was created by the U.S. Geological Survey and represents the average contact time, in units of days, compiled for every catchment of NHDplus for the conterminous United States. Contact time is the baseflow residence time in the subsurface.

3.10 Geology

Geology can have a significant influence on natural, background concentrations of nutrients and other inorganic constituents in stream waters. The linkage between geologic conditions and stream water chemistry has long been recognized (for example, U.S. Geological Survey, 1910 and U.S. Geological Survey, 1985). Stein and Kyonga-Yoon (2007) reported that catchment geology was the most influential environmental factor on water quality variability from undeveloped stream reaches in lightly-disturbed, natural areas located in Ventura, Los Angeles, and Orange counties, California. Stein and Kyonga-Yoon (2007) concluded that catchments underlain by sedimentary rock had higher stream flow concentrations of metals, nutrients, and total suspended solids, as compared to areas underlain by igneous rock. Additionally, the Utah Geological Survey hypothesized that organic-rich marine sedimentary rocks in the Cedar Valley of southern Utah may locally contribute to elevated nitrate observed in groundwater (Utah Geological Survey, 2001). Nitrogen found in the organic material of these rock strata are presumed by the Utah Geological Survey researchers to be capable of oxidizing to nitrate and may subsequently leach to groundwater. Further, the Las Virgenes Municipal Water District (LVMWD, 2012) recently reported that high background levels of biostimulatory substances (nitrogen and phosphate) in the Malibu Creek Watershed appear to be associated with exposures of the Monterey/Modelo Formation. Also worth noting, Domagalski (2013) states that knowledge about natural and geologic sources of phosphorus in watersheds are important for developing nutrient management strategies.

Consequently, in evaluating the effect of anthropogenic activities on nutrient loading to streams, it is also relevant to consider the potential impact on nutrient water quality which might result from local geology.

- ***Regional Geologic Setting***

The 1,300 square mile Pajaro River Basin extends across three distinct geologic provinces[64]. To a large extent, geologic provinces in the river basin are defined by the location of the northwest-trending San Andreas Fault. Figure 3-53 illustrates geologic provinces of the Pajaro River Basin, with a gamma-ray radiometric map overlay. Aerial measurements of gamma-ray flux measure natural background radioactivity in surficial geologic materials[65], and can provide insight into geologic variation. West of the San Andreas Fault, coastal areas of the lowermost Pajaro River Basin, and the western margins of the San Benito River subbasin in the Gabilan Range[66], are part of the distinct Salinian Block geologic terrain which is associated with the Central Coastal geologic province (see U.S. Geological Survey, 1995a). The Central Coastal geologic province is characterized by a prevailing Pliocene to Oligocene stratigraphy (including the Miocene-age Monterey Formation) and a series of ranges and intermontane valleys exhibiting northwest-oriented topographic and geologic structural trends typical of this part of California: The granitic nature of basement rock of the Salinian Block is illustrated by the gamma-ray radiometric data – note that higher radiometric signatures (greater than about 18 K+Th+U gamma ray composite[67]) in surficial geologic materials of the Gabilan Range are typical of outcropping acidic to intermediate igneous rock, such as granite and granodiorite (see Figure 3-53).

East of the San Andreas Fault, most of the rest of the Pajaro River Basin is associated with the Northern Coastal geologic province; this province includes the Diablo Range, the Santa Clara Valley, the San

[64] The convention for geologic provinces used here is based on digital data from U.S. Geological Survey, 2000 – U.S. Geological Survey's Digital Data Series DDS-60: *Geologic Provinces of the World, 2000 World Petroleum Assessment, all defined provinces.* Geologic provinces are defined on the basis structural style, dominant lithologies, and age of the geologic strata.

[65] Low levels of naturally-occurring radioactive elements occur in all rock material. Aerial gamma-ray surveys measure the gamma-ray flux produced by the radioactive decay of the naturally occurring elements K-40, U-238, and Th-232 in the top few centimeters of rock or soil (K= potassium, U= uranium, Th= thorium).

[66] Figure 3-2 previously illustrated the location of major mountain ranges associated with the Pajaro River Basin.

[67] See Table 1 in Ward, H.S. Undated. Gamma-Ray Spectrometry in Geological Mapping and in Uranium Exploration. Department of Geology and Geophysics, University of Utah Research Institute GL04048.

Francisco Bay Area, and the northern Coast Ranges. This geologic province is characterized by a prevailing Holocene to Pliocene stratigraphy. Furthermore, in contrast to the granitic basement rock of the Central Coastal geologic province, the basement rock of the Northern Coastal geologic province is characterized by highly deformed marine sedimentary rock of the Jurassic-Cretaceous Franciscan Complex (U.S. Geological Survey, 1995a). Finally, the uppermost San Benito River subbasin are associated with the San Joaquin Basin geologic province – basement rock of the western San Joaquin Basin geologic province is presumed to be Coast Range ophiolite and rocks of the Franciscan Complex (U.S. Geological Survey, 2007).

The broadly-defined geologic provinces of the Pajaro River Basin can be subdivided into distinct smaller scale fault blocks. Fault blocks vary in basement rock composition, structural style, and stratigraphy, (see McLaughlin, et al, 2001). These fault block terrains are bounded by faults and fault zones such as the San Andreas Fault zone and the Caleveras Fault zone. Examples of fault blocks within the Pajaro River Basin includes the Santa Cruz block (associated with the Pajaro Valley), and the New Almaden Block (which includes the Uvas and Llagas Creek watersheds). Geologic attributes of these fault blocks, such as faulting, lithology, and hydrostratigraphy can influence the nature and distribution of water resources of the Pajaro River Basin.

Figure 3-53. Generalized geologic provinces of the Pajaro River Basin, with gamma-ray radiometric map overlay shown as color gradient illustrating some aspects of geologic variation in the river basin.

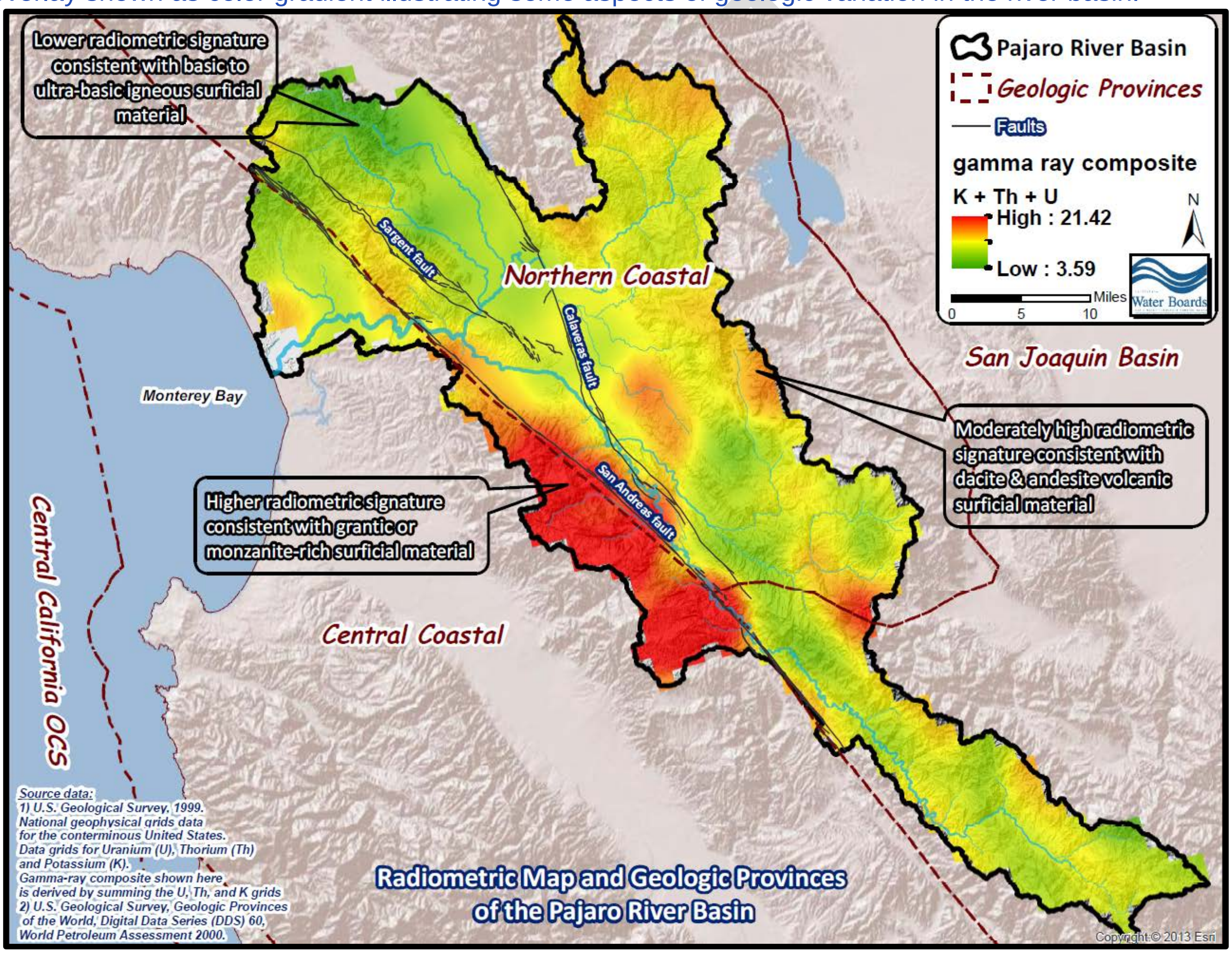
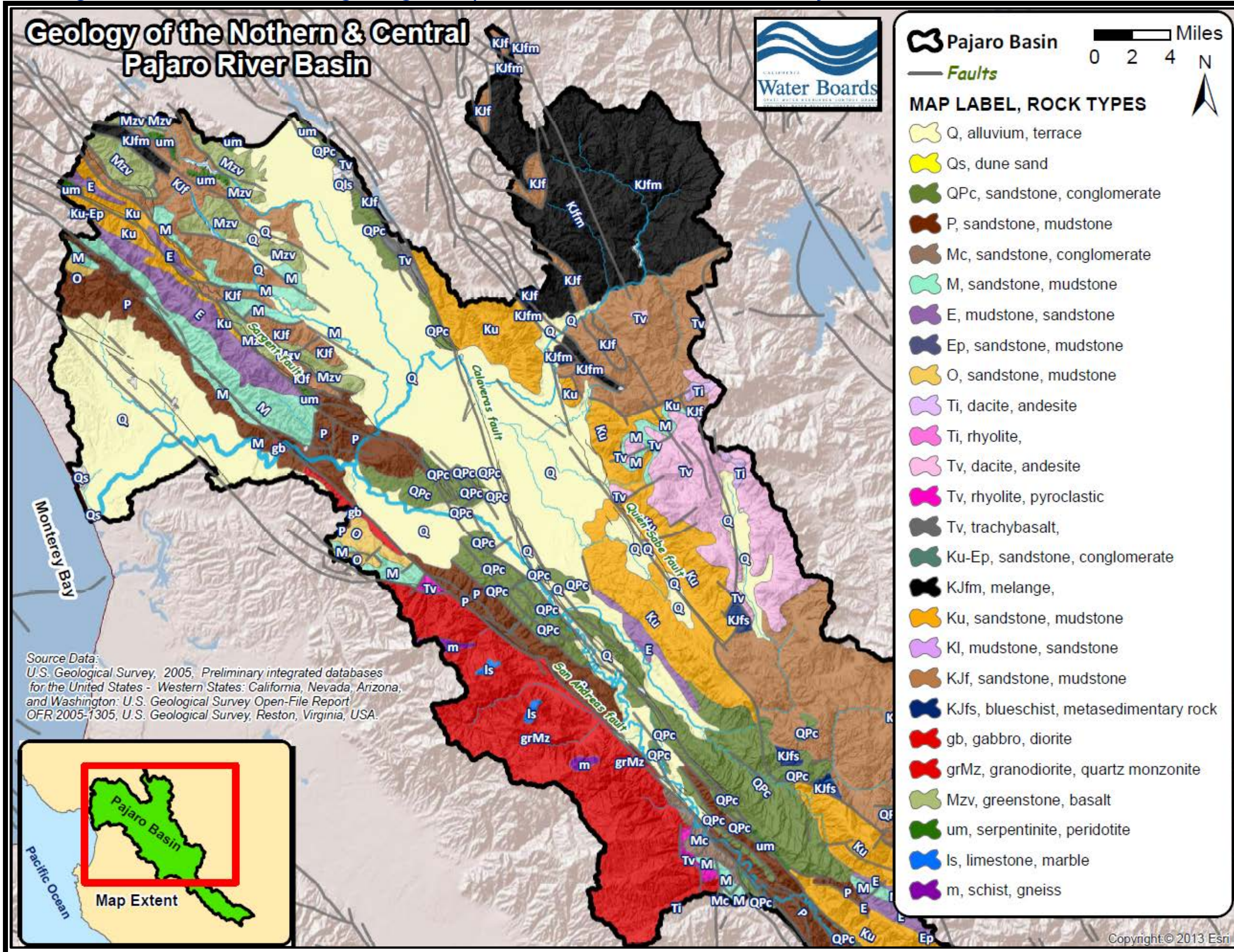


Figure 3-54 presents a generalized geologic map of the Pajaro River, Pacheco Creek, and lower San Benito River subbasins. Geology in the Pajaro River Basin include unconsolidated Quaternary deposits along stream reaches and valleys of lowland areas of the river basin; Tertiary and Mesozoic sedimentary rocks in many upland areas of the river basin; granodiorites and quartz monzonites in the Gabilan Range, and mafic and ultramafic rocks (basalt, greenstone, and serpentinite) in some upland reaches of the Santa Cruz Mountains (Llagas and Uvas Creek watersheds).

Figure 3-54. Generalized geologic map of the northern and central Pajaro River Basin.



Unit Label	Unit Age	Unit Label	Unit Age	Unit Label	Unit Age
Q	Pliocene to Holocene	Ep	Paleocene	KJf	Jurassic to Cretaceous
Qls	Quaternary	Ti	Tertiary	Mzv	Jurassic to Cretaceous
QPc	Miocene to Pleistocene	Tv	Tertiary (2.5-3.5 Ma)	um	Middle to Late Jurassic
Qs	Quaternary	Tv	Tertiary (9.5-13 Ma)	gb	Triassic to Cretaceous
P	Miocene to Pleistocene	Tv	Tertiary (22-24 Ma)	ls	Paleozoic to Mesozoic
Mc	Oligocene to Pleistocene	Ku-Ep	Late Cretaceous to Paleocene	m	Early Proterozoic to Cretaceous
M	Oligocene to Pliocene	Ku	Late Cretaceous		
O	Eocene to Miocene	grMz	Early to Late Cretaceous		
E	Paleocene to Oligocene	KJfs	Early Cretaceous		

➢ *Nitrogen Geochemistry*

While the aforementioned researchers (Stein and Kyonga-Yoon, 2007) indicate that catchment geology can influence "nutrient" concentrations, for clarity's sake it should be noted that igneous and metamorphic geology are likely to only influence phosphorus concentrations. Phosphorus is a relatively common minor element in all crystalline mineral assemblages, in contrast nitrogen is not a typical minor element found in crystalline material[68]. Nitrogen-enriched minerals are rare, and are only found in nitrate minerals formed in highly-arid evaporative environments[69]. The TMDL project area of the Pajaro River Basin does not contain nitrate-enriched evaporative sedimentary rocks.

Indeed, from the perspective of the geosphere (i.e., geologic materials and the solid parts of the earth), soils are in fact the most concentrated and active ambient reservoir for nitrogen in the geosphere (Illinois State Water Survey website, 2011). Almost all soil nitrogen exists in organic compounds. As such, ambient background nitrogen concentrations in TMDL project area surface waters are more likely to be associated with the natural nitrogen cycle (e.g., soils, nitrification, and atmospheric deposition), and are not likely to be associated with watershed geology.

With regard to non-mineralogical forms of nitrogen, organic nitrogen is indeed more abundant in sedimentary rocks than in igneous or metamorphic rocks. Nitrogen in sedimentary rocks is generally associated with organic matter, which is commonly deposited with sedimentary strata, mostly marine shales or mudstones (University of California-Davis, 2012, Utah Geological Survey, 2001). Some organic-rich marine mudstones can contain 600 ppm nitrogen on average (U.S. Geological Survey, 1985). Note that in contrast, organic compounds are only an infrequent and trace component in most igneous or metamorphic rocks, as these rocks are originally created at depth quite apart from the biosphere and surficial organic matter. It is worth noting that some parts of the Santa Cruz Mountains and Leeward Hills regions of the Pajaro River Basin contain significant amounts of marine mudstones, or Monterey Formation outcroppings (see Figure 3-55). These types of geologic materials conceivably might have elevated amounts of organic matter containing some nitrogen compounds, and thus could locally be a source of nitrogen to water resources of the river basin.

While organic-rich geologic materials can be a minor source of nitrogen to water resources, it should be recognized that although nitrogen can originate from geologic sources and other natural processes, elevated nitrogen concentrations present in streams, lakes, and groundwaters at concentrations exceeding drinking water standards (10 mg/L) are primarily due to anthropogenic (human) activities (SWRCB, 2013).

[68] See: U.S. Geological Survey, 1985, *Study and Interpretation of the Chemical Characteristics of Natural Water.* USGS Water-Supply Paper 2254.

[69] For example, the unique, nitrate-rich mineral deposits in the Atacama Desert of northern Chile (see: U.S. Geological Survey, 1981. Professional Paper 1188, *Geology and Origin of the Chilean Nitrate Deposits*)

Figure 3-55. Detailed map of geologic units and geologic materials (with associated numeric identifiers) in the Santa Cruz County and Santa Clara Valley portions of the Pajaro River Basin. Line-hatched units indicate marine mudstones or other rock units which conceivably might have elevated amounts of organic matter containing nitrogen compounds. A legend for the geologic units and geologic materials and their associated numeric identifiers shown on this map is presented in Figure 3-56.

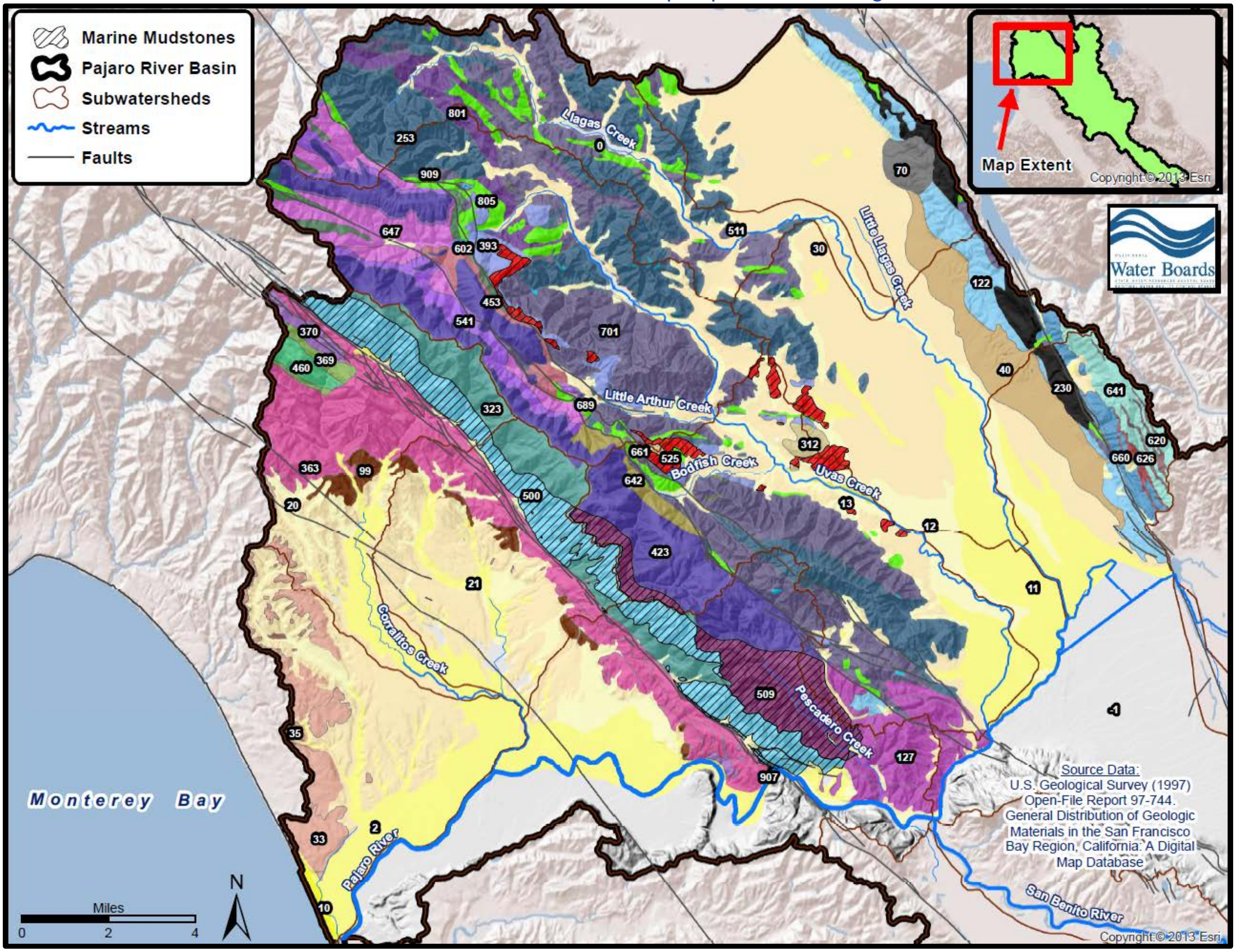


Figure 3-56. Legend for the geologic map shown previously in Figure 3-55.

Another geologic attribute of the Pajaro Basin that one might consider as a background source of nitrogen are natural oil seeps. Crude oils are complex mixtures of hydrocarbons containing minor amounts of sulfur and nitrogen as well as other elements. Natural oil seeps are not generally identified as a source of background nitrogen in U.S. Environmental Protection Agency-approved nitrogen TMDLS. However, some scientific researchers and organizations have noted that oil seeps can be a source of water degradation at localized scales[70] – therefore as a matter of due diligence, staff evaluated possible nitrogen contributions from natural oil seeps in the Pajaro Basin.

[70] See: U.S. Geological Survey, Pacific Coastal & Marine Science Center webpage "The Effects of Seeps on the Environment" http://walrus.wr.usgs.gov/seeps/environment.html or see *Environmental Science: A Global Concern 6th ed.* 2001. William P. Cunningham and Barbara Woodworth Saigo. Summary outline as accessed Jan. 2014 at: http://zoology.muohio.edu/oris/cunn06/

In general, California natural crude oils reportedly have relatively high nitrogen content relative to crude oils from other petroleum-producing areas of the United States (Smith, 1968). Historical published chemical analyses from central coast oil fields in Ventura and Santa Barbara counties indicate the nitrogen content of these crude oils range from 1.25 to 1.7 percent composition (Rogers, 1919).

Oil production in the Pajaro River Basin historically has been limited in scope; as the river basin is not a major oil producing province. Almost all historical commercial oil production in the river basin is limited to the petroleum reservoirs of the Sargent Oil Field located around Tar Spring Creek in southwestern Santa Clara County. Natural surface oils seeps are known to be associated with this oil field[71]. Figure 3-57 illustrates the locations of reported natural oil seeps in the vicinity of the Sargent Oil Field; these seeps are located along Tar Spring Creek which is located in the Lower Uvas Creek subwatershed (refer back to map of subwatersheds previously presented in Figure 3-5). In addition, photo documentation of a natural oil seep along Tar Spring Creek is presented in Figure 3-58.

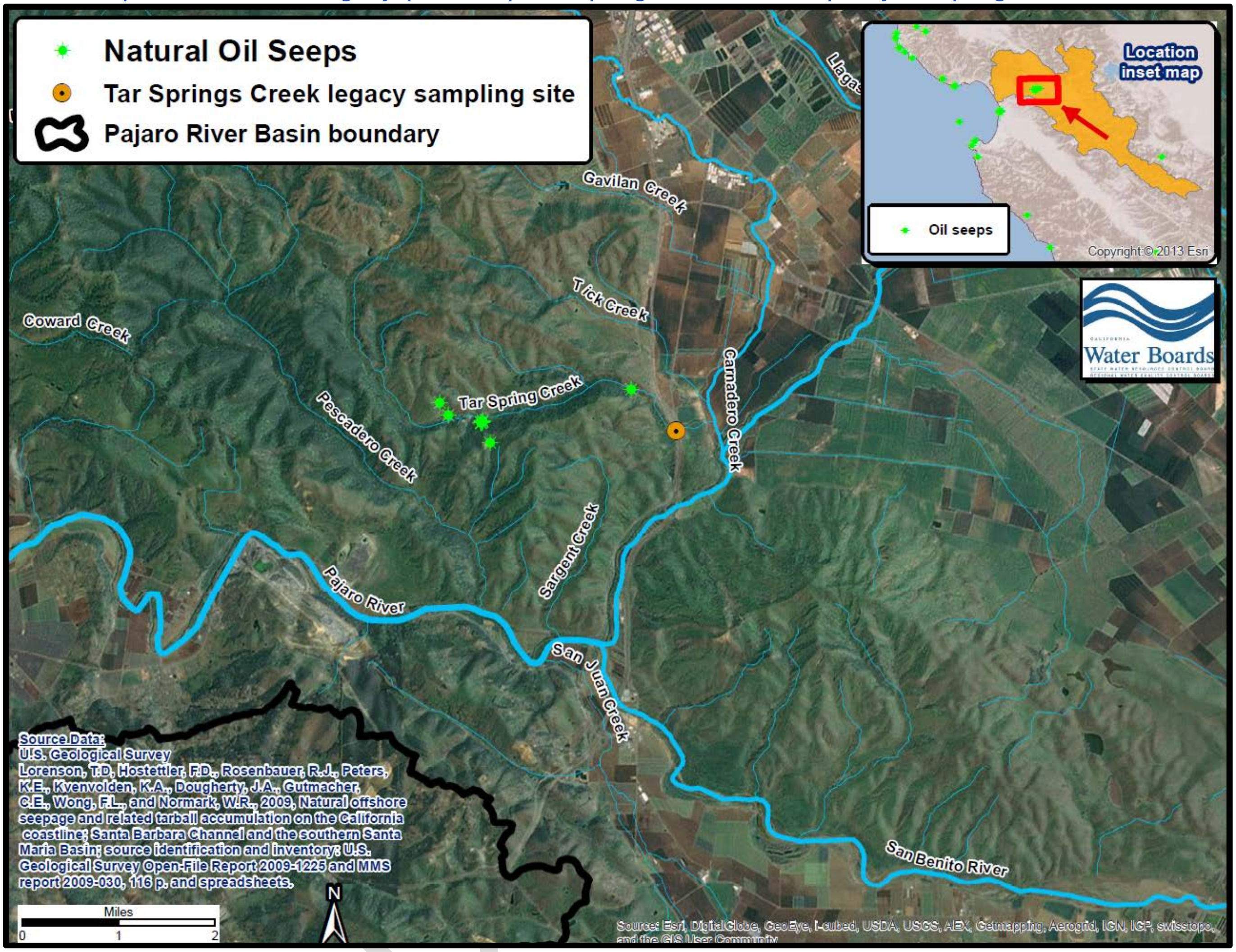
It should be noted that published field reconnaissance report that some of these oil seeps actively discharge, while other seeps are inactive (California Dept. of Conservation−Division of Oil and Gas, 1987). The maximum reported seep discharge along Tar Springs Creek was reported to discharge between zero to two gallons per day (California Dept. of Conservation−Division of Oil and Gas, 1987). As of 2002, Fedasko and Carnahan (2002) reported that oil and gas still seep from these areas and minor amounts reach Tar Creek, quantified as “less than one barrel a day” seeping into Tar Creek according to the Fedasko and Carnahan, (2002) report.

A geochemical study (Magoon et a., 2002) of Sargent Field oil samples indicated these are high density oils (range 12.6 to 24.3 API gravity), and thus these oils seeps locally would thus be expected to be relatively high in nitrogen content, perhaps 1.5 to over 2 weight percent nitrogen[72], consistent with other high density California crude oils.

[71] Northern Coastal Province (007), by Richard Stanley in National Oil and Gas Assessment, 1995. Online linkage: http://certmapper.cr.usgs.gov/noga/broker1995.jsp?theProvince=07&thePage=basin&theServlet=NogaMainResultsServ

[72] *“Heavy oil differ from light oils by their high viscosity (resistance to flow) at reservoir temperatures, high density (low API gravity), and significant contents of nitrogen, oxygen, and sulfur compounds and heavy-metal contaminants.”* Source wikipedia: http://en.wikipedia.org/wiki/Heavy_crude_oil. Emphasis added.

Figure 3-57. Location of reported natural oil seeps in the Pajaro River Basin (Tar Springs Creek catchment) and location of legacy (1969-70) Tar Springs Creek water quality sampling site.



Based on available data, it is possible to calculate a plausible estimate of the total mass of nitrogen discharged to land from reported natural oil seeps in this part of the Pajaro Basin. It should be emphasized that these estimates should be considered maximum values ("worst case" scenario), based on a maximum observed seep discharge of 2 gallons per day. As noted previously some of these oil seeps are inactive and in fact are not discharging to land and thus have a discharge rate of zero.

Table 3-28 presents plausible estimates for the maximum amount of nitrogen discharged to land in the Tar Springs Creek catchment from these natural oils seeps. Accordingly, staff estimates that a maximum of approximately 3.7 pounds nitrogen per day are discharged to land from reported natural oil seeps in the northern Pajaro River Basin.

Figure 3-58. Photo documentation of a natural oil seep along Tar Spring Creek, June 2000 (photo source: California Dept. of Conservation, Division of Oil. Gas, and Geothermal Resources, 2002).

Table 3-28. Estimated maximum amount of nitrogen discharged to land from natural oils seeps in Pajaro River Basin

Ave. specific gravity of central coast crude oil (kg/m^3)[A]	Ave. mass of one gallon of central coast crude oil (pounds)	Maximum seep discharge rate (gallons/day)[B]	Total number of identified seeps[C]	Maximum total mass of crude oil dishcarged [D] (pounds/day)	Average nitrogen content of crude oil (weight percent)[E]	Approximate total pounds of nitrogen discharged
943	**15.7**	**2**	**8**	(15.7 x 2) 8 = **251**	**1.48%**	**3.7 lbs/day** ***or*** **1,351 lbs./year**

[A] Data source: Rogers, 1919

[B] Data source: California Dept. of Conservation−Division of Oil and Gas, 1987

[C] Data source: Spatial data, see Figure 3-57. Note that some oil seeps spatially plot on top of one another at this geographic scale.

[D] On the basis of an estimated (2X8)= 16 gallons of oil discharge per day. This esimtate comports resonably well with Fedasko and Carnahan, (2002) whom estimated that "less than 1 barrel a day" oil from seeps discharge to Tar Springs Creek.

[E] Data source: Rogers, 1919

Even assuming all of this land-discharged oil seep nitrogen is transported to a surface waterbody, this represents a miniscule fraction of nitrogen loading to the Pajaro River and its tributaries. Based on the aforementioned information it is implausible that natural oil seeps in the TMDL project area are a significant or noteworthy contributing factor to the exceedances of nitrogen water quality objectives found in surface waters of the Pajaro River Basin. It should be noted however, that the Tar Springs Creek area reportedly includes outcroppings of tar sands (California Dept. of Mines and Geology, 1980), which presumably could contain nitrogen-rich hydrocarbons. The extent to which tar sands influences localized nitrogen surface water quality is unknown. Two nitrate water quality samples were collected from Tar Spring Creek at Highway 101 in 1969 and 1970 (see Figure 3-57 for sampling site location). The nitrate concentrations of these two samples were 0.97 mg/L and 2.71 mg/L, for an average nitrate concentration of 1.84 mg/L. This site does not appear to be influenced by upstream agriculture, residential, or developed land uses, and the observed nitrate concentrations were marginally elevated or at the high-end of nitrate concentrations one generally expects in lightly-impacted or undeveloped California central coast upland ecosystems. Obviously, two 1969-70 vintage nitrate water quality samples from Tar Spring Creek are completely inadequate to draw sweeping inferences from; however staff *hypothesizes* that these marginally elevated legacy nitrate water quality concentrations observed could possibly have resulted from localized stream contributions of nitrogen-bearing hydrocarbons from local oil seeps; from tar sands; from cattle manure sources[73]; or from a combination of the aforementioned.

➢ *Phosphorus Geochemistry*

Rocks and natural phosphatic deposits are the main natural reservoirs of phosphorus inputs to aquatic systems (USEPA, 1999). In contrast to geologic nitrogen, geologic phosphorus is largely concentrated in mineral material rather than in the organic matter of the rock matrix (see Table 5 of U.S. Geological Survey, 1995b). The potential for these natural phosphorus inputs may be assessed using digital data for California geology and rock geochemistry available from the U.S. Geological Survey's Mineral Resources On-line Spatial Data webpage and National Geochemical Database (http://mrdata.U.S. Geological Survey.gov/).

Phosphorus-prone Miocene Marine Sedimentary Rocks in California

Staff of the Central Coast Water Board previously reviewed geological data and concluded that in the California Central Coast region, Miocene-age marine sedimentary rocks could locally be an important natural source of elevated phosphorus yields to streams (Central Coast Regional Water Quality Control Board, 2012 and 2013). Also noteworthy, a U.S. Geological Survey researcher recently reached the same conclusion regarding the nexus between stream phosphorus water quality and California Miocene sedimentary rocks (Domagalski, 2013).

In the central coast region of California, most phosphate-enriched rocks are associated with Miocene-aged marine sedimentary rocks; primarily Miocene phosphatic mudstones and shales (U.S. Geological Survey, 2002). Phosphatic facies have been reported in the literature to exist in the Miocene-age Monterey and Santa Margarita formations (U.S. Geological Survey, 2002); both of these formations are located in California's central coast region. These unusual phosphatic deposits were formed in marine basins under special paleo-oceanic and tectonic conditions that existed along the western North American continental margin during the middle Miocene Epoch, approximately 10.8 to 15.5 million years ago (Hoppie and Garrison, 2001; White, undated power point presentation), with the majority of phosphatic deposition occurring approximately 13 to 14.8 million years ago (i.e., the Luisan to Early Mohnian stages of the Middle Miocene epoch) – see Figure 3-59. These marine phosphatic deposits were subsequently tectonically uplifted and are now exposed on land in parts of the California Coast Ranges.

It is important to recognize that phosphatic rocks are generally limited to the Middle Miocene strata (Luisian to Mohnian geologic stages) of the Monterey Formation (see Figure 3-59 for graphic illustration), and thus surface exposure of phosphatic rocks would not be expected to universally occur *everywhere* that Miocene sedimentary rocks outcrop at the land surface of the California central coast region.

[73] Calf. Dept. of Fish and Game (CDFG) staff surveyed Tar Creek in 1978 and reported "wallowing in the streambed by cattle". Source: CDFG (1978) as reported in Center for Ecosystem Management and Restoration (2008) – Steelhead/Rainbow Trout *(Oncorhynchus mykiss)* Resources South of the Golden Gate, California.

Figure 3-59. Generalized stratigraphic column for the Monterey formation, California Central Coast ranges. Stratigraphic equivalents of the Monterey Formation occur in parts of the upland regions of the Pajaro River Subbasin.

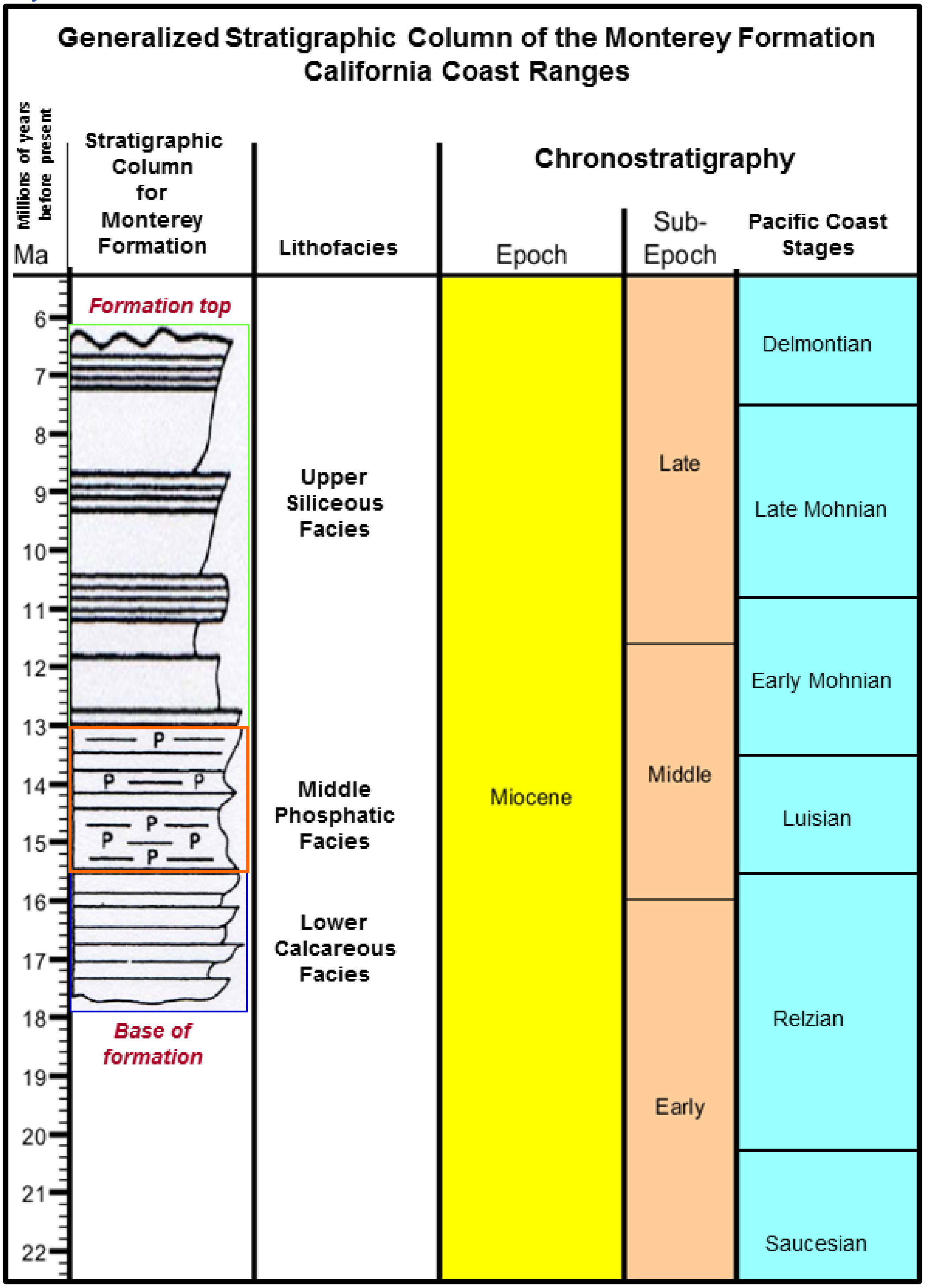


Figure 3-60 illustrates the distribution of Miocene-aged marine sedimentary rocks of the California central and southern coastal regions; these distributions constitute areas where there is presumably potential for phosphate-enriched mudstones and shales. Phosphorus geochemical samples (as weight percent P_2O_5) are available from the U.S. Geological Survey national geochemical database – sampling locations are illustrated on Figure 3-60.

Staff disaggregated U.S. Geological Survey rock and sediment phosphorus geochemical samples from the California central coast region into two groupings: samples collected from 1) areas containing Miocene-aged marine sedimentary rocks, and 2) areas NOT containing Miocene-aged marine sedimentary rocks. Cursory data review using histograms and quantile comparison plots in R[74] indicated that the raw phosphorus geochemical data was not normally distributed, while the log-transformed data appears to be normally distributed. Consequently, a non-parametric statistical evaluation approach was used. A two-sample Wilcoxon Test[75] of the two groupings of rock and sediment phosphorus geochemical data indicates that geologic materials in areas of Miocene marine sedimentary deposits are generally higher in phosphorus concentration (median = 0.440 P_2O_5 weight percent) than phosphorus in areas NOT containing Miocene marine sedimentary deposits (median = 0.228 P_2O_5 weight percent). In other words, the median of Miocene geologic materials are about twice as high in phosphorus (weight %) than the median of non-Miocene geologic materials.

Further, the differences in phosphorus content is highly statistically significant (P-value = 2.2e-16)[76] indicating a very small probability of observing this difference by random chance. Practically speaking, this suggests that geologic materials associated with Miocene marine deposits throughout California's central coast are generally higher in phosphorus content than geologic materials not associated with Miocene marine deposits.

R statistical summaries and Wilcoxon Test outputs for the Miocene and non-Miocene rock phosphorus geochemical samples discussed above are presented in Figure 3-61.

[74] R Core Team (2013). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org

[75] Also widely known as the Mann-Whitney test.

[76] By convention, P-values are considered to indicate statistical significance when the P-value < 0.05.

Figure 3-60. Map of Miocene-age marine sedimentary rocks in California, and locations of US Geological Survey phosphorus rock and sediment geochemical sampling locations.

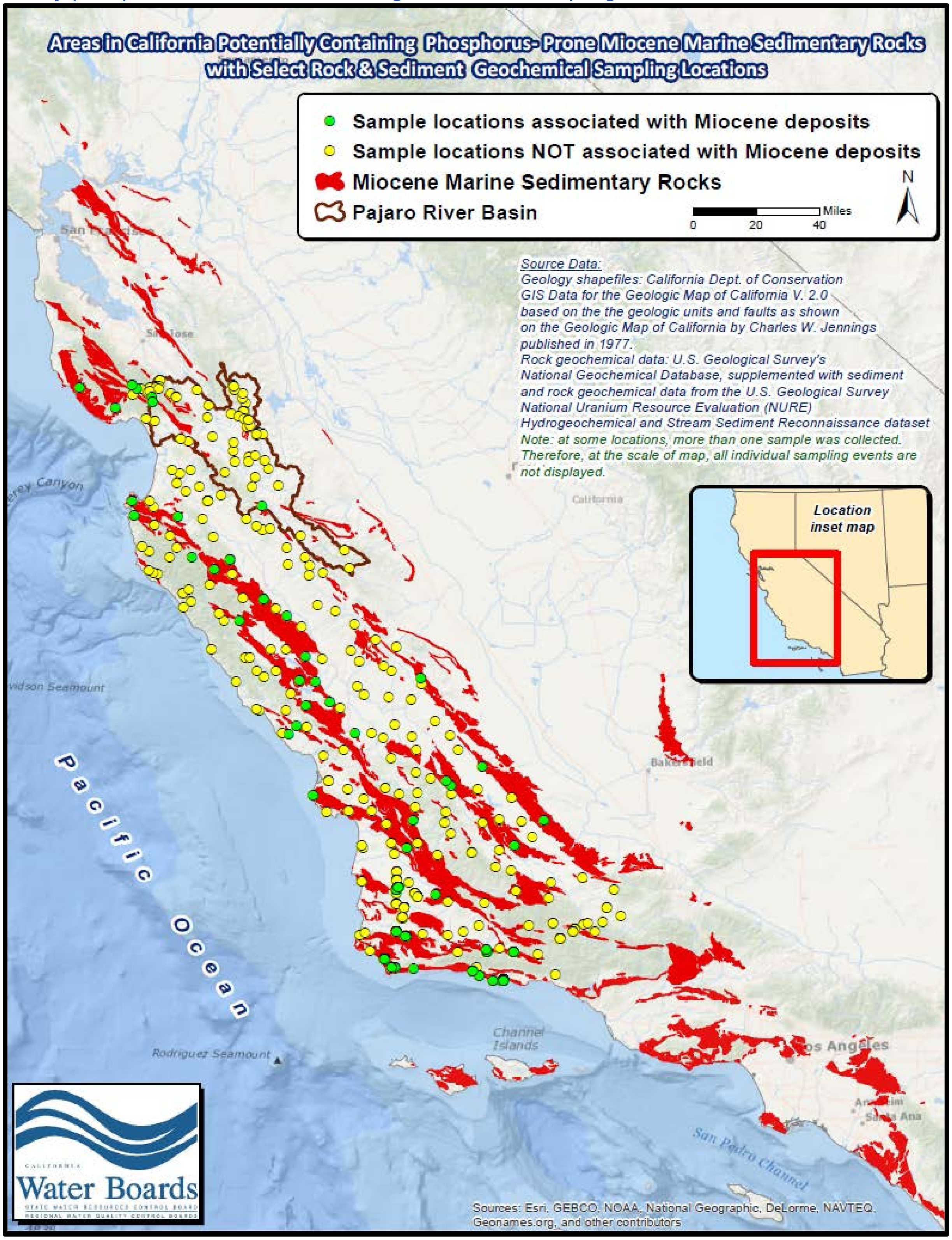


Figure 3-61. Screen prints of R outputs for Miocene and non-Miocene geologic materials samples.

R numerical summary for 1) phosphorus geochemical data in areas associated with Miocene marine deposits and 2) phosphorus geochemical data in areas not associated with Miocene marine deposits (refer to Figure 3-60 for sampling locations).

```
> numSummary(P_Miocene_NonMiocene_2[,"phosphorus"],
+   groups=P_Miocene_NonMiocene_2$geologic_age, statistics=c("mean", "sd",
+   "IQR", "quantiles"), quantiles=c(0,.25,.5,.75,1))
                 mean       sd  IQR    0%  25%    50%  75% 100% data:n
Miocene     1.4119441 2.632683 1.22 0.005 0.26 0.4400 1.48 28.0    590
Non-Miocene 0.5746667 1.456723 0.40 0.006 0.09 0.2275 0.49 21.8    534
```

R two-sample Wilcoxon test output for 1) phosphorus geochemical data in areas associated with Miocene marine deposits and 2) phosphorus geochemical data in areas not associated with Miocene marine deposits (refer to Figure 3-60 for sampling locations).

```
> tapply(P_Miocene_NonMiocene_2$phosphorus,
+   P_Miocene_NonMiocene_2$geologic_age, median, na.rm=TRUE)
    Miocene Non-Miocene
     0.4400      0.2275

> wilcox.test(phosphorus ~ geologic_age, alternative="two.sided",
+   data=P_Miocene_NonMiocene_2)

        Wilcoxon rank sum test with continuity correction

data:  phosphorus by geologic_age
W = 220626.5, p-value < 2.2e-16
alternative hypothesis: true location shift is not equal to 0
```

With regard to the phosphorus content of various rock types, Table 3-29 and Figure 3-62 present statistical summaries of the P_2O_5 weight percent of sampled rock types in the California central coast region. Note that sedimentary rock, such as sandstone and in particular, shale tends to be elevated in phosphorus content relative to other rock types[77].

[77] Note that these statistical summaries report values for phosphorite, which is an unusual and rare chemical sedimentary rock containing abnormally high amounts of phosphate.

Table 3-29. R numerical summary for phosphorus content (P_2O_5 weight %) reported in rock samples collected in the California central coastal region watersheds.

Output

	mean	sd	IQR	0%	25%	50%	75%	100%	data:n
CHERT	0.2612500	0.2060380	0.3625	0.05	0.0800	0.175	0.4425	0.59	16
igneous basic	0.2336364	0.1199394	0.1550	0.05	0.1350	0.250	0.2900	0.49	11
igneous intermediate	0.1800000	0.1824829	0.1650	0.06	0.0750	0.090	0.2400	0.39	3
limestone	0.2720000	0.3751933	0.0700	0.06	0.0800	0.130	0.1500	0.94	5
phosphorite	1.7700000	0.2828427	0.2000	1.57	1.6700	1.770	1.8700	1.97	2
sandstone	0.3350000	0.3187415	0.3125	0.09	0.1325	0.180	0.4450	1.19	14
shale	1.2406950	1.7844005	1.1300	0.05	0.3000	0.480	1.4300	21.50	777

Figure 3-62. Box and whiskers plot of phosphorus content (P_2O_5 weight %) in select rock type samples in the California central coastal region watersheds (sample locations: see Figure 3-60)

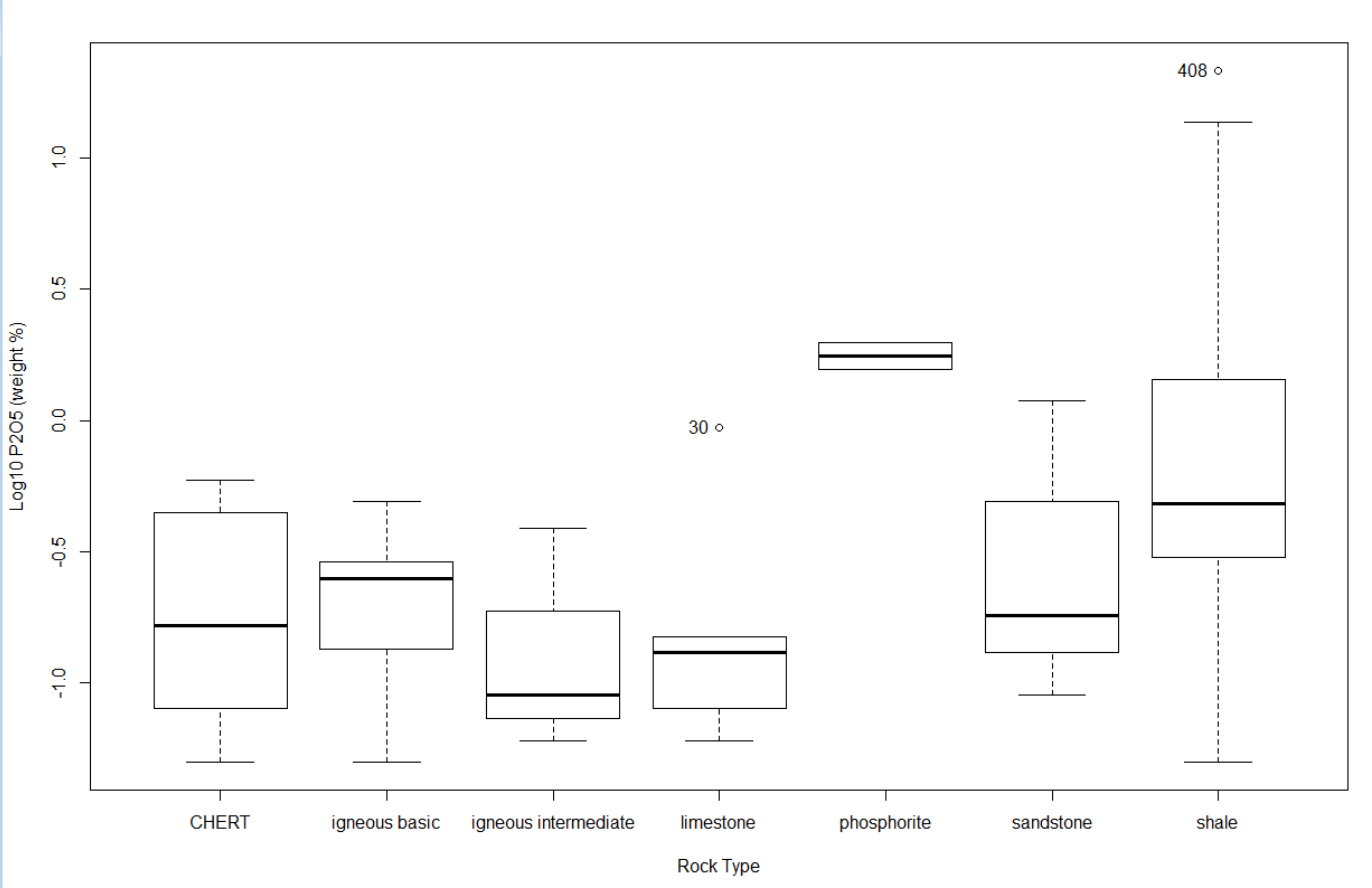
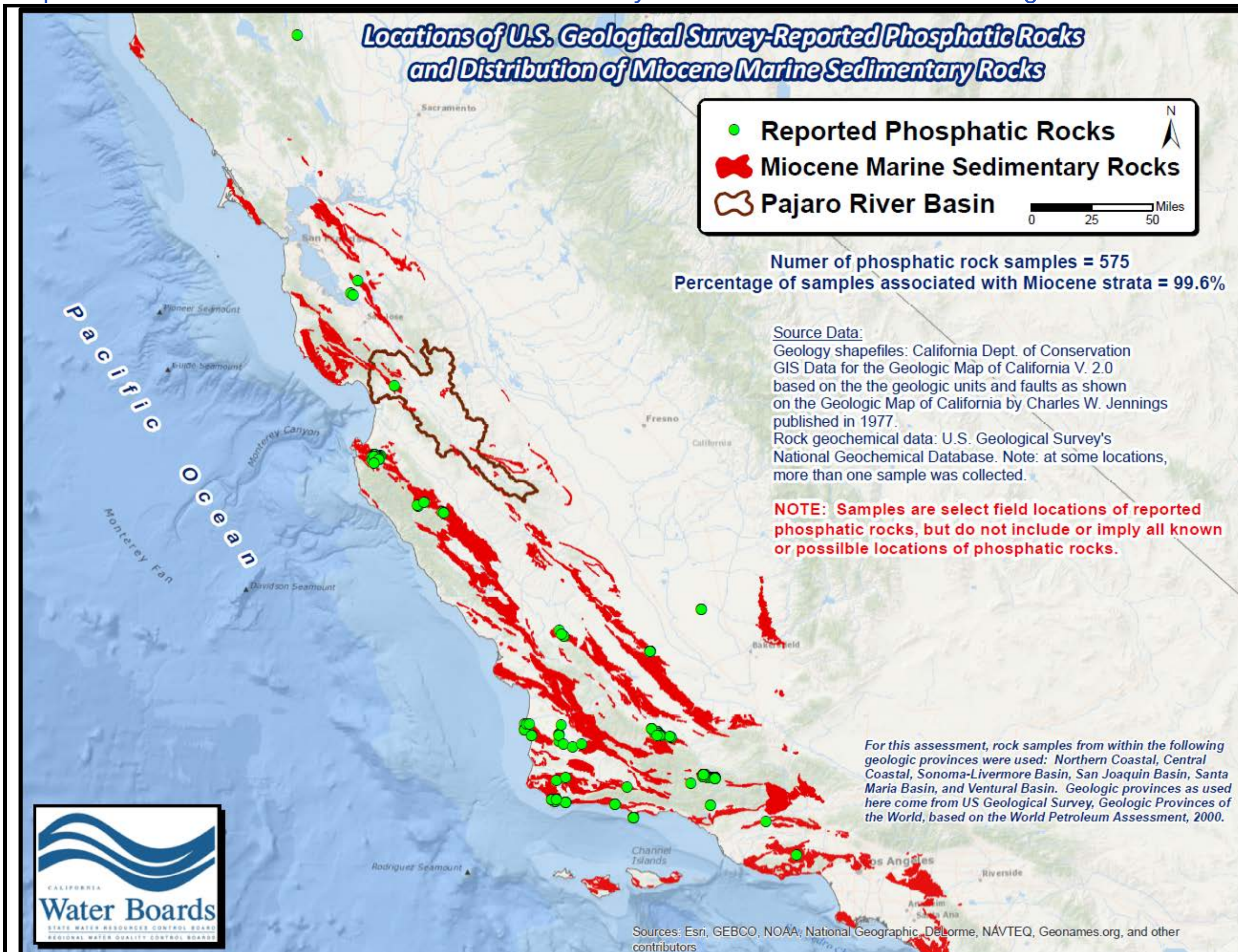


Figure 3-63 illustrates the locations of phosphatic rocks that have been sampled in the California. Noteworthy is that virtually all of these samples come from Miocene strata, as illustrated on Figure 3-63.

Figure 3-63. Map showing 1) locations of U.S. Geological Survey-reported phoshatic rocks; and 2) reported distribution of Miocene marine sedimentary rocks. Table that details findings included.



Stratigraphy/Formation	Geologic Age	Phosphatic Lithologies Present and Reported	Number of Reported Rock Geochemical Samples from the Formation
Santa Margarita Formation	Miocene	Phosphatic mudstones, phosphatic conglomerate, phosphorite, phosphatic sandstone, phosphatic siltstone,	411
Chamisal Formation	Miocene	Phosphatic sandstone	4
Monterey Group	Miocene	Phosphatic mudstone, phospatic conglomerate, phosphatic dolomite, phosphatic limestone, phosphorite, phosphatic siltstone, phosphatic sandstone	156
Great Valley Sequence	Cretaceous	Phosphatic siltstone	1
Modelo Shale	Miocene	Phosphatic pellets	1
Sisquoc Formation	Pliocene	Phospatic conglomerate	1
Temblor Formation	Miocene	Phosphatic sandstone	1

The occurrence of Miocene marine rocks in the Pajaro River Basin is illustrated in Figure 3-64. It is worth nothing that Pescadero Creek drains areas containing geologic materials characterized as Middle Miocene-age marine sediments[78] – recall that Middle Miocene strata of the California Central Coast are

[78] According to the Calif. Dept. of Conservation's online geologic maps website. Online linkage: http://www.conservation.ca.gov/cgs/information/geologic_mapping/Pages/googlemaps.aspx#atlasseries

well known to contain abundant phosphatic rocks. Field reporting documents the presence of laminated phosphatic shales locally in outcropping Miocene rocks of the river basin (see Figure 3-64). Also noteworthy, the phosphate as P concentration in water samples collected from Pescadero Creek tends to be quite high, with an average of 3 mg/L. Water quality samples from other stream reaches in the Pajaro River Basin are typically around 0.5 mg/L phosphate as P, or lower. It should be emphasized here that the presence of Miocene marine rocks should not be construed universally as unequivocal evidence of a natural phosphorus influence on water resources – for example phosphatic rocks are reportedly generally limited to the Middle Miocene (Luisian to Mohnian stages) strata of the Monterey Formation (refer back to Figure 3-59). Accordingly, staff merely concludes that Miocene marine rocks of California are *prone* to being relatively higher in phosphorus – but, it is beyond doubt that there is substantial variation in the geochemistry and lithology of California's Miocene deposits.

Figure 3-64. Distribution of Miocene marine strata in the northern Pajaro River Basin (refer back to Table 3-3 for listing of paired subwatershed name-numeric identifiers). Field observation reporting indicates phosphatic shales have been observed locally in Miocene marine strata of the Santa Cruz Mountains.

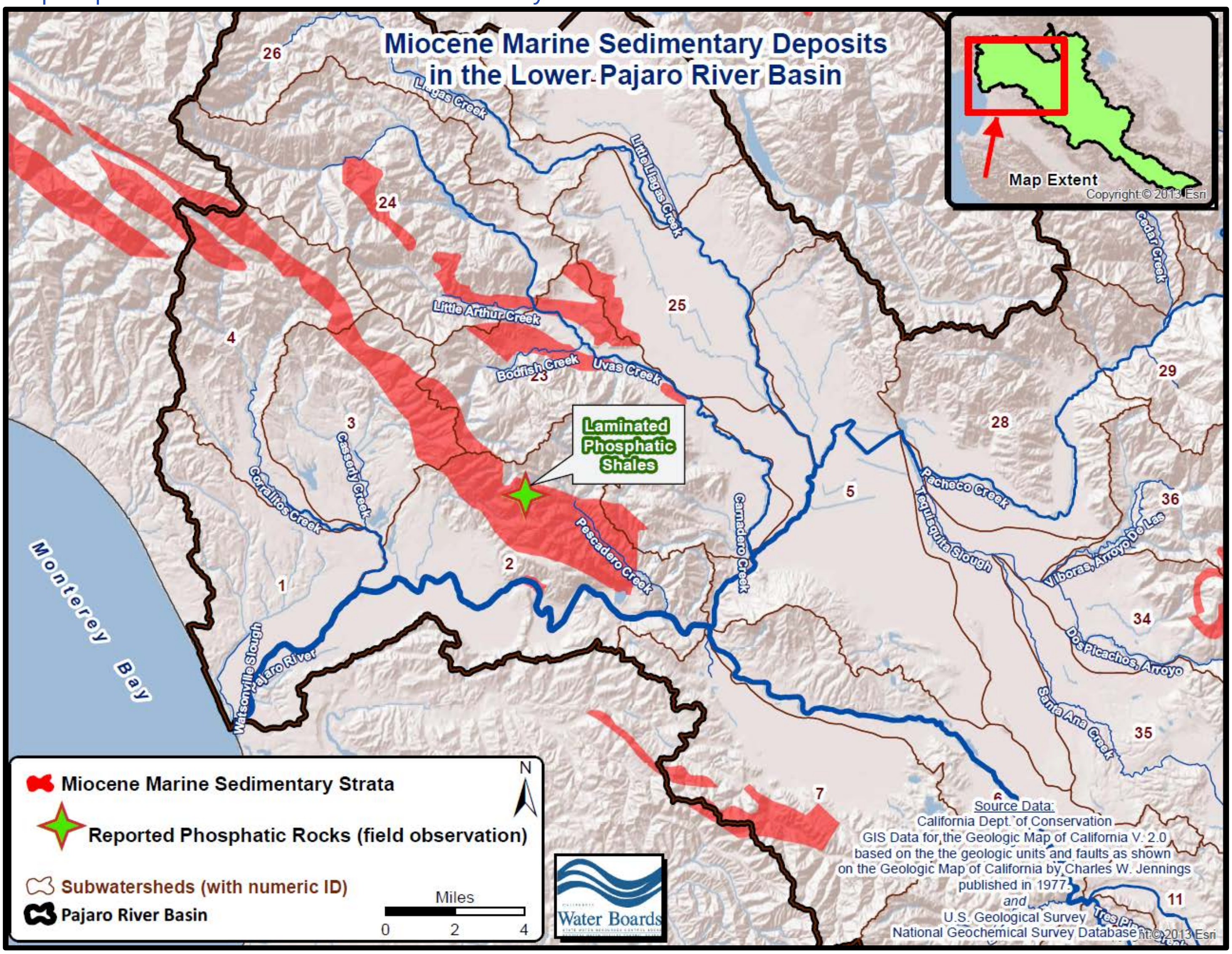
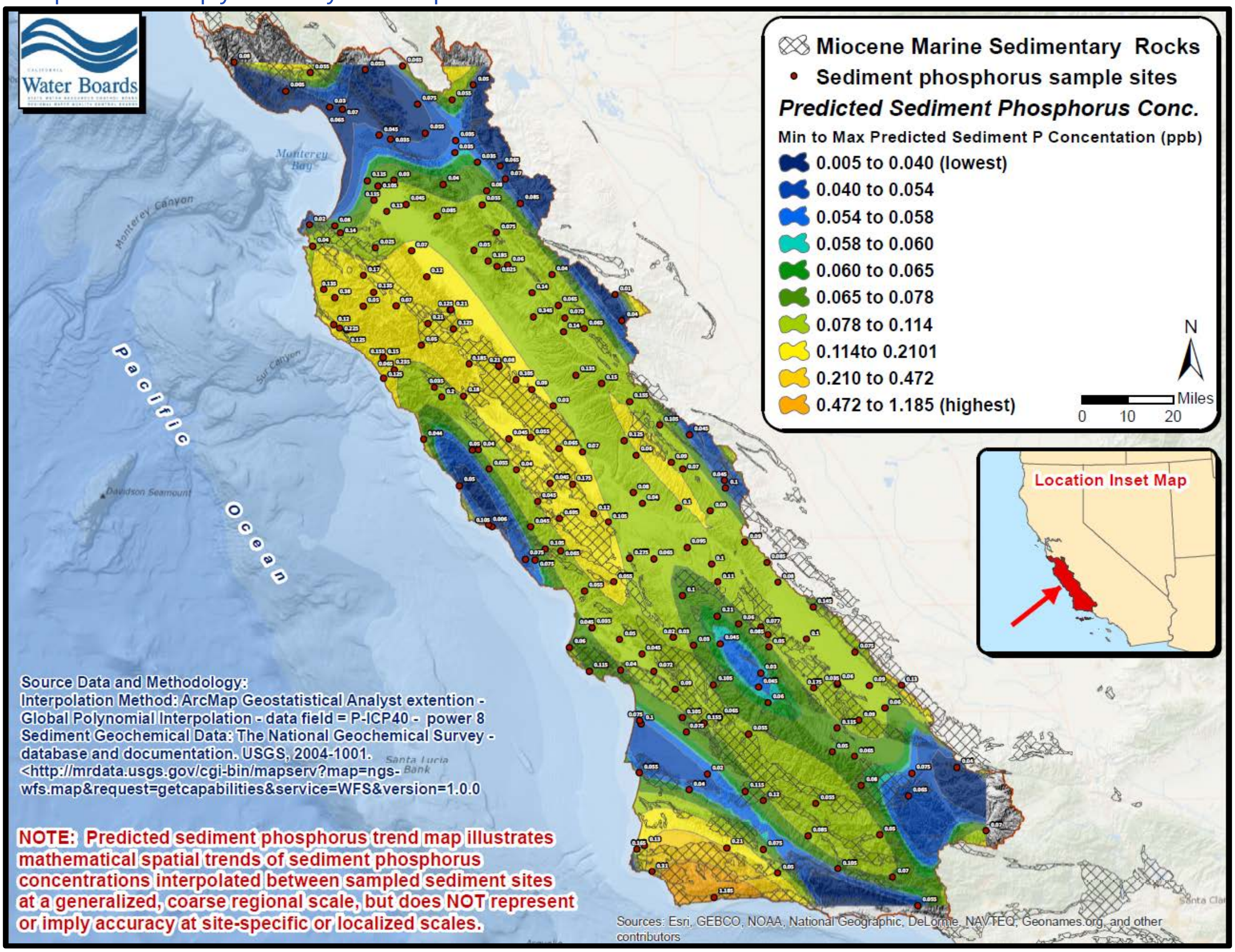


Figure 3-65 presents predicted spatial trends of sediment phosphorus concentrations based on a mathematical interpolation between sampling locations. Areas of the central coast region with the highest sediment phosphorus concentrations are often geographically associated with Miocene marine deposits. It should be noted that some areas of Miocene deposits have relatively moderate or average phosphorus concentrations. In general, the map suggests that stream bed sediments high in phosphorus concentrations can often be located in drainages associated with Miocene deposits, but this in not universally true and there is evidently substantial variation and other confounding factors influencing phosphorus concentrations in sediments and stream beds. For example, in areas draining Monterey Formation deposits, phosphatic-rich lithofacies are reportedly mostly associated with Middle Miocene strata (Luisian to Early Mohnian-stage)[79]. Geographic areas containing relatively younger Monterey Formation rocks (upper Early Mohnian to Delmontian-stage Miocene strata) may not be expected to contain abundant phosphatic facies (refer back to Figure 3-59).

Figure 3-65. Map showing interpolated values of sediment phosphorus concentrations in the California central coast region. The map illustrates predicted mathematical spatial trends of sediment phosphorus concentrations interpolated at a generalized coarse regional scale between sampled sites, but does NOT represent or imply accuracy at site-specific or localized scales.



[79] See: *Field Guide to Diagenesis, Deformation, and Fluid Flow in the Miocene Monterey Formation: Ventura-Santa Barbara-Jalama Beach-Grefco Quary/Lompoc.* Online linkage: http://www.beg.utexas.edu/eichhubl/Pages/Roadlogtext.html

In summary, geologic materials are generally not expected to cause or contribute significantly to exceedances of nutrient water quality criteria in the Pajaro River Basin. However it is important to recognize that phosphorus-prone Miocene marine sedimentary rocks (associated locally with fault blocks of the Santa Cruz Mountains) may be expected to influence nutrient water quality, specifically phosphorus concentrations, locally in some stream reaches. Published water quality guidelines for phosphorus may be anticipated to be unachievable locally in some stream reaches that drain phosphatic sediments associated with Miocene marine sedimentary deposits, on the basis of high observed phosphate concentrations in Pescadero Creek.

3.11 Soils & Stream Substrates

Soils have physical and hydrologic characteristics which may have a significant influence on the transport and fate of nutrients. Watershed researchers and TMDL projects often assess soil characteristics in conjunction with other physical watershed parameters to estimate the risk and magnitude of nutrient loading to waterbodies (Mitsova-Boneva and Wang, 2008; McMahon and Roessler, 2002; Kellog et al., 2006). The relationship between nutrient export (loads) and soil texture are illustrated in Figure 3-66 and Figure 3-67. Generally, fine-textured soils with lower capacity for infiltration of precipitation/water are more prone to runoff, and are consequently typically associated with a higher risk of nutrient loads to surface waters.

Figure 3-66. Median annual Total N and Total P export for various soil textures.

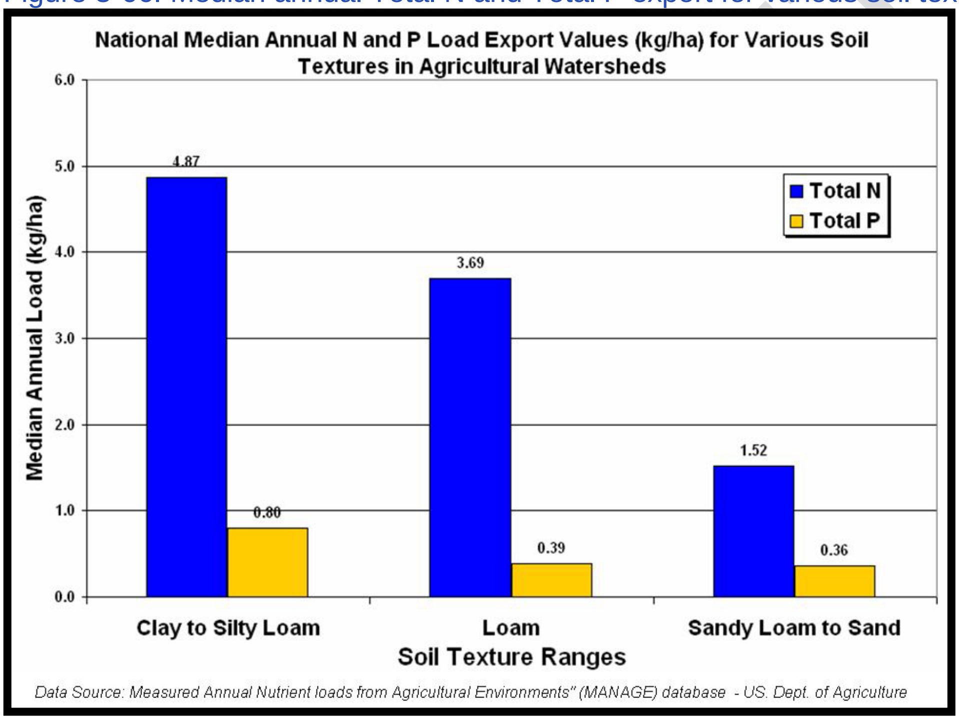
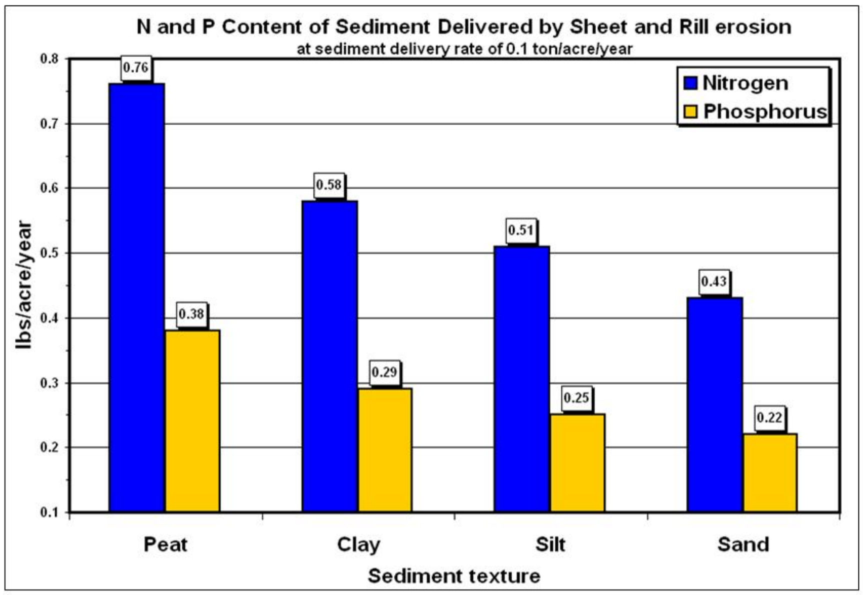


Figure 3-67. N and P content of sediment delivered by sheet and rill erosion.



