Central Coast Water Quality Data Synthesis, Assessment, and Management (SAM) Project

Central Coast Water Quality Data Assessment
Final Report

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Water quality and other data sets central to the SAM effort were collected by or with funding from a number of organizations including the Central Coast Regional Water Quality Control Board, Agriculture Preservation Inc., Applied Marine Sciences, U.S. Geological Survey, U.S. Department of Agriculture, State Water Resources Control Board, Monterey Bay National Marine Sanctuary, University of California Santa Cruz, University of California at Davis, and the California State University Monterey Bay.

Executive Summary

Implementation of the SAM project began on June 1, 2006 in order to facilitate region-wide water quality monitoring coordination, data dissemination, data management, and data analysis on the Central Coast of California. A 14 member Technical Advisory Committee (TAC) of water quality experts from around the state was formed to direct the activities of the SAM project. Water quality data was collected from 14 monitoring programs on the Central Coast and collated into a water quality database compatible with the statewide Surface Water Ambient Monitoring Program (SWAMP) and coupled to a GIS to facilitate data and analysis and dissemination. The purpose of this data assessment was to characterize existing and accessible water quality data sets, evaluate their applicability to fundamental questions about non-point source (NPS) pollution on the Central Coast, and identify important water quality and other data gaps.

The pollution management questions addressed were derived from the California NPS pollution program objectives (SWRCB, 2003). The questions and summary results follow:

1. What is the extent of impaired, threatened, and high quality water bodies on the Central Coast?

   Mapping of data provided by the State Water Resources Control Board (SWRCB) showed that in 2006 there were ninety-nine threatened or impaired water bodies distributed throughout the Central Coast (see Map 4.1). Relatively high proportions of impaired stream lengths occurred in the San Lorenzo-Soquel, Pajaro, Salinas, and Cuyama sub-basins. Water bodies within the San Francisco Coastal South sub-basin, the Carmel sub-basin; and the northern portion of the Central Coastal sub-basin, appear to be of relatively high quality.

2. What is the extent of impairments due to non-point sources compared to point sources?

   Analysis of SWRCB data revealed that nearly all of the water body impairments on the Central Coast are due to non-point sources. The greatest number of impaired water bodies is due to unknown or agricultural non-point sources. Bacterial pathogen indicators are the most prevalent causes for water body impairment and threat. Nutrient problems such as ammonia, nitrate, and orthophosphate are the second most common; followed by pesticides and sediments.

3. What are the relationships between land-use and ambient water quality conditions?

   A partial correlations analysis of satellite derived land-cover/land-use data and water quality data showed that nitrate concentrations were positively correlated with cultivated areas ($p \leq 0.01$), orchards/vineyards ($p \leq 0.001$), and bare/transitional ($p \leq 0.05$) land-uses within watersheds. Ammonia concentrations were positively correlated to developed ($p \leq 0.01$), bare/transitional ($p \leq 0.05$), and orchards/vineyards ($p \leq 0.05$) land-uses within watersheds. Total Suspended Solids (TSS) concentrations were positively correlated with bare/transitional ($p \leq 0.01$) and cultivated ($p \leq 0.01$) land-uses within watersheds.

4. Are there statistically significant temporal trends for water quality variables?
   Statistical tests of water quality data sets at individual stations and within plots that included stations from multiple programs were able to detect some trends between 2001 and 2006. For example, at the CCAMP Coastal Confluences ammonia concentrations decreased in the San Antonio subbasin (-0.052 mg/L/yr^{-1}); nitrate concentrations increased in the San Lorenzo (0.036 mg/L/yr^{-1}), Alisal-Elkhorn (1.57mg/L/yr^{-1}), and Central Coastal (0.41 mg/L/yr^{-1}) subbasins; orthophosphate concentrations increased in Alisal-Elkhorn subbasin (0.031 mg/L/yr^{-1}) and decreased in the San Lorenzo s (-0.007 mg/L/yr^{-1}), San Antonio (-0.002 mg/L/yr^{-1}), and Santa Barbara Coastal (-0.324 mg/L/yr^{-1} and -0.801 mg/L/yr^{-1}) subbasins.

5. Is there evidence that better land-use management practices have improved ambient water quality conditions?
   An indicator variable was calculated based on survey data from the Regional Water Quality Control Board (RWQCB) and representative farm area to quantify and map the level of management practice implementation at the watershed level. This metric can be used to identify watersheds with relatively high potential to show a change in water quality conditions due to changes in land management practices. In general, the water quality and management practice implementation data were not adequate to test hypotheses about relationships between water quality conditions and changes to land management practices upstream on a regional or large watershed scale.

Based on the analyses that were performed, the following are recommendations to address key information gaps (summarized from Chapter 5):

- The absence of a region-wide universal water quality data format for the Central Coast is an important barrier to regional water quality data analysis; information exchange, and coordination between monitoring organizations. A system should be created for automatic, seamless data integration that is based on the Surface Water Ambient Monitoring Program (SWAMP) formats and facilitates upward data flow toward a central location the California Environmental Data Exchange Network (CEDEN).
- The lack of coordination between monitoring organizations results in wasted resources and important data gaps that reduce our ability to understand the status and trends of water quality conditions. Two things that would help to identify opportunities to optimize resources are: (1) a regularly updated clearinghouse of information on all the

existing programs and (2) annual water quality conferences in the region to disseminate information and highlight the value of monitoring coordination efforts.

- Adequate detection of changes over time in water quality conditions requires that we (1) maintain commitments to sustain long term monitoring stations such as the CCAMP Coastal Confluences stations, (2) encourage flow measurement as a regular part of water quality monitoring, and (3) allocate sufficient resources to data analysis.
- Encourage cooperation of watershed stakeholders to collect and share information about changes in land management practices in a standardized way that will be useful for comparison with water quality data.
- Develop a monitoring design with the express purpose of evaluating relationships between changes in land-use management activities and water quality conditions at multiple watershed scales.
- Institutionalize a regional data node for ongoing data collection, analysis and multi-tiered reporting to facilitate the NPS pollution management objectives of regional stakeholders.

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1. INTRODUCTION

1.1 Overview

The Central Coast Region of California spans approximately 320 miles of shoreline, much of which lies adjacent to the Monterey Bay National Marine Sanctuary which was designated in 1992 for its ecological significance and exceptional beauty. Watersheds that drain the Central Coast region occupy approximately 14,390 square miles and support a multitude of land-uses including agriculture, industry, recreation, residences, and urban development. Within these watersheds, there is increasing pressure on resources that is driven by population growth and subsequent alteration of watershed surfaces. The population of California is projected to grow by approximately 7.5 million between the years 2000 and 2015. Human activities have altered the physical, chemical, and biological nature of Central Coast streams, lakes, wetlands, and shorelines. Currently, a number of Central Coast water bodies do not meet regulatory objectives. Without adequate water quality monitoring and data management and data analysis, we do not have a means to understand the degree to which these waterways have been altered, the ecological impacts of such modifications, or the effectiveness of improved land-use management practices.

Many Central Coast water bodies appear on the 2006 California State Water Board’s 303(d) List of Water Quality Limited Segments. Water bodies on this list do not meet standards for beneficial uses such as drinking water, ecological health, or recreation due to various pollutants. Pollutants such as bacteria, sediments, nutrients, metals, pesticides and herbicides are often associated with anthropogenic activities and modifications of the natural landscape. The Central Coast has relatively few industrial dischargers to waterways and the most important sources of pollutants are diffuse within a watershed and known as non-point sources. Such non-point sources are recognized as the most important overall contributor to water pollution in California.

The purpose of the Central Coast Water Quality Data Synthesis, Assessment, and Management (SAM) project is to facilitate region-wide water quality monitoring coordination, data management, and data analysis for addressing the sources, status, and trends of non-point source (NPS) pollution on the Central Coast. An important outcome will be the enhancement of data uniformity and data flow toward the Regional Water Quality Control Board (RWQCB) for use in water body assessment. Numerous monitoring programs collect water quality data on the Central Coast. These programs differ in their sampling locations, parameters, methods, and frequency. Since there are limited resources for water quality monitoring it is important that the data collected reflect the objectives and knowledge needs of Central Coast watershed stakeholders. The utility of the existing water quality data to address specific management questions related to NPS pollution is presently unclear. Coordination between monitoring organizations is required to understand how monitoring, data management, and data reporting can be done more efficiently to address management questions at a regional scale. This report communicates the activities, outcomes, and products of the first phase of the SAM project that were completed between June 2006 and December 2007.

1.2 Background and Objectives

Upon designation of the Monterey Bay National Marine Sanctuary (MBNMS), eight key water quality agencies entered into a Memorandum of Agreement establishing a Water Quality Protection Program (WQPP) for the MBNMS. The WQPP provides a comprehensive approach to maintaining and protecting water quality in the Monterey Bay National Marine Sanctuary and its watersheds. The WQPP has action plans for addressing various water pollutants that affect the Sanctuary and its resources. These plans focus on preventing pollution from urban areas, agricultural areas, and harbors, marinas, and on regional monitoring of pollutants. The need for water quality monitoring cooperation between agencies is highlighted in the MBNMS Joint Management Plan Review's 'Regional Monitoring, Data Access, and Interagency Coordination' Action Plan (MBNMS, 2006)

In recent years, staff from the WQPP, the Central Coast Regional Water Quality Control Board (RWQCB) and the California Coastal Commission (with staff support from the Resources Legacy Fund Foundation) have taken the lead in bringing local, state and federal agencies; researchers, and volunteer monitoring groups together to assess gaps and develop strategies to strengthen regional monitoring efforts. This has resulted in the formation of a much stronger partnership between all agencies and agreements to share data and other information related to water quality monitoring efforts in order to learn more about water quality conditions and threats in the Sanctuary and its adjacent watersheds. As a result, characterizations of most of the major monitoring efforts on the Central Coast have been cataloged and are currently available on the Sanctuary Integrated Monitoring Network (SIMoN) website[1].

Via the SIMoN website, locations and meta-data about monitoring programs can be viewed; however, actual data on water quality conditions is not accessible. Consequently, this level of monitoring synthesis is not appropriate to understand the adequacy of existing data for addressing pollution management questions. There presently exists no mechanism for regional collation, assessment, analysis, and reporting of water quality from multiple sources.

The SAM Project is organized into three integrated phases.

[1] www.mbnms-simon.org

Phase I: Collection, integration, and analysis of water quality data and ancillary information and production of a Data Assessment Report (this document).

Phase II: A workshop will be held to communicate the results of Phase I, and gather input from stakeholders to improve regional water quality monitoring and data coordination.

Phase III: A strategic plan will be developed to improve regional water quality monitoring efficiency, data management, and reporting.

The objectives of the initial phase of the project (Phase I), reported herein, was to compile the available water quality and ancillary data; develop tools for data integration and comparability assessment; perform analyses to assess the usefulness of existing data for answering NPS pollution management questions; and identify important information gaps. Subsequent phases of the project will use the results of Phase I and input from stakeholders to develop a strategic plan to encourage participation of all monitoring programs, enhance monitoring efforts, data management, and data dissemination.

1.3 Project Scope and Implementation

The SAM project operates as a close partnership between the U.S. Environmental Protection Agency (U.S. EPA), the MBNMS, SIMoN, the RWQCB, and the California Coastal Commission. The Monterey Bay Sanctuary Foundation was contracted as the lead agency to perform the work defined in a two year grant contract funded by the Resource Legacy Fund Foundation (RLFF) and the U.S. EPA that began on June 1, 2006. A Water Quality Analyst was hired by the Monterey Bay Sanctuary Foundation (MBSF) to begin work on June 1, 2006 to be the primary person responsible for completing the work defined in the contracts with the RLFF and the EPA. Funding is also allocated for the time of a MBSF GIS Analyst and a Project Supervisor. The general responsibilities of the Monterey Bay Sanctuary Foundation include the following:

- Develop a Quality Assurance Project Plan.
- Collect water quality data and documentation and compile them into an integrated database.
- Collect information on land-use management practice implementation.
- Facilitate water quality data transfer from monitoring organizations to the Surface Water Ambient Monitoring Program (SWAMP).
- Coordinate with SIMoN staff and RWQCB staff to facilitate water quality data access to data users.
- Develop a Data Assessment Report that compares available water quality and management practice data to NPS pollution questions and identifies information gaps.

- Hold a stakeholder workshop to generate solutions to fill information gaps.
- Develop a Strategic Plan for ongoing data integration, management, and reporting.

A Technical Advisory Committee (TAC) composed of 14 members from throughout the State representing various agencies, organizations, private consultants and academic institutions directs the activities of the SAM project. Many of the TAC members represent the major water quality data generating organizations in the region. The TAC meets approximately quarterly to review and make recommendations on the activities and progress of the SAM project, and provides comprehensive scientific oversight. The SAM TAC currently includes the following participants:

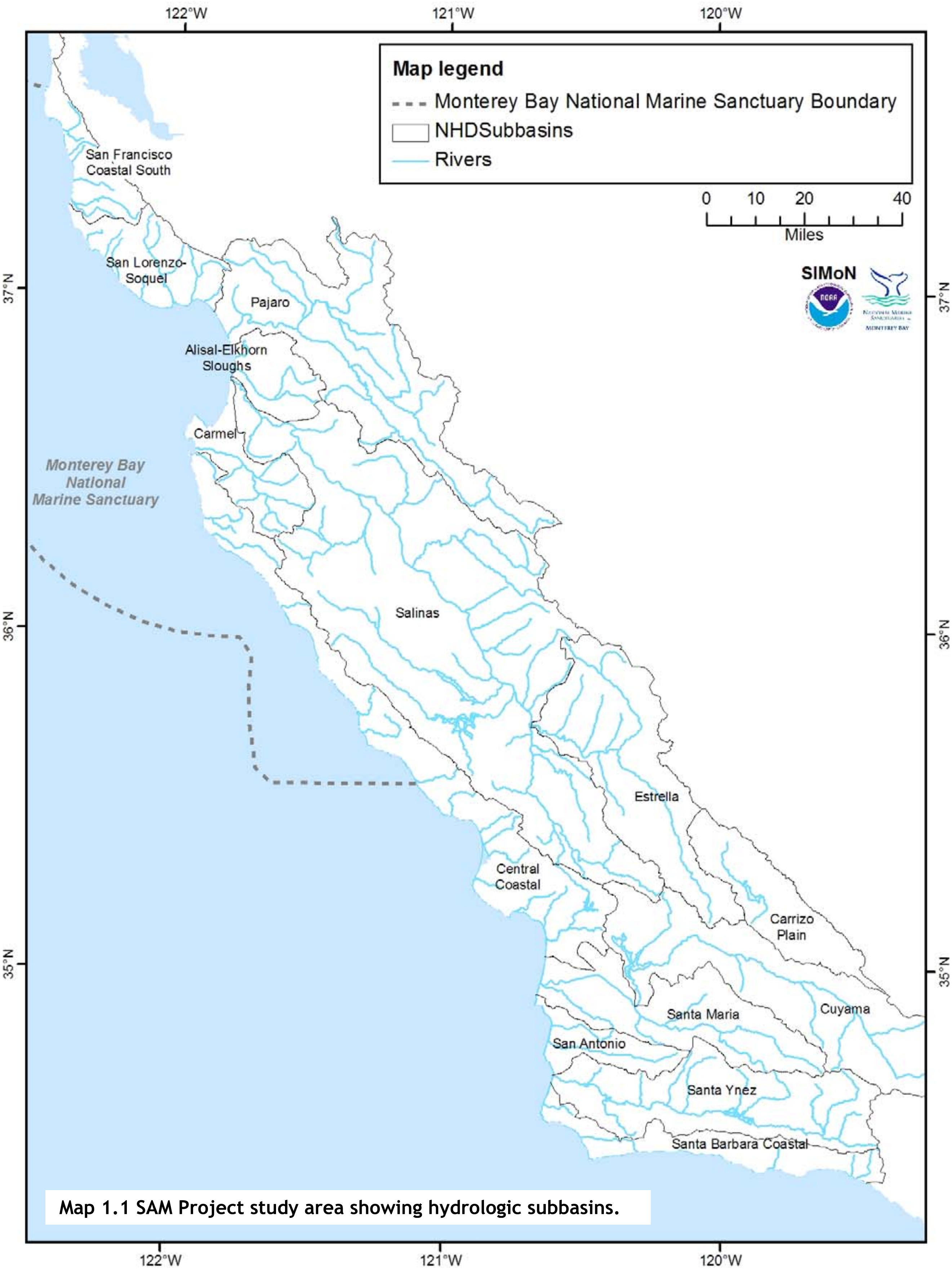
- Ross Clark, California Coastal Commission
- Karen Worcester, Central Coast Regional Water Quality Control Board
- Marc Los Huertos, California State University Monterey Bay
- Eric Stein, Southern California Coastal Water Research Project
- Sam Ziegler, U.S. EPA
- Dane Hardin, Applied Marine Sciences
- John Hunt, University of California, Davis
- Bridget Hoover, MBNMS
- Steve Lonhart, MBNMS/SIMoN
- Russell Fairey, Moss Landing Marine Labs
- John Largier, University of California, Davis
- Lauren Garske, University of California, Davis
- Amara Vandervort, Surface Water Ambient Monitoring Program
- David Paradies, Central Coast Regional Water Quality Control Board

The terrestrial boundary of the SAM project study area is defined by the limit of the Central Coast Regional Water Board District, with a small additional area in San Mateo County at the north end of the study area (see map 1.1). This area includes 12 geographic areas know as *subbasins* that are divided in the National Hydrography Dataset (NHD) administered by the U.S. Geological Survey[2] (see map 1.1). These areas are divided by watershed boundaries and represent either a single large watershed (such as the Pajaro subbasin), subsections of watersheds (such as the Salinas subbasin), or a collection of relatively small watersheds (such as the Central Coastal subbasin). In the text of this report, the study area is often referred to simply as the Central Coast.

Approximately half of the coastline of the study area drains to the MBNMS. Data collection was primarily from fresh water and estuarine environments, rather than marine environments,

[2] http://nhd.usgs.gov/

since this is where the majority of data exists. Data collection within this region was not exhaustive, but targeted toward those programs and measurement types that were on-going, were identified to have high potential for satisfying a minimum set of data quality criteria and sufficient documentation to facilitate translation too SWAMP formats. Data collection was focused geographically on the northern portion of the Central Coast, because of the abundance of data in the area, the interface with the MBNMS, and greater knowledge of data sets in this region.



Map 1.1 SAM Project study area showing hydrologic subbasins.

During phase I the adequacy of existing water quality and ancillary data was assessed relative to criteria defined by five NPS pollution management questions that were derived from the California Non-point Source (CA NPS) pollution program objectives (U.S. EPA, 2006). The CA NPS Program was developed by the State Water Resources Control Board, Regional Water Quality Control Boards, and the California Coastal Commission to manage and reduce water pollutants from non-point sources. The CA NPS Program was adopted by the State in 1999 and guides water quality protection efforts statewide as administered by these agencies. During Phase I of the SAM project, the utility of existing and accessible data was assessed relative to their usefulness for addressing the following NPS pollution questions on a regional scale:

6. What is the extent of impaired, threatened, and high quality water bodies on the Central Coast?
7. What is the extent of impairments due non-point sources compared to point sources?
8. What are the relationships between land-use and ambient water quality conditions?
9. Are there statistically significant temporal trends for water quality variables?
10. Is there evidence that better land-use management practices have improved ambient water quality conditions?

In addition to water quality data, management practice implementation data, reports from regulatory agencies, crop data, and satellite derived land cover/land-use data were also used. Critical data and resource gaps were identified relative to each NPS question.

1.4 Current Status, Outcomes and Products

On June 15, 2006 a letter was sent to invite members to be part of a Technical Advisory Committee for the SAM Project. To date, six of the eight scheduled meetings with the TAC have been completed. Data collection and processing began on August 1, 2006 and continued until May 1, 2007, at which time resources were diverted to data analysis. On April 12, 2007 a Quality Assurance Project Plan (QAPP) was finalized and approved by the Quality Assurance Officer at the RWQCB. Data integration and analysis results were presented to the TAC on June 1, 2007 and the TAC member's comments have been incorporated into the results that are communicated in this report.

The SAM project has been presented at a number of conferences and meetings during 2007 months including the MBNMS Currents Symposium, the MBNMS Research Advisory Panel, the Northern California Society of Environmental Toxicology and Chemistry, the Agricultural Water Quality Alliance, the Coat and Ocean Regional Round Table (CORRT) and the Elkhorn Slough Watershed Working Group. Informal partnerships/collaborations have been initiated with other organizations including the Monterey Bay Aquarium Research Institute (MBARI) and the Central and Northern California Ocean Observing Systems (CeNCOOS), and Elkhorn Slough National Estuarine Research Reserve (ESNERR). On April 5, 2007 a major data delivery was made to the RWQCB, which substantially increased the amount of water quality data that was readily available for regulatory water body assessment. In June, 2007 bacterial pathogens and nutrients data were delivered staff at MBARI for use in two independent research projects.

Specific products that have thus far resulted from the SAM Project include:

- A Quality Assurance Project Plan
- A spatially referenced relational water quality database
- Water quality data inventory tables and maps (provided to various partners)
- Data Assessment Report (this document)

1.5 Report Organization

This report contains an executive summary, 5 chapters, references, and 8 appendices. Chapter 1 provides and overview of the project, background, objectives, and project status. Chapter 2 contains descriptions of the steps and procedures that were used for water quality data and meta-data collection and integration, and a description of the SAM database structure, content, and functionality. Chapter 3 gives a characterization of the water quality data that was collated and examples of how data sets from multiple monitoring organizations may be used collectively to describe the status of water quality conditions. In Chapter 4, the data assessment questions are addressed sequentially, with descriptions of the methods of analysis that were employed for each question. Chapter 5 contains specific recommendations for filling the water quality data and information gaps that were identified. The appendices contain tables and figures referred to in the text of the report.

2. THE SAM DATABASE (SAMdb)

2.1 Data Sources

More than two dozen distinct monitoring programs have collected water quality data within the MBNMS or within Central Coast watersheds over the last decade. Data sets from several of these programs were used to populate the SAM database. Several programs also collect data on groundwater, sediments, animal tissues, and biological indices. Given the time constraints for the initial phase of the SAM Project and data management challenges associated with diverse data types, water quality data collection was limited to surface water chemistry data and surface water toxicity data (hereafter referred to as water quality data). In the future, other data types and monitoring programs may be included to address water quality management questions using the data integration framework that has now been established. Although the data compilation was not exhaustive, the data sources and types that were used provided a more complete data set than has previously been used to address NPS pollution management questions in the Central Coast Region.

Data candidates were identified using the SIMoN database of water quality projects and data types and through discussions with the TAC. Some of the programs listed in the SIMoN database were not included in the SAM data integration efforts due to time constraints. Selection preference was given to programs that were ongoing, had good potential to have high quality data, and were known to have collected substantial data sets at fixed locations over a period of greater than three years.

Water quality data was collected from the following Central Coast monitoring programs:

- **Central Coast Ambient Monitoring Program (CCAMP)**
  Central Coast Regional Water Quality Control Board
  http://www.ccamp.org/

- **Central Coast Long Term Environmental Assessment Network (CCLEAN)**
  Applied Marine Sciences
  http://www.cclean.org/

- **Ag Waiver Monitoring Program**
  Central Coast Water Quality Preservation Inc. (CCWQP)
  http://www.ccwqp.org/

- **Elkhorn Slough Volunteer Monitoring Program**
  Elkhorn Slough National Estuarine Research Reserve (ESNERR)
  http://www.elkhornslough.org/esnerr.htm

- **Snapshot Day, Urban Watch, Clean Streams, and First Flush Programs**
  MBNMS Citizen Watershed Monitoring Network/Coastal Watershed Council (CWC)
  http://montereybay.noaa.gov/monitoringnetwork/events.html
  http://www.coastal-watershed.org/

- **Santa Cruz County Environmental Health Services**
  http://sccounty01.co.santa-cruz.ca.us/eh/

- **Marc Los Huertos Ambient Monitoring (MaLoHAM)**
  University of California Santa Cruz / California State University Monterey Bay
  http://envs.ucsc.edu/shennan/Directory/Mark.html
  http://home.csumb.edu/l/loshuertosmarc/world/

- **Central Coastal Watershed Studies (CCoWS)**
  California State University Monterey Bay
  http://ccows.csumb.edu/index.htm

- **National Water Information System**
  US Geological Survey (USGS)
  http://waterdata.usgs.gov/nwis

- **The Marine Pollution Studies Laboratory at Granite Canyon**
  University of California Davis
  http://www.envtox.ucdavis.edu/GraniteCanyon/GraniteCanyon.htm

- **Center for Integrated Marine Technologies (CIMT)**
  University of California Santa Cruz
  http://cimt.ucsc.edu/

Descriptions and documentation of each of the monitoring programs listed can be found at the web addresses provided.

2.2 Data Management

For each monitoring organization, water quality data sets, metadata, and documentation were transferred in digital format from the source monitoring organization to the MBNMS. A contact person at each organization was established to provide ongoing technical assistance with data processing and data quality evaluation. Data and electronic documentation are stored on a Dell PC at the MBNMS office in Santa Cruz. Data are backed-up to an external hard drive daily and weekly to a server located at the MBNMS office in Monterey. Raw data files retain the original names that they had at the time of data transfer. Files from subsequent processing iterations leading to the final formatted data files are stored and the processing steps for each data set are recorded in a journal. Further details of the data management procedures and protocols are outlined in the SAM Quality Assurance Project Plan (QAPP).

The SAM project serves as a regional node for data collection, from which data is passed directly to staff of the Central Coast Ambient Monitoring Program (CCAMP) for automated formats and errors checking. Data is uploaded to CCAMP via a web interface. Prior to delivery, data that was collected from monitoring organizations was processed to have uniform formats that are compatible with the state-wide Surface Water Ambient Monitoring Program (SWAMP) in order to facilitate the flow of data toward more permanent data repositories such as the California Environmental Data Exchange Network (CEDEN).

2.3 Data Integration

Data sets from different monitoring organizations often use different software systems, notation, table formats, spatial referencing customs, and table structures for storing their data. These data storage characteristics reflect the objectives and resources of monitoring organizations. For example, the USGS, which maintains one of the largest water quality data repositories in the country, stores water quality parameter codes that denote the parameter that was measured, units, media, and analytical method information. In contrast, most other monitoring organizations store these types of information in different fields of a database.

To use disparate data sources collectively to address water quality management questions on a regional scale, it was necessary to standardize data sets. Compatible data formats and delivery to SWAMP is a requirement for state-funded grants under which a substantial amount of water quality data is collected on the Central Coast. For this reason, the SWAMP database was used as a model for integrating individual data sets. In addition to fulfilling grant requirements, initiating data flow toward a single regional repository in a standard format is helpful for improving regional monitoring efficiency, identifying data gaps, and facilitates use of data for regulatory purposes such as Clean Water Act sections 303(d) and 305(b) assessments.

Data sets were converted to the SWAMP formats using the data templates that have been developed by Moss Landing Marine Lab (MLML) and CCAMP staff and are available online[3]. This step ensures that data are SWAMP compatible in terms of data structure, parameter notation, units, and table formats. Transformations that have been made to the original data sets have been recorded and sequential steps of data processing have been retained. The tools for data formats and field contents notation transformation can be used to expedite the process of future data uploads. The sets of tables that were created using the CCAMP templates formed the building blocks for a relational water quality database that was implemented using the Microsoft Access software package.

When changing formats and structures of data tables, it is critical to understand precisely what is contained in someone else's data storage system. Data transformations were completed external to the monitoring organization by examining meta-data, data documentation, and published reports; and with technical assistance from the monitoring organization staff. The

[3] http://mpsl.mlml.calstate.edu/swdataformats.htm.

amount of effort that was required to transform data sets to SWAMP compatible formats and to acquire supporting documentation and knowledge for the data sets varied substantially from program to program. Often, it was not possible to fill the contents of fields in the CCAMP data templates with the information that was available. In the future, it will be more efficient and lessen the likelihood of errors occurring if these types of data transformations are performed by staff of the data collecting organization with technical support from a regional data coordinator.

2.4 Data Quality

A set of minimum data acceptance criteria were established to exclude only data sets that would have limited usefulness, given the objectives and timeframe of the SAM Project. Minimum data quality requirements were defined as measurements that included:

- Date and time
- Latitude and longitude coordinates
- Monitoring program identification
- Precisely defined analytes and units of measurement
- Digital formatting

Application of these criteria resulted in deletion of approximately 10% – 15% of the data that was collected for most monitoring programs.