Data source: Derived from AGNPS equations in Young, R.A., C.A. Onstad, D.D. Bosch, and W.P. Anderson, 1987. AGNPS, Agricultural –Non-Point-Source Pollution Model; A Large Watershed Analysis Tool. U.S. Department of Agriculture – Agriculture Res. Serv., Conservation Resource Report 35 – and reported in *"Pollutants Controlled Calculation And Documentation For Section 319 Watersheds Training Manual, Michigan Department of Environmental Quality.*

Thus, in the development of nutrient TMDLs it can be important to evaluate background, ambient concentrations of nutrients in soils. Soil nutrients can be a contributing source to nutrients in stream waters. Furthermore, the spreadsheet pollutant source estimation tool used in this TMDL project requires user-inputs for soil nutrients concentrations (refer to Section 6.1).

Predictive models and data on soil nitrogen are available from the International Geosphere-Biosphere Programme Data and Information Services (IGBP-DIS)[80] – see Figure 3-68, Table 3-30 and Figure 3-69 – and also from soil nitrogen data compiled by Post and Mann (1990) – see Table 3-31 and Figure 3-70. These data can be used to infer a plausible average soil nitrogen content that could be expected in the Pajaro River Basin.

Numerical summaries and box plots of the grid cell values from IGBP-DIS gridded surface indicate that the median soil total nitrogen density (g/m^2) for the Pajaro River Basin is quite similar to the median soil total nitrogen density for the conterminous United States (see Table 3-30 and Figure 3-69). It should be noted that a cursory review of quantile-comparison plots of the IGDP-DIS data indicates the gridded cell values are highly non-normally distributed, and thus the *median* (rather than the arithmetic mean) grid cell value is a better measure of the central tendency or "average" of the grid cell values for soil total nitrogen density.

[80] The IGBP-DIS Global Gridded Surfaces of Selected Soil Characteristics data set contains a data surfaces for total nitrogen density. The data surface was generated by the SoilData System, which was developed by the Global Soil Data Task of the International Geosphere-Biosphere Programme (IGBP) Data and Information Services (DIS). The SoilData System uses a statistical bootstrapping approach to link the pedon records in the Global Pedon Database to the FAO/UNESCO Digital Soil Map of the World. Availalble from the Oak Ridge National Laboratory Distributed Active Archive Center (ORNL DAAC).

Figure 3-68. Gridded surface of estimated soil total nitrogen density (g/m^2),from the IGBP-DIS dataset.

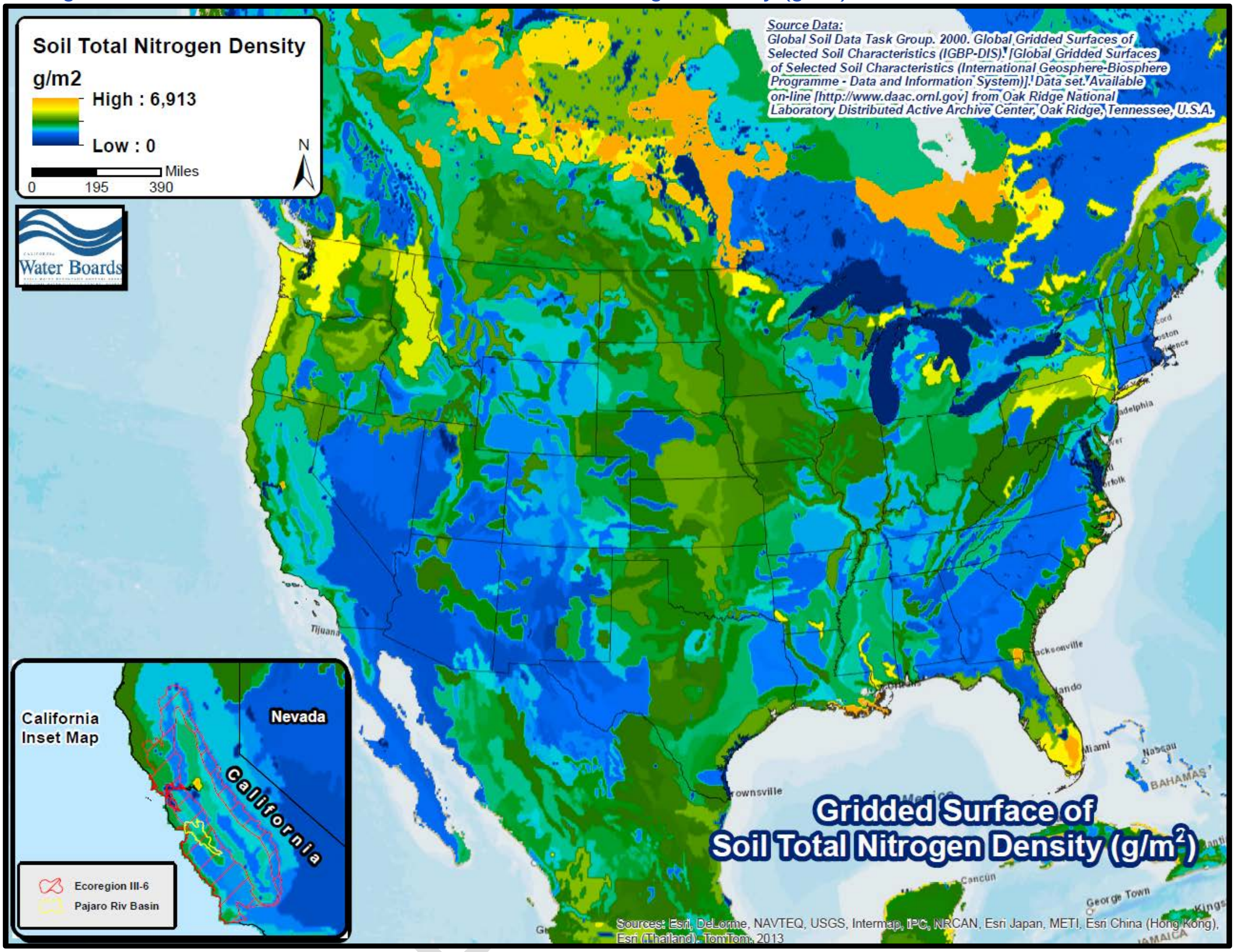
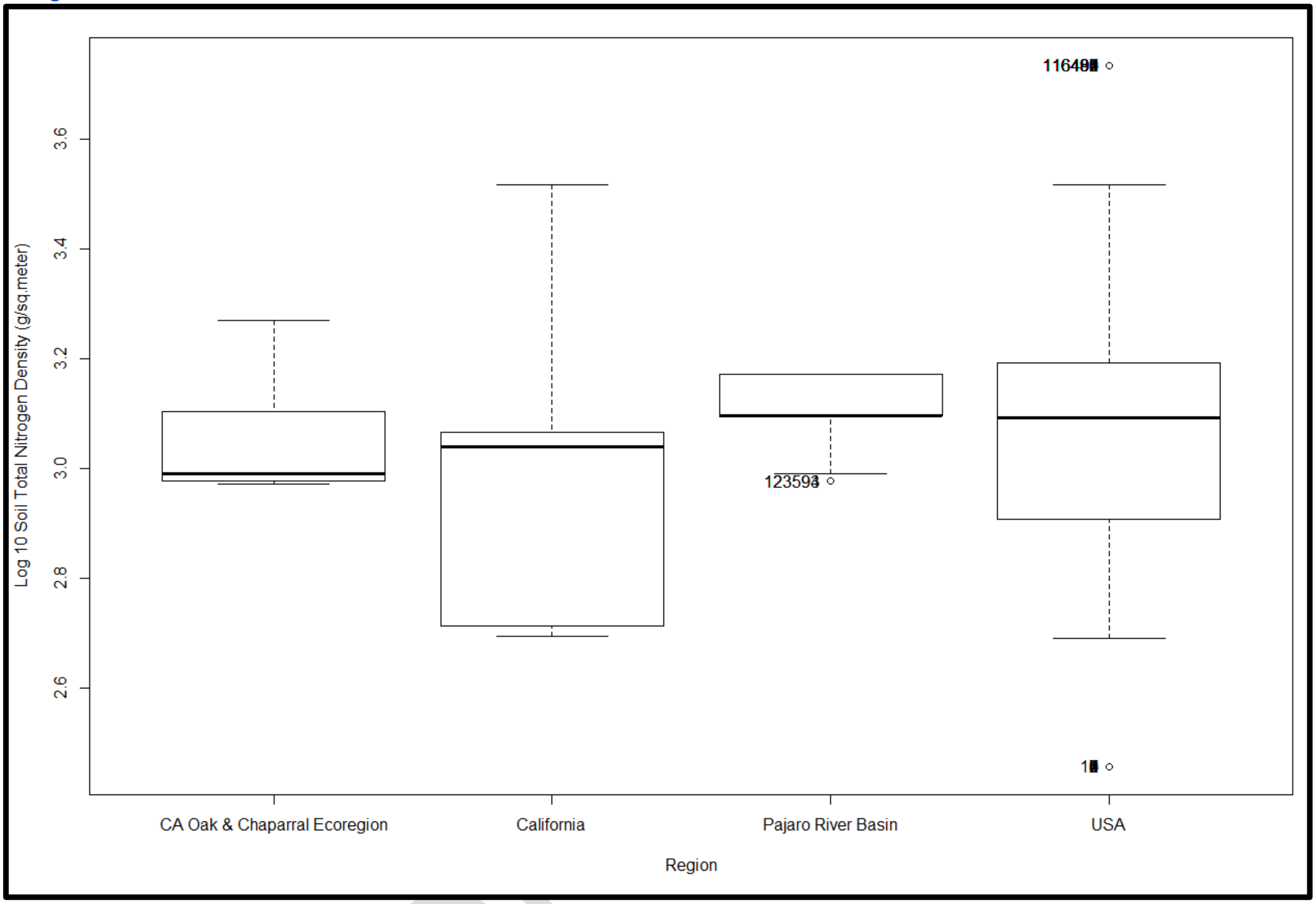


Table 3-30. Soil total nitrogen density statistics: Grid cell value statistics from the IGBP-DIS gridded surface shown previously in Figure 3-68 clipped to various geographic regions. Units = g/m^2.

Region	Mean	Standard Deviation	Min	25th %	50th % (median)	75th %	Max	Number of Grid Cell Values
Calif. Oak & Chaparral Ecoregion [A]	1,138	223	938	947	980	1,270	1,859	1,135
California (State-wide)	1,024	403	494	516	1,097	1,163	3,284	5,948
Pajaro River Basin	1,330	165	947	1,245	1,245	1,483	1,483	50
Conterminous USA	1,234	486	287	808	1,238	1,557	5,404	116,509

[A] See U.S. Environmental Protection Agency Level III and IV ecoregions of the continental United States online linage: http://www.epa.gov/wed/pages/ecoregions/level_iii_iv.htm

Figure 3-69. R-generated box and whiskers plot for soil total nitrogen density (g/m^2) for select geographic regions on the basis of the IGBP-DIS dataset.



Staff used the observed soil nitrogen analytical field data (Post and Mann, 1990) in conjunction with modelled soil nitrogen grids (IGBP-DIS) to infer a plausible average soil nitrogen concentration in the Pajaro River Basin. Figure 3-69 and Table 3-31 present box plots and numerical summaries of observed soil nitrogen concentration (%) on the basis of soil data reported by Post and Mann, 1990. Noteworthy, is that the median soil nitrogen concentration value for the entire dataset (i.e., the composite of all vegetation-land cover categories) is 0.068% (see Table 3-31). Also, recall as previously noted, that the median (50th percentile) soil total nitrogen density (g/m^2) in the Pajaro Basin is approximately equal to median soil total nitrogen density for the conterminous United States on the basis of IGBP-DIS gridded surface models (refer back to Table 3-30 and Figure 3-69). Thus, the median soil nitrogen concentration expected in the Pajaro River Basin comports reasonably well with a median expected soil nitrogen concentration for the conterminous United States. Therefore, a plausible median soil nitrogen content on a percentage basis (%) for the Pajaro River Basin can be assumed to be equal to the median soil nitrogen concentration derived from the Post and Mann (1990) data in Table 3-31, which is 0.068 % nitrogen.

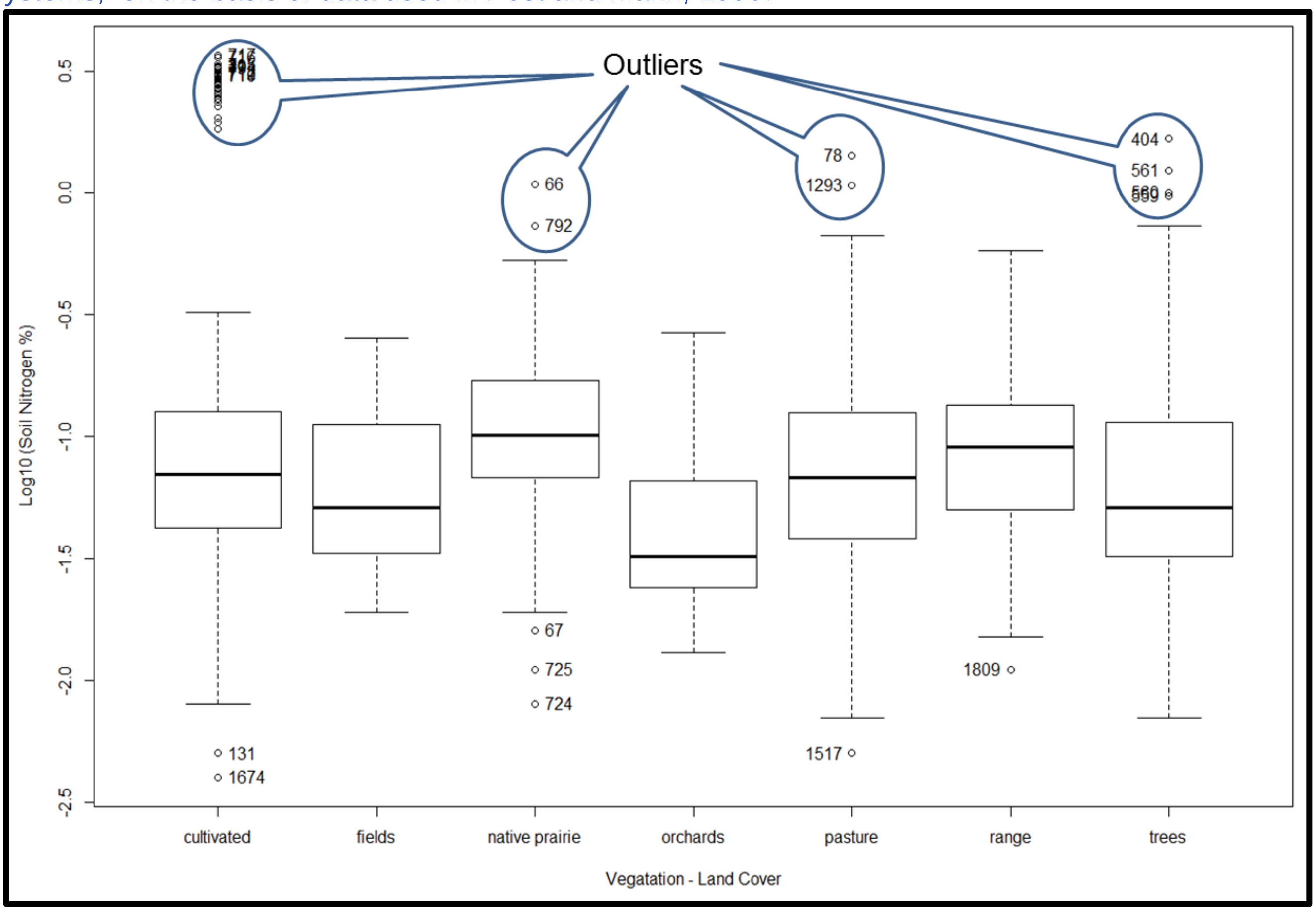
Table 3-31. Numerical summaries of United States observed soil total nitrogen (units = %) for select vegetative land cover systems on the basis of data used in Post and Mann, 1990[A].

Vegetation-Land Cover	Mean	Standard Deviation	Min	25th %	50th % (median)	75th %	Max	Number of Samples
cultivated	0.203694	0.565534	0.004	0.042	0.07	0.12675	3.67	654
fields	0.080465	0.064178	0.019	0.033	0.051	0.112	0.255	43
native prairie	0.142215	0.134856	0.008	0.068	0.101	0.1695	1.088	191

Vegetation-Land Cover	Mean	Standard Deviation	Min	25th %	50th % (median)	75th %	Max	Number of Samples
orchards	0.054706	0.061158	0.013	0.024	0.032	0.066	0.266	17
pasture	0.103363	0.126064	0.005	0.038	0.068	0.125	1.422	383
range	0.111329	0.096355	0.011	0.05025	0.0905	0.13475	0.581	82
trees	0.106121	0.155925	0.007	0.032	0.051	0.115	1.67	497
Numerical summary for composite of entire dataset	0.142525	0.355064	0.004	0.039	0.068	0.126	3.67	1869

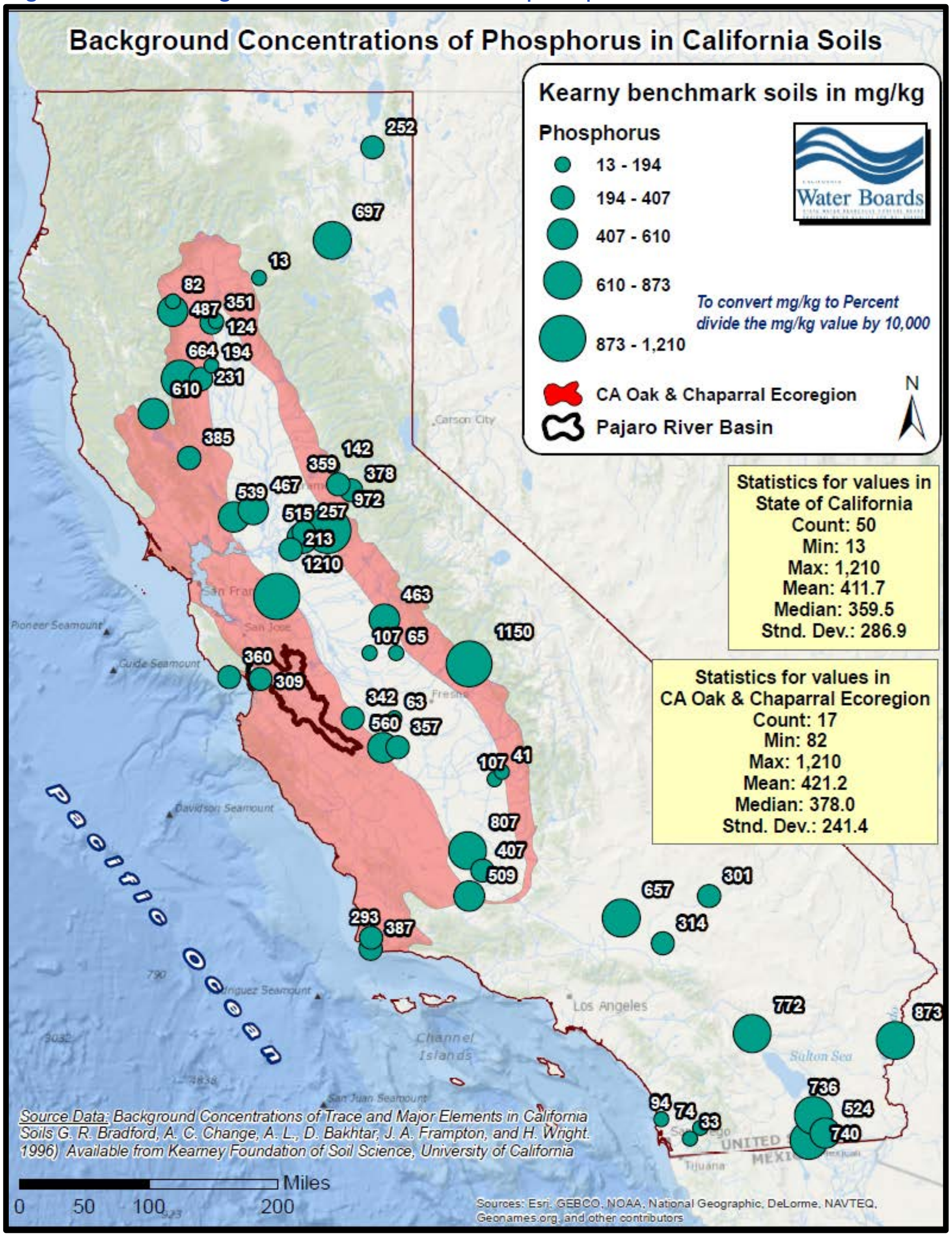
[A] Post, W.M. and L.K. Mann. 1990. *Changes in Soil Organic Carbon and Nitrogen as a Result of Cultivation*. In A.F. Bowman, editor, *Soils and the Greenhouse Effect*, John Wiley and Sons. The authors assembled and analyzed a data base of soil organic carbon and nitrogen information from a broad range of soil types from over 1100 profiles and representing major agricultural soils in the United States, using data compiled by the U.S. Dept. of Agriculture Soil Conservation Service National Soils Analytical Laboratory.

Figure 3-70. R-generated box and whiskers plot for soil total nitrogen (%) for select vegetative land cover systems, on the basis of data used in Post and Mann, 1990.



With regard to soil phosphorus, data on ambient soil concentrations of phosphorus in California soils is available from the University of California–Kearney Foundation of Soil Science (Kearney Foundation, 1996). Figure 3-71 illustrates background concentrations of phosphorus in California soils on the basis of Kearney benchmark soils selected from throughout the state (Kerney Foundation, 1996). The median soil phosphorus content in benchmark soils from within the California Oak and Chaparral Subecoregion is 378 mg/kg (0.0378 weight percent) – thus, this value may constitute a plausible average ambient background soil phosphorus content for the Pajaro River Basin (for a discussion of nutrient ecoregions refer back to Section 3.6).

Figure 3-71. Background concentrations of phosphorus in California soils.



Based on the aforementioned information, estimated average soil nutrient content (%) in the Pajaro River Basin can be summarized as follows:

AVERAGE SOIL NITROGEN CONTENT (%) IN THE PAJARO RIVER BASIN:

0.068%

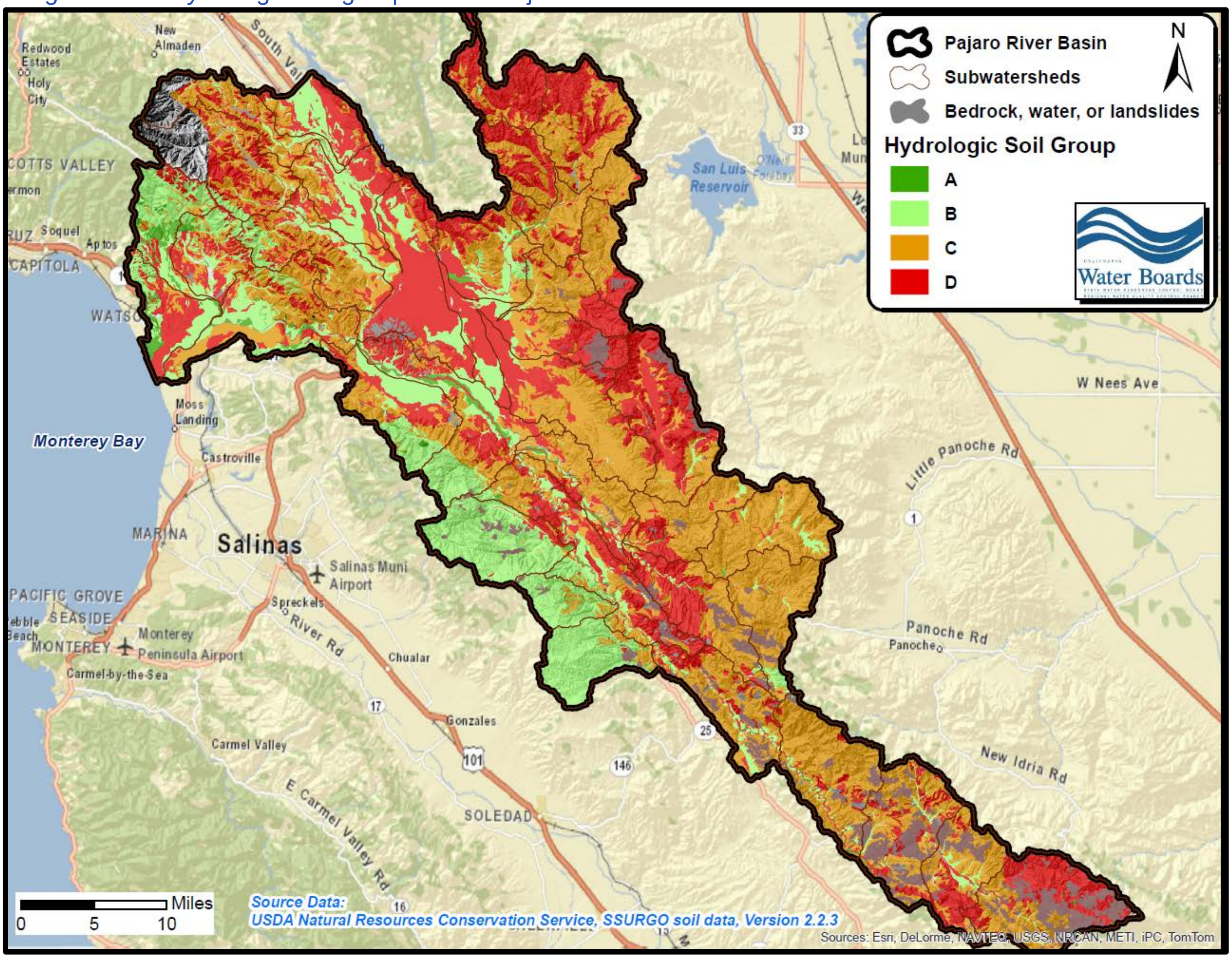
AVERAGE SOIL PHOSPHORUS CONTENT (%) IN THE PAJARO RIVER BASIN:

0.038%

Soils also play a key role in drainage, runoff, and subsurface infiltration in any given watershed. The soil survey for Monterey County was compiled by the U.S. Department of Agriculture National Resources

Conservation Service (NRCS) and is available online under the title of Soil Survey Geographic (SSURGO) Database. SSURGO has been updated with extensive soil attribute data, including Hydrologic Soil Groups. Hydrologic Soil Groups are a soil attribute associated with a mapped soil unit, which indicates the soil's infiltration rate and potential for runoff. Information on hydrologic soil groups in a necessary input parameter in the spreadsheet source estimation tool used in this TMDL project (see Section 6.1). Therefore, it is necessary to compile information on hydrologic soil groups in the Pajaro River Basin. Figure 3-72 illustrates the distribution of hydrologic soil groups in the project area along with a tabular description of the soil group's hydrologic properties. **Error! Reference source not found.** illustrates the observation that the weighted average hydrologic soil group in the Pajaro River Basin is hydrologic soil group "C".

Figure 3-72. Hydrologic soil groups in the Pajaro River Basin.



Hydrologic Soil Group Descriptions:	
A	Well-drained sand and gravel; high permeability
B	Moderate to well-drained; fine to moderately course texture; moderate permeability
C	Poor to moderately well-drained; moderately fine to fine texture; slow permeability
D	Poorly drained; clay soils, or shallow soils over nearly impervious layers(s)

As indicated in Table 3-32 and previously in Figure 3-72, the most frequently occurring soil groups in the Pajaro River Basin are poor to moderately well-drained hydrologic soil groups (HSG group C), followed by poorly drained clay soils or impervious layers (HSG group D). Occurrences of well-drained sand and gravel (HSG group A) are mostly limited to the channel belts depositional facies associated with streams corridors.

Table 3-32: Most frequently occurring Hydrologic Soil Groups (HSGs) in subwatersheds of the Pajaro River Basin.

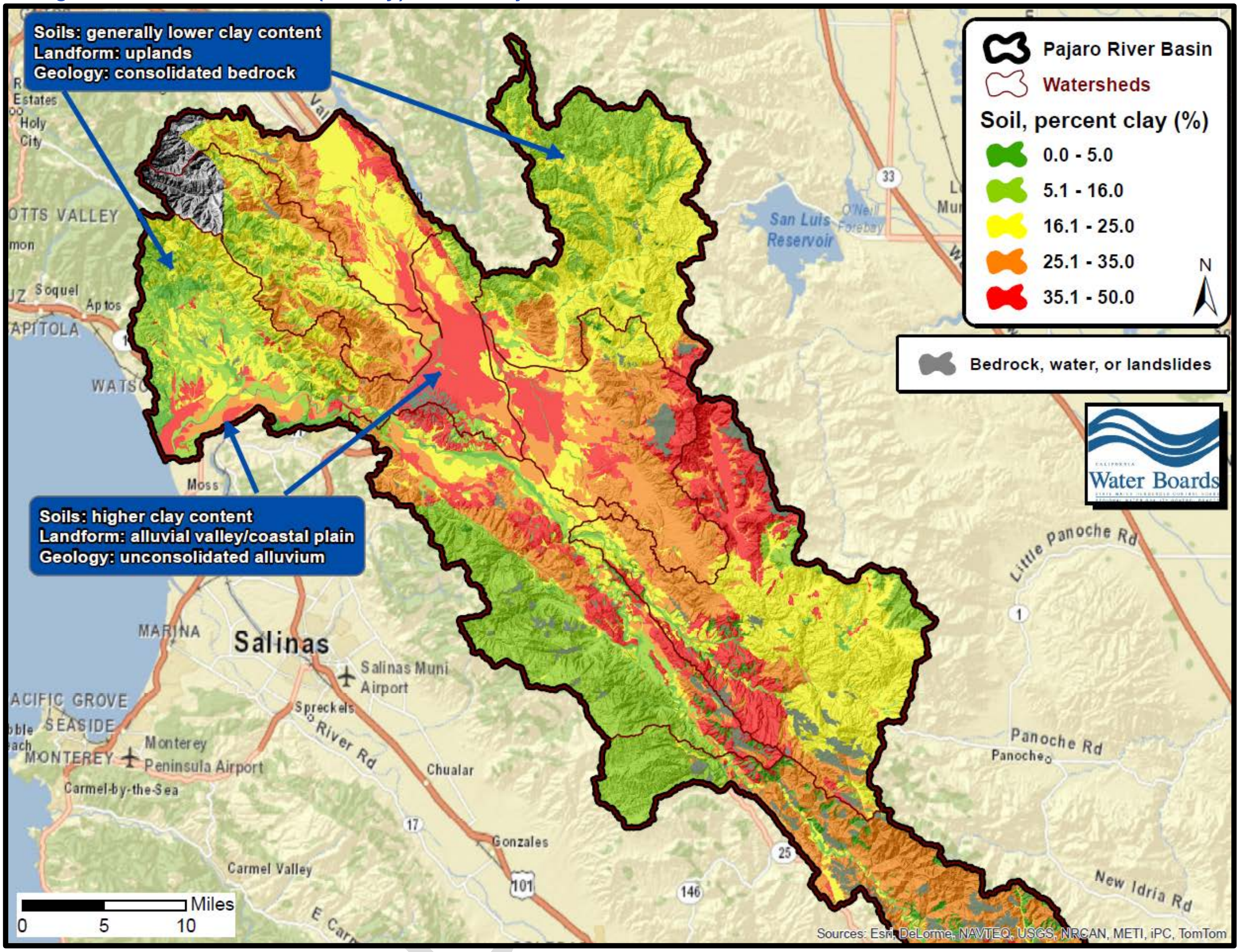
Subwatershed	Most frequently occurring HSG[A]	Subwatershed	Most frequently occurring HSG[A]
Arroyo De Las Viboras	C	Pescadero Creek	B
Bird Creek-San Benito River	B	Quien Sabe Creek	D
Cedar Creek	D	Rock Springs Creek-San Benito River	C
Clear Creek-San Benito River	D	Salsipuedes Creek	B
Corralitos Creek	B	San Juan Canyon	C
Hernandez Reservoir-San Benito River	D	Santa Ana Creek	C
James Creek-San Benito River	C	South Fork Pacheco Creek	C
Las Aguilas Creek	C	Stone Creek	B
Little Llagas Creek	D	Sulphur Creek-San Benito River	C
Los Muertos Creek	C	Tequisquita Slough	D
Lower Llagas Creek	D	Upper Llagas Creek	C
Lower North Fork Pacheco Creek	D	Upper North Fork Pacheco Creek	D
Lower Pacheco Creek	C	Upper Pacheco Creek	C
Lower Pajaro River	C	Upper Pajaro River	D
Lower Tres Pinos Creek	C	Upper Tres Pinos Creek	C
Lower Uvas Creek	C	Upper Uvas Creek	C
Middle Tres Pinos Creek	D	Watsonville Slough Frontal	D
Paicines Reservoir-San Benito River	C	Willow Creek	B

[A] Determined by spatial analysis – staff extracted digital SSURGO soil data using the spatial attributes of subwatershed shapefiles as a digital mask.

Additionally, the benthic sediment composition of streams is an important factor to consider, because the physical characteristics of stream substrates may play a role in algal productivity; for example, by influencing the turbidity (and therefore, light availability) of the overlying water column.

A cursory evaluation of regional soil textures and regional geology illustrate the substantial variability in soil conditions even at the reach-scale or subwatershed-scale. Figure 3-73 illustrates soil textures in terms of percent clay in the Pajaro River basin. Turbidity conditions in agricultural alluvial valleys with clay-rich soils and substrates would often be expected to have substantially different ambient turbidity conditions relative to stream reaches in upland areas, or in areas underlain by consolidated bedrock and sandy soil and substrate conditions. It should be recognized that unlike sand, silt, or gravel, which are typically transported as bedload, clay is often transported in colloidal suspension in the water column even at very low stream velocities, thereby contributing to ambient turbidity.

Figure 3-73. Soil texture (% clay) in the Pajaro River Basin.



3.12 Fish & Wildlife

Water quality plays an important role in fish and wildlife habitat. A number of the designated aquatic habitat beneficial uses for project area waterbodies (refer to Section 3.2 and Table 3-2) may be adversely affected by higher than natural nutrient levels and associated water quality stressors (wide DO and pH swings) that occur within the project area. Biostimulatory impairments, or toxicity associated with elevated nutrients and/or unionized ammonia can affect the entire aquatic food web, from algae and other microscopic organisms, through benthic macroinvertebrates (principally aquatic insect larvae), through fish, to the mammals and birds at the top of the food web. Consequently, it is relevant to be cognizant of and consider available information on aquatic habitat and fish resources in the project area. Is should also be noted that while there remains a fairly significant extent of viable estuarine and brackish water habitat in the Monterey Bay and northern Santa Cruz County coastal areas, the cumulative effect of human activities in the last century has severely degraded, reduced and restricted viable fresh water habitat in the Pajaro River Basin.

Further, it has long been recognized that biostimulation, excess nutrients, and water quality degradation has substantially degraded aquatic habitat locally in surface waters of the Pajaro River Basin. For example, over 20 years ago Swanson and Associates (1993) reported high nutrient levels in surface waters entering the Pajaro River lagoon which were resulting in dense phytoplankton blooms adversely impacting the natural oxygen balance of lagoon waters, and resulting in "shading" which limited natural benthic aquatic plant growth in deeper sections of the lagoon. Additionally, Smith in 1982 (as reported in Moyle et al., 1995) attributes disappearance of monterey roach fish in Monterey Bay watersheds to habitat alteration and lowered water quality including low dissolved oxygen.

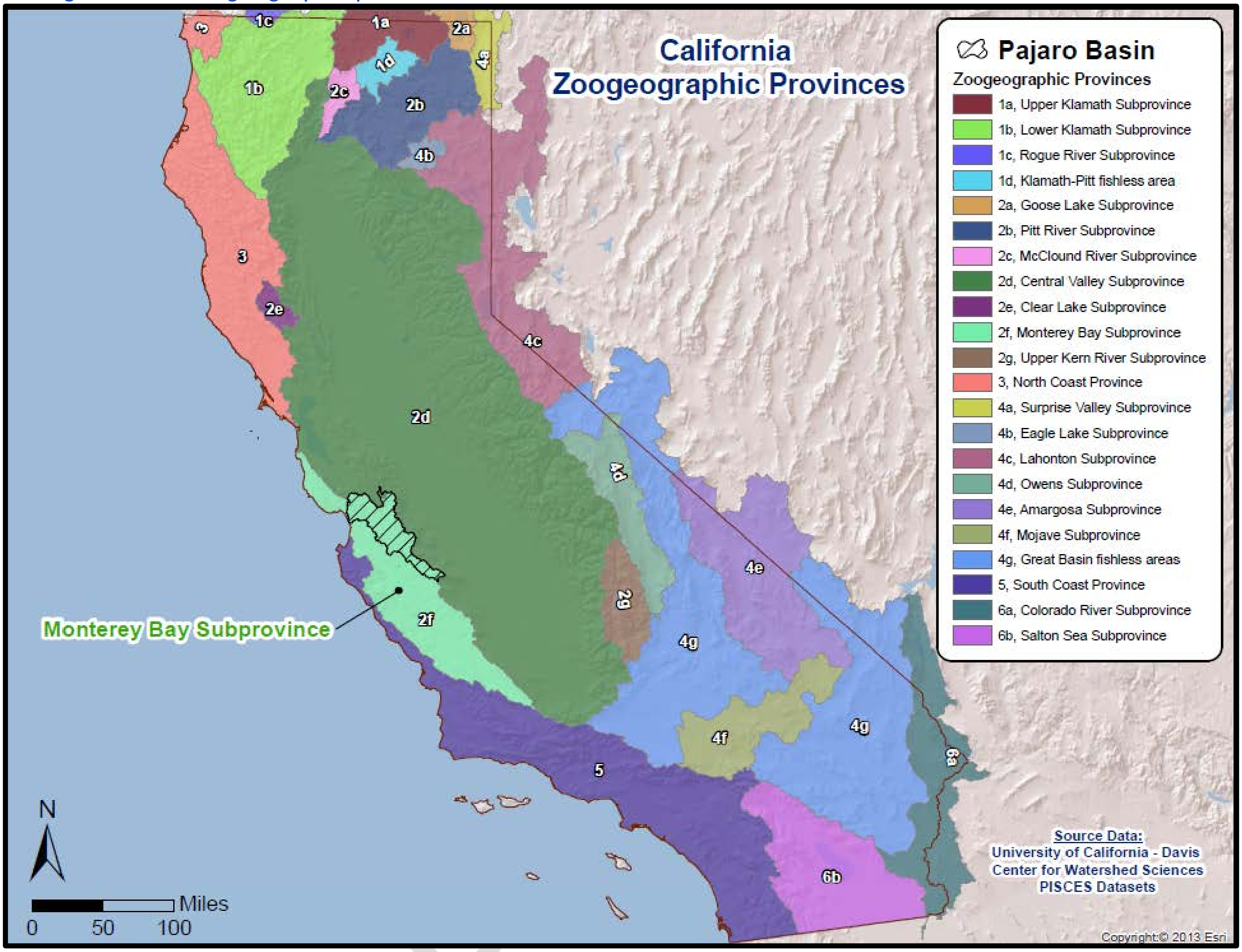
Fish are the most noticeable components of aquatic ecosystems, and their declines signals ecosystem deterioration; alternatively, healthy fish assemblages signal clean and healthy waters (Moyle, 2002). The California Department of Fish and Game reported in the second edition of Fish Species of Special Concern in California that the decline of California's fishes, and of other aquatic organisms, will continue and many extinctions will occur unless the widespread nature of the problem is addressed in a systematic effort to protect aquatic habitat in all drainages of the State (Moyle, et al., 1995). Note that researchers have recently reported that, due to the continuing impacts of anthropogenic changes, California is likely to lose a large proportion of its remaining native fish diversity (Marchetti et al., 2006). Stream reaches in the Pajaro River basin provide a range of potential warm freshwater, cold freshwater, and estuarine aquatic habitat. Also, modified drainage canals and ditches may locally and episodically provide migratory habitat or reproductive habitat for fishes and amphibians (Dr. Jerry Smith, written personal communication, July 3, 2013) – indeed, carp and fathead minnow have been observed spawning in Miller's Canal and in a flooded ditch that flows to Miller's Canal (J.R. Casagrande, 2010).

One way to begin to assess freshwater aquatic habitat of the Pajaro River Basin is to review regional information and the spatial distribution of California's zoogeographic provinces – see Figure 2-57. The Pajaro River Basin is located in the Monterey Bay zoogeographic subprovince. This subprovince is composed of the three major rivers that flow into Monterey Bay: the San Lorenzo River, the Pajaro River, and the Salinas River. Historically, the Monterey Bay subprovince and the Pajaro River had an array of freshwater native fish species characteristic of the Central Valley subprovince (Sacramento sucker, California roach, hitch, Sacramento blackfish, Sacramento pikeminnow, speckeled dace, thicktail chub, Sacramento perch, tule perch, and riffle sculpin), as well as saltwater dispersant fishes including the Pacific Lamprey, threespine stickleback, prickly sculpin, and steehead (Moyle, 2002).

The similarity of the freshwater fish fauna of the Monterey Bay subprovince with the Central Valley is likely due to hydrologic connectivity between the subprovince and the Central Valley sometime during the middle or late Pleistocene epoch, between 12 thousand to 50 thousand years ago[81] (Moyle, 2002),.

[81] Geologic evidence suggests that upper Coyote Creek (which now flows to the San Francisco Bay) has episodically changed course in the past, sometimes flowing into Llagas Creek, a Pajaro River tributary – thus providing a plausible hydrologic connection for lowland fishes of the Central Valley zoogeographic subprovince to have migrated into the Pajaro River Basin (Banner, 1907 as reported in Moyle, 2002).

Figure 3-74. Zoogeographic provinces of California.



➢ *Special Status Aquatic Species (Fish and Amphibians)*

The TMDL project area provides habitat to six special-status aquatic species[82] (fish, amphibians, and a crustacean) listed under the federal Endangered Species Act (ESA), and include:

- South-central California Coast steelhead DPS (Federal Status: threatened);
- Tidewater goby (Federal Status: endangered);
- California red-legged frog (Federal Status: threatened);
- California tiger salamander (Federal and State Status: threatened)
- Santa Cruz long-toed salamander (Federal and State Status: endangered)
- Vernal pool fairy shrimp (Federal Status: threatened)

➢ *Aquatic Species of Special Concern (Fish and Turtle)*

A Species of Special Concern (SSC) is a species, subspecies, or distinct population of an animal native to California that currently satisfies one or more criteria, as defined by the California Department of Fish

[82] Source: Calif. Dept. of Fish and Game – California Natural Diversity Database, 2013

and Wildlife (CDFW)[83]. "Species of Special Concern" is an administrative designation and carries no formal legal status. The intent of designating SSCs is to focus attention on animals at conservation risk and achieve conservation and recovery of these animals before they meet California Endangered Species Act criteria for listing as threatened or endangered. In terms of aquatic species, the TMDL project area provides habitat for the following aquatic Species of Special Concern that do not currently have special status legal protection:

- Rainbow Trout (fish), designated by CDFW as a Class 1 species *(population threatened)*
- Tidewater Goby (fish), designated by CDFW as a Class 1 species (*qualify as endangered*)
- Monterey Hitch (fish), designated by CDFW as a Class 2 species *(population vulnerable)*
- Monterey Roach (fish) designated by CDFW as a Class 3 species
- Riffle Sculplin (fish) designated by CDFW as a Class 4 species
- Central California Roach (fish), designated by CDFW as a Class 3 species
- White Sturgeon (fish), designated by CDFW as a Class 4 species
- Pacific Lamprey (fish), designated by CDFW as a Class 3 species
- Western pond turtle, which is designated by CDFW as a special concern species (noted to occupy the Pajaro River Flood Control Channel[84],

Clusters of Fish Recommended for Coordinated Ecosystem-Level Management

The California Department of Fish and and Wildlife (DFW) have recommended coordinated special ecosystem management strategies for regional clusters of potentially endangered species with similar environmental requirements (Moyle et al., 1995). These DFW-identified fish clusters carry no formal legal status but constitute recommendations as part of a systematic effort towards protecting and restoring fish resources of the State. DFW recommended a cluster of fish species needing coordinated ecosystem management for Monterey Bay streams (Moyle et al., 1995), which includes the following fish species found within the TMDL project area:

- Winter steelhead
- Monterey roach
- Monterey hitch
- Speckled dace
- Sacramento sucker
- Tidewater goby

Fish Resources in Project Area

Figure 3-75 illustrates estimated current presence of native fish assemblages in the Pajaro River Basin and their presumed distributions. It should be noted that these estimates of native fish distributions are subject to uncertainties and some assumptions, and are based on the best professional judgment of fisheries biologists at the University of California-Davis[85]. Figure 3-76 illustrates the estimated number of native species losses (extirpations) locally by individual subwatersehd within the Pajaro River Basin.

Table 3-33 presents a tabulation of current estimated species range for native fishes by subwatershed within the Pajaro River Basin. Table 3-34 presents a tabulation of recent field observations of native and introduced fish species, reported in surveys by Casagrande (2011) and others.

[83] See Calif. Department of Fish and Game species of special concern webpage, accessed Janaury 2014, online linkage: http://www.dfg.ca.gov/wildlife/nongame/ssc/.

[84] Source: Kittleson Environmental Consulting, 2009 Pajaro River Western Pond Turtle Survey – Draft Report, October 22, 2009.

[85] University of California, Davis – Center for Watershed Sciences, PISCES species occurrence database. PISCES is a database that standardizes, maps, and analyzes the distribution of fish species in California based on watershed units.

Figure 3-75. Best-known current ranges for native fish assemblages in Pajaro Basin (2012).

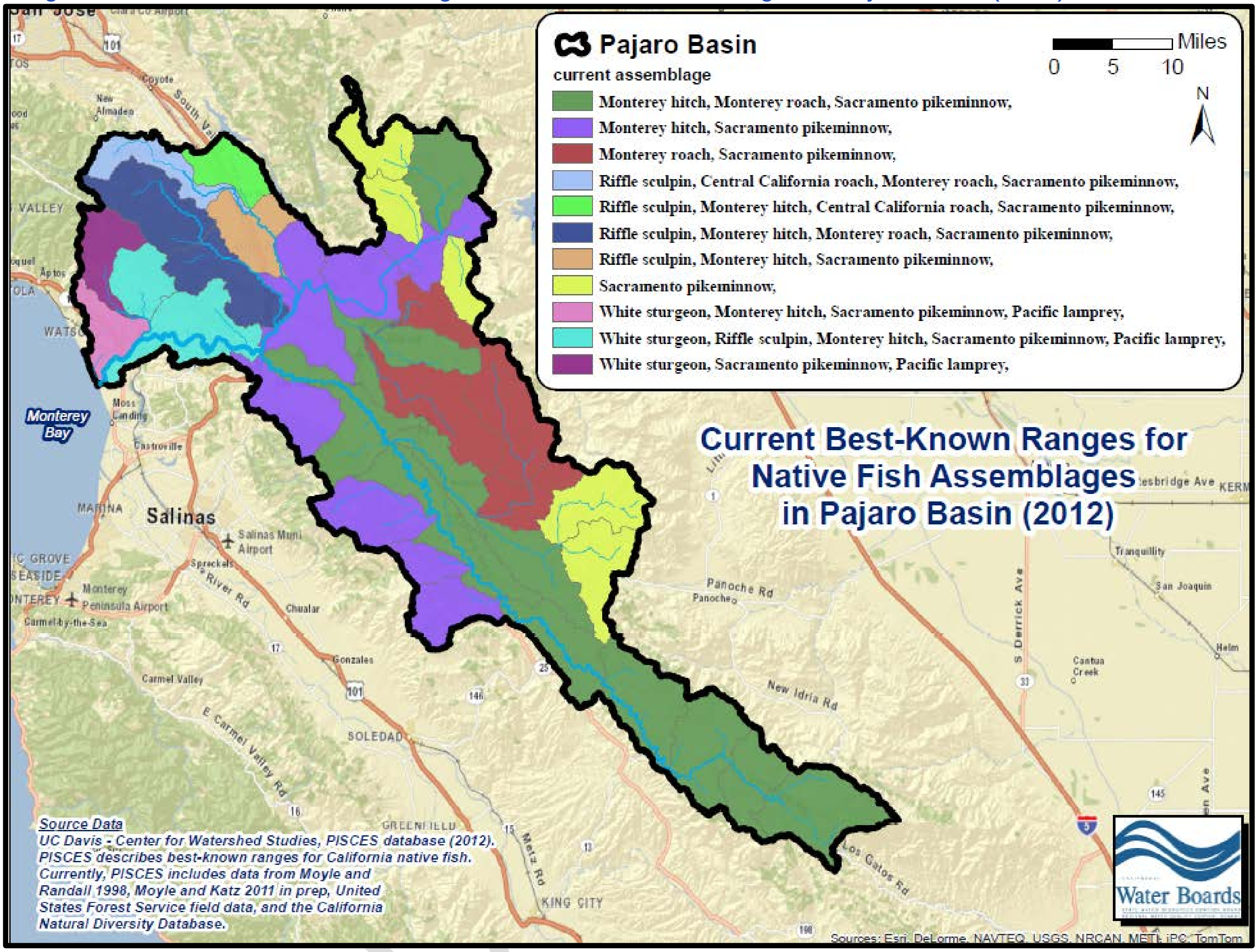


Figure 3-76. Estimated number of native species losses (extirpations) locally by individual subwatershed (source: PICSES database).

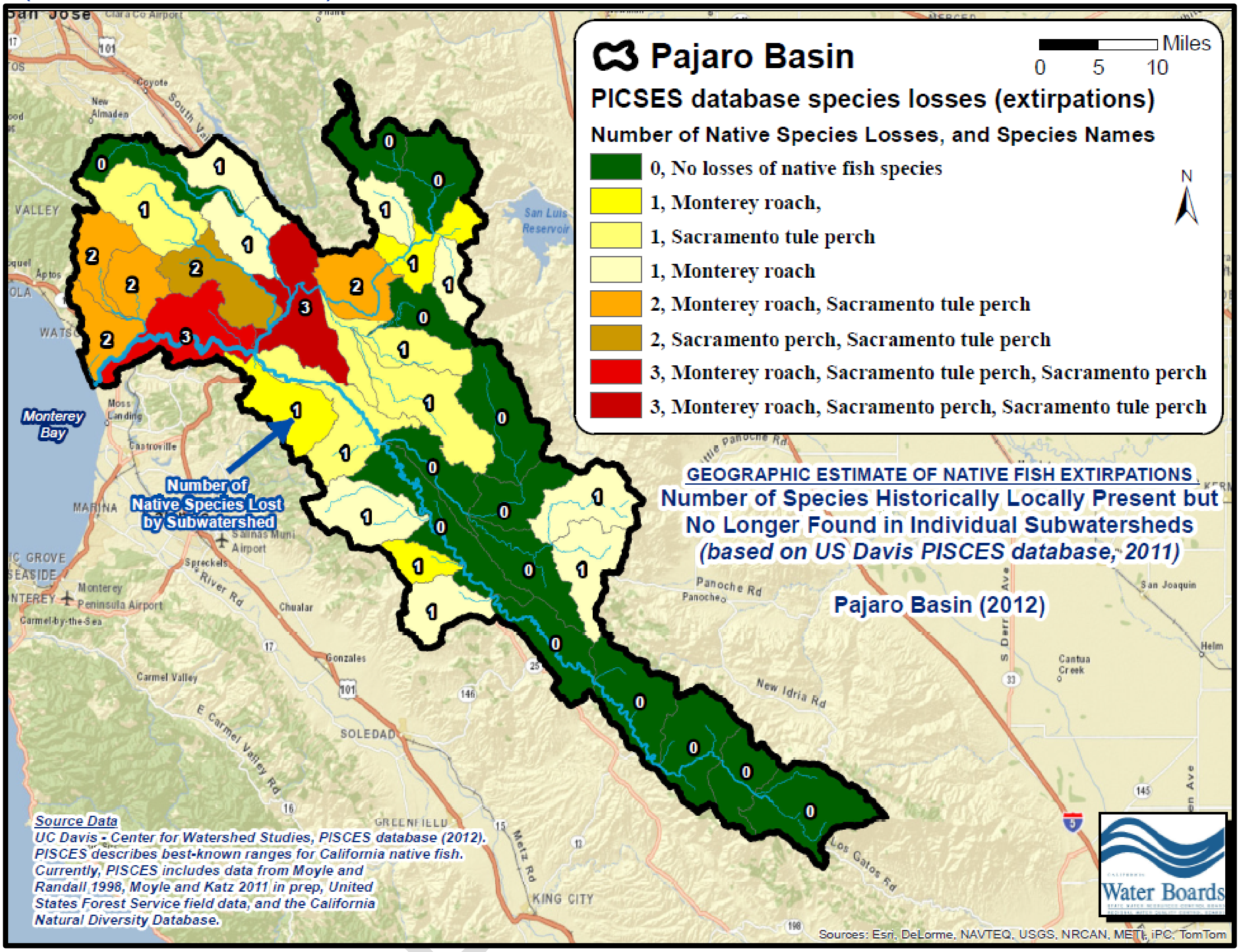


Table 3-33. Current estimated range (best professional judgment[A]) of native riverine fish species in the Pajaro River Basin.

Subbasin	Subwatershed	Rainbow Trout *Oncorhynchus mykiss*	Tidewater Goby *Eucyclogobius newberryi*	Monterey Hitch *Lavinia exilicauda*	Monterey Roach *Lavinia symmetricus subditus*	Sacramento Pikeminnow *Ptychocheilus grandis*	Riffle Sculpin *Cottus gulosus*	Central Calif. Roach *Lavinia symmetricus symmetricus*	White Sturgeon *Acipenser transmontanus*	Pacific Lamprey *Lampetra tridentata*	Speckled Dace *Rhinichthys osculus*	Threespine Stickleback *Gasterosteus aculeatus*	Staghorn Sculpin *Leptocottus armatus*
Pajaro River Subbasin	Upper Pajaro River	x		x		x					x		
	Upper Llagas Creek	x			x	x	x	x			x	x	
	Little Llagas Creek			x		x	x	x				x	
	Lower Uvas Creek	x		x	x	x	x				x		
	Upper Uvas Creek	x		x	x	x	x					x	
	Lower Llagas Creek	x		x		x	x						
	Watsonville Slough Frontal			x		x			x	x		x	x
	Lower Pajaro River	x	x	x		x	x		x	x	x	x	x
	Salsipuedes Creek	x		x		x	x		x	x		x	
	Corralitos Creek	x				x			x	x		x	
Pacheco Creek Subbasin	Tequisquita Slough	x		x	x	x							
	Lower North Fork Pacheco Creek	x		x	x	x							
	Lower Pacheco Creek	x		x		x							
	Upper Pacheco Creek			x		x							
	Santa Ana Creek				x	x					x		
	Arroyo De Las Viboras				x	x							
	South Fork Pacheco Creek	x				X							
	Cedar Creek	x				X							
	Upper North Fork Pacheco Creek					x							
San Benito River Subbasin	Paicines Reservoir-San Benito River	x		x	x	x					x		
	Bird Creek-San Benito River	x		x	x	x					x		
	Lower Tres Pinos Creek			x	x	x					x		
	Middle Tres Pinos Creek			x	x	x					x		
	Rock Springs Creek-San Benito River	x		x	x	x					x		
	Sulphur Creek-San Benito River	x		x	x	x					x		
	James Creek-San Benito River	x		x	x	x					x		
	Clear Creek-San Benito River	x		x	x	x					x		
	Hernandez Reservoir-San Benito River	x		x	x	x					x		
	San Juan Canyon			x		x					x		
	Stone Creek			x		x					x		
	Pescadero Creek	x		x		x					x		
	Willow Creek			x		x					x		
	Quien Sabe Creek				x	x							

Subbasin	Subwatershed	Rainbow Trout *Oncorhynchus mykiss*	Tidewater Goby *Eucyclogobius newberryi*	Monterey Hitch *Lavinia exilicauda*	Monterey Roach *Lavinia symmetricus subditus*	Sacramento Pikeminnow *Ptychocheilus grandis*	Riffle Sculpin *Cottus gulosus*	Central Calif. Roach *Lavinia symmetricus symmetricus*	White Sturgeon *Acipenser transmontanus*	Pacific Lamprey *Lampetra tridentata*	Speckled Dace *Rhinichthys osculus*	Threespine Stickleback *Gasterosteus aculeatus*	Staghorn Sculpin *Leptocottus armatus*
	Los Muertos Creek				x	x					x		
	Upper Tres Pinos Creek					x					x		
	Las Aguilas Creek					x					x		

[A] Source: Unviersity of California, Davis Center for Watershed Studies, PISCES database. THE PISCES database describes the best-known ranges for California's native fishes. The data are compiled from multiple sources and fish biology experts and is stored and exported as range maps.

Table 3-34. Field survey observations of native and introduced fish in the Pajaro River Basin.

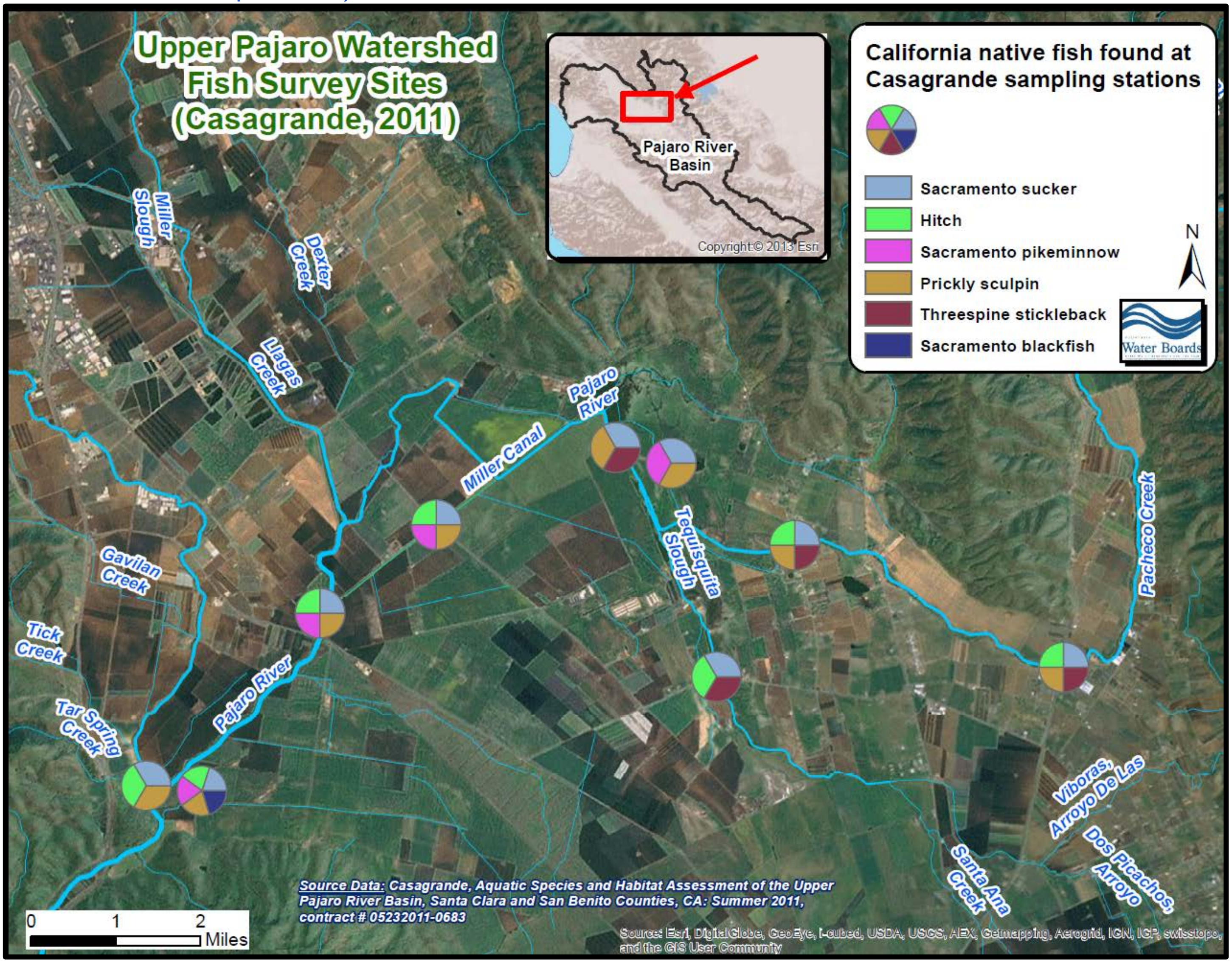
Watershed (HUC 10)	Waterbody	Fish Species Observed	Scientific Name	Relative Abundance	Literature Source
Pajaro River Watershed (Upper)	Pajaro River @ Carnadero Creek Confluence	Sacramento Sucker	*Catostomus occidentalis*	Common	Casagrande (2011)
		Hitch	*Lavinia exilicauda*	Abundant	
		Sacramento pikeminnow	*Ptychocheilus grandis*	Rare	
		Sacramento blackfish	*Orthodon microlepidotus*	Rare	
		Bluegill	*Lepomis macrochirus*	Rare	
		Black crappie	*Pomoxis nigromaculatus*	Rare	
		White catfish	*Ameiurus catus*	Rare	
		Common carp	*Cyprinus carpio*	Rare	
		Goldfish	*Carassius auratus*	Rare	
		Striped bass	*Morone saxatilis*	Common	
		Prickly sculpin	*Cottus asper*	Common	
		Fathead minnow	*Pimephales promelas*	Rare	
	Pajaro River @ Miller Canal Confluence	Sacramento Sucker	*Catostomus occidentalis*	Common	Casagrande (2011)
		Hitch	*Lavinia exilicauda*	Rare	
		Sacramento pikeminnow	*Ptychocheilus grandis*	Rare	
		Brown Bullhead	*Ameiurus nebulosus*	Rare	
		Striped Bass	*Morone saxatilis*	Common	
		Prickly sculpin	*Cottus asper*	Common	
		Common carp	*Cyprinus carpio*	Rare	
	Miller's Canal @ Frazer Lake Road	Sacramento sucker	*Catostomus occidentalis*	Common	Casagrande (2011)
		Hitch	*Lavinia exilicauda*	Common	
		Sacramento pikeminnow	*Ptychocheilus grandis*	Rare	
		Prickly sculpin	*Cottus asper*	Abundant	
		Bluegill	*Lepomis macrochirus*	Rare	
		Fathead minnow	*Pimephales promelas*	Rare	
		Mosquitofish	*Gambusia affinis*	Rare	
		Common carp	*Cyprinus carpio*	Not reported	

Watershed (HUC 10)	Waterbody	Fish Species Observed	Scientific Name	Relative Abundance	Literature Source
Pajaro River Watershed (Lower)	Beach Road Drainage Ditch	Mosquito fish	*Gambusia affinis*	Abundant	Kittleson (2005)
		Threespine stickleback	*Gasterostus aculaetus*	Common	
	Harkins Slough	Sacramento blackfish	*Orthodon microlepidotus*	Not reported	Swanson Hydrology and Geomorphology (2003)
		Stickleback	*Gasterostus*	Not reported	
		Carp	*Cyprinus carpio*	Not reported	
		Mosquito fish	*Gambusia*	Not reported	
		Black crappie	*Pomoxis nigromaculatus*	Not reported	
	Struve Slough	Stickleback	*Gasterostus*	Not reported	
	Larkin Creek from Harkins Slough upstream to about Windsong Way	Mosquito fish	*Gambusia*	Not reported	
		Stickleback	*Gasterostus*	Not reported	
		Prickly sculpin	*Cottus asper*	Not reported	
	Pajaro River Estuary	Brown smoothhound	*Mustelus henlei*	Rare	Swanson and Associates (1993)
		Round stingray	*Urolophus halleri*	Rare	
		Pacific herring	*Clupea harengis*	Abundant	
		Pacific sardine	*Sardinops sagax*	Uncommon	
		Northern anchovy	*Engraulis mordax*	Common	
		Coho (adult)	*Oncorhynchus kisutch*	Rare	
		Steelhead (hatchery)	*Oncorhynchus mykiss*	Uncommon	
		Plainfin midshipman	*Porichthys notatus*	Rare	
		Topsmelt	*Atherinops affims*	Abundant	
		California Grunion	*Leuresthes tenuis*	Uncommon	
		Threespine stickleback	*Gasterosteus aculeatus*	Common	
		Bay pipefish	*Syngnathus leptorhynchus*	Common	
		Staghorn sculpin	*Leptocottus armatus*	Abundant	
		Striped bass	*Morone saxatilis*	Uncommon	
		Shiner surfperch	*Cymatogaster aggregata*	Uncommon	
		Walleye surfperch	*Hyperprosopon argenteum*	Uncommon	
		White surfperch	*Phanerodonfurcatus*	Rare	
		Barred surfperch	*Amphistichus argentus*	Rare	
		Pile surfperch	*Damalichthys vacca*	Rare	
		Arrow goby	*Clevlandia ios*	Abundant	
		Tidewater goby	*Eucyclogobius newberryi*	Common	
		California Halibut	*Paralichthyes californicus*	Uncommon	
		Diamond Turbot	*Hypsopsetta guttulata*	Rare	
		English sole	*Parophyrs vetulus*	Uncommon	
		Starry Flounder	*Platichthyes stellatus*	Common	

Watershed (HUC 10)	Waterbody	Fish Species Observed	Scientific Name	Relative Abundance	Literature Source
Uvas Creek Watershed	Lower Carnadero Creek	Sacramento sucker	*Catostomus occidentalis*	Common	Casagrande (2011)
		California roach	*Lavinia symmetricus*	Common	
		Hitch	*Lavinia exilicauda*	Common	
		Prickly sculpin	*Cottus asper*	Abundant	
		steelhead	*Oncorhynchus mykiss*	Rare	
		Common carp	*Cyprinus carpio*	Rare	
Tequisquita Slough Watershed	Tequisquita Slough @ Shore Road	Sacramento sucker	*Catostomus occidentalis*	Rare	Casagrande (2011)
		Hitch	*Lavinia exilicauda*	Rare	
		Threespine stickleback	*Gasterosteus aculeatu*	Rare	
		Fathead minnow	*Pimephales promelas*	Rare	
		Common carp	*Cyprinus carpio*	Rare	
		Mosquitofish	*Gambusia affinis*	Common	
	Tequisquita Slough upstream of San Felipe Lake	Sacramento sucker	*Catostomus occidentalis*	Common	
		Prickly sculpin	*Cottus asper*	Abundant	
		Threespine stickleback	*Gasterosteus aculeatu*	Abundant	
		Green sunfish	*Lepomis cyanellus*	Rare	
		Fathead minnow	*Pimephales promelas*	Common	
		Common carp	*Cyprinus carpio*	Rare	
		Brown bullhead	*Ameiurus nebulosus*	Common	
Pacheco Creek Watershed	Pacheco Creek @ Hwy 156	Sacramento sucker	*Catostomus occidentalis*	Rare	Casagrande (2011)
		Hitch	*Lavinia exilicauda*	Common	
		Prickly sculpin	*Cottus asper*	Abundant	
		Threespine stickleback	*Gasterosteus aculeatu*	Common	
		Green sunfish	*Lepomis cyanellus*	Common	
	Pacheco Creek @ Lovers Lane	Sacramento sucker	*Catostomus occidentalis*	Rare	
		Hitch	*Lavinia exilicauda*	Rare	
		Prickly sculpin	*Cottus asper*	Common	
		Threespine stickleback	*Gasterosteus aculeatu*	Rare	
		Green sunfish	*Lepomis cyanellus*	Common	
		Largemouth bass	*Micropterus salmoides*	Rare	
		Common carp	*Cyprinus carpio*	Rare	
	Pacheco Creek upstream of San Felipe Lake	Sacramento sucker	*Catostomus occidentalis*	Common	
		Sacramento pikeminnow	*Ptychocheilus grandis*	Rare	
		Prickly sculpin	*Cottus asper*	Abundant	
		Green sunfish	*Lepomis cyanellus*	Rare	
		Bluegill	*Lepomis macrochirus*	Rare	

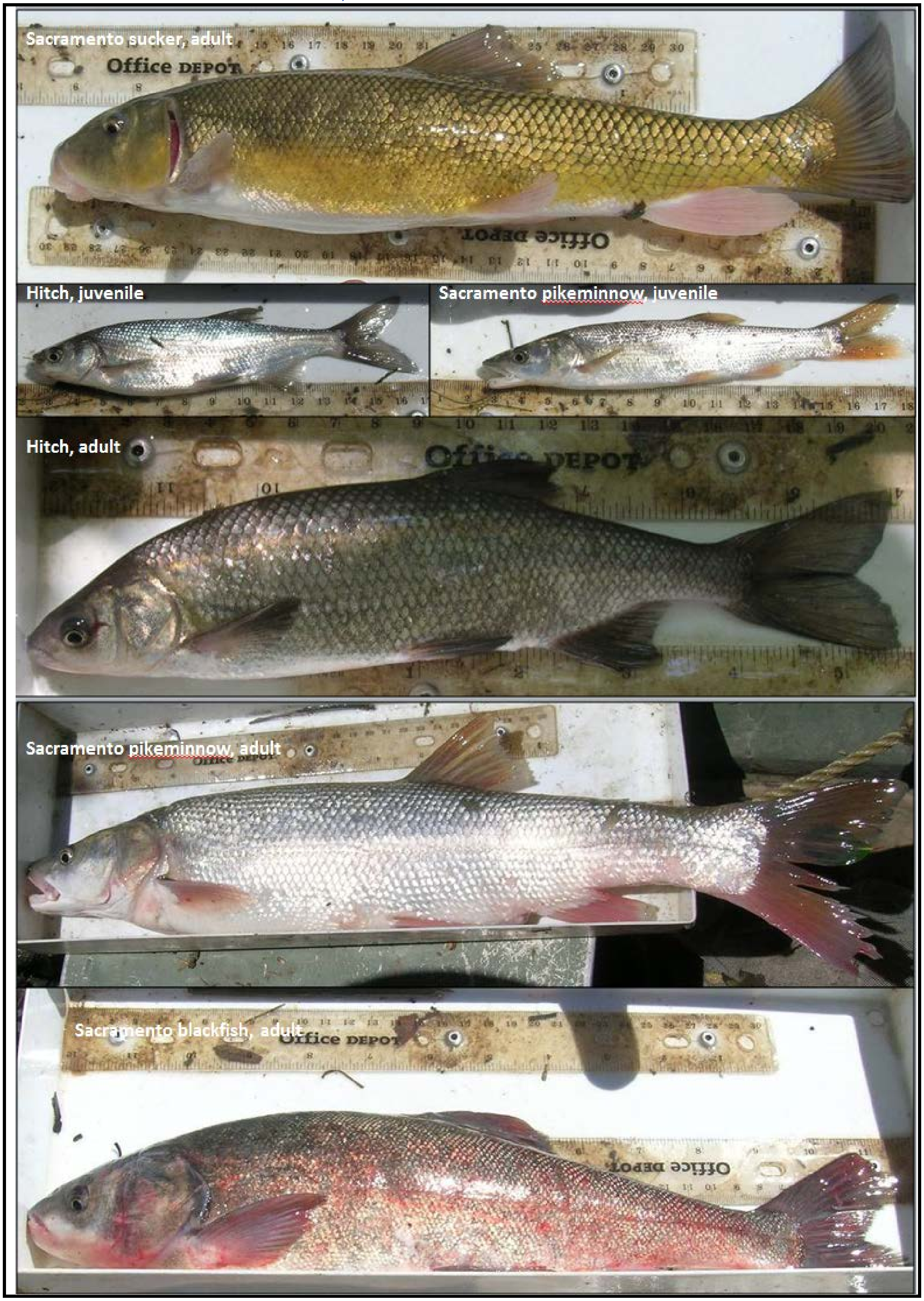
Casagrande (2011) assessed aquatic species in the upper Pajaro River Subbasin and the lower Pacheco Creek Subbasin in the summer of 2011 and found a total of 19 fish species; 8 native and 11 non-native species. The fish survey sites reported by Casagrande (2011) are illustrated in Figure 3-77.

Figure 3-77. Fish survey sites, upper Pajaro Watershed. Survey data from Casagrande 2011 (only native fish are shown in pie charts).



Casagrande (2011) assessed aquatic species in the upper Pajaro River subbasin and the lower Pacheco Creek subbasin in the summer of 2011 and found a total of 19 fish species; 8 native and 11 non-native species. The fish survey sites reported by Casagrande (2011) are illustrated in Figure 3-77.

Figure 3-78. Photo documentation of some aquatic species in TMDL project area. Photo credits: Joel Casagrande (2011). Note that all fish photos were taken in the Upper Pajaro River subbasin and/or the lower Pacheco Creek subbasin, unless otherwise noted.




Prickly sculpin, juvenile adult
Office DEPOT
Threespine stickleback, juvenile adult
Steelhead, juvenile
Bluegill-green sunfish hybrid, adult (left); bluegill, adult (center-left); and green sunfish (center-right, juvenile and right, adult)


Largemouth bass, adult from San Felipe Lake.
Striped bass, adult
Fathead minnow
Goldfish, adult
Common carp, sub-adult

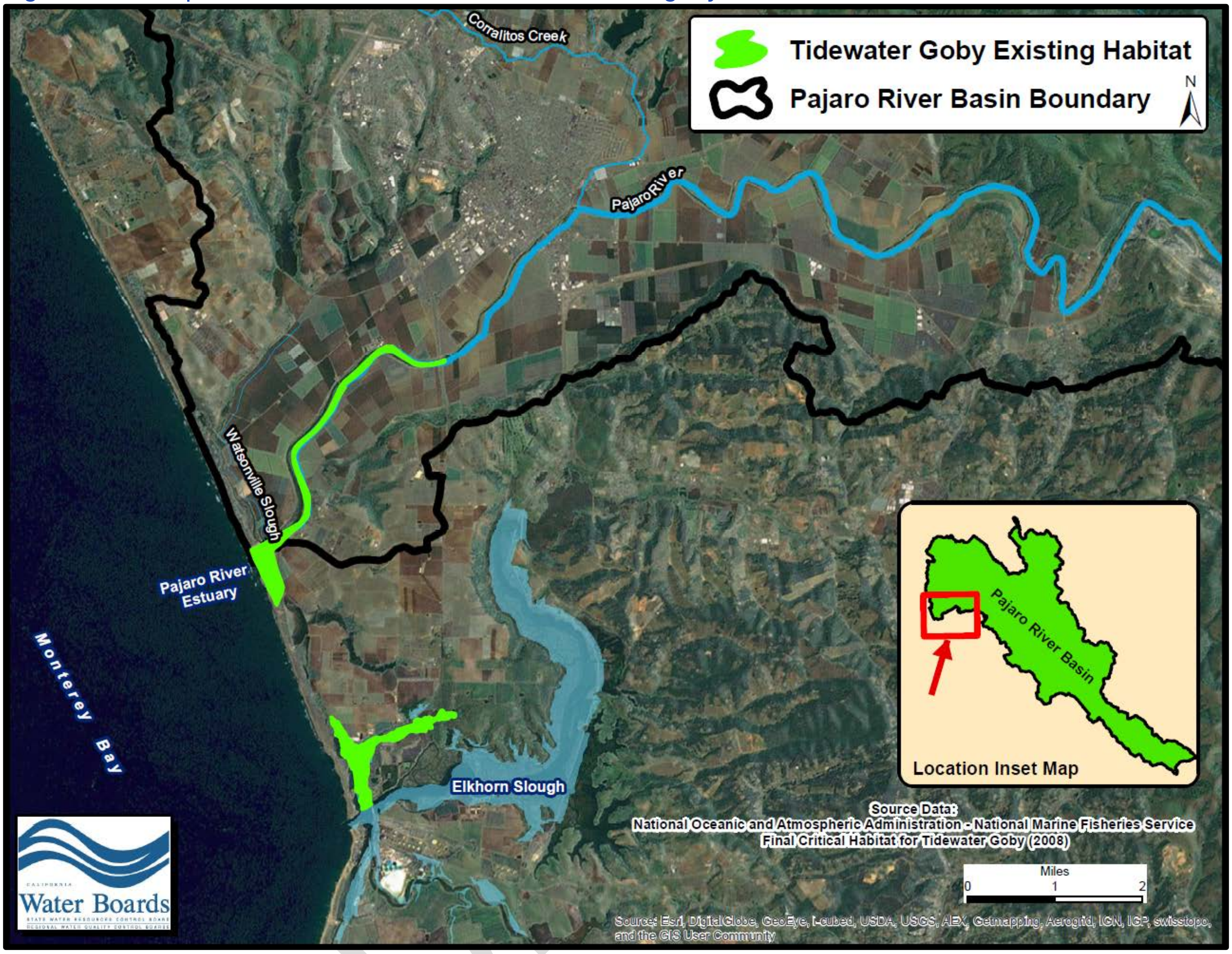

Common carp, adult, gravid
Brown bullhead, adult, gravid
Office DEPOT
White catfish, adult,
Mosquitofish, adult female
Water boatman,
Corixidae
California floater mussel shells on the bank of Pacheco Creek immediately upstream of its confluence with San Felipe Lake, 6 May 2006. Photo source in Casagrande 2011

- ***Tidewater Goby Critical Habitat & Steelhead Migratory & Spawning Habitat***

Figure 3-79 illustrates identified critical habitat for the endangered tidewater goby in coastal confluence areas of the Pajaro River Basin. "Critical habitat" is a term defined and used in the federal Endangered Species Act. It refers to specific geographic areas that contain features essential to the conservation of a threatened or endangered species and that may require special management and protection. Critical habitat may include areas that are not currently occupied by the species but that will be needed for its recovery[86].

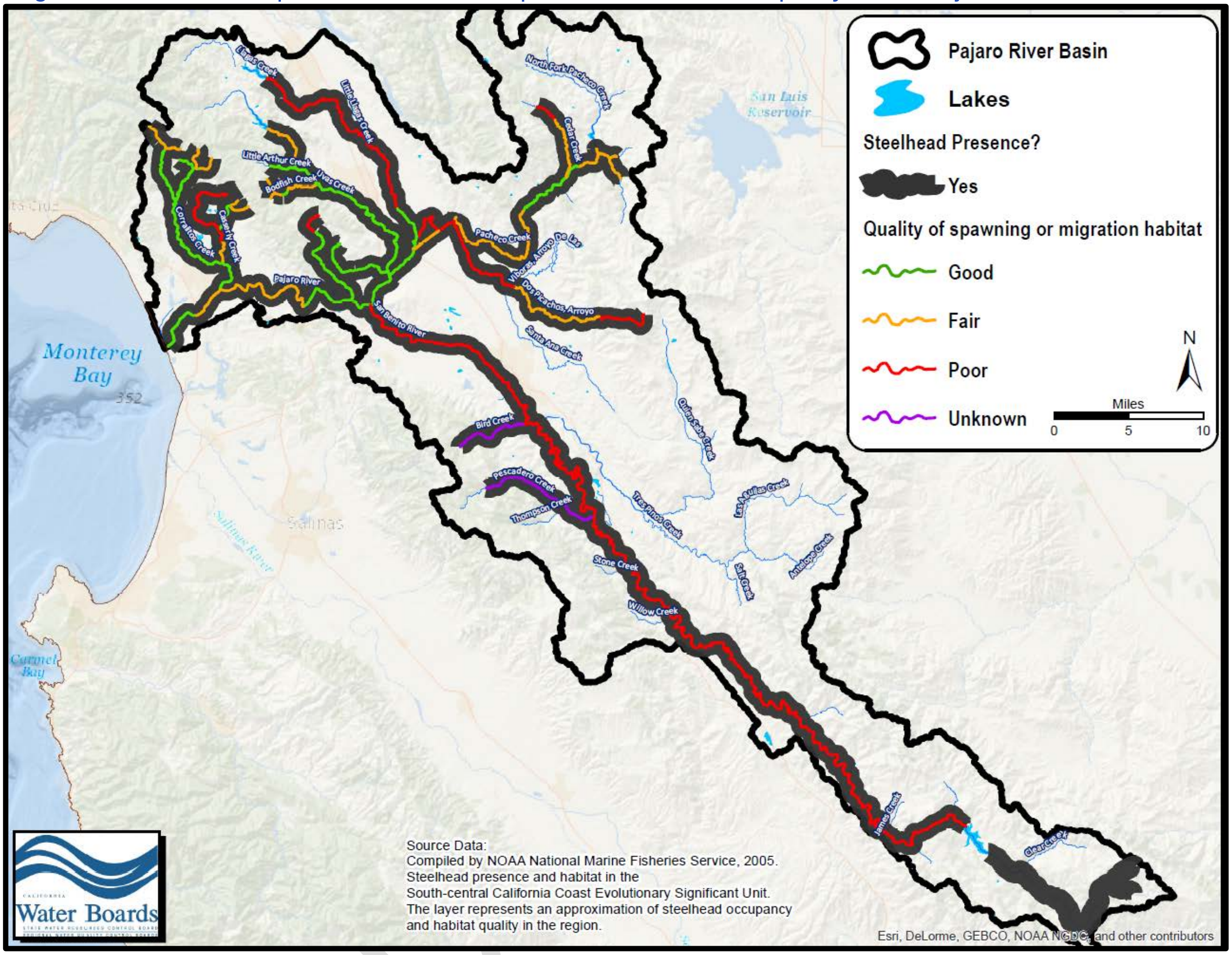
[86] See U.S. Fish and Wildlife Service, Critical Habitat frequently asked question webpage. Online linkage: http://www.fws.gov/endangered/what-we-do/critical-habitats-faq.html

Figure 3-79. Reported critical habitat areas for tidewater goby.



The Pajaro River and some tributaries provide migration and/or spawning habitat for steelhead trout, a federally listed endangered species. Figure 3-80 illustrates steelhead presence or absence in the Pajaro River Basin. This is observational data for the status of salmonid occupancy in a stream segment (stream reaches known or believed to be used by steelhead) but does not imply the existence of routine, robust and viable steelhead runs in all assessed reaches. The data is based on the South-central California Coast Evolutionary Significant Unit (SCCC-ESU) and was compiled by the National Marine Fisheries Service (NOAA Fisheries) Southwest Regional Office (SWR) in an effort to designate Critical Habitat for Steelhead in California.

Figure 3-80. Known or presumed steelhead presence and habitat quality in the Pajaro River Basin.



The NOAA-National Marine Fisheries Service (NMFS) reported Water Board staff in a letter dated November 10, 2011[60] that on January 5, 2006, the SCCC steelhead DPS was reaffirmed listed as threatened under the Federal Endangered Species Act. NMFS also indicated to Water Board staff that the most recent status review concluded that populations of SCCC-DPS steelhead are likely to become extinct in the next 50 years without intervention (Good et al., 2005 as reported by NMFS staff, personal communication, Nov. 10, 2011).

Habitat components for the survival and recovery of SCCC steelhead include, but are not limited to, uncontaminated estuarine areas and substrate and sufficient water quality to support growth and development. NMFS reports that the Pajaro, Salinas, Nacimiento/Arroyo Seco, and Carmel Rivers have experienced declines in steelhead runs of 90 percent or more during the last 30 years. Central Coast estuaries and lagoons play important roles in steelhead growth and survival. NMFS also communicated to Water Board staff that the most recent status review concluded that populations of SCCC-DPS steelhead are likely to become extinct in the next 50 years without intervention (Good et al., 2005 as reported by NMFS staff, personal communication, Nov. 10, 2011). Habitat components for the survival and recovery of SCCC steelhead include, but are not limited to, uncontaminated estuarine areas and substrate and sufficient water quality to support growth and development.

Also worth noting, Coho salmon were once present in the Pajaro River, but these salmon have not been seen in the river since at least the late 1960s (Pajaro River Watershed Integrated Regional Water Management Plan, 2007).

➢ *Other Aspects of the Aquatic Habitat of the Pajaro River Basin*

Finally, it is important to recognize that the Water Board is required to protect, maintain, or restore aquatic habitat beneficial uses of waters of the State broadly for the full array of species dependent on aquatic habitats, including vegetation, fish or wildlife, including invertebrates (refer to Section 4.1.4). A comprehensive review of the ecological resources and special-status animal and plant species of the Pajaro River Basin is available in the Pajaro River Watershed Integrated Regional Water Management Plan (2007.) It should be noted that the Pajaro River Basin contains many areas that are known to contain a number of rare amphibian species (see Figure 3-81) on the basis of biological richness data compiled by the California Department of Fish and Wildlife – thus highlighting the fact that viable freshwater aquatic habitat is critical for an entire terrestrial ecosystem in the broadest sense.

Also noteworthy is that while the focus in this section of the report is on fish, larval aquatic insects and other invertebrates are in fact the most common form of animal life in streams and lakes. Bioassessment field surveys in the Pajaro River and in Corralitos, Pacheco, and Llagas creeks have documented the presence of many species of mayflies, caddisflies, stoneflies, midges, aquatic worms, copepods (a type of zooplankton), cyclopoida (a type of small crustacean), as well as other types of aquatic invertebrates. (for example, Applied Science and Engineering Inc., 1999) – see Figure 3-82.

It is important to recognize that macroinvertebrates play important roles in the ecosystem and in the aquatic food web; they help break down organic debris, recycle nutrients, and provide food for fish, amphibians, and riparian birds[87]. While some macroinvertebrate organisms can live and thrive in polluted conditions, many others require clean water to survive[88]. The health of an aquatic ecosystem can often be inferred from the types and diversity of aquatic macroinvertebrates present.

[87] See California Invertegrate Digital Referecne Collection, online linkage: http://www.waterboards.ca.gov/water_issues/programs/swamp/docs/cwt/guidance/351e_bugstogo0414.pdf

[88] *Ibid*

Figure 3-81. Biological richness map for rare amphibian species, Pajaro River Basin & vicinity (2010).

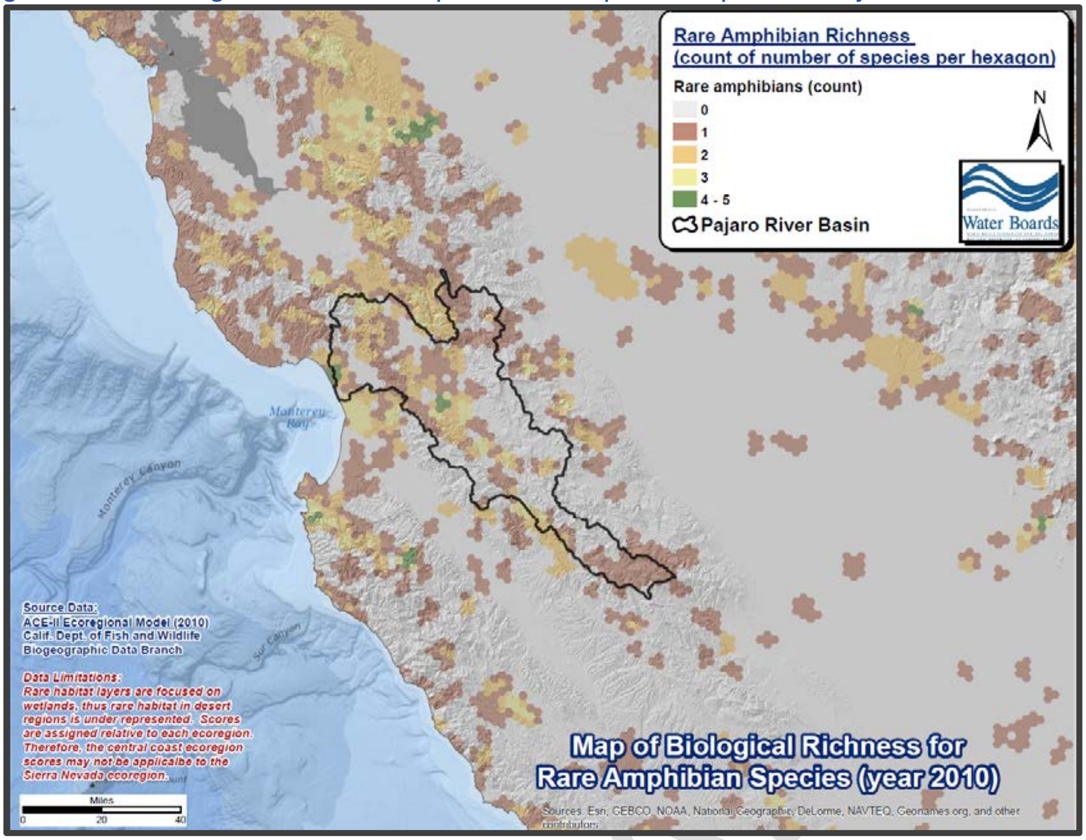
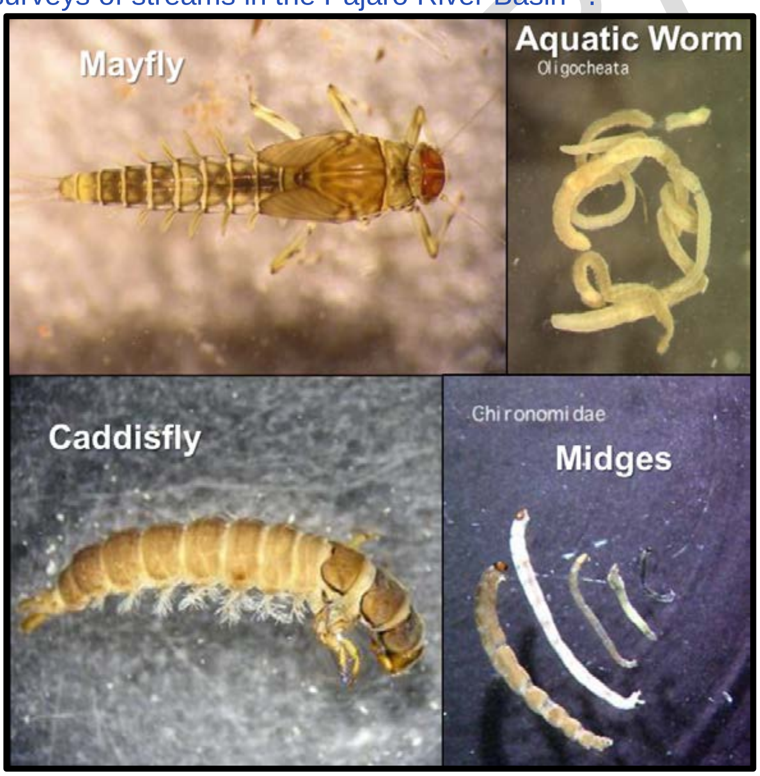


Figure 3-82. Photo reference of some aquatic macroinvertebrates which have been reported from field-surveys of streams in the Pajaro River Basin[89].



[89] Photo credits: California Digital Reference Collection, Aquatic Bioassessment Laboratory.

3.13 Coastal Receiving Waters & Downstream Impacts

It is important to recognize that excess nutrients in inland streams which drain alluvial or headwater reaches will ultimately end up in a receiving body of water (lakes, rivers, estuaries, bays, etc.) where the nutrient concentrations and total load may degrade the water resource. Excessive nutrient inputs from human activities upstream of coastal waterbodies, even hundreds of miles inland, can degrade the health of coastal ecosystems, especially estuaries[90]. The U.S. Environmental Protection Agency (USEPA) Scientific Advisory Board has stressed the importance of recognizing downstream impacts associated with excessive nutrients with respect to developing numeric nutrient concentration criteria for inland streams (USEPA, 2010, Worcester et al., 2010) – furthermore, downstream water quality must be protected in accordance with federal water quality standards regulations[91]. Numeric targets developed for inland surface streams should generally be applied to also minimize downstream impacts of nutrients in receiving waterbodies, which are exhibiting signs of eutrophication. In other words, tributary streams themselves may not exhibit detrimental water quality impacts associated with biostimulation, but because they may drain into a receiving waterbody that *is* showing signs of excessive biostimulation, the downstream effects of the tributaries should be considered.

For example, Furlong Creek, located in the Llagas Creek Watershed, does not appear to be currently exhibiting biostimulatory problems despite the fact that water column nutrient concentrations are quite high; for example dissolved oxygen balance in the creek to be generally within acceptable ranges. However Furlong is discharging its nutrient loads to receiving waters in Llagas Creek and the Pajaro River – some reaches of these downstream receiving waters do indeed show biostimulatory problems.

The Monterey Bay watersheds, which include the Pajaro River Basin, are noteworthy, in part, for being an area of California that drains directly to estuaries and ecologically sensitive coastal bay receiving waters (see Figure 3-83). Coastal estuaries, lagoons, and bays are ecologically sensitive areas that are especially prone to nutrient pollution loading from land activities and freshwater stream inputs. Pajaro River Basin streams ultimately drain into the Pajaro River-Watsonville Slough Estuary, and also periodically into Monterey Bay when the Pajaro River Estuary is open to ocean waters. As such, the Pajaro River-Watsonville Slough Estuary and Monterey Bay coastal waters represent the coastal confluence receiving waters for Pajaro River Basin streams. It is important to recognize that some of these downstream receiving waters are managed as sensitive ecological areas and accordingly have been designated as National Marine Protection Areas – specifically, the Monterey Bay National Marine Sanctuary (see Figure 3-84). The Monterey Bay National Marine has legally established goals and conservation objectives[92]. The Monterey Bay National Marine Sanctuary was established and is managed in part to sustain, conserve, and restore the protected area's natural biodiversity, populations, habitats, fisheries, and ecosystems. Local resource professionals and local agencies have indeed indicated that the Pajaro River's water quality is critical to the protection and sustainability of this offshore marine environment (Pajaro River Watershed Integrated Regional Water Management Plan, 2014). Also worth noting: the California Coastal Commission has identified the Pajaro River and Watsonville Slough coastal area as Critical Coastal Areas (CCA)[93].

[90] National Oceanic and Atmospheric Adminstration, "State of the Coast" webpage. Online linkage: http://stateofthecoast.noaa.gov/hypoxia/welcome.html

[91] 40 C.F.R. 131.10(b) states: *"In designating uses of a water body and the appropriate criteria for those uses, the state shall take into consideration the water quality standards of downstream waters and shall ensure that its water quality standards provide for the attainment and maintenance of the water quality standards of downstream waters."*

[92] See National Oceanic and Atmospheric Administration – National Marine Protected Areas website. Online linkage: http://marineprotectedareas.noaa.gov/

[93] Pursuant to the federal Coastal Zone Act Reauthorization Amendments of 1990, the state's Critical Coastal Areas (CCA) Program is a program to foster collaboration among local stakeholders and government agencies, to better coordinate resources and focus efforts on coastal waters in critical need of protection from polluted runoff.

As noted previously in Section 2.1, algal toxins resulting, in part, from nutrient-enriched inland streams of the Pajaro River Basin have resulted in deaths of the endangered California southern sea otters, according to recent findings by researchers. This further highlights the importance of recognizing that pollutant loads from freshwater sources within the Pajaro River Basin can discharge into coastal waterbodies which are formally recognized and managed as sensitive ecological receiving waters.

Figure 3-83. Hydrologic areas of California that drain directly to major coastal estuaries and bays.

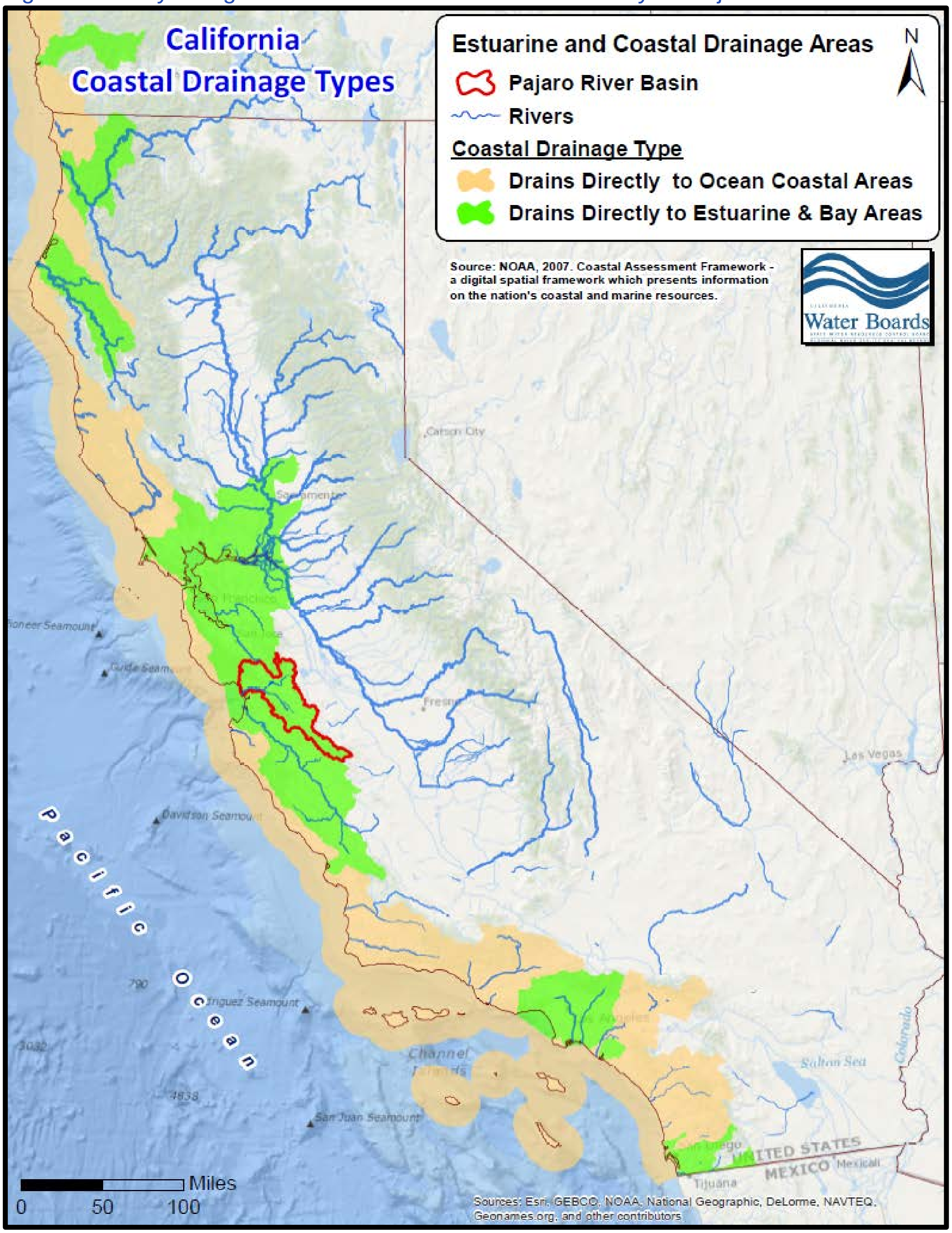
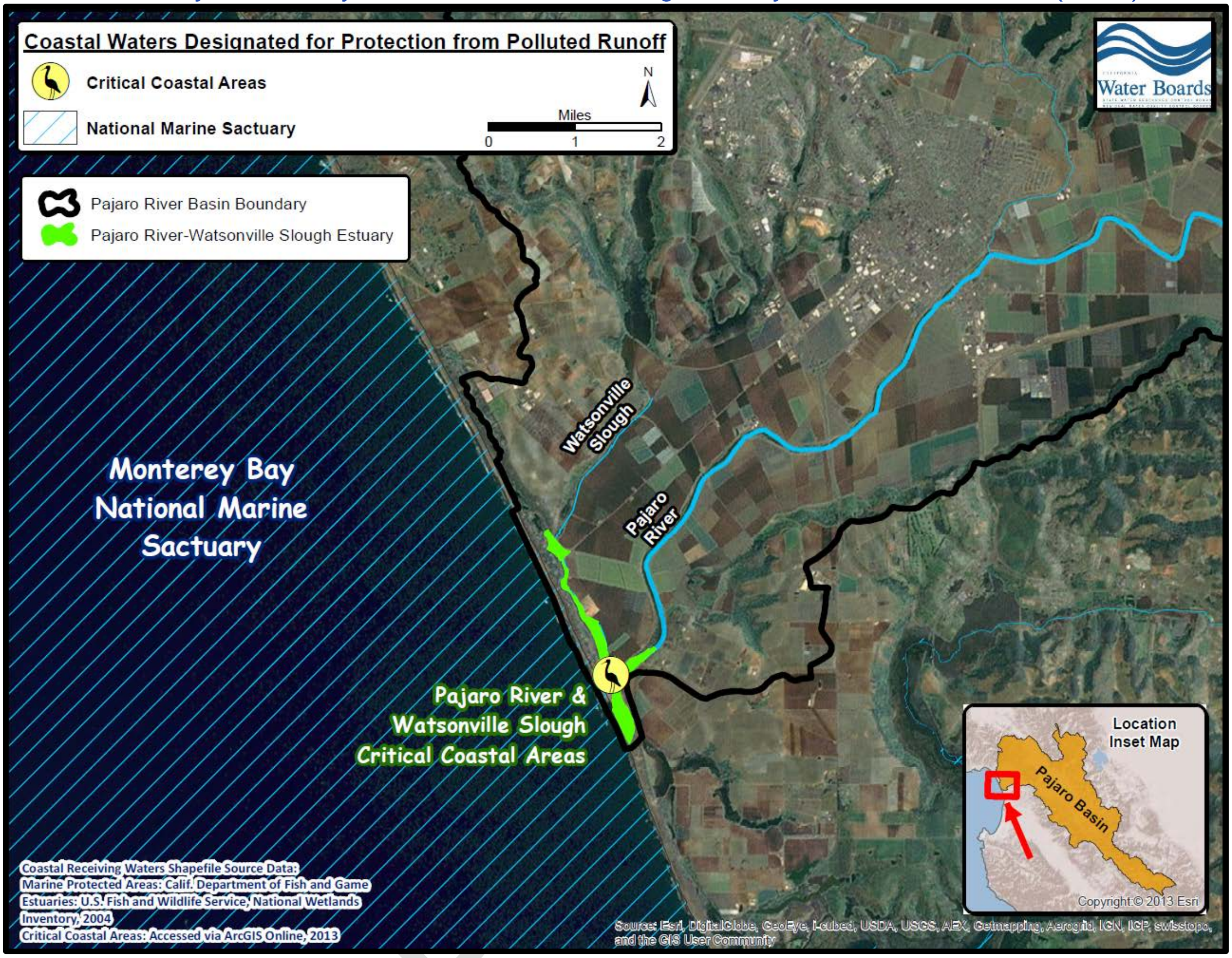


Figure 3-84. Coastal confluence receiving waters of the Pajaro River Basin: Monterey Bay National Marine Sanctuary and the Pajaro River-Watsonville Slough Estuary Critical Coastal Areas (CCAs).

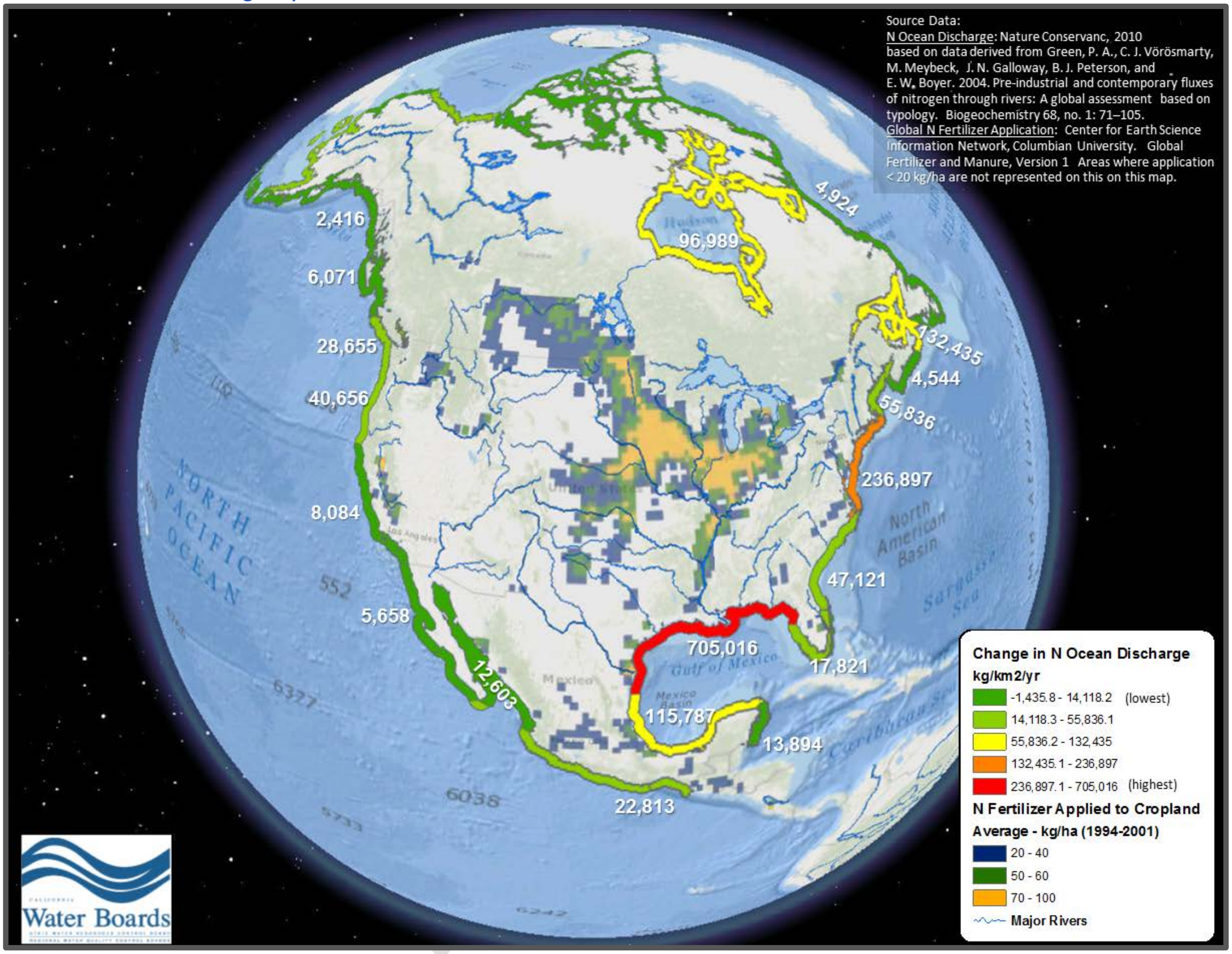


Indeed, nutrient impacts to coastal waters have been recognized as a significant national environmental problem. According to the U.S. Environmental Protection Agency, 78% of assessed coastal waters in the nation exhibit eutrophication[94]. However, according to data published by Green et al. (2004), it should be noted that at regional-scales, California's offshore marine coastal waters are relatively unimpacted by land-based nitrogen discharges as compared to other coastal areas of the United States (see Figure 3-85). For example, California coastal waters do not have nutrient-related problems even approaching the scale and severity of the Gulf of Mexico hypoxia zone (also known as the Gulf of Mexico "dead zone") which is caused by nutrient enrichment originating from the Mississippi River Basin[95].

[94] U.S. Environmental Protection Agency: Memorandum from Acting Assisstant Administrator Nancy K. Stoner. March 16, 2011. Subject: "Working in Partnership with States to Address Phosphorus and Nitrogen Pollution through Use of a Framework for State Nutrient Reductions".

[95] "Dead zones" are a common symptom of nutrient pollution. According to Dr. Bob Diaz of the Virginia Insittute of Marine Science, the number of "dead zones"—areas of seafloor with too little oxygen for most marine life—has increased by a third between 1995 and 2007. Dead zones are now a key stressor of marine ecosystems and rank with over-fishing, habitat loss, and harmful algal blooms as global environmental problems. See http://www.vims.edu/research/topics/dead_zones/

Figure 3-85. Globe view showing 1) estimated increase in discharges of nitrogen to coastal waters between pre-industrial times and contemporary times by marine ecoregion (units = kg nitrogen/km^2/year); and 2) estimated nitrogen fertilizer applied to cropland (where application >20 kg/ha), by grid cell (years 1994-2001, units = kg/ha).



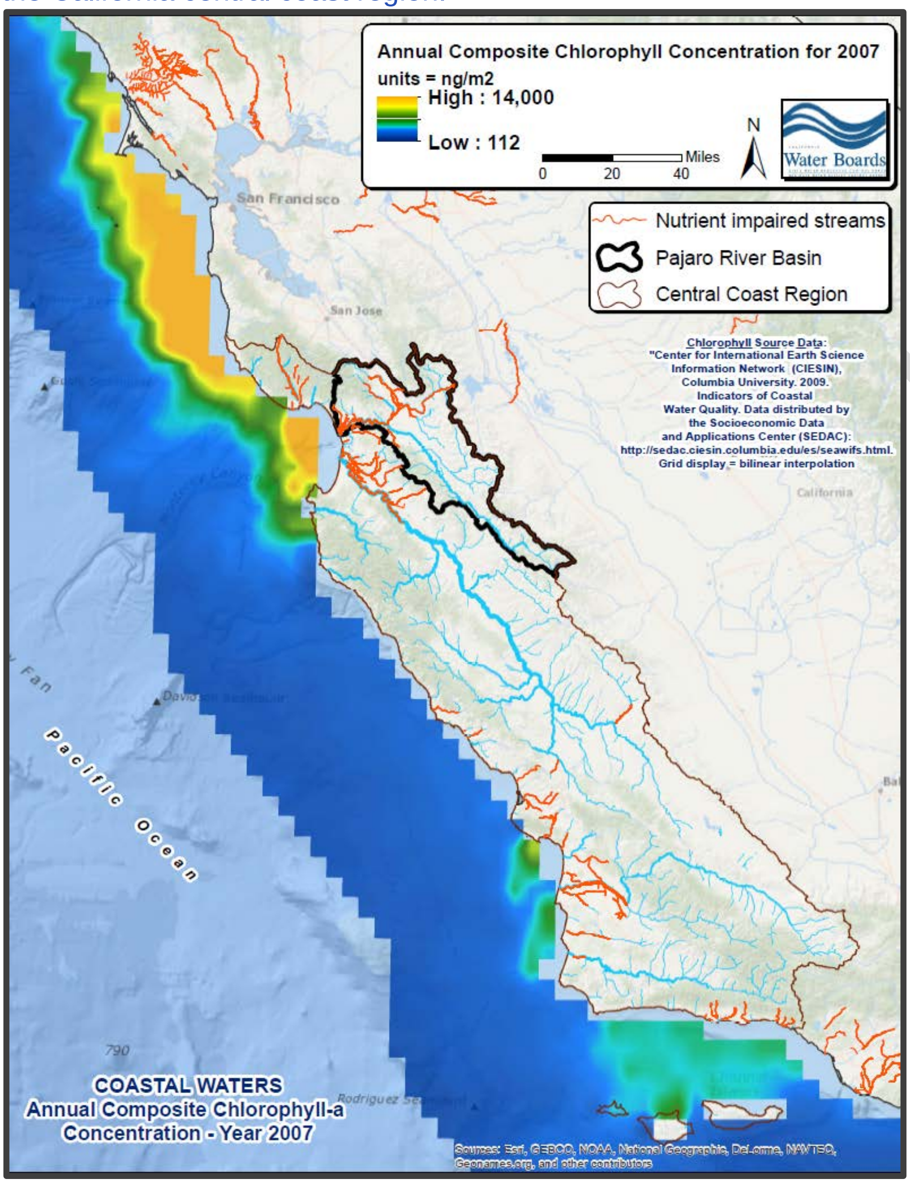
While California offshore coastal waters – at marine ecoregional scales – are generally in relatively good condition with respect to nutrient pollution, at more localized scales researchers have reported a number of problems in some near-shore coastal areas in the Monterey Bay National Marine Sanctuary. Some of these near shore coastal areas are characterized by elevated levels of nitrates, sediment, pesticides, and fecal bacteria which originate, in part, from freshwater sources such as runoff and inland streams of Monterey Bay watersheds (Monterey Bay National Marine Estuary–Sanctuary Integrated Monitoring Network website, accessed March, 2014). In addition, Lane et al. (2009) provided evidence that algal blooms in Monterey Bay may periodically result from sources of nitrogen associated with Pajaro River discharges. It should be noted however, that algal blooms in Monterey Bay may also be periodically caused by ocean basin upwelling processes which are unrelated to human activities.

Chlorophyll-a is a water quality parameter that is a proxy for measuring biomass and algae. Spatial data compiled and reported by the Goddard Space Flight Center and the Center for International Earth Science Information Network - CIESIN - Columbia University[96] illustrate trends of chlorophyll-a

[96] Goddard Space Flight Center - GSFC, and Center for International Earth Science Information Network - CIESIN - Columbia University. 2009. Indicators of Coastal Water Quality: Change in Chlorophyll-a Concentration 1998-2007. Palisades, NY:

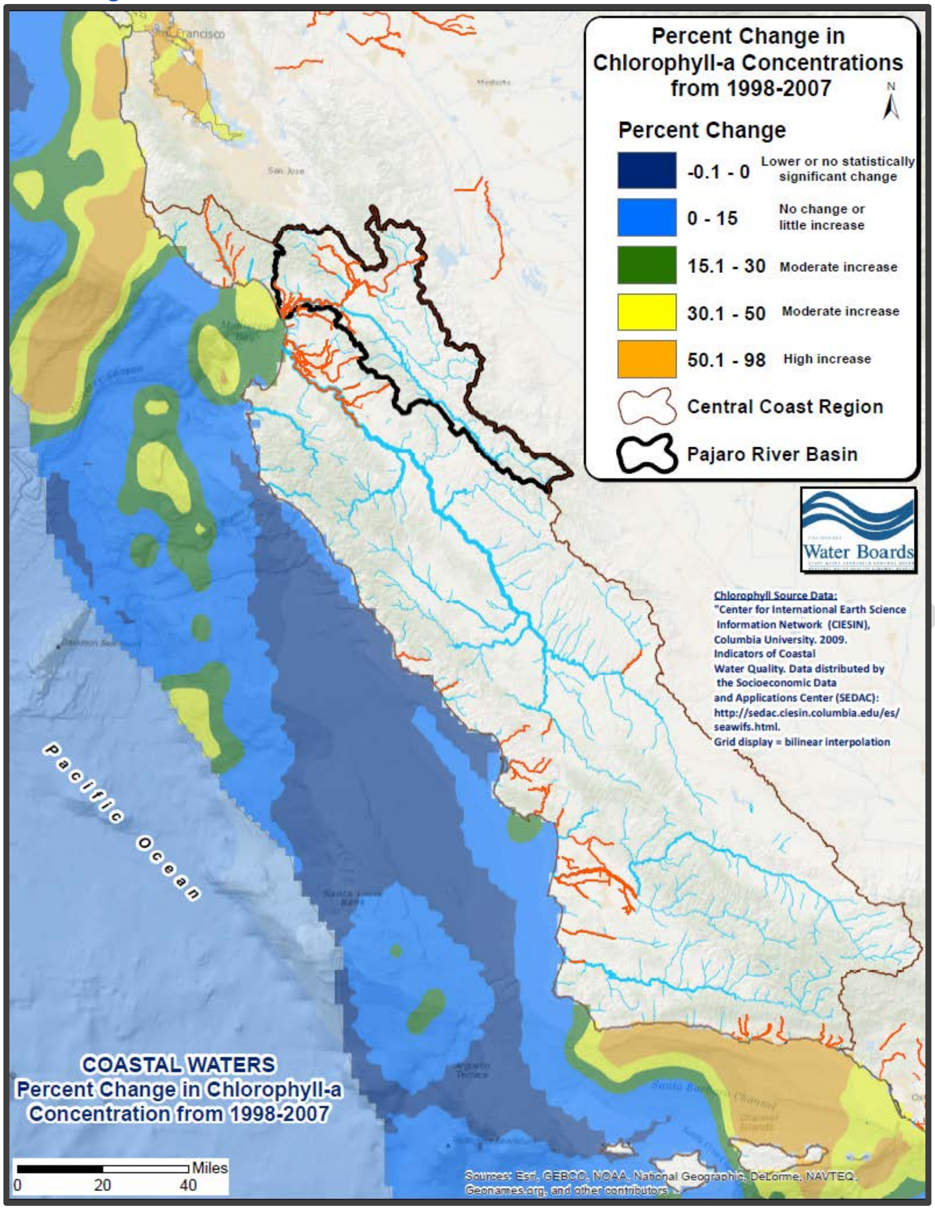
concentrations on a pixel-by-pixel basis. Annual composite chlorophyll-a concentrations in California central coastal waters for 2007 are shown in Figure 3-86. Trends in changing concentrations from 1999-2007 are shown in Figure 3-87; these data suggest statistically significant increases in chlorophyll-a concentrations from 1998-2007 locally in coastal waters of Monterey Bay and in the southern California coastal waters. It is important to recognize that statistical significance is a measure of the association between two variables, but does not prove causation. Chlorophyll-*a* concentration can be related to many factors besides nutrient loads; for example, the extent and persistence of cloud cover and solar radiation, or ocean upwelling processes which are not anthropogenic in nature.

Figure 3-86. Map illustrating estimated annual composite chlorophyll-a concetrations for the year 2007, in the California central coast region.



NASA Socioeconomic Data and Applications Center (SEDAC). http://sedac.ciesin.columbia.edu/data/set/icwq-change-in-chlorophyll-a-concentration-1998-2007.

Figure 3-87. Map highlighing coastal waters characterized by statistically significant change (% increase) in chlorophyll-a concentrations (green-yellow-orange shades), and coastal waters characterized by no statistically significant increases or little change (blue shades) between 1998 and 2007, California central coast region.



In summary due to reported river-based nutrient related water quality impacts in near-shore coastal areas of Monterey Bay, and impacts to the endangered southern sea otter originating from the Pajaro River Basin, this TMDL does consider and take into account biostimulatory impairments and downstream impacts to receiving coastal marine and estuarine waters.

4 WATER QUALITY STANDARDS

TMDLs are requirements pursuant to the federal Clean Water Act. The broad objective of the federal Clean Water Act is to "restore and maintain the chemical, physical and biological integrity of the Nation's waters[97]." Water quality standards are provisions of state and federal law intended to implement the

[97] Federal Water Pollution Control Act (33 U.S.C. 1251 et seq.) Title 1, Section 101.(a)

federal Clean Water Act. In accordance with state and federal law, California's water quality standards consist of:

- <u>Beneficial uses</u>, which refer to legally-designated uses of waters of the state that may be protected against water quality degradation (e.g., drinking water supply, recreation, aquatic habitat, agricultural supply, etc.)
- <u>Water quality objectives</u>, which refer to limits or levels (numeric or narrative) of water quality constituents or characteristics that provide for the reasonable protection of beneficial uses of waters of the state.
- <u>Anti-degradation policies</u>, which are implemented to maintain and protect existing water quality, and high quality waters.

Therefore, beneficial uses, water quality objectives, and anti-degradation policies collectively constitute water quality standards. Beneficial uses, relevant water quality objectives, and anti-degradation requirements that pertain to this TMDL are presented below in Section 4.1, Section 4.2, and Section 4.3 respectively.

4.1 Beneficial Uses

California's water quality standards designate beneficial uses for each waterbody (e.g., drinking water supply, aquatic life support, recreation, etc.) and the scientific criteria to support that use. The California Central Coast Water Board is required under both State and Federal Law to protect and regulate beneficial uses of waters of the state.

The Water Quality Control Plan for the Central Coastal Basin (Basin Plan – 2011 version) identifies beneficial uses for waterbodies of California's central coast region. Beneficial uses for surface waters in the Pajaro River Basin are presented in Table 4-1. The Basin Plan also states that surface water bodies within the region that do not have beneficial uses specifically designated for them are assigned the beneficial uses of "municipal and domestic water supply" and "protection of both recreation and aquatic life." The Water Board has interpreted this general statement of beneficial uses to encompass the beneficial uses of REC-1 and REC-2, MUN, along with all beneficial uses associated with aquatic life. The finding comports with the Clean Water Act's national interim goal of water quality [CWA Section 101(a)(2)] which provides for the protection and propagation of fish, shellfish and wildlife. As such, consistent with the Central Coast Basin Plan the Water Board has interpreted "aquatic life" as WARM, COLD, and SPWN for the 2008 impaired waterbody Clean Water Act 303(d) list. It should be noted that the COLD beneficial use may not be appropriate for all inland waterbodies which are not currently listed in the Basin Plan's Table 2-1. However, staff does not have the authority to unilaterally designate or de-designate beneficial uses within the context of a permit or in a project report. The State Water Resources Control Board (SWRCB) has indeed upheld that a basin plan amendment is the appropriate vehicle to de-designate beneficial uses(s) on a case-by-case basis (see for example, SWRCB, Order WQO 2002-0015). The Water Board could in the future conclude on a case-by-case basis that (for example) the COLD beneficial use does not apply to specific stream reaches that are not currently listed in Basin Plan Table 2-1 if stakeholders, resource professionals, and/or staff present evidence that the uses do not exist and are highly-improbable. Alternatively, changes to beneficial uses designations in the Basin Plan can occur during the triennial Basin Plan review process; stakeholders, interested parties, and the general public may participate and submit data for the triennial review.

Table 4-1. Central Coastal Basin Plan (June 2011 edition) designated beneficial uses for Pajaro River Basin surface water bodies.

Waterbody Names	MUN	AGR	IND	GWR	REC1	REC2	WILD	COLD	WARM	MIGR	SPWN	BIOL	RARE	EST	FRESH	NAV	COMM	SHELL
Corralitos Lagoon					X	X	X	X									X	
Palm Beach Pond	X				X	X	X		X				X				X	
Pinto Lake	X	X		X	X	X	X		X		X						X	

Waterbody Names	MUN	AGR	IND	GWR	REC1	REC2	WILD	COLD	WARM	MIGR	SPWN	BIOL	RARE	EST	FRESH	NAV	COMM	SHELL
Kelley Lake	X	X		X	X	X	X		X		X						X	
Drew Lake	X	X		X	X	X	X		X		X						X	
Tynan Lake	X	X		X	X	X	X		X		X						X	
Warner Lake	X	X		X		X	X										X	
Pajaro River Estuary					X	X	X	X	X	X	X	X	X	X			X	X
Pajaro River	X	X	X	X	X	X	X	X	X	X	X				X		X	
San Benito River	X	X	X	X	X	X	X		X		X				X		X	
Bird Creek	X	X		X	X	X	X		X			X					X	
Pescadero Creek (S. Benito)	X	X		X	X	X	X	X	X	X	X						X	
Tres Pinos Creek	X	X	X	X	X	X	X		X		X						X	
Hernandez Reservoir	X	X		X	X	X	X		X		X				X	X	X	
Tequisquita Slough				X	X	X	X		X		X						X	
San Felipe Lake	X	X		X	X	X	X	X	X	X					X	X	X	
Pacheco Creek	X	X		X	X	X	X	X	X	X	X	X	X		X		X	
Pacheco Lake	X	X		X	X	X	X	X	X		X		X		X	X	X	
Llagas Creek (above Chesbro Res.)	X	X		X	X	X	X	X	X				X		X		X	
Chesbro Reservoir	X	X		X	X	X	X		X	X	X		X		X	X	X	
Llagas Creek (below Chesbro Res.)	X	X	X	X	X	X	X	X	X	X	X		X				X	
Alamias Creek	X	X		X	X	X	X	X	X	X	X						X	
Live Oak Creek	X	X		X	X	X	X	X	X	X							X	
Little Llagas Creek	X	X		X	X	X	X		X								X	
Carnadero Creek	X			X	X	X	X	X	X	X			X				X	
Uvas Creek, downstream	X	X	X	X	X	X	X	X	X	X	X		X				X	
Uvas Res.	X	X		X	X	X	X		X		X		X		X	X	X	
Little Arthur Creek	X	X		X	X	X	X	X	X	X	X						X	
Bodfish Creek	X	X		X	X	X	X	X	X	X	X		X				X	
Black Hawk Canyon Creek	X				X	X	X		X	X	X		X				X	
Uvas Creek, upstream	X			X	X	X	X	X		X	X		X		X		X	
Little Uvas Creek	X	X		X	X	X	X		X								X	
Swanson Canyon Creek	X			X	X	X	X										X	
Alec Canyon Creek	X			X	X	X	X	X		X	X						X	
Croy Creek	X			X	X	X	X		X				X				X	
Eastman Canyon Creek	X	X		X	X	X	X		X								X	
Pescadero Creek	X	X		X	X	X	X	X		X	X	X					X	
Soda Lake						X	X		X				X				X	
Salsipuedes Creek	X	X		X	X	X	X	X		X	X						X	
Corralitos Creek	X	X	X	X	X	X	X	X	X	X	X						X	
Browns Creek	X	X	X	X	X	X	X	X	X	X	X						X	
Gamecock Creek	X			X	X	X	X	X		X	X						X	
Ramsey Gulch	X			X	X	X	X	X		X	X						X	
Redwood Creek	X				X	X	X	X		X	X						X	
Mormon Gulch	X			X	X	X	X	X									X	

Waterbody Names	MUN	AGR	IND	GWR	REC1	REC2	WILD	COLD	WARM	MIGR	SPWN	BIOL	RARE	EST	FRESH	NAV	COMM	SHELL
Clipper Gulch	X			X	X	X	X	X									X	
Cookhouse Gulch	X			X	X	X	X	X									X	
Shingle Mill Gulch	X			X	X	X	X	X		X	X						X	
Rattlesnake Gulch	X			X	X	X	X	X									X	
Diablo Gulch Creek	X			X	X	X	X	X									X	
Eureka Gulch	X			X	X	X	X	X									X	
Rider Gulch Creek	X			X	X	X	X	X		X	X						X	
Watsonville Slough					X	X	X		X		X	X	X	X			X	
Struve Slough					X	X	X		X		X	X	X	X			X	
Hanson Slough					X	X	X		X		X	X	X	X			X	
Harkins Slough					X	X	X		X		X	X	X	X			X	
Galligan Slough					X	X	X		X		X		X	X			X	

MUN: Municipal and domestic water supply.
AGR: Agricultural supply.
IND: Industrial service supply
GWR: Ground water recharge.
REC1: Water contact recreation.
REC2: Non-Contact water recreation.
WILD: Wildlife habitat.
COLD: Cold Fresh water habitat
WARM: Warm fresh water habitat
MIGR: Migration of aquatic organisms.
SPWN: Spawning, reproduction, and/or early development
BIOL: Preservation of biological habitats of special significance.
RARE: Rare, threatened, or endangered species
EST: Estuarine habitat
FRESH: Freshwater replenishment.
COMM: Commercial and sport fishing.
SHELL: Shellfish harvesting..

A narrative description of the designated beneficial uses of project area surface waters which are most likely to be potentially at risk of impairment by water column nutrients are presented below.

4.1.1 Municipal & Domestic Water Supply (MUN)

Uses of water for community, military, or individual water supply systems including, but not limited to, drinking water supply. According to State Board Resolution No. 88- 63, "Sources of Drinking Water Policy" all surface waters are considered suitable, or potentially suitable, for municipal or domestic water supply except under certain conditions (see Basin Plan, Chapter 2, Section II.)

The nitrate numeric water quality objective protective of the MUN beneficial use is legally established as 10 mg/L[98] nitrate as nitrogen (see Basin Plan, Table 3-2). This level is established to protect public health (refer back to Section 2.1 for a description of health risks related to nitrate).

4.1.2 Ground Water Recharge (GWR)

*Uses of water for natural or artificial recharge of ground water for purposes of future extraction, **maintenance of water quality**, or halting of saltwater intrusion into freshwater aquifers. Ground water recharge includes recharge of surface water underflow. (emphasis added) - (see Basin Plan, Chapter 2, Section II.)*

The groundwater recharge (GWR) beneficial use is recognition by the state of the fundamental nature of the hydrologic cycle, and that surface waters and ground water are not closed systems that act independently from each other. Underlying groundwaters are, in effect, receiving waters for stream waters that infiltrate and recharge the subsurface water resource. Most surface waters and ground waters of the central coast region are both designated with the MUN (drinking water) and AGR (agricultural supply) beneficial uses. The MUN nitrate water quality objective (10 mg/L) therefore applies to *both* the stream waters, and to the underlying groundwater. This numeric water quality objective and

[98] This value is equivalent to, and may be expressed as, 45 mg/L nitrate as NO3.

the MUN and AGR designations of underlying groundwater is relevant to the extent that portions project area streams recharge the underlying groundwater resource.

The Basin Plan GWR beneficial use explicitly states that the designated groundwater recharge use of surface waters are to be protected to maintain groundwater quality. Note that surface waters and ground waters are often in direct or indirect hydrologic communication. As such, where necessary, the GWR beneficial uses of the surface waters need to be protected so as to support and maintain the MUN or AGR beneficial use of the underlying ground water resource. Indeed, protection of the groundwater recharge beneficial use of surface waters has been recognized in State Water Board–approved California TMDLs[99]. The U.S. Environmental Protection Agency also recognizes the appropriateness of protecting designated groundwater recharge beneficial uses in the context of California TMDLs (USEPA 2002, USEPA 2003). The Basin Plan does not specifically identify numeric water quality objectives to implement the GWR beneficial use, however a situation-specific weight of evidence approach can be used to assess if GWR is being supported, consistent with Section 3.11 of the California Listing Policy (SWRCB, 2004). Section 5.2 of this project report presents data, lines of evidence, and assessments regarding whether or not project area designated GWR beneficial uses are currently being supported.

4.1.3 Agricultural Supply (AGR)

Uses of water for farming, horticulture, or ranching including, but not limited to, irrigation, stock watering, or support of vegetation for range grazing (see Basin Plan, Chapter 2, Section II.).

In accordance with the Basin Plan, interpretation of the amount of nitrate which adversely effects of the agricultural supply beneficial of waters of the State use shall be derived from the University of California Agricultural Extension Service guidelines, which are found in Basin Plan Table 3-3. Accordingly, severe problems for sensitive crops could occur for irrigation water exceeding 30 mg/L[100]. It should be noted that The University of California Agricultural Extension Service guideline values are flexible, and may not necessarily be appropriate due to local conditions or special conditions of crop, soil, and method of irrigation.

High concentrations of nitrates in irrigation water can potentially create problems for sensitive crops (e.g., grapes, avocado, citrus, sugar beets, apricots, almonds, cotton) by detrimentally impacting crop yield or quality. Nitrogen in the irrigation water acts the same as fertilizer nitrogen and excesses may cause problems just as fertilizer excesses cause problems[101]. For example, according to Ayers and Westcot (1985)[102] grapes are sensitive to high nitrate in irrigation water and may continue to grow late into the season at the expense of fruit production; yields are often reduced and grapes may be late in maturing and have a lower sugar content. Maturity of fruit such as apricot, citrus and avocado may also be delayed and the fruit may be poorer in quality, thus affecting the marketability and storage life. Excessive nitrogen can also trigger and favor the production of green tissue (leaves) over vegetative tissue in sensitive crops. In many grain crops, excess nitrogen may promote excessive vegetative growth producing weak stalks that cannot support the grain weight. According to the *Draft Conclusions of the*

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[99] for example, RWQCB-Los Angeles Region, Calluguas Creek Nitrogen Compounds TMDL, 2002. Resolution No. 02-017, and approved by the California Office of Administrative Law, OAL File No. 03-0519-02 SR; and RWQCB-Central Coast Region, TMDLs for Nitrogen Compounds and Orthophosphate in the Lower Salinas River and Reclamation Canal Basin and the Moro Cojo Slough Subwatershed, Resolution No. R3-2013-0008 and approved by the California Office of Administrative Law, OAL File No. 2014-0325-01S.

[100] The University of California Agricultural Extension Service guideline values are flexible, and may not necessarily be appropriate due to local conditions or special conditions of crop, soil, and method of irrigation. 30 mg/L nitrate-N is the recommended uppermost threshold concentration for nitrate in irrigation supply water as identified by the Univ. of Californnia Agricultural Extension Service which potentially cause severe problems for sensitive crops (see Table 3-3 in the Basin Plan). Selecting the.least stringent threshold (30 mg/L) therefore conservatively identifies exceedances which could detrimentally impact the AGR beneficial uses for irrigation water.

[101] 1 mg/L NO3-N in irrigation water = 2.72 pounds of nitrogen per acre foot of applied water.

[102] R.S. Ayers (Soil and Water Specialist, Univ. of Calif.-Davis) and D.W. Westcot (Senior Land and Water Resources Specialist – Calif. Central Valley Regional Water Quality Control Board) published in UN-FAO Irrigation and Drainage Paper 29 Rev.1

Agricultural Expert Panel (SWRCB, 2014), the yield and quality of cotton and almonds will suffer from excess nitrogen. These problems can usually be overcome by good fertilizer and irrigation management. However, regardless of the type of crop many resource professionals recommend that nitrate in the irrigation water should be credited toward the fertilizer rate[103] especially when the concentration exceeds 10 mg/L nitrate as N[104]. Should this be ignored, the resulting excess input of nitrogen could cause problems such as excessive vegetative growth and contamination of groundwater[105]. It should be noted that irrigation water that is high in nitrate does not necessarily mean that in contains enough nitrate to eliminate the need for additional nitrogen fertilizer; however, the grower may be able to reduce and replace the amount of fertilizer normally applied with the nitrate present in the irrigation water[106].

Further, the Basin Plan provides water quality objectives for nitrate which are protective of the AGR beneficial uses for livestock watering. While nitrate (NO3) itself is relatively non-toxic to livestock, ingested nitrate is broken down to nitrite (NO2$^-$); subsequently nitrite enters the bloodstream where it converts blood hemoglobin to methemoglobin. This greatly reduces the oxygen-carrying capacity of the blood, and the animal suffers from oxygen starvation of the tissues[107]. Death can occur when blood hemoglobin has fallen to one-third normal levels. Resource professionals[108] report that nitrate can reach dangerous levels for livestock in streams, ponds, or shallow wells that collect drainage from highly fertilized fields. Accordingly, the Basin Plan identifies the safe threshold of nitrate as N for purposes of livestock watering at 100 mg/L[109].

Also noteworthy is that the AGR beneficial use of surface water not only applies to several stream reaches of the project area, but can also apply to the groundwater resources underlying those stream reaches. The groundwater in some of these reaches is recharged by stream infiltration. Therefore, the groundwater recharge (GWR) beneficial use of stream reaches provides the nexus between protection of designated AGR beneficial uses of both the surface waters and the underlying groundwater resource (refer back to Section 4.1.2).

4.1.4 Aquatic Habitat (WARM, COLD, MIGR, SPWN, WILD, BIOL, RARE, EST)

WARM: Uses of water that support warm water ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates.

COLD: Uses of water that support cold water ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish or wildlife, including invertebrates.

MIGR: Uses of water that support habitats necessary for migration or other temporary activities by aquatic organisms, such as anadromous fish.

SPWN: Uses of water that support high quality aquatic habitats suitable for reproduction and early development of fish.

WILD: Uses of water that support terrestrial ecosystems including, but not limited to, preservation and enhancement of terrestrial habitats, vegetation, wildlife (e.g., mammals, birds, reptiles, amphibians, invertebrates), or wildlife water and food sources.

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[103] Crediting of irrigation source-water nitrogen may not be a 1:1 relationship as some irrigation water may not be retained entirely within the cropped area.

[104] Colorado State University Extension - Irrigation Water Quality Criteria. Authors: T.A. Bauder, Colorado State University Extension water quality specialist; R.M. Waskom, director, Colorado Water Institute; P.L. Sutherland, USDA/NRCS area resource conservationist; and J.G. Davis, Extension soils specialist and professor, soil and crop sciences

[105] University of Calif.-Davis, Farm Water Quality Planning Reference Sheet 9.10. Publication 8066. Author: S. R. Grattan, Plant-Water Relations Specialist, UC-Davis.

[106] Monterey County Water Resources Agency – Santa Clara Valley Water District, Fact Sheet 4. *Using the Nitrate Present in Soil and Water in Your Fertilizer Calculations.*

[107] New Mexico State University, Cooperative Exention Service. Nitrate Poisoning of Livestock. Guide B-807.

[108] University of Arkansas, Division of Agriculture - Cooperative Extension. "Nitrate Poisoning in Cattle". Publication FSA3024.

[109] 100 mg/L nitrate-N is the Basin Plan's water quality objective protective of livestock watering, and is based on National Academy of Sciences-National Academy of Engineering guidelines (see Table 3-3 in the Basin Plan).

BIOL: Uses of water that support designated areas or habitats, such as established refuges, parks, sanctuaries, ecological reserves, or Areas of Special Biological Significance (ASBS), where the preservation or enhancement of natural resources requires special protection.

RARE: Uses of water that support habitats necessary, at least in part, for the survival and successful maintenance of plant or animal species established under state or federal law as rare, threatened, or endangered.

EST: Uses of water that support estuarine ecosystems including, but not limited to, preservation or enhancement of estuarine habitats, vegetation, fish, shellfish, or wildlife (e.g., estuarine mammals, waterfowl, shorebirds). An estuary is generally described as a semi-enclosed body of water having a free connection with the open sea, at least part of the year and within which the seawater is diluted at least seasonally with fresh water drained from the land. Included are water bodies which would naturally fit the definition if not controlled by tidegates or other such devices.

The Basin Plan water quality objectives protective of aquatic habitat beneficial uses and which is most relevant to nutrient pollution[110] is the biosimulatory substances objective and dissolved oxygen objectives for aquatic habitat. The biostimulatory substances objective is a narrative water quality objective that states "*Waters shall not contain biostimulatory substances in concentrations that promote aquatic growths to the extent that such growths cause nuisance or adversely affect beneficial uses*."

The Basin Plan also requires that in waterbodies designated for WARM habitat dissolved oxygen concentrations shall not be depressed below 5 mg/L and that in waterbodies designated for COLD and SPWN dissolved oxygen shall not be depressed below 7 mg/L. Further, since unionized ammonia is highly toxic to aquatic species, the Basin Plan requires that the discharge of waste shall not cause concentrations of unionized ammonia (NH3) to exceed 0.025 mg/L (as n) in receiving waters.

4.1.5 Water Contact Recreation (REC-1)

REC-1: Uses of water for recreational activities involving body contact with water, where ingestion of water is reasonably possible. These uses include, but are not limited to, swimming, wading, water-skiing, skin and scuba diving, surfing, white water activities, fishing, or use of natural hot springs. (see Basin Plan, Chapter 2, Section II.).

The Basin Plan water quality objective protective of water contact recreation beneficial uses and which is most relevant to nutrient pollution is the general toxicity objective for all inland surface water, enclosed bays, and estuaries (Basin Plan Chapter 3, section II.A.2.a.). The general toxicity objective is a narrative water quality objective that states:

"All waters shall be maintained free of toxic substances in concentrations which are toxic to, or which produce detrimental physiological responses in, human, plant, animal, or aquatic life. Compliance with this objective will be determined by use of indicator organisms, analyses of species diversity, population density, growth anomalies, toxicity bioassays of appropriate duration, or other appropriate methods as specified by the Regional Board."

Because illnesses are considered detrimental physiological responses in humans, the narrative toxicity objective applies to algal toxins. Possible health effects of exposure to blue-green algae blooms and their toxins can include rashes, skin and eye irritation, allergic reactions, gastrointestinal upset, and other effects including poisoning (refer back to Section 2.1) Note that microcystins are toxins produced by cyanobacteria (blue-green algae) and are associated with algal blooms, elevated nutrients, and biostimulation in surface waterbodies. The State of California Office of Environmental Health Hazard Assessment (OEHHA) has published peer-reviewed public health action-level guidelines for algal cyanotoxins (microcystins) in recreational water uses; this public health action-level for microcystins is

[110] Nutrients, such as nitrate, do not by themselves necessarily directly impair aquatic habitat beneficial uses. Rather, they cause indirect impacts by promoting algal growth and low dissolved oxygen that impair aquatic habitat uses.

0.8 μg/L[111] (OEHHA, 2012). This public health action level can therefore be used to assess attainment or non-attainment of the Basin Plan's general toxicity objective and to ensure that REC-1 designated beneficial uses are being protected and supported.

4.2 Water Quality Objectives & Criteria

The Central Coast Region's Water Quality Control Plan (Basin Plan) contains specific water quality objectives that apply to nutrients and nutrient-related parameters. In addition, the Central Coast Water Board uses established, scientifically-defensible numeric criteria to implement narrative water quality objectives, and for use in Clean Water Act Section 303(d) Listing assessments. These water quality objectives and criteria are established to protect beneficial uses and are compiled in Table 4-2.

4.3 Anti-degradation Policy

In accordance with Section II.A. of the Basin Plan, wherever the existing quality of water is better than the quality of water established in the Basin Plan as objectives, **such existing quality shall be maintained** unless otherwise provided by provisions of the state anti-degradation policy. Practically speaking, this means that where water quality is *better* than necessary to support designated beneficial uses, such existing high water quality shall be maintained and further lowering of water quality is not allowed except under conditions provided for in the anti-degradation policy.

The U.S. Environmental Protection Agency has also issued detailed guidelines for implementation of federal anti-degradation regulations for surface waters (40 CFR 131.12). The State Water Resources Control Board has interpreted Resolution No. 68-16 (i.e., the state anti-degradation policy) to incorporate the federal anti-degradation policy in order to ensure consistency. It is important to note that federal policy only applies to surface waters, while state policy applies to both surface and ground waters.

Indeed, the U.S. Environmental Protection Agency recognizes the validity of using TMDLs as a tool for implementing anti-degradation goals:

> *"Identifying opportunities to protect waters that are not yet impaired: TMDLs are typically written for restoring impaired waters; however, states can prepare TMDLs geared towards maintaining a "better than water quality standard" condition for a given waterbody-pollutant combination, and they can be a useful tool for high quality waters."*
>
> From: USEPA, 2014. Opportunities to Protect Drinking Water Sources and Advance Watershed Goals Through the Clean Water Act: A Toolkit for State, Interstate, Tribal and Federal Water Program Managers. November 2014.

[111] Includes microcystins LR, RR, YR, and LA.

Table 4-2. Compilation of Basin Plan water quality objectives and numeric criteria for nutrients and nutrient-related parameters.