Since the water quality data that were collated into the SAMdb were collected by a number of organizations over the years, procedures for data collection and data management vary from program to program and also over time for individual programs. Different laboratories employ different techniques with different levels of precision and detection limits. It is essential that the methods, reliability, accuracy, and precision of data are documented. Because the SAMdb contains data that have already been collected and processed, the quality of the integrated data set is strongly dependent on Quality Assurance/Quality Control (QA/QC) procedures that have been implemented by the source monitoring organizations. Documentation of methods and QA/QC procedures provides a means to assess data comparability. This type of assessment is particularly relevant when water quality data is used to assess spatial patterns or trends over time.

Data that do not meet contemporary standards for QA/QC procedures and documentation may not be useful for some applications. However, such data are often part of the longest records of water quality conditions and may be the only information available for assessing long term changes over time. Consequently, for the SAM database to have maximum utility, a data scoring system was devised as a quick means to compare the relative quality of different data sets.

The data scoring system is based on data documentation and can be used whether or not the data comes with a QAPP. The scoring system contained in Tables 2.1 and 2.2 are adapted from a study conducted in the Fox River watershed in Illinois. The project conducted by McConkey, et. al, (2004) involved integrating data sets from several sources to a common relational database. Using this system, data quality is scored based on the presence/absence or acceptability of data documentation components. This system was applied to a limited number of the SAM data sets on a trial basis as part of the initial data integration effort.

For data sets that have a Quality Assurance Project Plan (QAPP) available, the QAPP score is based on presence/absence or acceptability of the individual QAPP elements that are required by both the US EPA and by SWAMP. The determination of whether individual elements were scored on presence/absence or acceptability is based on a judgment of the importance of that element to the overall data quality (McConkey, et. al, 2004). The QAPP elements are divided into groups shown in table 2.3. SWAMP requirements for each element are used as a standard for the high score. To achieve the highest score, data documentation elements do not have to fulfill the specific SWAMP requirements, but must have a similar level of rigor to be considered SWAMP comparable. The criteria for data scores for individual QA/QC elements are qualitative categories. Determination of which qualitative characterizations best fit a QA/QC element of a given data set is based on best professional judgment.

When a QAPP is not available, alternative documentation describing sampling procedures and analytical methods were examined. Table 2.1 describes the data documentation elements that were evaluated in the absence of a QAPP. Similar to the evaluation when a QAPP is available, data documentation elements are scored based on either presence/absence or their acceptability. A score of 40 is possible for data sets with or without a QAPP by adding up all of the elements that are scored based on presence or acceptability (see tables 2.1 and 2.3). The quality level of the data for each program is quantified with a score from 1 to 4 based on categories listed in table 2.2.

Table 2.1 Water quality data evaluation elements

QAPP	Rating Factors	Possible Values	Score
Available	Presence of components	Present Not present	1 0
	Acceptability of components	SWAMP comparable More lenient but acceptable Unspecified or unacceptable	3 2 0
	Approval	SWAMP Approved Internal documents Nonexistent or unknown	2 1 0
Not available	Training and certification	Trained sampling crew Certified laboratory	6 or 0 6 or 0
	Documents and records	Required and available Required but not available Not required and unknown	4 2 0
	Method Quality Objectives	SWAMP comparable More lenient but acceptable Unspecified or unacceptable	6 4 0
	Sample handling and custody	SWAMP comparable More lenient but acceptable Unspecified or unacceptable	6 4 0
	Analytical Method	Standard methods (USEPA 2003) Non-standard Unknown	6 2 0
	Quality control	SWAMP comparable More lenient but acceptable Unspecified and unacceptable	6 4 0

Table 2.2 Quality assurance ratings

Quality Level	**Min Quality Score**	**Data Rating**
Excellent	32	5
Good	27	4
Acceptable	22	3
Poor	17	2
Very Poor	0	1
No Information		0

Table 2.3 QAPP evaluation elements

Element Group	ID	Element Name	Evaluation Criteria
Project Management	A1	Title and Approval Sheet	Presence
Project Management	A2	Table of Contents	Presence
Project Management	A3	Distribution List	Presence
Project Management	A4	Project/Task Organization	Presence
Project Management	A5	Problem Definition/Background	Presence
Project Management	A6	Project/Task Description	Presence
Project Management	A7	Quality Objectives and Criteria	Presence
Project Management	A8	Special Training/Certification	Presence
Project Management	A9	Documents and Records	Presence
Data Generation	B1	Sampling Process Design	Presence
Data Generation	B2	Sampling Methods	Acceptability
Data Generation	B3	Sample Handling and Custody	Acceptability
Data Generation	B4	Analytical Methods	Acceptability
Data Generation	B5	Quality Control	Acceptability
Data Generation	B6	Instrument/Equipment Testing, Inspection, and Maintenance	Acceptability
Data Generation	B7	Instrument/Equipment Calibration and Frequency	Acceptability
Data Generation	B8	Inspection/Acceptance of Supplies and Consumables	Presence
Data Generation	B9	Non-direct Measurements	Presence
Data Generation	B10	Data Management	Presence
Assessment and Oversight	C1	Assessments and Response Actions	Presence
Assessment and Oversight	C2	Reports to Management	Presence
Data Validation and Usability	D1	Data Review, Verification, and Validation	Acceptability
Data Validation and Usability	D2	Verification and Validation Methods	Presence
Data Validation and Usability	D3	Reconciliation with User Requirements	Presence

Whenever there have been changes to a monitoring program's methods and procedures over time, efforts were made to obtain historical documentation. A number of historical data sets lacked adequate documentation or such documentation was not accessible or difficult to interpret, which often limited it usefulness for data qualification. In some instances, measurements will need to be evaluated on a parameter by parameter basis due to differences in procedures. The application the system described in this section for the SAM data sets should therefore be thought of as an initial trial run, as the ideas surrounding data qualification are evolving. Furthermore, future efforts to qualify data sets in an integrated database will need to articulate with the statewide efforts underway by the statewide SWAMP and CEDEN programs which will include scoring systems based both information management/content and comparability of analytical methods.

2.5 SAMdb Conceptual Design, Implementation, and Functionality

Water quality measurement results are usually associated with information such as the date, time, location, analytical methods, or monitoring program. The function of a database is to store all of this information in a useful way to accomplish specific objectives. The SAMdb was designed to facilitate regional water quality data analysis, support efficient data movement to a state-wide repository, require minimal effort for data updates, and have flexibility to incorporate new data types. The U.S. EPA and the USGS maintain the most complete national water quality databases. On the Central Coast, the SWAMP data format conventions will facilitate storage in a state-wide CEDEN database. From here, water quality data can be integrated into larger databases such as the US EPA's STORET system.

The conceptual design of the SAMdb mimics the SWAMP database in a number of important ways. The same table and field names have been used whenever possible, and fields in the SAMdb contain the same information as the fields of the SWAMP database. All of the field contents have been converted to notation that is consistent with SWAMP standards.

The SAMdb is a relational database, which is a collection of tables that are related to one another by one or more data fields. Data fields are split up into tables that include a unique identifier for each 'record' or row that link records between tables. The tables represent specific elements of the water quality monitoring data such as the monitoring stations, sampling events, laboratory analysis, monitoring project, and numeric results. For clarity, the following discussion has the names of SAMdb tables italicized.

Some of the important types of information that are captured as fields in the tables in the SAMdb are illustrated in figure 1. A table titled *tblStation* contains information on the monitoring station such as latitude and longitude coordinates, river reach, watershed, subbasin, etc. The table *tblSampleResult* includes fields such as the time and date of a sample event, the number and type of samples, analytes that were measured, numeric results, measurement units, and information fields related to the lab analysis. The table *tblProjects* contains information about the monitoring project and the monitoring organization such contact information and the name of the parent organization or agency.

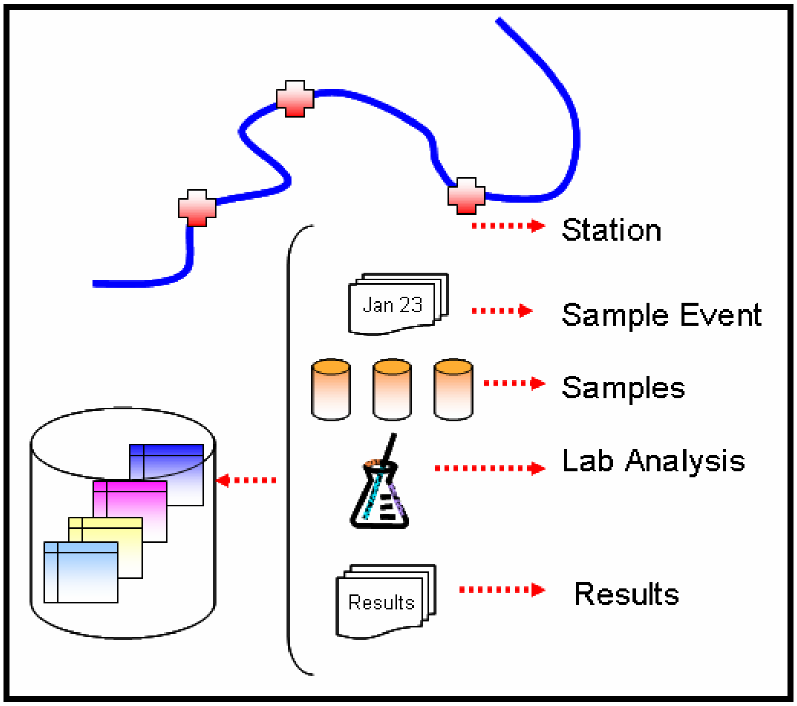


Figure 2.1. Schematic of monitoring data components recorded in the SAMdb

The SAMdb is implemented in the Microsoft Access software package with all of the links between tables established. Individual stations are related to monitoring projects via a field in the table *tblSampleResult*. Similarly measurements by different programs can be grouped into categories (e.g. metals, organics, nutrients) since they are related to monitoring organizations via the tables *tblProjects*, *tblSampleResult* and the lookup table *luAnalyte*. Measurements can be categorized and quantified relative to specific parameters, monitoring programs, spatial location, watershed, sample timing, etc. Data can be added, edited, and reorganized in many different ways without modifying the existing data table structures. Figure 2.2 illustrates the relationships between the core tables and lookup tables contained in the database.

Data in the SAMdb can be manipulated and accessed through queries which bring data stored in separate tables together using common fields and criteria. For example, a user may want to know how many nitrate samples were taken at stations located in the Salinas watershed during the last five years by the Central Coast Watershed Studies (CCOWS) projects. This can be accomplished with a query that includes the tables *tblStation*, t*blSampleResult*, and *tblProjects* with criteria specified for appropriate data fields (see figure 2.3).

The SAMdb is loosely coupled to a Geographic Information System (GIS) through unique station codes and spatial coordinates to allow production of maps from database queries and from data analysis. The GIS is implemented in the ArcGIS software system developed by ESRI and was used for map production throughout the project. Spatial data fields from the CalWater data set and the National Hydrography Dataset (NHD) are included in both the SAMdb and the GIS. Since watersheds connect landscape processes and human activities via waterways, they are often a relevant spatial unit for water quality data analysis. Each station record in the SAMdb is associated with a river reach and a hierarchical nesting of watershed boundaries that facilitates data analysis at multiple watershed scales. Figure 2.4 is a screenshot displaying the Monterey Bay area with some of the elements contained in the GIS and water quality monitoring stations along the perimeter and within the Monterey Bay highlighted for data extraction. The system allows a user to combine spatial, temporal, and programmatic, and measurement type criteria to select or analyze data. It can be used, for example, to spatially lump sampling locations by watershed to display the range of pollutant concentrations in different watersheds or sub-watersheds.

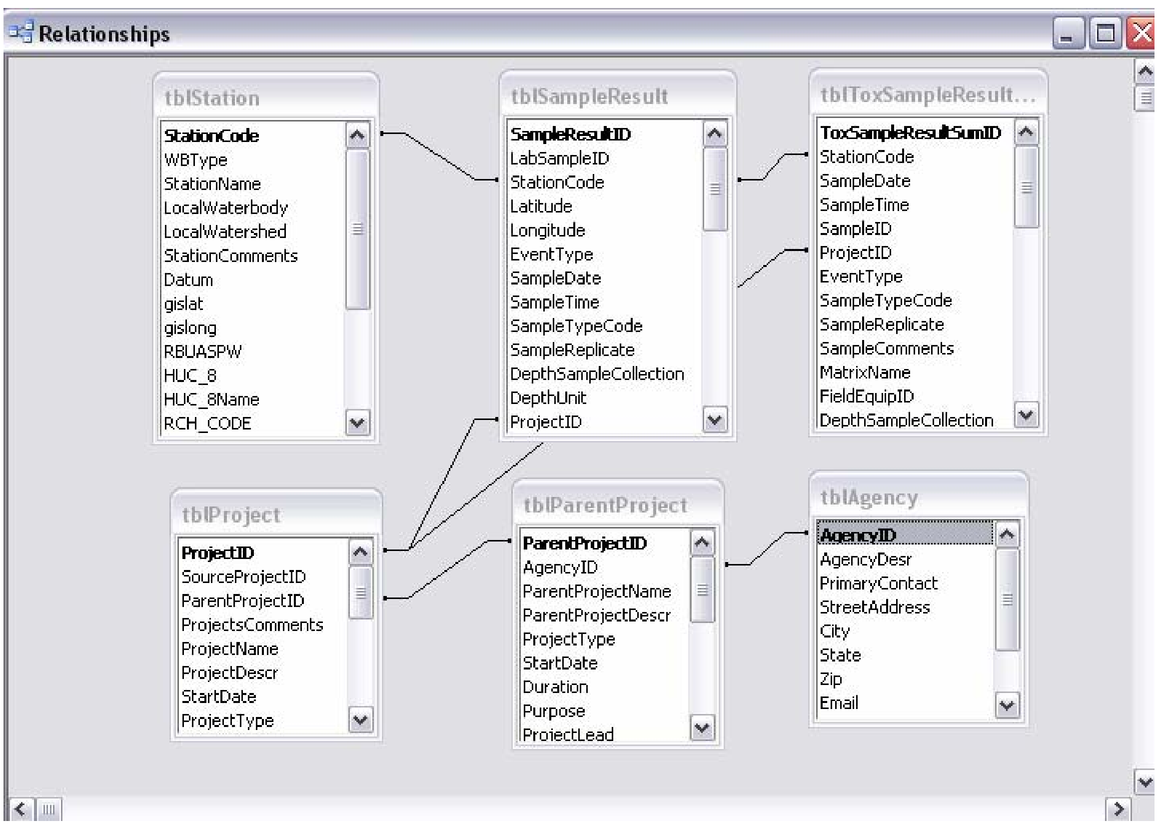


Figure 2.2 Screenshot of core table relationships contained in the SAMdb

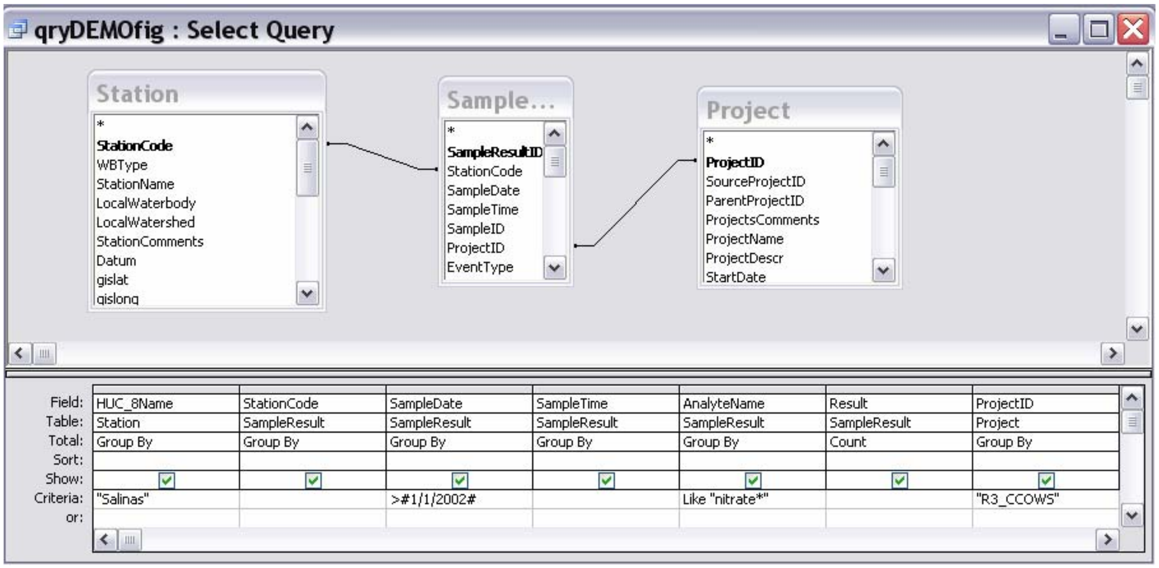


Figure 2.3 Screenshot of a query performed in the SAMdb

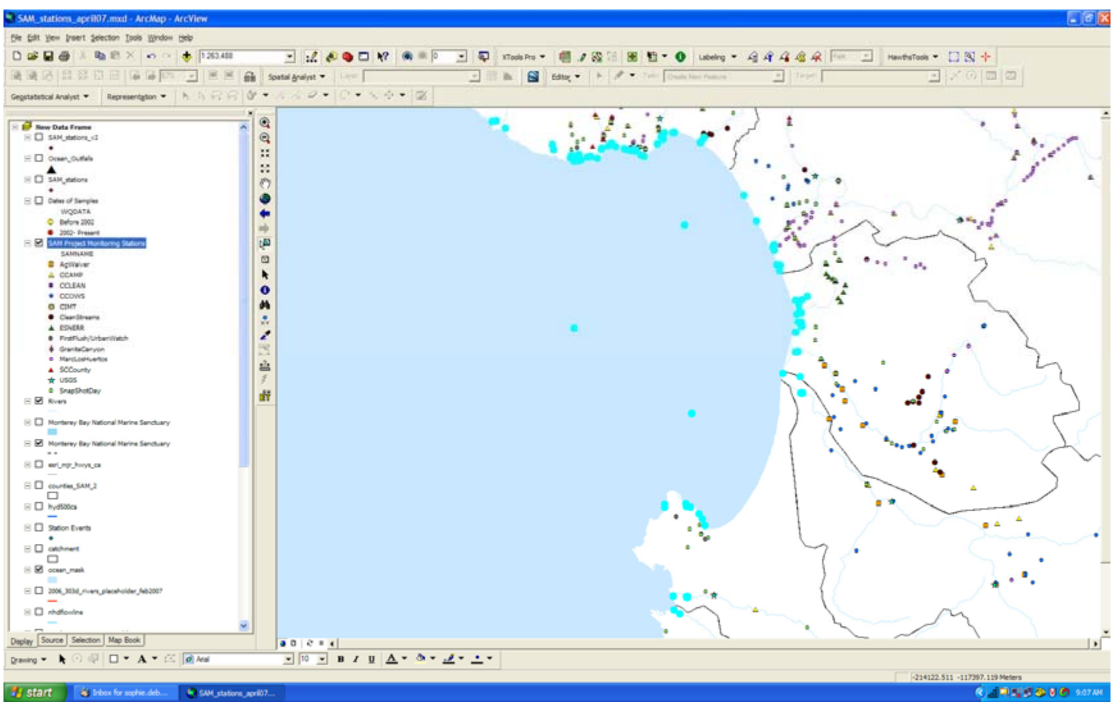


Figure 2.4 Screenshot of the GIS that is coupled to the SAMdb

2.6 SAMdb Development, Updates and Data Access

For SAMdb to remain useful for assessing water quality management questions it will need to be updated and maintained. Data updates have been performed for some monitoring organizations, and should continue at the least on an annual basis if the SAMdb is to be used for ongoing water quality status assessments. The database can be expanded in the future to include additional monitoring programs and new data types such as sediment chemistry/toxicity, mussel tissue chemistry/toxicity, and bioassessment data.

The structure of the SAMdb was simplified considerably from the SWAMP database to expedite data analysis and batch uploads of data, since there was uncertainty about the nature of queries that would need to be required and since the SWAMP database structure is still in a state of development. Development of the SAMdb into a more permanent repository will require a number of steps including further table normalization; data update and validation procedures and protocol development; creation of automated data upload scripts; and possibly migration to more powerful software such as the open source MySQL package. Additionally, formal documentation and construction of a user interface would be required for distribution to a wide audience. Currently, water quality data is available to users on an individual basis by contacting the MBNMS/SIMoN.

The SAMdb serves as an adequate regional node for collection, processing, analysis, and dissemination of water quality data sets. A more practical alternative to developing the SAMdb into the regional repository will be to continue its use as an intermediate node and use resources to move data toward the California Environmental Data Exchange Network (CEDEN) for permanent storage. Infrastructure for the CEDEN system is already in place, it has a relatively stable funding source, and sufficient technical resources. This arrangement would allow future efforts of the SAM project to focus on data analysis, reporting, monitoring coordination, and development of technical tools to enhance data integration.

3.0 DATA CHARACTERIZATION

The first section of this chapter contains a summary of water quality data that were collected as part of the SAM project. The sections that follow contain a characterization of the data relative to a set of 10 key parameters were selected for detailed analysis:

- ammonia
- nitrate
- orthophosphate

- dissolved Oxygen
- temperature
- pH
- total suspended solids (TSS)
- *E.coli*
- fecal coliform
- toxicity

The following parameter groups are also represented:
- metals
- persistent organic pollutants

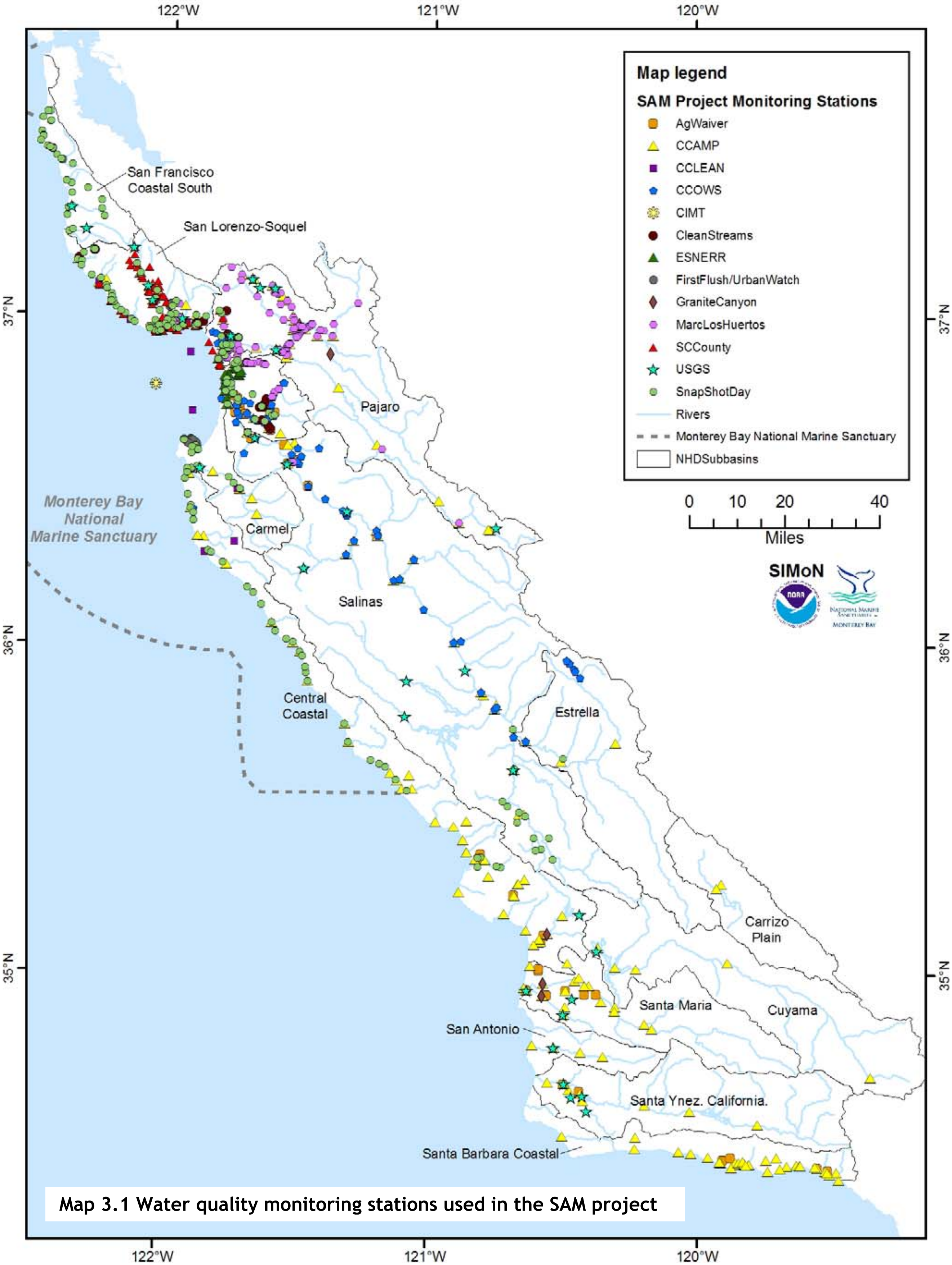
Throughout the remainder of this report, the term *parameter* is used to refer to water quality measurements that include physical and chemical variables. Data are characterized with maps and a discussion of the spatial patterns that were observed for data abundance and parameter levels.

Although the data collection effort was not exhaustive, the data used in this characterization is representative of data that exists for the Central Coast. Some examples of data not used include data from some small volunteer monitoring groups; data collected by point source dischargers; organizations without digitally stored data files; projects that had very short durations and/or are not presently ongoing. Also, there exist data sets derived from automatic sensors at a limited number of locations, such as the LOBO network in the Monterey Bay and the Elkhorn Slough, with extremely high time resolution (e.g. 15 minute intervals), that were not collected for the data management challenges that they presented.

3.1 Data Inventory

The SAMdb contains data from 14 monitoring programs that collectively sample approximately 900 sites on the Central Coast. Surface water chemistry, discharge, and toxicity data was compiled for the time period 1970 – 2007. Approximately 80% of the data was collected after 1990. Together, these data total approximately 400,000 measurements of 98 different parameters. The locations of monitoring stations where data was collected are shown in map 3.1. Since the time of data collection, a few stations have changed locations. The First Flush and Urban Watch program stations are shown together since they share the same station locations and operate under the same QAPP.

The number of measurements that were collected for different water quality parameter categories is shown in figure 3.1. The parameter categorization used follows the SWAMP conventions and are listed in Appendix 1. Physical parameters such as temperature, dissolved oxygen, and streamflow discharge make up the largest number of measurements. Inorganic measurements (e.g. chlorine, hardness) are the second most abundant, followed by nutrients (e.g. nitrate, ammonia, and orthophosphate) and then bacteria (e.g. enterrococcus, fecal coliform, *E. coli*). There were far fewer measurements of biological (e.g. algae cover, phytoplankton), metals (copper, zinc, lead, magnesium), toxicity, and organic pollutants in comparison. Organic pollutants such as chophyrifos and diazinon, and water toxicity have been measured less than any other water quality constituent on the Central Coast. The makeup of the water quality measurements that have been made on the Central Coast have to do the monitoring objectives of programs, their knowledge of pollutants of concern, and costs involved with different types of measurements.