Constituent Parameter	Source of Water Quality Objective/Criteria	Numeric Target	Primary Use Protected
Unionized Ammonia as N	Basin Plan numeric objective	0.025 mg/L	General Objective for all Inland Surface Waters, Enclosed Bays, and Estuaries *(toxicity objective)*
Nitrate as N	Basin Plan numeric objective	10 mg/L	MUN, GWR (Municipal/Domestic Supply; Groundwater Recharge)
Nitrate as N	Basin Plan numeric criteria (Table 3-3 in Basin Plan)	5 – 30 mg/L *California Agricultural Extension Service guidelines*	AGR (Agricultural Supply – irrigation water) *"Severe" problems for sensitive crops at greater than 30 mg/L* *"Increasing problems" for sensitive crops at 5 to 30 mg/L*
Nitrate (NO3-N) plus Nitrite (NO2-N)	Basin Plan numeric objective (Table 3-4 in Basin Plan)	100 mg/L *National Academy of Sciences-National Academy of Engineers guidelines*	AGR (Agricultural Supply - livestock watering)
Nitrite (NO2_N)	Basin Plan numeric objective (Table 3-4 in Basin Plan)	10 mg/L *National Academy of Sciences-National Academy of Engineers guidelines*	AGR (Agricultural Supply - livestock watering)
Dissolved Oxygen	General Inland Surface Waters numeric objective	Dissolved Oxygen shall not be depressed below 5.0 mg/L Median values should not fall below 85% saturation.	General Objective for all Inland Surface Waters, Enclosed Bays, and Estuaries.
	Basin Plan numeric objective WARM, COLD, SPWN	Dissolved Oxygen shall not be depressed below 5.0 mg/L (WARM) Dissolved Oxygen shall not be depressed below 7.0 mg/L (COLD, SPWN)	Cold Freshwater Habitat, Warm Freshwater Habitat, Fish Spawning
	Basin Plan numeric objective AGR	Dissolved Oxygen shall not be depressed below 2.0 mg/L	AGR (Agricultural Supply)
pH	General Inland Surface Waters numeric objective	pH value shall not be depressed below 7.0 or raised above 8.5.	General Objective for all Inland Surface Waters, Enclosed Bays, and Estuaries.
	Basin Plan numeric objective MUN, AGR, REC1, REC-2	The pH value shall neither be depressed below 6.5 nor raised above 8.3.	Municipal/Domestic Supply, Agricultural Supply, Water Recreation
	Basin Plan numeric objective WARM, COLD	pH value shall not be depressed below 7.0 or raised above 8.5	Cold Freshwater Habitat, Warm freshwater habitat
Biostimulatory Substances	Basin Plan narrative objective[A]	see report Section **Error! Reference source not found.**	General Objective for all Inland Surface Waters, Enclosed Bays, and Estuaries *(biostimulatory substances objective)* -- (e.g., WARM, COLD, REC, WILD, EST)
Chlorophyll *a*	Basin Plan narrative objective[A]	40 µg/L *Source: North Carolina Administrative Code, Title 151, Subchapter 2B, Rule 0211*	Numeric listing criteria to implement the Basin Plan biostimulatory substances objective for purposes of Clean Water Act Section 303(d) Listing assessments.
Microcystins *(includes Microcytins LA, LR, RR, and YR)*	Basin Plan narrative objective[B]	0.8 µg/L *Calif. Office of Environmental Health Hazard Assessment Suggested Public Health Action Level*	REC-1 (water contact recreation)

[A] *The Basin Plan biostimulatory substances narrative objective states: "Waters shall not contain biostimulatory substances in concentrations that promote aquatic growths to the extent that such growths cause nuisance or adversely affect beneficial uses." (Biostimulatory Substances Objective, Basin Plan, Chapter 3)*

[B] *The Basin Plan toxicity narrative objective states: "All waters shall be maintained free of toxic substances in concentrations which are toxic to, or which produce detrimental physiological responses in, human, plant, animal, or aquatic life.." (Toxicity Objective, Basin Plan, Chapter 3)*

4.4 California CWA Section 303(d) Listing Policy

The Central Coast Water Board assesses water quality monitoring data for surface waters every two years to determine if they contain pollutants at levels that exceed protective water quality standards. In accordance with the Water Quality Control Policy for developing California's Clean Water Act (CWA) Section 303(d) List (SWRCB, 2004) – hereafter referred to as the *California Listing Policy* – water body and pollutants that exceed protective water quality standards are placed on the State's 303(d) List of impaired waters. The *California Listing Policy* also defines the minimum number of measured exceedances needed to place a water segment on the 303(d) list for toxicants (Listing Policy, Table 3.1) and for conventional or other pollutants (*California Listing Policy*, Table 3.2). The minimum number of measured exceedances for toxicants is displayed in Table 4-3 and for conventional and other pollutants in Table 4-4.

With regard to the water quality constituents addressed in this TMDL, it is important to note that nitrate and unionized ammonia are [112] considered a toxicants in accordance with the *California Listing Policy*, while low dissolved oxygen, chlorophyll a and pH, are conventional pollutants. Thus, impairments by nitrate and unionized ammonia are assessed on the basis of Table 4-3, while impairments by dissolved oxygen and chlorophyll a are assessed on the basis of Table 4-4.

Table 4-3. . Minimum number of measured exceedances needed to place a water segment on the 303(d) list for toxicants.

Sample Size	Number of Exceedances needed to assert impairment
2 – 24	2
25 – 36	3
37 – 47	4
48 – 59	5
60 – 71	6
72 – 82	7
83 – 94	8
95 – 106	9
107 – 117	10
118 – 129	11

For sample sizes greater than 129, the minimum number of measured exceedances is established where α and β < 0.2 and where |α - β| is minimized.
α = Excel® Function BINOMDIST(n-k, n, 1 – 0.03, TRUE)
β = Excel® Function BINOMDIST(k-1, n, 0.18, TRUE)
where n = the number of samples,
k = minimum number of measured exceedances to place a water on the section 303(d) list,

[112] See Section 7 Definitions-Toxicants in *Water Quality Control Policy for Developing California's Clean Water Act Section 303(d) List*, SWRCB (2004).

Table 4-4. Minimum number of measured exceedances needed to place a water segment on the 303(d) list for conventional and other pollutants.

Sample Size	Number of Exceedances needed to assert impairment
5-30	5
31-36	6
37-42	7
43-48	8
49-54	9
55-60	10
61-66	11
67-72	12
73-78	13
79-84	14
85-91	15
92-97	16
98-103	17
104-109	18
110-115	19
116-121	20

For sample sizes greater than 121, the minimum number of measured exceedances is established where α and β < 0.2 and where |α - β| is minimized.
α = Excel® Function BINOMDIST(n-k, n, 1 – 0.10, TRUE)
β = Excel® Function BINOMDIST(k-1, n, 0.25, TRUE)
where n = the number of samples,
k = minimum number of measured exceedances to place a water segment on section 303(d) list

4.4.1 CWA Section 303(d) Listings in Pajaro River Basin

The final 2010 303(d) List and 303(d)/305(b) Integrated Report for the Central Coast showing waterbodies with nutrient or potential nutrient-related impairments in the Pajaro River Basin are shown in Table 4-5.

Table 4-5. 303(d) listed waterbodies.

WATER BODY NAME	WBID	ESTIMATED SIZE AFFECTED	UNIT	POLLUTANT
Beach Road Ditch	CAR3051003020080603123839	0.8	Miles	Low Dissolved Oxygen
Beach Road Ditch	CAR3051003020080603123839	0.8	Miles	Nitrate
Carnadero Creek	CAR3053002019990223155037	1.8	Miles	Low Dissolved Oxygen
Carnadero Creek	CAR3053002019990223155037	1.8	Miles	Nitrate
Furlong Creek	CAR3053002019990222111932	8.5	Miles	Nitrate
Harkins Slough	CAR3051001320080603122917	7.3	Miles	Chlorophyll-a
Harkins Slough	CAR3051001320080603122917	7.3	Miles	Low Dissolved Oxygen
Llagas Creek (below Chesbro Reservoir)	CAR3053002020020319075726	16	Miles	Low Dissolved Oxygen
Llagas Creek (below Chesbro Reservoir)	CAR3053002020020319075726	16	Miles	Nutrients
McGowan Ditch	CAR3051003020100620223644	2.6	Miles	Nitrate
Millers Canal	CAR3053002020080603171000	2.1	Miles	Chlorophyll-a

WATER BODY NAME	WBID	ESTIMATED SIZE AFFECTED	UNIT	POLLUTANT
Millers Canal	CAR3053002020080603171000	2.1	Miles	Low Dissolved Oxygen
Pacheco Creek	CAR3053002020020103133745	25	Miles	Low Dissolved Oxygen
Pajaro River	CAR3051003019980826115152	32	Miles	Low Dissolved Oxygen
Pajaro River	CAR3051003019980826115152	32	Miles	Nitrate
Pajaro River	CAR3051003019980826115152	32	Miles	Nutrients
Pinto Lake	CAL3051003020020124122807	115	Acres	Chlorophyll-a
Pinto Lake	CAL3051003020020124122807	115	Acres	Low Dissolved Oxygen
Salsipuedes Creek (Santa Cruz County)	CAR3051003020080603123522	2.6	Miles	Low Dissolved Oxygen
San Juan Creek (San Benito County)	CAR3052005020090204001958	7.3	Miles	Low Dissolved Oxygen
San Juan Creek (San Benito County)	CAR3052005020090204001958	7.3	Miles	Nitrate
Struve Slough	CAR3051003020080603125227	2.8	Miles	Low Dissolved Oxygen
Tequisquita Slough	CAR3053002020011121091332	7.2	Miles	Low Dissolved Oxygen
Uvas Creek (below Uvas Reservoir)	CAR3052002120080603163208	7.8	Miles	Low Dissolved Oxygen
Watsonville Creek	CAR3051003020080603171443	5.1	Miles	Low Dissolved Oxygen
Watsonville Creek	CAR3051003020080603171443	5.1	Miles	Nitrate
Watsonville Slough	CAR3051003019981209150043	6.2	Miles	Low Dissolved Oxygen

- pH 303(d) Listings

303(d)-listed pH impairments have been identified for some streams of the Pajaro River Basin. It should be noted that while water column pH impairments can sometimes result from biostimulation in any given watershed, staff are not addressing the pH 303(d) listings for streams in the Pajaro River Basin in this TMDL. Our reasoning is as follows:

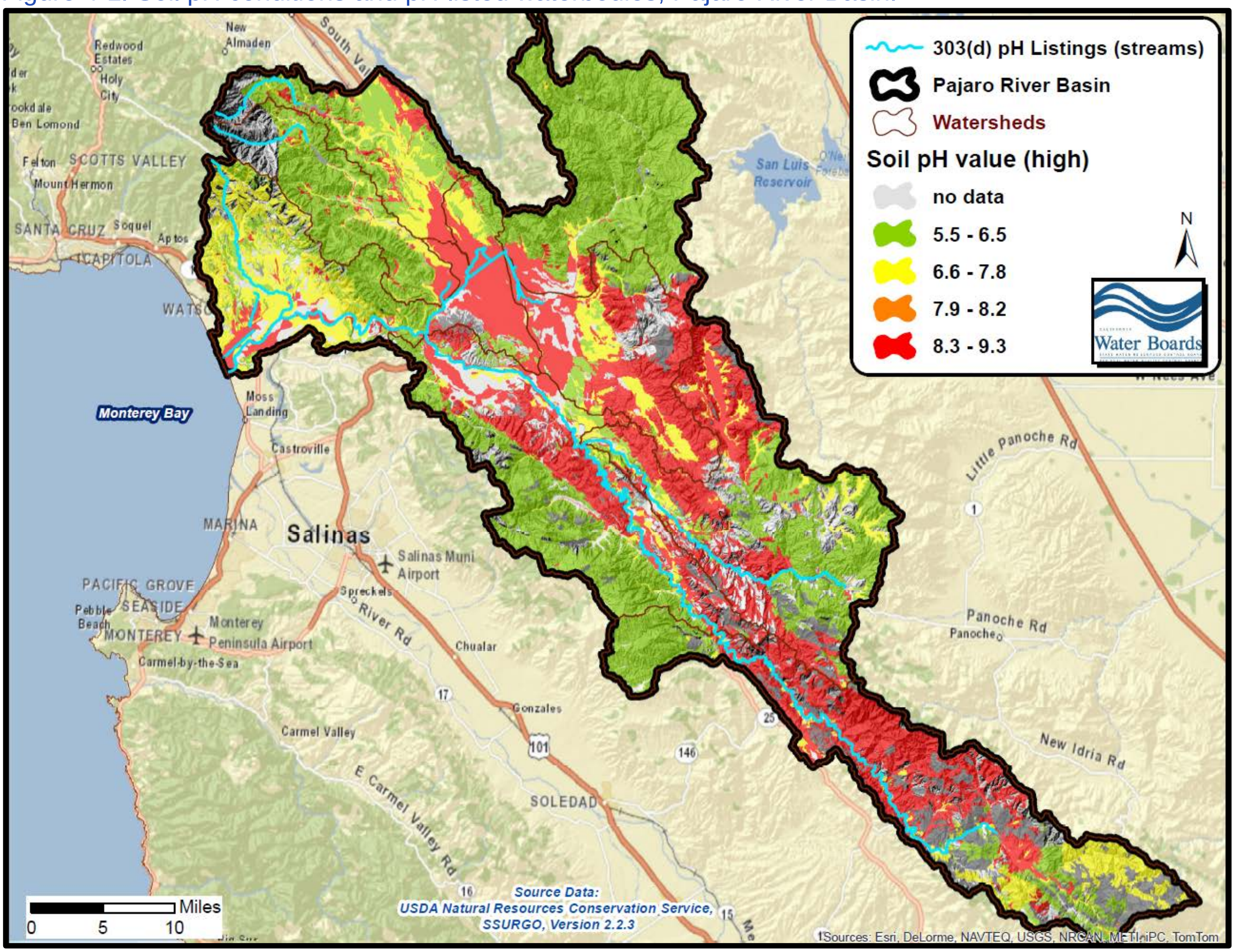
1) The California Nutrient Numeric Endpoints (NNE) approach recommends that a pH value of 9.0 (for cold water aquatic habitat beneficial uses) or a pH of 9.5 (for warm water aquatic habitat beneficial uses) represent the pH numeric endpoints which are indicative of a presumptive photosynthesis-driven pH impairment[113]. These numeric endpoints are well over the Central Coast Basin Plan's water quality pH objective of 8.3 (drinking and agricultural supply beneficial uses). Only 0.02% of pH samples in the TMDL project area exceed 9.5 pH (sample size = 1,149). Further, only 2.2% of samples exceed 9.0 pH. As such, based on California NNE guidance the current pH-based impairments in the project area cannot credibly be attributed to biostimulatory impairments.
2) In some areas of the Pajaro River Basin, ambient soil conditions are quite alkaline. Locally, some soils range up to 9.3 pH units. A soil pH map of the Pajaro River Basin is presented in Figure 4-1 Climatic conditions, geology, plants, and physical surroundings can influence soil pH. In temperate climates that support dense forests, soils tend to be acidic, with pH ranging between 4.0 and 5.5. North American Midwest grasslands tend to have slightly acidic soils (pH 6.0 to 6.5), while in contrast alkaline soils (pH greater than 7.0) are often associated with arid regions characterized by high water evaporation rates (Pleasant, 2014). Local geologic conditions can also influence soil pH independent of climate; for example, alkaline soils are known to develop on limestone bedrock, irrespective of climatic conditions. Climatically, the Pajaro River Basin is an arid Mediterranean climate and locally the river basin has relatively high rates of evapotranspiration (refer back to Section 3.7 and Figure 3-25), thus these climatic conditions locally can promote formation of alkaline soils. Also worth noting, historic natural alkali meadows existed in the southern Santa Clara

[113] See Table 3-2 in Tetra Tech (2006): Technical Approach to Develop Nutrient Numeric Endpoints for California (July 2006, prepared for USEPA Region IX, Contract No. 68-C-02-108-To-111).

Valley (refer back to Figure 3-7), thus high pH water quality may have naturally prevailed in waterbodies of this area. In addition, 303(d) pH listings on upper Uvas and upper Llagas creeks occur in upland areas of the river basin which are relatively lightly-disturbed by humans, suggesting a natural cause for these pH impairments. It should be recognized that the upper Uvas Creek and upper Llagas Creek subwatersheds[114] are characterized in large part by mafic to ultramafic rocks (basalt, peridotite, serpentinite) – refer back to the geologic map in Figure 3-54; these rock types are known to promote the formation of high pH (alkaline) soils[115].

On the basis of the aforementioned information, staff hypothesizes that natural conditions – such as alkaline soils, geology, and/or climatic conditions – cause or contribute to 303(d)-listed pH impairments in the Pajaro River Basin. These conditions would thus be unrelated to water column photosynthesis and biostimulation. Therefore, at this time staff recommends that Pajaro River Basin stream pH 303(d)-listings be addressed through a separate TMDL process or a future water quality standards action.

Figure 4-1. Soil pH conditions and pH-listed waterbodies, Pajaro River Basin.



114 A map of subwatersheds was previously presented in Figure 3-5.

115 For example: Stanford University Department of Geology, Geology 299 field class, field blog entitled *"Ultramafics in the Field".* Ultramafic rocks, such as peridotite, are noted to be associated with highly alkaline soils. Online linkage: http://web.stanford.edu/group/warrenlab/cgi-bin/wordpress/

5 PRELIMINARY WATER QUALITY DATA ANALYSIS

The data used for this Project included water quality data from the Central Coast Ambient Monitoring Program (CCAMP) and several other entities shown below. CCAMP is the Central Coast Water Board's regionally-scaled water quality monitoring and assessment program. The Water Board's CCAMP data is collected by the Board's in-house staff consisting of trained field scientists and technicians who adhere to the sampling and reporting protocols consistent with the State's Surface Water Ambient Monitoring Program (SWAMP). SWAMP is a state framework for coordinating consistent and scientifically defensible methods and strategies for water quality monitoring, assessment, and reporting. Substantial amounts of water quality data for the Pajaro River basin are also available from the Cooperative Monitoring Program of Central Coast Water Quality Preservation, Inc. (CCWQP). CCWQP also periodically publishes reports with information that pertains to nutrient pollution (for example, CCWQP, 2010).

During TMDL development, staff conducted further data quality control and data filtering. These included 1) filtering the data to extract only grab samples and field measurements (thus excluding field blanks and duplicates); 2) converting nutrient data reported in compound molecular reporting conventions to the elemental reporting convention (e.g., converting nitrate molecular (NO_3) concentration values to nitrate as elemental nitrogen (N) values); 3) quantifying censored data[116] by using a simple substitution method and setting the censored data equal to half the method detection limit (MDL)[117]. For samples where an MDL was not reported, staff set the non-detects equal to half the median MDL that was reported for that 4) eliminating suspicious or low-quality data (data having inadequate, dubious or indeterminate documentation or reporting) and when we could not make clarifications to said data with the assistance of the data provider, we eliminated them so as not to introduce suspect data into our final dataset; 5) combining and averaging the water quality data from monitoring sites which were in close proximity to each other (<200 meters), on the same stream reach, and when there was no compelling reason to treat them, for TMDL purposes, as individual, discrete monitoring sites[118]; consistent with guidance published in the *California Listing Policy* (SWRCB, 2004); and 6) combining sample results collected on the same date and from the same monitoring site[119], and representing these results with a single resultant value consistent with guidance published in the *California Listing Policy* (SWRCB 2004).

5.1 Preface: Nitrogen and Phosphorus Analytical Reporting Convention

Water quality data using different analytical reporting conventions can result in confusion, and even scientists and regulators have to practice diligence to avoid mixing-up and conflating nitrate

[116] Censored data are non-quantified measurements of constituents that are reported as less than the detection limit, because the sample constituent exists in a concentration lower than can reliably be detected and reported by the laboratory.

[117] Simple substitution methods, such as setting censored data equal to half the method detection limit for the constituent, is a method widely used in the environmental sciences (see, for example: U.S. Geological Survey, Data Series 152, *Water-Quality, Streamflow, and Ancillary Data for Nutrients in Streams and Rivers Across the Nation, 1992-2001;* also see *Alley (editor), 1993, Regional Water Quality Data).* It should be noted that for datasets characterized by large amounts or ratios of censored data, simplistic substitution methods introduce bias to statistical procedures. Large ratios of censored data (non-detects) are particularly common during water quality investigations involving trace elements and synthetic organic compounds.

[118] The California Listing Policy section 6.1.5.2 states: *"Samples collected within 200 meters of each other should be considered samples from the same station or location."* It should be recognized that TMDLs are watershed studies which endeavor to identify waterbody impairments at the stream reach scale. Typically, a monitoring program consisting of high-resolution, fine-scale monitoring – such as discrete monitoring locations upgradient and downgradient of a pipe or culvert – is more appropriate for field-scale or implementation studies.

[119] The California Listing Policy section 6.1.5.6 states: *"for data that is not temporally independent (e.g., when multiple samples are collected at a single location on the same day), the measurements shall be combined and represented by a single resultant value*." In these cases, Central Coast Water Board staff used an arithmetic mean of the sample results to represent a single resultant value; however, for dissolved oxygen the minimum value reported was used to represent a single resultant value consistent with the guidance in California Listing Policy section 6.1.5.6.

concentrations which are reported in different conventions. Mixing up and conflating analytical nitrate reporting conventions can result in apples-to-oranges comparisons. Nitrate concentration values are commonly reported as either molecular nitrate (NO_3), or as nitrate as elemental nitrogen (i.e., NO_3-N or nitrate as N). Note that the maximum contaminant level (MCL) in drinking water as molecular nitrate (NO_3) is 45 mg/L, whereas this MCL when reported as elemental nitrogen (NO_3-N) is 10 mg/L. While these two nitrate numeric values would appear to represent different concentrations, these concentration values are in fact actually equivalent to each other − the only difference being whether or not the molecular weight of the oxygen atoms in the nitrate molecule is included in the analytical reporting. Table 5-1 illustrates the difference between the two analytical reporting conventions.

National and USEPA water quality standards, water quality modeling tools, most scientific literature, and most TMDLs use the elemental nitrogen reporting convention (i.e., written as either nitrate as nitrogen; NO3-N; or nitrate as N). Likewise, this TMDL project report uses the elemental nitrogen convention (i.e., nitrate as N).

Table 5-1. Illustration of EQUIVALENT nitrate concentrations in two different analytical reporting conventions.

Nitrate reporting convention used by most California Public Water Districts & Agencies	multiply nitrate as NO_3 by: $\left(\frac{14 \text{ gram/mole N}}{62 \text{ gram/mole } NO_3}\right)$ to convert to nitrate as N	Nitrate reporting convention used by U.S. Environmental Protection Agency, U.S. Geological Survey, in most scientific literature, and in this TMDL progress report
Nitrate as NO_3 (mg/L)	**Reporting Equivalent as nitrogen (N) >>>>**	**Nitrate as N (mg/L)**
44.3*****	☞	10
22.1	☞	5
11.1	☞	2.5
4.4	☞	1
2.2	☞	0.5

***** In California, the drinking water standard for nitrate as NO3 is established to two significant figures, and is 45 mg/l

Similarly, in this TMDL project ammonia is reported as elemental nitrogen (e.g., un-ionized ammonia as nitrogen – NH_3-N), and phosphate is reported as elemental phosphorus (e.g., orthophosphate as phosphorus – PO_4-P).

Also worth noting, is that most nitrogen analytical measurements include and report nitrate (NO_3) plus nitrite (NO_2), but because concentrations of nitrite (NO_2) are typically insignificant relative to nitrate, this mixture is simply called “nitrate” in this TMDL progress report, and in most regulatory contexts.

5.2 Water Quality Data Sources and Monitoring Sites

The water quality data used for this TMDL project included data from several sources are presented in Table 5-2. Many sources of stream quality data are available for the Pajaro River basin; Central Coast Water Board staff also invited interested parties to voluntarily submit their water quality data, should they choose to do so in support of TMDL development. Consequently, additional water quality data was kindly provided to Central Coast Water Board staff by the Pajaro Valley Water Management Agency and the City of Watsonville.

Table 5-2. Stream and river water quality monitoring data used in this TMDL progress report.

Monitoring Entity/Program	Number of Monitoring Sites	Temporal Representation	Geographic Range of Stream Water Quality Monitoring
Central Coast Water Board – Central Coast Ambient Monitoring Program (CCAMP)	41	Dec. 1997 to Sept. 2013	Pajaro River basin (Basin-wide)
Central Coast Water Quality Preservation, Inc. – Cooperative Monitoring Program	18	Jan. 2006 to Dec. 2013	Focusing on agricultural valley floor reaches of the Pajaro Valley, southern Santa Clara Valley and the San Juan Valley
City of Watsonville	2	May 2009 to July 2013	Pajaro River @ Watsonville
U.S. Environmental Protection Agency – Environmental Monitoring & Assessment Program	5	June 2001 to June 2003	Uvas Creek Watershed, Pacheco Creek Watershed, and Salsipuedes Creek Subwatershed, with a primary focus on upland reaches and headwater tributary reaches
Monterey Bay National Marine Sanctuary Monitoring Programs	19	Jan. 2002 to May 2006	Lower Pajaro River Subwatershed, Watsonville Slough Subwatershed, and Corralitos Creek Subwatershed
University of California, Davis Marine Pollution Studies Laboratory at Granite Canyon	5	Jan. 2008 to Oct. 2009	Lower Pajaro River Valley with a focus on estuarine reaches of the lower Pajaro River-Watsonville Slough area
Pajaro Valley Water Management Agency	22	Dec. 2002 to Dec. 2013	Pajaro Valley, including lower Pajaro River, Watsonville Slough, Corralitos Creek, and Salsipuedes Creek subwatersheds.
University of California Santa Cruz Grant Study and Dr. Marc Los Huertos monitoring data	62	Oct. 2000 to March 2007	Pajaro River basin (Basin-wide)
County of Santa Cruz Environmental Health Services	4	March 1999 to May 2006	Corralitos Creek and the lower Pajaro River
Lion's Gate Limited Partnership – Cordevalle Golf Club	4	April 1997 to June 2013	West Branch, Llagas Creek focusing on creek water quality within a golf course.
U.S. Environmental Protection Agency Storage and Retrieval (STORET) Dataset	49	Dec. 1951 to Dec. 1994	Pajaro River basin (Basin-wide, older legacy data)
State Water Resources Control Board, Surface Water Ambient Monitoring Program – data from the Perennial Stream Survey & the Statewide Reference Condition Management Plan	8	June 2008 to June 2010	Pajaro River, Llagas Creek, and headwater tributary reaches of the Uvas Creek Subwatershed and the Upper San Benito River Watershed
U.S. Geological Survey – National Water Information System data	16	May 1952 to July 2011	Pajaro River basin (Basin-wide with a primary focus on legacy data)

Monitoring Entity/Program	Number of Monitoring Sites	Temporal Representation	Geographic Range of Stream Water Quality Monitoring
Coastal Watershed Council	15	May 2001 to May 2010	Surface waters of the Watsonville Slough Subwatershed and Corralitos Creek
San Jose State University and Merrit Smith Consulting Grant Data – Contract Number 0-212-253-0	7	June 1992 to July 1993	Llagas Creek Watershed and the upper Pajaro River legacy data
Julie Renee Casagrande Master's Theses –San Jose State Univ. *"Aquatic Ecology of San Felipe Lake, San Benito County, CA" (2010)*	2 *stream sites*	May 2005 to Nov. 2006	Pacheco Creek and Tequisquita Slough at confluence with San Felipe Lake

Figure 5-1 illustrates the location of the Pajaro River basin stream water quality monitoring sites used in this report. Due to the size of the river basin, and the large number of stream monitoring sites, more-legible and higher resolution illustrations of the stream monitoring sites are presented in Figure 5-2, Figure 5-3 and Figure 5-4.

Figure 5-1. Pajaro River basin stream and river water quality monitoring locations used in this TMDL progress report.

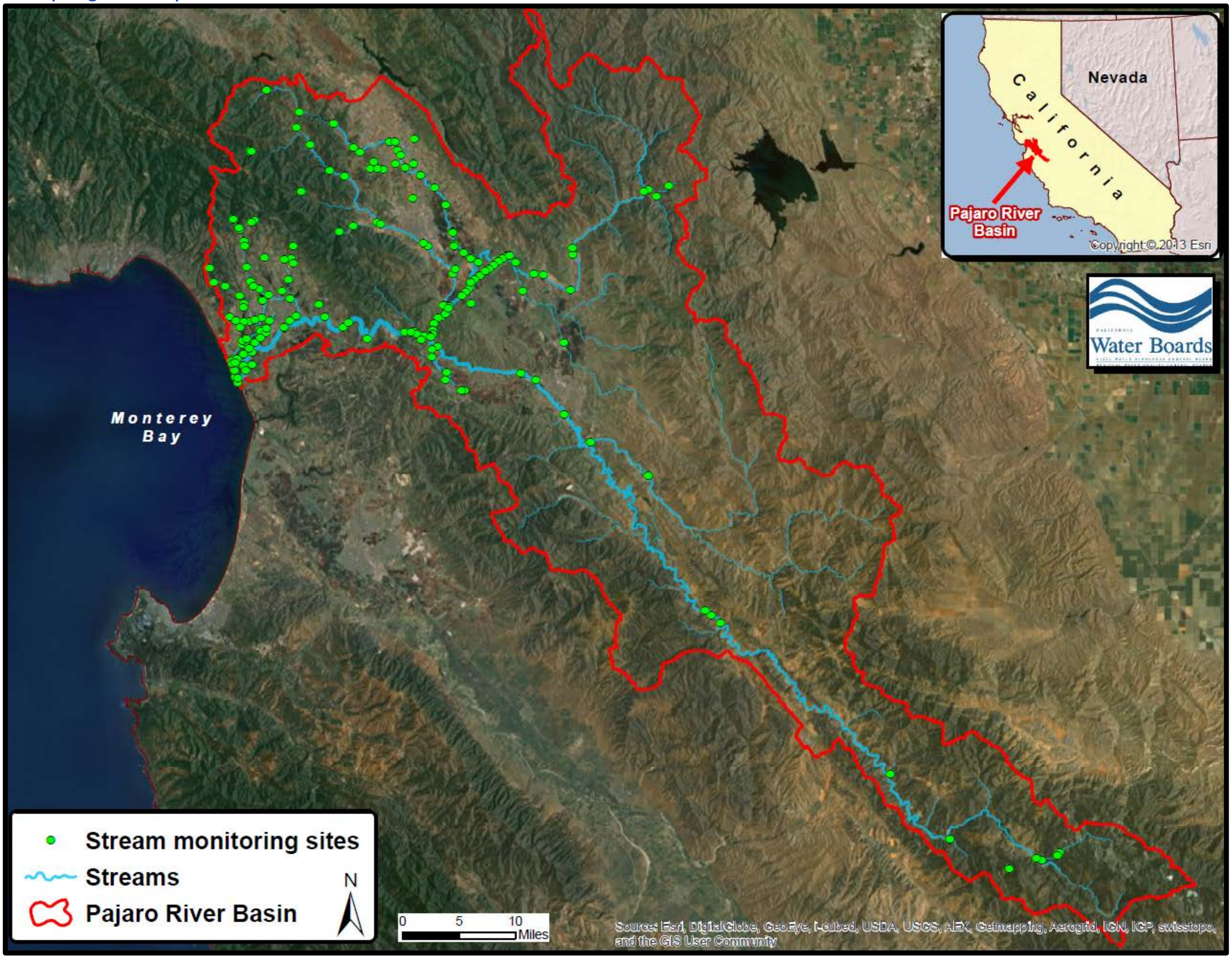


Figure 5-2. Stream and river water quality monitoring locations in the Pajaro Valley area, including sites in the lower Pajaro River Subwatershed, the Watsonville Slough Subwatershed, the Corralitos Creek Subwatershed, and the Salsipuedes Creek Subwatershed – Santa Cruz and Monterey counties.

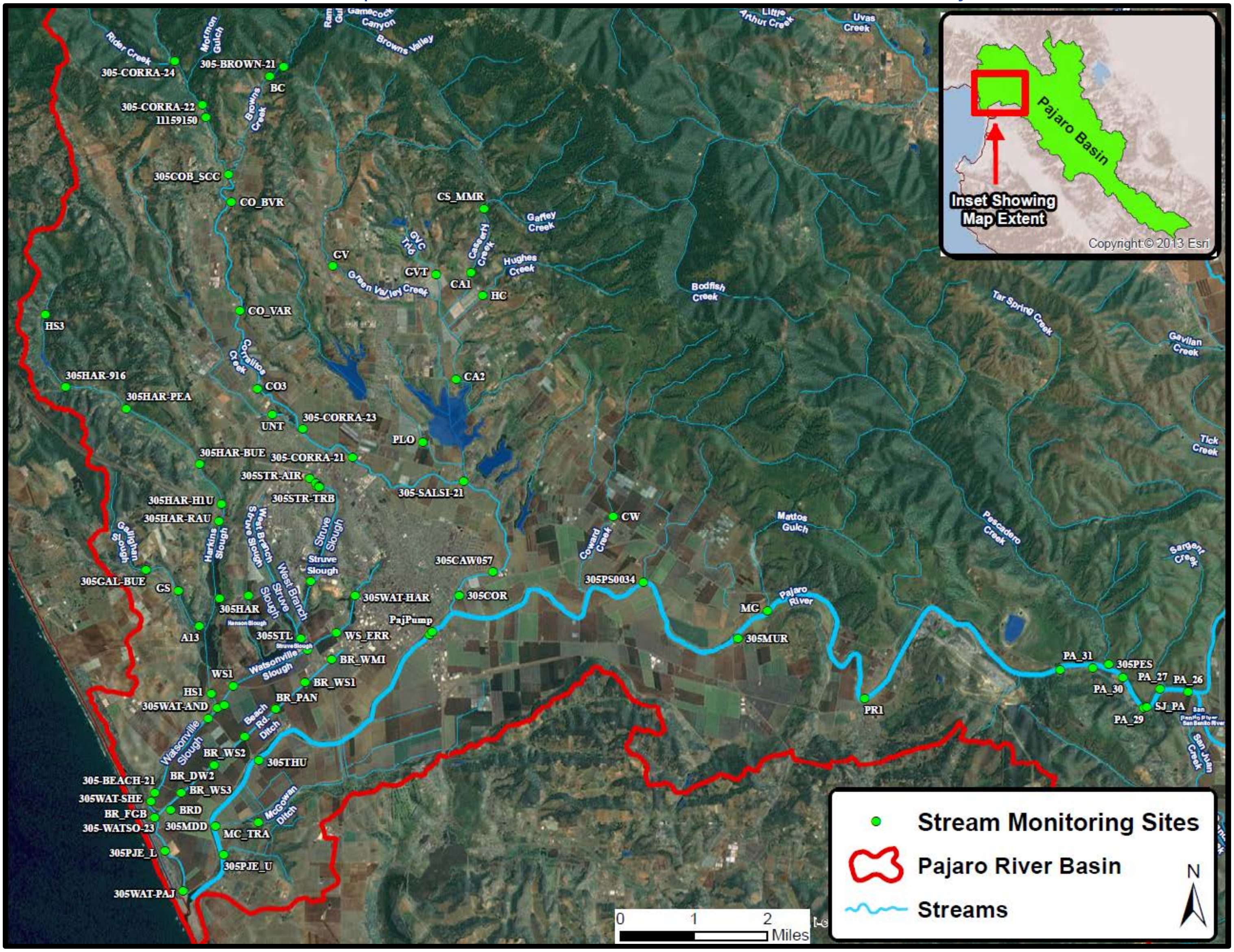


Figure 5-3. Stream and river water quality monitoring locations in the southern Santa Clara Valley area and San Juan Valley area, including sites in the upper Pajaro River Watershed, the Lllagas Creek Watershed, the Uvas Creek Watershed, the Pacheco Creek Watershed, and the Lower San Benito River Watershed – Santa Clara and San Benito counties.

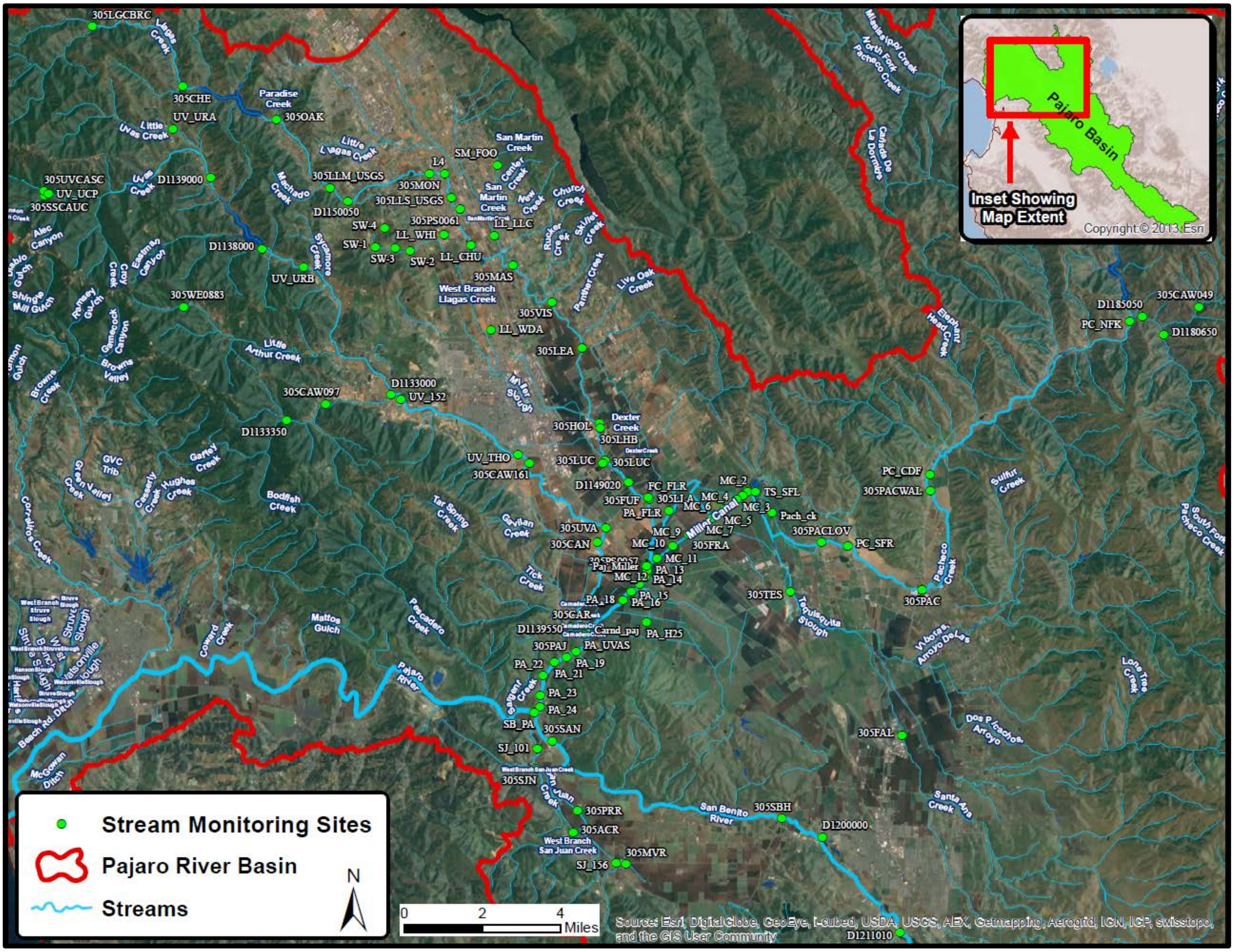
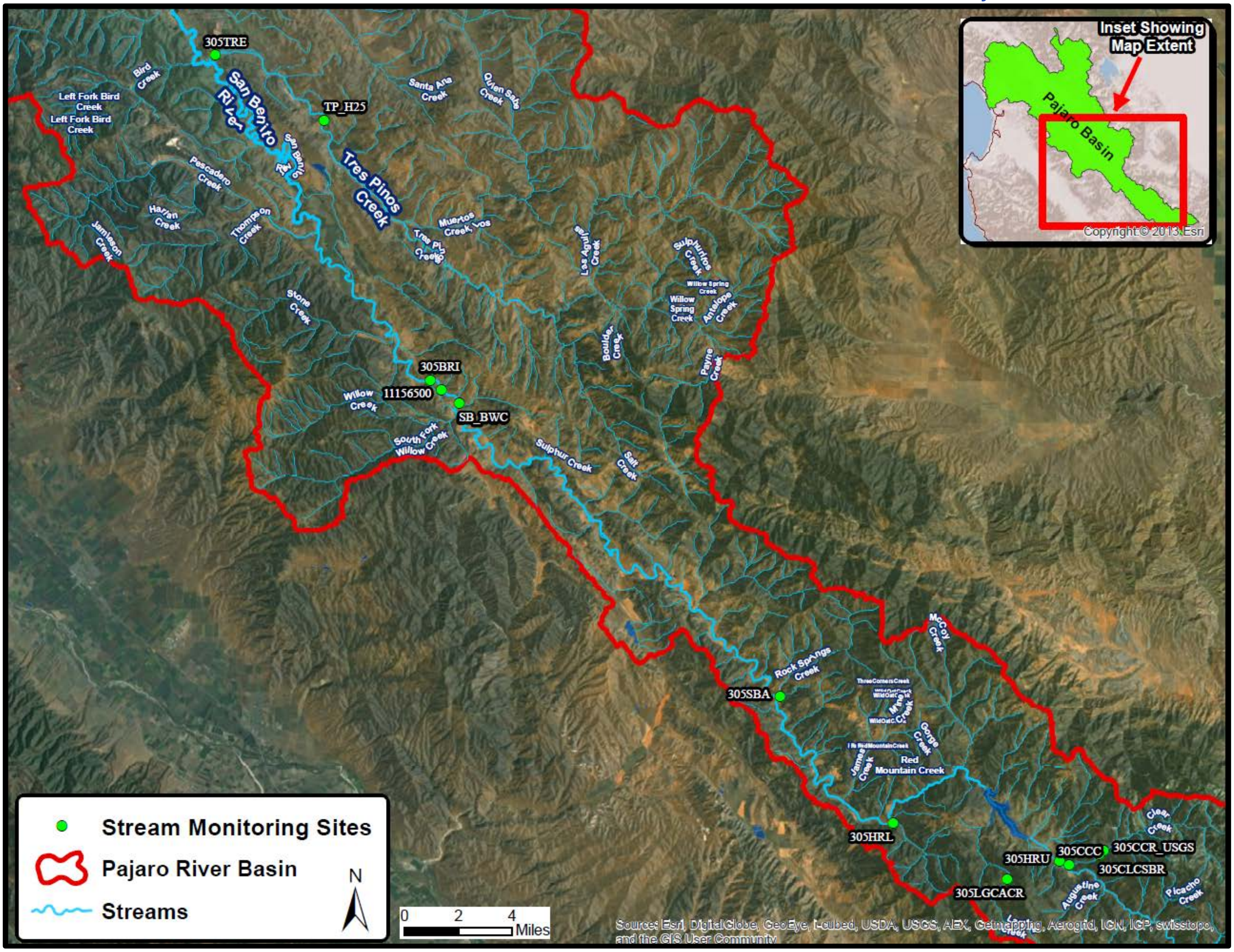


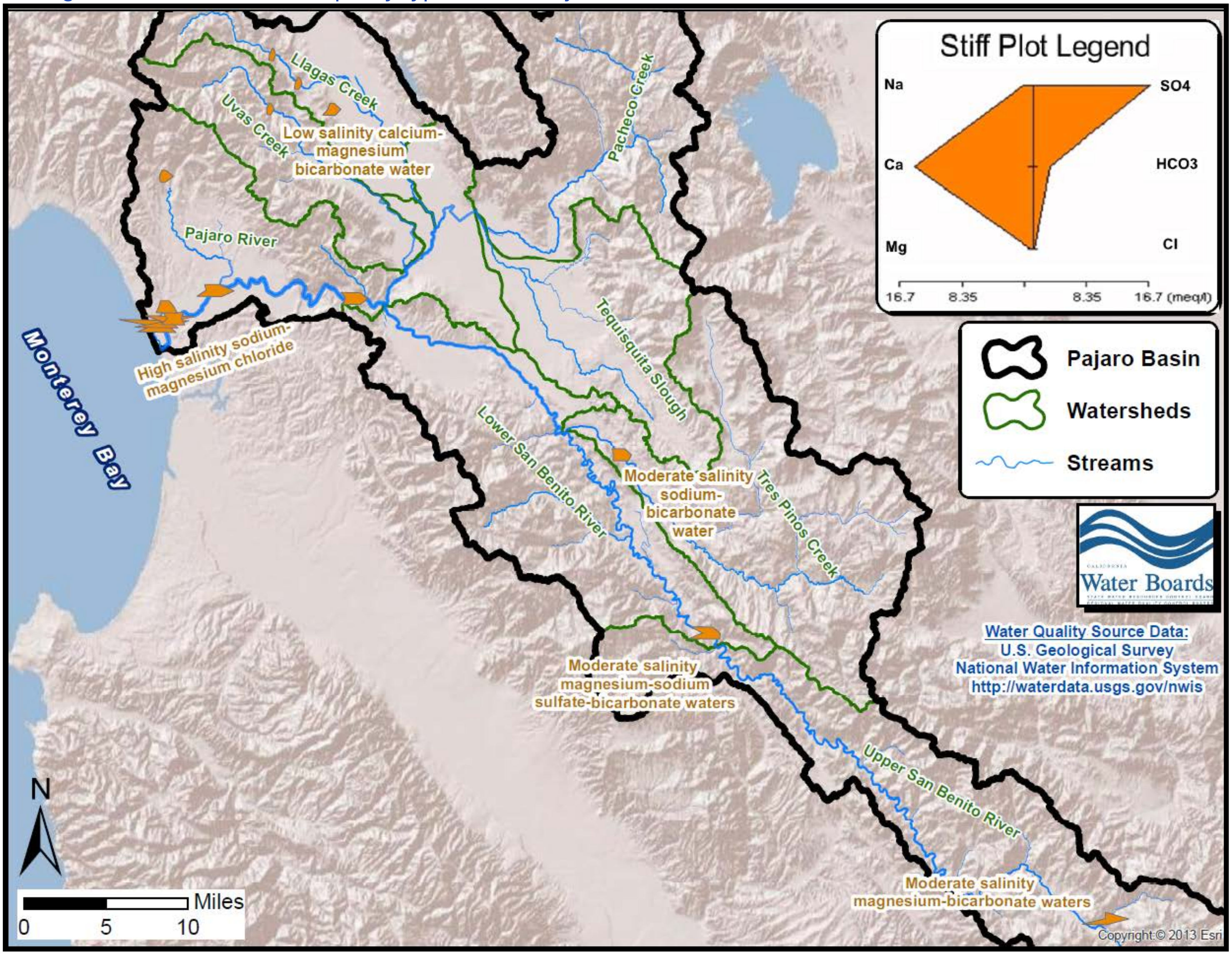
Figure 5-4. Stream and river water quality monitoring locations from the middle and upper reaches of the San Benito River Watershed and the Tres Pinos Creek Watershed – San Benito County.



5.3 General Water Quality Types in Streams of the Pajaro River Basin

U.S. Environmental Protection Agency guidance on development of water quality criteria for biostimulatory substances, such as nitrate, recommend that these criteria be developed taking into account spatial, physical, hydraulic, and chemical variation in streams within any given region or basin. Figure 5-5 illustrates generalized variations in water quality types in streams of the Pajaro River basin on the basis of general minerals and Stiff diagrams. Stiff diagrams are a representation of general minerals and electrical conductivity. Much of the data represented here are from pre-1990 sampling events, so these should be considered historical, or baseline conditions in the river basin.

Figure 5-5. General water quality types in the Pajaro River basin on the basis of Stiff Plots.



Surface water quality in the upper San Benito and Tres Pinos watersheds can be characterized as moderate salinity, magnesium-bicarbonate waters ($Mg\text{-}HCO_3$) or sodium bicarbonate–sulfate ($Na\text{-}HCO_3\text{-}SO_4$) waters. Surface water quality in the Llagas, Uvas, and Upper Corralitos Creek watersheds, draining the Santa Cruz Mountains, can be generally characterized as lower salinity, magnesium-bicarbonate ($Mg\text{-}HCO_3$) or calcium-bicarbonate waters ($Ca\text{-}HCO_3$). The lower reaches of the river basin, which includes the Pajaro River, can be characterized as higher salinity sodium–magnesium bicarbonate–sulfate waters ($Na\text{-}Mg\ HCO_3\text{-}SO_4$). Limited data from agricultural ditches in the lowermost reaches of the river basin, near Watsonville, were characterized by higher salinity sodium chloride waters (Na-Cl).

5.4 Water Quality Spatial Trends

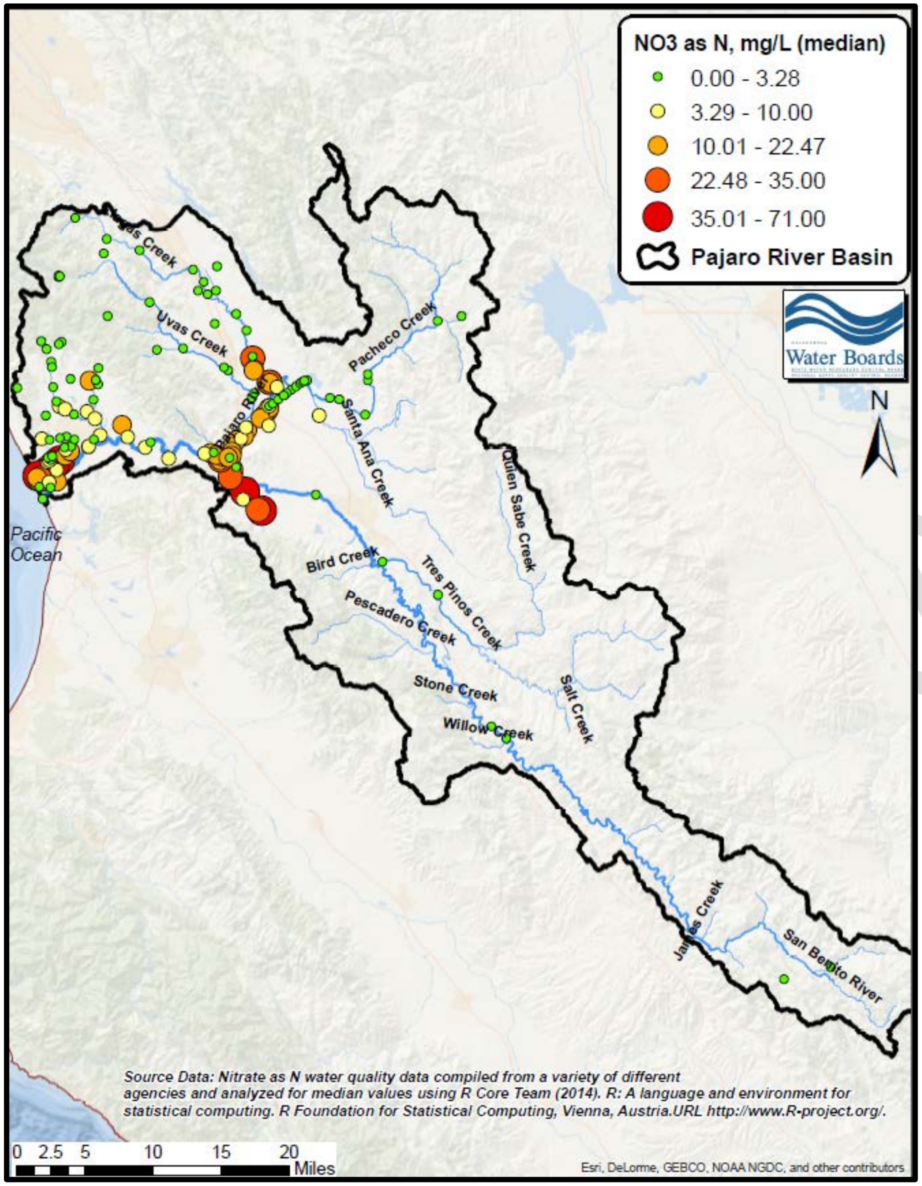
Figure 5-6 through Figure 5-14 illustrate spatial variations[120] and statistical distributions[121] of nitrate (as N) and orthophosphate (as P) concentrations at stream monitoring sites throughout the Pajaro River basin.

As indicated by the spatial and statistical distributions shown in the figures, elevated nutrient concentrations are most characteristic of the valley-floor areas of the northern Pajaro River basin – specifically in stream reaches associated with the lower Pajaro River subwatershed, the Watsonville Slough subwatershed, the Upper Pajaro River subwatershed, the lower Llagas Creek subwatershed, and the San Juan Canyon subwatershed. Additionally, as shown in Figure 5-6 and Figure 5-7, lowlands of the valley floor reaches of the Pajaro Valley and Santa Clara Valley are expected to have a higher intensity of nitrogen and phosphorus inputs from human activities (primarily fertilizer inputs) relative to the rest of the river basin more broadly.

[120] The spatial datasets illustrating estimated nitrogen and phosphorus land inputs of fertilizer and mansure were created and used by the U.S. Geological Survey (U.S. GEOLOGICAL SURVEY) specifically to estimate nitrogen and phosphorus inputs from manure and fertilizer per watershed segment in the application of the national SPAtially Referenced Regression On Watershed attributes (SPARROW) model. Citation: *Attributes for NHDPlus Catchments (Version 1.1) for the Conterminous United States: Nutrient Inputs from Fertilizer and Manure, Nitrogen and Phosphorus (N&P) 2002. U.S. Geological Survey.*

[121] Statistical distributions can be represented as box plots, as illustrated in this section of the report. For those unfamiliar with the nature and utility of box plots please refer to: http://en.wikipedia.org/wiki/Box_plot

Figure 5-6. (A) Surface water NO_3 as N (median concentration values – mg/L); and (B) estimated total nitrogen inputs (kg/hectare - year 2002) from fertilizer and compost, Pajaro River basin.



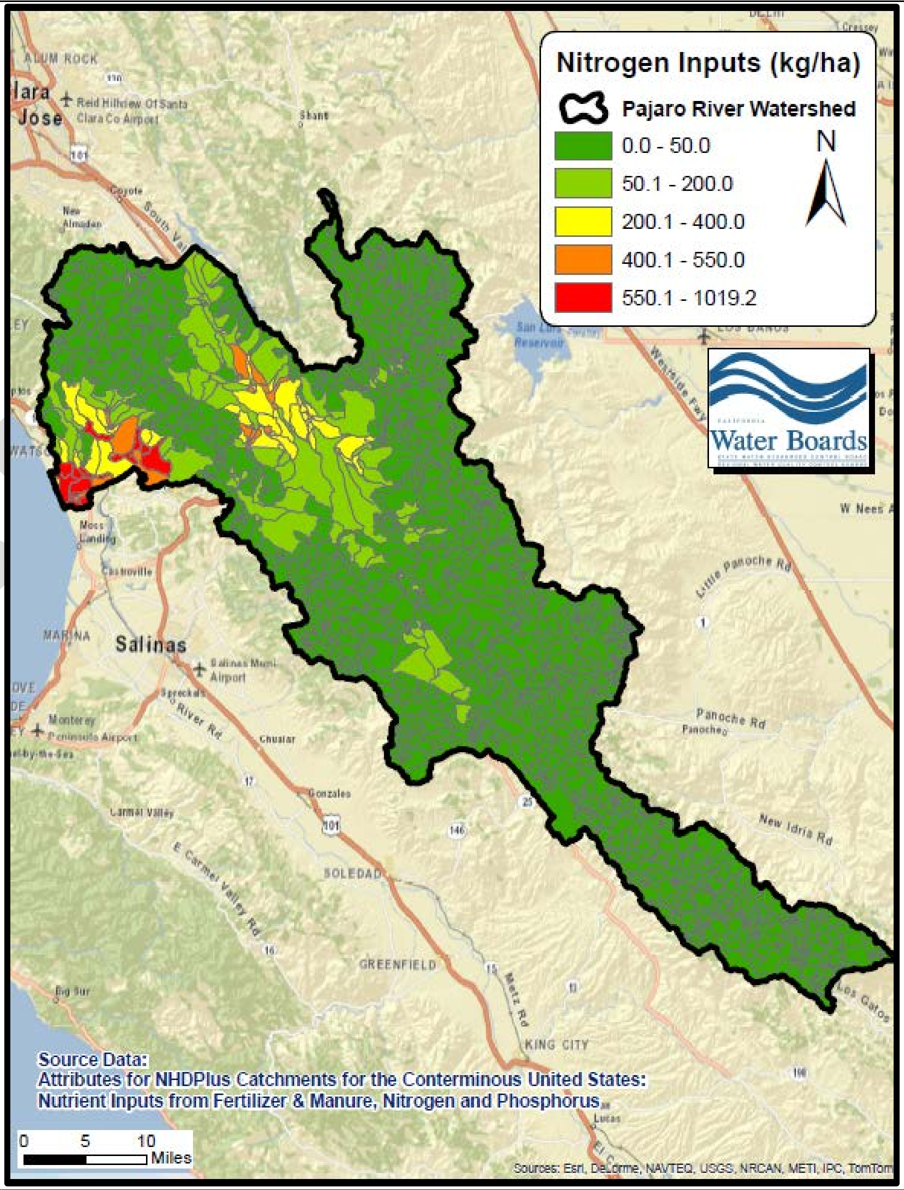


Figure 5-7. (A) Surface water orthophosphate as P (median concentration values – mg/L); and (B) estimated total phosphorus inputs (kg/hectare - year 2002) from fertilizer and compost, Pajaro River basin.

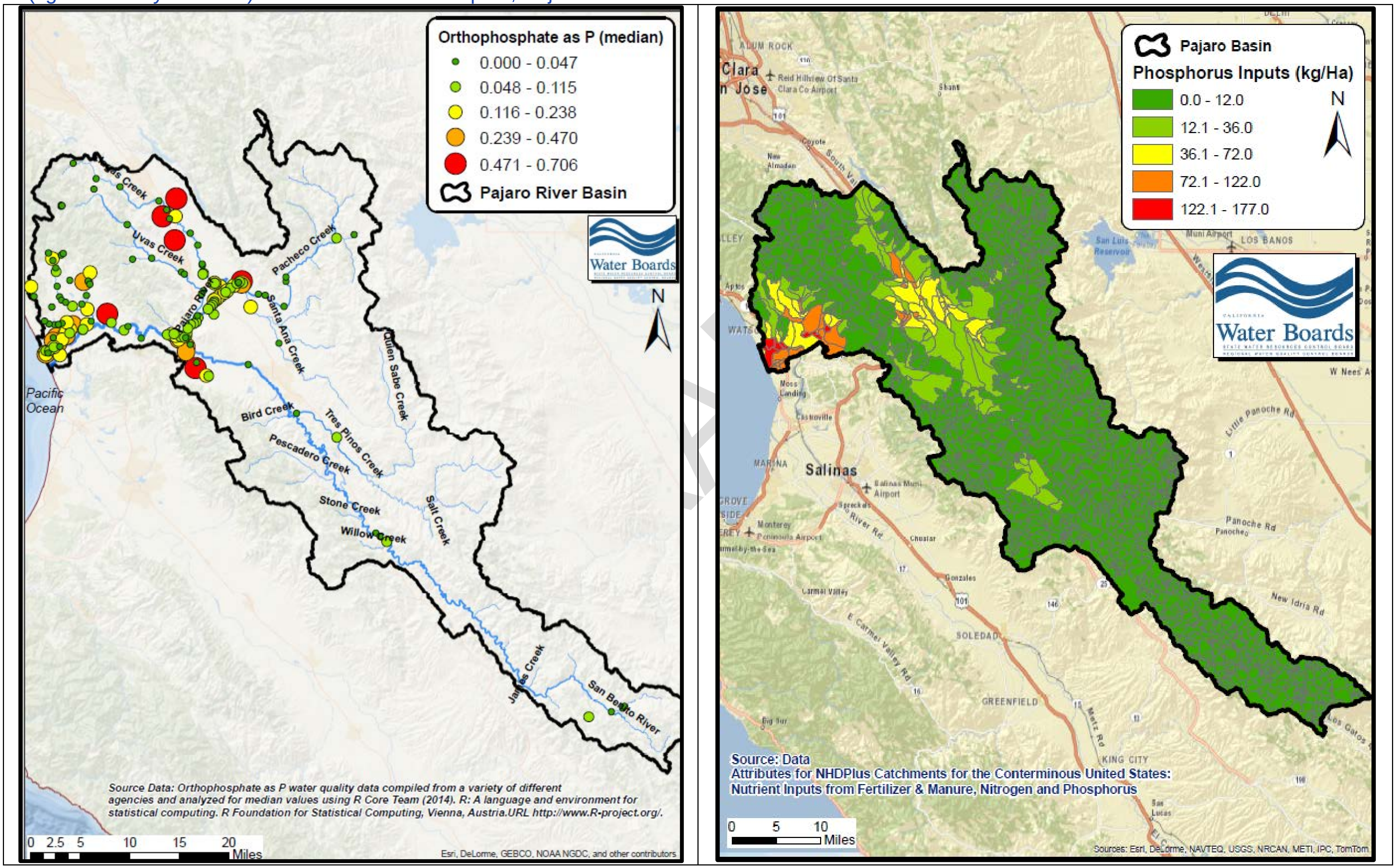


Figure 5-8. Surface water NO_3 – N concentrations (median value), TMDL project area, northern section.

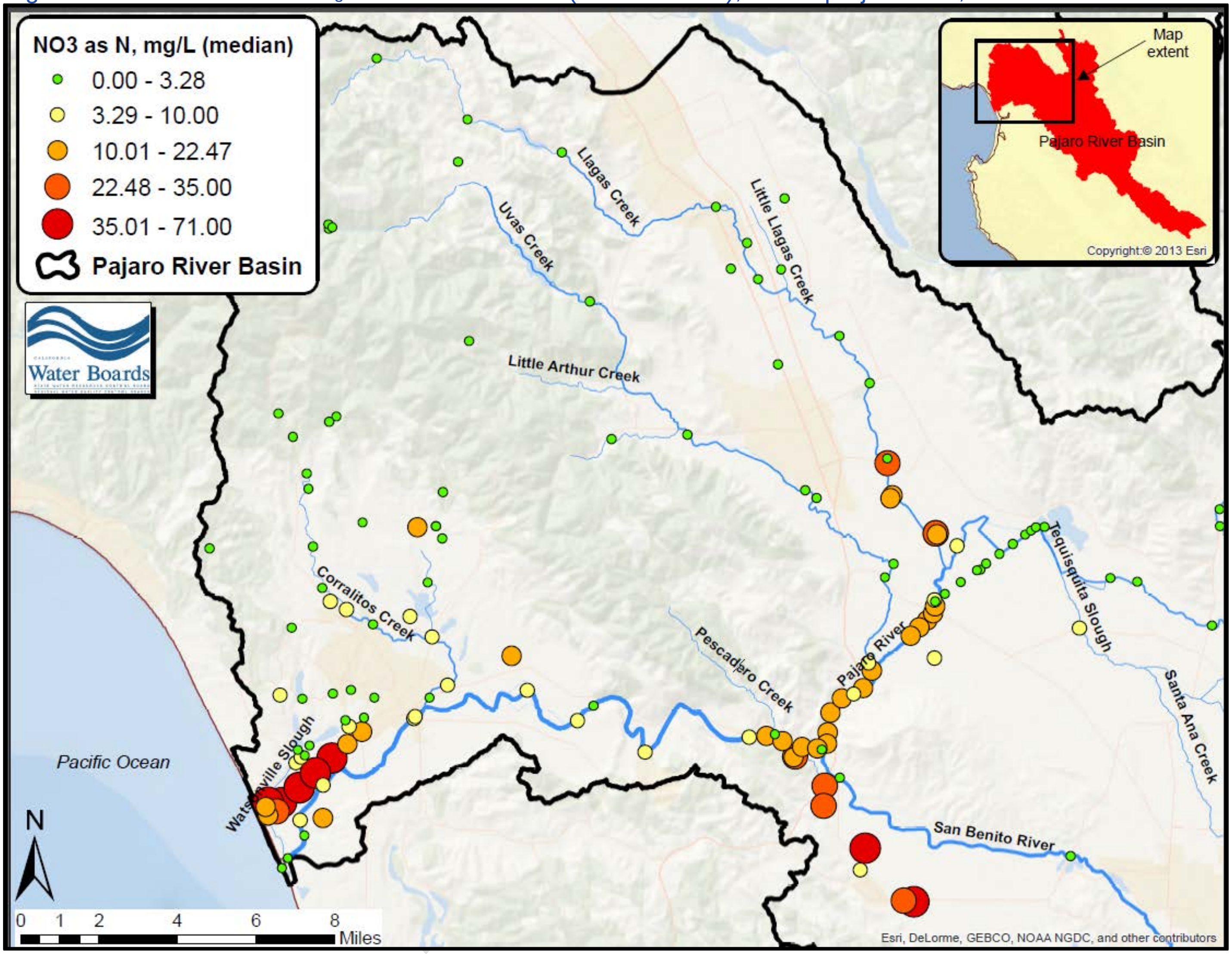


Figure 5-9. Surface water Orthophosphate as P concentrations (median value), TMDL project area, northern section.

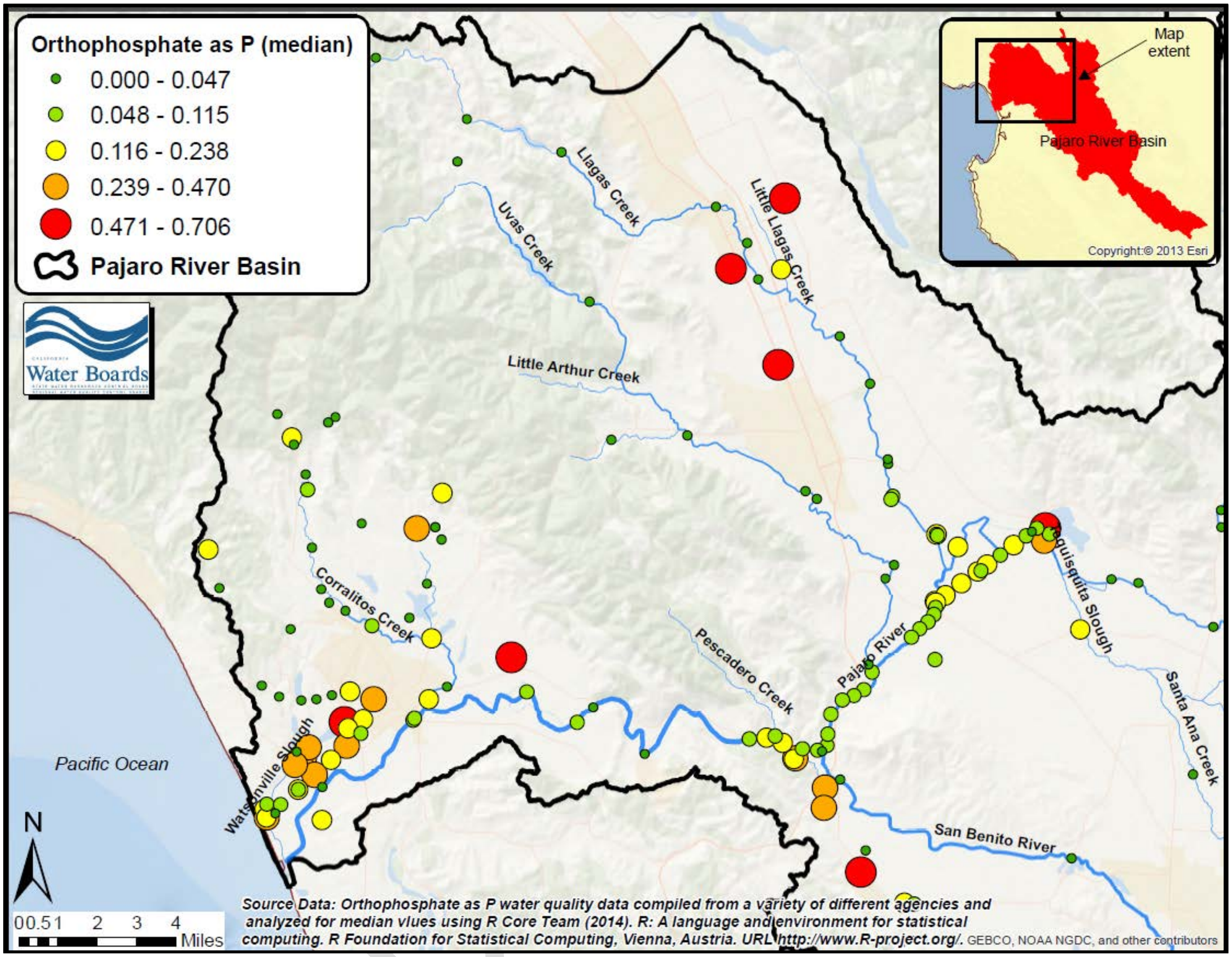


Figure 5-10. Box and whiskers plot, nitrate as N water quality data for all monitored streams within the Pajaro River basin, ordered alphabetically. For reference, the nitrate as N water quality standard for drinking water is 10 mg/.

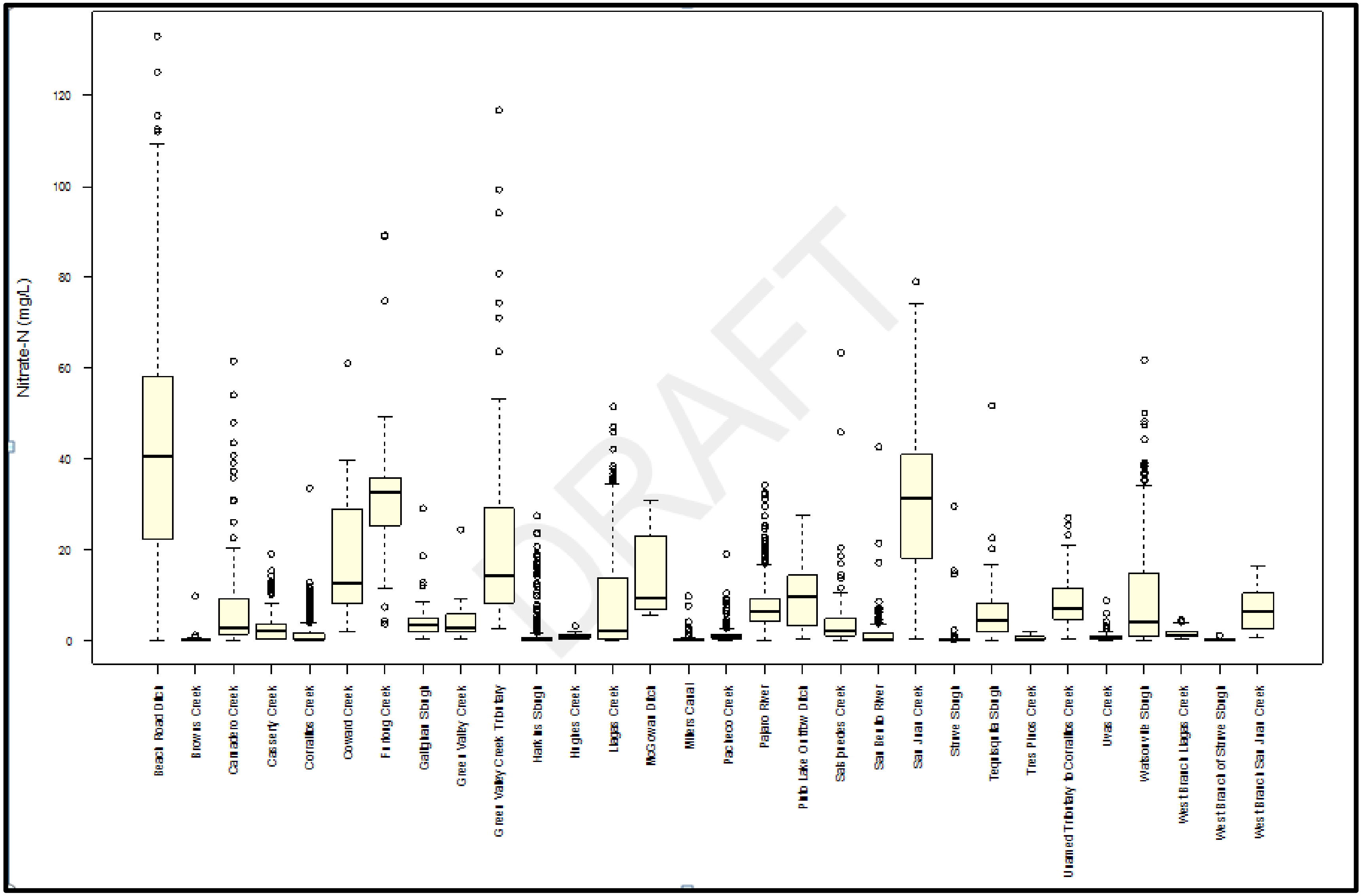


Figure 5-11. Box and whiskers plot, nitrate as N water quality data, Pajaro River. Sites shown from most downstream site to the most upstream site. The most downstream sites are on the far left and the most upstream site is on the far right. For reference, the nitrate as N water quality standard for drinking water is 10 mg/.

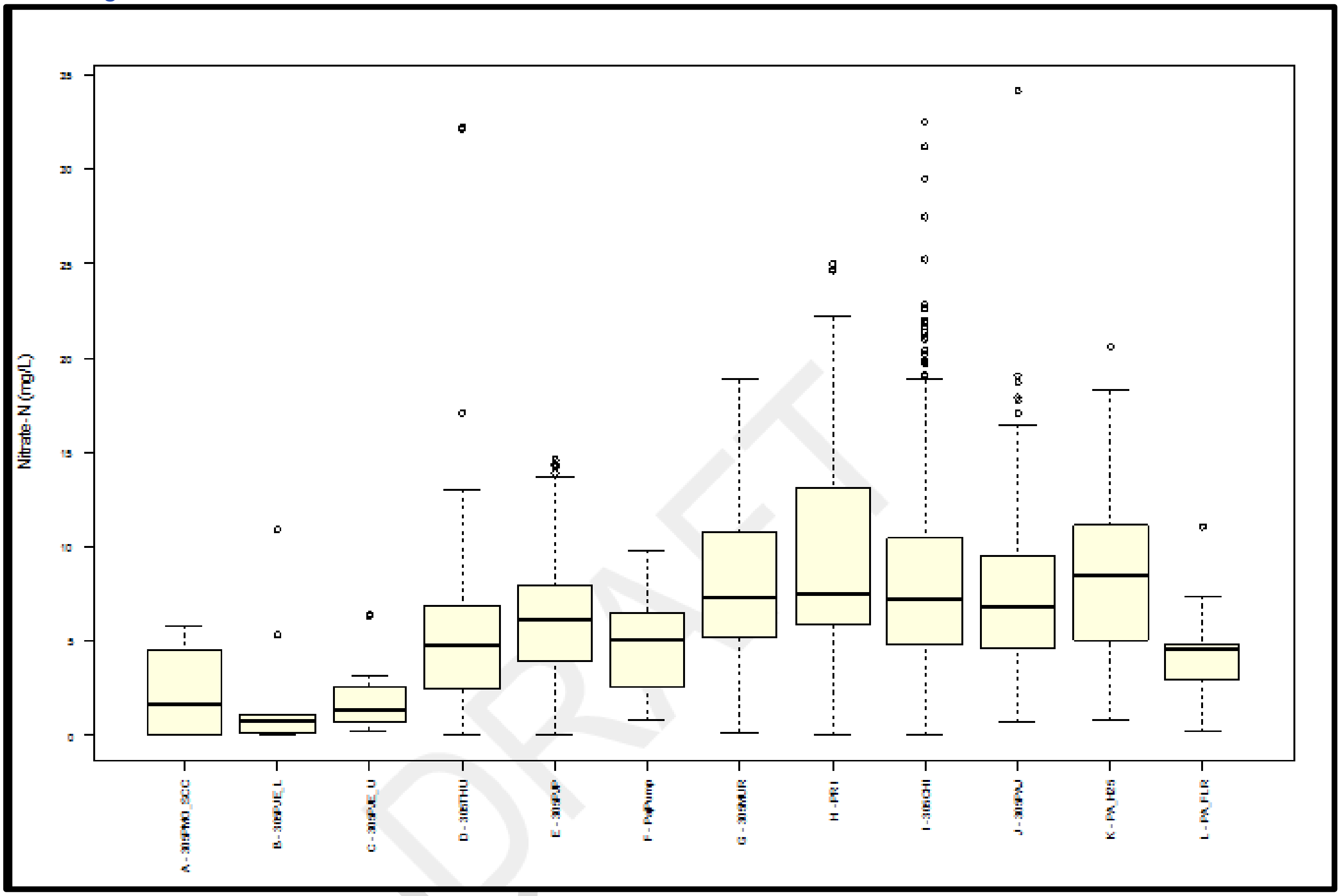


Figure 5-12. Box and whiskers plot, nitrate as N water quality data, Llagas Creek. Sites shown from most downstream site to the most upstream site. The most downstream sites are on the far left and the most upstream site is on the far right. For reference, the nitrate as N water quality standard for drinking water is 10 mg/.

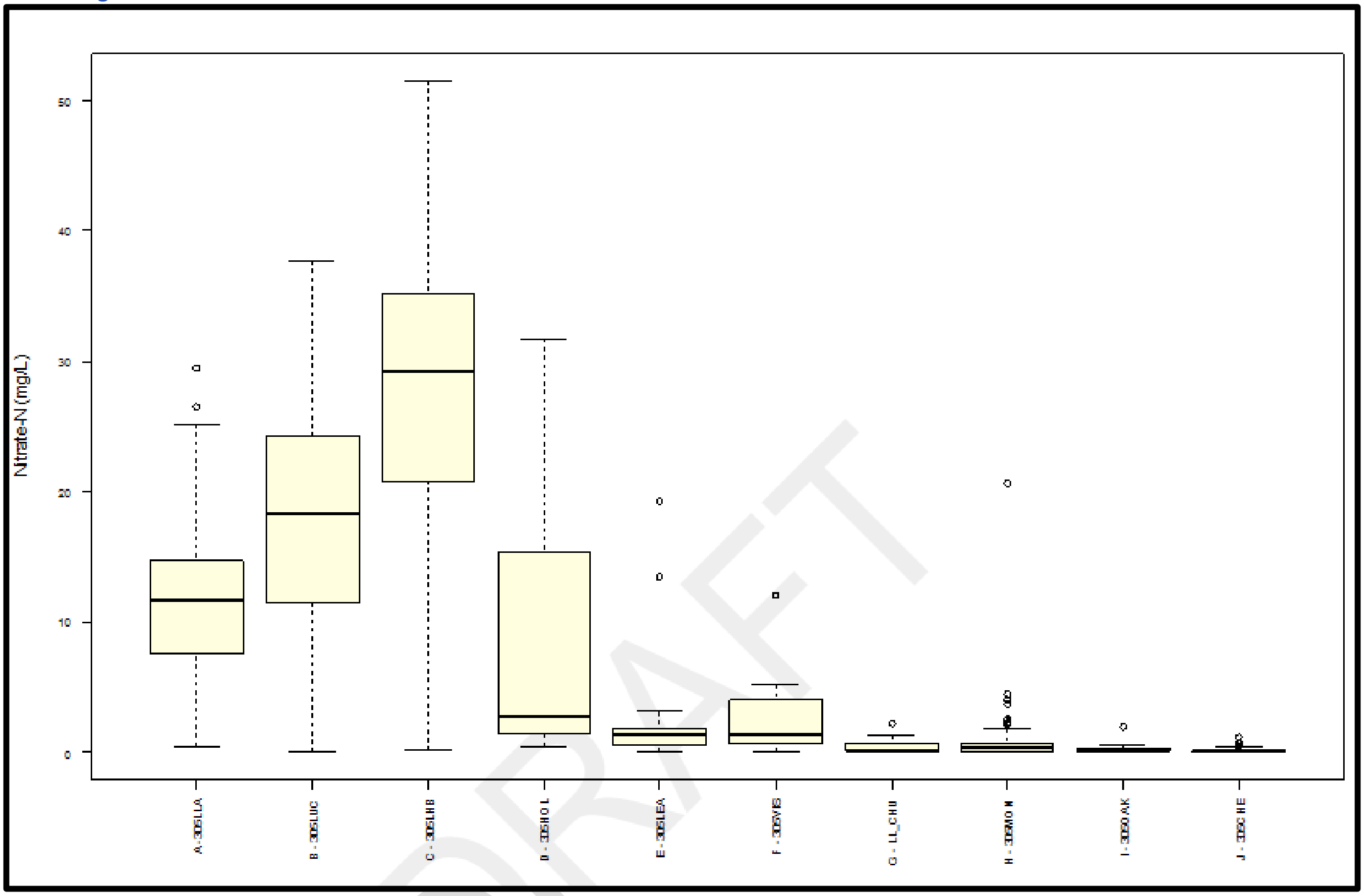


Figure 5-13. Box and whiskers plot, nitrate as N water quality data, Watsonville Slough. Sites shown from most downstream site to the most upstream site. The most downstream sites are on the far left and the most upstream site is on the far right. For reference, the nitrate as N water quality standard for drinking water is 10 mg/.

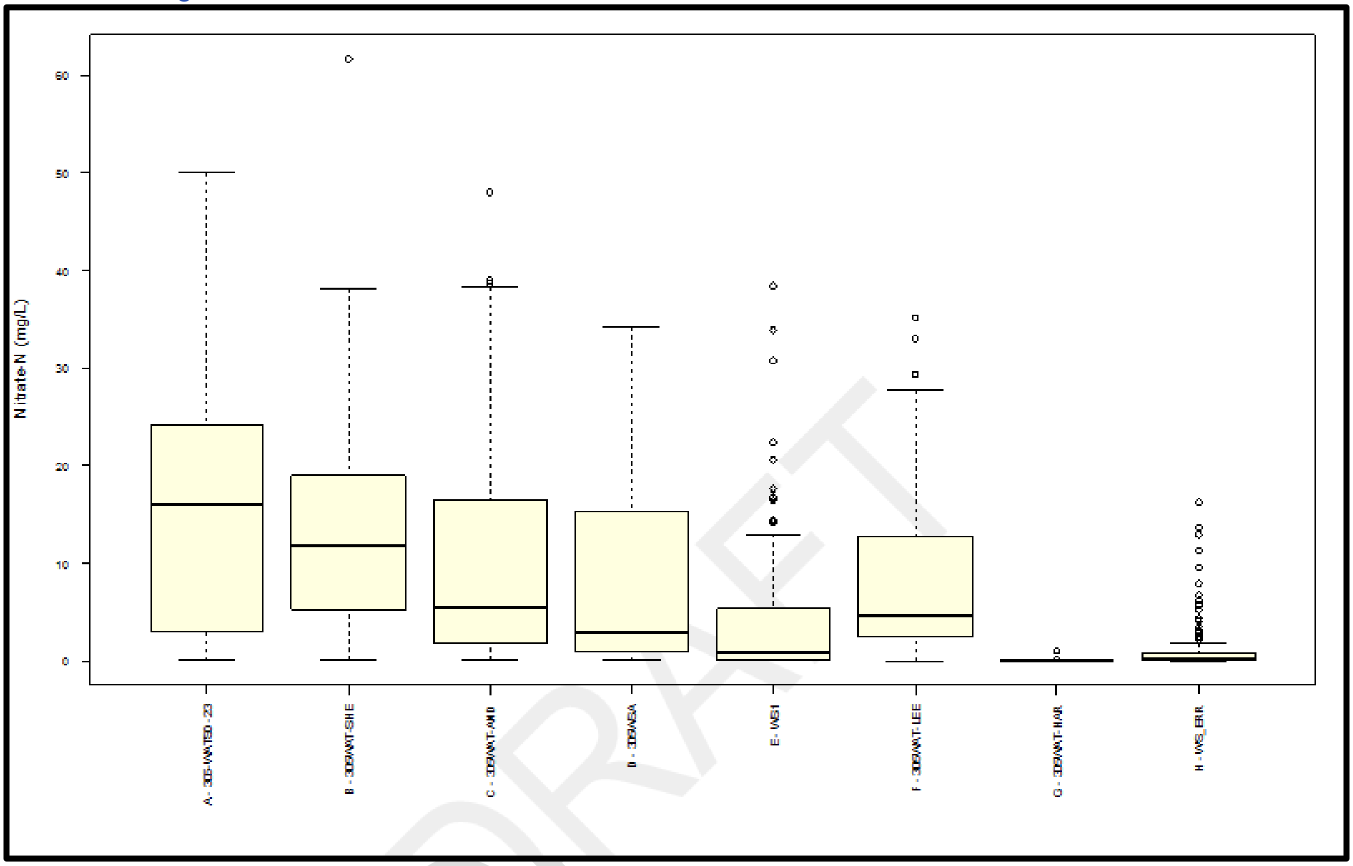
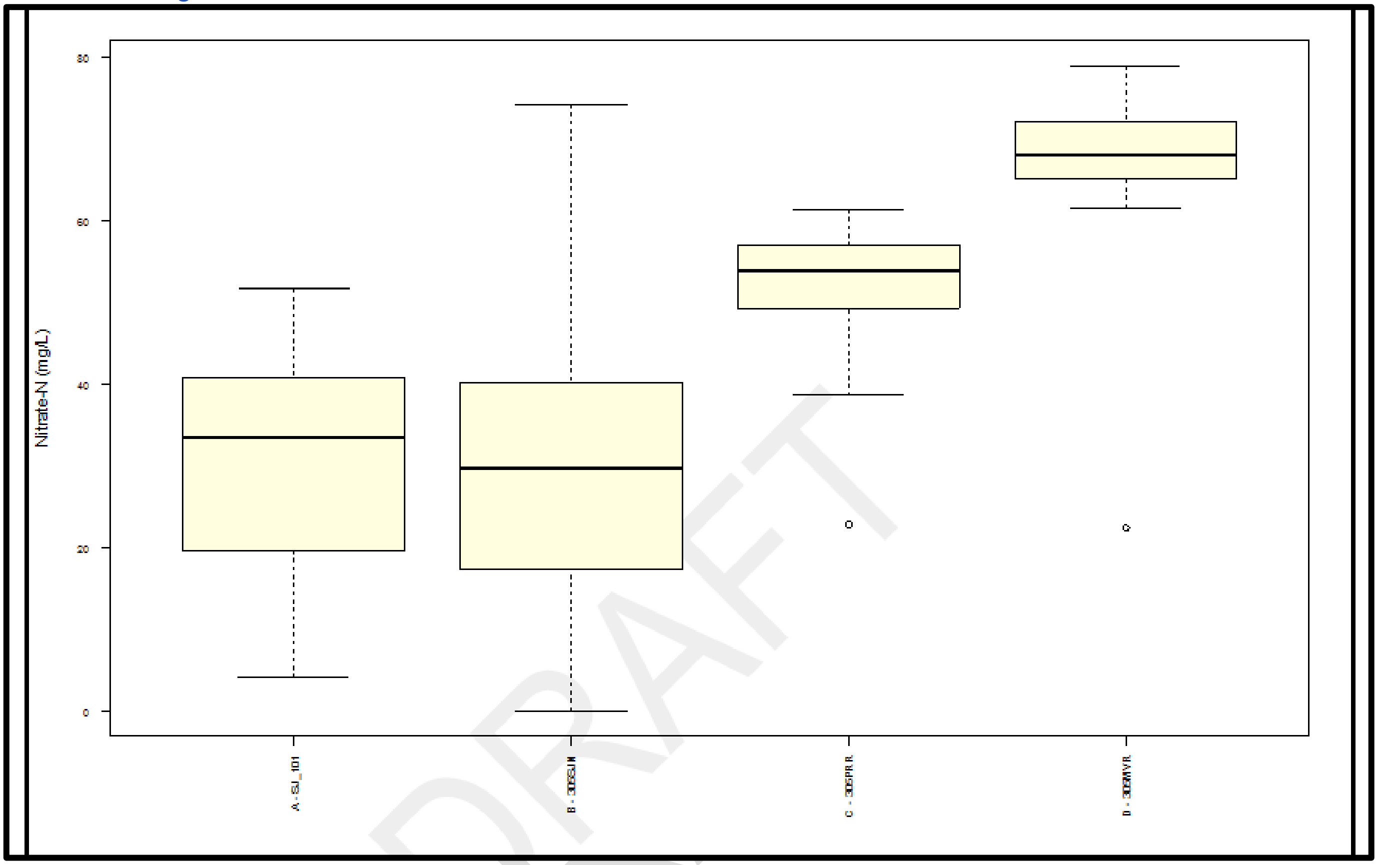


Figure 5-14. Box and whiskers plot, NO_3 as N water quality data, San Juan Creek. Sites shown from most downstream site to the most upstream site. The most downstream sites are on the far left and the most upstream site is on the far right. For reference, the nitrate as N water quality standard for drinking water is 10 mg/.



5.1 Water Quality Temporal Trends

Figure 5-15 through Figure 5-21 illustrate time series plots of nitrate as N concentrations at several key stream monitoring sites in the Pajaro River basin, where stream nitrate concentrations are known to be highly elevated about natural background conditions. In addition, Central Coast Water Board staff performed Kendall's tau[122] nonparametric correlation tests using R[123] on these time series datasets shown, and the results of the kendal's tau tests are presented in Table 5-3. The correlation tests indicate that nitrate concentrations in the Pajaro River monitoring sites, and at the Llagas Creek monitoring site, have a positive (increasing) trend over the periods of record (tau ranging from 0.084 to 0.296) and these correlations are both statistically significant (p-value < 2.2 e-16). Practically speaking, this means there is a trend of increasing nitrate as N concentrations over the periods of record at these monitoring sites and there is a very low probability that it could be due to random chance.

Also noteworthy is that nitrate as N concentrations have been decreasing at the Watsonville Slough monitoring site over the period of record, and this decreasing trend is statistically significant.

[122] As described by the U.S. Geological Survey (U.S. Geological Survey, 2002b), the Kendall's tau test statistic is a nonparametric measure of the monotonic correlation between the variables. By convention, Kendall's tau correlation coeefficients are considered statistically significant when probabilities (p-values) are less than 0.05.

[123] R Development Core Team (2011). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org/.

It should be noted that the periods of record used for these data trends are quite long, with data extending back a decade or even several decades. More recent trends in improving water quality (recent trends seen at temporal scales less than a decade) have been compiled by the Central Coast Ambient Monitoring Program, and may show some improvements in water quality at some stream reaches over the last few years. Central Coast Water Board staff will endeavor to include these findings in a final TMDL report. PENDING

Table 5-3. Tabular summary of temporal trends and significance of nitrate as N concentrations at several key stream monitoring sites in the Pajaro River basin. Graphs that illustrate the time series data summarized herein are presented in Figure 5-15 through Figure 5-21.

Stream Monitoring Site	Associated Watershed & Subwatershed	No. of Samples	Temporal Representation	tau	p-value	Interpretation of Nitrate-N Concentration Temporal Trends and Significance
Pajaro River @ Thurwatcher Bridge	Pajaro River Watershed Lower Pajaro River Subwatershed	442	1998–2013	0.084	0.00857	Increasing Trend and Statistically Significant
Pajaro River @ Porter	Pajaro River Watershed Lower Pajaro River Subwatershed	395	2000–2013	0.152	7.016E-6	Increasing Trend and Statistically Significant
Pajaro River @ Murphy's Crossing	Pajaro River Watershed Lower Pajaro River Subwatershed	337	1998–2013	0.142	0.000113	Increasing Trend and Statistically Significant
Pajaro River @ Chittenden Gap	Pajaro River Watershed Lower Pajaro River Subwatershed	755	1952–2013	0.296	<2.2E-16	Increasing Trend and Statistically Significant
Llagas Creek @ Bloomfiled Ave.	Llagas Creek Watershed Lower Llagas Creek Subwatershed	343	1992–2011	0.182	4.68E-7	Increasing Trend and Statistically Significant
Watsonville Slough @ Shell Rd.	Pajaro River Watershed Watsonville Slough Subwatershed	130	2003–2013	-0.205	4.504E-7	Decreasing trend and Statistically Significant
San Juan Creek @ Anzar Rd.	Lower San Benito River Watershed San Juan Canyon Subwatershed	227	2003–2011	-0.068	0.1254	Decreasing Trend and Not Statistically Significant

Figure 5-15. Time series (1997-2010), nitrate as N – lower Pajaro River at Thuwatcher Bridge.

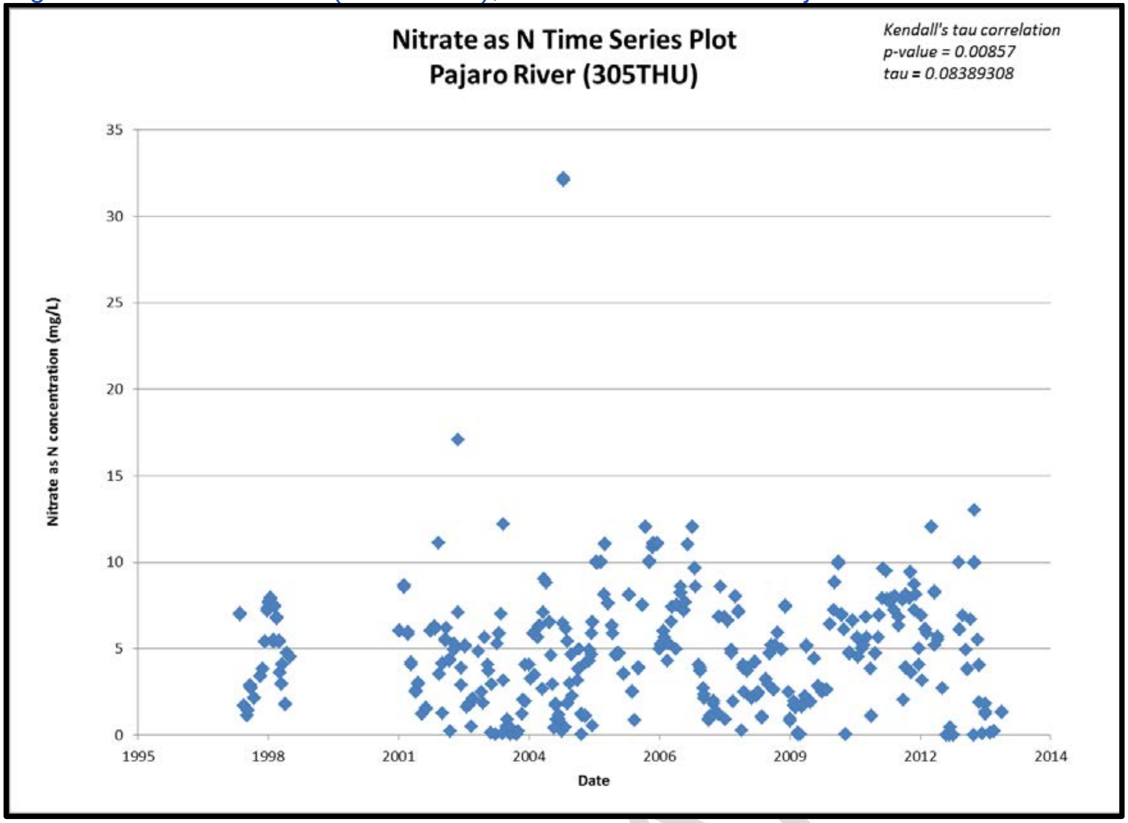


Figure 5-16. Time series (2000-2013), nitrate as N – Pajaro River at Porter.

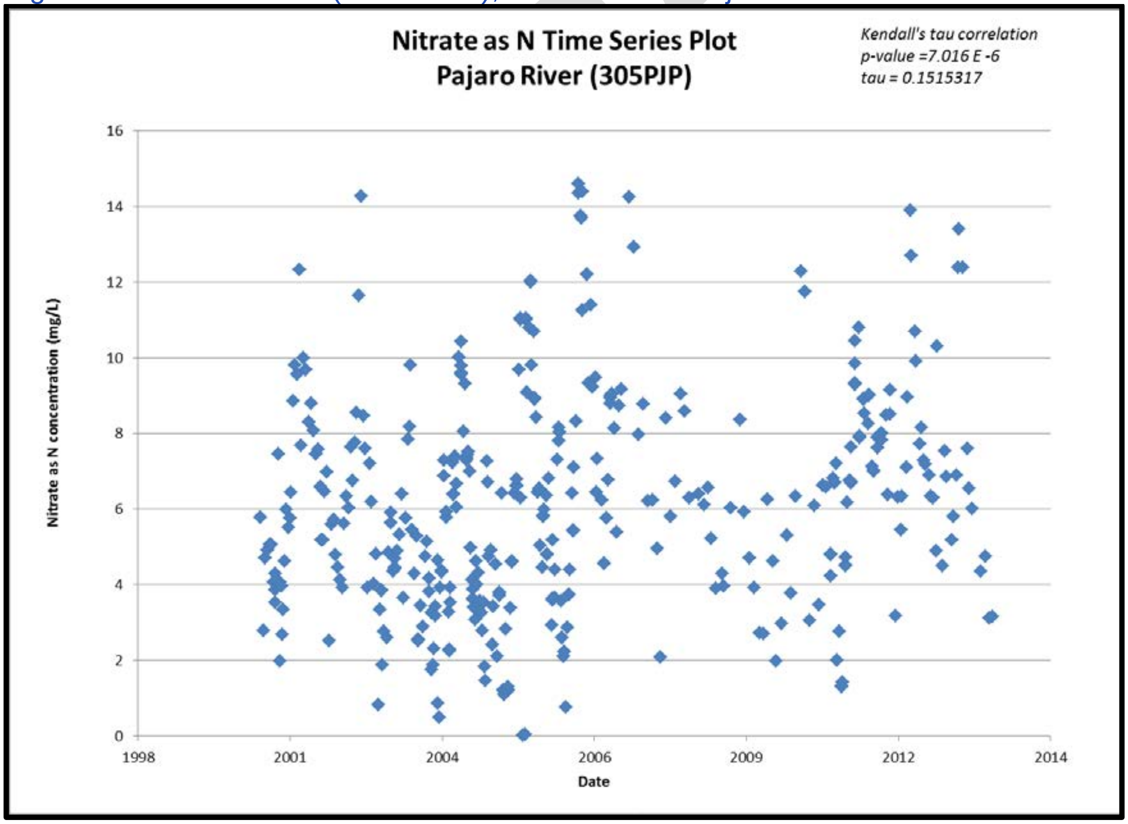


Figure 5-17. Time series (1998-2013), nitrate as N – Pajaro River at Murphy's Crossing.

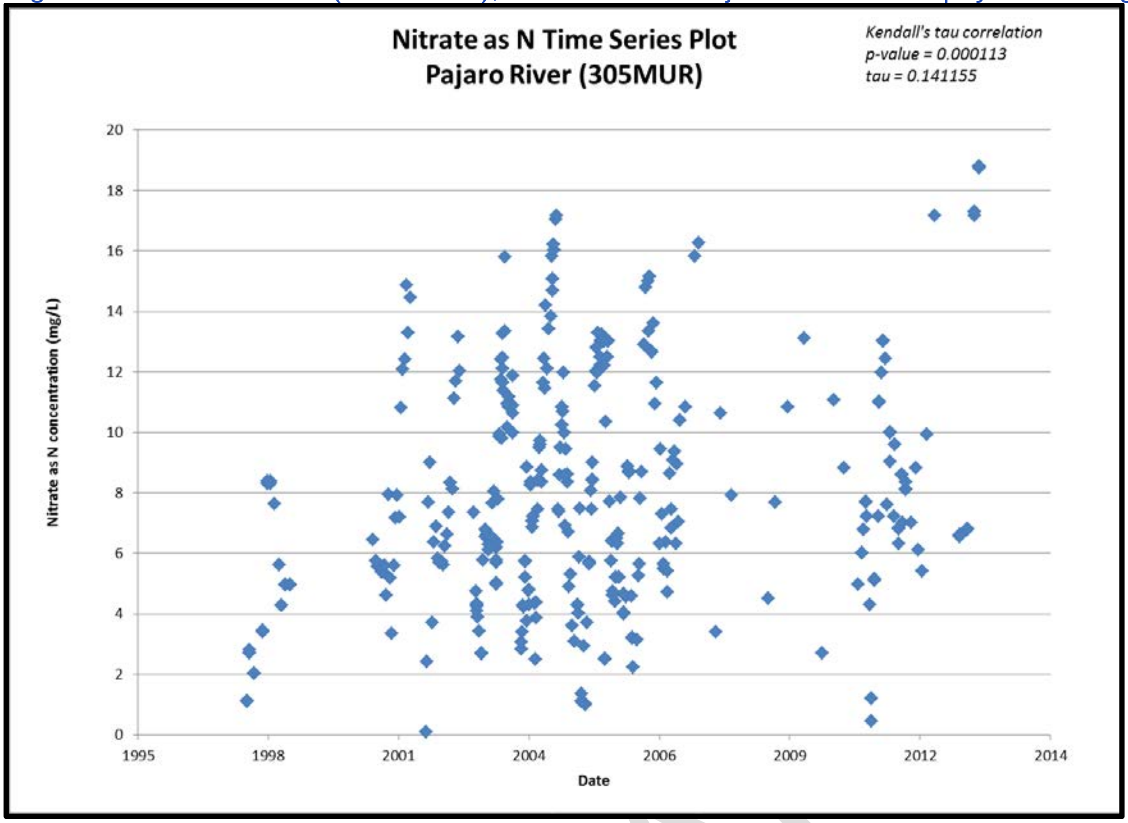


Figure 5-18. Time series (1952-2013), nitrate as N – Pajaro River at Chittenden Gap.

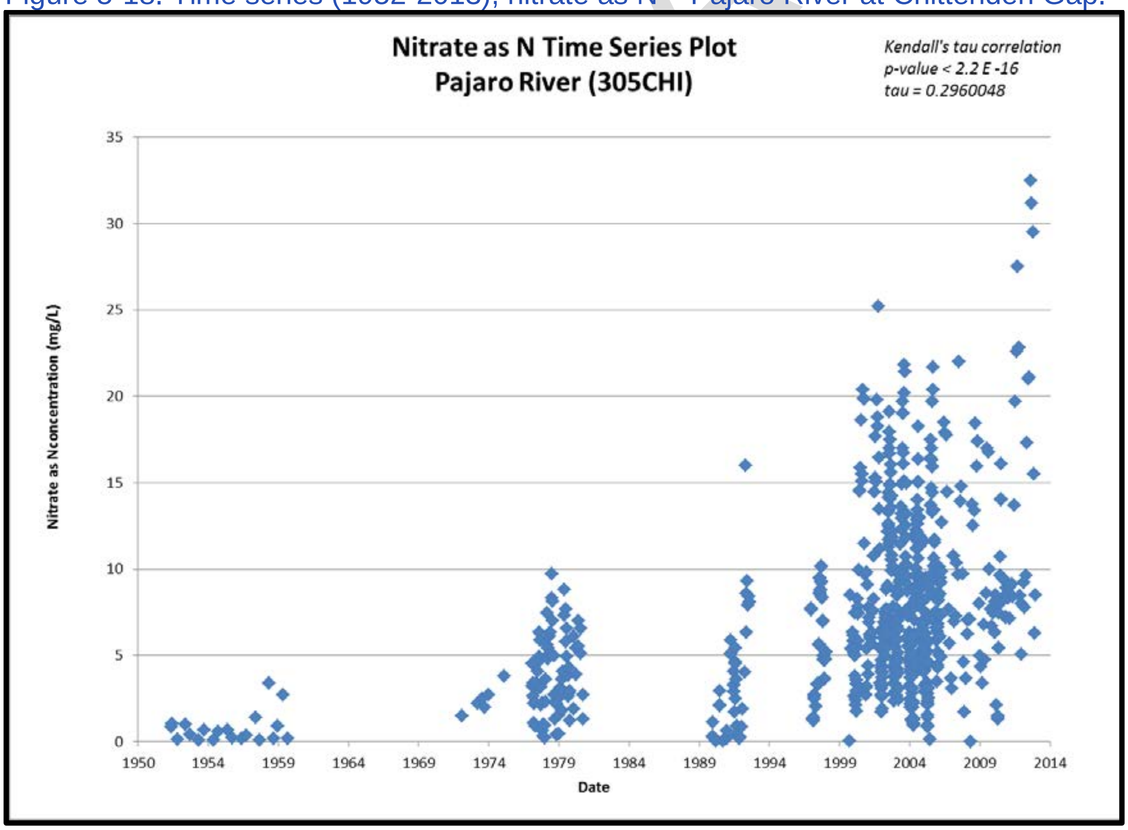


Figure 5-19. Time series (1992-2006), nitrate as N – Llagas Creek at Bloomfield Avenue.

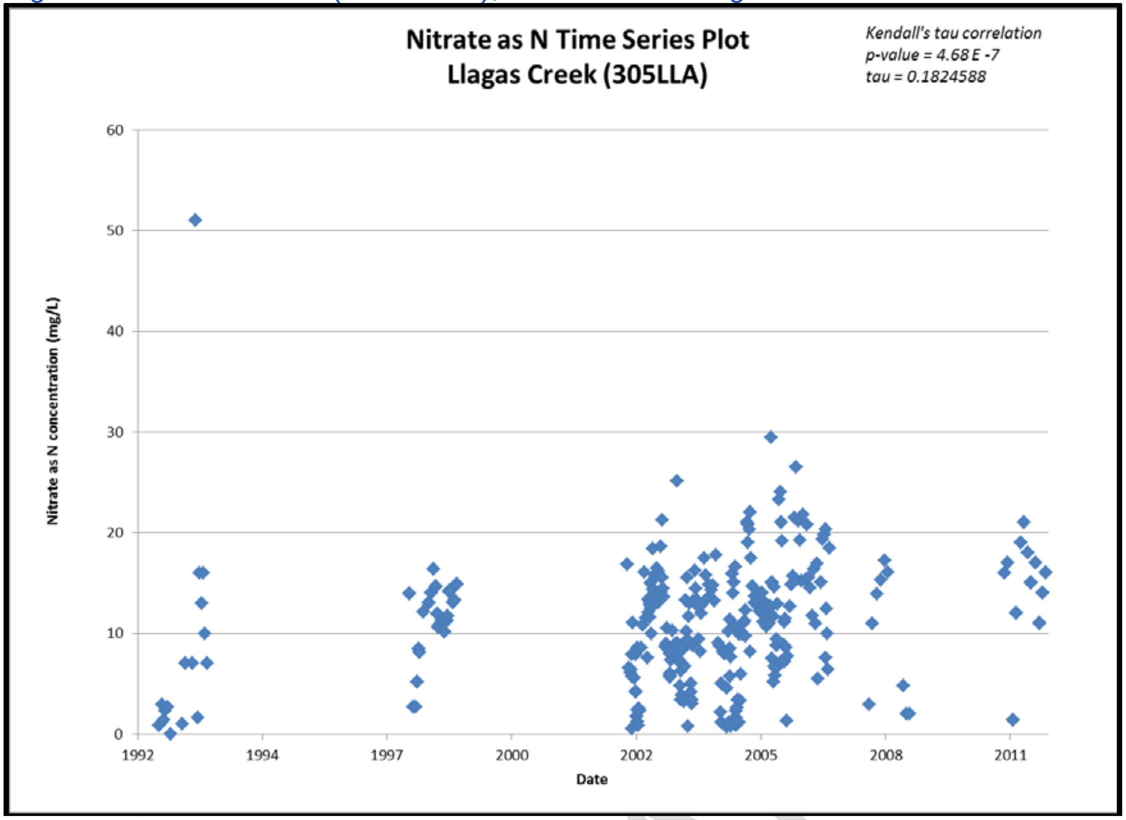


Figure 5-20. Time series (1994-2013), nitrate as N – Watsonville Slough at Shell Road.

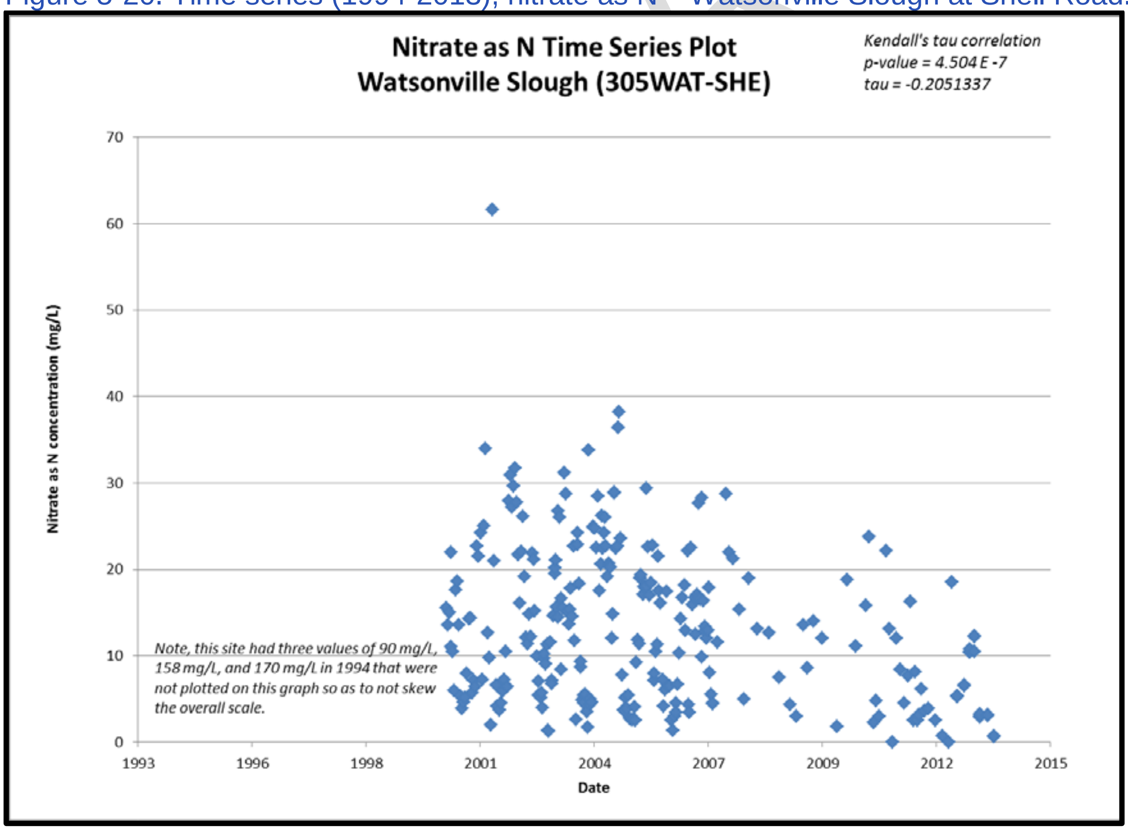


Figure 5-21. Time series (2003-2011), nitrate as N – Lower San Juan Creek at Anzar Road.

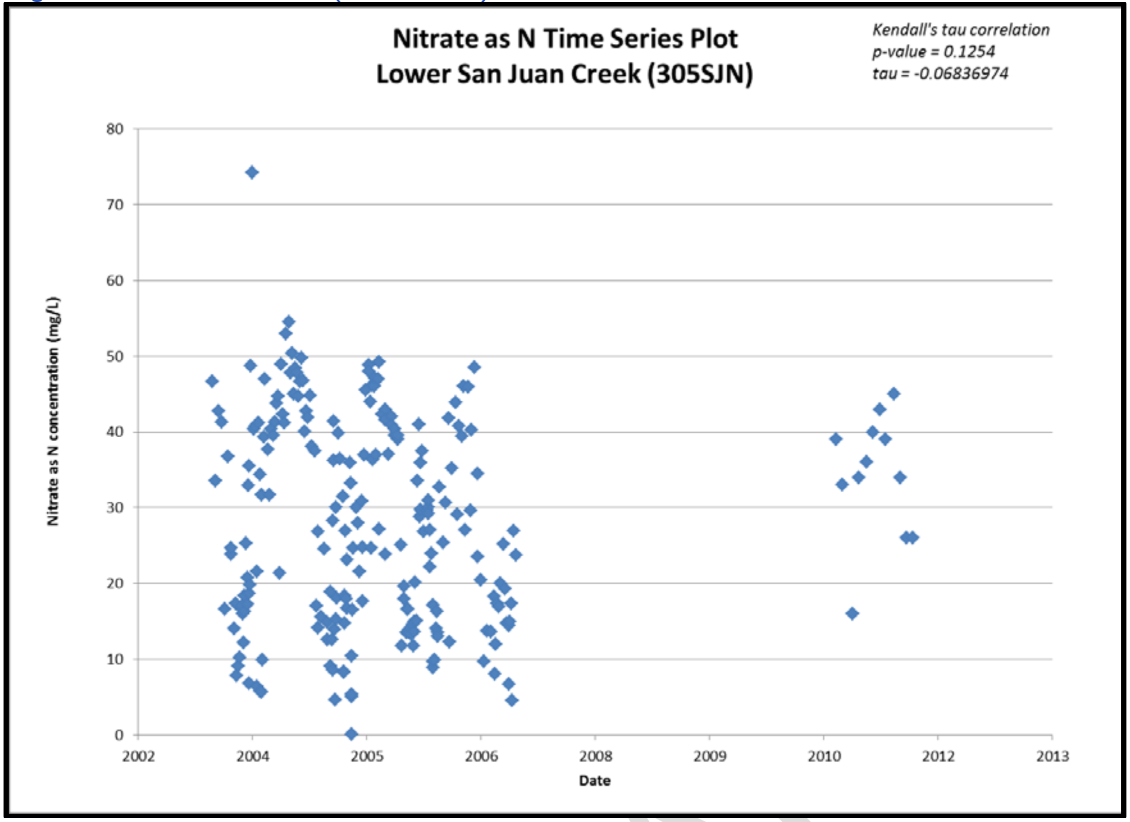


Figure 5-22 through Figure 5-21 illustrate time series plots of orthophosphate as P concentrations at several key stream monitoring sites in the Pajaro River basin, where stream nitrate concentrations are known to be highly elevated about natural background conditions. In addition, Central Coast Water Board staff performed Kendall's tau nonparametric correlation tests using R on these time series datasets shown, and the results of the kendal's tau tests are presented in Table 5-3. The correlation tests indicate that orthophosphate concentration trends in the Pajaro River monitoring sites, and at the Llagas Creek monitoring site are generally not significant. Practically speaking, this means this means the associations between time and orthophosphate concentrations are not statistically significant at these stream monitoring sites and there is an unacceptably high probability that these two variables are not strongly associated.

However, noteworthy is that orthophosphate as P concentrations have been decreasing at the Watsonville Slough monitoring site over the period of record, and this decreasing trend is statistically significant.

It should be noted that the periods of record used for these data trends are quite long, with data extending back a decade or even several decades. More recent trends in improving water quality (recent trends seen at temporal scales less than a decade) have been compiled by the Central Coast Ambient Monitoring Program, and may show some improvements in water quality at some stream reaches over the last few years. Central Coast Water Board staff will endeavor to include these findings in a final TMDL report. PENDING

Table 5-4. Tabular summary of orthophosphate as P concentrations temporal trends and significance at several key stream monitoring sites in the Pajaro River basin. Graphs illustrating the time series data summarized herein are presented in Figure 5-22 through Figure 5-28.

Stream Monitoring Site	Associated Watershed & Subwatershed	No. of Samples	Temporal Representation	tau	p-value	Interpretation of Orthophosphate-P Concentration Temporal Trends and Significance
Pajaro River @ Thurwatcher Bridge	Pajaro River Watershed Lower Pajaro River Subwatershed	273	1972–2013	0.0446	0.293	Increasing Trend and Not Statistically Significant
Pajaro River @ Porter	Pajaro River Watershed Lower Pajaro River Subwatershed	360	2000–2013	0.0539	0.128	Increasing Trend and Not Statistically Significant
Pajaro River @ Murphy's Crossing	Pajaro River Watershed Lower Pajaro River Subwatershed	291	1998–2013	-0.102	0.0110	Decreasing Trend and Statistically Significant
Pajaro River @ Chittenden Gap	Pajaro River Watershed Lower Pajaro River Subwatershed	629	1976–2013	-0.0337	0.208	Decreasing Trend and Not Statistically Significant
Llagas Creek @ Bloomfiled Ave.	Llagas Creek Watershed Lower Llagas Creek Subwatershed	290	1992–2011	-0.00321	0.935	Decreasing Trend and Not Statistically Significant
Watsonville Slough @ Shell Rd.	Pajaro River Watershed Watsonville Slough Subwatershed	255	2000–2013	-0.200	3.16 E -6	Decreasing trend and Statistically Significant
San Juan Creek @ Anzar Rd.	Lower San Benito River Watershed San Juan Canyon Subwatershed	318	2003–2013	-0.0845	0.0248	Decreasing Trend and Statistically Significant

Figure 5-22. Time series (1972 – 2013), orthophosphate as P – Pajaro River at Thuwatcher Bridge.

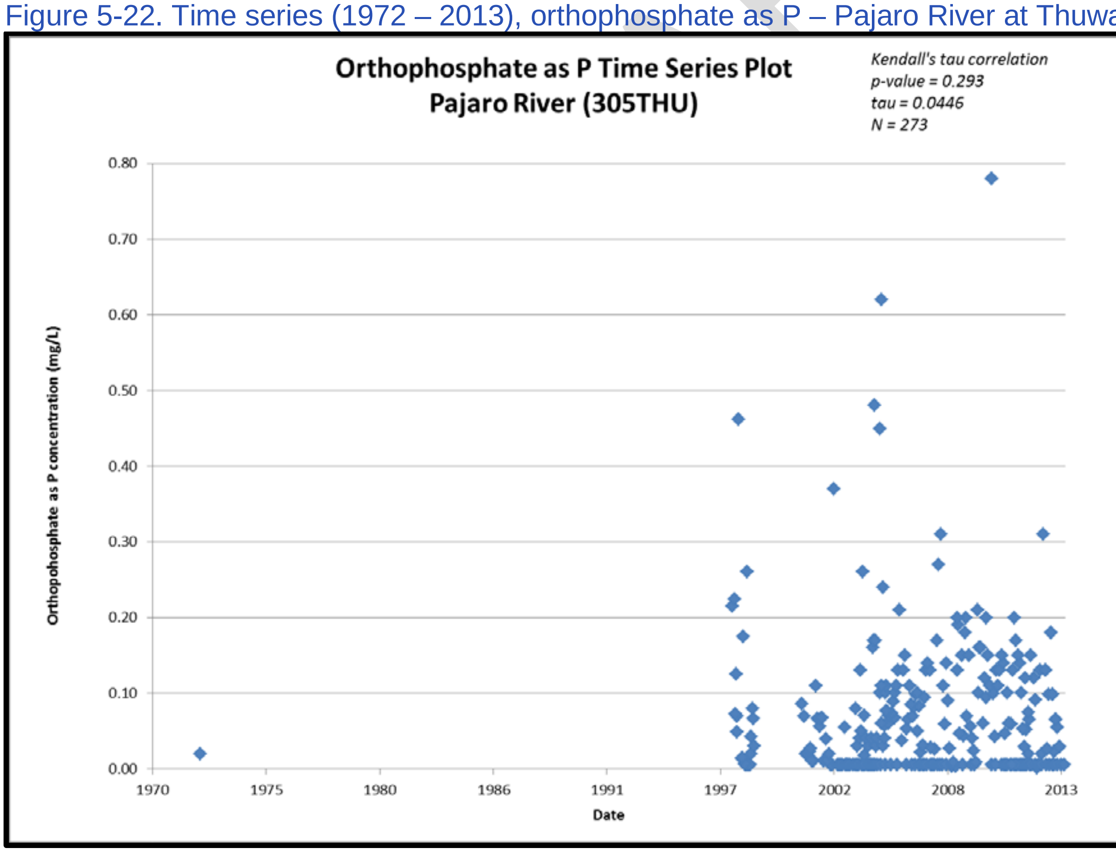


Figure 5-23. Time series (2000 – 2013), orthophosphate as P - Pajaro River at Porter.

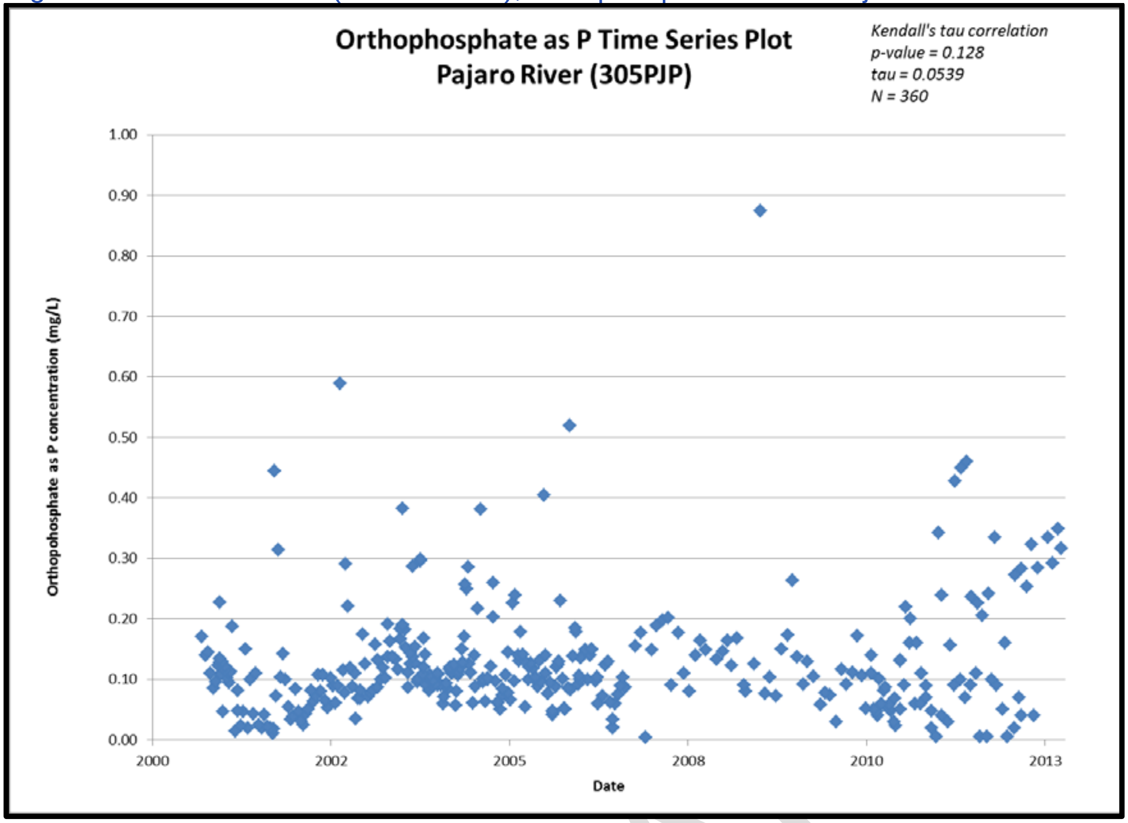


Figure 5-24. Time series (1998-2013), orthophosphate as P – Pajaro River at Murphy's Crossing.

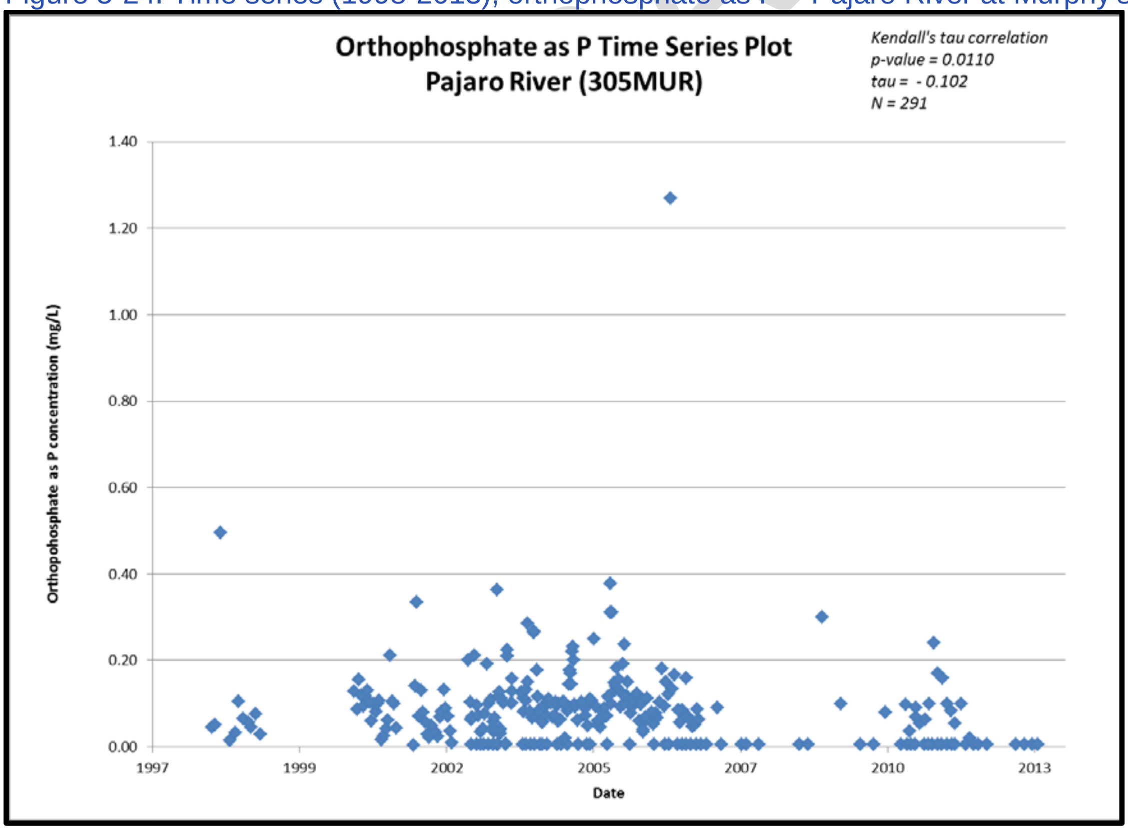


Figure 5-25. Time series (1976 – 2013), orthophosphate as P – Pajaro River at Chittenden Gap.

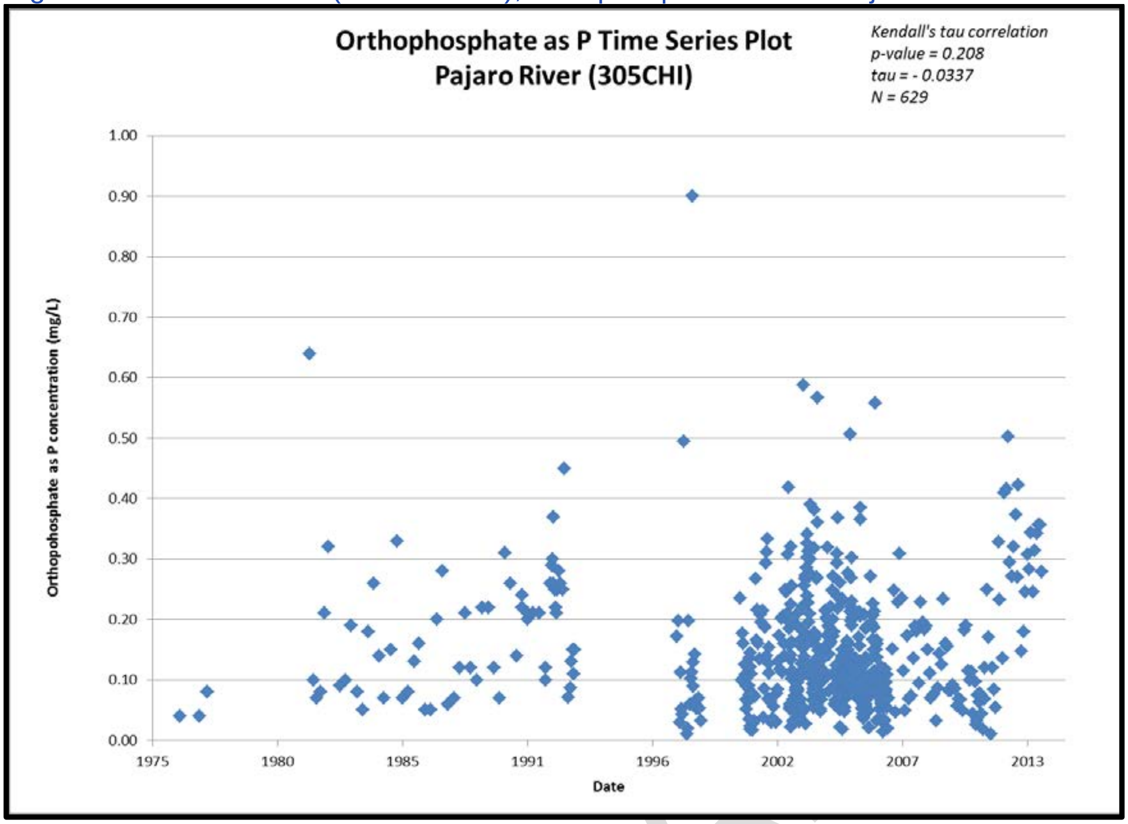


Figure 5-26. Time series (1992 – 2011), orthophosphate as P – Llagas Creek at Bloomfield Avenue.

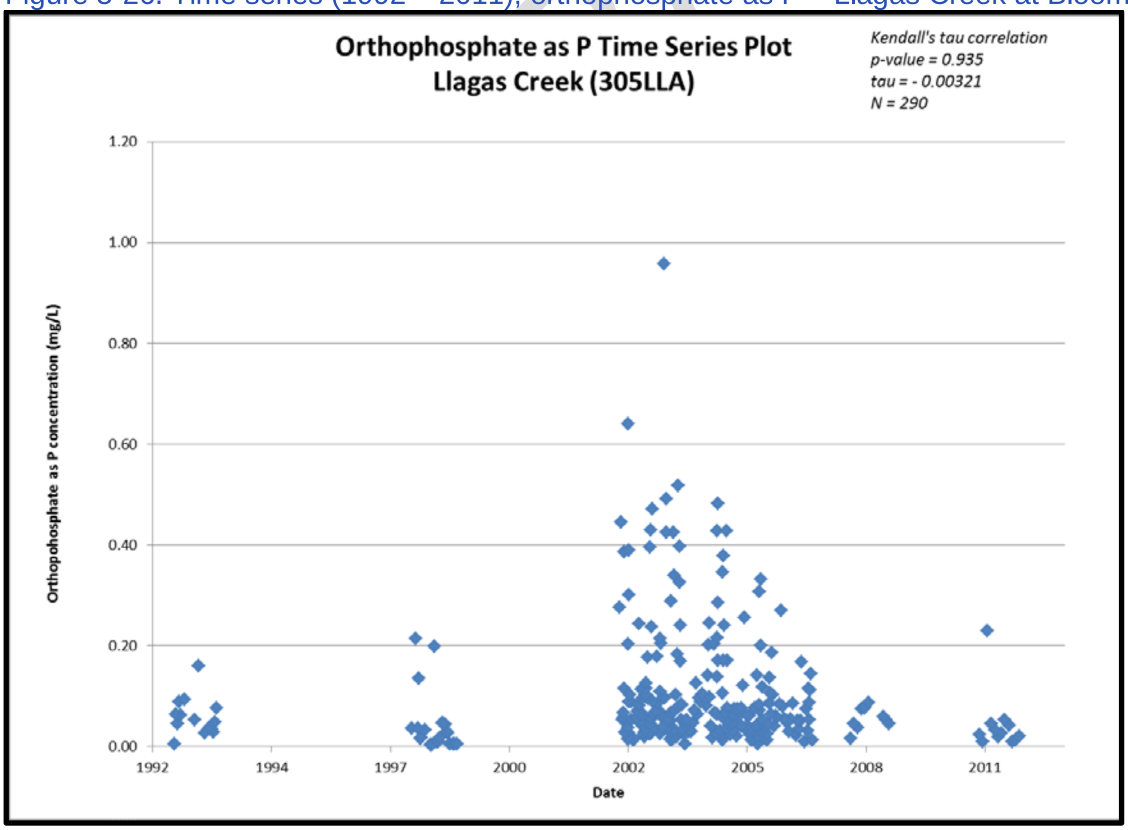


Figure 5-27. Time series (2000 – 2013), orthophosphate as P – Watsonville Slough at Shell Road.

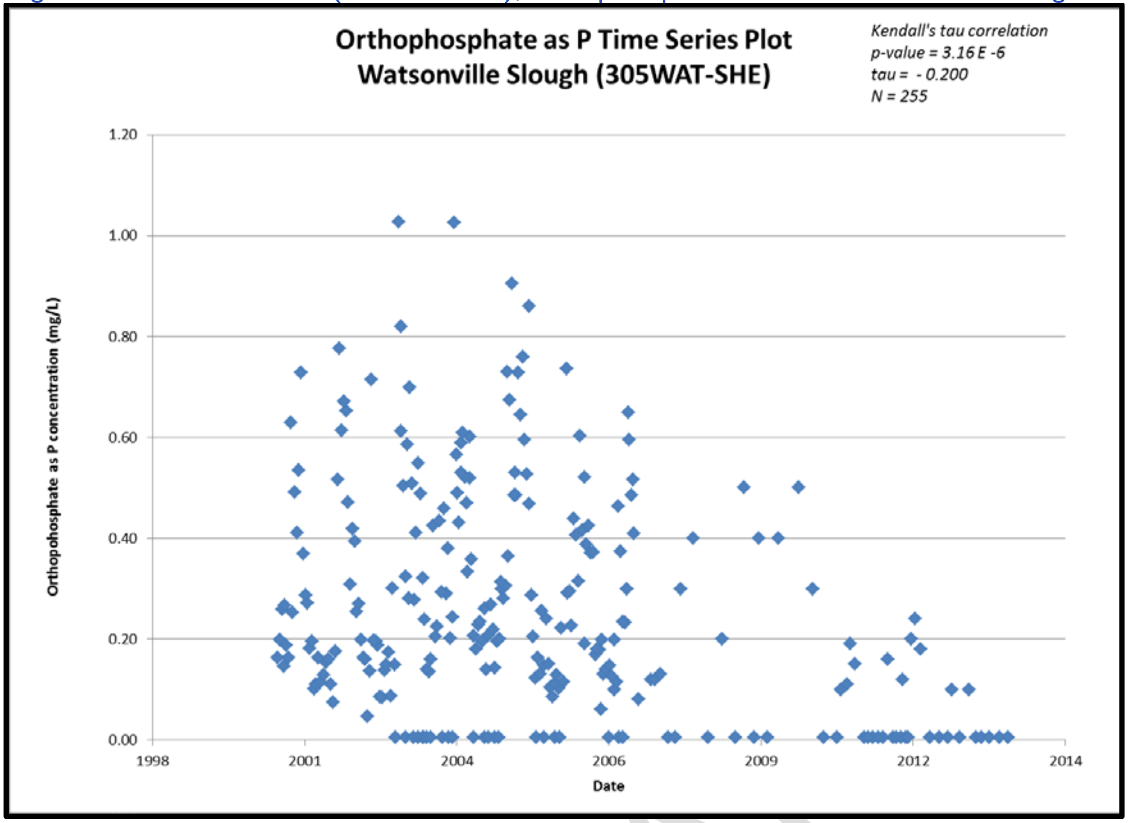
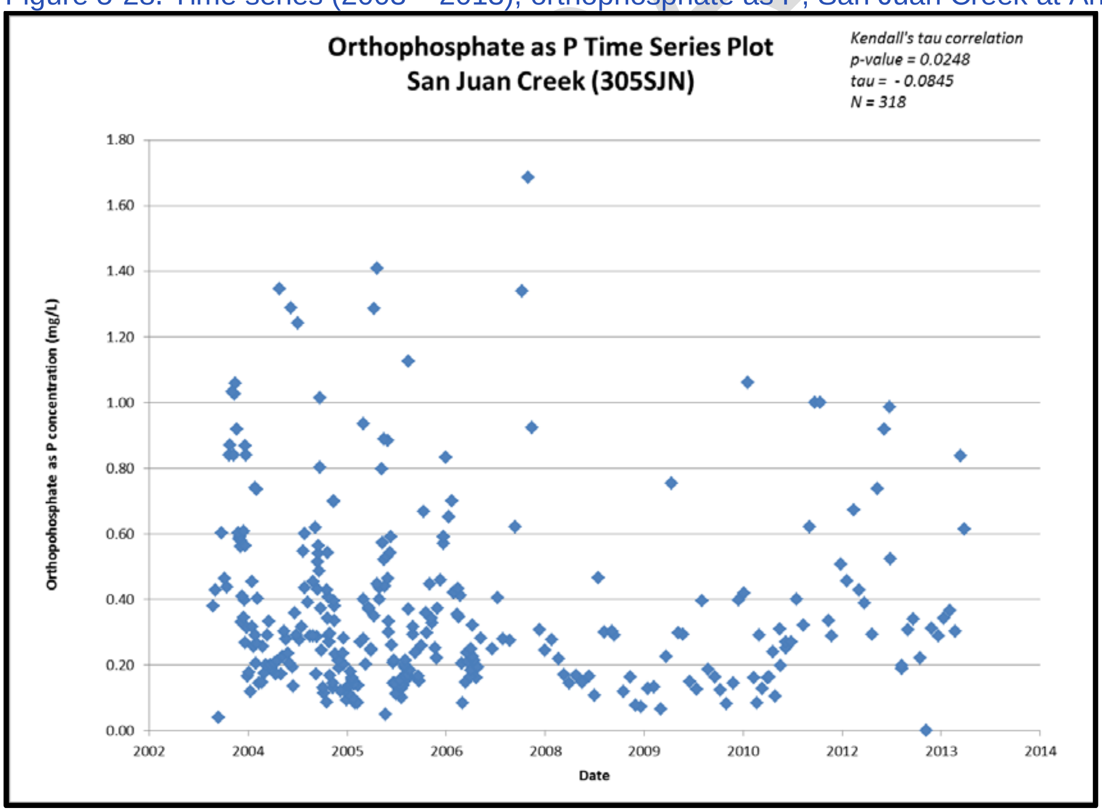


Figure 5-28. Time series (2003 – 2013), orthophosphate as P, San Juan Creek at Anzar Road.



5.1 Water Quality Flow-based Trends

Analysis of seasonal trends is not always appropriate as a surrogate for flow-based trends because of the California central coast's mediterranean climate and flashy flow conditions. While precipitation-driven high flow conditions are typically limited to the wet season months, the flashy, event-driven nature of regional hydrologic flow patterns, as well as persistent drought conditions, also means that there can be substantial and sustained periods of low flow and base flow conditions in the wet season. As such, it is relevant to assess possible flow-based patterns of nitrate-loading to representative project area stream reaches. Flow-based pollutant loading variation can be assessed using load duration curves. Load duration curves provide a graphical context for looking at monitoring data and can also potentially be used to focus and inform implementation decisions (Stiles and Cleland, 2003). A load duration curve is the allowable loading capacity of a pollutant, as a function of flow. A flow duration curve is transformed into a load duration curve by multiplying the flow by the water quality objective and a conversion factor. Flow duration record summaries developed for this project report are presented in Appendix X pending. The methodology for constructing load duration curves for this project report is based on the methodologies previously presented in the Central Coast Water Board's Fecal Coliform TMDL for the Lower Salinas River Watershed (2010).

Load duration curves for the Pajaro River at Chittenden and for Llagas Creek at Gilroy are presented in Figure 5-29 through Figure X pending. The target loads shown in these load duration curves are based on regulatory standards or published water quality guidelines, but do not necessarily represent the TMDLs themselves. Rather, the target loads in this context are for informational purposes, providing a uniform reference to assess pollutant loads as a function of flow. Summary observations of flow-based trends are presented in Table 5-5.

Table 5-5. Summary of flow-based trends in pollutant loads.

		Critical Flow Conditions *(The Flow Regime Exhibiting Highest Frequency (%) of Observed Daily Loads Exceeding the Reference Target Loads)*		
Watershed	**Stream Reach**	**Nitrate as N** [A]	**Orthophosphate** [B]	**Chlorophyll *a*** [C]
Pajaro River Watershed	Pajaro River at Chittenden	**Low flow conditions** Strong flow-based trend observed	**No obvious flow-based trends** Exceedances of target load slightly more common (9% of samples) during low flow conditions	**Pending**
Pajaro River Watershed	Pajaro River at Watsonville	**Low flow conditions** Strong flow-based trend observed	**Pending**	
Llagas Creek Watershed	Llagas Creek @ Gilroy	**Low-Moderate flow conditions** Flow-based trends are observed *Note that at very high flows (>50cfs) and at very low flows (<1 cfs) the exceedance frequency or exceedance magnitude relative to the target load is substantially less.*	**No obvious flow-based trends** Infrequent and episodic exceedances of target load occur during low flow conditions	**Pending**

[A] Reference target load based on Basin Plan MUN standard for nitrate as N (10 mg/L)
[B] Reference target load based on State of Nevada phosphate criteria for Class B streams (0.3 mg/L as P)
[C] Reference target based on Central Coast reference condition for chlorophyll *a*, published by Worcester et al. (2010): 15 mcg/L

Figure 5-29. Nitrate as N load duration curve for the Pajaro River at Chittenden.

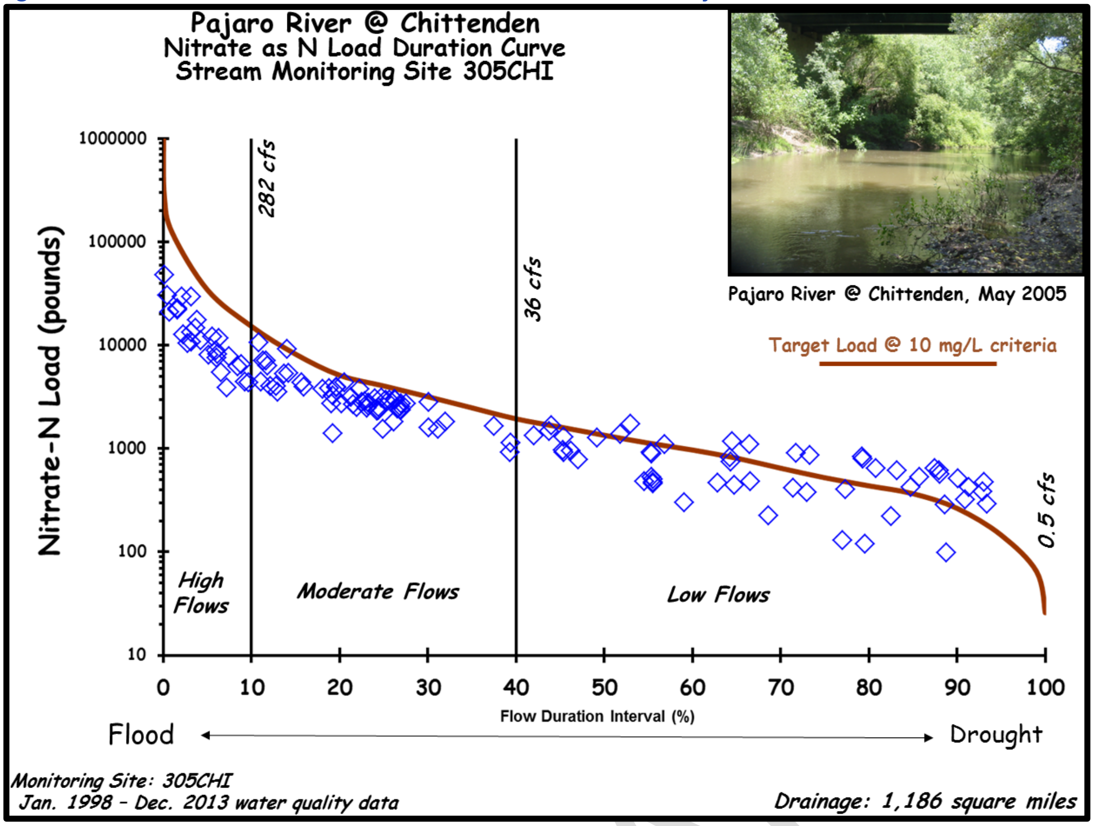


Figure 5-30. Orthophosphate as P load duration curve for the Pajaro River at Chittenden.

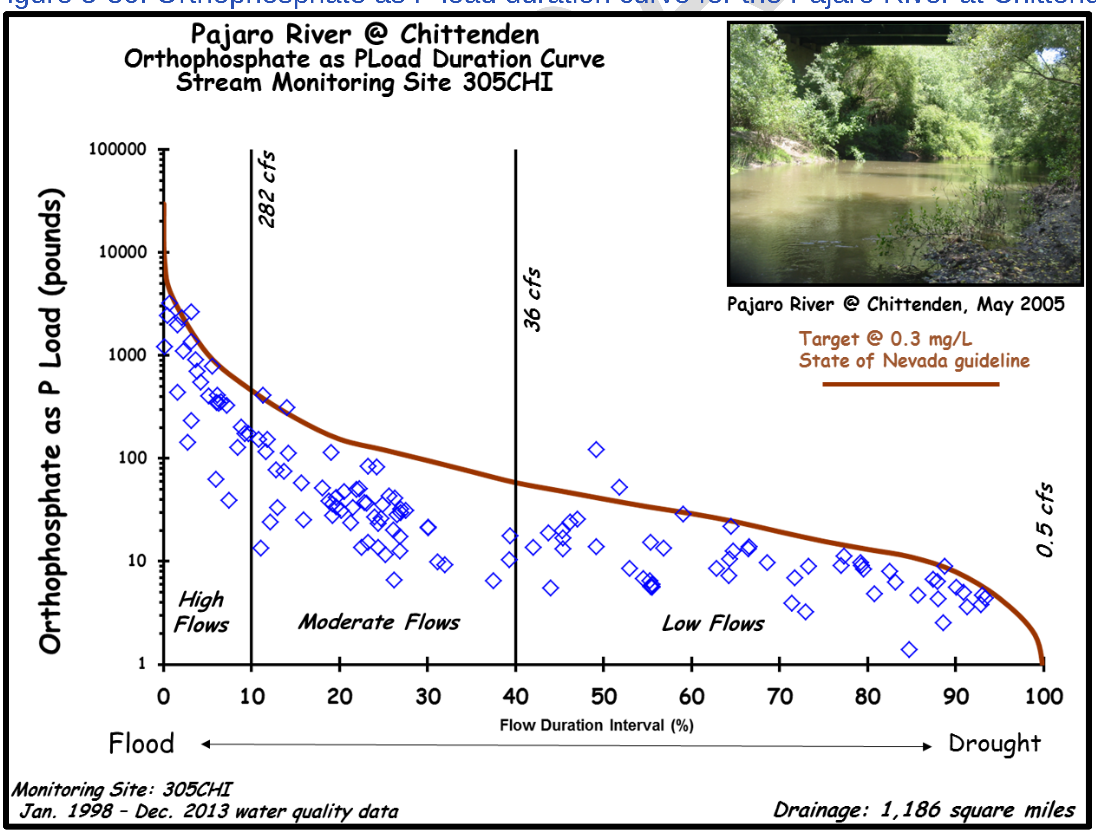


Figure 5-31. Nitrate as N load duration curve for the Pajaro River at Watsonville.