Map 3.1 Water quality monitoring stations used in the SAM project

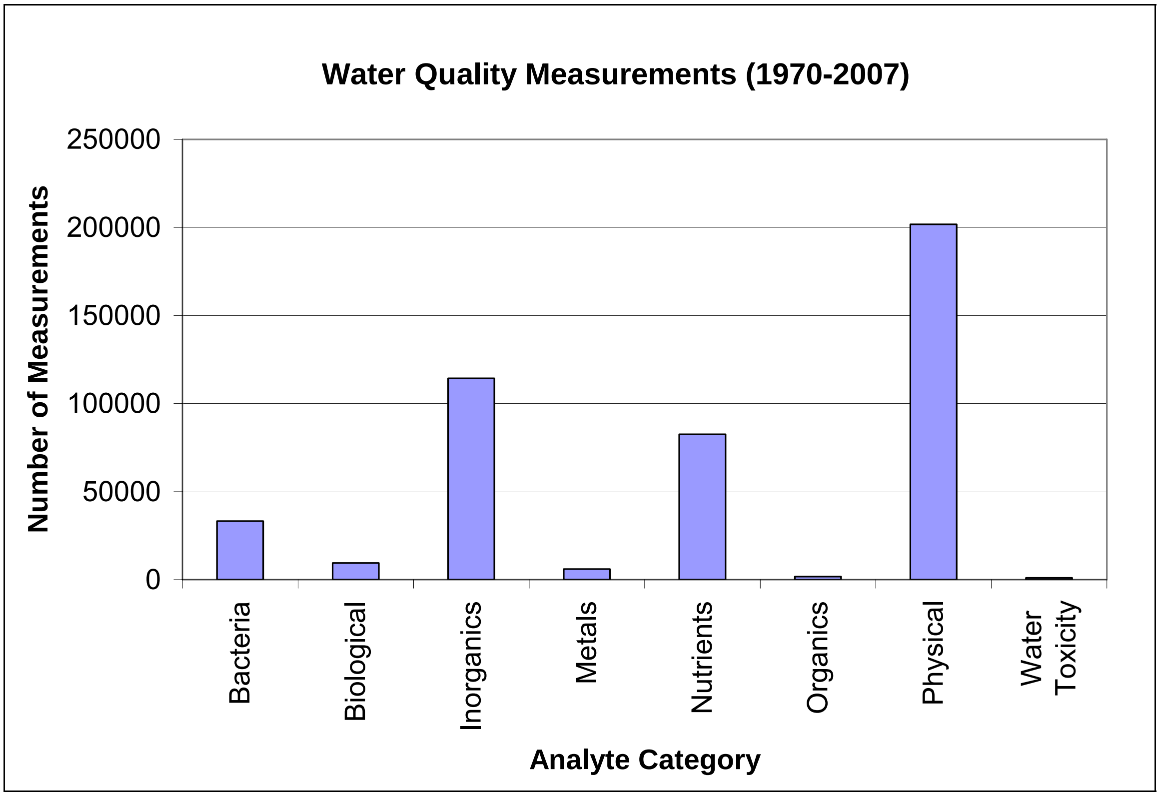


Figure 3.1 Data types collected on the Central Coast

Table 3.1 is a summary of the data that was collected from each monitoring program in terms of data type, time extent, measurement frequency, and program status. Parameter groups may contain different specific parameters for individual monitoring programs. Table 3.1 was created from a combination analysis of data provided by monitoring programs and review of program documentation. Monitoring frequency does not necessarily represent the frequency of monitoring at every station associated with the program. For some programs the monitoring frequency was highly variable across stations, time, and individual parameters. In these cases, the frequency was estimated as the frequency that data was collected at the greatest number of stations or for the greatest number of parameters between 2002 and 2007. The status of monitoring for specific parameter group was determined by examination of the most current data that was available or review of program documentation.

Table 3.1 Water Quality Data Inventory

Frequency		Status	
█	≥ bimonthly	▶	ongoing
▒	≥ monthly	—	episodic/indeterminate
☰	≥ quarterly	■	terminated
░	≥ annually	∅	not monitored

	Physical			Pathogens			Inorganics			Metals			Nutrients			Organics			Toxicity		
	Extent (yrs.)	Frequency	Status	Extent (yrs.)	Frequency	Status	Extent (yrs.)	Frequency	Status	Extent (yrs.)	Frequency	Status	Extent (yrs.)	Frequency	Status	Extent (yrs.)	Frequency	Status	Extent (yrs.)	Frequency	Status
AgWaiver	≥ 3	▒	▶	∅	∅	∅	≥ 3	▒	▶	∅	∅	∅	≥ 3	▒	▶	∅	∅	∅	≥ 3	☰	▶
CCAMP	≥ 10	▒	▶	≥ 10	▒	▶	≥ 10	▒	▶	≥ 10	░	▶	≥ 10	▒	▶	≥ 5	▒	▶	≥ 5	☰	▶
CCLEAN	≥ 5	▒	▶	≥ 5	▒	▶	≥ 5	▒	▶	∅	∅	∅	≥ 5	▒	▶	≥ 5	░	▶	∅	∅	∅
CCoWS	≥ 3	█	—	≥ 1	▒	—	≥ 3	█	—	∅	∅	∅	≥ 3	▒	—	≥ 3	▒	—	∅	∅	∅
CIMT	≥ 1	▒	▶	∅	∅	∅	≥ 1	▒	▶	∅	∅	∅	≥ 1	▒	▶	∅	∅	∅	∅	∅	∅
Clean Streams	≥ 1	▒	—	≥ 3	▒	—	≥ 1	▒	—	≥ 1	▒	—	≥ 3	▒	—	∅	∅	∅	∅	∅	∅
ESNERR	≥ 10	▒	▶	∅	∅	∅	≥ 5	▒	▶	∅	∅	∅	≥ 10	▒	▶	∅	∅	∅	∅	∅	∅
First Flush	≥ 5	░	▶	≥ 5	░	▶	≥ 1	░	—	≥ 5	░	▶	≥ 5	░	▶	≥ 5	░	▶	≥ 1	░	—
Granite Canyon	≥ 3	☰	▶	∅	∅	∅	∅	∅	∅	≥ 3	☰	▶	∅	∅	∅	≥ 3	☰	▶	≥ 3	☰	▶
MaLoHAM	≥ 5	▒	—	∅	∅	∅	≥ 5	☰	—	∅	∅	∅	≥ 5	█	—	∅	∅	∅	≥ 1	☰	—
SC County	≥ 10	▒	▶	≥ 10	▒	▶	∅	∅	∅	∅	∅	∅	≥ 10	▒	▶	∅	∅	∅	∅	∅	∅
Snapshot Day	≥ 5	░	▶	≥ 5	░	▶	∅	∅	∅	∅	∅	∅	≥ 5	░	▶	∅	∅	∅	∅	∅	∅
Urban Watch	≥ 5	▒	▶	≥ 5	▒	▶	≥ 5	▒	▶	∅	∅	∅	≥ 5	▒	▶	∅	∅	∅	∅	∅	∅
USGS	≥ 10	☰	▶	≥ 10	☰	■	≥ 10	☰	■	∅	∅	∅	≥ 10	☰	—	∅	∅	∅	∅	∅	∅

Four of the 14 programs listed in table 3.1 have been collecting data for 10 years or more (CCAMP, ESNERR, SC County, and USGS). The ESNERR has been measuring some water quality constituents for as long as 18 years, and the USGS and SC County data sets contain records spanning more than 30 years for some parameters. Most data types have been collected by the various programs for periods of about 3 to 9 years at a frequency of monthly or less. Some programs, such as First Flush and Snapshot Day collect data on an annual basis at a large number of sampling sites. A few types of data are collected at relatively high frequency sampling intervals. The CCoWS program collects physical and inorganic measurements (sediments) at equal to or greater than bi-monthly frequency (see table 3.1). The Marc Los Huertos Ambient Monitoring (MaLoHAM) has collected a bi-monthly nutrients data set over the last 8 years.

The status of data collection for most data types are classified as ongoing (table 3.1). This is largely because data collection for the SAM project focused on programs that were known to be ongoing. For the CCoWS, Clean Streams, and MaLoHAM programs collection some data types that are episodic or the status is indeterminate. Reasons for episodic/indeterminate status often include changes in program objectives and/or funding availability.

Water quality measurements can be collected in different types of water bodies. The measurement types and methods used are often specific to the type water body that is sampled. The vast majority of water quality measurements occur in the rivers and streams of the Central Coast. Every program monitors streams and rivers, and some programs monitor locations at harbors, shorelines, lakes, storm drains, and reclamation ditches. For instance, the Urban Watch and First Flush programs concentrate on storm drains; CCAMP and the Ag Waiver programs have many stations to monitor ditches that drain agricultural lands; the ESNERR monitors the estuarine water quality; and CCLEAN and SC County monitor more ocean locations than the other programs.

3.2 Water quality objectives

Identification of water quality problems is facilitated by specification of standards against which water quality parameters can be compared. Compilations of water quality standards relevant to the Central Coast are provided by Merrit (2003) and by Marshack (2007). Watson et al. (2003) reviews a number of standards for nutrients in comparison to natural ambient levels, including sources that were used to develop the standards used by the Coast Ambient Monitoring Program (CCAMP) which is run by the Central Coast Regional Water Quality Control Board (RWQCB). The RWQCB is the primary agency responsible for water quality regulation on the Central Coast and implements a 'Basin Plan' which contains narrative and numeric objectives for many water quality constituents. From the Basin Plan and other water quality guidelines, the CCAMP program has developed 'Attention Levels' as standards to indicate water quality problems that have been used in a report on the Pajaro watershed (Worcester et al., 1998, revised 2003). The relevant standards that were used for comparison in this study are listed in table 3.2 along with their cited basis.

Table 3.2 Water quality standards for key parameters

Parameter	CCAMP Tentative Attention Level	Attention Level Cited Basis	Alternative Criteria	Alternative Criteria Basis
Ammonia (NH_3-N)	0.025 mg/L (Unionized Ammonia)	Basin Plan cold water fish habitat	2.2 - 5.0 mg/L (Total Ammonia)[4]	Marchack (2007)
Nitrate (NO_3-N)	2.25 mg/L	SJSU and Merritt Smith (1994)	10 mg/L	Basin Plan Drinking Water Standard
Orthophosphate (PO_4-P)	0.12 mg/L	SJSU and Merritt Smith (1994)		
Dissolved Oxygen	< 7.0 mg/L	Basin Plan standard for cold water fish habitat		
pH	Acceptable range= 7-8.5	Basin Plan		
Temperature	22 C	Moyle (1976) protection of steelhead		
Total Suspended Solids (TSS)	500 mg/L	none given		
E. coli	126 MPN/100 mL (30 day geometric mean)	U.S. EPA steady freshwater objective	406 MPN/100 mL single sample	US EPA freshwater moderately or lightly used
Fecal Coliforms	200 MPN/100mL (30 day geometric mean)	Basin Plan water body contact	400 MPN/100mL 10% samples during 30 day period.	US EPA freshwater
Copper	30 ug/L	Basin Plan cold water fish habitat		
Diazinon			500 ng/L	California Dept of Fish & Game 4-day average

[4] The U.S. EPA criteria is temperature and pH dependent and based on 30 day average continuous concentration with early life stage fish present. The range given was calculated using the inter-quartile range of pH and temperature measurements for Central Coast stations.

3.3 Spatial patterns for key parameters

3.3.1 Maps explanation

Depiction of statistical information on maps is useful for identifying patterns and synthesizing useful information from the large amount of data that was collated. The following sections present a discussion of the data one parameter at a time to illustrate spatial patterns of data abundance and parameter measurements for each of the key parameters. Spatial patterns are investigated at a regional scale, with hydrologic subbasins used as the main unit of analysis/discussion. For each parameter, there is a qualitative discussion of the monitoring effort, measurement results, and a comparison with water quality objectives. For simplicity of presentation the data are described collectively as measurements collected at 'Central Coast stations' rather than differentiating individual monitoring programs from one another.

Two types of maps are presented for each parameter. For each parameter, the first map displays the number of measurements (excluding QA samples) that were taken at monitoring sites within the study area from 2002 to 2007, and the second map shows the calculated mean value (or geometric mean value) of that parameter over the same time period. Selection of the most recent 5 year time period was arbitrary, but nonetheless reflects the fact that resource managers are often interested in the most current data sets available. The maps showing the number of measurements depict the spatial distribution of the relative level of monitoring effort for each parameter. Measurements that used different analytical methods or reporting conventions, e.g. nitrate measured as N and nitrate as NO_3 are lumped together, so that all nitrate measurements are counted. For these maps, stations were categorized based on the average measurement frequency, e.g. the first category represents stations where there were up to 5 measurements taken for the 5 year period. The last two maps show the count of measurements for parameter groups (metals and organic pollutants) rather than for single parameters. It is important to note that while these maps illustrate the relative level of monitoring effort, the adequacy of the data collected cannot be judged in the absence of a specified purpose for the data.

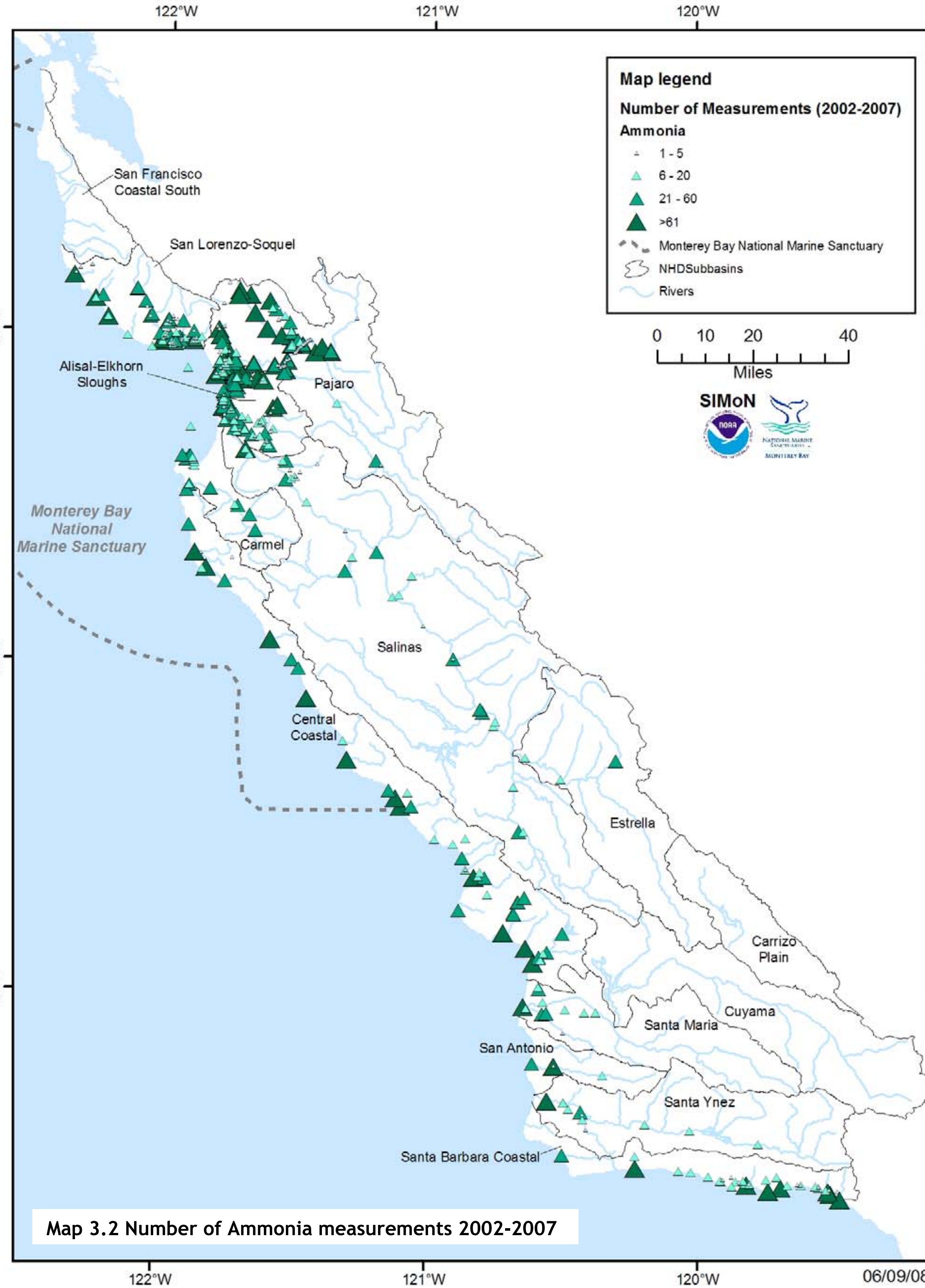
The second set of maps shows mean measurement values for the region over the 5 year period. The mean value is strongly influenced by outlying data values and is not as representative of the overall water quality conditions at a location compared to the median or the geometric mean. However, since extreme values tend to drive water quality regulation, using the mean values can illustrate where problems exist in a way that is more meaningful in the context of comparisons with water quality criteria. The data are displayed as quartiles which divide the data into four parts broken by values at the 25th, 50th, and 75th percentiles (first, second, and third quartiles). For each station, the mean concentration from each station was placed into a quartile category. These maps can be compared with water quality objectives for specific parameters to indicate the level of problem that exists at different locations. By mapping measurements that are averaged over time, variation in the data is reduced and the value that is mapped is more representative of the overall water quality conditions compared to using a single measurement. For the calculations on which these maps are based, non-detect values were censored to one-half of the detection limit. When different measurement types/units existed for a single parameter, the most abundant data type was mapped.

3.3.2 Ammonia

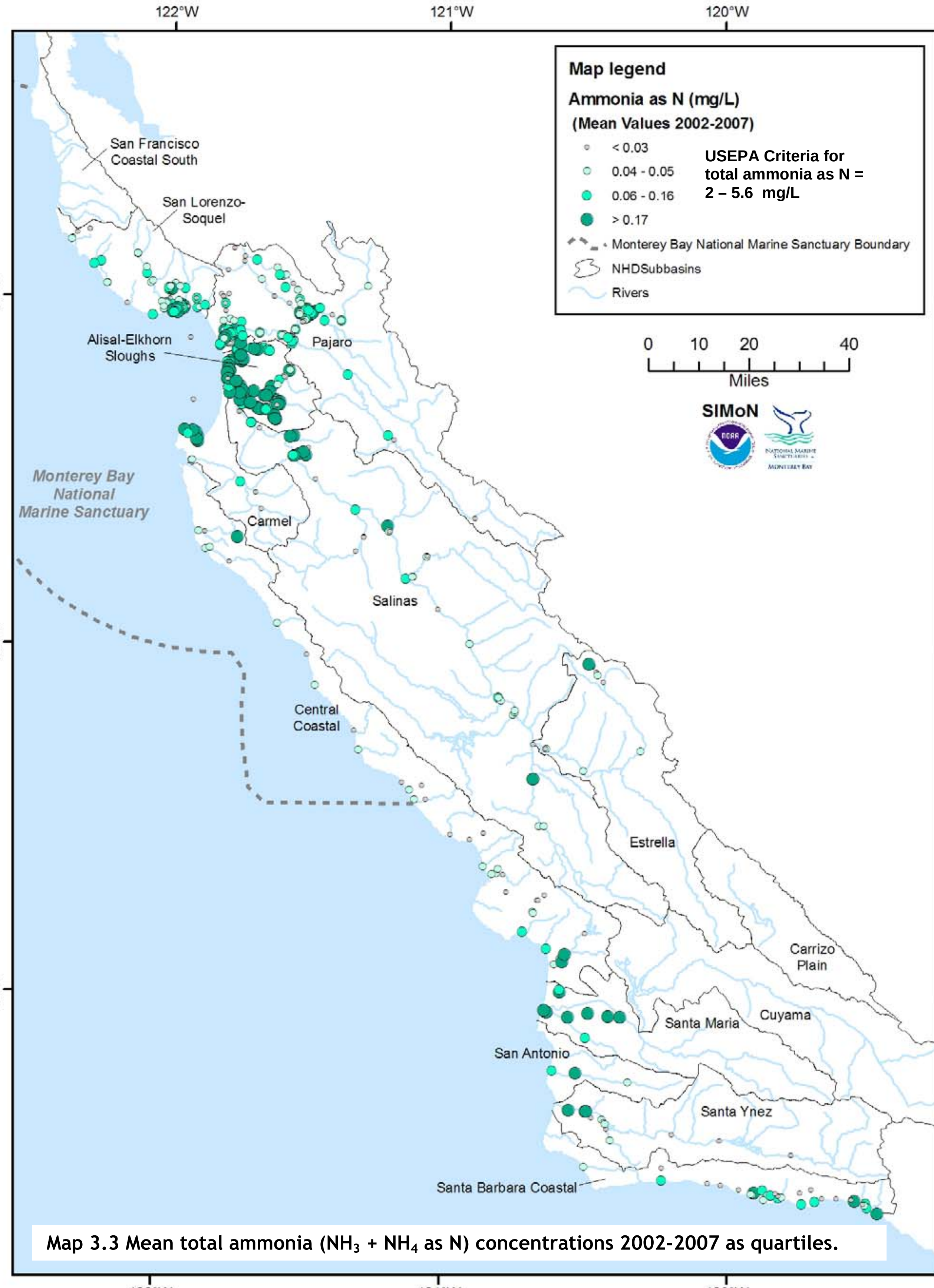
Map 3.2 shows that within the study area, collection of ammonia data is focused in the Pajaro watershed and within the Alisal-Elkhorn Slough subbasin. Greater than 100 measurements have been collected in the last five years at numerous stations in these watersheds. All of the stations that have had more than 100 ammonia samples from 2002-2007 were collected as part of MaLoHAM program. Two locations in the Alisal-Elkhorn subbasin have above 2000 samples that were taken in-situ with automatic sampling devices. The watersheds in the San Francisco Coastal South subbasin have no ammonia measurements, and the northern portion of the San Lorenzo-Soquel subbasin had very few measurements. All of the stations that measure ammonia in the Salinas Valley are located on the main stem of the river. There were no ammonia measurements available for the San Francisco Coastal South, Cuyama, and Carrizo Plain subbasins.

Map 3.3 shows the concentration of total ammonia (NH3 + NH4+ as N) at Central Coast stations, which is the form reported by most monitoring organizations. Although the ammonium ion (NH4+) is not as toxic as unionized ammonia, there is reason to believe that regardless of its lower toxicity, it can still be important because it is generally present in much greater concentrations than un-ionized ammonia. (U.S. EPA, 1999). There were stations with ammonia concentrations in the upper 25th percentile spread across of the Central Coast. There were a large number of stations with relatively high ammonia concentrations in the Alisal-Elkhorn subbasin, lower portion of the Salinas subbasin, Central Coastal subbasin watersheds near Morro Bay, lower Santa Ynez, lower Santa Maria, and within the cities of Santa Cruz and Monterey. However, very few stations exceeded the U.S. EPA criteria for total ammonia which was between 2 – 5.6 mg/L depending on the temperature and pH conditions at the time of measurement. It is possible that evaluation relative to the CCAMP attention level for unionized ammonia (NH_3 as N) of 0.025 mg/L would result in identification of potentially harmful levels of ammonia that are not apparent when considering only total ammonia.

Comparison of the maps in maps 3.2 and 3.3 reveals that for most of the Central Coast, there is a high degree of monitoring effort focused in areas that have relatively high ammonia levels. A notable exception to this pattern is along the big sur coast where ammonia levels are very low and stations have been sampled as frequently as stations with greater potential for ammonia problems to exist.



Map 3.2 Number of Ammonia measurements 2002-2007



Map 3.3 Mean total ammonia (NH_3 + NH_4 as N) concentrations 2002-2007 as quartiles.

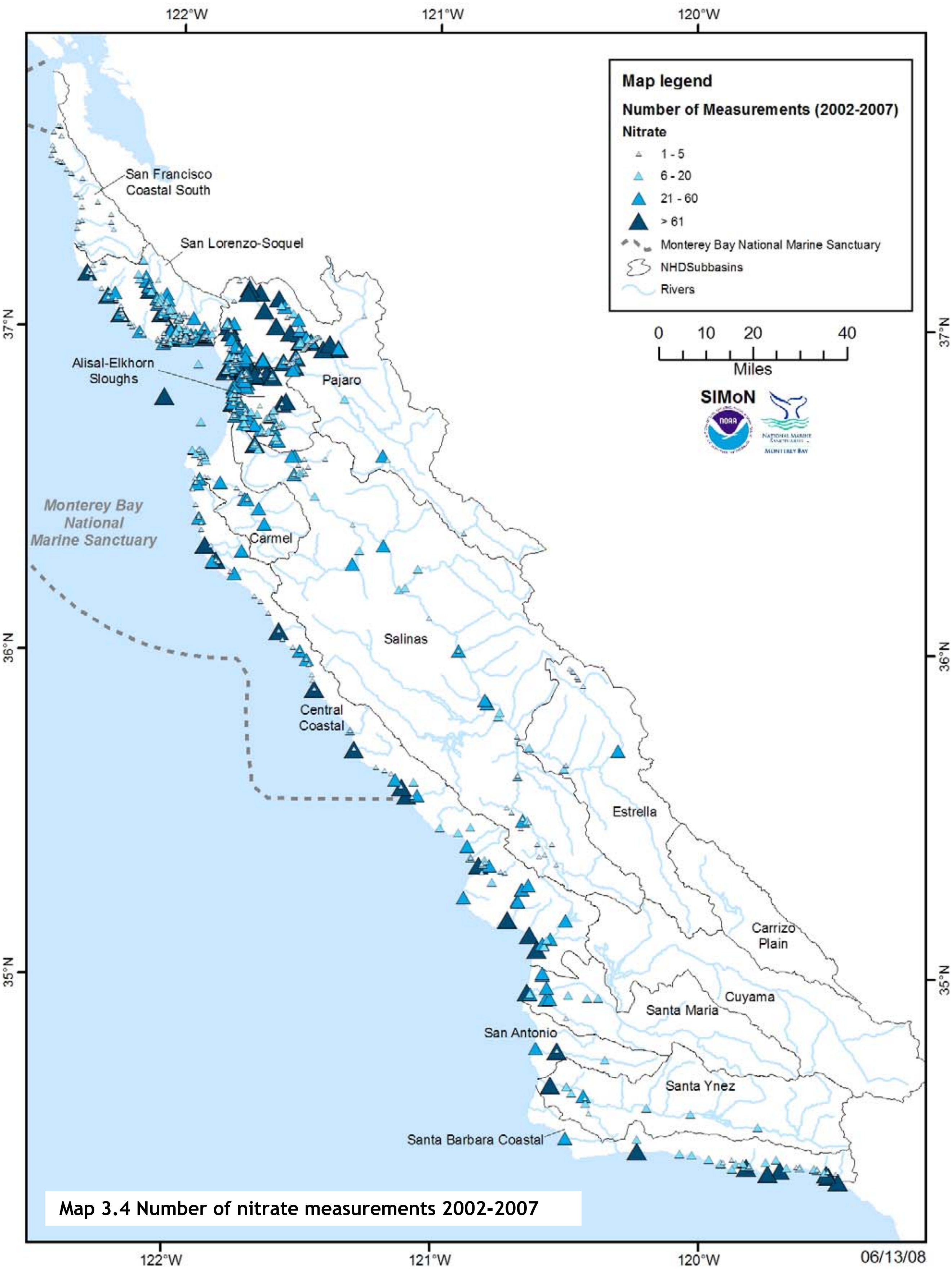
3.3.3 Nitrate

The number of nitrate measurements that were made from 2002 to 2007 at Central Coast stations is shown in Map 3.4. The data density was greatest in the lower Pajaro watershed where above 60 measurements collected at numerous stations. Most of these measurements come from the MaLoHAM program. The stations that are sampled most often had more than 400 measurements. Other stations with a high number of measurements include San Lorenzo-Soquel subbasin stations operated by Santa Cruz county and the CIMT sensor located in the Monterey Bay. All but one of the stations in the Salinas watershed had less than 60 measurements taken from 2002-2007. There were very few measurements in the San Francisco Coastal South subbasin and no measurements in the Carrizo Plain and Cuyama subbasins.

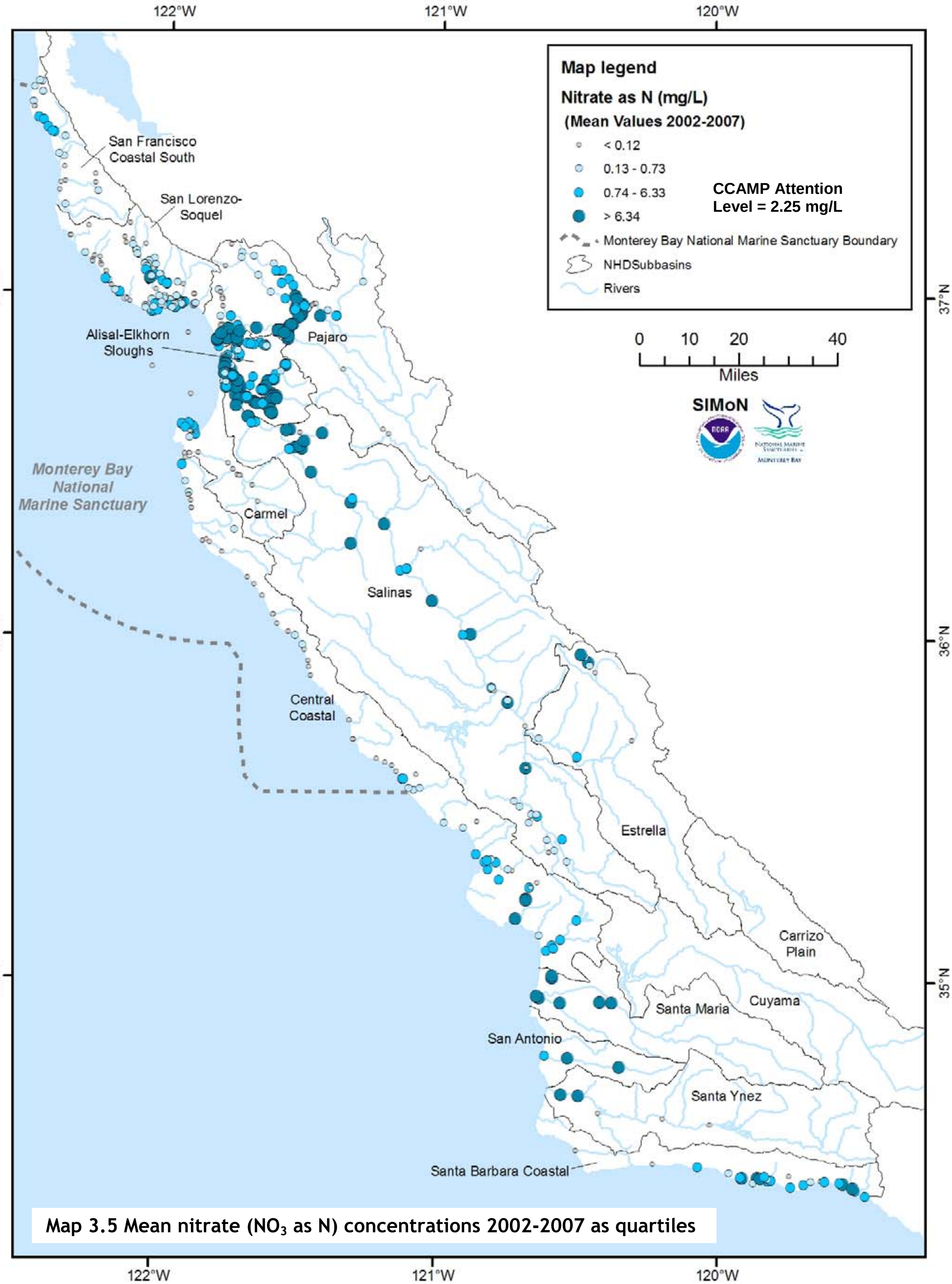
Map 3.5 shows mean nitrate ($N0_3$ as N) concentrations for the study area. Stations located in the Pajaro, Alisal-Elkhorn, Salinas, Santa Maria, Estrella and Santa Ynez subbasins had nitrate levels in the upper 25% of all Central Coast stations. Map 3.5 shows that nitrate levels were relatively low in the San Francisco Coastal South, San Lorenzo-Soquel, Carmel, and the northern portion of the Central Coastal subbasins.

The CCAMP attention level for nitrate is 2.25 mg/L (see table 3.2). About 35% of the stations on the Central Coast with nitrate measurements had mean values that exceeded this objective. The highest mean nitrate levels are above 100 mg/L. A less stringent, but regulatory, objective is the Central Coast Basin Plan municipal and domestic use standard which is set at 10 mg/L as a maximum. Approximately 19% of the station mean values exceeded this objective.

A comparison of maps 3.4 and 3.5 reveals that there were relatively few measurements in the upper reaches of the Pajaro, Salinas, Cuyama, Santa Maria, and Santa Ynez watersheds and relatively high nitrate levels downstream. The measurements lower down in these watersheds may indicate substantial nitrate sources further upstream in addition to those in close proximity to the stations where nitrate is measured.



Map 3.4 Number of nitrate measurements 2002-2007



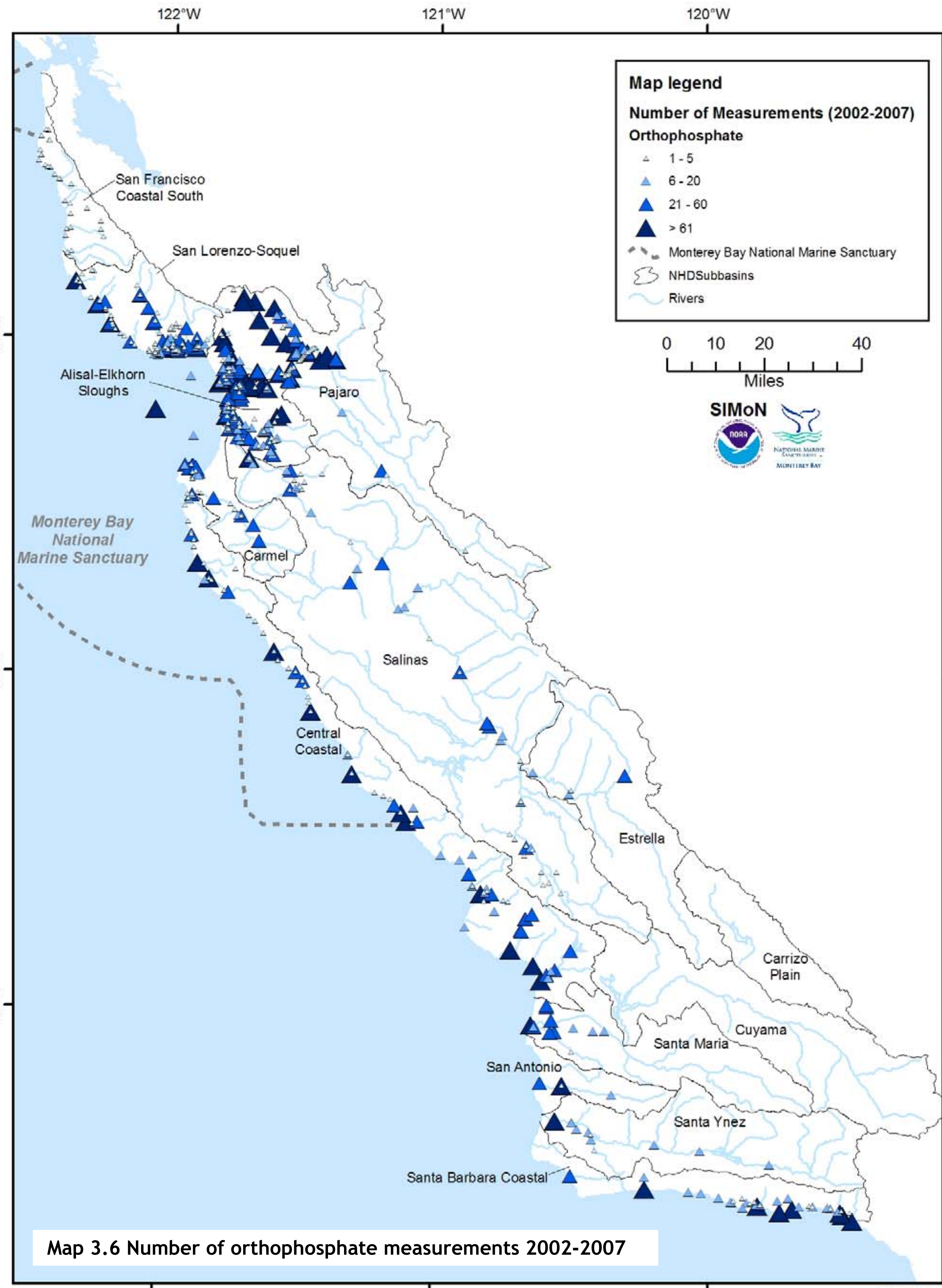
Map 3.5 Mean nitrate (NO_3 as N) concentrations 2002-2007 as quartiles

3.3.4 Orthophosphate

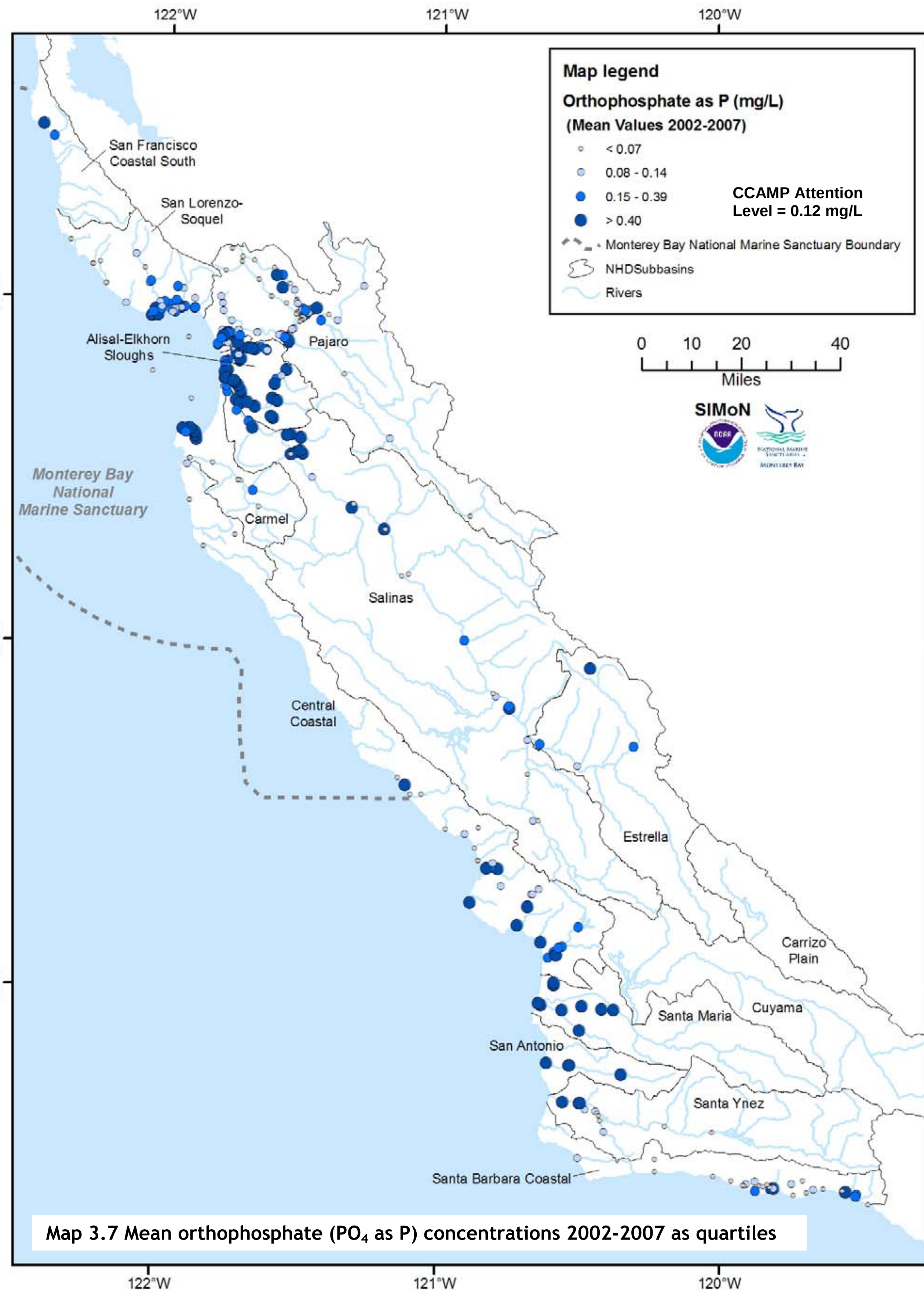
Map 3.6 illustrates that orthophosphate measurements from 2002 to 2007 are most abundant in the Pajaro watershed, Elkhorn Slough, and at the automatic CIMT sensor in the Monterey Bay from 2002-2007. There were no measurements in the Carrizo Plain subbasin or the Cuyama subbasin. There were relatively few measurements made in the upper portions of the Pajaro, Salinas, Estrella, and Santa Maria subbasins and in the San Francisco Coastal South subbasin,

There were numerous stations in most of the region's subbasins with mean orthophosphate (PO_4 as P) levels above the third quartile value (0.40 mg/L) for all Central Coast stations (see map 3.7) The Pajaro, San Lorenzo-Soquel, Elkhorn-Alisal Sloughs, Carmel, and lower Salinas subbasins had the greatest number of stations with average measurements in the upper quartile. Several stations in the lower Pajaro watershed and near the city of San Luis Obispo had mean orthophosphate levels above 5 mg/L. The highest measurements in these areas were above 9 mg/L. Stations near heavily urbanized areas of Santa Cruz, Monterey, and San Luis Obispo also showed relatively high mean orthophosphate levels. Approximately 53% of Central Coast stations where orthophosphate was measured had average values that exceeded the CCAMP attention level for orthophosphate (0.12 mg/L).

Most areas with relatively high orthophosphate concentrations appear to have a commiserate level of monitoring effort. Exceptions include areas in Salinas subbasin, the northern portion of the San Francisco Coastal South subbasin, and the Monterey Peninsula in the Carmel subbasin. About half of the stations in the Salinas watershed exceed the CCAMP Attention Level, and many of those stations had less than 20 measurements recorded from 2002 to 2007.



Map 3.6 Number of orthophosphate measurements 2002-2007



Map 3.7 Mean orthophosphate (PO_4 as P) concentrations 2002-2007 as quartiles

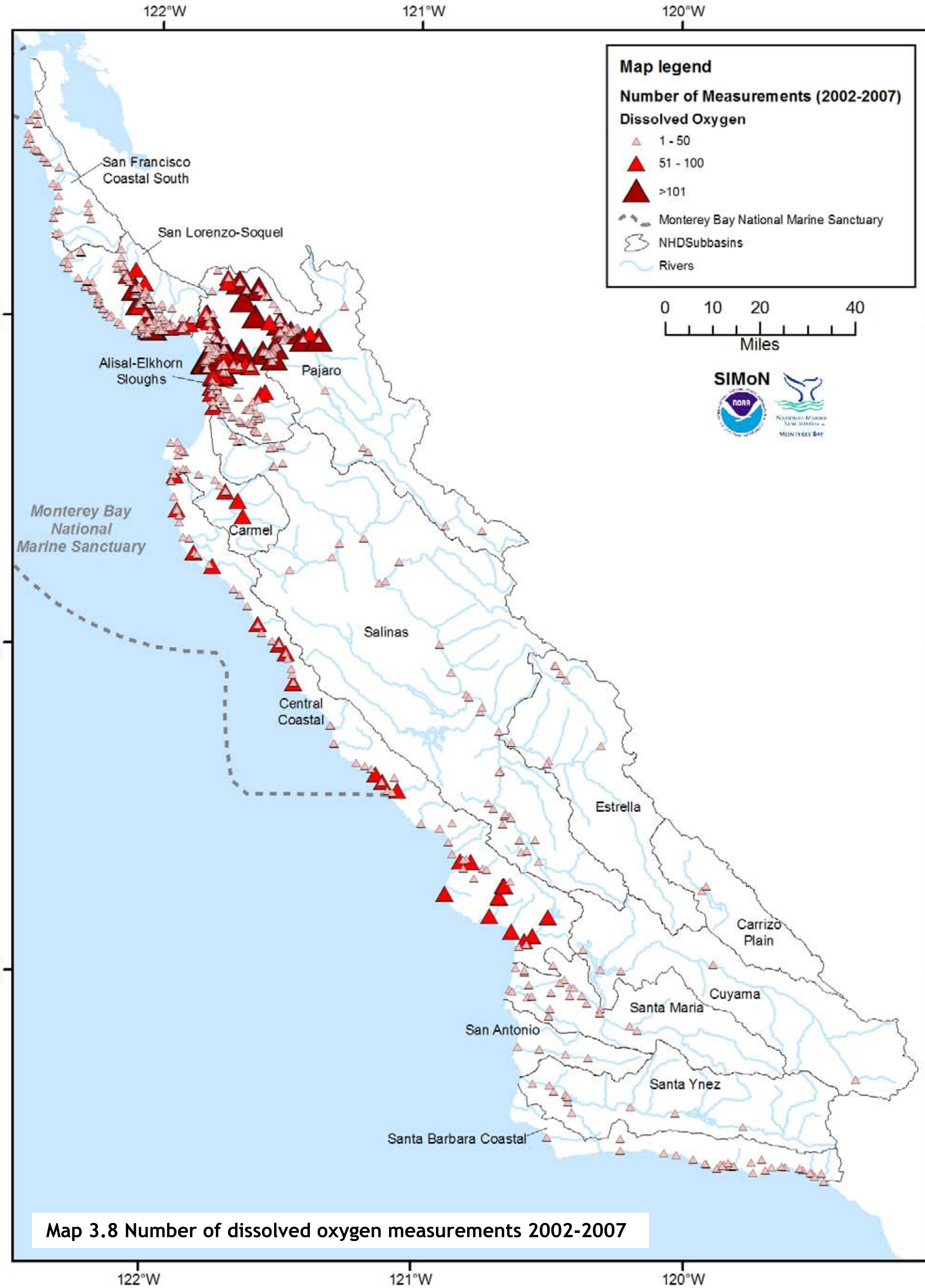
3.3.5 Dissolved Oxygen

The number of dissolved oxygen (and oxygen saturation) measurements within the study area are shown in map 3.8. More than sixty measurements occurred between 2002-2007 at stations in the Pajaro, San Lorenzo-Soquel, Alisal-Elkhorn, Carmel and southern Central Coastal subbasins. The greatest spatial density of stations with a high number of measurements is in the lower Pajaro subbasin, the Alisal-Elkhorn subbasin, and the San Lorenzo river valley in the San Lorenzo-Soquel subbasin. There were relatively few measurements in the San Francisco Coastal south subbasin and the Estrella subbasin. There were no measurements in the Cuyama and Carrizo Plain subbasins.

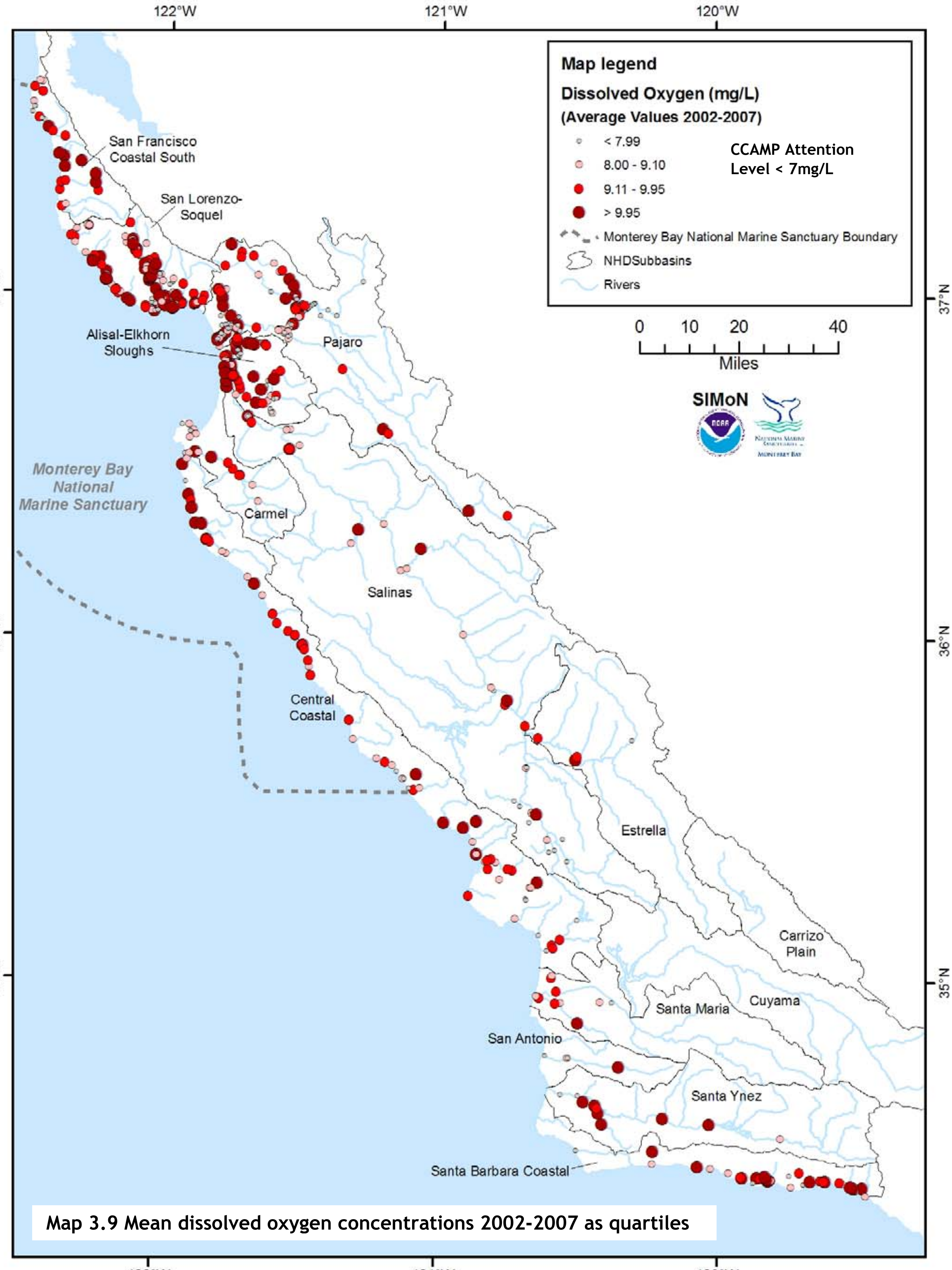
Map 3.9 shows the dissolved oxygen concentrations for Central Coast stations. All of the Central Coast subbasins had stations with dissolved oxygen levels below the first quartile value (7.99 mg/L). The lowest mean levels of dissolved oxygen were below 5 mg/L at stations in the Pajaro, San Lorenzo-Soquel, and South San Francisco Coastal subbasins.

The CCAMP Attention Level, derived from the Basin Plan for cold water fish habitat, is a minimum value of 7.0 mg/L. Approximately 13% of the Central Coast stations that measured dissolved oxygen had mean values that were below this threshold. Stations with mean values below this threshold are located in the San Francisco Coastal South, San Lorenzo-Soquel, Pajaro, Salinas, Alisal-Elkhorn, Carmel, Central Coastal, and Santa Ynez subbasins.

Most areas with low dissolved oxygen have more than 60 measurements from 2002-2007. Some stations in the upper Salinas, Carmel, and San Francisco Coastal South subbasin had dissolved oxygen levels below 7 mg/L and relatively few measurements.



Map 3.8 Number of dissolved oxygen measurements 2002-2007

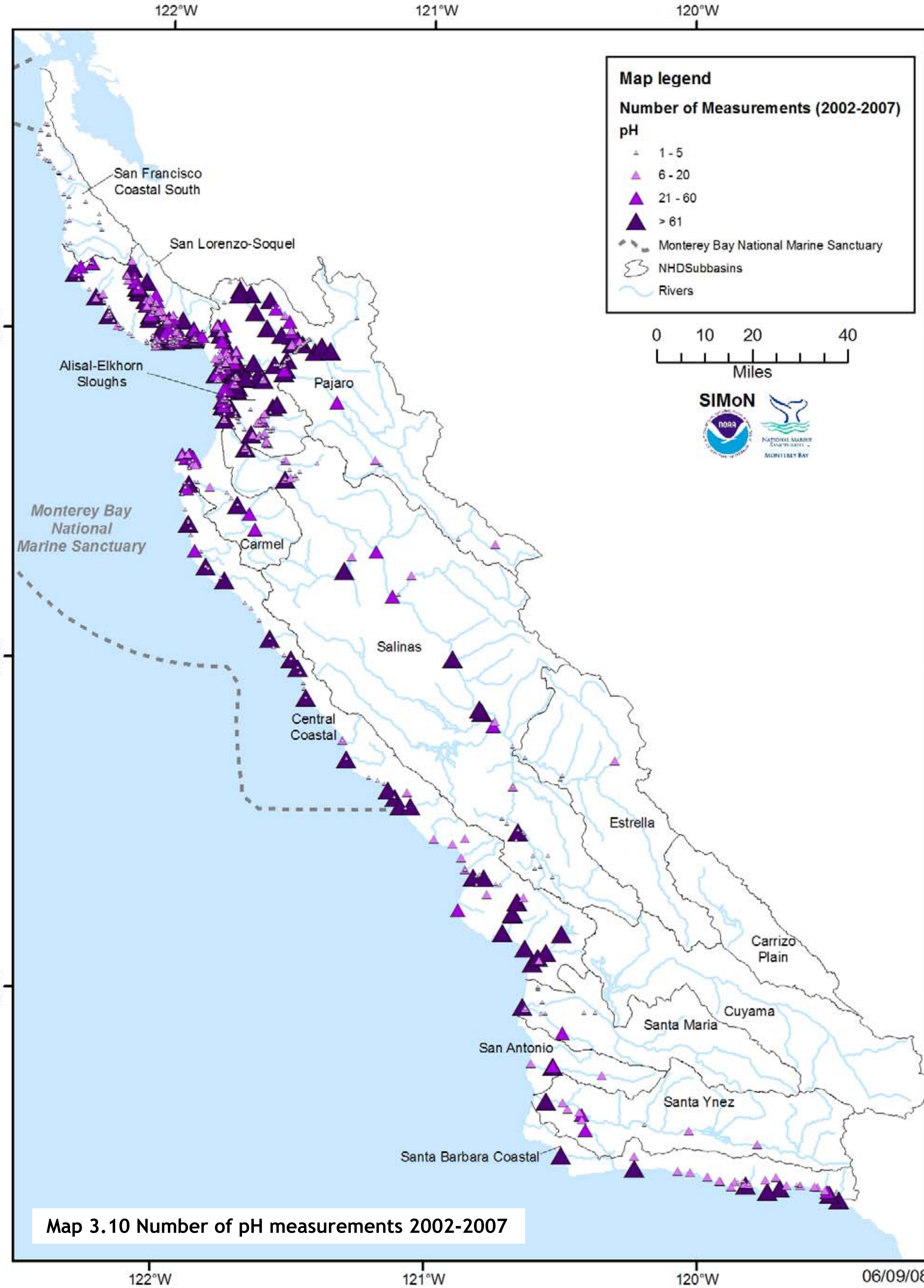


Map 3.9 Mean dissolved oxygen concentrations 2002-2007 as quartiles

3.3.6 pH

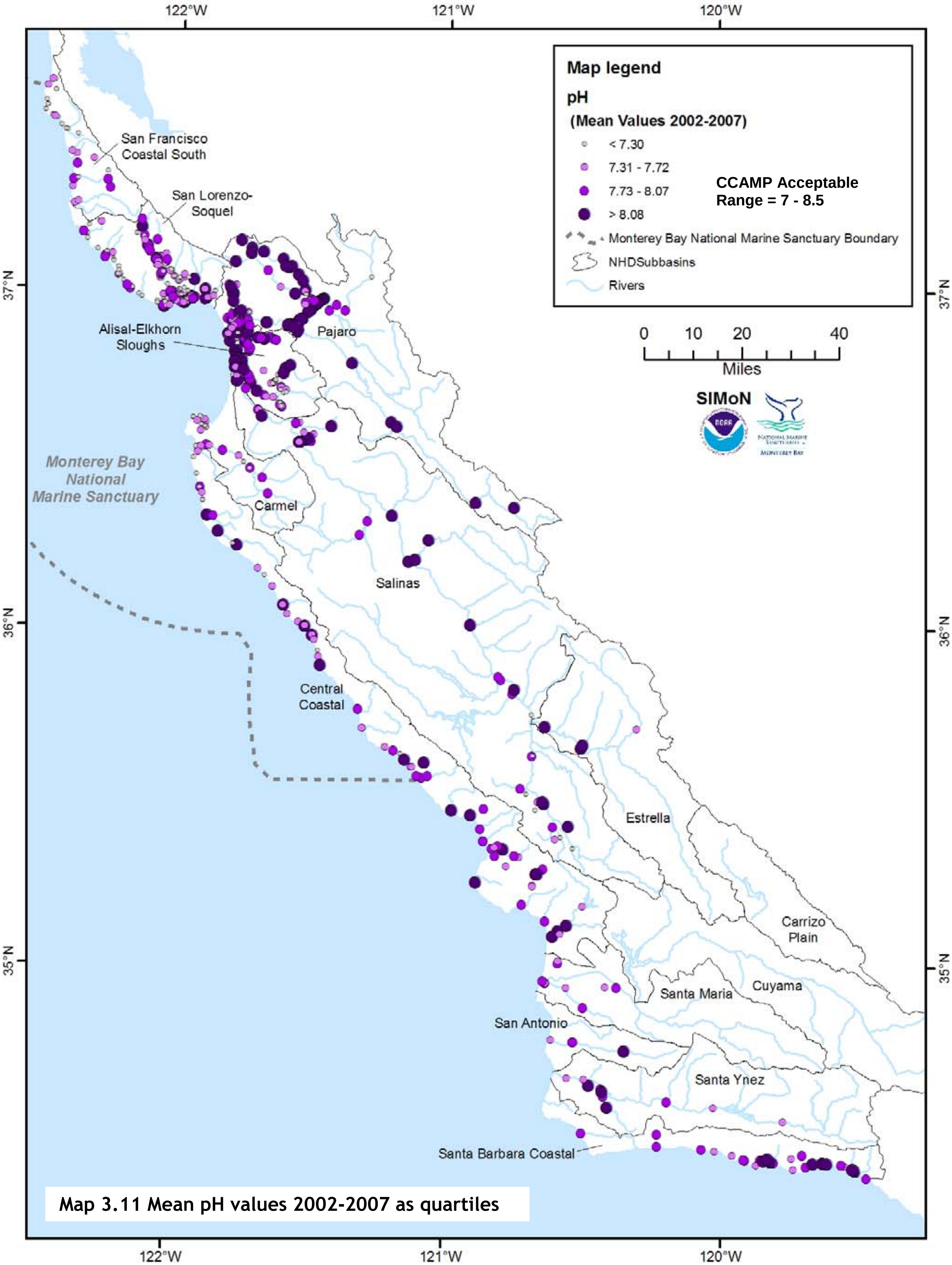
The spatial distribution of pH measurements for Central Coast stations is shown in map 3.10. More than 60 measurements occurred between 2002-2007 at stations in the Pajaro, San Lorenzo-Soquel, Alisal-Elkhorn, Carmel, Central Coastal, Santa Ynez, Santa Maria, and Santa Barbara Coastal subbasins. The greatest spatial density of stations with above 60 measurements was in the lower Pajaro watershed, the Elkhorn Slough, and the San Lorenzo river valley. There were less than 6 measurements at most stations in the San Francisco Coastal South subbasin. Measurements were not available for the Carrizo Plain and Cuyama subbasins and there were very few measurements in the upland watersheds of the Salinas watershed.