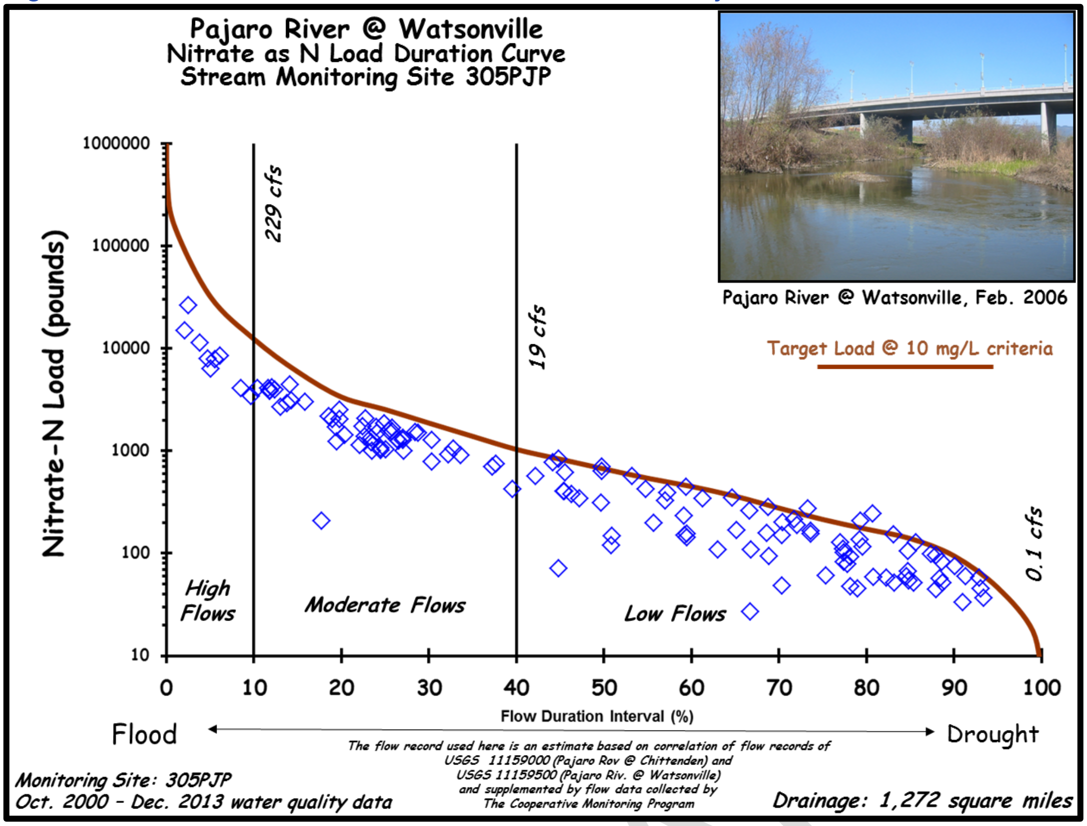


Figure 5-32. Nitrate as N load duration curve for Llagas Creek near Gilroy

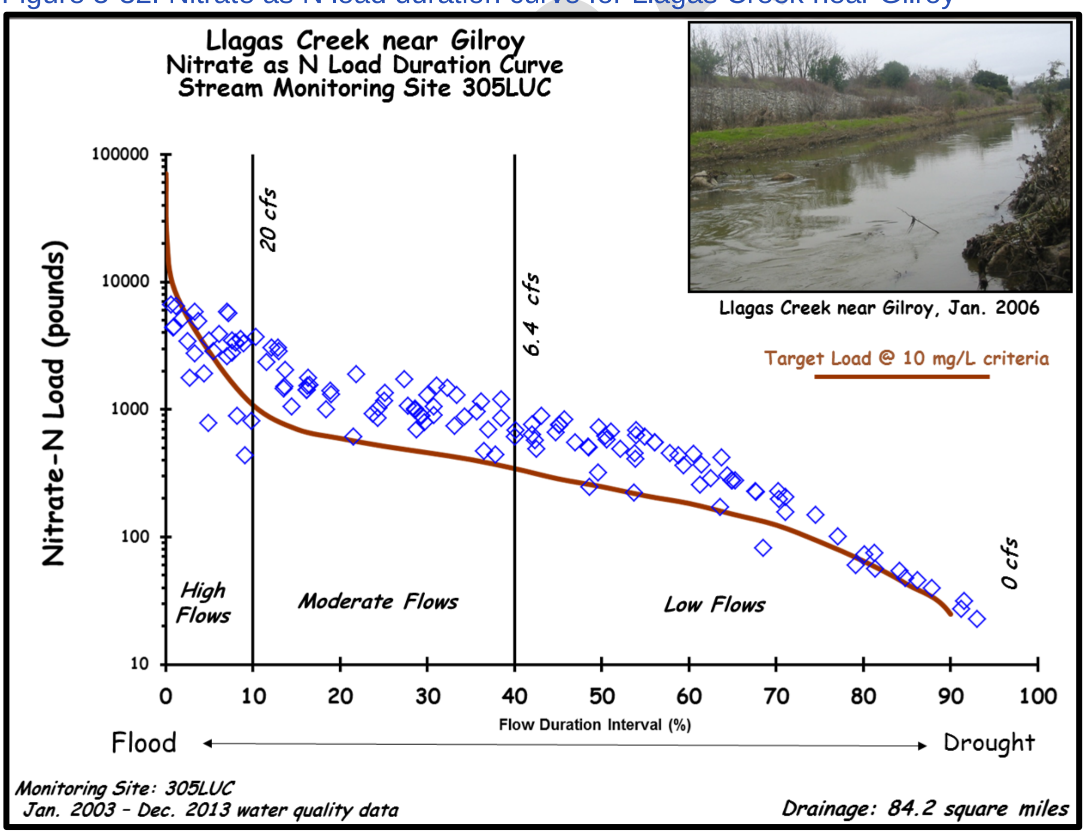
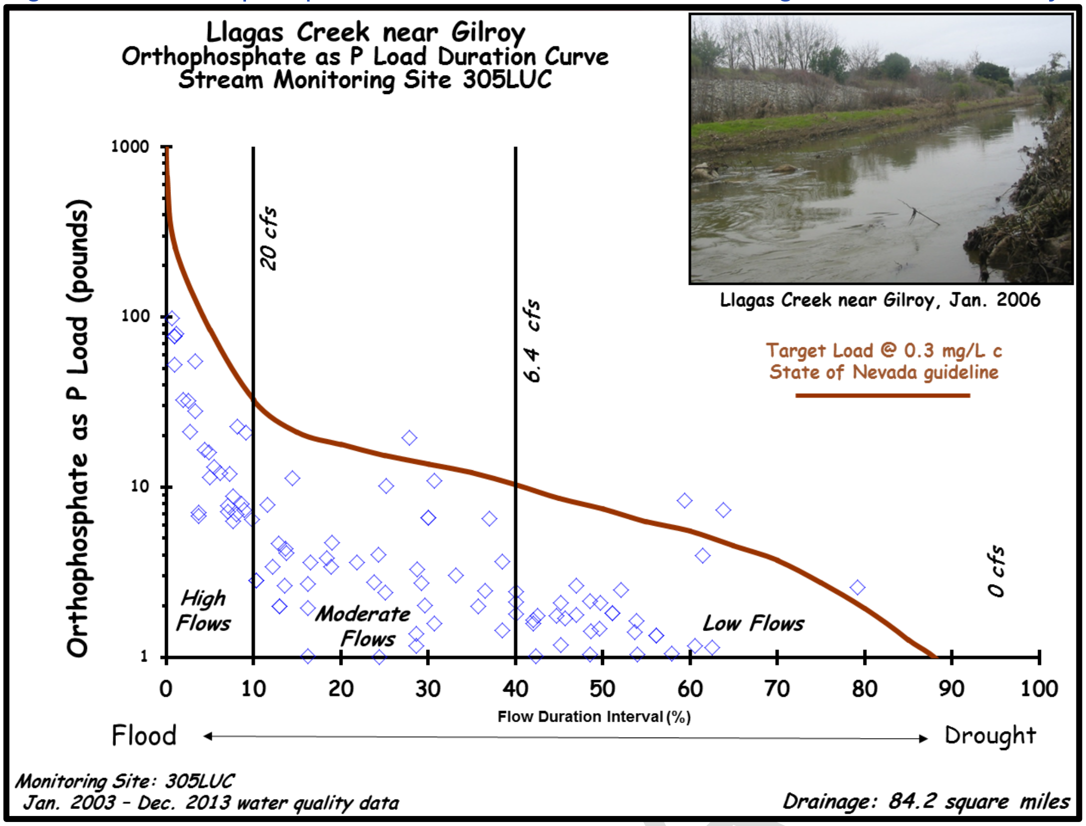


Figure 5-33. Orthophosphate a P load duration curve for Llagas Creek near Gilroy



5.2 Data Assessment of Potential for GWR Impairments

Data and narrative for this section is pending

5.3 Summary Water Quality Statistics

5.3.1 Statistical Summary of 1999-2010 Monitoring Data

summary statistics for the last ten years of water quality data for the TMDL project area. As noted above, these water quality data represent the suite of samples that are used in this TMDL to assess water quality status and impairment, consistent with the California 303(d) Listing Policy and the Water Quality Control Plan for the Central Coast Region.

Table 5-6. Summary statistics for nitrate as N (units=mg/L) and exceedances of drinking water standard in streams of the Pajaro River basin.

Waterbody	Monitoring Site ID	No. of Samples	Temporal Representation		Arithmetic Mean	Min	25%	50% (median)	75%	Max	No. Exceeding 10mg/L (MUN Standard)	% Exceeding 10 mg/L
Beach Road Ditch	**All sites**	1,140	10/4/2000	12/17/2013	40.55	0.00	22.30	40.46	57.94	133.00	1,020	89%
	BRD	103	12/10/2002	12/17/2013	34.63	0.02	24.86	30.74	45.31	69.38	98	95%
	305-BEACH-21	181	10/4/2000	5/2/2009	43.05	0.02	31.22	44.85	57.94	115.50	162	90%
	BR_WMI	164	10/4/2000	3/20/2007	21.49	0.00	17.13	21.15	26.50	85.80	138	84%
	BR_WS3	177	10/25/2000	3/20/2007	53.87	2.99	41.85	56.54	67.06	125.00	170	96%
	BR_WS1	29	1/16/2001	12/12/2006	35.28	0.30	5.23	22.47	60.61	112.49	20	69%
	BR_WS2	162	11/22/2000	3/20/2007	49.76	0.67	37.30	48.30	63.44	112.00	160	99%
	BR_FGB	165	10/4/2000	3/20/2007	24.09	0.70	8.78	19.98	34.57	133.00	118	72%
	BR_DW2	49	2/13/2001	12/29/2002	71.69	55.64	66.42	71.00	76.49	88.79	49	100%
	BR_PAN	54	1/30/2001	9/21/2004	50.37	0.69	38.38	54.64	62.01	84.69	52	96%
	BR_THU	56	12/5/2000	9/21/2004	44.90	0.20	31.42	48.20	57.33	97.38	53	95%
Bodfish Creek	305CAW097	1	5/27/2003	5/27/2003	0.09	0.09	0.09	0.09	0.09	0.09	0	0%
Browns Creek	**All sites**	125	12/10/2002	12/17/2013	0.19	0.02	0.02	0.02	0.23	9.72	0	0%
	BC	100	12/10/2002	12/17/2013	0.24	0.02	0.02	0.02	0.23	9.72	0	0%
	305-BROWN-21	25	5/8/2004	11/20/2004	0.03	0.02	0.02	0.02	0.02	0.12	0	0%
Carnadero Creek	**All sites**	157	1/25/2005	12/10/2013	7.77	0.01	1.40	2.70	9.12	61.55	39	25%
	305CAN	101	1/24/2006	12/10/2013	7.22	0.01	1.20	1.84	4.67	61.55	19	19%
	305CAR	56	1/25/2005	12/13/2011	8.78	0.58	2.48	4.96	13.01	39.12	20	36%
Casserly Creek	**All sites**	163	12/10/2002	12/17/2013	3.21	0.02	0.45	2.26	3.73	18.98	19	12%
	CA1	63	1/21/2003	4/1/2013	0.36	0.02	0.02	0.23	0.55	1.58	0	0%
	CC_CAS	1	3/11/2003	3/11/2003	7.42	7.42	7.42	7.42	7.42	7.42	0	0%
	CA2	98	12/10/2002	12/17/2013	5.03	0.02	2.55	3.28	6.81	18.98	19	19%
	CS_MMR	1	8/17/2006	8/17/2006	0.33	0.33	0.33	0.33	0.33	0.33	0	0%
Clear Creek	305CLCSBR	1	6/11/2008	6/11/2008	0.14	0.14	0.14	0.14	0.14	0.14	0	0%
Corralitos Creek	**All sites**	961	7/11/2000	12/17/2013	1.40	0.00	0.02	0.23	1.59	33.51	12	1%
	305COB_SCC	8	7/11/2000	5/8/2006	0.10	0.02	0.06	0.08	0.14	0.24	0	0%
	305-CORRA-21	342	10/4/2000	5/21/2013	2.23	0.02	0.67	1.25	2.94	33.51	4	1%
	CO_BVR	225	10/4/2000	12/17/2013	0.10	0.01	0.02	0.05	0.11	4.07	0	0%
	305-SALSI-21	31	5/1/2004	11/20/2004	5.31	0.02	3.50	5.00	6.61	12.82	3	10%
	305-CORRA-24	134	7/11/2000	12/17/2013	0.11	0.01	0.02	0.02	0.05	4.97	0	0%
	305-CORRA-22	10	5/17/2003	5/1/2010	0.27	0.04	0.05	0.07	0.43	1.03	0	0%
	CO3	96	12/12/2002	12/17/2013	2.43	0.02	0.23	0.79	3.73	11.75	3	3%
	CO_VAR	85	1/16/2001	4/1/2013	0.09	0.00	0.02	0.02	0.05	2.94	0	0%
	305-CORRA-23	30	5/8/2004	11/20/2004	4.55	1.00	3.00	4.00	5.00	10.86	2	7%

Waterbody	Monitoring Site ID	No. of Samples	Temporal Representation		Arithmetic Mean	Min	25%	50% (median)	75%	Max	No. Exceeding 10mg/L (MUN Standard)	% Exceeding 10 mg/L
Unnamed tributary to Corralitos Creek	UNT	93	12/12/2002	12/17/2013	8.93	0.02	4.60	7.23	11.53	26.89	31	33%
Coward Creek	CW	9	4/3/2003	1/23/2012	20.04	1.81	8.36	12.43	28.70	61.02	6	67%
Furlong Creek	**All sites**	159	3/11/2003	12/13/2011	31.12	3.58	25.30	32.59	35.83	89.12	155	97%
	305FUF	54	1/25/2005	12/13/2011	34.13	4.40	29.64	35.00	38.55	89.12	52	96%
	FC_FLR	105	3/11/2003	3/13/2007	29.56	3.58	23.82	31.15	34.80	74.70	103	98%
Gallighan Slough	GS	76	12/12/2002	12/17/2013	4.35	0.40	2.03	3.50	4.80	29.15	4	5%
Green Valley Creek	GV	99	12/10/2002	12/17/2013	3.84	0.40	1.80	2.71	5.65	24.41	1	1%
Tributary to Green Valley Creek	GVT	99	12/10/2002	12/17/2013	21.48	2.49	8.36	14.24	29.14	116.62	67	68%
Harkins Slough	**All sites**	300	12/12/2002	12/17/2013	2.08	0.01	0.02	0.02	0.68	27.35	27	9%
	305HAR-BUE	3	5/17/2003	5/7/2005	0.14	0.05	0.06	0.07	0.19	0.31	0	0%
	305HAR	168	12/12/2002	12/17/2013	0.15	0.01	0.02	0.02	0.02	4.10	0	0%
	305-HARKI-22	4	5/17/2003	5/7/2005	4.93	0.02	0.19	3.94	8.67	11.83	1	25%
	HS1	105	12/12/2002	12/17/2013	5.39	0.02	0.02	1.13	9.94	27.35	26	25%
	HS3	20	1/16/2003	4/16/2012	0.59	0.02	0.17	0.36	0.57	3.39	0	0%
Hughes Creek	HC	23	1/21/2003	1/31/2013	0.95	0.20	0.45	0.90	1.24	3.16	0	0%
Laguna Creek	305LGCACR	1	7/16/2008	7/16/2008	0.00	0.00	0.00	0.00	0.00	0.00	0	0%
Little Arthur Creek	305WE0883	1	6/28/2001	6/28/2001	0.17	0.17	0.17	0.17	0.17	0.17	0	0%
Llagas Creek	**All sites**	1,290	1/19/1998	12/10/2013	7.75	0.00	0.20	1.92	13.97	51.50	454	35%
	305OAK	146	2/10/1998	3/13/2007	0.20	0.01	0.07	0.15	0.30	1.96	0	0%
	305LGCBRC	2	7/11/2006	6/30/2010	0.00	0.00	0.00	0.00	0.00	0.00	0	0%
	305VIS	20	2/10/1998	5/25/2004	2.52	0.01	0.68	1.32	4.03	12.10	1	5%
	305CHE	109	2/10/1998	3/13/2007	0.15	0.00	0.03	0.07	0.17	1.19	0	0%
	LL_CHU	51	10/1/2002	12/17/2004	0.42	0.00	0.07	0.20	0.79	2.21	0	0%
	305LHB	42	6/9/2004	3/26/2008	26.90	0.20	21.16	29.24	34.74	51.50	36	86%
	305HOL	33	2/10/1998	1/25/2008	10.81	0.46	1.50	2.82	15.33	31.72	14	42%
	305LEA	58	12/15/2002	5/25/2011	1.78	0.01	0.63	1.29	1.77	19.21	2	3%
	305MON	252	2/10/1998	3/13/2007	0.60	0.00	0.07	0.30	0.78	20.60	1	0%
	305LUC	252	2/10/1998	12/10/2013	17.80	0.02	11.54	18.36	24.23	37.70	200	79%
	305PS0061	1	6/17/2009	6/17/2009	0.01	0.01	0.01	0.01	0.01	0.01	0	0%
	305LLA	324	1/19/1998	12/13/2011	11.27	0.52	7.57	11.71	14.70	29.45	200	62%

Waterbody	Monitoring Site ID	No. of Samples	Temporal Representation		Arithmetic Mean	Min	25%	50% (median)	75%	Max	No. Exceeding 10mg/L (MUN Standard)	% Exceeding 10 mg/L
West Branch Llagas Creek	**All sites**	52	2/12/1998	7/18/2013	1.50	0.02	0.74	1.10	2.00	4.46	0	0%
	SW2	17	2/12/1998	7/18/2013	1.34	0.32	0.79	1.00	2.00	3.00	0	0%
	SW1	17	5/14/1998	4/25/2013	1.00	0.02	0.45	1.00	1.00	3.00	0	0%
	SW3	6	12/16/2003	7/22/2005	2.32	1.20	1.81	2.00	2.75	4.00	0	0%
	LL_WDA	5	12/15/2002	3/15/2003	2.26	0.70	1.44	2.09	2.69	4.37	0	0%
	LL_WHI	7	12/15/2002	5/2/2003	1.91	0.36	0.73	1.56	2.75	4.46	0	0%
West Branch Llagas Creek Tributary	SW4	3	10/19/2004	7/25/2005	1.38	0.02	1.01	2.00	2.06	2.12	0	0%
Little Llagas	LL_LLC	4	12/23/2002	5/11/2004	1.67	0.01	0.87	1.77	2.57	3.11	0	0%
Mattos Gulch	MG	1	4/20/2006	4/20/2006	0.23	0.23	0.23	0.23	0.23	0.23	0	0%
McGowan Ditch	**All sites**	7	11/14/2006	9/22/2009	15.04	5.49	6.91	9.13	22.93	31.00	3	43%
	305MDD	6	1/6/2008	9/22/2009	13.84	5.49	6.83	8.09	19.98	31.00	2	33%
	MC_TRA	1	11/14/2006	11/14/2006	22.25	22.25	22.25	22.25	22.25	22.25	1	100%
Miller's Canal	**All sites**	401	2/10/1998	5/30/2013	0.31	0.00	0.03	0.09	0.30	9.58	0	0%
	305FRA	391	2/10/1998	5/30/2013	0.32	0.00	0.03	0.09	0.31	9.58	0	0%
	MC_4	1	7/12/2006	7/12/2006	0.04	0.04	0.04	0.04	0.04	0.04	0	0%
	MC_5	1	7/12/2006	7/12/2006	0.08	0.08	0.08	0.08	0.08	0.08	0	0%
	MC_6	1	7/12/2006	7/12/2006	0.11	0.11	0.11	0.11	0.11	0.11	0	0%
	MC_7	1	7/12/2006	7/12/2006	0.09	0.09	0.09	0.09	0.09	0.09	0	0%
	MC_9	1	7/12/2006	7/12/2006	0.07	0.07	0.07	0.07	0.07	0.07	0	0%
	MC_10	1	7/12/2006	7/12/2006	0.21	0.21	0.21	0.21	0.21	0.21	0	0%
	MC_11	1	7/12/2006	7/12/2006	0.22	0.22	0.22	0.22	0.22	0.22	0	0%
	MC_12	1	7/12/2006	7/12/2006	0.25	0.25	0.25	0.25	0.25	0.25	0	0%
	MC_2	1	7/12/2006	7/12/2006	0.01	0.01	0.01	0.01	0.01	0.01	0	0%
	MC_3	1	7/12/2006	7/12/2006	0.02	0.02	0.02	0.02	0.02	0.02	0	0%
Pacheco Creek	**All sites**	489	1/19/1998	12/13/2011	1.14	0.01	0.34	0.64	1.26	18.95	2	0%
	305CAW049	1	5/29/2003	5/29/2003	0.04	0.04	0.04	0.04	0.04	0.04	0	0%
	PC_CDF	1	9/2/2003	9/2/2003	0.01	0.01	0.01	0.01	0.01	0.01	0	0%
	305PAC	252	1/19/1998	12/13/2011	1.68	0.01	0.44	1.16	1.99	18.95	2	1%
	305PACLOV	87	11/11/2003	3/13/2007	0.66	0.02	0.29	0.54	0.85	7.04	0	0%
	PC_NFK	1	7/17/2006	7/17/2006	0.44	0.44	0.44	0.44	0.44	0.44	0	0%
	PC_SFR	105	10/1/2002	8/29/2006	0.63	0.17	0.38	0.56	0.73	2.14	0	0%
	305PACWAL	42	9/2/2003	10/24/2006	0.27	0.02	0.05	0.13	0.42	1.82	0	0%
Pajaro River	**All sites**	2371	1/19/1998	12/17/2013	7.15	0.00	4.13	6.44	9.22	34.14	482	20%
	305PMO_SCC	4	12/11/2001	4/3/2003	2.26	0.00	0.00	1.62	3.88	5.81	0	0%
	PR1	99	12/12/2002	12/17/2013	9.58	0.02	5.88	7.46	13.11	25.00	37	37%

Waterbody	Monitoring Site ID	No. of Samples	Temporal Representation		Arithmetic Mean	Min	25%	50% (median)	75%	Max	No. Exceeding 10mg/L (MUN Standard)	% Exceeding 10 mg/L
	PajPump	20	5/15/2009	12/7/2010	4.72	0.79	2.75	5.07	6.45	9.81	0	0%
	305PS0057	1	6/16/2009	6/16/2009	7.78	7.78	7.78	7.78	7.78	7.78	0	0%
	305PAJ	319	1/19/1998	12/13/2011	7.51	0.72	4.68	6.77	9.48	34.14	71	22%
	305CHI	611	1/19/1998	12/10/2013	8.27	0.01	4.74	7.15	10.45	32.50	164	27%
	PA_H25	87	7/8/2003	3/13/2007	8.67	0.76	5.05	8.45	11.09	20.60	29	33%
	305PJP	395	10/4/2000	12/10/2013	6.17	0.01	3.96	6.05	7.93	14.60	37	9%
	305MUR	337	2/10/1998	6/26/2013	7.97	0.10	5.20	7.35	10.81	18.80	94	28%
	305THU	440	1/19/1998	12/17/2013	5.01	0.02	2.49	4.77	6.90	32.22	32	7%
	PA_UVAS	1	7/13/2006	7/13/2006	16.20	16.20	16.20	16.20	16.20	16.20	1	100%
	305PJE_L	12	1/6/2008	9/22/2009	1.77	0.02	0.11	0.69	1.09	10.90	1	8%
	305PJE_U	12	1/6/2008	9/22/2009	2.15	0.20	0.74	1.38	2.26	6.42	0	0%
	305PS0034	1	6/17/2008	6/17/2008	8.95	8.95	8.95	8.95	8.95	8.95	0	0%
	PA_FLR	17	12/23/2002	5/25/2004	4.17	0.18	2.93	4.54	4.79	11.03	1	6%
	PA_13	1	7/12/2006	7/12/2006	11.85	11.85	11.85	11.85	11.85	11.85	1	100%
	PA_14	1	7/12/2006	7/12/2006	11.90	11.90	11.90	11.90	11.90	11.90	1	100%
	PA_15	1	7/12/2006	7/12/2006	12.00	12.00	12.00	12.00	12.00	12.00	1	100%
	PA_16	1	7/12/2006	7/12/2006	11.90	11.90	11.90	11.90	11.90	11.90	1	100%
	PA_18	1	7/12/2006	7/12/2006	11.85	11.85	11.85	11.85	11.85	11.85	1	100%
	PA_19	1	7/13/2006	7/13/2006	15.60	15.60	15.60	15.60	15.60	15.60	1	100%
	PA_21	1	7/13/2006	7/13/2006	15.40	15.40	15.40	15.40	15.40	15.40	1	100%
	PA_22	1	7/13/2006	7/13/2006	15.50	15.50	15.50	15.50	15.50	15.50	1	100%
	PA_23	1	7/13/2006	7/13/2006	15.40	15.40	15.40	15.40	15.40	15.40	1	100%
	PA_24	1	7/13/2006	7/13/2006	14.95	14.95	14.95	14.95	14.95	14.95	1	100%
	PA_26	1	7/13/2006	7/13/2006	13.50	13.50	13.50	13.50	13.50	13.50	1	100%
	PA_27	1	7/13/2006	7/13/2006	17.20	17.20	17.20	17.20	17.20	17.20	1	100%
	PA_29	1	7/13/2006	7/13/2006	21.05	21.05	21.05	21.05	21.05	21.05	1	100%
	PA_30	1	7/13/2006	7/13/2006	15.25	15.25	15.25	15.25	15.25	15.25	1	100%
	PA_31	1	7/13/2006	7/13/2006	16.65	16.65	16.65	16.65	16.65	16.65	1	100%
Pescadero Creek	305PES	4	2/10/1998	2/19/1998	1.30	1.19	1.21	1.30	1.40	1.41	0	0%
Pinto Lake Outflow Ditch	PLO	92	12/12/2002	8/15/2013	9.62	0.23	3.43	9.61	13.90	27.57	44	48%
Salsipuedes Creek	**All sites**	363	1/19/1998	11/21/2013	3.55	0.01	1.14	1.90	4.85	63.42	12	3%
	305CAW057	1	6/24/2003	6/24/2003	6.71	6.71	6.71	6.71	6.71	6.71	0	0%
	305COR	362	1/19/1998	11/21/2013	3.54	0.01	1.13	1.88	4.82	63.42	12	3%
San Benito River	**All sites**	451	1/19/1998	12/12/2011	1.29	0.00	0.02	0.20	1.50	42.60	3	1%
	305SBH	2	1/24/2008	2/22/2008	0.29	0.20	0.24	0.29	0.33	0.37	0	0%
	SB_BWC	1	6/19/2006	6/19/2006	0.01	0.01	0.01	0.01	0.01	0.01	0	0%

Waterbody	Monitoring Site ID	No. of Samples	Temporal Representation		Arithmetic Mean	Min	25%	50% (median)	75%	Max	No. Exceeding 10mg/L (MUN Standard)	% Exceeding 10 mg/L
	SB_PA	1	7/13/2006	7/13/2006	0.10	0.10	0.10	0.10	0.10	0.10	0	0%
	305SAN	395	1/19/1998	12/12/2011	1.46	0.00	0.03	0.40	1.91	42.60	3	1%
	305BRI	52	1/24/2005	12/12/2011	0.05	0.01	0.01	0.02	0.12	0.19	0	0%
San Juan Creek	**All sites**	419	11/6/2002	12/10/2013	30.59	0.13	18.08	31.10	41.02	78.90	390	93%
	305SJN	333	7/22/2003	12/3/2012	28.81	0.13	17.08	29.20	40.10	74.31	305	92%
	305SNJ	12	1/29/2013	12/10/2013	37.99	20.20	32.55	39.35	43.88	57.20	12	100%
	SJ_101	53	11/6/2002	9/29/2004	30.97	4.17	19.57	33.41	40.82	51.66	52	98%
	SJ_156	2	8/4/2003	3/29/2005	34.52	22.00	28.26	34.52	40.79	47.05	2	100%
	305MVR	9	1/24/2008	12/17/2008	64.36	22.50	65.20	68.05	72.14	78.90	9	100%
	SJ_PA	1	7/13/2006	7/13/2006	27.00	27.00	27.00	27.00	27.00	27.00	1	100%
	305PRR	9	1/24/2008	12/17/2008	50.05	22.90	49.32	53.90	57.12	61.40	9	100%
West Branch San Juan Creek	305ACR	9	1/24/2008	12/17/2008	6.62	0.51	2.40	6.24	10.30	16.46	3	33%
San Martin Creek	SM_FOO	1	2/25/2004	2/25/2004	1.20	1.20	1.20	1.20	1.20	1.20	0	0%
Struve Slough	**All sites**	137	5/17/2003	12/12/2011	0.63	0.01	0.02	0.03	0.07	29.41	4	3%
	305STR-HAR	5	5/17/2003	5/7/2005	0.08	0.02	0.02	0.09	0.10	0.20	0	0%
	305STL	132	5/17/2003	12/12/2011	0.65	0.01	0.02	0.03	0.07	29.41	4	3%
West Branch of Struve Slough	305-WSTRU-21	7	5/17/2003	8/30/2004	0.21	0.02	0.02	0.02	0.20	1.00	0	0%
Swanson Creek	305SSCAUC	1	6/29/2010	6/29/2010	0.02	0.02	0.02	0.02	0.02	0.02	0	0%
Tequisquita Slough	**All sites**	233	1/19/1998	12/10/2013	5.53	0.01	1.81	4.36	8.29	51.75	32	14%
	TS_SFL	2	6/23/2006	7/12/2006	0.06	0.02	0.04	0.06	0.07	0.09	0	0%
	305TES	231	1/19/1998	12/10/2013	5.57	0.01	1.87	4.37	8.31	51.75	32	14%
Tres Pinos Creek	**All sites**	51	2/19/1998	10/19/2011	0.41	0.01	0.02	0.11	0.79	1.85	0	0%
	305TRE	50	2/19/1998	10/19/2011	0.42	0.01	0.02	0.10	0.80	1.85	0	0%
	TP_H25	1	6/22/2006	6/22/2006	0.27	0.27	0.27	0.27	0.27	0.27	0	0%
Uvas Creek	**All sites**	701	1/19/1998	12/13/2011	0.69	0.00	0.20	0.54	0.99	8.86	0	0%
	305CAW161	1	5/19/2003	5/19/2003	1.56	1.56	1.56	1.56	1.56	1.56	0	0%
	305UVCASC	1	6/29/2010	6/29/2010	0.02	0.02	0.02	0.02	0.02	0.02	0	0%
	UV_URA	77	1/7/2003	3/13/2007	0.32	0.00	0.03	0.09	0.30	2.64	0	0%
	305UVA	193	1/19/1998	12/13/2011	1.11	0.01	0.63	0.99	1.30	8.86	0	0%
	UV_UCP	1	7/10/2006	7/10/2006	0.01	0.01	0.01	0.01	0.01	0.01	0	0%
	UV_152	223	10/1/2002	3/13/2007	0.63	0.06	0.26	0.58	0.86	5.95	0	0%
	UV_THO	90	11/12/2002	3/13/2007	0.91	0.09	0.52	0.91	1.18	2.71	0	0%
	UV_URB	115	10/15/2002	3/13/2007	0.17	0.01	0.07	0.12	0.25	1.10	0	0%
Watsonville Slough	**All sites**	1184	2/12/1998	12/17/2013	8.41	0.00	0.87	4.18	14.48	61.64	403	34%
	305WAT-AND	292	10/4/2000	12/17/2013	9.71	0.02	1.76	5.42	16.48	48.06	119	41%

Waterbody	Monitoring Site ID	No. of Samples	Temporal Representation		Arithmetic Mean	Min	25%	50% (median)	75%	Max	No. Exceeding 10mg/L (MUN Standard)	% Exceeding 10 mg/L
	305WAT-SHE	270	10/25/2000	12/17/2013	13.05	0.02	5.30	11.89	18.98	61.64	154	57%
	WS1	108	12/12/2002	12/17/2013	4.41	0.01	0.02	0.90	5.14	38.42	19	18%
	305-WATSO-23	25	5/17/2003	9/22/2009	19.35	0.02	3.14	16.00	24.17	50.00	16	64%
	WS_ERR	173	10/4/2000	3/20/2007	1.17	0.00	0.09	0.24	0.80	16.26	4	2%
	305WAT-HAR	15	5/17/2003	5/7/2005	0.17	0.02	0.02	0.02	0.05	1.00	0	0%
	305WAT-LEE	171	10/4/2000	3/20/2007	8.29	0.01	2.46	4.76	12.79	35.20	54	32%
	305WSA	130	2/12/1998	7/18/2013	7.86	0.03	0.94	2.89	15.19	34.18	37	28%

Table 5-7. TMDL project area summary statistics for orthophosphate as P (units = mg/L).

Waterbody	Monitoring Site ID	No. of Samples	Temporal Representation		Arithmetic Mean	Min	25%	50% (median)	75%	Max	No. Exceeding 0.3 mg/L[A]	% Exceeding 0.3 mg/L
Beach Road Ditch	**All sites**	1,117	10/4/2000	12/17/2013	0.249	0.003	0.055	0.116	0.253	4.953	234	21%
	305-BEACH-21	169	10/4/2000	3/20/2007	0.204	0.005	0.050	0.109	0.229	1.525	29	17%
	BR_DW2	49	2/13/2001	12/29/2002	0.099	0.003	0.031	0.081	0.140	0.430	2	4%
	BR_FGB	165	10/4/2000	3/20/2007	0.279	0.015	0.110	0.198	0.396	1.440	56	34%
	BR_PAN	56	1/30/2001	9/21/2004	0.345	0.014	0.061	0.156	0.298	1.878	14	25%
	BR_THU	57	12/5/2000	9/21/2004	0.520	0.004	0.069	0.328	0.847	2.267	29	51%
	BR_WMI	165	10/4/2000	3/20/2007	0.271	0.021	0.068	0.093	0.172	4.953	20	12%
	BR_WS1	29	1/16/2001	12/12/2006	0.500	0.004	0.204	0.320	0.584	2.044	16	55%
	BR_WS2	162	11/22/2000	3/20/2007	0.247	0.008	0.076	0.125	0.218	1.976	29	18%
	BR_WS3	177	10/25/2000	3/20/2007	0.221	0.004	0.046	0.097	0.208	1.886	30	17%
	BRD	88	12/10/2002	12/17/2013	0.069	0.005	0.005	0.005	0.005	0.670	9	10%
Browns Creek	BC	85	12/10/2002	12/17/2013	0.028	0.005	0.005	0.005	0.005	0.470	1	1%
Carnadero Creek	**All sites**	128	1/25/2005	12/10/2013	0.059	0.001	0.014	0.036	0.072	0.455	5	4%
	305CAN	100	1/24/2006	12/10/2013	0.058	0.001	0.005	0.028	0.070	0.455	5	5%
	305CAR	28	1/25/2005	12/13/2011	0.060	0.016	0.036	0.046	0.085	0.170	0	0%
Casserly Creek	**All sites**	143	12/10/2002	12/17/2013	0.093	0.005	0.005	0.005	0.120	1.890	8	6%
	CA1	58	1/21/2003	4/1/2013	0.072	0.005	0.005	0.005	0.070	1.890	1	2%
	CA2	83	12/10/2002	12/17/2013	0.106	0.005	0.005	0.005	0.160	0.890	7	8%
	CC_CAS	1	3/11/2003	3/11/2003	0.146	0.146	0.146	0.146	0.146	0.146	0	0%
	CS_MMR	1	8/17/2006	8/17/2006	0.130	0.130	0.130	0.130	0.130	0.130	0	0%
Clear Creek	305CLCSBR	1	6/11/2008	6/11/2008	0.004	0.004	0.004	0.004	0.004	0.004	0	0%
Corralitos Creek	**All sites**	758	10/4/2000	12/17/2013	0.073	0.005	0.005	0.054	0.096	1.459	21	3%
	305-CORRA-21	314	10/4/2000	5/21/2013	0.103	0.005	0.032	0.079	0.117	1.459	14	4%

Waterbody	Monitoring Site ID	No. of Samples	Temporal Representation		Arithmetic Mean	Min	25%	50% (median)	75%	Max	No. Exceeding 0.3 mg/L[A]	% Exceeding 0.3 mg/L
	305-CORRA-22	6	5/17/2003	5/1/2010	0.353	0.018	0.095	0.227	0.587	0.888	3	50%
	305-CORRA-24	86	12/10/2002	12/17/2013	0.015	0.005	0.005	0.005	0.005	0.150	0	0%
	305-SALSI-21	1	5/1/2004	5/1/2004	0.136	0.136	0.136	0.136	0.136	0.136	0	0%
	CO_BVR	188	10/4/2000	12/17/2013	0.075	0.005	0.005	0.068	0.102	0.511	2	1%
	CO_VAR	80	1/16/2001	4/1/2013	0.055	0.005	0.005	0.042	0.081	0.508	1	1%
	CO3	83	12/12/2002	12/17/2013	0.014	0.005	0.005	0.005	0.005	0.670	1	1%
Unnamed tributary to Corralitos Creek	UNT	78	12/12/2002	12/17/2013	0.198	0.005	0.005	0.005	0.328	1.650	21	27%
Coward Creek	CW	9	4/3/2003	1/23/2012	0.509	0.080	0.100	0.570	0.740	1.200	6	67%
Furlong Creek	**All sites**	132	3/11/2003	12/13/2011	0.283	0.005	0.086	0.141	0.260	6.600	27	20%
	305FUF	27	1/25/2005	12/13/2011	0.478	0.005	0.054	0.098	0.380	6.600	7	26%
	FC_FLR	105	3/11/2003	3/13/2007	0.233	0.008	0.089	0.151	0.257	1.578	20	19%
Gallighan Slough	GS	67	12/12/2002	12/17/2013	0.033	0.005	0.005	0.005	0.005	0.700	3	4%
Green Valley Creek	GV	84	12/10/2002	12/17/2013	0.159	0.005	0.005	0.005	0.128	4.120	14	17%
Green Valley Creek Tributary	GVT	84	12/10/2002	12/17/2013	1.880	0.005	0.138	0.470	1.940	19.600	54	64%
Harkins Slough	**All sites**	229	12/12/2002	12/17/2013	0.145	0.005	0.005	0.005	0.180	1.840		18%
	305HAR	114	12/12/2002	12/17/2013	0.069	0.005	0.005	0.005	0.025	0.980	9	8%
	305HAR-BUE	3	5/17/2003	5/7/2005	0.043	0.018	0.018	0.018	0.055	0.092	0	0%
	305-HARKI-22	3	5/17/2003	5/7/2005	0.412	0.160	0.271	0.381	0.538	0.695	2	67%
	HS1	89	12/12/2002	12/17/2013	0.221	0.005	0.005	0.005	0.340	1.840	25	28%
	HS3	20	1/16/2003	4/16/2012	0.212	0.005	0.005	0.140	0.298	1.090	5	25%
Hughes Creek	HC	20	1/21/2003	1/31/2013	0.031	0.005	0.005	0.005	0.038	0.130	0	0%
Laguna Creek	305LGCACR	1	7/16/2008	7/16/2008	0.055	0.055	0.055	0.055	0.055	0.055	0	0%
Llagas Creek	**All sites**	1,162	1/19/1998	12/10/2013	0.071	0.000	0.023	0.042	0.076	0.958	44	4%
	305CHE	98	2/10/1998	3/13/2007	0.043	0.002	0.015	0.024	0.037	0.424	2	2%
	305HOL	17	2/10/1998	1/25/2008	0.039	0.002	0.005	0.010	0.027	0.336	1	6%
	305LEA	48	12/15/2002	5/25/2011	0.062	0.001	0.020	0.039	0.082	0.220	0	0%
	305LGCBRC	2	7/11/2006	6/30/2010	0.014	0.009	0.012	0.014	0.017	0.019	0	0%
	305LHB	41	6/9/2004	3/26/2008	0.051	0.008	0.018	0.035	0.057	0.378	1	2%
	305LLA	275	1/19/1998	12/13/2011	0.102	0.003	0.032	0.056	0.105	0.958	23	8%
	305LUC	240	2/10/1998	12/10/2013	0.082	0.001	0.031	0.056	0.088	0.456	8	3%
	305MON	238	2/10/1998	3/13/2007	0.057	0.002	0.024	0.038	0.059	0.598	5	2%
	305OAK	134	2/10/1998	3/13/2007	0.064	0.001	0.022	0.042	0.070	0.812	3	2%
	305PS0061	1	6/17/2009	6/17/2009	0.026	0.026	0.026	0.026	0.026	0.026	0	0%

Waterbody	Monitoring Site ID	No. of Samples	Temporal Representation		Arithmetic Mean	Min	25%	50% (median)	75%	Max	No. Exceeding 0.3 mg/L[A]	% Exceeding 0.3 mg/L
	305VIS	17	2/10/1998	6/9/2004	0.036	0.000	0.009	0.017	0.042	0.209	0	0%
	LL_CHU	51	10/1/2002	12/17/2004	0.052	0.008	0.022	0.034	0.049	0.356	1	2%
West Branch Llagas Creek	**All sites**	12	12/15/2002	5/2/2003	0.716	0.204	0.459	0.628	0.838	1.661	11	92%
	LL_WDA	5	12/15/2002	3/15/2003	0.694	0.472	0.608	0.648	0.805	0.936	5	100%
	LL_WHI	7	12/15/2002	5/2/2003	0.731	0.204	0.417	0.494	0.963	1.661	6	86%
Little Llagas	LL_LLC	4	12/23/2002	5/11/2004	0.143	0.019	0.034	0.137	0.245	0.279	0	0%
Mattos Gulch	MG	1	4/20/2006	4/20/2006	0.005	0.005	0.005	0.005	0.005	0.005	0	0%
McGowan Ditch	MC_TRA	1	11/14/2006	11/14/2006	0.130	0.130	0.130	0.130	0.130	0.130	0	0%
Millers Canal	**All sites**	362	2/10/1998	5/30/2013	0.139	0.000	0.033	0.067	0.161	6.140	24	7%
	305FRA	352	2/10/1998	5/30/2013	0.140	0.000	0.033	0.064	0.162	6.140	24	7%
	MC_10	1	7/12/2006	7/12/2006	0.153	0.153	0.153	0.153	0.153	0.153	0	0%
	MC_11	1	7/12/2006	7/12/2006	0.147	0.147	0.147	0.147	0.147	0.147	0	0%
	MC_12	1	7/12/2006	7/12/2006	0.132	0.132	0.132	0.132	0.132	0.132	0	0%
	MC_2	1	7/12/2006	7/12/2006	0.053	0.053	0.053	0.053	0.053	0.053	0	0%
	MC_3	1	7/12/2006	7/12/2006	0.030	0.030	0.030	0.030	0.030	0.030	0	0%
	MC_4	1	7/12/2006	7/12/2006	0.096	0.096	0.096	0.096	0.096	0.096	0	0%
	MC_5	1	7/12/2006	7/12/2006	0.142	0.142	0.142	0.142	0.142	0.142	0	0%
	MC_6	1	7/12/2006	7/12/2006	0.115	0.115	0.115	0.115	0.115	0.115	0	0%
	MC_7	1	7/12/2006	7/12/2006	0.129	0.129	0.129	0.129	0.129	0.129	0	0%
	MC_9	1	7/12/2006	7/12/2006	0.142	0.142	0.142	0.142	0.142	0.142	0	0%
Pacheco Creek	**All sites**	467	1/19/1998	12/13/2011	0.061	0.002	0.018	0.029	0.056	1.288	16	3%
	305PAC	214	1/19/1998	12/13/2011	0.084	0.002	0.020	0.038	0.066	1.288	14	7%
	305PACLOV	86	11/11/2003	3/13/2007	0.036	0.005	0.018	0.026	0.034	0.343	1	1%
	305PACWAL	41	9/2/2003	10/24/2006	0.026	0.003	0.012	0.015	0.026	0.169	0	0%
	Pach_conf	19	5/31/2005	11/3/2006	0.087	0.033	0.065	0.065	0.098	0.196	0	0%
	PC_CDF	1	9/2/2003	9/2/2003	0.012	0.012	0.012	0.012	0.012	0.012	0	0%
	PC_NFK	1	7/17/2006	7/17/2006	0.103	0.103	0.103	0.103	0.103	0.103	0	0%
	PC_SFR	105	10/1/2002	8/29/2006	0.044	0.003	0.019	0.026	0.039	0.554	1	1%
Pajaro River	**All sites**	1,979	1/19/1998	12/17/2013	0.110	0.001	0.048	0.090	0.140	1.336	91	5%
	305CHI	559	1/19/1998	12/10/2013	0.138	0.010	0.070	0.110	0.182	0.900	39	7%
	305MUR	291	2/10/1998	6/26/2013	0.087	0.003	0.030	0.073	0.109	1.270	8	3%
	305PAJ	273	1/19/1998	12/13/2011	0.111	0.003	0.055	0.088	0.145	0.459	8	3%
	305PJP	360	10/4/2000	12/10/2013	0.126	0.004	0.074	0.105	0.144	0.874	18	5%
	305PS0034	1	6/17/2008	6/17/2008	0.105	0.105	0.105	0.105	0.105	0.105	0	0%
	305PS0057	1	6/16/2009	6/16/2009	0.155	0.155	0.155	0.155	0.155	0.155	0	0%
	305THU	271	1/19/1998	12/17/2013	0.071	0.001	0.005	0.040	0.100	0.780	8	3%
	PA_13	1	7/12/2006	7/12/2006	0.113	0.113	0.113	0.113	0.113	0.113	0	0%
	PA_14	1	7/12/2006	7/12/2006	0.075	0.075	0.075	0.075	0.075	0.075	0	0%
	PA_15	1	7/12/2006	7/12/2006	0.068	0.068	0.068	0.068	0.068	0.068	0	0%

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	PA_16	1	7/12/2006	7/12/2006	0.068	0.068	0.068	0.068	0.068	0.068	0	0%
	PA_18	1	7/12/2006	7/12/2006	0.058	0.058	0.058	0.058	0.058	0.058	0	0%
	PA_19	1	7/13/2006	7/13/2006	0.090	0.090	0.090	0.090	0.090	0.090	0	0%
	PA_21	1	7/13/2006	7/13/2006	0.067	0.067	0.067	0.067	0.067	0.067	0	0%
	PA_22	1	7/13/2006	7/13/2006	0.067	0.067	0.067	0.067	0.067	0.067	0	0%
	PA_23	1	7/13/2006	7/13/2006	0.089	0.089	0.089	0.089	0.089	0.089	0	0%
	PA_24	1	7/13/2006	7/13/2006	0.091	0.091	0.091	0.091	0.091	0.091	0	0%
	PA_26	1	7/13/2006	7/13/2006	0.089	0.089	0.089	0.089	0.089	0.089	0	0%
	PA_27	1	7/13/2006	7/13/2006	0.104	0.104	0.104	0.104	0.104	0.104	0	0%
	PA_29	1	7/13/2006	7/13/2006	0.147	0.147	0.147	0.147	0.147	0.147	0	0%
	PA_30	1	7/13/2006	7/13/2006	0.123	0.123	0.123	0.123	0.123	0.123	0	0%
	PA_31	1	7/13/2006	7/13/2006	0.130	0.130	0.130	0.130	0.130	0.130	0	0%
	PA_FLR	17	12/23/2002	5/25/2004	0.325	0.083	0.126	0.176	0.314	1.336	5	29%
	PA_H25	86	7/8/2003	3/13/2007	0.109	0.010	0.051	0.073	0.138	0.686	3	3%
	PA_UVAS	1	7/13/2006	7/13/2006	0.092	0.092	0.092	0.092	0.092	0.092	0	0%
	PajPump	20	5/15/2009	12/7/2010	0.062	0.005	0.016	0.060	0.093	0.170	0	0%
	PR1	84	12/12/2002	12/17/2013	0.032	0.005	0.005	0.005	0.005	0.320	2	2%
Pescadero Creek	305PES	2	2/10/1998	2/19/1998	0.071	0.030	0.051	0.071	0.092	0.112	0	0%
Pinto Lake Outflow Ditch	PLO	81	12/12/2002	8/15/2013	0.046	0.005	0.005	0.005	0.005	1.160	2	2%
Salsipuedes Creek	305COR	326	12/18/1997	11/21/2013	0.152	0.006	0.092	0.130	0.186	0.887	17	5%
San Benito River	**All sites**	386	1/19/1998	12/12/2011	0.039	0.000	0.011	0.022	0.046	0.454	3	1%
	305BRI	26	1/24/2005	12/12/2011	0.008	0.002	0.005	0.005	0.011	0.028	0	0%
	305SAN	355	1/19/1998	12/12/2011	0.042	0.000	0.012	0.023	0.049	0.454	3	1%
	305SBH	3	1/24/2008	2/22/2008	0.029	0.024	0.026	0.028	0.032	0.036	0	0%
	SB_BWC	1	6/19/2006	6/19/2006	0.085	0.085	0.085	0.085	0.085	0.085	0	0%
	SB_PA	1	7/13/2006	7/13/2006	0.022	0.022	0.022	0.022	0.022	0.022	0	0%
San Juan Creek	**All sites**	392	11/6/2002	12/10/2013	0.359	0.001	0.169	0.289	0.440	1.685	181	46%
	305MVR	9	1/24/2008	12/17/2008	0.093	0.022	0.041	0.067	0.143	0.196	0	0%
	305PRR	9	1/24/2008	12/17/2008	0.048	0.031	0.039	0.047	0.054	0.078	0	0%
	305SJN	305	7/22/2003	12/3/2012	0.371	0.039	0.173	0.290	0.453	1.685	141	46%
	305SNJ	13	1/29/2013	12/10/2013	0.332	0.001	0.222	0.306	0.342	0.836	8	62%
	SJ_101	53	11/6/2002	9/29/2004	0.399	0.104	0.238	0.318	0.462	1.455	31	58%
	SJ_156	2	8/4/2003	3/29/2005	0.182	0.078	0.130	0.182	0.234	0.286	0	0%
	SJ_PA	1	7/13/2006	7/13/2006	0.385	0.385	0.385	0.385	0.385	0.385	1	100%
West Branch of San Juan Creek	305ACR	9	1/24/2008	12/17/2008	1.049	0.384	0.493	0.706	1.215	2.545	9	100%

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San Martin Creek	SM_FOO	1	2/25/2004	2/25/2004	0.630	0.630	0.630	0.630	0.630	0.630	1	100%
Struve Slough	**All sites**	107	5/17/2003	12/12/2011	0.581	0.018	0.347	0.551	0.724	2.275	84	79%
	305STL	104	5/17/2003	12/12/2011	0.592	0.029	0.350	0.565	0.740	2.275	83	80%
	305STR-HAR	3	5/17/2003	5/7/2005	0.193	0.018	0.074	0.130	0.280	0.430	1	33%
West Branch of Struve Slough	305-WSTRU-21	3	5/17/2003	5/7/2005	0.085	0.018	0.018	0.018	0.119	0.220	0	0%
Swanson Creek	305SSCAUC	1	6/29/2010	6/29/2010	0.015	0.015	0.015	0.015	0.015	0.015	0	0%
Tequisquita Slough	**All sites**	244	1/19/1998	12/10/2013	0.282	0.001	0.154	0.216	0.326	2.635	70	29%
	305TES	223	1/19/1998	12/10/2013	0.265	0.001	0.148	0.206	0.307	2.635	57	26%
	Teq_conf	19	6/17/2005	11/3/2006	0.449	0.130	0.245	0.326	0.652	0.978	11	58%
	TS_SFL	2	6/23/2006	7/12/2006	0.615	0.577	0.596	0.615	0.634	0.653	2	100%
Tres Pinos Creek	**All sites**	26	2/19/1998	10/19/2011	0.040	0.001	0.005	0.009	0.072	0.178	0	
	305TRE	25	2/19/1998	10/19/2011	0.037	0.001	0.005	0.007	0.059	0.178	0	0%
	TP_H25	1	6/22/2006	6/22/2006	0.106	0.106	0.106	0.106	0.106	0.106	0	0%
Uvas Creek	**All sites**	673	1/19/1998	12/13/2011	0.049	0.001	0.017	0.030	0.049	0.456	13	
	305UVA	169	1/19/1998	12/13/2011	0.058	0.002	0.018	0.035	0.073	0.456	3	2%
	305UVCASC	1	6/29/2010	6/29/2010	0.013	0.013	0.013	0.013	0.013	0.013	0	0%
	UV_152	221	10/1/2002	3/13/2007	0.048	0.001	0.019	0.030	0.048	0.439	4	2%
	UV_THO	89	11/12/2002	3/13/2007	0.046	0.003	0.016	0.029	0.043	0.448	2	2%
	UV_UCP	1	7/10/2006	7/10/2006	0.006	0.006	0.006	0.006	0.006	0.006	0	0%
	UV_URA	77	1/7/2003	3/13/2007	0.052	0.003	0.017	0.030	0.051	0.448	3	4%
	UV_URB	115	10/15/2002	3/13/2007	0.039	0.001	0.016	0.028	0.041	0.319	1	1%
Watsonville Slough	**All sites**	1,083	8/26/1998	12/17/2013	0.346	0.005	0.142	0.255	0.472	6.390	477	44%
	305WAT-AND	279	10/4/2000	12/17/2013	0.335	0.005	0.162	0.263	0.475	2.100	126	45%
	305WAT-HAR	3	5/17/2003	5/7/2005	0.219	0.018	0.159	0.300	0.320	0.340	2	67%
	305WAT-LEE	171	10/4/2000	3/20/2007	0.304	0.012	0.135	0.215	0.348	3.902	54	32%
	305WAT-SHE	255	10/25/2000	12/17/2013	0.261	0.005	0.104	0.199	0.409	1.028	89	35%
	305-WATSO-23	3	5/17/2003	5/7/2005	0.466	0.018	0.209	0.399	0.690	0.980	2	67%
	305WSA	106	8/26/1998	4/30/2013	0.508	0.033	0.280	0.449	0.629	2.400	76	72%
	WS_ERR	173	10/4/2000	3/20/2007	0.298	0.006	0.125	0.238	0.417	1.334	71	41%
	WS1	93	12/12/2002	12/17/2013	0.597	0.005	0.150	0.360	0.710	6.390	57	61%

A 0.3 mg/L is not a California regulatory Standard, it is a State of Nevada phosphate criteria for Class B and most Class A streams. It is used in this table as a numeric guideline indicating sites which may have elevated orthophosphate concentrations.

5.4 Photo Documentation of Biostimulation

Water Board staff, researchers, and other public entities periodically photo-document evidence of biostimulation and excessive algal growth at water quality monitoring sites in the TMDL project area. Photographic documentation of biostimulatory effects on surface waters of the project area is shown in Figure 5-35; it should be noted that these photos represent conditions that are episodic and not a constant baseline condition. It is also important to recognize that not all biomass, like macrophytes, can or should be expected to be removed from streams. Algae are natural components of freshwater systems and play roles essential to the health of the ecosystem. While an overall goal of nutrient TMDLs is to significantly reduce excessive and harmful amounts of biomass in freshwater systems, some level of biomass is necessary to provide habitat to fish and other aquatic organisms.

Figure 5-34. Location of stream biostimulation photos.

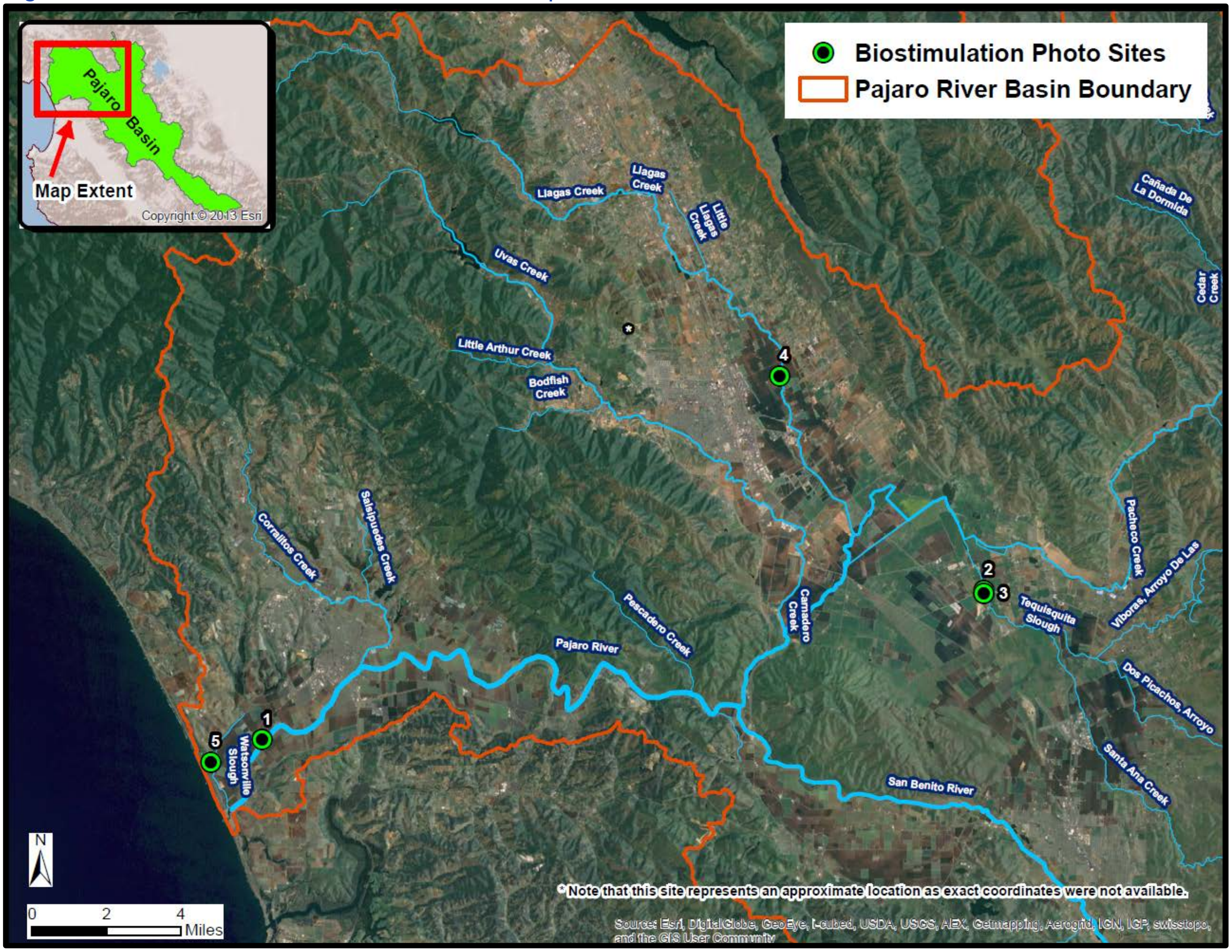


Figure 5-35. Photo documentation of biostimulation in the Pajaro River basin.

Photo documentation

Photo documentation

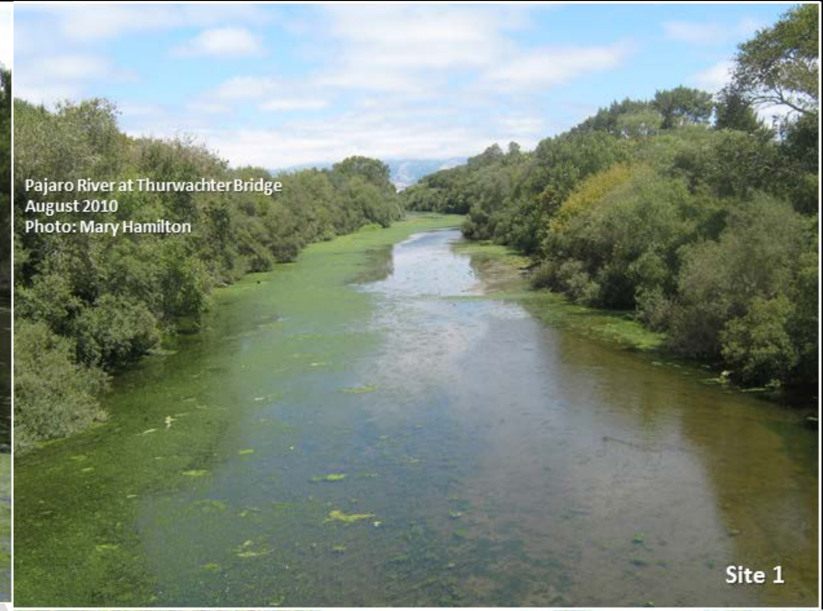


Photo documentation

5.5 Assessment of Biostimulatory Impairments

Under development.

6 PRELIMINARY SOURCE ANALYSIS

6.1 Introduction: Source Assessment Using STEPL Model

Both nitrogen and phosphorus reach surface waters at an elevated rate as a result of human activities (USEPA, 1999). In this TMDL project report nutrient source loading estimates were accomplished using the US Environmental Protection Agency's STEPL model. STEPL (Spreadsheet Tool for Estimating Pollutant Load version 4.0) allows the calculation of nutrient loads from different land uses and source categories. STEPL provides a Visual Basic (VB) interface to create a customized, spreadsheet-based model in Microsoft (MS) Excel. STEPL calculates watershed surface runoff; nutrient loads, including nitrogen, phosphorus based on various land uses and watershed characteristics. STEPL has been used previously in USEPA-approved TMDLs to estimate source loading[124].

For source assessment purposes, STEPL was used to estimate nutrient loads at the project area-scale. STEPL could also be used to allow for subwatershed-scale loading estimates. The annual nutrient loading estimate in STEPL is calculated based on the runoff volume and the pollutant concentrations in the runoff water as influenced by factors such as the land use distribution, precipitation data, soil characteristics, groundwater inputs, and management practices. Additional documentation and information on the model can be found at: http://it.tetratech-ffx.com/steplweb/models$docs.htm.

STEPL input parameters used in this TMDL project are outlined in Table 6-1. STEPL spreadsheet results are presented in Appendix E. It should be emphasized that average annual nutrient load estimates calculated by STEPL are indeed estimates and subject to uncertainties; actual loading at the stream-reach scale can vary substantially due to numerous factors over various temporal and spatial scales.

Table 6-1. Spreadsheet Tool for Estimating Pollutant Loads version 4.0 (STEPL) input data.

Input Category	STEPL Input Data	Sources of STEPL Input Data
Mean Annual Rainfall	Range = 14.8 to 32.7 inches/year depending on location of individual subwatersheds	PRISM precipitation dataset, accounting for orographic effects Refer back to report Section 0 and refer back to Table 3-19.
Mean Rain Days/Year *(where daily precipitation event >0.01 inches)*	Range = 46 to 58 days per year depending on location of individual subwatersheds	Western Regional Climate Data Center, http://www.wrcc.dri.edu/coopmap/ Weather stations used for STEPL inputs: Weather station: (044025) Hollister 2 Weather station: (047721) San Benito Willow Creek Weather station: (043417) Gilroy Weather station: (045853) Morgan Hill Weather station: (049473) Watsonville Waterworks
Weather Station *(for rain correction factors)*	San Francisco WSO Airport Provided as a default in STEPL	San Francisco WSO Airport as provided in STEPL version 4.0 *(this is the closest weather station to the Pajaro River basin available in STEPL version 4.0 for rain correction factors)*
Land Cover	See STEPL spreadsheets See Appendix E	Farmland Mapping and Monitoring Program (2010) data. Refer back to Table 3-6 in report Section 3.3.
Urban Land Use Distributions (%) *(impervious surfaces categories)*	STEPL default values See Appendix E	STEPL, version 4,0 default values for urban land use category distributions.

[124] For example, see USEPA, 2010: Decision Document for Approval of White Oak Creek Watershed (Ohio) TMDL Report. February 25, 2010; and Indiana Dept. of Environmental Management, 2008. South Fork Wildcat Creek Watershed Pathogen, Sediment, and Nutrient TMDL.

Input Category	STEPL Input Data	Sources of STEPL Input Data
Agricultural Animals	See STEPL spreadsheets Appendix E	Estimates of quantities of agricultural animals by individual subwatersheds from information developed and reported by Tetra Tech, Inc. for use in STEPL version 4.0 See: http://mingle.tetratech-ffx.com/steplweb2/steplweb.html
Septic system discharge and failure rate data	See STEPL spreadsheets Appendix E	Input data derived from sewage disposal and onsite wastewater treatment systems (septics) data reported by U.S. Census Bureau and by State Water Resources Control Board – refer to report Section 6.6 and Table 6-22 . Default values given in STEPL version 4.0 were used for septic failure rates (%).
Hydrologic Soil Group (HSG)	B, C, or D The predominant HSG present is identified for each individual subwatershed	U.S. Department of Agriculture National Resources Conservation Service (NRCS) Soil Survey Geographic (SSURGO) Database – refer back to Table 3-32 in report Section 3.11
Soil N and P concentrations (%)	N = 0.068% P = 0.038%	Data available from the International Geosphere–Biosphere Programme Data Information System; Post and Mann (1990); and the Kearney Foundation of Soil Science–University of California, Davis. Refer back to report Section 3.11.
NRCS reference runoff curve numbers	STEPL default values	NRCS default curve numbers provided in STEPL version 4.0
Universal Soil Loss Equation (USLE) Parameters	See STEPL spreadsheets Appendix E USLE inputs for each individual subwatershed, based on county-level USLE data	County-level USLE data as developed and reported by Tetra Tech, Inc. for use in STEPL version 4.0. See: http://mingle.tetratech-ffx.com/steplweb2/steplweb.html
Nutrient (total N and total P) concentrations in runoff (mg/L)	Agricultural Lands mean N = 11.4 mg/L mean P = 0.64 mg/L Urban Lands N = 1.9 to 3.62 mg/L (range) P = 0.15 to 0.5 mg/L (range) Grazing Lands (aka, rangeland) mean N = 0.25 mg/L mean P = 0.21 mg/L Woodlands mean N = 0.2 mg/L mean P = 0.1 mg/L	• Agricultural lands mean N runoff concentration data from Southern California Coastal Water Research Project, Technical Report 335 (Nov. 2000), Appendix C; and the U.S. Dept. of Agriculture's MANAGE database – refer to Figure 6-15 in report Section 6.3. • Agricultural lands mean P runoff concentration data from Southern California Coastal Water Research Project, Technical Report 335 (Nov. 2000), Appendix C • Urban lands N runoff concentrations from commercial, industrial, residential, transportation, and open space land categories were derived from the arithmetic means of N concentrations reported in the National Stormwater Quality Database (version 3, Feb. 2, 2008) – see Table 6-3 in report Section 6.2. Urban N runoff concentrations for institutional, urban-cultivated, and vacant land categories are the default valued provided in STEPL version 4.0. • Urban lands P runoff concentrations from commercial, industrial, residential, transportation, and open space land categories were derived from the arithmetic means of P concentrations reported in the National Stormwater Quality Database (version 3, Feb. 2, 2008) – see Table 6-4 in report Section 6.2. Urban P runoff concentrations for institutional, urban-cultivated, and vacant land categories are the default valued provided in STEPL version 4.0. • Grazing lands mean N runoff concentration. from California Rangeland Watershed Laboratory rangeland presentation for stream water quality (average of the concentrations given for moderate grazing intensity and no grazing land use categories) http://rangelandwatersheds.ucdavis.edu/Recent%20Outreach/tate%20oakdale%20mar%202012.pdf • Grazing lands (aka, rangeland) mean P runoff concentration is derived from the arithmetic mean of dissolved P concentrations in runoff from all land use categories defined as native grasses, native grasslands, and native prairie reported in the U.S. Dept. of Agriculture MANAGE database (version year 2013). • Forest mean N runoff concentration: staff used STEPL version 4.0 default values • Forest mean P runoff concentration: staff used STEPL version 4.0 default values
Nutrient (nitrate and phosphorus) concentrations in shallow groundwater (mg/L)	Valley floor (agricultural lands) NO_3-N = 5.93 P = 0.04 Valley floor (urban lands) NO3-N = 1.8 P = 0.04 Uplands (woodlands & rangeland) NO3-N = 0.14 P = 0.04	• Mean groundwater nitrate (NO_3-N) and phosphorus concentrations values are derived on the basis of data available from the U.S. Geological Survey Groundwater Vulnerability Assessment (GWAVA) model; the U.S. Geological Survey National Water Quality Assessment Program (NAWQA); and the U.S. Geological Survey National Geochemical Database. Refer back to the discussion in report Section 3.9, and refer back to Figure 3-43, Table 3-24, Figure 3-45, and Table 3-27.

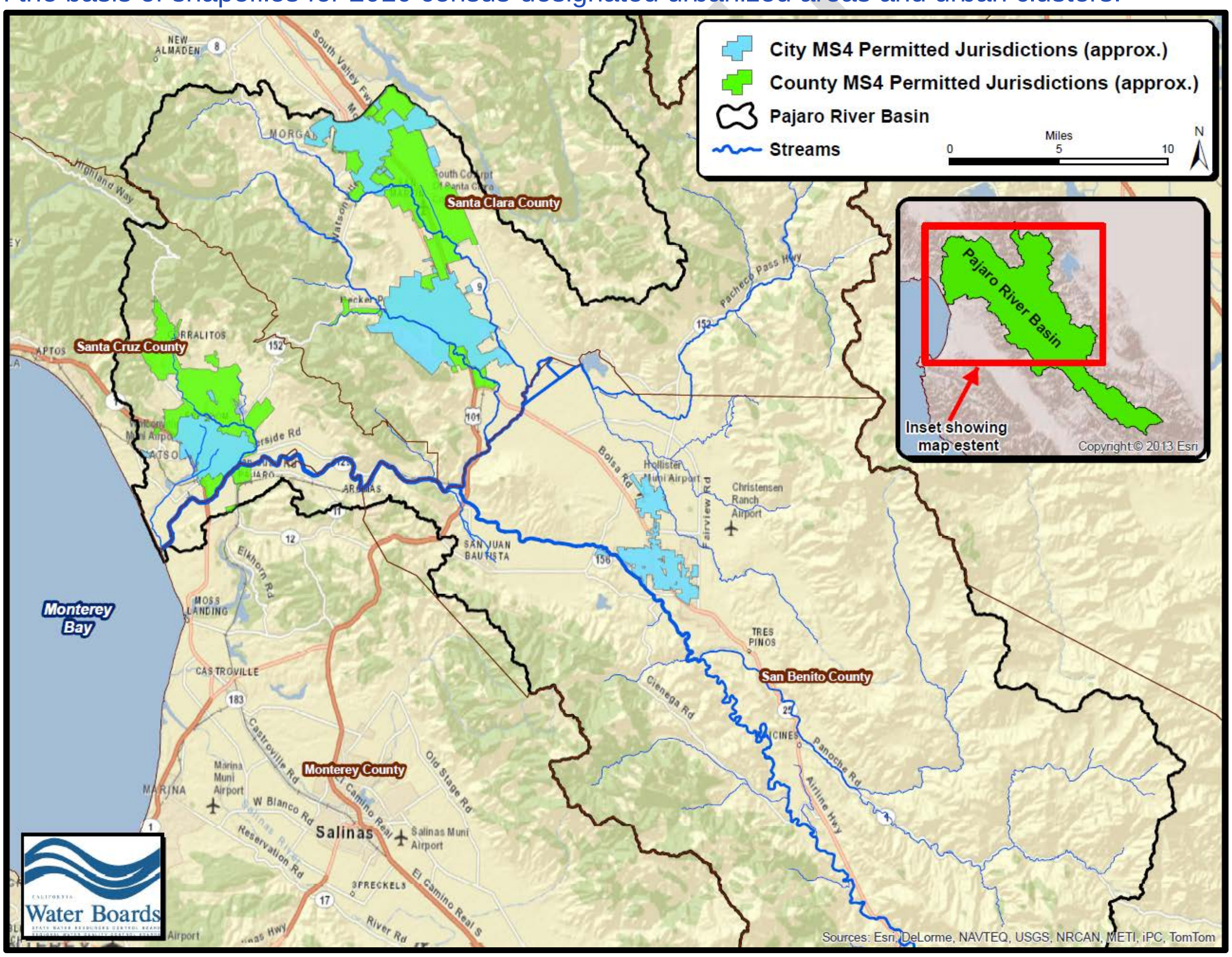
Assumptions: composted manure was assumed to not be applied to cropland in the Pajaro River basin, and it is presumed that chemical fertilizers are almost universally used for fertilization in the river basin. This assumption is supported by reporting from local resource professionals and local stakeholders.