Map 3.11 shows that there were mean pH values below the first and above the third quartile value for all of the Central Coast subbasins. The highest mean pH values (> 9.0) were observed in the Pajaro, Alisal-Elkhorn, Santa Ynez, and Santa Barbara Coastal subbasins. The lowest values (< 6.5) were at stations in the Pajaro, San Francisco Coastal South, and the San Lorenzo-Soquel subbasins. The CCAMP Attention levels for pH follow the Basin Plan Objectives and give an acceptable range of 7 to 8.5. The mean values of approximately 13% of the Central Coast stations that were monitored pH fell outside of this range. Most areas that showed potential for problems relative to pH had stations that were frequently monitored from 2002 to 2007. Exceptions to this pattern include watersheds in the upper reaches of the Salinas watershed, where the main river stem measurements show relatively high pH levels, and the southern



Map 3.10 Number of pH measurements 2002-2007

upland areas of the Pajaro watershed.



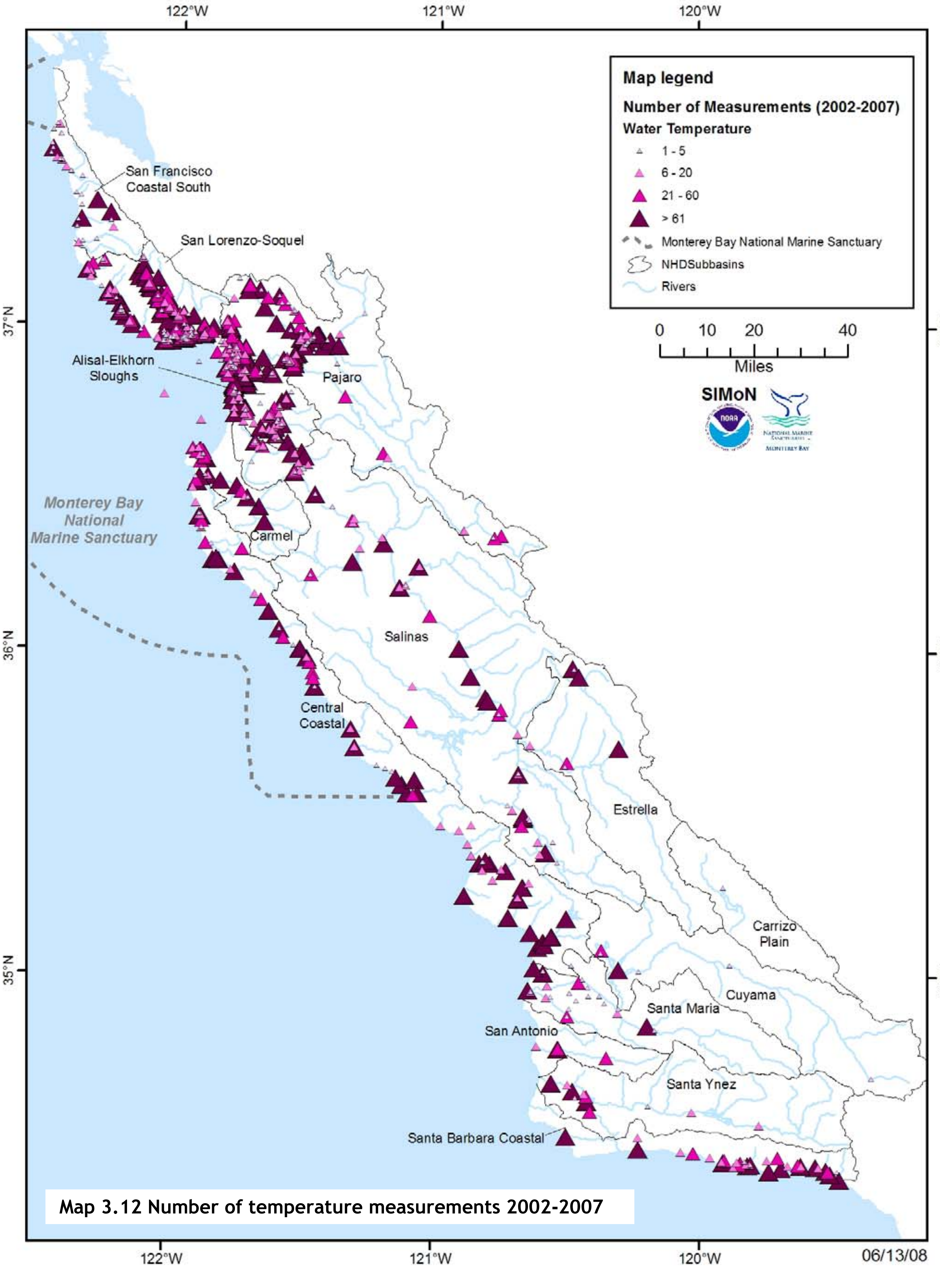
Map 3.11 Mean pH values 2002-2007 as quartiles

3.3.7 Temperature

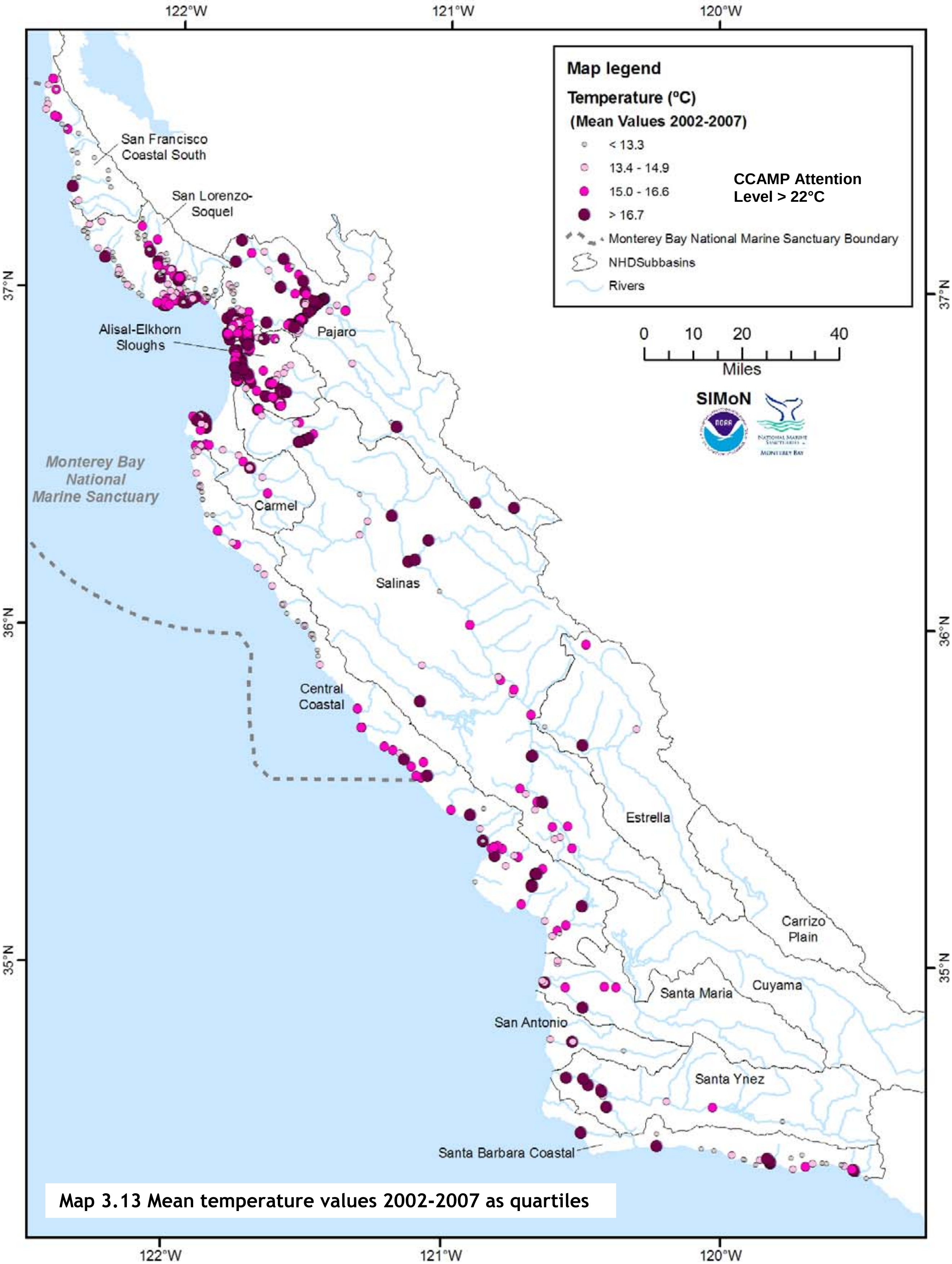
The number of temperature measurements for Central Coast stations is shown in map 3.12. More than 60 measurements occurred between 2002 and 2007 at stations in all Central Coast subbasins excluding the Carrizo Plain. The greatest spatial density of stations with a high number of measurements occurred in the lower Pajaro subbasin the Elkhorn Slough (Alisal-Elkhorn subbasin), and the San Lorenzo river valley (San Lorenzo-Soquel subbasin).

Map 3.13 shows the distribution of temperatures (°C) that were measured at Central Coast stations from 2002 to 2007. The CCAMP Attention Level for water temperature is 22°C and is based on the maximum tolerance for cold water fish. Approximately 1% of the Central Coast stations that monitored temperature had average values that were above the CCAMP Attention Level. These stations are located in the Alisal-Elkhorn, San Lorenzo-Soquel, Salinas, and Santa Barbara Coastal subbasins.

Very few locations on the Central Coast show problems relative to water temperature, but it is one of the most frequently measured parameters on the Central Coast. The measurement effort that has been applied can be justified in that it is one of the easiest measurements to make and it is required for understanding biological response to a number of other water quality constituents (e.g. ammonia).



Map 3.12 Number of temperature measurements 2002-2007



Map 3.13 Mean temperature values 2002-2007 as quartiles

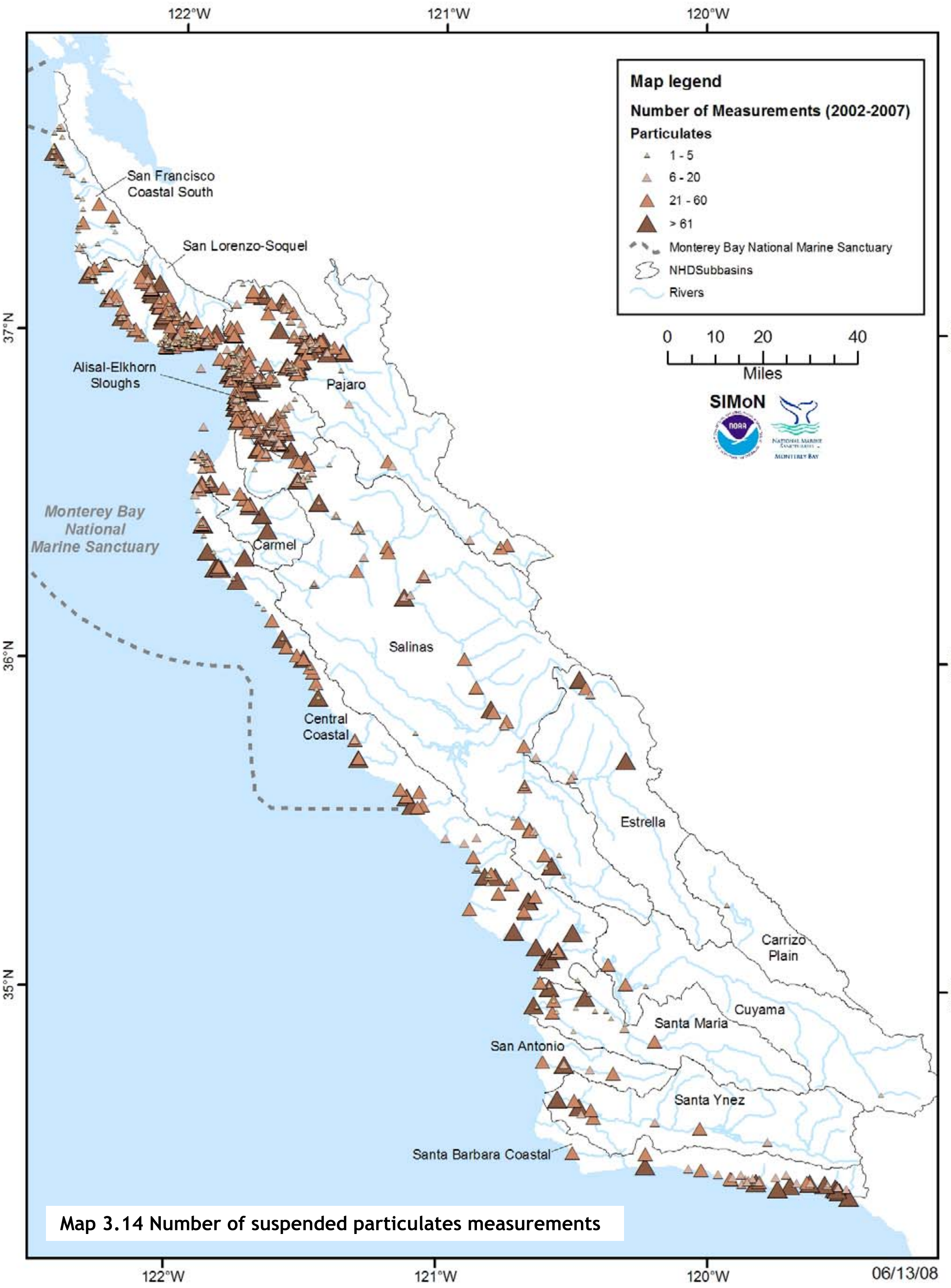
3.3.8 Total Suspended Solids

The number of measurements to quantify suspended particulates (total suspended solids, turbidity, etc.) that were taken at Central Coast stations from 2002 to 2007 is shown in map 3.14. There were more than 60 measurements at stations in all subbasins, excluding the Carrizo Plain and the Cuyama subbasins. Few stations in the Salinas subbasin had greater than 60 measurements.

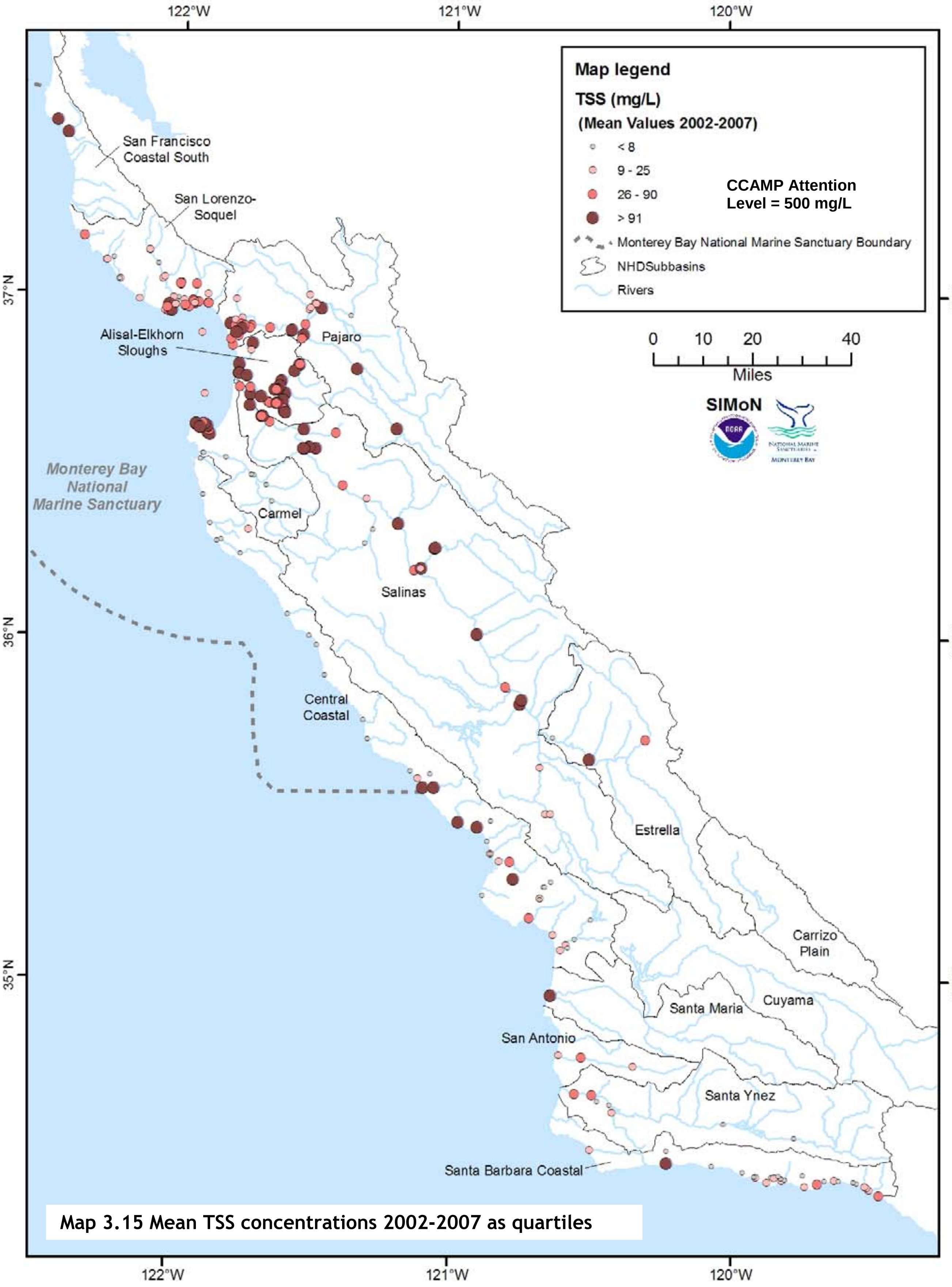
Map 3.15 shows that total suspended solids (TSS) average concentrations (mg/L) were above the third quartile (90 mg/L) most frequently at stations in the Salinas, Alisal-Elkhorn, Pajaro, Carmel, and southern Central Coastal subbasins. Note that many Central Coast stations had measurements of suspended particulates other than TSS, and are therefore not shown on map 3.15. The highest TSS concentrations were above 1,000 mg/L and were found in the Alisal-Elkhorn, Salinas, and Central Coastal subbasins. Some of the extremely high values were one time measurements that probably occurred during storm events. TSS concentrations were generally lowest along the northern portions of the San Lorenzo-Soquel and Central Coastal subbasins, as well as in the Santa Maria, upper Carmel, and Santa Barbara Coastal subbasins.

The CCAMP tentative Attention Level for TSS is 500 mg/L. Approximately 6% of the mean values of Central Coast stations that monitored TSS exceeded this threshold. These stations were located in the Alisal-Elkhorn, Salinas, Pajaro, and Central Coastal subbasins.

Most areas on the Central Coast with relatively high TSS concentration also had a relatively high number of measurements. Exceptions to this pattern included the northern portion of the San Francisco Coastal subbasin and upland watersheds of the Salinas subbasin. Maps 3.14 and 3.15 illustrate that there are stations with relatively high TSS concentrations along the main stem of the Salinas that may have important contributions of suspended solids from tributaries that are not frequently measured.



Map 3.14 Number of suspended particulates measurements



Map 3.15 Mean TSS concentrations 2002-2007 as quartiles

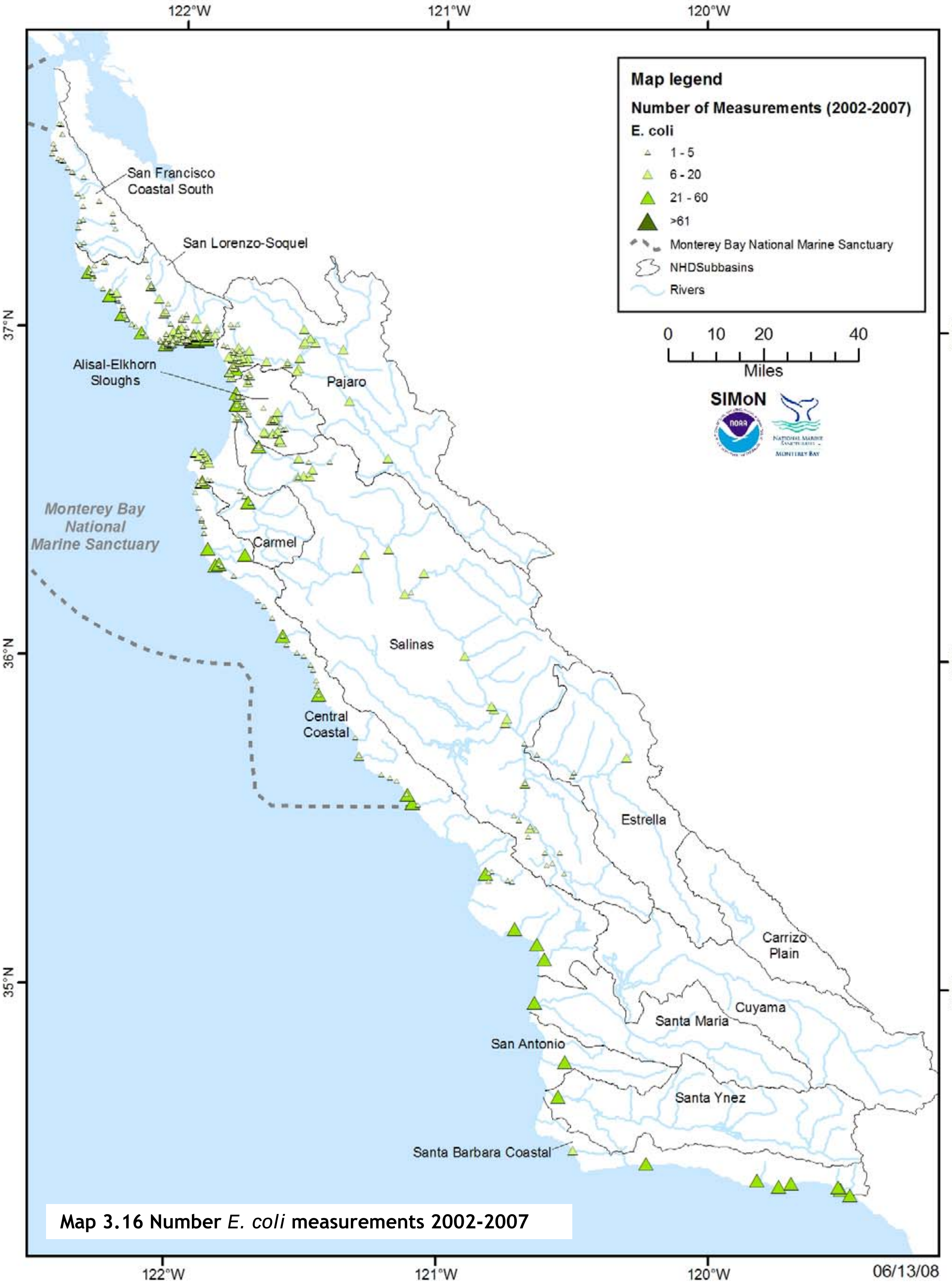
3.3.9 *E. coli*

The number of *E. coli* bacteria measurements collected at Central Coast stations for 2002-2007 are shown in Map 3.16. Stations with at least a single *E. coli* measurement were concentrated around the Monterey Bay in the San Lorenzo-Soquel, Pajaro, Alisal-Elkhorn, and Salinas subbasins. Stations with above 60 measurements were located in watersheds and shorelines around the Monterey Bay and along coastal areas of the Central Coastal, San Antonio, Santa Ynez, and Santa Barbara Coastal subbasins. There were relatively few *E. coli* measurements collected in most areas of the Salinas subbasin. In general, very few measurements were collected in upland watersheds far from the coastal watershed outlets.

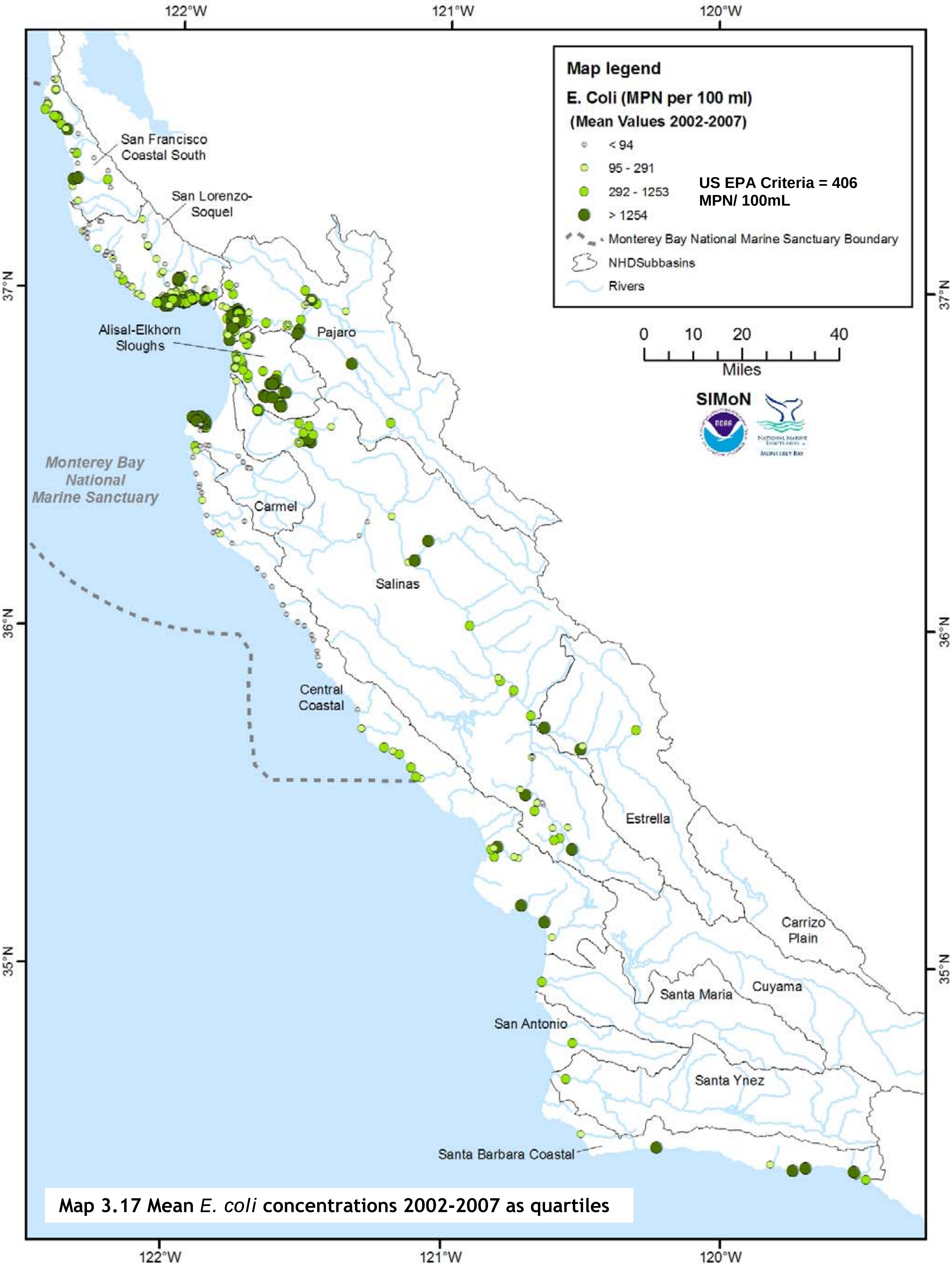
The *E. coli* mean concentrations (MPN/100 mL) were highest near Santa Cruz in the San Lorenzo-Soquel subbasin, in the lower portion of the Pajaro subbasin, and in urbanized areas of the Salinas and Alisal-Elkhorn subbasins (see Map 3.17). Concentrations were relatively low along the northern portion of the San Lorenzo-Soquel and Central Coastal subbasins. The highest *E. coli* levels were above 8,000 MPN/100 mL and were observed in the San Francisco South, San Lorenzo-Soquel, Carmel, Pajaro, Estrella, and Central Coastal subbasins.

The CCAMP Attention Level for *E. coli* is 126 MPN/100 mL as a 30 day geometric mean, which follows the U.S. EPA freshwater steady state objective. In this context, the U.S. EPA standard which specifies 406 MPN/100 mL as a single sample maximum for freshwater moderately or lightly used areas is more useful for comparison between stations. Forty-four percent of the Central Coast stations' mean values exceeded this objective. Most of the stations that exceeded the 406 MPN/100 mL criteria were located in the San Lorenzo-Soquel, Pajaro, Alisal-Elkhorn, Salinas, and Carmel subbasins.

From a comparison of maps 3.16 and 3.17 it is evident that most areas with high *E. coli* concentrations are located also areas where most samples are collected. However, large areas of the Salinas subbasin, the San Francisco Coastal south subbasin, and upland watersheds of the Pajaro subbasin have high mean *E. coli* concentrations relative to other areas and few measurements from 2002-2007. For some areas with fewer *E. coli* measurements, other bacterial pathogen indicators, such as fecal coliform, were measured more frequently.



Map 3.16 Number *E. coli* measurements 2002-2007



Map 3.17 Mean *E. coli* concentrations 2002-2007 as quartiles

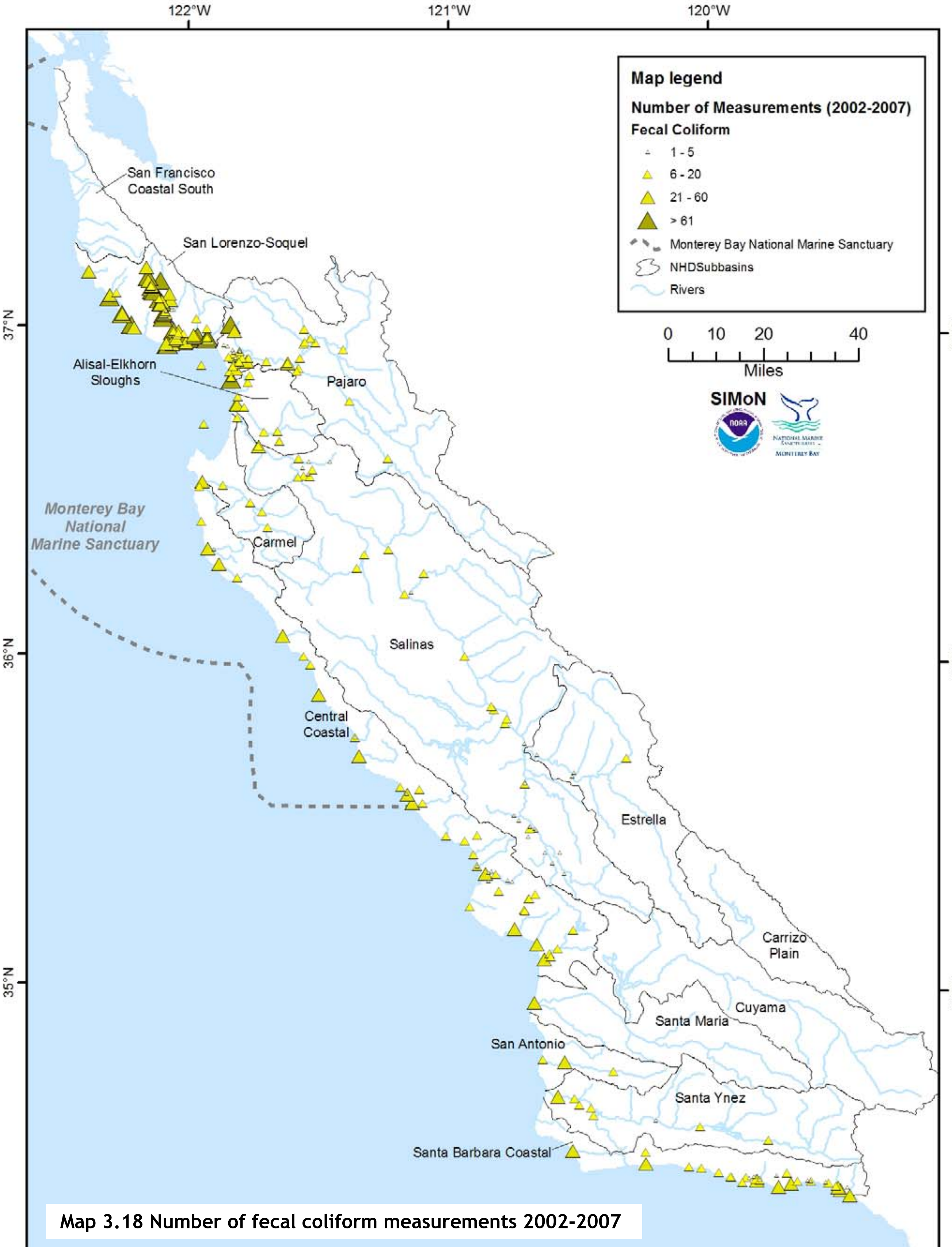
3.3.10 Fecal Coliform

The number of fecal coliform measurements at Central Coast stations from 2002 to 2007 is shown in Map 3.18. The greatest density of stations that measure fecal coliform is within the San Lorenzo-Soquel subbasin. Fifteen percent of the stations had greater than 60 measurements, nearly all of which were monitored by Santa Cruz County. The maximum number of measurements was above 300. There were more stations that sampled ocean water for fecal coliform compared to any of the other key parameters. There were relatively few measurements in the Salinas, Carmel, Central Coastal, Estrella, Santa Maria, Santa Marian, Santa Ynez, and Santa Barbara Coastal subbasins. There were not fecal coliform measurements collected for the San Francisco Coastal, Carrizo Plain, and Cuyama subbasins. Data for some of these areas may have been collected by county environmental health programs, but was not available and or accessible during the time of data compilation.

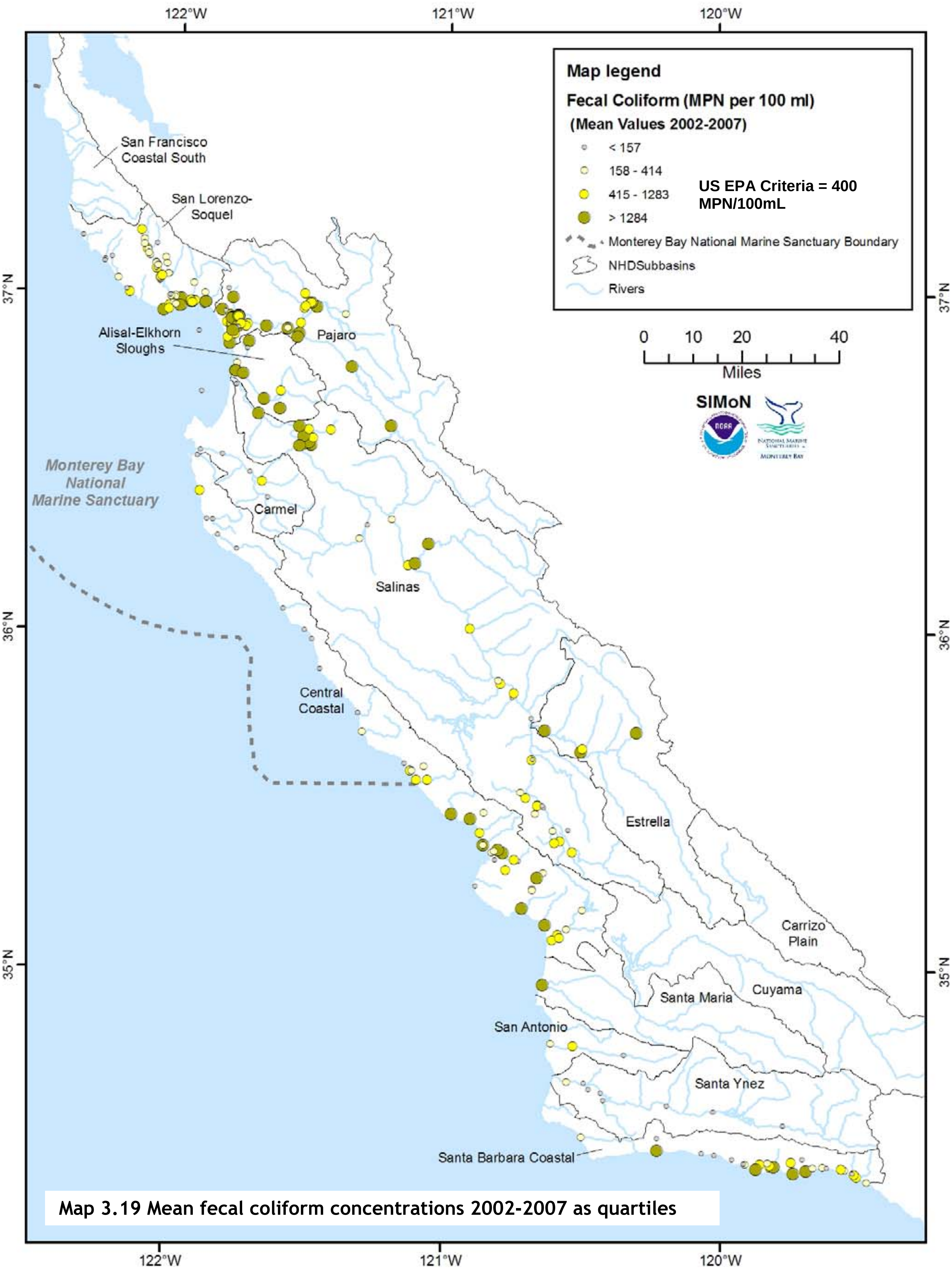
Map 3.19 shows that fecal coliform mean concentrations were highest in the San Lorenzo-Soquel, Pajaro, Alisal-Elkhorn, Salinas, Estrella, Central Coastal, Santa Maria, and Santa Barbara Coastal subbasins. The highest values were above 8,000 MPN/100mL and were observed in the San Lorenzo-Soquel and Pajaro subbasins. Stations with mean values above the third quartile value (1283 MPN/100 mL) are generally clustered near urbanized areas.

The CCAMP Attention Level for fecal coliform that is derived from the Basin Plan specifies that samples should not exceed 200 MPN/100 mL as a thirty day geometric mean. Given the variability in the number of sample from one station to another, a more convenient standard for comparison is the U.S. EPA criteria of 400 MPN/100 mL (10% of samples in 30 day period). Fifty-three percent of the Central Coast stations had mean levels of fecal coliform that were above this value. Stations' mean values were usually below this level in the Santa Maria subbasin, the Carmel subbasin, the northern portion of the Central Coastal subbasin and the northern coastal areas of the San Lorenzo-Soquel subbasin.

A comparison of Maps 3.18 and 3.19 shows that most areas with high mean fecal coliform concentrations have greater than 20 measurements for 2002-2007, but there are also areas with high concentration levels and relatively few measurements. Only two sites in the Salinas subbasin had more than 20 measurements. Three stations in the Estrella subbasin had mean concentration levels above 1000 MPN/100 mL and each station had 8 or fewer measurements available. For some areas with fewer fecal coliform measurements, other bacterial pathogen indicators were, such as *E. coli*, were measured more frequently.



Map 3.18 Number of fecal coliform measurements 2002-2007



Map 3.19 Mean fecal coliform concentrations 2002-2007 as quartiles

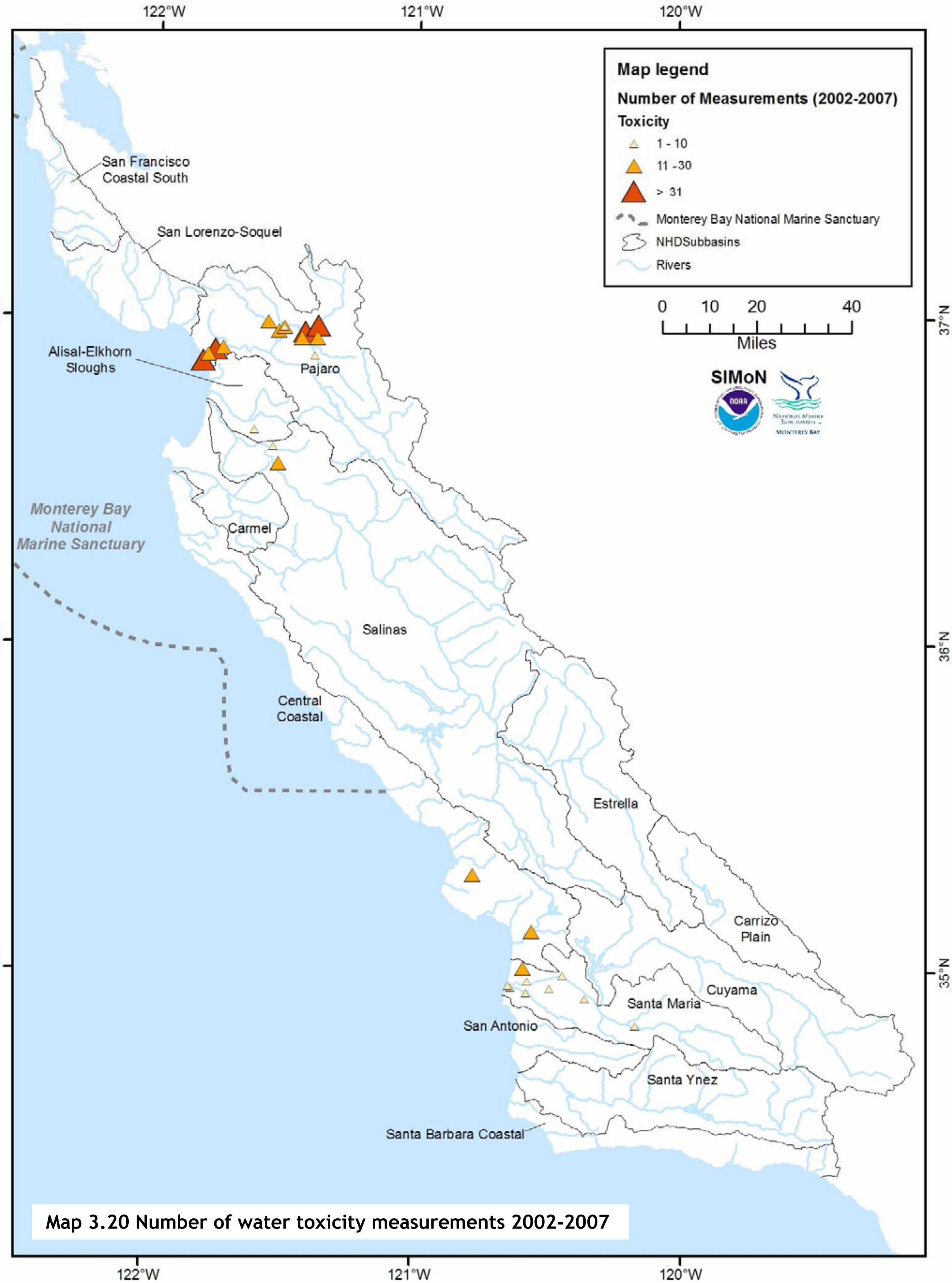
3.3.11 Water Toxicity

Toxicity is unlike any of the other key parameters discussed in that is an integrative measure of the health of waterways. Map 3.20 illustrates that toxicity testing is done at very few stations on the Central Coast. There have been water toxicity measurements from 2002 to 2007 in the Pajaro, Salinas, Central Coastal, and the Santa Maria subbasins. The toxicity measurements shown on map 3.21 map are for water toxicity to the species *Ceriodaphnia dubia*. The greatest number of measurements occurred in the Pajaro subbasin that had four sites with more than 30 toxicity tests. Toxicity measurements are by far the least abundant of the set of the key parameters considered in this report

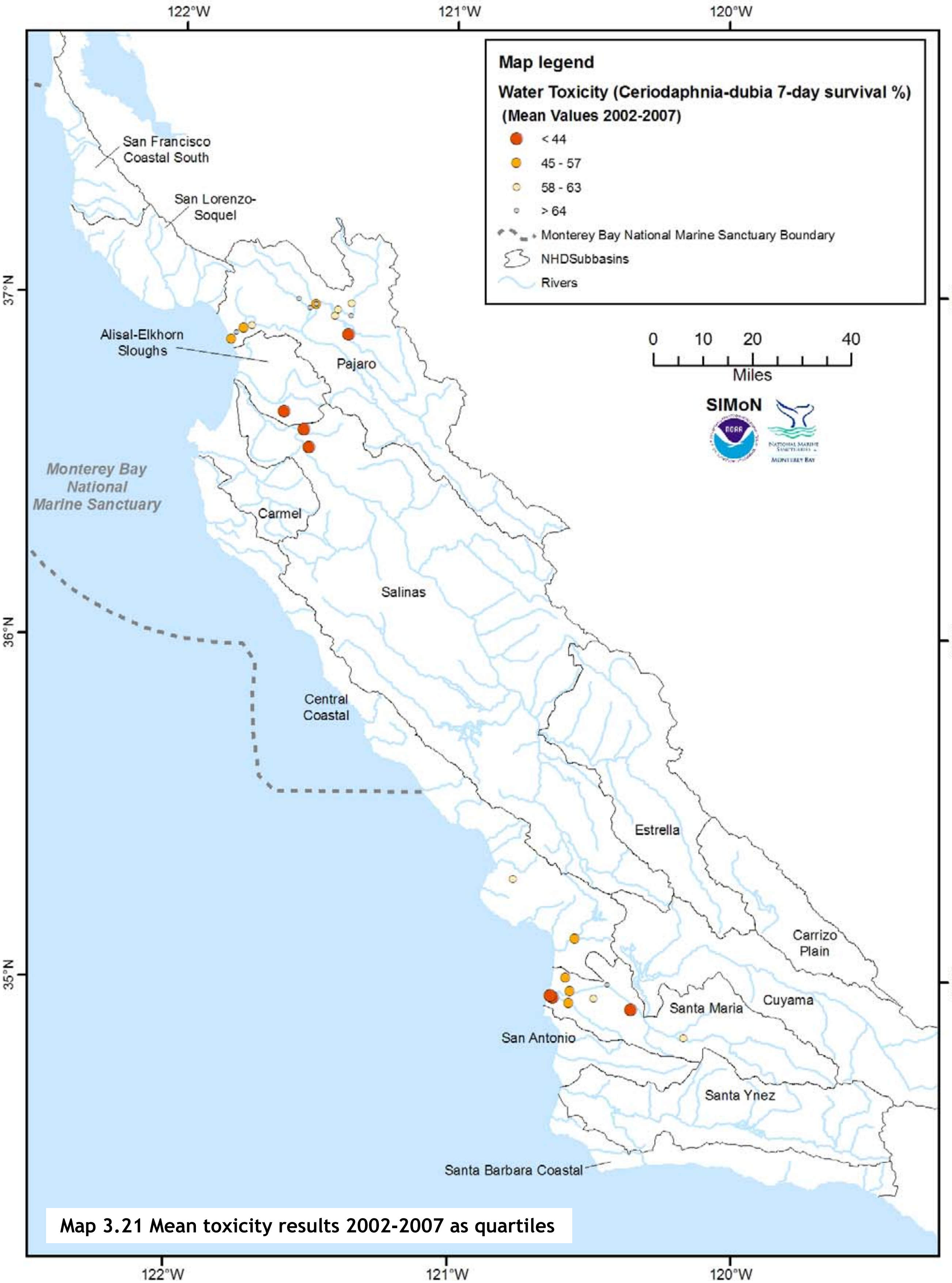
Map 3.21 represents mean toxicity levels at stations as percent survival of the test species, *Ceriodaphnia dubia*, so that lower percent survival indicates more toxic conditions. The values represented on map 3.21 do not take into account statistical significance of the test species survival rate relative to a control sample. Stations with the lowest percent survival were in the Alisal-Elkhorn, Pajaro, Salinas, and Santa Maria subbasins.

The Basin Plan criteria for water toxicity to *Ceriodaphnia dubia* is based on a test of significance of the percent survival between the sample and a control. This is a different metric than is shown in Map 3.21 which displays only the raw percent survival rate for the test species at each station. By an examination of the toxicity statistical tests it was found that 78% of the Central Coast stations that were tested for toxicity had at least one toxicity result that was significant when compared to a control. One station in the Pajaro subbasin had 24 significant results, and one in the Salinas subbasin had 26 significant toxicity results. These are not unexpected, since toxicity testing has largely been performed in areas where problems are known to exist, and many of the waterbodies have been placed on the State Water Board List of Impaired Waterbodies.

Toxicity is an integrative measure of waterway health. A large percentage of the sites that were sampled showed significantly toxic conditions. Although there is additional toxicity data based on sediments and tissue samples that were not included in this analysis, a review of these additional data supports the assessment that there is a lack of toxicity data at most Central Coast locations.



Map 3.20 Number of water toxicity measurements 2002-2007



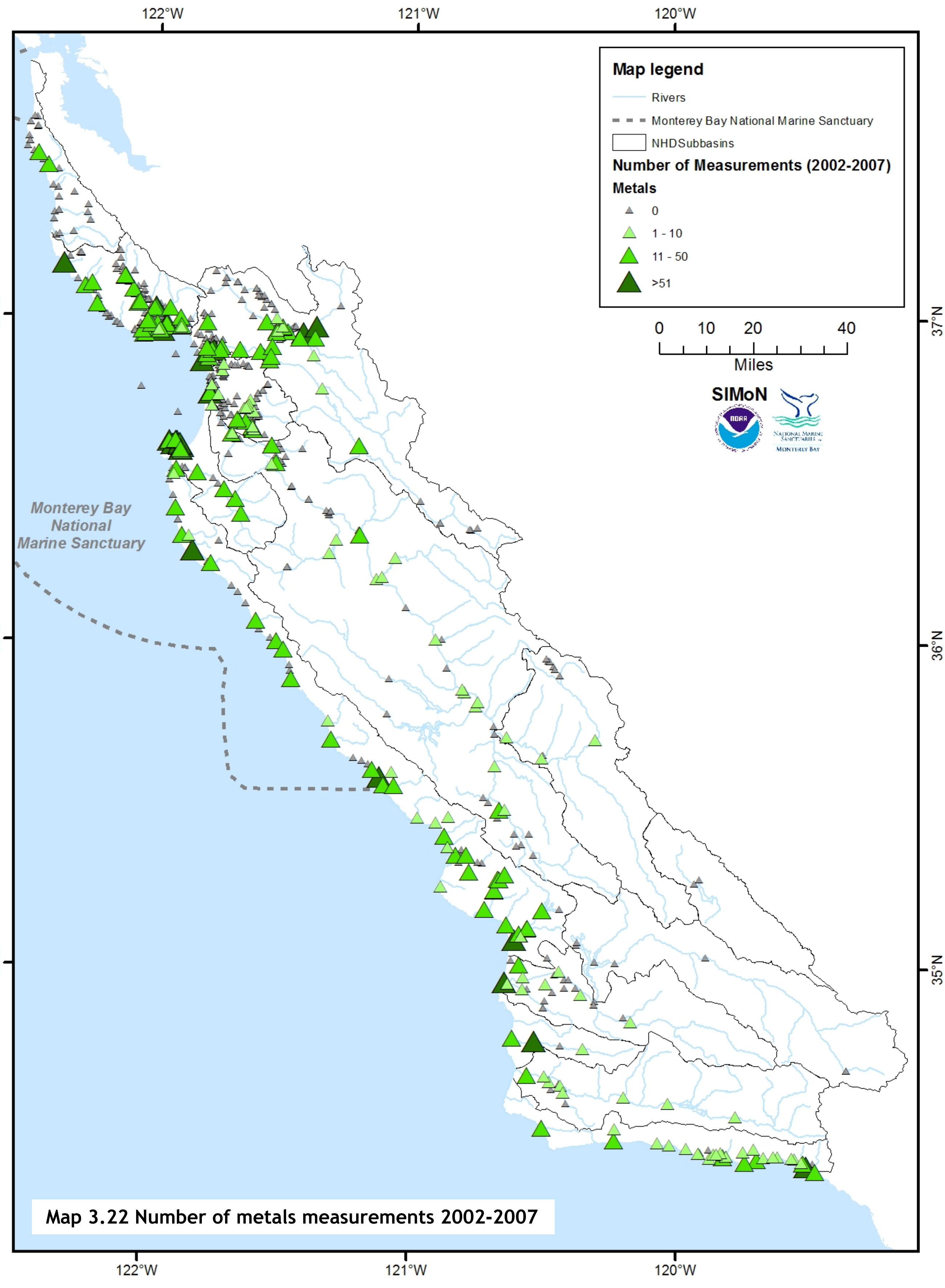
Map 3.21 Mean toxicity results 2002-2007 as quartiles

3.3.12 Metals

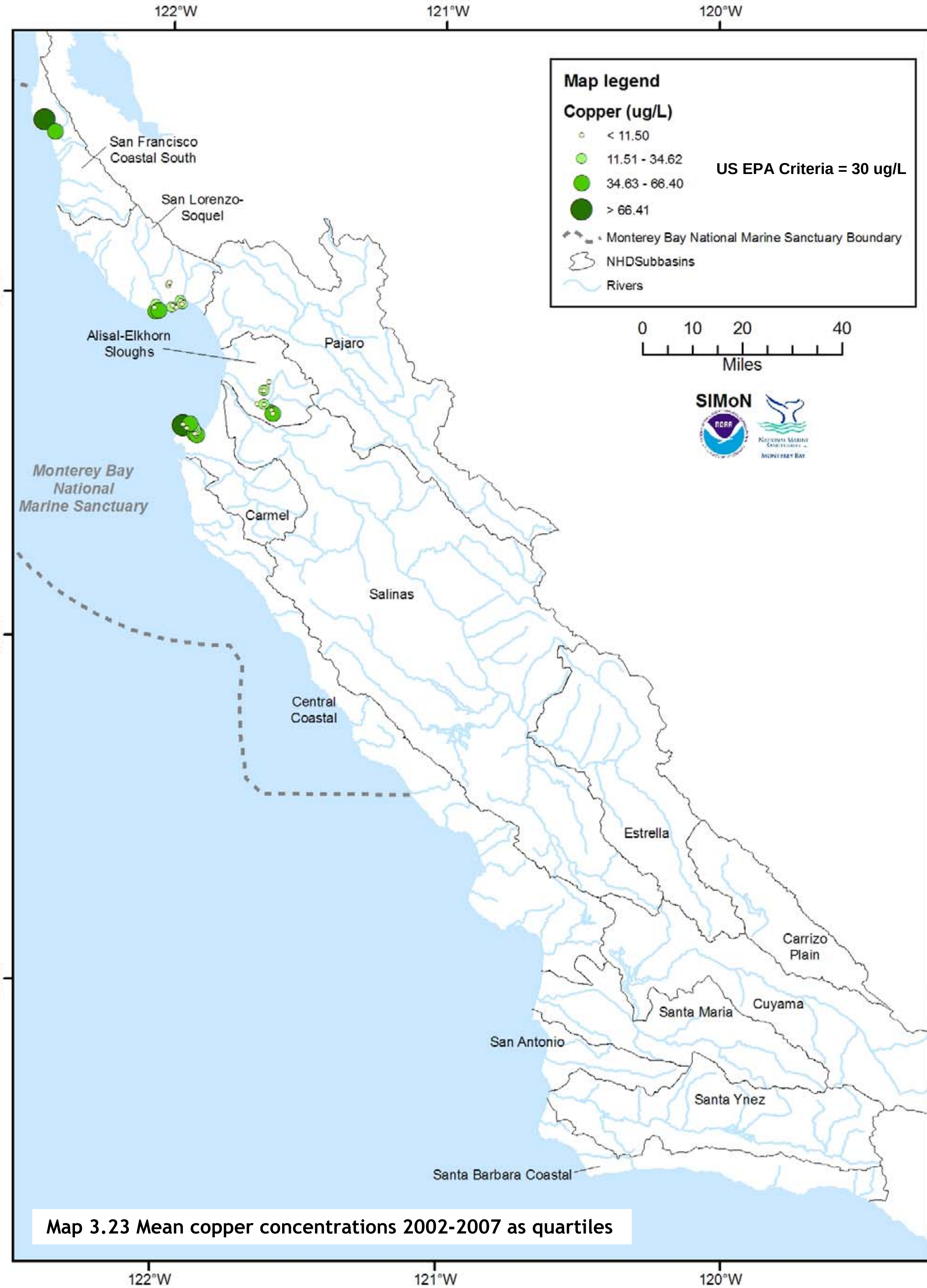
The metals measured on the Central Coast included copper, zinc, lead, and magnesium. The total number of measurements for all metals 2002-2007 for each location is shown on Map 3.22. The Magnesium and Boron were measured at the most stations, 188 and 161 locations, respectively. There were more than 60 measurements of metals at some stations in most of the Central Coast subbasins. The Carrizo Plain and Cuyama subbasins had no metals measurements recorded and the San Francisco Coastal South subbasin had very few measurements. The density of stations with a high number of metals measurements was greatest in the San Lorenzo-Soquel, Pajaro, Carmel, and Central Coastal subbasins.