6.2 Urban Runoff (Municipal Stormwater)

Urban runoff, in the form of municipal separate storm sewer system (MS4) discharges, can be a contributor of nutrients to waterbodies. USEPA policy explicitly specifies that National Pollutant Discharge Elimination System (NPDES)-regulated urban stormwater discharges are point source discharges and, therefore, must be addressed by the waste load allocation component of a TMDL.[125] The Water Board is the permitting authority for NPDES urban stormwater permits in the Central Coast region.

Figure 3-70 illustrates the locations and extent of currently enrolled MS4 permit entities in the Pajaro River basin. Within residential areas, potential controllable nutrient sources can include lawn care fertilizers, grass clippings, organic debris from gardens and other green waste, trash, and pet waste (Tetra Tech, 2004). Many of these pollutants enter surface waters via runoff without undergoing treatment. Impervious cover characterizes urban areas and refers to roads, parking lots, driveways, asphalt, and any surface cover that precludes the infiltration of water into the soil. Pollutants deposited on impervious surface have the potential of being entrained by discharges of water from storm flows, wash water, or excess lawn irrigation, etc. and routed to storm sewers, and potentially being discharged to surface water bodies.

Figure 6-1. Generalized and approximate boundaries of permitted MS4 entities in the Pajaro River basin, on the basis of shapefiles for 2010 census-designated urbanized areas and urban clusters.



[125] See 40CFR 130.2(g) & (h) and USEPA Office of Water Memorandum (Nov. 2002) *"Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on Those WLAs"*

Table 6-2 presents a tabulation of currently enrolled municipal stormwater permit entities having NPDES-permitted jurisdictions within the Pajaro River basin.

Table 6-2. Tabulation of enrolled municipal stormwater permit entities with NPDES-permitted jurisdictions in the Pajaro River basin[A].

Type	Status	Owner/Operator Name
Phase II Small MS4	Active	City of Watsonville
Phase II Small MS4	Active	City of Gilroy
Phase II Small MS4	Active	City of Morgan Hill
Phase II Small MS4	Active	City of Hollister
Phase II Small MS4	Active	County of Monterey
Phase II Small MS4	Active	County of Santa Clara
Phase II Small MS4	Active	County of Santa Cruz

[A] On the basis of reporting from the: State Water Resources Control Board, Storm Water Multiple Application and Report Tracking System (SMARTS)

Site-specific urban stormwater runoff and storm drain outfall nutrient concentration data for the Pajaro River basin are not available, so estimates of nutrient loading to streams from these sources must be based on plausible approximations and indirect evidence. It should be noted that there is a large quantity of nationwide and California-specific data characterizing nutrient concentrations in urban runoff (see Figure 6-2). Staff filtered the available data to include only data regionally from California and other arid western states. These data (> 1,000 total samples) illustrate that total nitrogen concentrations in urban runoff virtually never exceed the 10 mg/L drinking water regulatory standard for nitrate–N[126] (see Table 6-3). However, the available data suggest that urban runoff nutrient concentrations can episodically be elevated high enough above natural background to potentially contribute to a risk of biostimulation in surface waters (e.g., the data show urban runoff total nitrogen concentrations is episodically > 4 mg/L, and total phosphorus concentrations > 0.5 mg/L) – see Table 6-3, Figure 6-2, Table 6-4, and Figure 6-3.

Table 6-3. Total nitrogen concentrations in urban runoff (units = mg/L) from National Stormwater Quality Database (NSQD version 3) for sites in NSQD rain zones 5, 6, and 9[A] (arid west and southwest). Temporal range of data is Dec. 1978 to July 2002. Note that the nitrate as N drinking water quality standard is not necessarily directly comparable to total nitrogen aqueous concentrations shown here[B], but the water quality standard is shown in the table for informational purposes.

Stormwater Runoff Category	Predominant land use at monitoring site location	No. of Samples	Arithmetic Mean	Min	25%	50% (median)	75%	90%	Max	No. Exceeding Drinking Water Standard (>10 mg/L)	% Samples Exceeding 10 mg/L
Urban runoff	**All Sites**	1,085	3.08	0.03	1.30	2.03	3.62	6.50	68.03	35 of 1,085	**3.2%**
	commercial	162	2.71	0.50	1.18	1.80	3.28	5.53	15.90	–	Not calculated for individual land use types
	freeways	322	2.51	0.03	1.10	1.71	2.80	5.25	36.15	–	
	industrial	198	3.53	0.26	1.34	2.15	4.65	7.86	17.90	–	
	open space	68	2.75	0.73	1.45	1.98	3.34	5.30	9.14	–	
	residential	335	3.62	0.20	1.51	2.64	4.39	7.10	68.03	–	

[A] Includes central and southern California, Arizona, Colorado, central and west Texas, and western South Dakota and includes monitoring locations from cities of Arlington (TX), Aurora (CO), Austin (TX), Castro Valley (CA), Colorado Springs (CA), Dallas (TX), Denver (CO), Fort Worth (TX), Fresno (CA), Garland (TX), Irving (TX), Los Angeles (CA), Maricopa City (AZ), Mesquite (TX), Orange County (CA), Plano (TX), Sacramento (CA), Rapid City (SD), Riverside (CA), San Bernardino (CA), San Diego (CA), Tucson (AZ).

[B] Total nitrogen measured in aqueous systems includes nitrate as well as other compounds and phases of nitrogen, such as ammonia and organic nitrogen.

[126] Elevated nitrogen levels in urban runoff can, however, locally contribute to biostimulatory impairments of receiving waters where eutrophication has been identified as a water quality problem regarless of whether or not the nitrogen levels exceed the drinking water quality standard.

Figure 6-2. Box plot of total nitrogen concentrations in urban runoff from National Stormwater Quality Database (NSQD) monitoring locations in NSQD rain zones 5,6, and 9 (arid west and southest). Raw statistics for this dataset were previosly shown in Table 6-3. Note that the nitrate as N water quality standard is not necessarily directly comparable to total nitrogen aqueous concentrations shown here, but the water quality standard is shown on the graph for informational purposes. Temporal range of data is Dec. 1978 to July 2002.

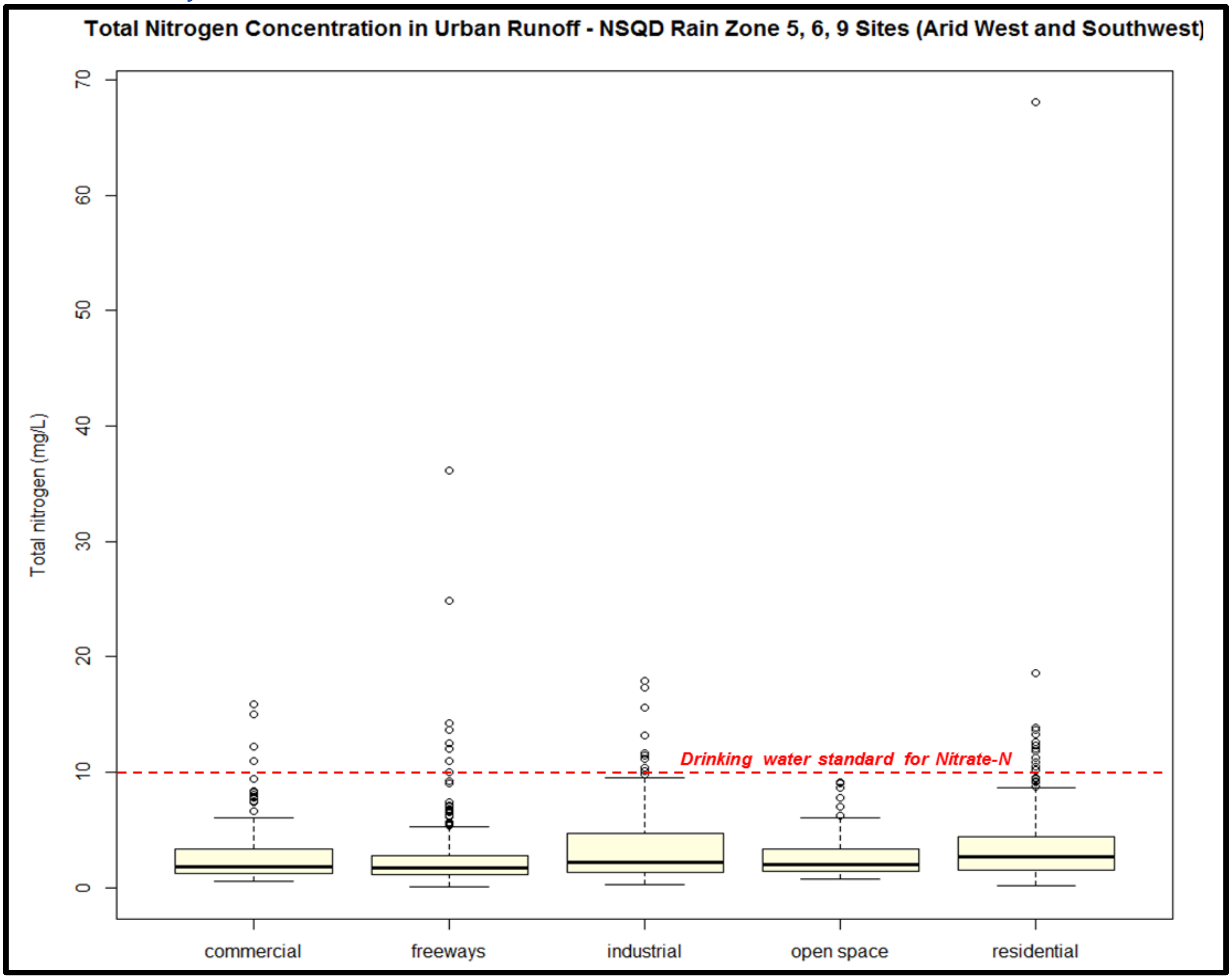


Table 6-4. Total phosphorus as P concentrations in urban runoff (units = mg/L) from National Stormwater Quality Database (NSQD version 3) for sites in NSQD rain zones 5, 6, and 9[A] (arid west and southwest). Temporal range of data is Dec. 1978 to July 2002.

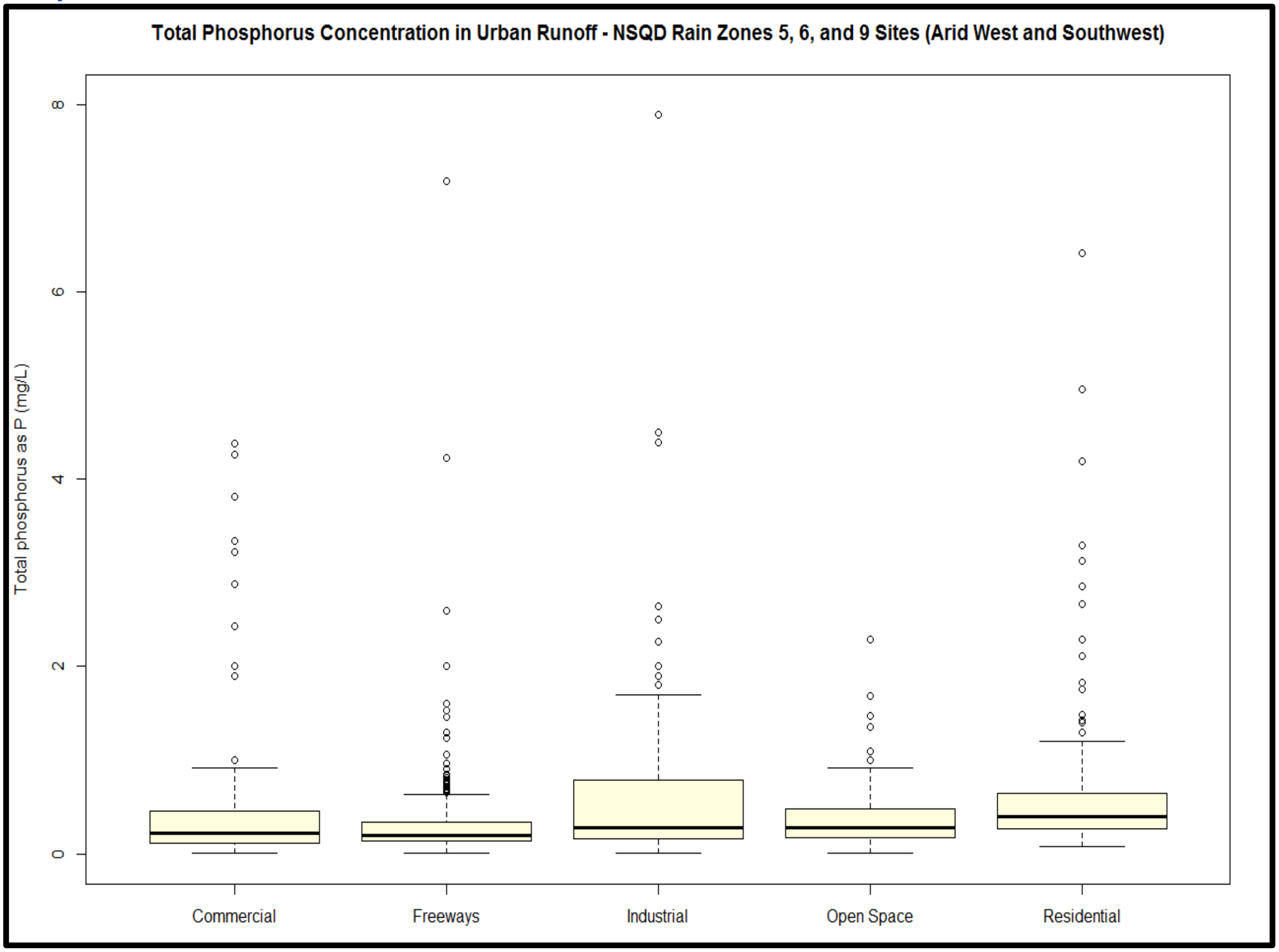
Stormwater Runoff Category	Predominant land use at monitoring site location	No. of Samples	Arithmetic Mean	Geometric Mean	Min	25%	50% (median)	75%	90%	Max
Urban runoff	**All Sites**	1,160	0.550	0.287	0.01	0.16	0.29	0.49	0.92	80.2
	commercial	381	0.590	0.24	0.01	0.11	0.22	0.46	0.80	15.60
	freeways	192	0.525	0.21	0.01	0.14	0.20	0.34	0.54	80.20
	industrial	76	0.614	0.34	0.01	0.16	0.28	0.78	1.46	7.90
	open space	348	0.401	0.24	0.01	0.17	0.28	0.48	0.96	2.29
	residential	381	0.555	0.42	0.08	0.27	0.40	0.64	1.00	6.42

[A] Includes central and southern California, Arizona, Colorado, central and west Texas, and western South Dakota and includes monitoring locations from cities of Aurora (CO), Austin (TX), Carlsbad (CA), Castro Valley (CA), Colorado Springs (CA), Dallas (TX), Denver (CO), Encinitas (CA), Fort Worth (TX), Garland (TX),

Stormwater Runoff Category	Predominant land use at monitoring site location	No. of Samples	Arithmetic Mean	Geometric Mean	Min	25%	50% (median)	75%	90%	Max

Fresno (CA), Garland (TX), Irving (TX), Maricopa City (AZ), Mesquite (TX), Plano (TX), Rapid City (SD), San Diego (CA), Tucson (AZ).

Figure 6-3. Box plot of total phosphorus as P concentrations in urban runoff from National Stormwater Quality Database (NSQD) monitoring locations in NSQD rain zones 5,6, and 9 (arid west and southest). Raw statistics for this dataset were previously shown in Table 6-4. Temporal range of data is Dec. 1978 to July 2002.



Average annual nutrient loads delivered to surface waterbodies in the Pajaro River basin from urban runoff were estimated on the basis of the STEPL input parameters previously identified in Section 6.1 – these estimated loads are tabulated in Table 6-5.

Table 6-5. Estimated average annual nutrient loads (lbs./year) delievered to surface waterbodies from urban runoff (i.e., municipal stormwater) in the Pajaro River basin.

Source	N Load (lb/yr)	P Load (lb/yr)
Urban Runoff (i.e., municipal stormwater)	182,542	21,565

Based on the aforementioned information, stormwater from MS4s are estimated to be relatively minor source of nutrient loading to streams of the Pajaro River basin. However, because MS4 stormwater sources can potentially have significant localized effect on water quality, waste load allocations will be assigned to NPDES MS4 stormwater permits.

6.3 Industrial & Construction Stormwater

According to guidance from the State Water Resources Control Board, all NPDES point sources should receive a waste load allocation (communication from Jonathan Bishop, Chief Deputy Director, State Water Resources Control Board, August 2014), and thus NPDES–permitted industrial stormwater and construction stormwater entities should be considered during TMDL development. Similarly, USEPA guidance recommends disaggregating stormwater sources in the waste load allocation of a TMDL where feasible, including disaggregating industrial stormwater discharges (USEPA, 2014).

As of December, 2014 there are 72 active NPDES stormwater-permitted industrial facilities in the Pajaro River basin, and 87 active NPDES stormwater-permitted construction sites in the Pajaro River basin[127]. Table 6-6 and Table 6-7 present a tabulation of stormwater-permitted industrial facilities and construction sites, respectively.

Table 6-6. List of active NPDES stormwater-permitted industrial facilities located in the Pajaro River basin as of December 5, 2014.

Site/Facility Name	Facility City	Site/Facility Name	Facility City
Sandman Inc DBA Star Concrete	Gilroy	Kents Oil Service Inc	Morgan Hill
Metech Recycling Inc	Gilroy	Morgan Hill Unified School District Transportation Facility	Morgan Hill
Pacific Coast Recycling Inc	Gilroy	Andpak Inc	Morgan Hill
Cardlock Fuels System Inc	Gilroy	Greif Packaging LLC	Morgan Hill
Gilroy Bin	Gilroy	Moreno Petroleum Co	Pajaro
A and S Metals	Gilroy	Willis Const Co	San Juan Bautista
Olam West Coast Inc	Gilroy	Calstone Company	San Martin
Christopher Ranch LLC	Gilroy	South County Airport	San Martin
Gilroy Unified Sch Dis	Gilroy	Alf Auto Wreckers	San Martin
Pacific Coast Recycling Inc	Gilroy	San Martin Transfer Station	San Martin
Recology South Valley	Gilroy	Paicines Quarry	Tres Pinos
Freeman Quarry	Gilroy	A & S Metals	Watsonville
International Paper	Gilroy	North Star Biofuels LLC	Watsonville
Gilroy Energy Ctr LLC KC	Gilroy	Watsonville Bin	Watsonville
Gilroy Maintenance Facility	Gilroy	Greenwaste Recovery Inc	Watsonville
Architectural Facades Unlimit	Gilroy	Cascade Properties	Watsonville
Z Best Products	Gilroy	Sunland Garden Prod Inc	Watsonville
South Cnty Reg Ww Auth Gilroy	Gilroy	Gerry S Foreign Auto Wreckers	Watsonville
TIN Inc dba Temple Inland	Gilroy	Smith & Vandiver Corp	Watsonville
Boral Roofing	Gilroy	River Run Vintners	Watsonville
Pacheco Pass Recology	Gilroy	Westlake Transport Inc	Watsonville
San Benito Recycling	Hollister	S Martinelli & Co	Watsonville
RJR Environmental Prof Svs Inc DBA RJR Recycling	Hollister	Salsipuedes Auto Wreckers	Watsonville
Peninsula Packaging Company	Hollister	Granite Rock Co Watsonville Co	Watsonville
KMG Electronic Chemicals Inc	Hollister	Coast Auto Supplies & Dism Inc	Watsonville

[127] On the basis of information publically available in the State Water Resource Control Board's Storm Water Multiple Applications & Report Tracking System (SMARTS). https://smarts.waterboards.ca.gov/smarts/faces/SwSmartsLogin.jsp

Site/Facility Name	Facility City	Site/Facility Name	Facility City
Herbert Family Organic Farm Inc	Hollister	Del Mar Food Prod Corp	Watsonville
BAE Systems Land & Armaments LP	Hollister	Watsonville Municipal Ser Cen	Watsonville
San Benito Auto Wreckers	Hollister	Watsonville City Airport	Watsonville
Spring Grove Sch	Hollister	Watsonville Landfill	Watsonville
Pacific Scientific Energetic Materials Company California	Hollister	Roy Wilson Yard	Watsonville
Brent Redmond Trans	Hollister	Mizkan Americas Inc	Watsonville
Hollister City Airport	Hollister	Santa Cruz Cnty Buena Vista La	Watsonville
San Benito Cnty John Smith Rd landfill	Hollister	S Martinelli & Co	Watsonville
Trical Soil Fumigation	Hollister	Lewis Rd Sanitary Landfill	Watsonville
TenCate Advanced Composites USA Inc	Morgan Hill	Hildebrand & Sons Trucking	Watsonville

Table 6-7. List of active NPDES stormwater-permitted construction site facilities located in the Pajaro River basin as of December 5, 2014.

Site/Facility Name	Facility City	Site/Facility Name	Facility City
Twin Creeks Residential Development	Gilroy	Diamond Creek	Morgan Hill
GCF Frozen Inc	Hollister	Madrone Plaza Arbors and Villas	Morgan Hill
Hollister Municipal Airport Runway Rehabilitation	Hollister	Lands of McBain	Gilroy
Joint Trunk Sewer Replacement	Gilroy	Walnut Grove	Morgan Hill
Lessalt Water Treatment Plant	Hollister	Highlands at Eagle Ridge	Gilroy
South County Recycled Water Pipeline Short Term Phase 1B Project Camino Arroyo Service Line	Gilroy	Walnut Park 13 Phase 2	Hollister
Shadow Pines	Morgan Hill	Oak Place	Gilroy
Pajaro River	Watsonville	Mission Ranch Phase 12A	Morgan Hill
Rajkovich Property	Hollister	Edmunson Piazza	Morgan Hill
Morgan Hill 3	Morgan Hill	Gilroy Sobrato Apartments	Gilroy
New Distribution Facility For UNFI	Gilroy	Rucker Elementary School	Gilroy
Glen Loma Ranch Phase 1A	Gilroy	Rataul Residence	Morgan Hill
Parking Lot C Expansion	Gilroy	Kim Son Meditation Center	Watsonville
Hollister Solar	Hollister	MH CLayton Phase I	Morgan Hill
Rocha property	Watsonville	Morgan Hill Residences	Morgan Hill
East Dunne Park	Morgan Hill	Medina Residence	Watsonville
Dara Farms	Hollister	PAN PACIFIC RV CENTERS	Morgan Hill
Ladd Lane Hillock Extension	Hollister	Ironhorse North	Morgan Hill
Creekside 6	Hollister	Villas of San Marco Phase 2 and 3	Morgan Hill
Loden Place	Morgan Hill	Walnut Park 13 Phase 1	Hollister
Mission Ranch Phase 13	Morgan Hill	Hollister Courthouse	Hollister
Stonebridge 2	Hollister	Foster Farms Hollister Ranch Complex	Hollister
Masoni III	Gilroy	Storemore Westage America	Watsonville
Santana Ranch Grading Phase 1 & 2	Hollister	Schafer Ave	Morgan Hill
Hecker Pass	Gilroy	Jasper Park	Morgan Hill
Silver Oaks	Hollister	Hollister Hills SVRA	Hollister
Morgan Hill 3	Morgan Hill	Carriage Hills III 8 Lots	Gilroy
Christopher High School Track & Field	Gilroy	Butterfield South	Morgan Hill
Kamboj School Road	San Juan Bautista	Womens Center and Parking Lots	Hollister
Primary Influent Forcemain Construction	Gilroy	ARCO AMPM Watsonville	Watsonville
Rancho Hills	Gilroy	New CA5 Building Storage	Gilroy
Mission Ranch Phase 12B	Morgan Hill	Anderson Visitor Center	Morgan Hill

Site/Facility Name	Facility City		Site/Facility Name	Facility City
Evans circle phase 1	Watsonville		Lone Hill Drive	Morgan Hill
Z BEST Composting Facility	Gilroy		Oliveri	Gilroy
Blanca Terrace	Watsonville		Lions Creek Trail Projects	Gilroy
Connemara Phase 1	Morgan Hill		Lands of Leavesley Road	Gilroy
Gilroy Self Storage	Gilroy		Mission Ranch Phase 10 and 11	Morgan Hill
Eden West	Hollister		Perham Residence	Gilroy
Vintage Estates	Morgan Hill		Mast Condo Dev	Morgan Hill
Harvest Park	Gilroy		George Chiala Farms	Morgan Hill
Gilroy Monterey Manor	Gilroy		Gilroy Cannery Proj	Gilroy
Pajaro Neighborhood Park	Pajaro		Creek Side At Eagle Ridge	Gilroy
Creekside 5	Hollister			

Site specific industrial and construction stormwater runoff nutrient data for the Pajaro River basin are not available, so direct inferences about nutrient loading to surface waters from these facilities in the river basin are not possible. However, there is a large amount of statewide stormwater runoff nitrate water quality from a wide range of industrial facilities, and also from some construction sites providing a plausibly good statial representation of a variety of these types of sites within California (see Figure 6-4) . These data can give some insight into expected nitrate and nitrogen concentrations typically found in stormwater runoff from industrial and construction sites throughout California (see Table 6-8, Table 6-9, Table 6-10, and Figure 6-5). Based on the available data, stormwater runoff from industrial and construction facilities throughout California typically have relatively low nutrient concentrations averaging less than 2 mg/L for nitrate as N and for total nitrogen. Further, as the large number of samples collected statewide indicate, the nitrate concentrations in stormwater runoff from these facilities almost never exceed or even approach the numeric threshold for the drinking water standard = 10 mg/L nitrate as N.

Therefore, indirect and anecdotal evidence suggests that NPDES stormwater-permitted industrial facilities and construction sites in the Pajaro River basin would not be expected to be a significant risk or cause of the observed nutrient water quality impairments, and these types of facilities are generally expected to be currently meeting waste load allocations identified in this report. To maintain existing water quality and prevent any further water quality degradation, these permitted industrial facilities and construction operators shall continue to implement and comply with the requirements of the statewide Industrial General Permit or the Construction General Permit, respectively.

The information outlined above does not conclusively demonstrate that stormwater from all industrial facilities and construction sites are meeting proposed waste load allocations. More information will be obtained during the implementation phase of these TMDLs to further assess the level of nutrient contributions to surface waters from these source categories, and to identify any actions needed to reduce nutrient loading.

Figure 6-4. California industrial and contruction stormwater permitted sites with reported nitrate water quality results. Site specific industiral and construction stormwater runoff nutrient data for the Pajaro River basin are not available, so statewide data are presented in this section for informational purposes and as supporting lines of indirect evidence.

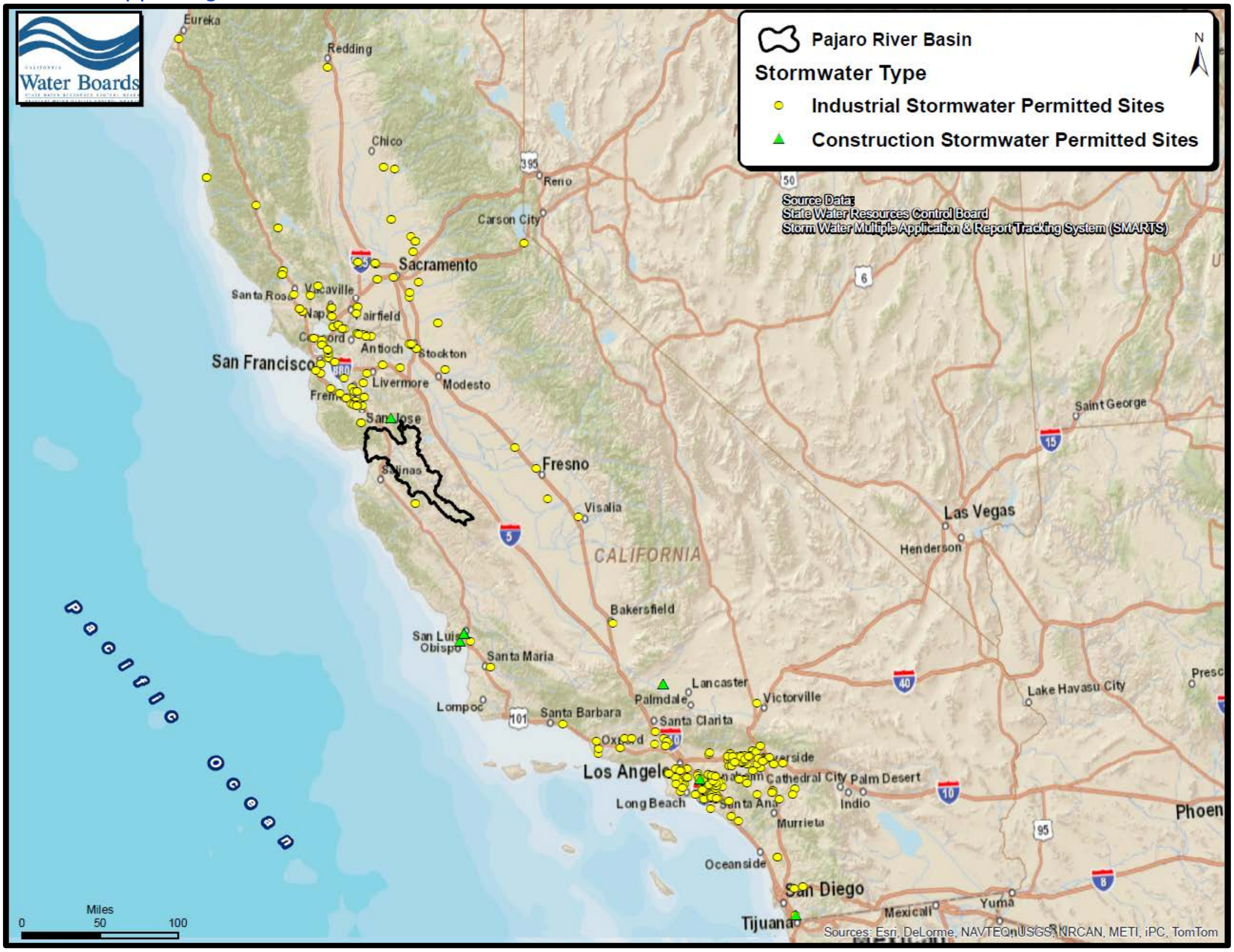


Table 6-8. Nitrate as N concentrations in industrial stormwater runoff (units = mg/L) from permitted California facility sites shown previously in Figure 6-4 and as reported in the State Water Resources Control Board's Stormwater Multiple Application & Report Tracking System. Site specific data for the Pajaro River basin are not available, so statewide data are presented for informational purposes. Temporal range of data is Oct. 2005 to Nov. 2014.

Stormwater Runoff Category	No. of Samples	Geometric Mean	Min	10%	25%	50% (median)	75%	90%	Max	No. Exceeding Drinking Water Standard (>10 mg/L)	% Samples Exceeding 10 mg/L
Industrial stormwater runoff	1,906	0.78	0	0.1	0.25	0.72	2.1	6	13,100	119 of 1,906	**3.2%**

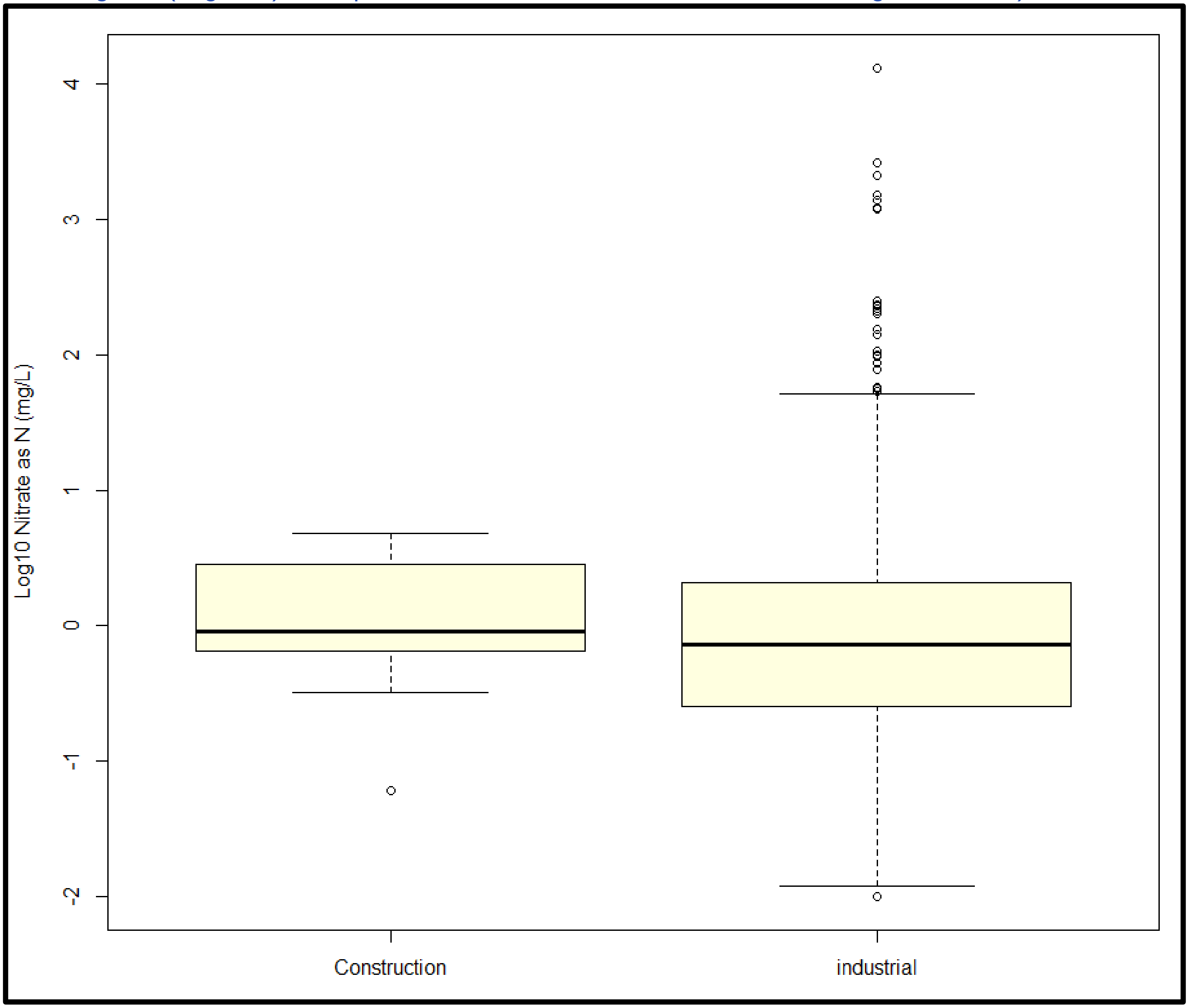
Table 6-9. Total nitrogen as N concentrations in industrial stormwater runoff (units = mg/L) from permitted California facility sites shown previously in Figure 7 4 and as reported in the State Water Resources Control Board's Stormwater Multiple Application & Rep

Industrial Stormwater: Type of Facility	No. of Samples	Arithmetic Mean	Min	10%	25%	50%	75%	90%	Max	No. of samples.
All industrial stormwater facilities	76	1.53	0.01	0.02	0.08	0.32	1.30	3.85	22.00	76
Aircraft Parts and Auxiliary Equipment	8	0.48	0.21	0.28	0.33	0.37	0.60	0.79	0.97	8.00
Aluminum Die-Castings	12	0.13	0.02	0.06	0.08	0.12	0.17	0.21	0.24	12.00
Chemicals and Allied Products	2	0.43	0.40	0.41	0.42	0.43	0.45	0.45	0.46	2.00
Coating Engraving and Allied Services	7	2.67	0.01	0.01	0.01	0.01	4.33	8.92	10.00	7.00
Electroplating Plating Polishing Anodizing and Coloring	5	0.05	0.02	0.02	0.03	0.04	0.05	0.08	0.10	5.00
Fabricated Plate Work (Boiler Shops)	3	0.15	0.07	0.08	0.08	0.09	0.19	0.24	0.28	3.00
Fertilizers Mixing Only	4	1.58	0.10	0.13	0.18	0.31	1.72	4.05	5.60	4.00
General Warehousing and Storage	1	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	1.00
Industrial Valves	1	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	1.00
Pesticides and Agricultural Chemicals	6	2.48	0.72	0.79	0.91	1.70	2.45	4.95	7.40	6.00
Plastics Material and Synthetic Resins and Nonvulcanizable Elastomers	2	0.06	0.02	0.03	0.04	0.06	0.08	0.09	0.10	2.00
Poultry Slaughtering and Processing	1	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.00
Prepared Feed and Feed Ingredients for Animals and Fowls	2	13.00	4.00	5.80	8.50	13.00	17.50	20.20	22.00	2.00
Printed Circuit Boards	2	0.02	0.01	0.01	0.02	0.02	0.03	0.03	0.03	2.00
Refuse Systems	4	0.47	0.05	0.16	0.34	0.46	0.59	0.79	0.92	4.00
Sheet Metal Work	2	0.10	0.07	0.07	0.08	0.10	0.11	0.12	0.13	2.00
Soaps and Other Detergents Except Specialty Cleaners	10	2.66	0.51	1.13	1.73	3.20	3.47	3.75	4.20	10.00
Trucking Except Local	2	1.43	0.16	0.41	0.80	1.43	2.07	2.45	2.70	2.00
Wood Office Furniture	2	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	2.00

Table 6-10. Nitrate as N concentrations in construction stormwater runoff (units = mg/L) from permitted California construction sites as shown previously previously in Figure 6-4 and as reported in the State Water Resources Control Board's Stormwater Multiple Application & Report Tracking System. Site specific data for the Pajaro River basin are not available, so statewide data are presented for informational purposes. Temporal range of data is July 2010 to Feb. 2014.

Stormwater Runoff Category	No. of Samples	Arithmetic Mean	Min	10%	25%	50% (median)	75%	90%	Max	No. Exceeding Drinking Water Standard (>10 mg/L)	% Samples Exceeding 10 mg/L
Construction stormwater runoff	21	1.64	0.06	0.32	0.65	0.9	2.8	4.5	4.8	0 of 21	**0%**

Figure 6-5. Box plot of reported nitrate as N concentrations observed in California industrial and construction stormwater sites. Site specific data for the Pajaro River basin are not available, so statewide data are presented for informational purposes. The vertical axis is log concentrations (log10=1 represents a concentration of 10 mg/L nitrate at N, log10=0 represents a concentration of 1 mg/L nitrate as N; log10 = (negative)one represents a nitrate as N concentration of 0.1 mg/L, as so on).



6.1 Municipal Wastewater Treatment Facilities

Municipal wastewater can potentially be a source of nutrient loads to streams in any given watershed. Further information will be reviewed during current TMDL development to assesss what, if any, implementation or permitting requirements are needed at the SCRWA facility to protect designated beneficial uses of surface waters of the Pajaro River.

Figure 6-6 illustrates the location of municipal wastewater treatment plants within the Pajaro River basin. Table 6-11 presents a tabulation of municipal wastewater treatment facilities and their operating agencies within the river basin. Only three of these facilities are authorized to discharge to surface waters under NPDES-permitted conditions.

The following boxed-text is narrative from the source analysis section of 2005 Central Coast Water Board-approved nitrate TMDL progress report for the Pajaro River and Llagas Creek, and is being used here as a placeholder. Further assessment of municipal wastewater as a potential source of nutrient loads to streams of the Pajaro River basin, as warranted, will be included in the final draft TMDL report.

> "Currently, there are no wastewater treatment plants or other point sources that are permitted discharge directly to the Pajaro River or Llagas Creek. However, the Water Board has permitted a new discharge to the Pajaro River. The South County Regional Wastewater Authority (SCRWA) facility currently uses at wastewater treatment pond system and a permit to release tertiary treated wastewater into the Pajaro River during specific flow conditions has recently been granted. The discharge is planned to begin in 2006 and is provided effluent limits that meet the nitrate numeric targets established for this TMDL. The nitrate-related effluent limits that have been permitted are 5 mg/L nitrate-N as a 30-day mean and 10 mg/L nitrate-N for a daily maximum. The 2005 Pajaro River nitrate TMDL reported that the SCRWA facility was implementing best available technologies to reduce nitrate concentrations to these levels."

Further information will be reviewed during current TMDL development to assesss what, if any, implementation or permitting requirements are needed at the SCRWA facility to protect designated beneficial uses of surface waters of the Pajaro River.

Figure 6-6. Location of muncipal wastewater treatment plants in the Pajaro River basin.

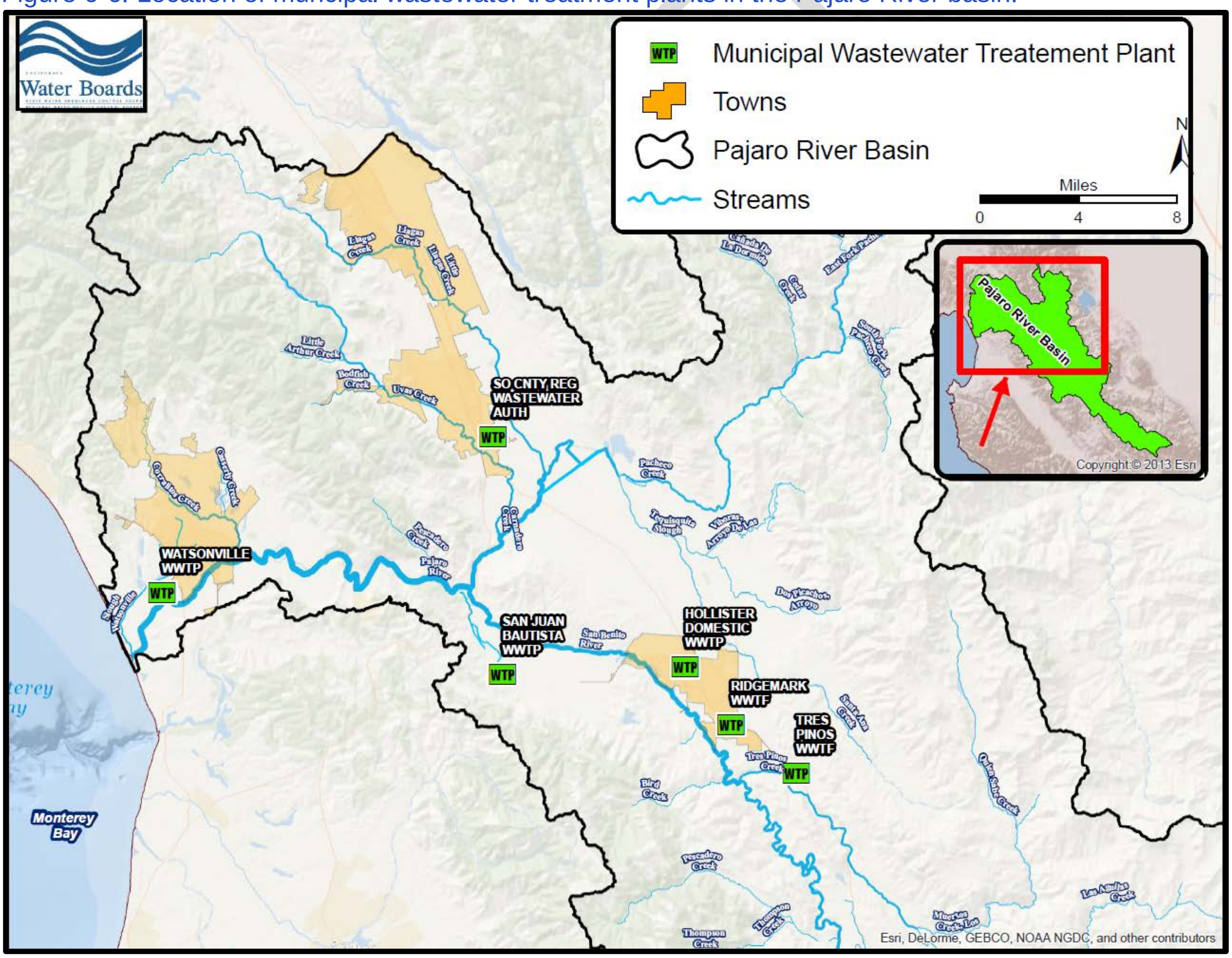


Table 6-11. Tabulation of municipal wastewater treatement facilities in the Pajaro River basin as reported in the California Integrated Water Quality System (CIWQS).

Facility Name	Agency	Project Type	Regulatory Measure Status	Regulatory Measure Type[A]	Order No.	NPDES No.
Hollister Domestic WWTP	Hollister City	Wastewater Treatment Facility	Active	WDR	R3-2008-0069	N.A.
San Juan Bautista WWTP	San Juan Bautista City	Wastewater Treatment Facility	Active	NPDES Permit	R3-2009-0019	CA0047902
Tres Pinos WWTP	Tres Pinos WD	Wastewater Treatment Facility	Active	WDR	R3-2012-0015	N.A.
SCRWA Reclaiming WW Facility	South County Regional WW Authority	Wastewater Treatment Facility	Active	WDR	98-052	N.A.
SCRWA WWTP	South County Regional WW Authority	Wastewater Treatment Facility	Active	NPDES Permit	R3-2010-0009	CA0049964
Pajaro Valley WMA & City of Watsonville Water Reclamation	Pajaro Valley Water Management Agency	Wastewater Treatment Facility	Active	WDR	R3-2008-0039	N.A.
Watsonville WWTP	Watsonville City	Wastewater Treatment Facility	Active	NPDES Permit	R3-2014-0006	CA0048216
Ridgemark Estates WWTP	Sunnyslope CWD	Wastewater Treatment Facility	Active	WDR	R3-2004-0065	N.A.

N.A. = not applicable
[A] WDR = waste discharge requirements (discharges of waste to land); NPDES = national pollutant discharge elimination system permit, referring here to discharges that do or may potentially discharge to surface receiving waters.

6.2 Golf Courses

Some concerns have been raised about the surface water quality impact of chemicals, including fertilizers, applied on golf courses (Hindahl et al, 2009; Minnesota Dept. of Agriculture website accessed June 27, 2013). The regular use of fertilizers on golf courses can result in concerns that these chemicals may be transported into creeks that flow through golf courses following application.

Figure 6-7 presents a map showing locations of golf courses within the Pajaro River basin. Worth noting is that, in general, these golf courses are not spatially associated or closely linked with streams that have been impaired by nutrient pollution. Specifically, these golf courses are located in the Uvas Creek watershed, the San Benito River Subbasin, the Tres Pinos Creek Watershed, the Salsipuedes Creek subwatershed, and upper reaches of the Llagas Creek Watershed.

Some golf course water quality data is available for the Pajaro River basin. Table 6-12 and Table 6-13 present data from the West Banch Llagas Creek as it flows through the Cordevalle golf course located near San Martin. In general, nitrate and phosphorus concentrations remain relatively low as the creek flows through the golf course. Limited amounts of golf course creek data are also available from several nearby bay area golf courses in Santa Clara County – these data indicate that nitrate concentrations in these Santa Clara County golf course creeks are typically relatively low (see Figure 6-8 and Table 6-14).

An additional line of indirect evidence is available from published studies which researched golf course creek and runoff water quality. On balance, national and regional studies conducted over many years report no significant or widespread impacts on surface water quality in golf courses following application of fertilizers (Hindahl et al, 2009, Miltner and Hindahle, 2009, Baris, et al., 2010). While golf course runoff does not generally appear to cause violations of water quality standards in creeks, a couple of studies from Texas and North Carolina have reported a marginal increase in nutrient concentrations as runoff and creeks flow through and exit some golf courses (Mallin and Wheeler, 2000, King et al, 2001) – landscape management practices appeared to play a critical role in whether or not nutrient water quality problems were observed in golf course creeks and downstream receiving waters (Mallin and Wheeler, 2000).

Figure 6-7. Golf courses in the Pajaro River basin on the basis of data available from the Geographic Names Information System (GNIS).

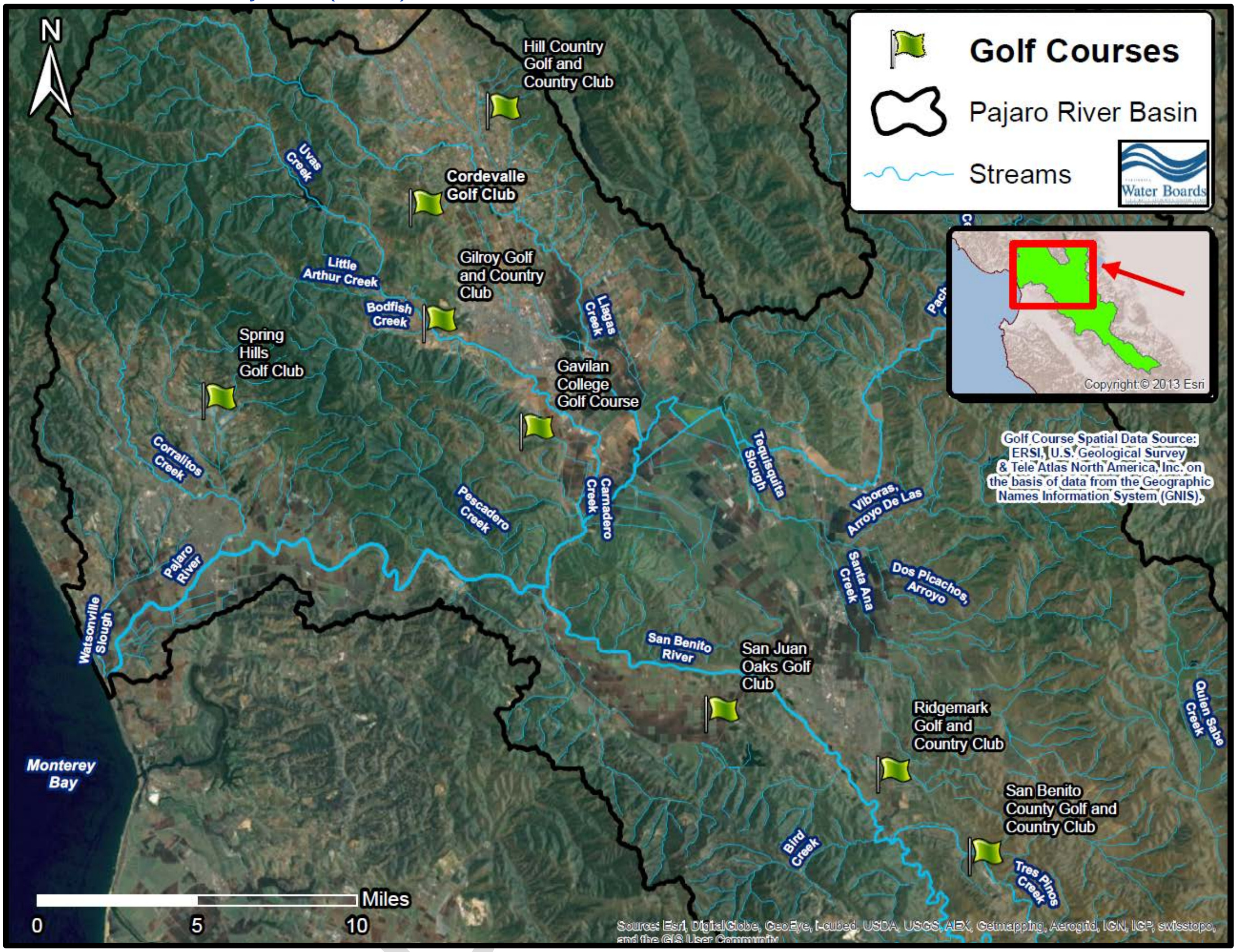


Table 6-12. Nitrate as N water quality data from the West Branch Llagas Creek where if flows through the Coredevalle golf course, southern Santa Clara County (units = mg/L).

Stream	Monitoring Site	No. of Samples	Arithmetic Mean	Min	25%	50% (median)	75%	Max
West Branch Llagas Creek @ Cordevalle Golf Course	All Sites	42	1.28	0.018	0.537	1	2	4
	SW1	18	0.96	0.018	0.452	0.929	1	3
	SW2	18	1.27	0.1	0.757	1	1.92	3
	SW3	6	2.32	1.198	1.805	2	2.75	4

Source data: monitoring data submitted to the Central Coast Regional Water Quality Control Board.

Table 6-13. Phosphorus as P water quality data from the West Branch Llagas Creek where if flows through the Coredevalle golf course, southern Santa Clara County (units = mg/L).

Stream	Monitoring Site	No. of Samples	Arithmetic Mean	Min	25%	50% (median)	75%	Max
West Branch Llagas Creek @ Cordevalle Golf Course	All Sites	46	0.21	0.01	0.01	0.09	0.2	1.2
	SW1	20	0.21	0.01	0.01	0.11	0.23	1.2
	SW2	20	0.14	0.01	0.01	0.01	0.16	0.9
	SW3	6	0.42	0.01	0.03	0.35	0.75	1

Stream	Monitoring Site	No. of Samples	Arithmetic Mean	Min	25%	50% (median)	75%	Max

Source data: monitoring data submitted to the Central Coast Regional Water Quality Control Board.

Figure 6-8. Nitrate as N water quality data from creeks in three golf courses in the California central coasta and bay area regions – Cordevalle golf course (near San Martin/Gilroy), Riverside golf course (at Coyote Creek), and Saratoga golf course (at Prospect Creek). Sample size = 76.

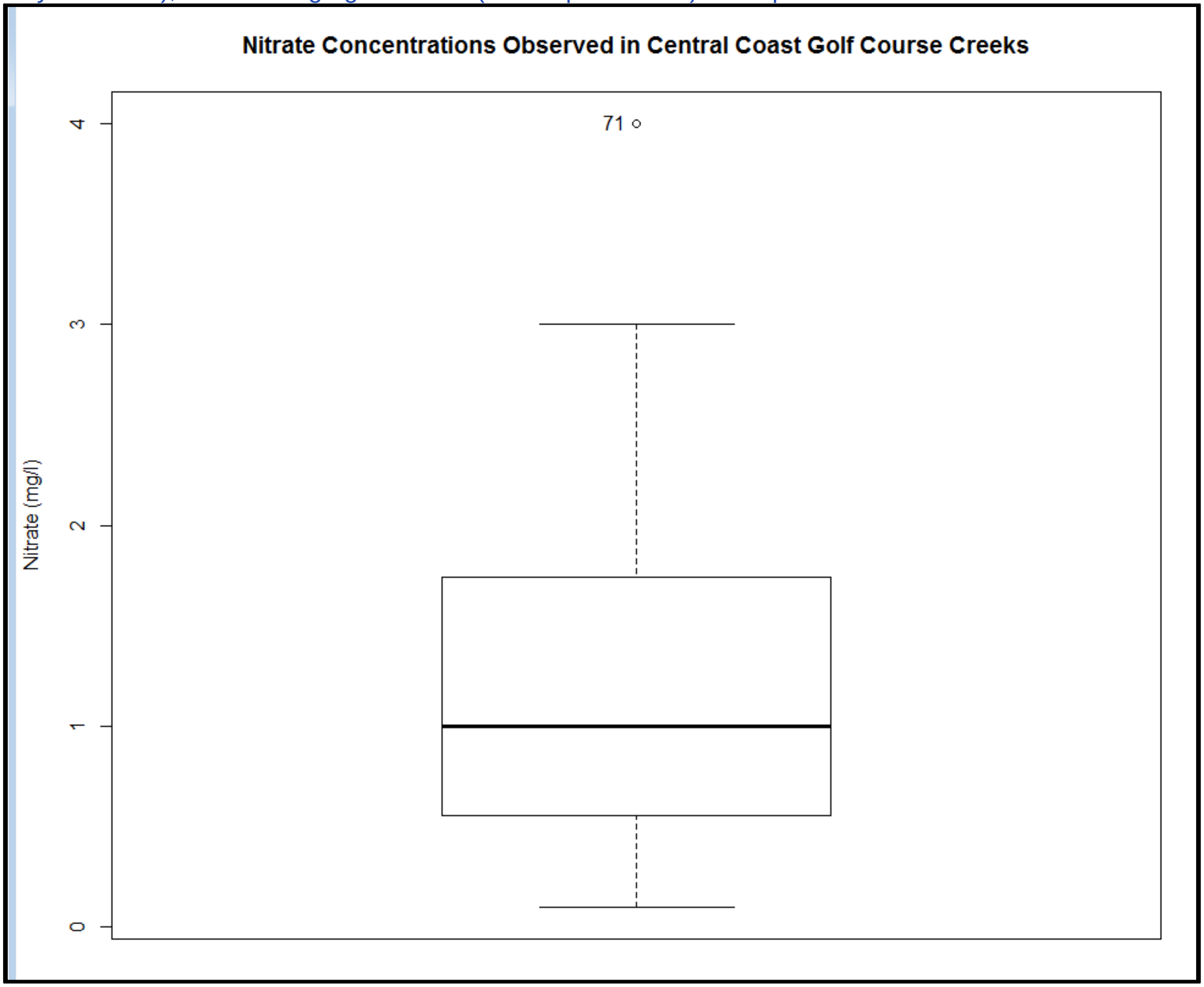


Table 6-14. Numerical summary of golf courses creeks water quality data from California central coast and bay area regions.

	mean	sd	IQR	0%	25%	50%	75%	100%	data:n
Cordevalle Golf Course	1.2725891	0.8190669	1.412903	0.10	0.5870968	1.0	2.00	4.0	65
COYOTE C A RIVERSIDE GOLF COURSE	0.2000000	0.0000000	0.000000	0.20	0.2000000	0.2	0.20	0.2	3
PROSPECT C AT SARATOGA GOLF COURSE NR SARATOGA C	0.9742857	0.3820060	0.480000	0.62	0.7100000	0.8	1.19	1.6	7
Prospect Creek at SARATOGA GOLF COURSE NR SARATOGA C	1.2000000	NA	0.000000	1.20	1.2000000	1.2	1.20	1.2	1

Golf course creeks water quality data source: U.S. Environmental Protection Agency's Storage and Retrieval Dataset (STORET)

Based on available data, formal regulatory actions or regulatory oversight of golf courses to implement these TMDLs is unwarranted. Available data from gold course Creeks in the Pajaro River basin, regionally, and nationally, suggest that golf courses would be expected to be meeting anticipated load allocations protective of designated beneficial uses in streams of the river basin.. Because anti-degradation is an element of all water quality standards, golf courses should continue to implement turf management practices which help to protect and maintain existing water quality in surface waters and which prevent any further surface water quality degradation.

It should be noted that information developed in this report does not conclusively demonstrate that all golf courses in the Pajaro River basin are currently meeting proposed nutrient load allocations for discharges to surface waters. Central Coast Water Board staff will obtain more information, if merited, during the implementation phase of the TMDL to further assess the levels of nutrient contribution from these source categories, and to identify any actions if necessary to reduce nutrient loading to surface waters.

6.3 Cropland

Fertilizers or compost applied to cropland can constitute a significant source of nutrient loads to waterbodies. The primary concern with the application fertilizers on crops or forage areas is that the application can exceed the uptake capability of the crop. If this occurs, the excess nutrients become mobile and can be transported to either nearby surface waters, to groundwaters, or the atmosphere (Tetra Tech, April 29, 2004).

As of summer 2014, there were 1,152 farming operations, entities, or operators in the Pajaro River basin enrolled in the Central Coast Water Board's, irrigated lands regulatory program[128]. The overwhelming majority of these farming operations are found in the Pajaro River Valley, the Santa Clara Valley, and the San Juan Valley (a valley near the confluence of San Juan Creek and the San Benito River, with the Pajaro River).

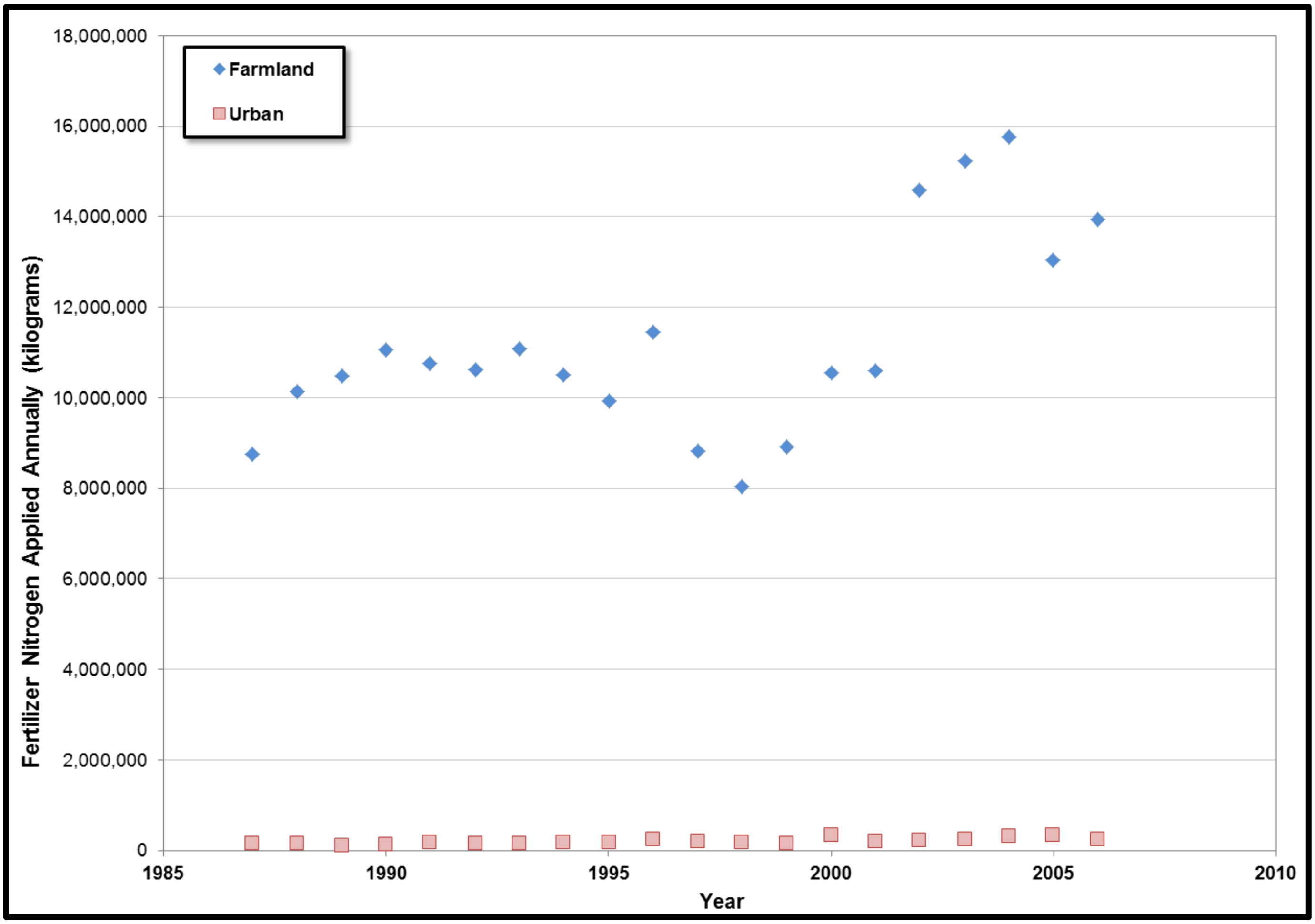
Farming operations in the river basin are quite diversified, with row crops, orchards, vineyards, nurseries, and greenhouses represented. Row crops are the most commonly reported farming operation in the river basin. Berry crops (e.g., blackberry, raspberry, strawberry) are generally grown in the lowermost reaches of the river basin: the lower Pajaro River, Corrilitos Creek, Salsipuedes Creek, and Watsonville Slough subwatersheds, while prominent row crops, such as lettuce and broccoli are grown throughout the Pajaro River Valley, the southern Santa Clara Valley, and the San Juan Valley[129]. A large proportion of the river basin's greenhouses are located in the Llagas Creek watershed (Santa Clara valley), while most nurseries appear to be located in the lower reaches of the river basin (Salsipuedes Creek, Corrilitos Creek, and Watsonville Slough subwatersheds). Vineyards tend to be located in upland reaches of the river basin (e.g., upland/foothill reaches of the Corrilitos Creek, Uvas Creek and Llagas Creek watersheds, as well as the lower San Benito River and Tres Pinos Creek watersheds)[130].

Figure 6-9 and Figure 6-10 illustrate estimated temporal trends of the amounts of nitrogen and phosphorus from fertilizers applied within the Pajaro River basin, on the basis of data of data published by the U.S. Geological Survey[131]. These data indicate that commercially-sold fertilizers are

[128] Information available for State Water Resources Control Board's Geotracker information management system.
[129] *Ibid*
[130] *Ibid*
[131] U.S. Geological Survey, 2012 – *County-Level Estimates of Nitrogen and Phosphorus from Commercial Fertilizer for the Conterminous United States, 1987-2006.* Scientific Investigations Report 2012-5207. This dataset contains county-level estimates of nitrogen and phosphorus from fertilizer, for both farm and non-farm uses, for the conterminous United States, for 1987 through 2006. Since these data are reported at the county-level, Central Coast Water Board staff coverted these estimates spatially to the scale of the Pajaro River Basin, by assuming that farm fertilizer is applied equally and uniformly

overwhelming used on farmlands – based on the available data, Central Coast Water Staff estimates that around 97 to 98 percent of the nitrogen and phosphorus from fertilizers is applied to farmland in the Pajaro River basin, and around two to three percent are applied in urbanized areas. These estimates comport quite well with California Department of Food and Agriculture reporting indicating that for the annual period July 2007 to July 2008, non-farm entities purchased about 3% of fertilizing materials sold in Monterey County[132], thus providing an indirect, anecdotal line of supporting evidence to Central Coast Water Board staff's estimates. It should be noted that the aforementioned U.S. Geological Survey commercial fertilizer estimates may not include fertilizing materials such as peat, potting soils, compost, and soil additives[133]; these materials can often be used in some residential landscaping.

Figure 6-9. Estimates of fertilizer nitrogen applied annually (kilogram, 1987-2006) in the Pajaro River basin in urbanized areas and in farmland

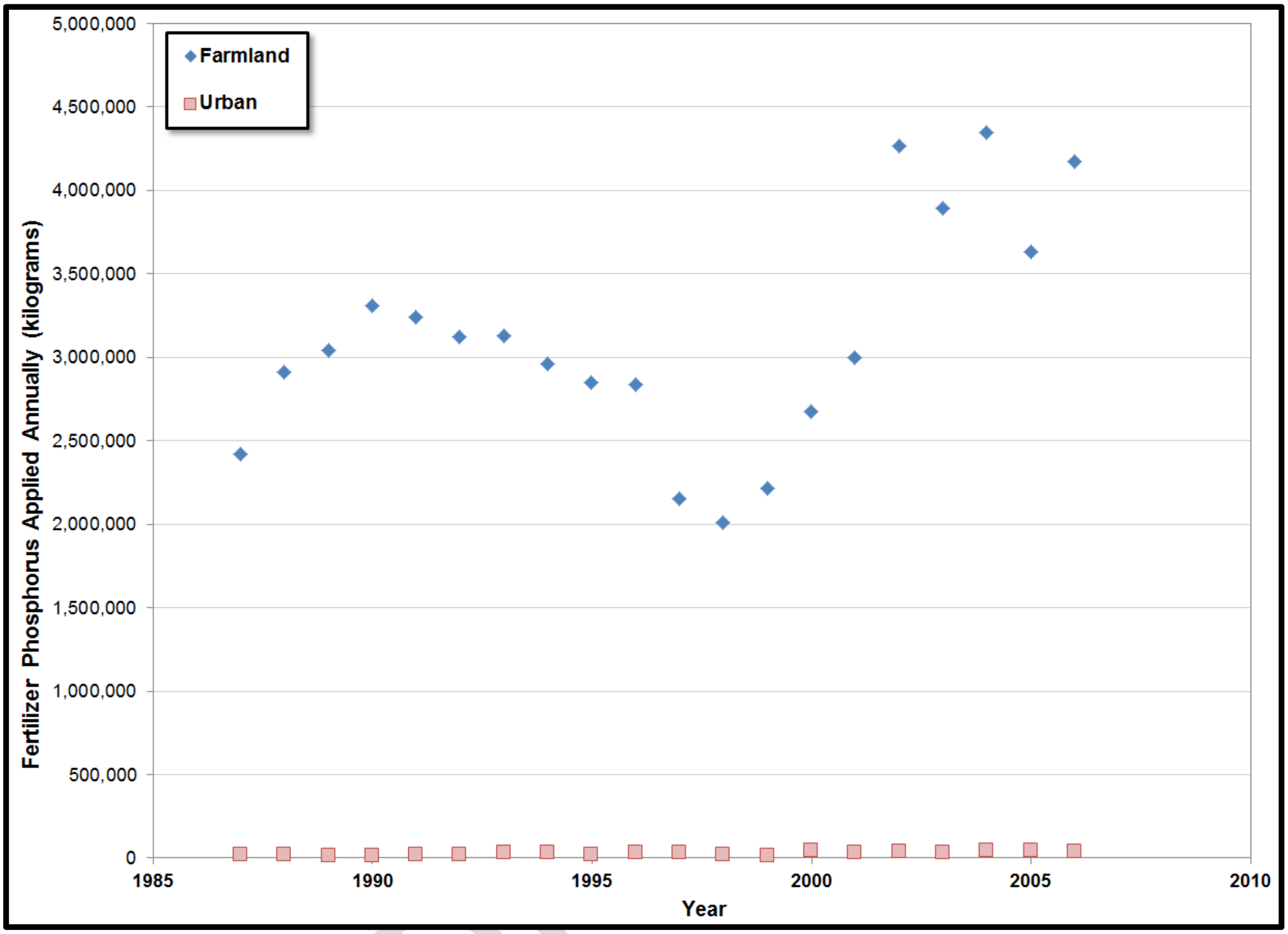


throughout a given county on farmland, and non-farm fertilizer is likewise applied uniformly on urbanized areas of a given county. Then we adjusted the U.S. Geological Survey estimates by multiplying by a ratio. The ratio was calculated by dividing the amount of urban or farmland within the portions of the four counties (Santa Cruz, Santa Clara, San Benito, and Monterey) which geographically intersect the river basin, to the total amount of urban or farmland found in each of the four counties. The 2010 Farmland Mapping and Monitoring Program Land Cover dataset was used in the land use ratio calculations.

[132] California Department of Food and Agriculture Tonnage Report of Commercial Fertilizers and Agricultural Minerals, July 2007-July 2008.