Map 3.23 shows copper concentrations for Central Coast stations. The highest mean concentrations for 2002-2007 were found on the Monterey peninsula of the Carmel subbasin and in El Granada in the San Francisco Coastal South subbasin. These measurements were collected during first flush storm events at storm drain outfalls. The CCAMP Attention Level for copper is set according to the Basin Plan for cold water fish habitat at 30ug/L. Twenty percent of the Central Coast stations that measured copper had mean values that exceeded this comparison criteria which were located in urbanized areas of the the San Francisco Coastal South, San Lorenzo Soquel, Alisal-Elkhorn, and Carmel subbasins.

Metals have not been measured as often as many other water quality constituents on the Central Coast. Some of the copper measurements indicate that particular areas may be problematic and measurements should continue in those locations. Monitoring effort could be increased in areas like El Granada where there have been only 3 copper measurements, all of which are far above the CCAMP Attention Level.



Map 3.22 Number of metals measurements 2002-2007



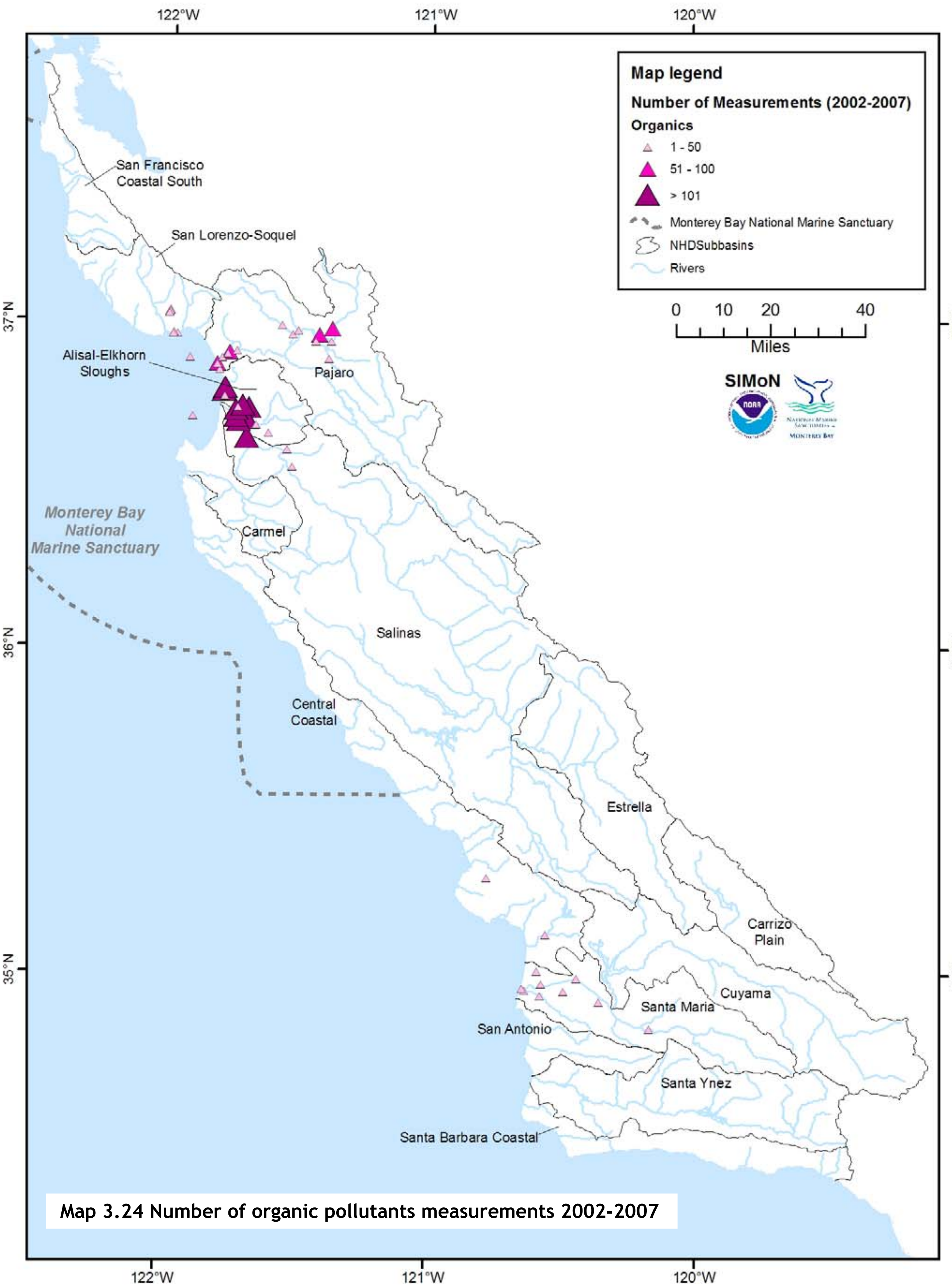
Map 3.23 Mean copper concentrations 2002-2007 as quartiles

3.3.13 Persistent Organic Pollutants (POPs)

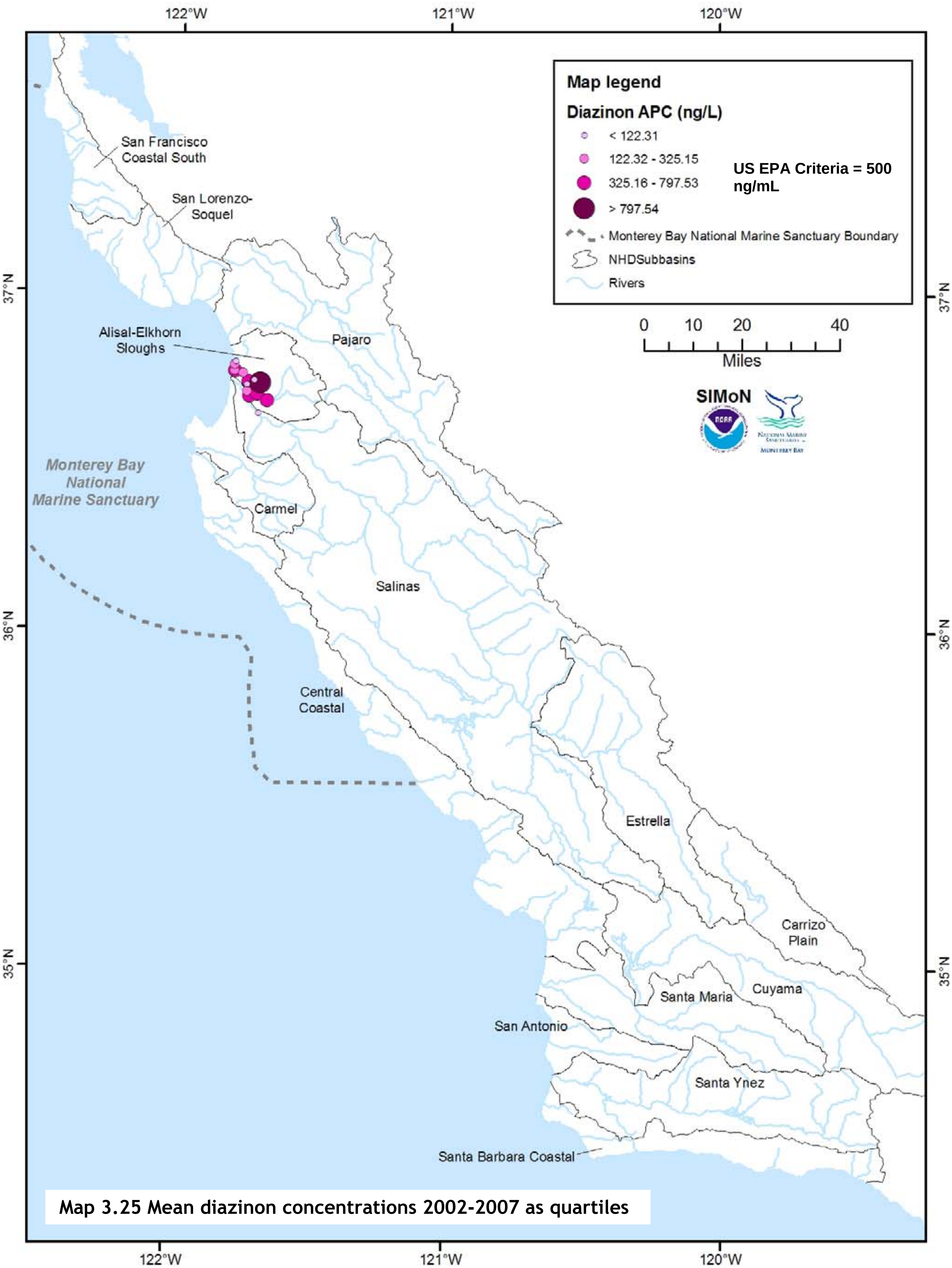
Persistent Organic Pollutants (POPs) are chemical substances that persist in the environment, bioaccumulate through the food web, and pose a risk of causing adverse effects to human health and the environment. Many POPs are currently or were in the past used as pesticides. Others are used in industrial processes and in the production of a range of goods. Though there are a few natural sources of POPs, most POPs are created by humans in industrial processes, either intentionally or as byproducts.

A suite of hundreds of different chemicals makes up the category of persistent organic pollutants (POPs) and includes groups of compounds such as petroleum hydrocarbons, chlorinated pesticides, organophosphates, and polychlorinated biphenyls. Map 3.24 shows the total number of times POPs were measured on the Central Coast. Measurements were made in the San Lorenzo-Soquel, Alisal-Elkhorn, Salinas, Central Coastal, and Santa Maria Watersheds. Most areas of the Central Coast do not have monitoring programs to measure POPs. The greatest number of measurements occurred in the Salinas and Alisal-Elkhorn subbasins. The samples that were collected in the Monterey Bay are made by active, high-volume passive sampling devices that are part of the CCLEAN program. Much of POP data that is collected is in the form of sediment and tissue analyses that were not included in this evaluation. The measurements that have been made in the water are, however, reflective of the locations and frequency of POP data collection on the Central Coast.

Diazinon is an organophosphate insecticide. As of December, 2004, it became unlawful to sell diazinon outdoor, non-agricultural products. It is still legal for consumers to use diazinon products purchased before this date. Map 3.25 shows diazinon measurements at Central Coast stations. Additional measurements taken at six of the CCLEAN sampling stations (included on map 3.24) were not available for mapping, but these measurements rarely showed diazinon concentrations above detectable levels and diazinon is no longer measured by the CCLEAN program. All of thefifteen stations that had diazinon measurements available were located in the Salinas and Alisal-Elkhorn subbasins (see map 3.25). Mean levels of diazinon exceeded the California Department of Fish and Game 4 day average criteria of 500 ng/L at 3 of these stations.



Map 3.24 Number of organic pollutants measurements 2002-2007



Map 3.25 Mean diazinon concentrations 2002-2007 as quartiles

3.3.14 Summary

The maps presented in Section 3.3 are a synthesized subset of recent water quality data collected on the Central Coast. The process of integrating the data and viewing it in a spatial context clarifies some important information gaps concerning the level of monitoring effort relative to the level of problems that exists for particular water quality parameters. This evaluation was made at a regional scale, and necessarily used large spatial groupings as the unit for comparison (subbasins). Other patterns may emerge when the data is examined over a smaller geographic extent.

The spatial patterns indicate that in general, the regional scale distribution of monitoring effort is commiserate with the water pollution problems that are known to exist. There are a number of subbasin scale exceptions that have been mentioned relative to each key parameter. For parameters such as ammonia, nitrate, orthophosphate, *E. coli,* fecal coliform and toxicity, a high proportion of the stations that monitored those constituents exceeded the CCAMP attention levels and other regulatory criteria. This supports the notion that there is a need for the relatively high level of monitoring effort that is expended in such areas. The fact that more monitoring stations are often located in areas where problems are know to exist is a factor in the high percentage of stations exceeding water quality objectives for some parameters. Allocating resources to areas that are likely to be problematic based on other knowledge is a sensible approach when monitoring resources are limited or a monitoring objective is to illuminate previously unknown water quality issues. A drawback to the type of targeted monitoring designs commonly employed by organizations on the Central Coast is that it does not lend itself to statistical inference about the water body conditions in the watershed as a whole beyond the monitoring stations themselves.

For the set of key parameters that were considered, a number of common spatial patterns emerged. As would be expected, many parameter measurements were concentrated near population centers and around the Monterey Bay. There were relatively few measurements in upland watersheds away from main river stems or watershed outlets. Other than bacteria and physical parameters, there are very few stations with regular measurements in the marine environment. In areas around the Monterey Bay, water quality stations are often located in very close proximity to one another. These stations are often monitored by more than one organization that may collect data on different parameters at different times.

Some of the data deficiencies that were observed are related to data access rather than data collection. For example, some data from cities and counties were not available in a digital format, and limited data processing resources resulted in the use of an incomplete data sets from the CCAMP and Ag Waiver Network programs that did not include the most recently collected data. Consequently, the data collected by these programs may be somewhat underrepresented in terms of the amount of data that has been collected. Funding shortages such as those experienced by the CCAMP program which resulted in a gap in sampling from 2003-2004 were also factors that contributed to data deficiencies.

The analysis presented in this chapter demonstrates how a regionally integrated database can be used to examine spatial patterns of the relative levels of water quality problems and monitoring effort on the Central Coast. It is important to note that the adequacy of monitoring effort cannot be judged in the absence of a monitoring objective. For example, some of the stations with relatively low sample counts may have adequate data to accomplish the objectives of the monitoring program. The next chapter evaluates the collective adequacy of currently available data based on its utility for answering a set of specific resource management questions.

4.0 DATA ASSESSMENT

This chapter is organized around five water quality management questions (listed in section 1.3) that are derived from the California Non-point source (NPS) pollution program objectives that are referenced in the CA NPS Five Year Implementation Plan (2003-2008)[5]. These questions have been used as metrics for assessing the utility of existing and accessible water quality data and other information. Each water quality management question is a separate section of the chapter and is addressed using the water quality data that were integrated from 14 monitoring programs on the Central Coast and other types of ancillary data that are compared to the water quality data. The types of ancillary data that were used (e.g. satellite derived land cover, survey results, and technical reports) and the methods of analysis are explained in the individual sections.

The data assessment questions are addressed using a mixture of original analysis of data and previously documented data analyses. Sections 4.1 and 4.2 address questions that relate to the application of regulatory criteria. The contents of these sections rely heavily on data analysis that has already been completed and published in technical reports. Sections 4.3, 4.4, and 4.5 contain original data analysis and the scope of the investigation was limited to the set of 10 key parameters that are listed in Chapter 3.

The questions used for the data assessment are broad in scope. The goals of this chapter are to demonstrate the level at which the data assessment questions can be addressed using a regionally integrated data set and resources that are readily available; and to indicate important information gaps that will be required to address these questions in a more complete and more conclusive manner in the future.

4.1 What is the Extent of Impaired, Threatened, and High Quality Water bodies on the Central Coast?

4.1.1 Water quality limited segments

Under Section 303(d) of the 1972 Clean Water Act, states are required to develop a list of water quality limited segments that do not meet water quality standards, which is commonly referred to as the 303d list. The law requires that the states establish priority rankings for water on the lists and develop action plans, called Total Maximum Daily Loads (TMDL), to improve water quality. The Regional Water Quality Control Boards (RWQCBs) are primarily responsible for developing the list, which is approved by both the State Water Resources Control Board (SWRCB) and the U.S. EPA.

[5] http://www.swrcb.ca.gov/nps/5yplan.html.

The 303d list is created using a ‘line of evidence approach’ that compares water quality measurements to numeric and narrative water quality standards that are specific to the beneficial use of water bodies. The RWQCBs are required to solicit all available data to make the determination of whether or not to list or to de-list a water body. Data of varying quality levels can be used provided the data are of sufficiently high quality to make determinations of water quality standards attainment.

4.1.2 Impaired and threatened water bodies on the Central Coast

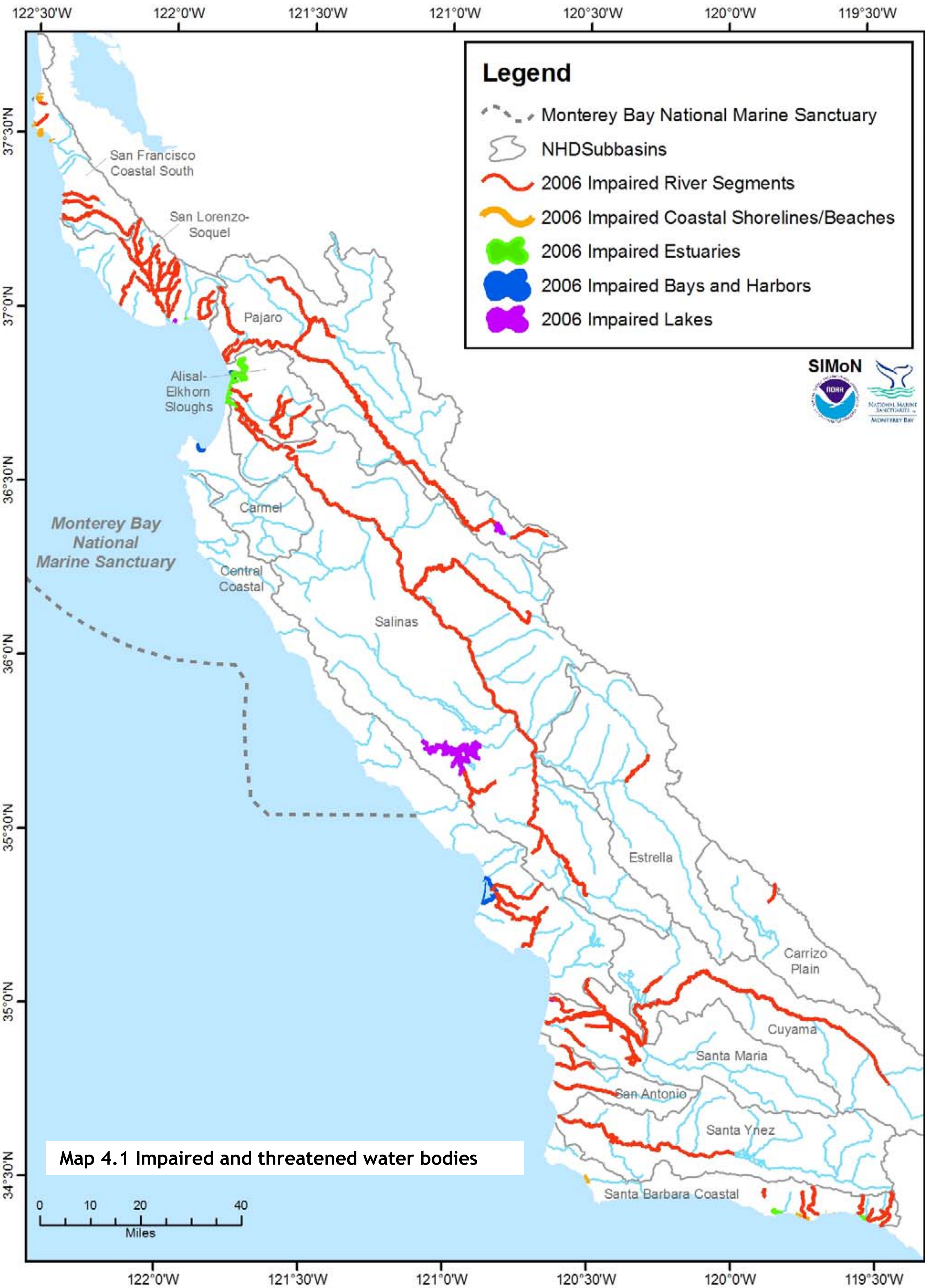
Impaired water bodies are water quality limited segments of surface waters that do not meet or are not expected to meet water quality standards. To date, a functional definition for threatened water bodies that would differentiate them from other water quality limited segments, such as impaired, has not been reported by the SWRCB. A new system of ‘Integrated Reporting’ is currently being implemented by the SWRCB that will offer two categorizations of 303d listed water bodies on the basis of whether or not a Total Maximum Daily Load (TMDL) is required (SWRCB, 2007). Such a categorization system may provide a regionally consistent way to judge severity of water quality limitation. Since this system is still in development, for the purposes of the following analysis, impaired and threatened water bodies are considered together and are also referred to as water quality limited segments or 303d listed water bodies.

The 2006 303d List of Water Quality Limited Segments was acquired from the SWRCB that had been approved on October 26, 2006 by the SWRCB. At the time the document was approved it had not yet received final approval from the U.S. EPA, so there may be minor differences between the data that were used in this report and the final U.S. EPA approved 303d List. A GIS layer for the draft 2006 303d list was created using an existing 2002 303d GIS layer and by comparing the 2002 and 2006 303d lists.

The National Hydrography Dataset (NHD) was used to create a new 303d GIS layer. The NHD is a comprehensive set of digital spatial data that contains information about surface water features such as lakes, ponds, streams, rivers, springs and wells. Within the NHD, surface water features are combined to form “reaches”, which provide the framework for linking water-related data to the NHD surface water drainage network. Reaches are represented as line segments whose length does not necessarily correspond to length of individual water bodies, or to the extent of the affected area specified on the 303d list. The water bodies that were not on the 2006 list were removed from a copy of the 2002 303d GIS layer. Water bodies were selected on the NHD layer if they matched the “Water body Name” field in the 2006 303dlist.

Map 4.1 shows threatened and impaired water quality limited segments for the Central Coast. The locations of water bodies were verified by making sure they were in the “CalWater Watershed” noted on the 2006 303d list. There were 18 new water bodies to include in the new GIS layer but 4 of those were not included in the NHD layer and therefore, were not added to the draft 2006 303d layer.

There are ninety-nine Central Coast water bodies included on the 2006 303d list, at least one of which occurred in all of the subbasins except for Carmel (see Map 4.1). The spatial extent and density (stream segments per watershed area) varies considerably from one subbasin to another. For example, In the San Lorenzo –Soquel subbasin, most of the tributaries to the San Lorenzo River are listed, covering nearly the entire watershed area (see map 4.1). In contrast water bodies in the Pajaro, Salinas, and Santa Maria and Cuyama subbasins are listed along nearly the entire length of the main river stems, with few tributaries listed. The spatial distribution of known impaired and threatened water bodies on the Central Coast is partially a function of the locations of water quality monitoring stations and partially a function of the water quality conditions in different areas of watersheds.



Map 4.1 Impaired and threatened water bodies

Rivers and streams make up the majority of water bodies that are listed on the 2006 303d, as shown in figure 4.1. The number of 303d listed water bodies shown in figure 4.1 does not take into account the affected length or area for each water body. Since water bodies are different sizes, the number of impaired water bodies does not necessarily reflect the relative level of problems in watersheds. The aerial or river length extent of impaired water bodies of different types for 2006 was as follows: bays and harbors made up 2077 acres; coastal shorelines, 0.66 miles; estuaries, 2818 acres; lakes and reservoirs, 6441 acres; rivers and streams, 1018 miles; and saline lakes, 2627 acres.

Determining the extent of impairment is accomplished by best professional judgment of the listing agency and the units of measurement are variable from one listing to another (e.g. length or area depending on water body type). The lack of a standardized system for evaluating the extent of impairment may make it difficult to compare the health of watersheds across the region or to evaluate change over time in a meaningful way.

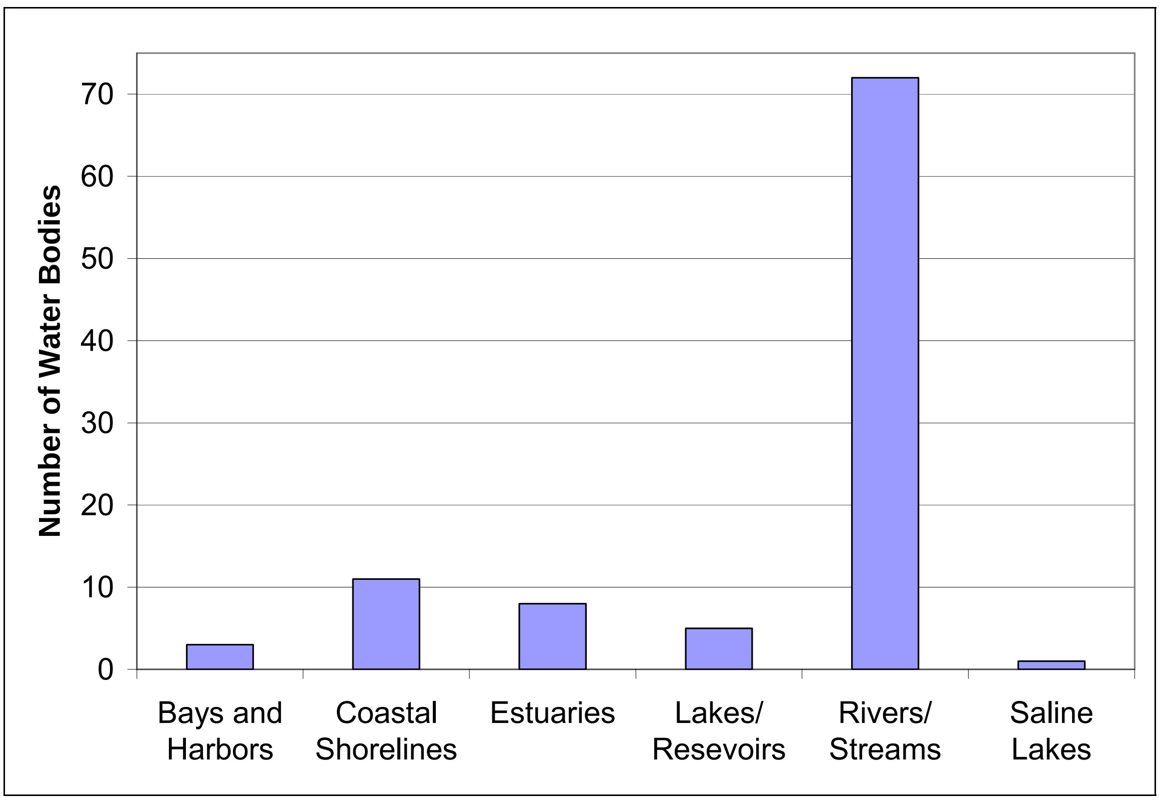


Figure 4.1 Number of different types of impaired or threatened water bodies.

4.1.3 High quality water bodies

A number of Central Coast water bodies may be relatively unaffected by pollutants and support designated beneficial uses. Water bodies that were not threatened or impaired are potentially high quality. Examination of map 4.1 revealed areas such as the San Francisco Coastal South subbasin, the Carmel subbasin; the northern portion Central Coastal subbasin; the Estrella subbasin; and the Carrizo Plain subbasin; upland watersheds of the Pajaro, Salinas, Santa Maria, and Santa Ynez; and the eastern portion of the Santa Barbara Coastal subbasin had relatively few impaired and threatened water bodies. This could either be because pollutant levels do not exceed regulatory standards, or because there is insufficient data in some of these locations to determine whether or not a water body should placed on the 303d list.