[133] See U.S. Environmental Protection Agency "Commercial Fertilizer Purchased" webpage @ http://www2.epa.gov/nutrient-policy-data/commercial-fertilizer-purchased#table1

Figure 6-10. Estimates of fertilizer phosphorus applied annually (kilogram, 1987-2006) in the Pajaro River basin in urbanized areas and in farmland



California fertilizer application rates on specific crop types are available from the U.S. Department of Agriculture, National Agricultural Statistics Service, as shown in Table 6-15 and Figure 6-11. Estimates of nitrogen application rates on California crops, as reported by California resource professionals and agencies, are presented in Table 6-16. Where the reporting from these different federal and state sources overlap (aka, strawberries, lettuce, broccoli), the nitrogen application estimates comport reasonably well with each other.

Table 6-15. Calif. Reported fertilizer application rates (National Agricultural Statistics Service).

Crop	Application Rate per Crop Year (pounds per acre) in California			Source
	Nitrogen	Phosphate	Potash	
Tomatoes	243	133	174	2007 NASS report
Sweet Corn	226	127	77	2007 NASS report
Rice	124	46	34	2007 NASS report
Cotton	123	74	48	2008 NASS report
Barley	73	19	7	2004 NASS report
Oats[1]	64	35	50	2006 NASS report
Head Lettuce	200	118	47	2007 NASS report
Cauliflower	232	100	43	2007 NASS report

Broccoli	216	82	49	2007 NASS report
Celery	344	114	151	2007 NASS report
Asparagus	72	20	46	2007 NASS report
Spinach	150	60	49	2007 NASS report
Strawberries[2]	155	88	88	University of Delaware Ag, Nutrient Recommendations on Crops webpage

[1]insufficient reports to publish fertilizer data for P and potash; used national average from 2006 NASS report for P and K

[2] median of ranges, calculated from table 1, table 4, and table 5 @ http://ag.udel.edu/other_websites/DSTP/Orchard.htm

Figure 6-11. California fertilizer application rates on crops (source: USDA-NASS, 2004-2008).

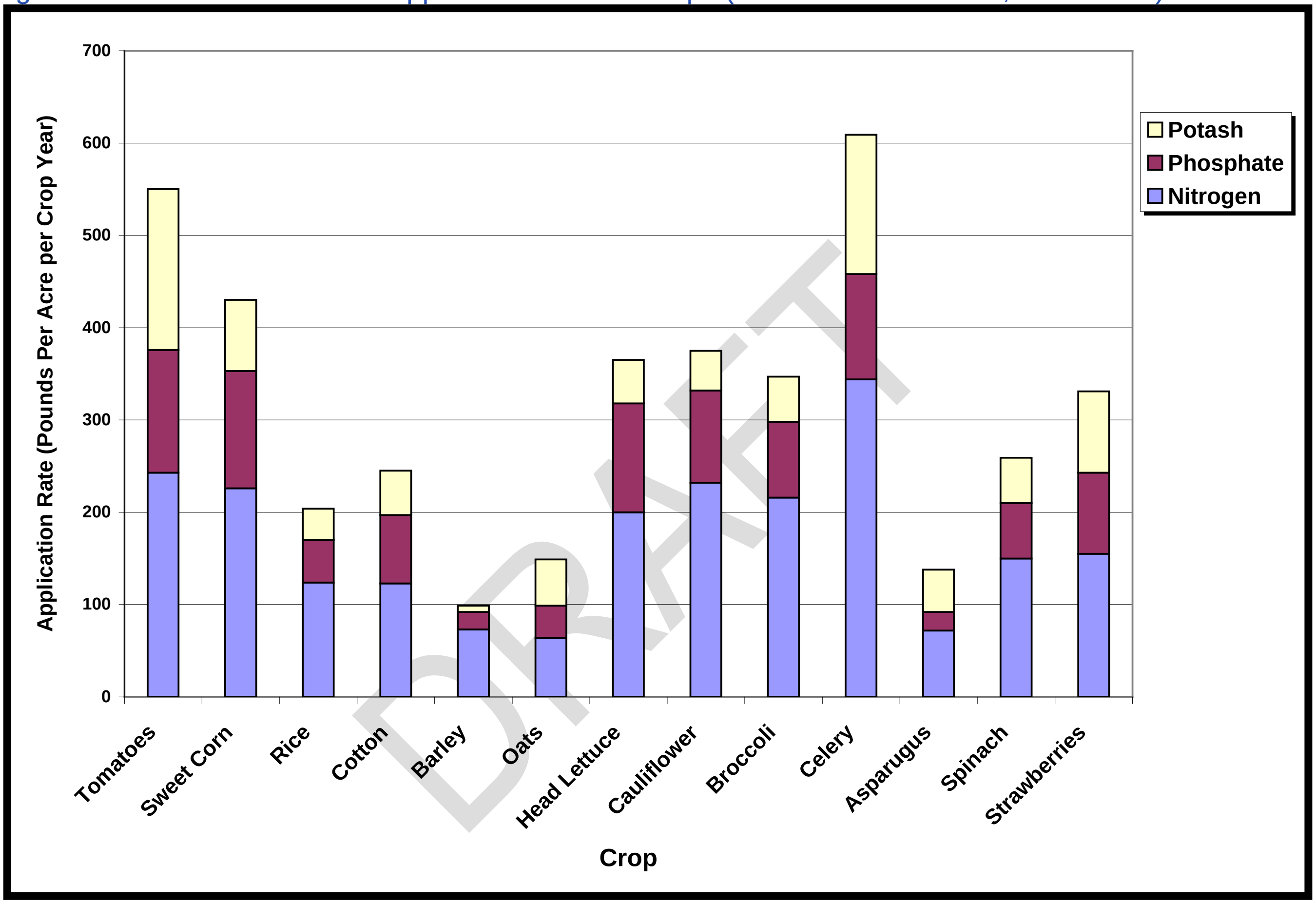


Table 6-16. Nitrogen application rates on California crops, reported by California resource professionals and agencies.

Crop Type	Estimated Crop Application Rates (lbs N/acre)	Source of Application Estimate
Lettuce	150	7, 9
Broccoli	200	8
Celery	275	4
Misc. Vegetables	150	5
Strawberries	180	11
Rasberries	60	6
Grapes	19.76	12
Citrus	170	10
Avocados	50	5
Nuts	200	13
Misc. Fruit	151	14

Crop Type	Estimated Crop Application Rates (lbs N/acre)	Source of Application Estimate
Seed	150	5
Flowers	300	5
Nurseries	300	5
Field Crops	50	5

Notes:
1. Table/estimate compiled by Peter Meertens, Central Coast Water Board, October 2009
2. 2008 Crop Report for Monterey County, Agricultural Commissioner's Office
3. A crop acre is the number of crops per acre per year (i.e. three lettuce crops grown on one acre in one year is three crop acres)
4. Tim Hartz, Fertilizer Symposium presentation, Santa Maria, November 2008
5. Peter Meertens, Central Coast Water Board staff, based on similar crop type.
6. Univ. of Calif. Cooperative Extension (UCCE), 2005 Sample Cost to Produce Fresh Market Rasberries, Santa Cruz & Monterey Counties
7. UCCE, 2009 Sample Costs to Produce Romaine Hearts, Central Coast Region - Monterey County
8. UCCE, 2004 Sample Costs to Produce Fresh Market Broccoli, Central Coast Region - Monterey County
9. UCCE, 2009 Sample Costs to Produce Iceberg Lettuce, Central Coast Region - Monterey County
10. UCCE, 2005 Sample Cost to Produce Mandarins, Ventrura County (170 trees/ acre 1lb N/ tree)
11. UCCE, 2005 Sample Costs to Produce Strawberries, Santa Barbara County
12. UCCE, 2004 Sample Cost to Establish and Produce Wine Grapes, Chardonay, North Coast Region - Sonoma County
13. UCCE, 2007 Sample Cost to Establish a Walnut Orchard and Produce Walnuts, Sacramento County (N rate for established orchard)
14. UCCE, 2004 Sample Cost to Establish and Produce Fresh Market Nectarines, San Joaquin Valley

Because of variability in nitrogen and phosphorus application rates noted above, undoubtedly the estimated magnitude of nutrient loads to land and to streams from agricultural lands can vary substantially based on crop type (Harmel et al., 2006). Nutrient loads refer to the amount of nitrogen or phosphorus exported from an area or specific land use over a specific time period (e.g., typically, kilograms per hectare per year). Harmel et al. (2006) report nutrient loading values that range from a national median of 21.9 kg/ha nitrogen for soybean crop, to a national median of 3.02 kg/ha nitrogen for sorghum. Therefore, it is important to be cognizant of local agricultural conditions and crop types in order to gage a plausible level of risk of nutrient loading to surface water from these sources.

Figure 6-12. Grower-reported frequencies of crop type–categories in the Pajaro River basin, as reported to the Central Coast Water Board, Summer 2014.

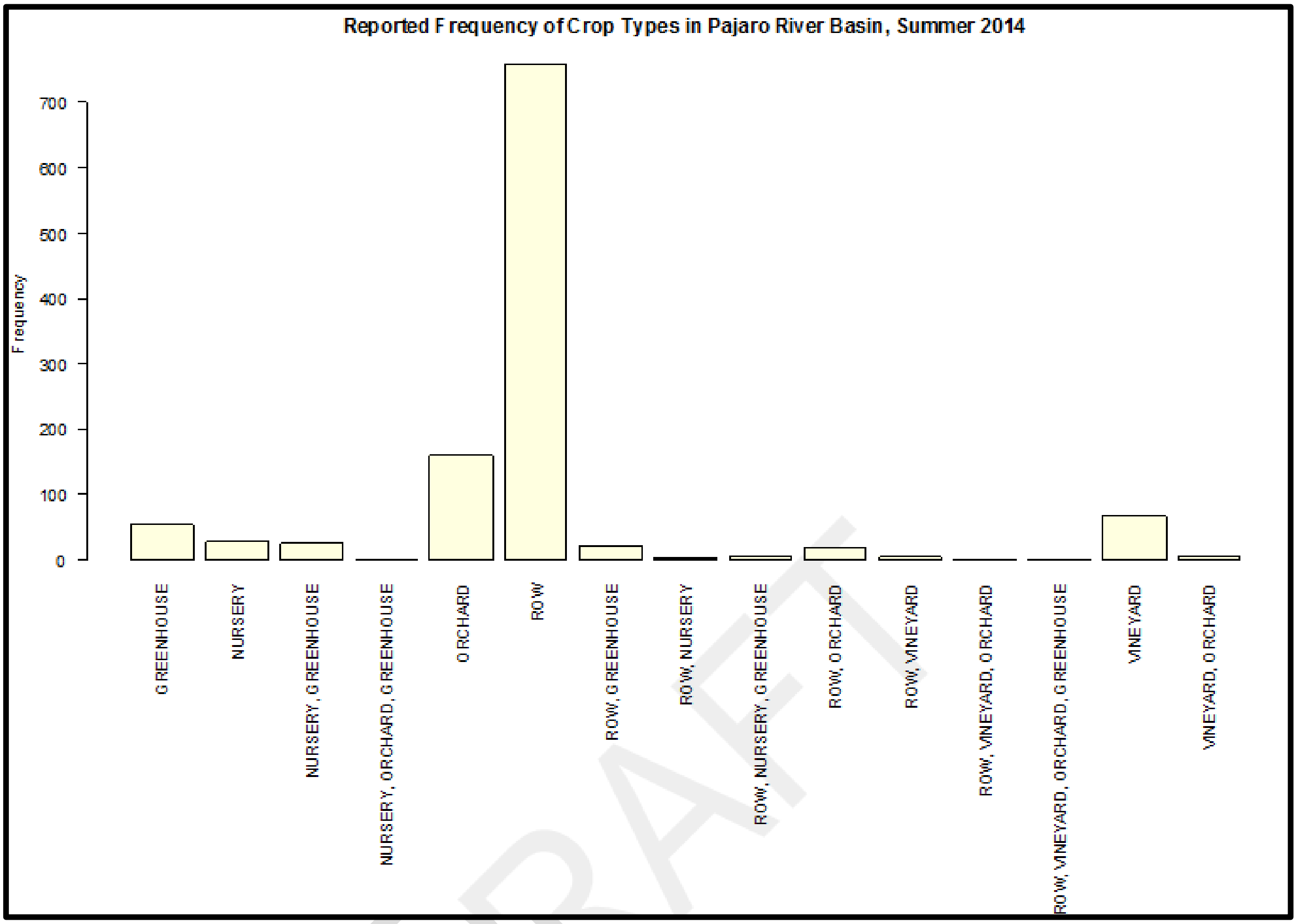
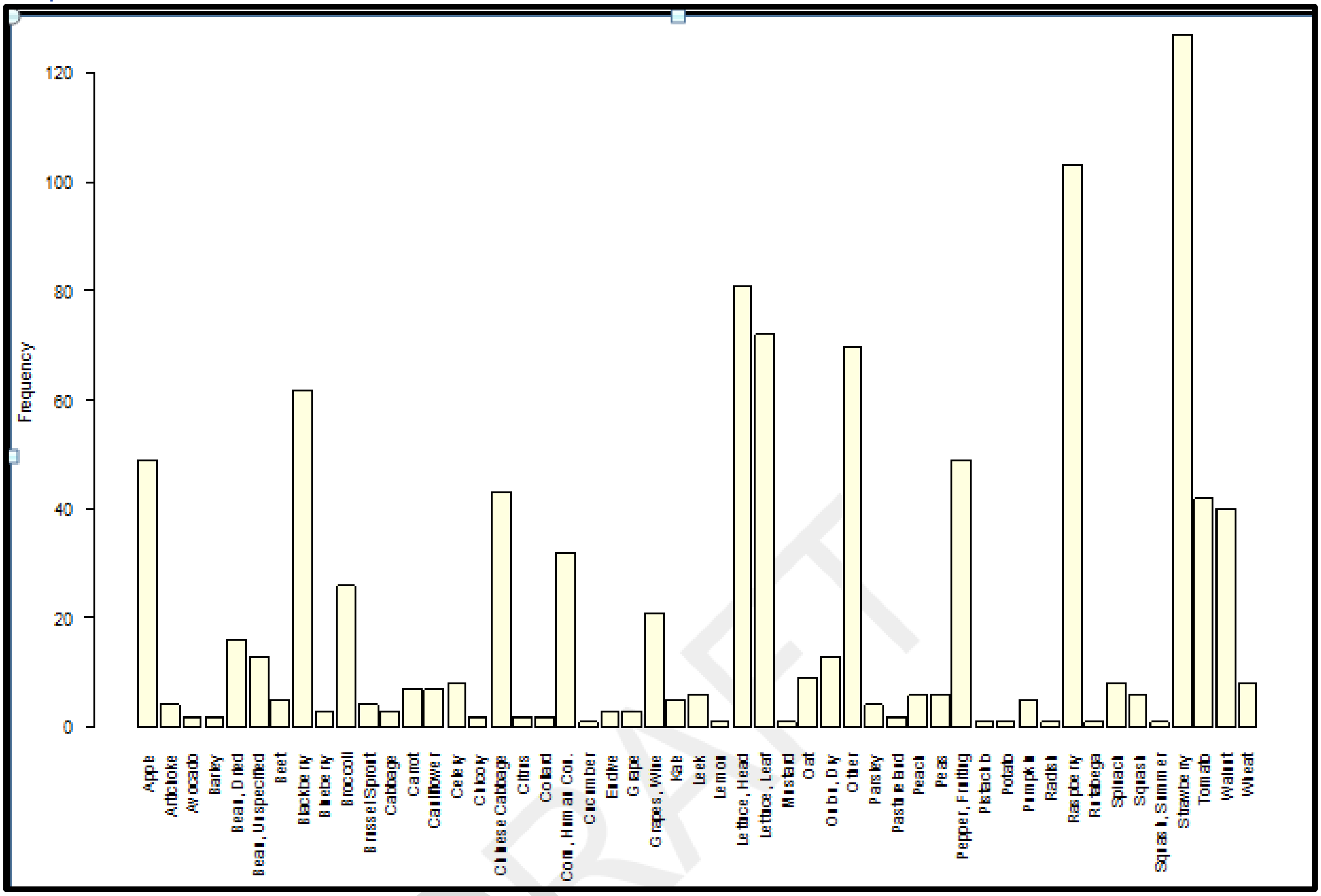


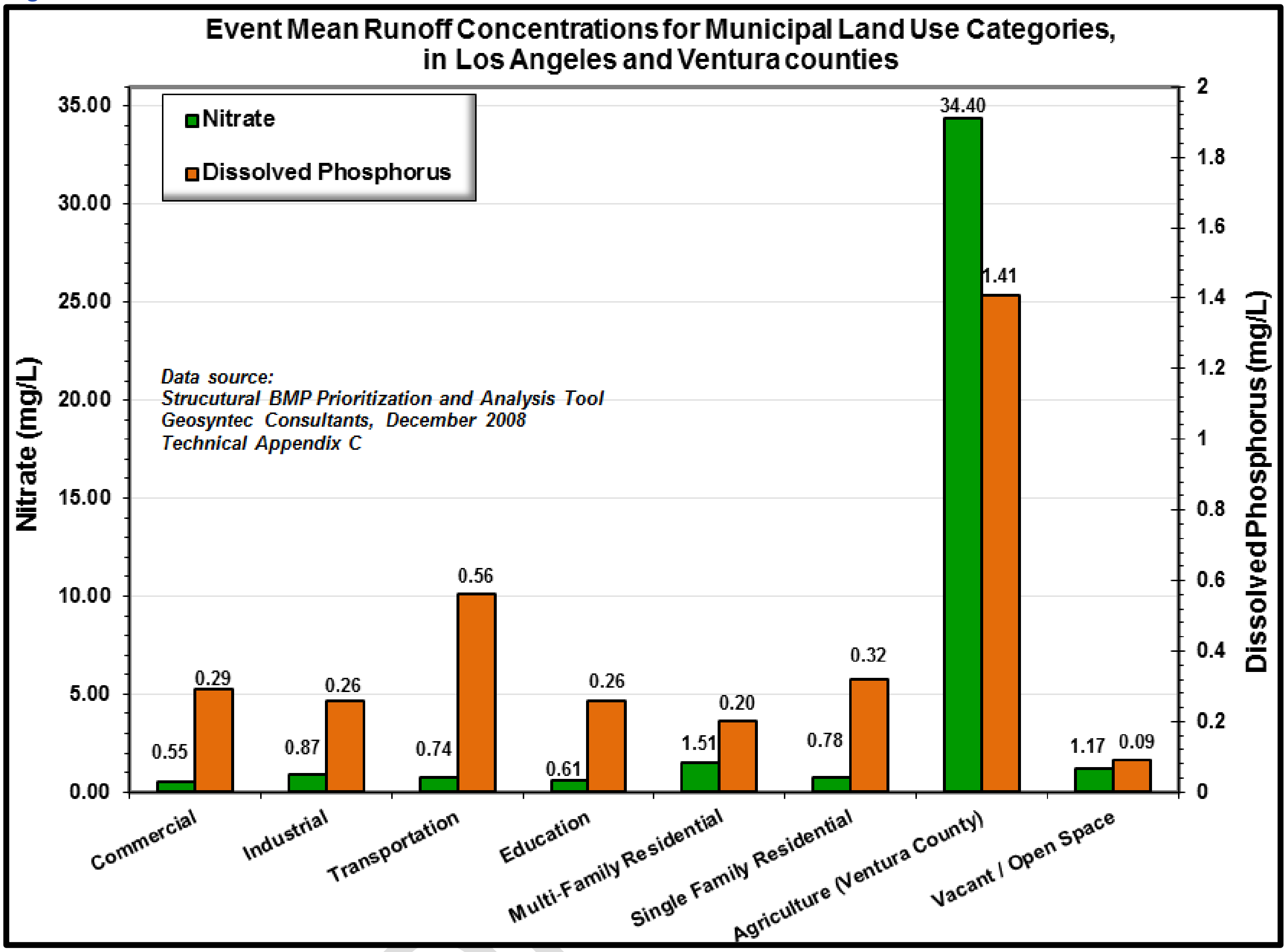
Figure 6-12 illustrates the frequency generalized crop type–categories in the Pajaro River basin, on the basis of reporting from growers to the Central Coast Water Board. This reporting does not include acreage, so this reporting should not be conflated with the geographic size, distribution, and importance of a particular crop type–category. However, this type of information does provide insight into which crop types are most frequently reported by growers in the river basin. Row crops are the most commonly reported crop type–category within the Pajaro River basin. The most frequently reported crops, as of Summer 2014, in the Pajaro River basin are berries (e.g., strawberries, blackberries), head lettuce, and leaf lettuce, with other row crops, vineyards, orchards, and nurseries having noteworthy roles in the river basin's cultivated agricultural production (see Figure 6-13).

Figure 6-13. Grower–reported frequencies of specific cultivated crops in the Pajaro River basin, as reported to the Central Coast Water Board, Summer 2014.



Because of the relative intensity of fertilizer applications on many types of cultivated crops as outlined previosuly, nutrient concentrations in agricultural surface runoff are often expected to be higher than in nutrient concentrations in municipal and residential runoff, as illustrated in Figure 6-14 (data is from Geosyntec Consultants, 2008). Nutrient concentrations in runoff and drainage are important to consider as discussed below.

Figure 6-14. Runoff event mean nutrient concentration data for municipal land use categories, Los Angeles and Ventura counties.

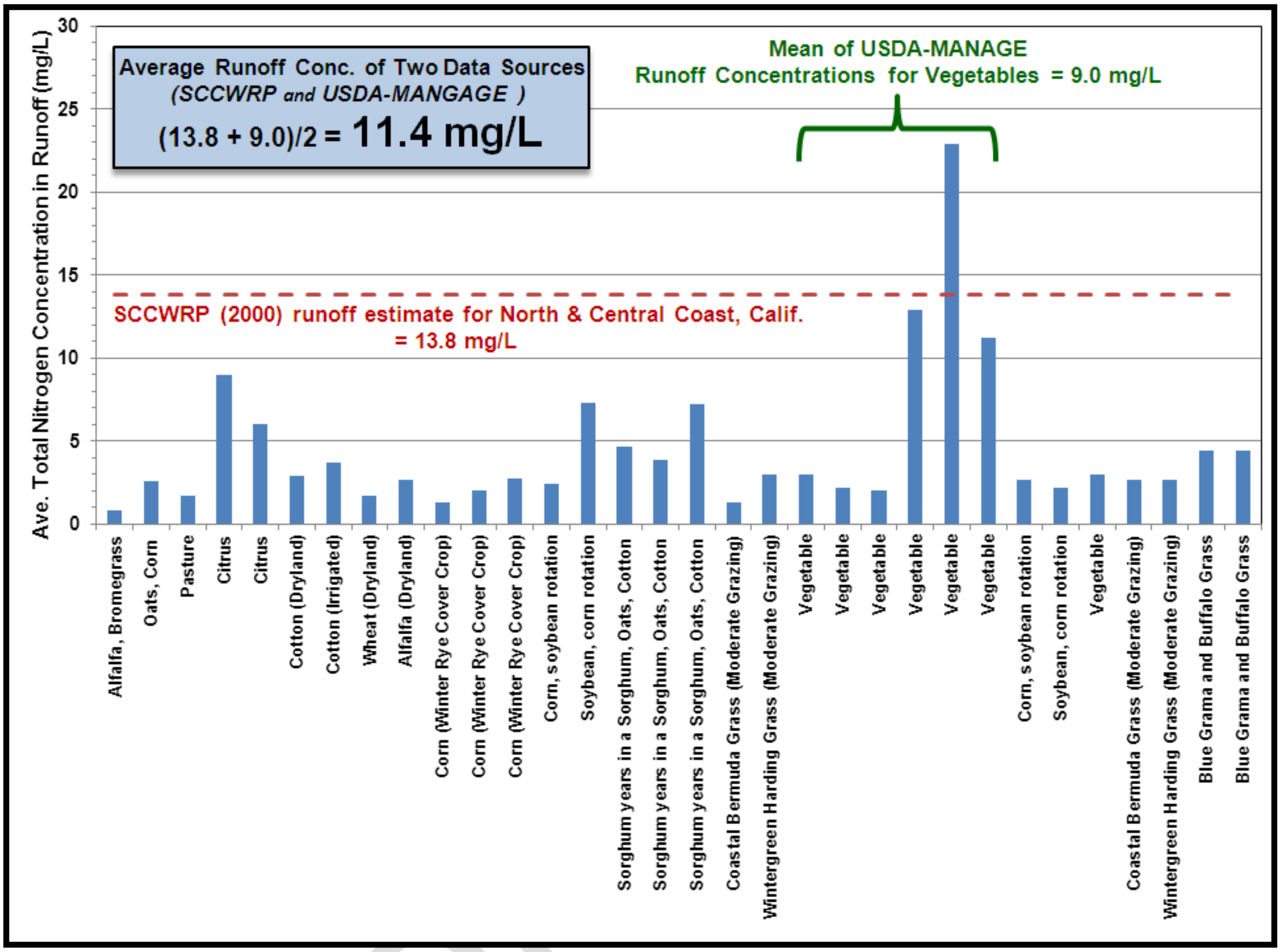


To develop nutrient loading estimates for agricultural lands in the Pajaro River basin, it is necessary to have plausible estimates of nutrient concentrations in agricultural runoff. Estimates for the average concentration of nitrogen in agricultural runoff used in this project report was derived using two data sources: Southern California Coastal Water Research Project (SCCWRP, 2000) and the U.S. Department of Agricultural-Agricultural Research Service's MANAGE database[134]. Because of the nature of crop types grown in the Pajaro River basin, as outlined previously, agricultural runoff concentrations were weighted towards vegetable crops. An average of the SCCWRP nitrogen runoff concentration estimate (13.8 mg/L) and the MANAGE database runoff mean (9.0 mg/L) for vegetable crops[135] is equivalent to 11.4 mg/L nitrogen-N, as illustrated in Figure 6-15. Average concentration of phosphorus-P in agricultural runoff used in this TMDL progress report is taken from the aforementioned SCCWRP (2000) report = 0.64 mg/L phosphate-P.

[134] Manage Nutrient Database - Nutrient Loss Database for Agricultural Fields in the US. The primary objective of this effort was to compile measured annual nitrogen (N) and phosphorus (P) load and concentration data representing field-scale transport from agricultural land uses. http://www.ars.usda.gov/Research/docs.htm?docid=11079

[135] Vegetable crops are the dominant type of crop cover in the TMDL project area.

Figure 6-15. Estimated nitrogen as N concentrations in agricultural lands runoff on the basis of averaging runoff concentrations from two different datasets.



Finally, average annual nutrient loads delivered to surface waterbodies in the Pajaro River basin from cropland discharges were estimated on the basis of the STEPL input parameters previously identified in Section 6.1 – these estimated loads are tabulated in Table 6-17.

Table 6-17. Estimated average annual nutrient loads (lbs./year) delievered to surface waterbodies from cropland in the Pajaro River basin.

Source	N Load (lb/yr)	P Load (lb/yr)
Cropland	1,869,231	204,350

6.4 Grazing Lands (Rangeland)

Grazing lands, as defined by the Farmland Mapping and Monitoring (FMMP) land cover dataset used in this report refers to lands where the vegetation is *suitable* for cattle foraging; it does not imply those lands are necessarily actively being grazed by livestock. Therefore, the FMMP "grazing lands" land cover category could also be considered equivalent to rangeland – whether grazed or ungrazed – and therefore Central Coast Water staff interchangeably use "rangeland" with "grazing lands" in this report to refer to grasslands of the Pajaro River basin, which may or may not be used locally for forage by livestock.

The only human activity associated with grazing lands that could conceivably contribute to nutrient loading to surface waterbodies is livestock grazing. Livestock and other domestic animals that spend significant periods of time in or near surface waters can contribute significant loads of nitrogen and phosphorus through their manure because they use only a portion of the nutrients fed to them and the remaining nutrients are excreted (Tetra Tech, 2004). The remainder of nutrients loads to streams from grazing lands is associated with natural background.

Expected nutrient concentrations in rangeland runoff can be estimated from data reported by the Unviersity of California, Davis Rangeland Watershed Laboratory, and from the U.S. Department of Agriculture – refer to Figure 6-16 and Table 6-18. On the basis of these data, nutrient concentrations in from ungrazed grasslands or from moderately grazed lands are exected to typically be relatively low.

Figure 6-16. Average nutrient creek water quality in California rangelands based on ten years of data as reported by the Rangeland Watershed Laboratory at University of California, Davis. Based on this reporting, the average nitrate as N creek water quality from a composite of moderatly grazed rangelands and ungrazed rangelands is 0.25 mg/L (figure credit: Rangeland Watershed Laboratory http://rangelandwatersheds.ucdavis.edu).

Stream Water Quality

Grazing Intensity	Sediment mg/L	Nitrate mg/L	*E. Coli* cfu/100ml
None 4000+ lb/ac RDM	2	0.1	310
Moderate 800 lb/ac RDM	7	0.4	425

Table 6-18. Total dissolved phosphorus as P concentrations in native grasslands runoff (units = mg/L) from the U.S. Department of Agriculture's MANAGE database [A].

Runoff Category	Types of Land Cover at Monitoring Sites	No. of Samples	Arithmetic Mean	Min	10%	25%	50% (median)	75%	90%	Max
Runoff from Grazing Lands (aka, rangeland)	Native grassland Native grass (no grazing) Native grass (light grazing) Native grass (moderate grazing) Native grass (heavy grazing) Native prairie	19	0.21	0.01	0.028	0.09	0.17	0.24	0.526	0.67

[A] California or Pajaro River basin specific data for grasslands runoff are not available. Data available for phosphorus concentrations in grasslands runoff in the MANAGE database come from northern, south-central, and west Texas and from central Oklahoma.

In terms of manure from livestock, another potential source category could be considered. Livestock and domestic animals. such as horses, which occur in rural residential areas and are housed within corraled or confined animal areas, can also be considered a potential source of nutrients to surface waters. The management of these animals are notably different from range livestock on lightly-grazed rangelands. Figure 6-17 presents spatial estimates of rural residential areas within the northern Pajaro River basin. On balance, these rural residential areas occur in areas where streams are not impaired by nutrients on the basis of available data. Thus, in general it is expected that owners and operators of livestock and domestic animals on rural residential lands would currently achieving any load allocations or nutrient water quality targets identified for this TMDL report. The current nutrient load from this source category – while not expected to result in water quality standards violations – is unknown because STEPL does not provide an option to calculate loads from this land use category.

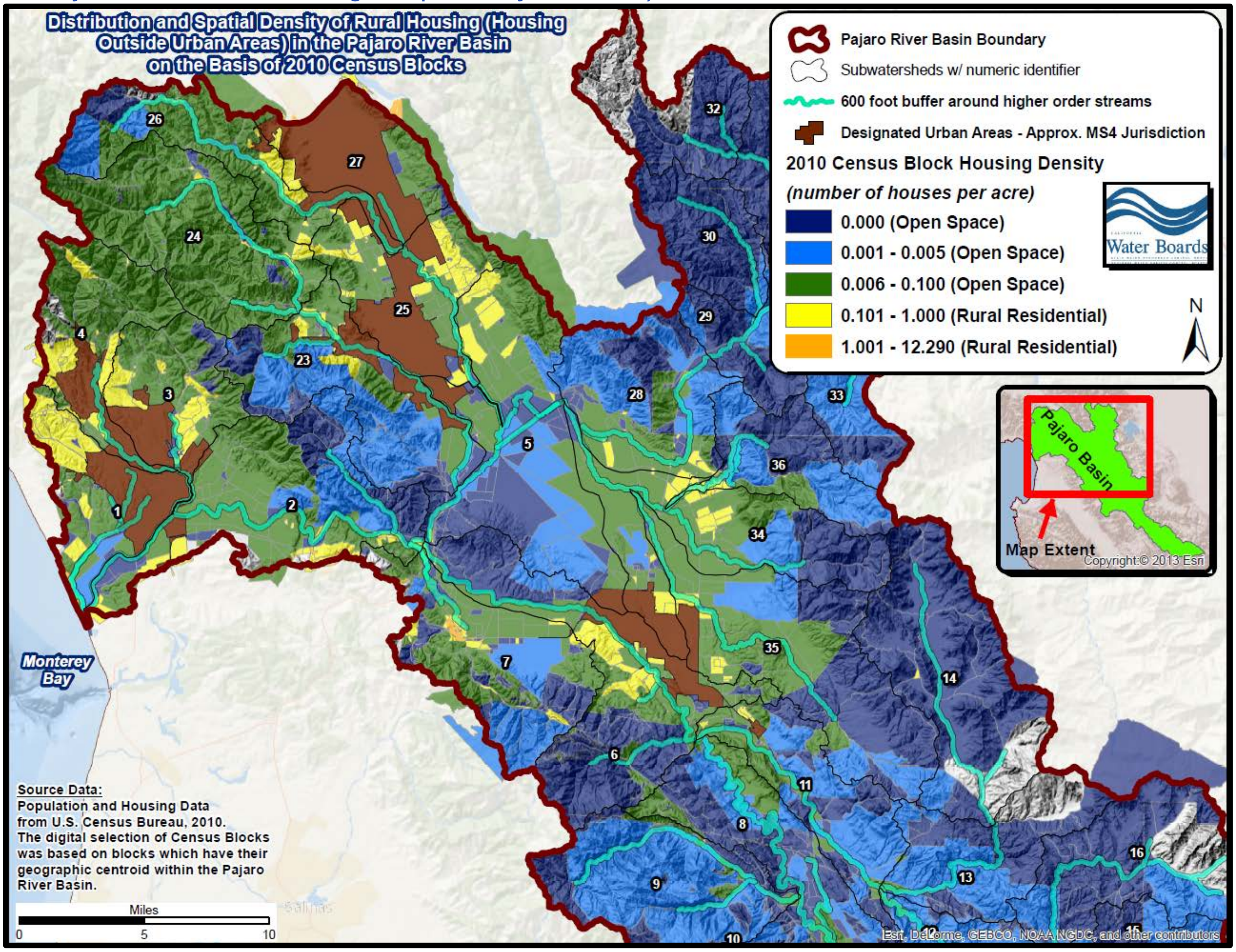
This assessment does not imply there is no risk at all from confined animals or corralled animals in rural residential areas. To maintain existing water quality and prevent any further water quality degradation, owners and operators of confined livestock and domestic animals in rural residential areas which do not drain to a municipal separate stormwater sewer system, as well as livestock owners/operators of unconfined livestock on rangelands, should begin or continue to self-assess, self-monitor and make animal management and manure management decisions which comport with accepted manure management practices or rangeland management practices recommended or published by reputable resource professionals or local agencies.

The information outlined above does not conclusively demonstrate that discharges from all confined animal facilities and properties are meeting proposed load allocations. More information will be obtained during the implementation phase of these TMDLs to further assess the level of nutrient contributions to surface waters from this source categories, and to identify any actions needed to reduce nutrient loading.

It is important to note that the Pajaro River basin is in fact currently subject to a Domestic Animal Waste Discharge Prohibition and livestock owners are subject to compliance with an approved indicator bacteria TMDL load allocation[136]. As a practical matter, implementation efforts owners and operators of livestock and domestic animals to comply with this prohibition and with the indicator bacteria load allocations will also reduce the risk of nitrogen and phosphorus loading to surface waters from domestic animal waste.

[136] Central Coast Water Board Resolution No. R3-2009-0008 (March 2009).

Figure 6-17. Distribution and spatial density of rural housing (housing outside census-designated urban areas) in the Pajaro River basin on the basis of 2010 Census block data. Blue and green shades are characaterized by "open space" (areas with zero housing units to less than one housing unit per every ten acres); yellow and orange shades are characterized by "rural residential" areas (areas with housing density more than one housing unit per every ten acres).



Summing up, average annual nutrient loads delivered to surface waterbodies in the Pajaro River basin from grazing lands (i.e., rangeland) were estimated on the basis of the STEPL input parameters previously identified in Section 6.1 – these estimated loads are tabulated in Table 6-19.

Table 6-19. Estimated average annual nutrient loads (lbs./year) delievered to surface waterbodies from grazing lands (i.e., rangeland) in the Pajaro River basin.

Source	N Load (lb/yr)	P Load (lb/yr)
Grazing Lands	377,410	249,930

6.5 Woodlands & Undeveloped Areas

Streams in lightly disturbed or undeveloped woodlands and open space are generally characterized by low concentrations of nutrients in surface waters on the basis of regional data previously presented in report Section 3.6 and on the basis of water quality data collected from across the conterminous United States – also see Table 6-20. Thus, surface waters and surface runoff from woodland areas of the Pajaro River basin would be expected to have quite low nutrient concentrations relative to other types of land use categories which are more influnced by human activities

Table 6-20. Mean annual flow-weighted nutrient concentrations observed in undeveloped stream basins of the conterminous United States.

Water Quality Parameter	No. of sampled streams	Arithmetic Mean	Min	25%	50% (median)	75%	90%	Max	No. Exceeding Drinking Water Standard (>10 mg/L)	% Samples Exceeding 10 mg/L
Nitrate as N	82	0.15	0.00	0.03	0.09	0.20	0.44	0.77	0 of 82	0%
Total nitrogen	63	0.39	0.10	0.17	0.25	0.50	0.72	2.57	N.A.	N.A.
Total phosphorus	63	0.04	0.02	0.02	0.02	0.04	0.08	0.20	N.A.	N.A.

Source data: Clark et al. (2000). Nutrient Concentrations and Yields in Undeveloped Basins of the United States.

Average annual nutrient loads delivered to surface waterbodies in the Pajaro River basin from woodlands were estimated on the basis of the STEPL input parameters previously identified in Section 6.1 – these estimated loads are tabulated in Table 6-21.

Table 6-21. Estimated average annual nutrient loads (lbs./year) delievered to surface waterbodies from woodlands in the Pajaro River basin.

Source	N Load (lb/yr)	P Load (lb/yr)
Woodlands & undeveloped areas	44,199	22,434

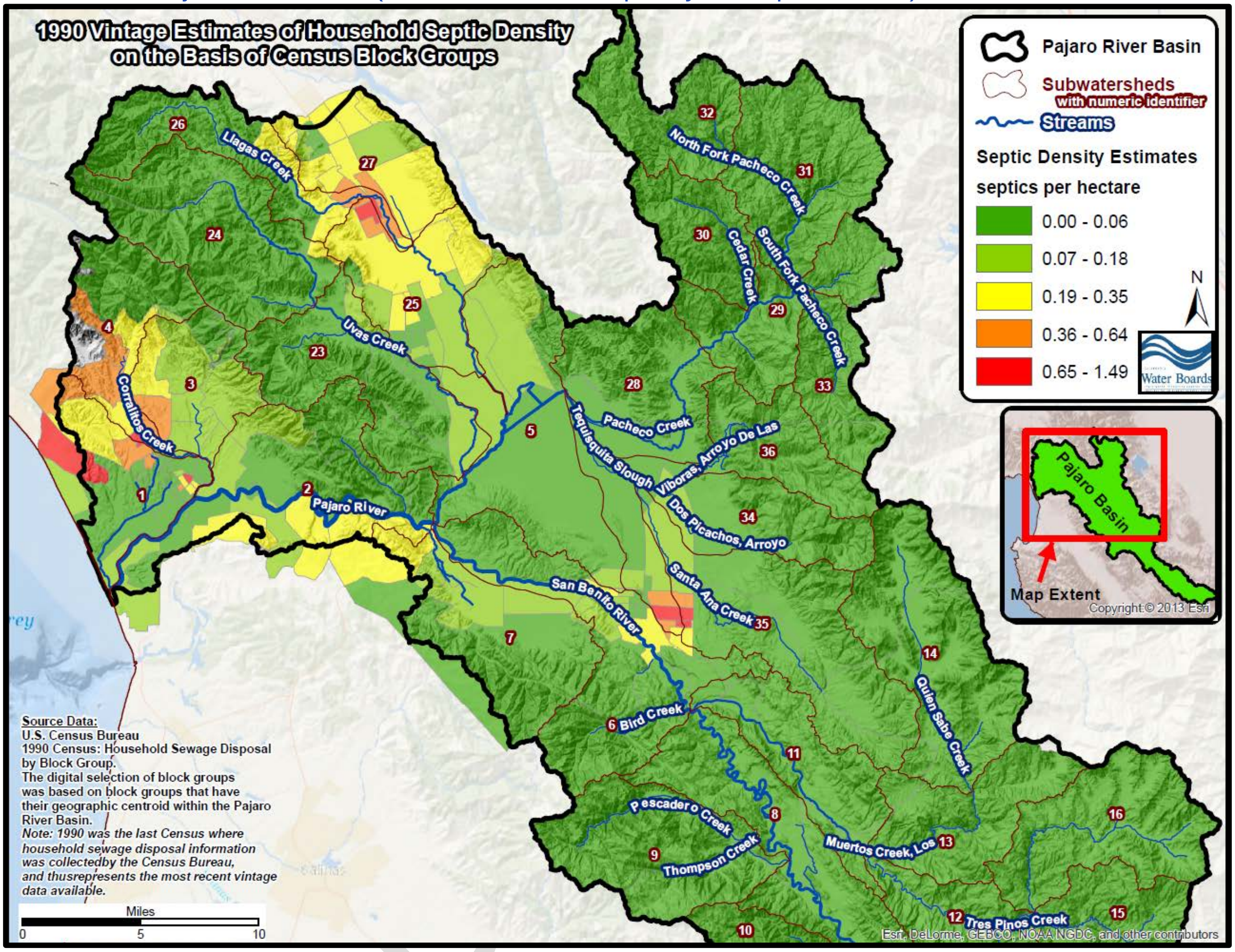
6.6 Onsite Wastewater Treatment Systems (Septics)

In any given watershed, onsite wastewater treatment systems (OWTS), also known as septic systems, are sometimes assessed as a possible source of nutrient or fecal bacteria surface water pollution. According to USEPA, the distribution and density of OWTS vary widely by region and by state[137]. Statewide, California has a fairly low distribution of its population served by OWTS – around 10 percent. In contrast, in the New England states, about half the population is served by OWTS[138]. An estimated distribution of OWTS density in the Pajaro River basin, based on 1990 vintage data, is presented in Figure 6-18. Based on the 1990 vintage Census Bureau data, about 30 percent of the population of the Pajaro River basin is served by OWTS. 1990 was the last decennial national census that collected household sewage disposal data.

[137] USEPA septic systems webpage, http://water.epa.gov/infrastructure/septic/FAQs.cfm#faq2

[138] *Ibid*

Figure 6-18. 1990 vintage estimates of household septic density on the basis of census block groups in the northern Pajaro River basin (units = number of septic systems per hectare).



The State Water Resources Control Board recently estimated the number of existing onsite wastewater treatment systems (OWTS) found within 600 feet of 303(d)-listed California waterbodies, including streams within the Pajaro River basin (SWRCB, 2008). These estimates was based on the assumption that only homes and businesses within 600 feet of the impaired water bodies would have the potential to have an impact on surface waters. The OWTS counts were based on an investigation using multiple sources: The main sources for the investigation are TOPO! (a U.S. Geological Survey [U.S. Geological Survey] map based program), Zillow.com, Realtor.com, and Google Maps. TOPO! were used to track water bodies through forest canopy, urban settings, and in some areas where the water body had few distinguishing features from the surrounding landforms.

In addition, Central Coast Water Board staff estimated approximately 70 OWTS within a 600 foot buffer of Watsonville Slough based on the presence of housing units in the Rio Boca road and Pajaro Dunes area (see Figure 6-19). Consequently, Pajaro River basin 303(d)-listed streams with estimates of the number OWTS located within a 600 buffer of the stream, are tabulated in Table 6-22.

Figure 6-19. Generalized and estimated spatial distribution of sewered areas, and areas with relatively high densities of housing units served by septic systems within 600 feet of a stream.

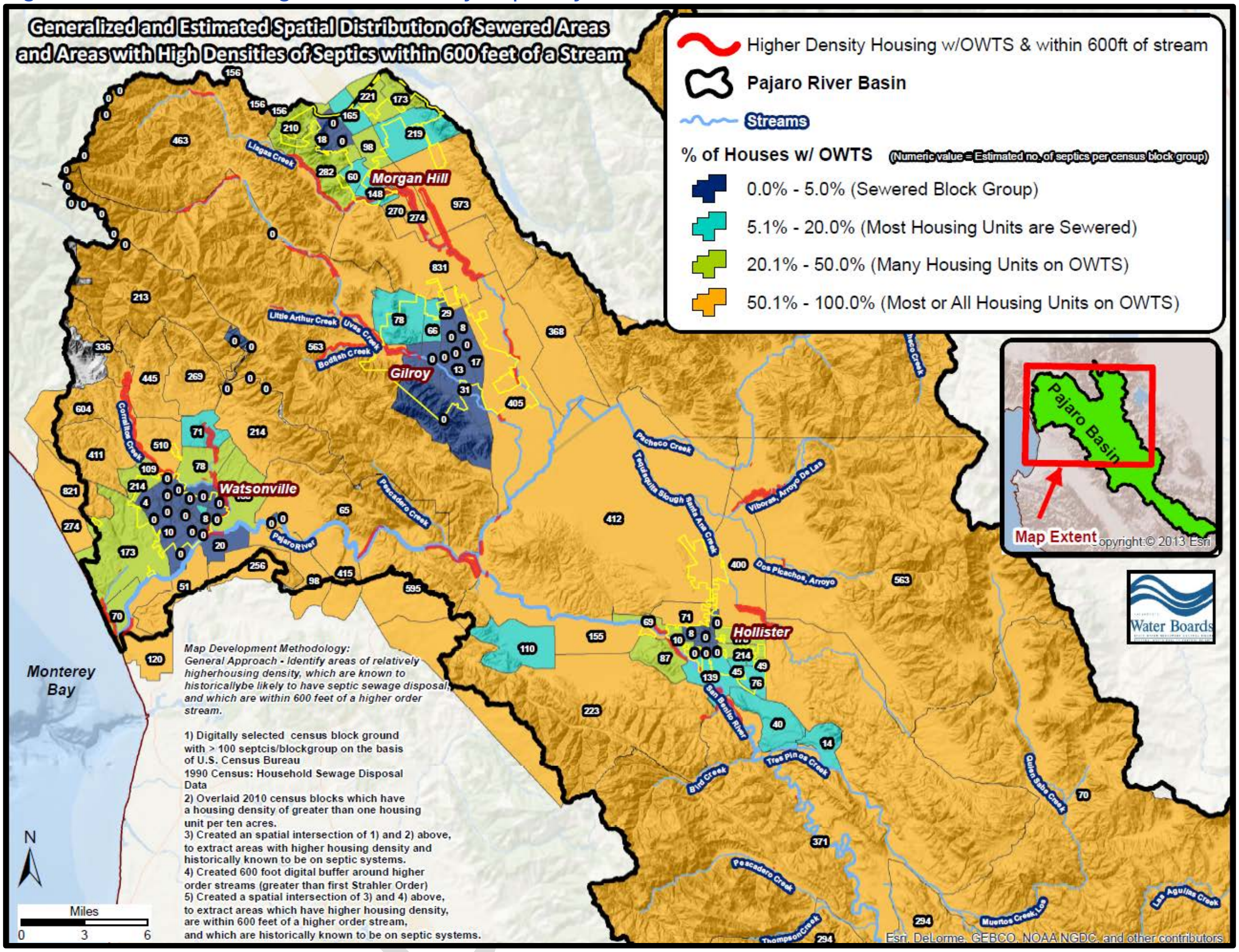


Table 6-22. Estimated locations and number of onsite wastewater treatment systems (OWTS) proximal to streams of the Pajaro River basin.

Stream	Estimated OWTS within 600 Feet of Stream	Subwatershed
Corrilitos Creek	200[A]	Corrilitos Creek Subwatershed
Llagas Creek (at San Martin)	150 [A, B]	Upper Llagas Creek Subwatershed
Llagas Creek (downstream of San Martin)	150 [A, B]	Lower Llagas Creek Subwatershed
Pajaro River (downstream of San Benito River confluence)	125[A]	Lower Pajaro River Watershed
San Benito River	100[A]	Bird Creek–San Benito River Subwatershed
Tequisquita Slough	31[A]	Tequisquita Slough Subwatershed
Watsonville Slough	70[C]	Watsonville Slough Subwatershed
	Total = 826	

[A] Data source: SWRCB (State Water Resources Control Board), 2008. AB 885 On-site Wastewater Treatment Systems Program DEIR.
[B] SWRCB (State Water Resources Control Board), 2008 DEIR literature source indicates there are an estimated 300 OWTS within 600 feet of Llagas Creek. Central Coast Water Board staff divided the 300 OWTS evenly between the upper Llagas Creek Subwatershed and the Lower Llagas Creek Subwatershed.
[C] Data source: Estimated on the basis of information developed in Figure 6-19.

Finally, the average annual nutrient loads delivered to streams in the Pajaro River basin from OWTS were estimated on the basis of the STEPL input parameters previously identified in Section 6.1 – these estimated loads are tabulated in Table 6-23. Because of the small and negligible magnitude of these loads, nutrient loading to streams from this source category is considered to be insignificant and negligible in the Pajaro River basin. It should be noted that OWTS impacts to underlying groundwater can locally be significant, but these potential OWTS groundwater impacts are outside the scope of the TMDL. Although not directly related to the Pajaro River basin, it is worth noting that researchers have concluded that at the basin-scale and regional-scale of the nearby Salinas Valley, OWTS impacts to groundwater are relatively insignificant compared to agricultural fertilizer impacts (University of California-Davis, 2012).

Table 6-23. Estimated average annual nutrient loads (lbs./year) delievered to surface waterbodies from onsite wastewater treatment systems (e.g, septic systems) in the Pajaro River basin.

Source	N Load (lb/yr)	P Load (lb/yr)
Onsite Wastewater Treatment Systems	566	222

6.7 Shallow Groundwater

Shallow groundwater provides the base flows to streams and can locally be an substantial source of surface water flows especially during low flow conditions or during the dry season (refer back to report Section 3.9). Nitrate in ground water can occur from both leaching of anthropogenic sources at the land surface, and from natural sources. Note that controllable phosphorus leaching to groundwater is presumed to be negligible in this project report; phosphorus readily binds to sediment, is relatively insoluble, and is generally not expected to be leached to groundwater from surface sources in significant amounts. Phosphorus in groundwater is generally expected to result from leaching of geologic materials in the subsurface.

Average annual nutrient loads delivered to surface waterbodies in the Pajaro River basin from shallow groundwater were estimated on the basis of the STEPL input parameters previously identified in Section 6.1 – these estimated loads are tabulated in Table 6-24.

Table 6-24. Estimated average annual nutrient loads (lbs./year) delievered to surface waterbodies from shallow groundwater in the Pajaro River basin.

Source	N Load (lb/yr)	P Load (lb/yr)
Shallow groundwater inputs to streams	384,812	19,074

6.8 Atmospheric Deposition

Atmospheric inputs of nutrients in rainfall are a source of loading in any watershed. Because nitrogen can exist as a gaseous phase (while phosphorus cannot), nitrogen is more prone to atmospheric transport and deposition. It is important to recognize however that atmospheric deposition of nutrients is typically more significant in lakes and reservoirs, than in creeks or streams (USEPA, 1999). This is because the surface area of a stream is typically small compared to the area of a watershed.

The STEPL spreadsheet model staff used in source analysis does estimate atmospheric inputs of nutrients to surface waterbodies. Consequently, staff used available information of atmospheric nutrient loading, and river basin parameters, to develop estimates independent of the STEPL spreadsheet (see Table 6-25). The total summed length of all NHDplus digitized surface water flowlines in the Pajaro River basin, is approximately 10.7 E+06 feet, and the average width streams in the Pajaro River basin is assumed to be approximately 10 feet. Accordingly, the total surface area of project area surface waterbodies is approximately 997 hectares as calculated in ESRI™ ArcMap® 10.1 using a digital NHD flowline buffer equal to ten feet in width. With an estimated average annual total nitrogen atmospheric deposition rate of 5.42 kg of nitrogen/ha/year (refer back to Figure 3-27), the typical annual load from atmospheric deposition in the river basin would thus be 5,404 kg of nitrogen/year, or equivalent to 11,914 pounds of nitrogen/year.

Atmospheric phosphorus can be found in organic and inorganic dust particles. The general atmospheric deposition rate for total phosphorus can be estimated as 0.6 kg of phosphorus/ha/year (USEPA 1994, as reported in San Diego Regional Water Quality Control Board, 2006). Accordingly, using the summed totally stream surface area presented above, the typical annual load of phosphorus would thus be 598 kg of total phosphorus/year, or equivalent to 1,319 pounds/year (see Table 6-26).

A tabular summary of the aforementioned estimates for nutrient atmospheric deposition in the Pajaro River basin is presented in Table 6-26.

Table 6-25. Nutrient atmospheric deposition in the Pajaro River basin: parameters considered and used.

Parameters Considered	Estimates
Total summed length of all streams in the Pajaro River basin	10,734,285 ft.
Total summed surface area of all streams in the Pajaro River basin	997 hectares[A]
Estimated average annual atmospheric deposition rate of total nitrogen to streams in the Pajaro River basin	5.42 kg/hectare per year
Estimated average annual atmospheric deposition rate of total phosphorus to streams in the Pajaro River basin	0.6 kg/hectare per year

[A] Calculated from the total summed length of NHD stream flowlines and a digitized 10 foot-wide polygon centered on the NHD flowlines .

Table 6-26. Estimated average annual atmospheric deposition of total nitrogen and total phosphorus to streams of the Pajaro River basin (lbs./year).

Source	N Load (lb/yr)	P Load (lb/yr)
Atmospheric deposition	11,914	1,319

6.9 Summary of Sources

It is worth reiterating that these are estimates for the Pajaro River basin. It is understood there will be substantial variation due to real-time conditions or due to local and site specific conditions. More information will be collected during TMDL implementation to assess controllable sources of nutrient pollution. It is important to recognize also that average "annual" nitrate load estimates at the river basin-scale do not adequately represent inter-annual variability, or the variability, the magnitude, and the seasonal and flow-based variability of nutrient stream loads at local scales

Table 6-27 presents a summary of nutrient source categories and estimated annual nutrient loads to streams of the Pajaro River basin.

The estimated relative source contributions (%) of source categories are also shown graphically in are also shown graphically in Figure 6-20. Further, Figure 6-21 presents estimates of the average annual nutrient yield (aka, the "intensity" of loading to streams) from various land use/land cover categories. These estimates indicate that nutrient yields from cropland are expected to be much higher than other land use/land cover categories, while urban land uses can also be expected to deliver nutrient yields well in excess of natural background conditions. Nutrient yields from grazing lands (aka, rangeland) and from woodlands and undeveloped areas are expected to be relatively low. Figure 6-21 presents estimates of the average annual nutrient load and yield to streams for subwatersheds in the Pajaro River basin. Unsurprisingly, the highest nutrient yields are expected to be from valley floor subwatersheds with substantial areas of agriculture, urban, and developed lands. Lastly, it worth noting that shallow groundwater is expected, locally, to be a significant source of nutrients to streams on the basis of information presented in this section of the report.

It is worth reiterating that these are estimates for the Pajaro River basin. It is understood there will be substantial variation due to real-time conditions or due to local and site specific conditions. More information will be collected during TMDL implementation to assess controllable sources of nutrient pollution. It is important to recognize also that average “annual” nitrate load estimates at the river basin-scale do not adequately represent inter-annual variability, or the variability, the magnitude, and the seasonal and flow-based variability of nutrient stream loads at local scales.

Table 6-27. Estimated average annual nutrient source loads to streams of the Pajaro River basin.

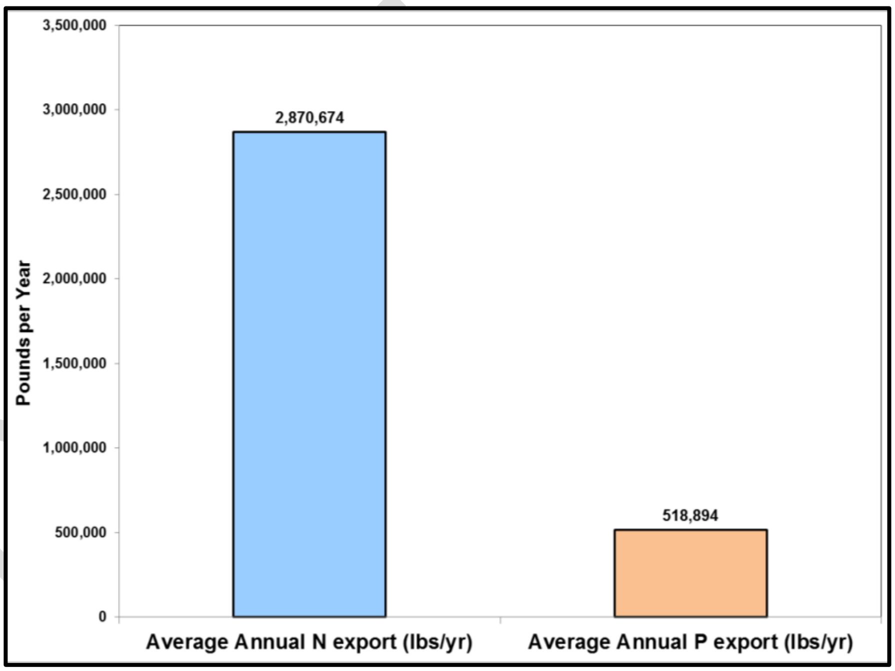
Sources	N Load (lb/yr)	P Load (lb/yr)	Bar Chart – Total Nitrogen and Phosphorus Annual Load
Urban	182,542	21,565	
Cropland	1,869,231	204,350	
Grazing Lands	377,410	249,930	
Woodlands, Undeveloped, Restricted	44,199	22,434	
Onsite Wastewater Treatment Systems (septics)	566	222	
Shallow Groundwater	384,812	19,074	
Atmospheric Deposition	11,914	1,319	
Average Annual Total	2,870,674	518,894	

Figure 6-20. Estimated average annual nitrogen and phosphorus source contributions (%) to streams of the Pajaro River basin

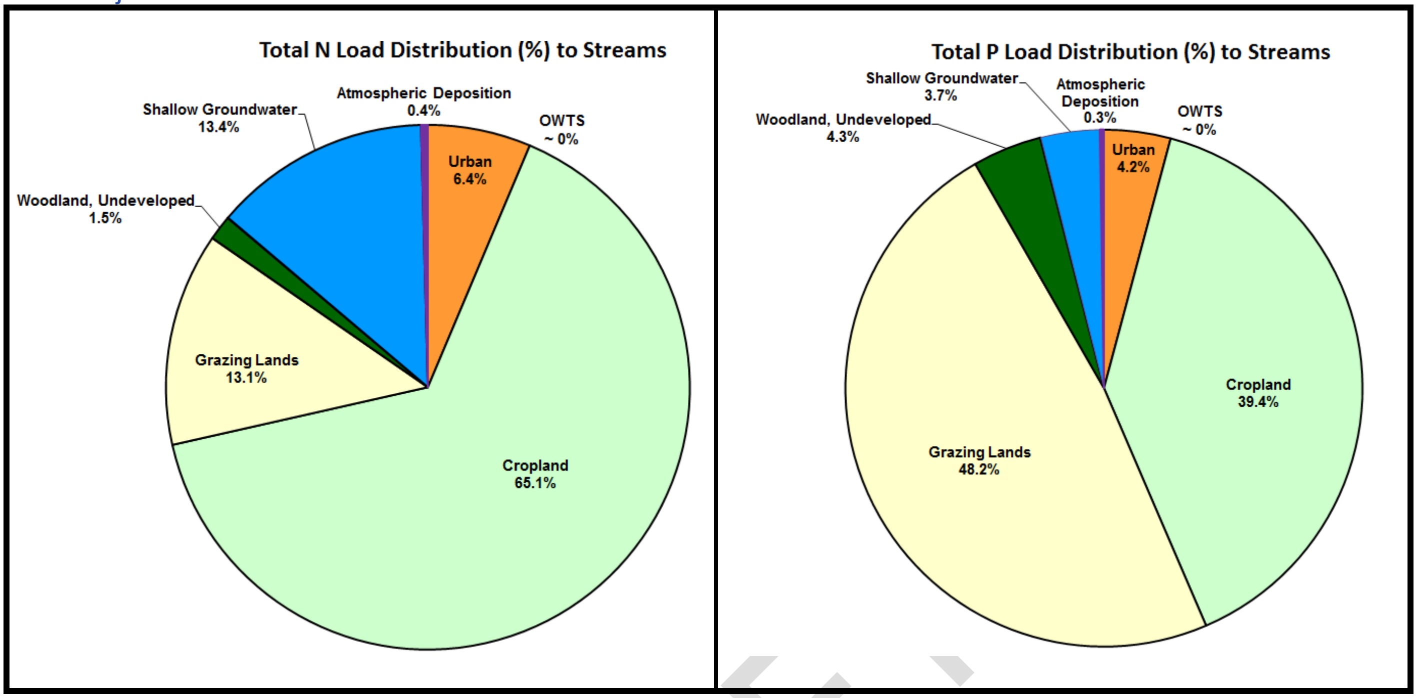


Figure 6-21. Estimated average annual nitrogen and phosphorus source yields (pounds per acre per year) to streams of the Pajaro River basin from various land use/land cover categories.

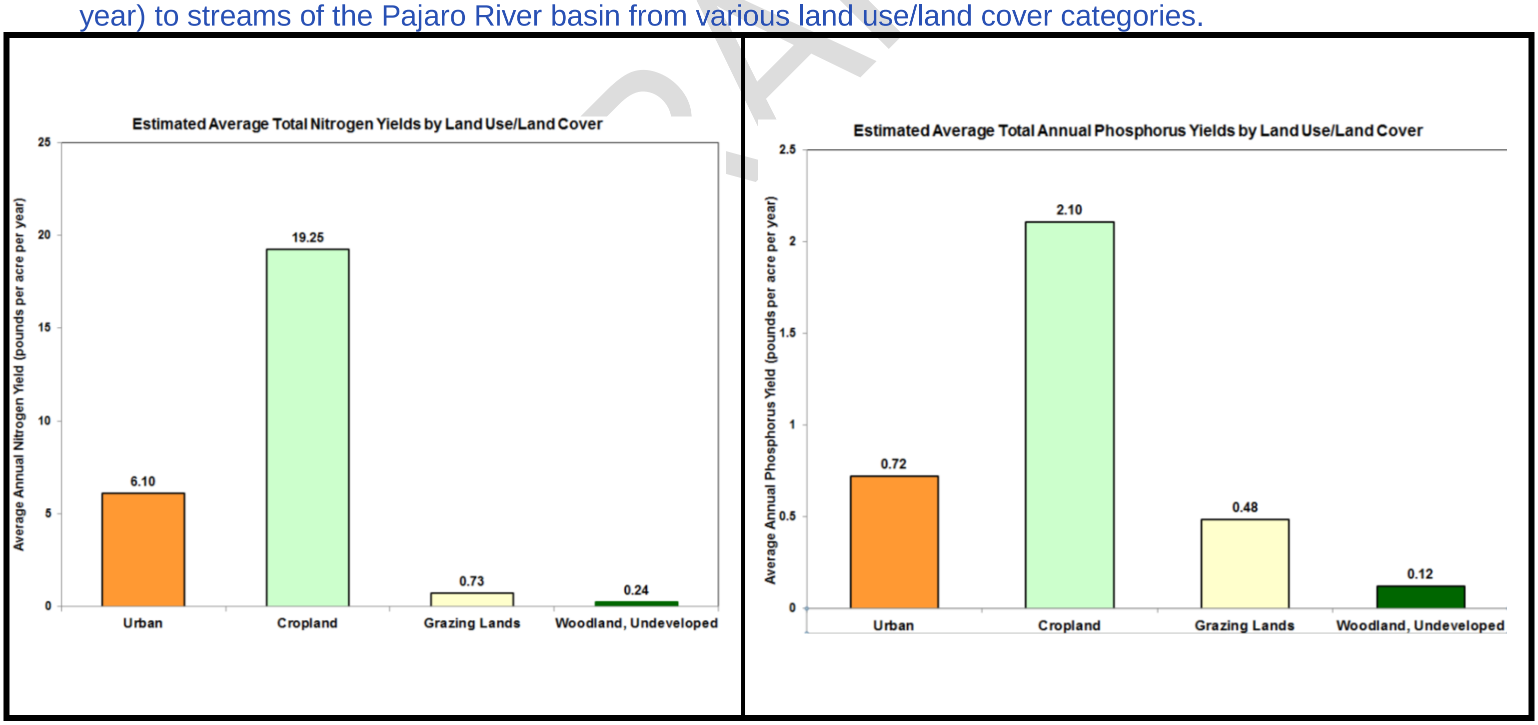


Table 6-28. Estimated average annual nutrient loads and nutrient yields by subwatershed.

Subwatershed	Urban and Built up Land	Cropland	Grazing Lands	Woodlands, Undeveloped, Restricted	Total	Predicted N Load *(pounds)*	Predicted P Load *(pounds)*	Predicted Annual N Yield *(pounds per acre per year)*	Predicted Annual P Yield *(pounds per acre per year)*
Arroyo De Las Viboras	0	327	14,229	184	14,740	18,289	7,606	1.2	0.52
Bird Creek-San Benito River	3,034	3,779	17,505	8,424	32,742	90,814	15,156	2.8	0.46
Cedar Creek	0	0	7890	4,876	12,766	9,755	6,002	0.8	0.47
Clear Creek-San Benito River	0	0	13,205	21,625	34,843	19,314	11,605	0.6	0.33
Corralitos Creek	1,108	2,594	178	13,909	17,789	114,848	9,558	6.5	0.54
Hernandez Reservoir-San Benito River	0	178	8,821	9,888	19,512	15,690	7,109	0.8	0.36
James Creek-San Benito River	0	10	16,330	12,401	28,740	16,615	9,736	0.6	0.34
Las Aguilas Creek	0	0	24,509	220	24,730	17,753	11,096	0.7	0.45
Little Llagas Creek	5,257	2,216	5,284	2,636	15,392	98,191	14,550	6.4	0.95
Los Muertos Creek	0	42	18176	710	18,928	13,075	7,661	0.7	0.40
Lower Llagas Creek	5,442	5,378	4,721	4,467	20,007	177,780	23,851	8.9	1.19
Lower North Fork Pacheco Creek	0	0	24,891	688	25,746	25,322	16,046	1.0	0.62
Lower Pacheco Creek	192	4,172	15,796	1,717	21,986	117,935	21,973	5.4	1.00
Lower Pajaro River	963	11,321	11,680	9,321	33,285	293,027	26,565	8.8	0.80
Lower Tres Pinos Creek	231	2,179	13,973	1,468	17,850	43,292	9,457	2.4	0.53
Lower Uvas Creek	1,602	4,142	13,677	6,269	25,690	146,597	24,277	5.7	0.95
Middle Tres Pinos Creek	0	19	22,470	508	22,997	16,222	10,343	0.7	0.45
Paicines Reservoir-San Benito River	16	4,354	26,909	2,610	33,976	86,775	18,611	2.6	0.55
Pescadero Creek	87	672	13,486	11,420	25,665	25,600	7,831	1.0	0.31
Quien Sabe Creek	0	3,172	29268	116	32,662	83,090	20,011	2.5	0.61
Rock Springs Creek-San Benito River	0	303	23,080	6,397	29,781	24,813	11,979	0.8	0.40

Subwatershed	Urban	Cropland	Grazing	Woodlands,	Total	Predicted	Predicted	Predicted	Predicted
Salsipuedes Creek	1,342	4,019	2,344	7,993	15,881	124,894	9,864	7.9	0.62
San Juan Canyon	927	6,136	11,360	5,774	24,415	146,067	19,161	6.0	0.78
Santa Ana Creek	853	7,084	24,603	1,177	33,717	131,947	22,765	3.9	0.68
South Fork Pacheco Creek	0	0	11,497	10	11,507	11,801	7,226	1.0	0.63
Stone Creek	0	5	8,133	1,922	10,060	6,410	3,490	0.6	0.35
Sulphur Creek-San Benito River	0	461	20911	2,802	24,174	22,397	9,719	0.9	0.40
Tequisquita Slough	1,966	8,966	12,638	2,393	25,964	205,065	26,291	7.9	1.01
Upper Llagas Creek	1,232	505	14,056	2,713	18,737	48,257	14,729	2.6	0.79
Upper North Fork Pacheco Creek	0	0	1,372	15,667	17,040	5,707	2,916	0.3	0.17
Upper Pacheco Creek	0	0	18,094	222	18,316	18,012	10,932	1.0	0.60
Upper Pajaro River	1,313	19,596	13,487	1,070	35,466	441,210	49,577	12.4	1.40
Upper Tres Pinos Creek	0	81	20,916	2,243	23,240	17,435	9,956	0.8	0.43
Upper Uvas Creek	201	316	15,576	13,491	29,823	44,352	18,633	1.5	0.62
Watsonville Slough	4,178	5,049	292	5,952	15,472	167,708	14,595	10.8	0.94
Willow Creek	0	41	15,962	2,583	18,585	12,699	6,696	0.7	0.36

7 CASE STUDIES, SUCCESS STORIES, AND EXISTING IMPLEMENTATION EFFORTS

More information may be added to this section as appropriate. Central Coast Water Board staff encourage stakeholders to inform us of existing or planned activities aimed at reducing nutrient loading to water resources of the Pajaro River basin, so we can give credit to them in the final TMDL report.

Protecting California's water resources depends on the proactive engagement of citizens, land owners, researchers, and businesses. Proactive efforts by citizens that may result in improved water quality protection are commendable and should be recognized.

7.1 Integrated Regional Water Management Plan

The 2007 Pajaro River Watershed Integrated Regional Water Management Plan (IRWM) is a collaborative effort by the Pajaro Valley Water Management Agency, San Benito Water District, and the

Santa Clara Valley Water District to identify regional projects and resource management strateties for the benefit of the Pajaro River Watershed. The water quality objectives identified in the Pajaro River Watershed IRWM include:

1. Meet or exceed all applicable groundwater, surface water, wastewater, and recycled water quality regulatory standards.
2. Protect or improve the quality of water supply souces;
3. Meet or exceed water quality targets established by stakeholders;
4. Aid in meeting TMDLs for the Pajaro River Watershed
5. Minimize impacts from stormwater through implementation of established Best Management Practices or other stormwater management plans.

The IRWM includes planning and implementation strategies to protect drinking water quality, agricultural water quality, improve nutrient management, and to protect and restore ecological systms, including preserving the environmental health of the Pajaro River Watershed by identifying opportunities to restore and enhance natural resources of streams, watersheds, wetland, and the Monterey Bay.

7.2 Pajaro Valley Water Management Agency Irrigation Efficiency Webpage

The Pajaro Valley Water Management Agency maintains a webpage with copious amounts of information and education materials pertaining to irrigation efficiency and agricultural water management.

http://www.pvwma.dst.ca.us/conservation/agriculture.php

7.3 Salt and Nutrient Management Plans

Placeholder

http://www.pvwma.dst.ca.us/board-and-committees/salt-nutrient.php
http://www.sbcwd.com/reports/Salt%20&%20Nutrient%20Mgmnt%20Plan%20Work%20Plan.pdf

7.4 Santa Clara Valley Water District Fertilizer Management Fact Sheets

The Santa Clara Valley Water District in conjunction with the Monterey County Water Resources Agency have published fact sheets on the following topics:

Fact Sheet 1- Fertilizer Management for Cool-Season Vegetables
Fact Sheet 2- On Farm Handling of Fertilizers
Fact Sheet 3- Water Management for Cool-Season Vegetables
Fact Sheet 4- Using Nitrate Present in Soil/Water in Fertilizer Calculations
Fact Sheet 5- On Farm Nitrogen Determination Sap, Soil and Water

These fact sheets are available online from the Pajaro Valley Water Management Agency at:

http://www.pvwma.dst.ca.us/conservation/agriculture.php

7.5 Pajaro Valley Community Water Dialogue

This is community forum consisting of Pajaro Valley stakeholders whose goal, in part, is to identify and implement sustainable agricultural land management and irrigation best practices. Pilot projects include precision irrigation practices and soil moisture monitoring currently utilized by some prominent berry growers in the Pajaro Valley.

http://www.pajarowatershed.org/Content/10111/CommunityWaterDialogue.html

7.6 California Farm Water Success Stories (Pacific Institute)

The Pacific Institute (a non-profit research and policy analysis organization) has created an interactive database and map, which contains more than 30 case studies of reported farm water quality success stories in California. The database is searchable by location, production type, irrigation method, and stewardship practice. The online database may be accessed at:

http://www.pacinst.org/reports/success_stories/

REFERENCES

Pending