By comparing Map 4.1 to the maps of key parameter measurements that were presented in Chapter 3 (sections 3.1.2 – 3.3.12), it is possible to assess for which areas the available data are likely to support water bodies categorized as high quality. For the upland watersheds of the Santa Maria, Estrella, Pajaro, and Salinas subbasins, it appears that a lack of existing water quality data would make it difficult to determine their quality level based only on available water quality data. However, other knowledge about the geography and land-use activities in these areas could be used to inform such a determination. Other areas such as the San Francisco Coastal South subbasin, the Carmel subbasin; and the northern portion of the Central Coastal subbasin, have had substantial water quality data collected, which may support categorization of many of their water bodies as ‘high quality’.

4.2 What is the extent of impairments due to non-point sources compared to point sources?

In this section, the 2006 303d List of Water Quality Limited Segments is used as a basis for comparing point and non-point causes of impaired/threatened water bodies along with their associated sources. The term ‘cause’ is used to refer to the specific pollutant or pollutant category that resulted in a water body being placed on the 303d list, while the term ‘source’ refers to the activity or land-use that was identified during the listing process as being responsible for origination of the pollution problem. Both of these terms are used consistently with the meanings used in 303d reporting.

4.2.1 Point and non-point sources

Water pollution may result from point sources or diffuse (non-point) sources. Point sources can be related to a single outlet compared to non-point sources that may have outlets at many different locations spread over a large area. The distinction between the two is scale dependent since a diffuse source at the regional scale may result from a large number of individual point sources. An important difference between the two is that a point source that is identified can be collected, treated, or controlled. Major point sources include domestic wastewater and industrial wastes discharges. Most agricultural activities such as fertilizer or pesticide application are considered diffuse sources.

The Central Coast has fewer point source dischargers to waterways compared to some other areas of the California coast such as San Francisco Bay or the Southern California Bight. As authorized by the Clean Water Act, the National Pollutant Discharge Elimination System (NPDES) permit program controls water pollution by regulating point sources that discharge pollutants into waters of the United States. Central Coast point source dischargers are required to obtain a permit from the RWQCB. Table 4.1 lists permitted dischargers located on the Central Coast and primary effluents.

Table 4.1 Point source dischargers on the Central Coast

Point Source Discharger	**Primary Effluent**
RMC Lonestar	non-contact cooling water and storm water runoff
Pacific Mariculture, Inc.	aquaculture wastewater
Santa Cruz City DPW	treated sanitary wastewater
Watsonville City	treated sanitary wastewater
Moss Landing Power Plant	cooling water
Monterey Regional WPCA	treated sanitary wastewater
Hopkins Marine Station	marine lab waste seawater
Monterey Bay Aquarium	public aquarium waste seawater
Carmel Area Wastewater District	treated sanitary wastewater
Highlands Sanitary Association	treated sanitary wastewater
Highlands Inn Investors	treated sanitary wastewater
Ragged Point Inn	treated sanitary wastewater
San Simeon Community SD	treated sanitary wastewater
Abalone Farm Inc., The	aquaculture wastewater
Morro Bay & Cayucos SD	treated sanitary wastewater
Duke Energy	cooling water
Pacific Gas & Electric	cooling water
Avila Beach CSD	treated sanitary wastewater
South SLO Co. Sanitation District	treated sanitary wastewater
Tosco Corporation	refinery wastewater
Chevron U.S.A. Inc.	desalination brine
Cultured Abalone Inc.	aquaculture wastewater
Summerland Sanitary District	treated sanitary wastewater
Montecito Sanitary District	treated sanitary wastewater
Goleta Sanitary District	treated sanitary wastewater
Santa Barbara City DPW	treated sanitary wastewater
Carpinteria Sanitary District	treated sanitary wastewater

4.2.2 Causes of impairment and threat

Many of the 303d water bodies are listed for more than a single pollutant or pollutant category. The proportion of the total number of impaired and threatened water bodies on the Central Coast that are due to various pollutant categories are shown in figure 4.2. Bacterial pathogen indicators such as fecal coliform and total coliform bacteria are the most prevalent cause for water body impairment/threat. Nutrient problems such as ammonia, nitrate, and orthophosphate are the second most common; followed by pesticides such as chlophyrifos, DDT, and dieldrin; followed by sediments. The number of water bodies that are impaired/threatened due to metals, organic pollutants (other than pesticides), salinity, and toxicity are small in comparison.

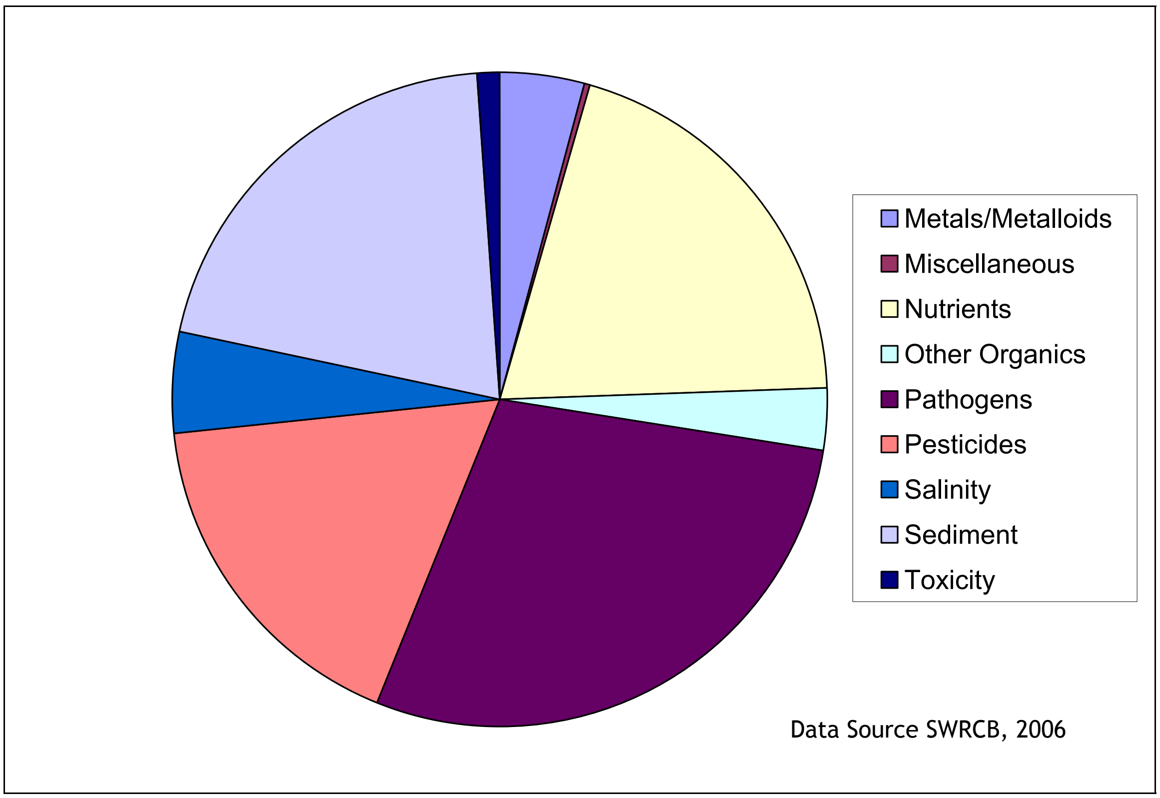


Figure 4.2 Causes of impairment and threat for Central Coast water bodies. The graph shows the number of water bodies listed due to each cause relative to the total number of 303d listed water bodies.

4.2.3 Sources of impairment and threat

Just as a water body may be impaired or threatened by a more than a single pollutant, pollutants may have more than a single source. The contributions of various sources to different pollutants that have been specified as causes on the 2006 303d list are shown in figure 4.3. Each pie chart represents the total number of water bodies that has been listed on the 2006 303d list due to a certain pollutant category, which is divided up into sections that show the proportion of the total that is due to a specific source.

The primary sources of impairment/threat that are due to nutrient problems are either unknown, which account for about half of the listed water bodies, or from agriculture. Other sources account for relatively small proportions of the number water bodies listed for nutrients (see figure 4.3). Pathogen sources are divided mostly between urban runoff, agriculture, unknown sources, and natural sources with some problems that are due to land disposal and marinas. Figure 4.3 shows that only two sources were identified for toxicity – three quarters were unknown and one quarter of the sources attributable to urban runoff. Impairment or threat of water bodies due to sediments derived primarily from habitat modification, agriculture, land development, and silviculture. Agriculture and unknown sources account for the largest proportions of salinity sources, with smaller contributions from urban runoff and natural sources. Resource extraction and unknown sources represent the majority of sources for metals, along with natural sources. Agriculture was cited as the source for about two-thirds of 303d listed water bodies that had pesticides and organic pollutants specified as the cause for water quality limitation.

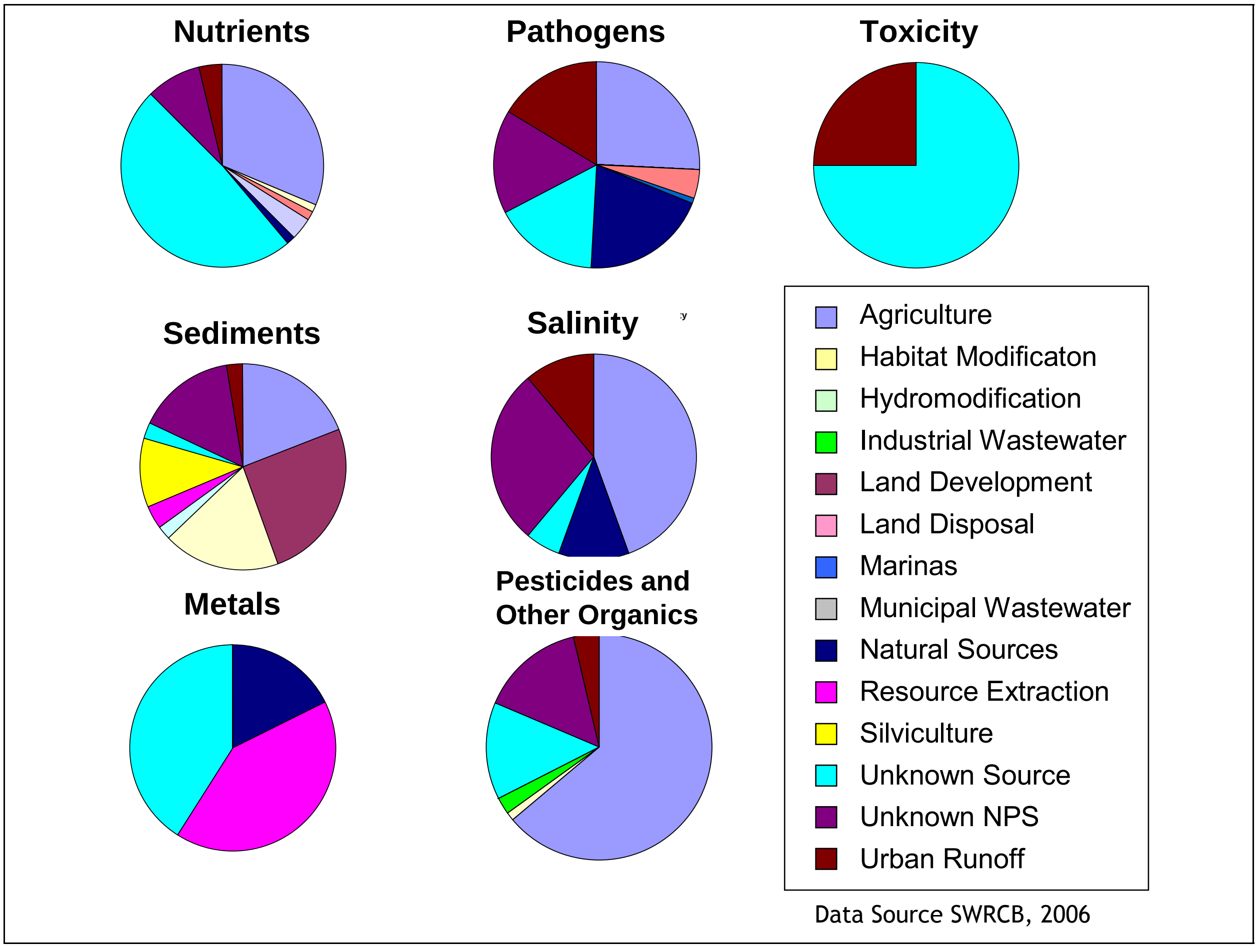


Figure 4.3 Sources of water body impairment and threat divided by pollutant category.

4.2.4 Comparison of point source and non-point sources

The pollutant sources cited for 303d listing can be categorized into point and non-point (diffuse). Pollution problems originating from point sources are due to nutrients, pesticides and other organics, and salinity which derive from agriculture and municipal runoff sources. Figure 4.4 illustrates that the vast majority of pollution sources causing water quality limitation are due to non-point sources. According to the 2006 303d list, only four water bodies on the Central Coast are impaired/threatened by pollutants that can be identified as originating from a point source, each of which also has non-point sources that contribute to their water quality limitation. Sources that were specified as unknown were categorized as non-point sources in figure 4.4, although there may be unidentified point sources that contribute to the pollution problems for some of these water bodies.

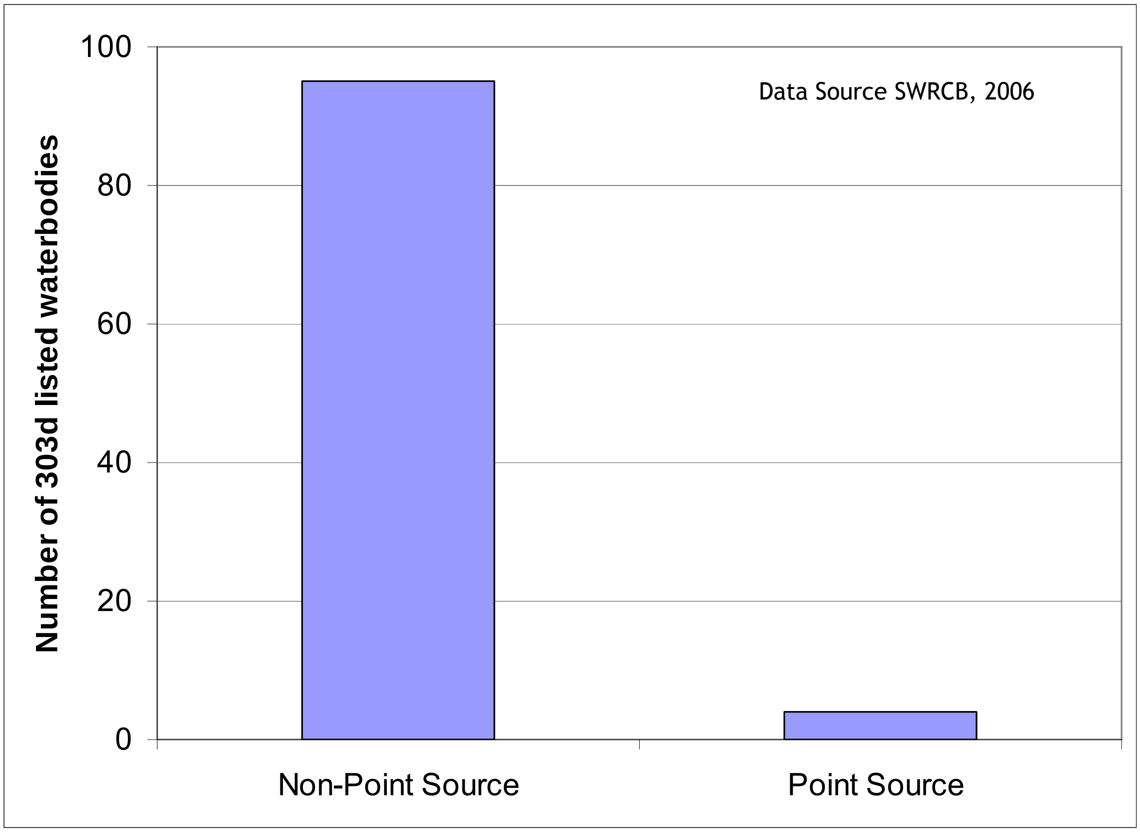


Figure 4.4 Comparison of sources attributable to point sources and non-point sources

Based on the 2006 303d list that was compiled by the SWRCB, most of the water quality problems on the Central Coast are due to non-point sources. Most of the non-point sources causing water body limitation are listed as 'unknown'. Agriculture is the second most prevalent source that was cited, contributing to substantial water quality limitations that are due to nutrients, pathogens, sediments, salinity, pesticides and other organics. Urban runoff is specified as a source for many of the water bodies that are listed due to pathogens, toxicity, and salinity, and relatively few of the water bodies that were listed for nutrients, sediments, and organics (see figure 4.3).

4.3 What are the relationships between land-use and ambient water quality conditions?

4.3.1 Land-use and water quality

Water pollution can result from human activities that alter the natural land surface cover. Central Coast watersheds support a diversity of land cover/land-use types including natural landscapes such as forests, low lying shrublands, grasslands, and rangelands; urban development of various levels of intensity; low lying wetlands; and cultivation in irrigated crops, vineyards, orchards, and greenhouses. For simplicity the term land-use will be used to refer to both modified and natural land cover types. Although changes in land-use within a watershed are generally expected to cause changes in water quality, the effects are likely to be non-uniform across land-use types and interrelated with one another. Understanding relationships between land-use and water quality variables is necessary if land-use data are to be used to predict stream ecosystem conditions, predict pollutant loads, or to inform the design of water quality monitoring programs.

On the Central Coast, studies have qualitatively linked water quality conditions to upstream patterns of land-use or anthropogenic activities within a watershed. For example, Anderson et al. (2003) found that the primary source of high nutrient concentrations was irrigated agriculture. Studies by Hunt et al. (1999), Kolowski et al. (2004), Anderson et al. (2006), and Anderson et al. (2003) found high pesticide concentrations and/or acutely toxic conditions downstream of irrigated agricultural areas in Central Coast watersheds. In other regions, patterns or changes in land-use have been quantitatively linked to in-stream water quality variables such as physical parameters (Banks and Wachal, 2007; Hamill and McBride, 2003); nutrients (Ahearn et al., 2005; Hamill and McBride, 2003; King et al., 2005); pesticides (Banks and Wachal, 2007) and sediments (Hamill and McBride, 2003; Ahearn et al., 2005).
Although qualitative relationships are apparent on the Central Coast, statistically significant quantitative relationships can be more difficult to demonstrate due to the scale dependent, non-linear nature of the land-use – water quality relationship (e.g. Banks and Wachal, 2007).

4.3.2 Water quality data

Water quality data were extracted from the SAMdb for comparison with land cover variables. The selection criteria represented a compromise between eliminating stations without adequate data for a common set of parameters and making sure that there was sufficient geographic coverage to represent various land-use types on the Central Coast. Water quality stations were selected that had at least 9 measurements over the period 1998-2007 for a subset of six of the ten key parameters that were listed in Chapter 3. The parameters used were total ammonia (NH_3 + NH_4 as N), nitrate (NO_3 as N), orthophosphate (PO_4 as P), pH, total suspended solids (TSS), fecal coliform, and pH. There were 94 stations from the SAMdb that met these criteria, which were all sampled by the CCAMP program (see map 4.2).

Since the water quality stations that were used were not based on a probabilistic design, inferences cannot be drawn from the results of this analysis to the larger population of watersheds on the Central Coast. However, the stations that were used capture the watershed drainage area of most of the Central Coast region and include watersheds with a diverse mix of land-use proportionality, size, location, elevation, rainfall, vegetation, and soils.

The data were extracted from the SAMdb and non-detect values were censored to one-half the value of the highest detection limit used for each parameter. The mean value for the time period 1998-2007 was calculated to represent the water quality condition at each station. The data sets exhibited a positive skewness due to the high number of measurements that were at or near the detection limit for some stations. Such non-normality can be problematic when using parametric methods for comparing water quality to land-use patterns (Banks and Wachal, 2007). To normalize the water quality variables, a log transformation was applied. The resulting values for the water quality variables for the 94 stations are listed in Appendix 2.

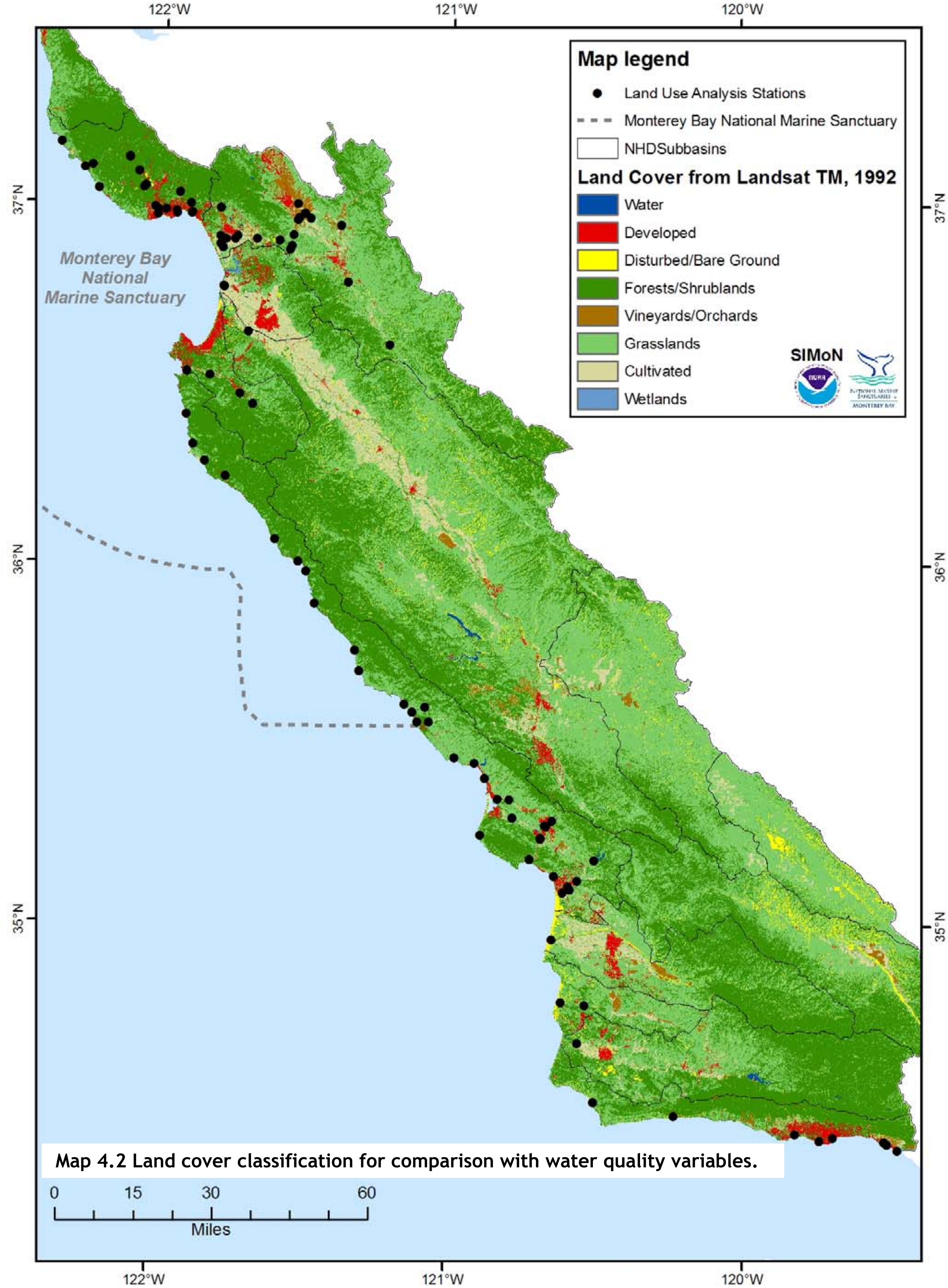
4.3.3 Land-use data

The contributing watershed area draining to each station was calculated using the National Hydrography Dataset (NHD) in a GIS. For each of these areas, the percent land-use was calculated from the NHD land cover data layer that is based on the National Land Cover Dataset (NLCD, 1992)[6]. The NLCD land cover classes that occurred within the study area were aggregated into six categories and percentages for each of these categories were calculated for contributing watershed areas for comparison with water quality data. The categorization of each land-use is listed in table 4.2. The NLCD layer was reclassified into seven land-use categories. The land-use categories along with each of the water quality stations that were used for the analysis are shown in map 4.2. The percentage of each land-use class within each station's contributing watershed area was used for comparison with water quality variables.

[6] http://www.mrlc.gov/index.asp

Table 4.2 Land-use categories that were created from the 1992 NLCD

1992 NLCD Class	Land Use Category
Low Intensity Residential	Developed
High Intensity Residential	Developed
Commercial/Industrial/Transportation	Developed
Urban/Recreational Grasses	Developed
Bare Rock/Sand/Clay	Bare/transitional
Quarries/Strip Mines/Gravel Pits	Bare/transitional
Transitional	Bare/transitional
Deciduous Forest	Forest/Shrub
Evergreen Forest	Forest/Shrub
Mixed Forest	Forest/Shrub
Shrubland	Forest/Shrub
Grasslands/Herbaceous	Grasslands
Pasture/Hay	Grasslands
Orchards/Vineyards	Orchards/Vineyards
Row Crops	Cultivated
Small Grains	Cultivated
Fallow	Cultivated
Woody Wetlands	Wetlands
Emergent Herbaceous Wetlands	Wetlands



Map 4.2 Land cover classification for comparison with water quality variables.

Relationships Between Land-use and Water Quality

Regression and correlation analysis are methods commonly used for comparing land-use to water quality. Land-use category percentages within a watershed are often not independent because increasing the proportional area of one requires decreasing the proportion of another land-use category (Van Sickle, 2003). A significant relationship between a response variable and a land-use variable may be accompanied by significant relationships with one or more land-use variables (King et al., 2005). Covariation of within-watershed land-use category percentages has been shown to affect relationships with water quality variables, and in some cases to reverse the direction of a correlation (King et al., 2005).

4.3.4.1 Land-use correlations analysis

A Pearson product moment correlations matrix that was calculated for the land-use categories (N=94, table 4.3) reveals that some of the land-use category percentages are not independent. All of the land-use percentage pairs that show the strongest association ($r = -0.36$ to -0.84, $p < 0.01$) covary negatively with one another, while positive correlations were less strong ($r = 0.20$ to 0.25, $p < 0.05$) but still significant. To account for the observed covariation of land-use category percentages, a partial correlations analysis was applied when testing relationships with the water quality variables.

Table 4.3 Pearson product moment correlation matrix for land-use category percentages. (* p = 0.001, ** p = 0.01, *p = 0.05)**

	Develpd	Bare/trns	For/shrb	Grasslnd	Cult	Wetlnd	Orch/Vin
Develpd	--						
Bare/trns	0.04	--					
For/ Shrb	-0.36***	-0.32**	--				
Grsslnd	-0.13	0.25*	-0.84***	--			
Cult	0.08	0.20*	-0.32**	0.23*	--		
Wetlnd	0.02	0.13	-0.19	0.19	0.11	--	
Orch/Vin	0.10	0.02	-0.30**	0.07	-0.07	0.16	--

4.3.4.2 Partial correlations analysis results

Consideration of land-use and water quality variables two at a time requires removing the effects of the other variables that are not of interest. Partial correlation analysis solves this problem, because it enables comparison of variables two at a time while holding the others constant. To test the partial correlation between two variables *i* and *k*, holding two other variables *l* and *p* constant, we can use the null hypothesis H_0: $\rho_{lq} = 0$, we can use:

$$t = \frac{\rho_{ik\ldots}}{s_{r_{ik\ldots}}},$$

where ρ_{ik} is the partial correlation between *i* and *k*,

$$s_{r_{ik\ldots}} = \sqrt{\frac{1 - r_{ik\ldots}^2}{n - M}}$$

n is the number of samples, and *M* is the total number of variables in the multiple correlation (Zar, 1984).

The test results would be identical to employing a regression technique and using a ‘partial F statistic’, since stepwise multiple-regression isolates the residual effect of each predictor variable in the same way. The partial correlations approach has the advantage that it does not obscure the fact that similar results could be obtained with competing land-use categories that may be excluded by the stepwise procedure in an effort to specify a ‘best’ model (King, et al., 2005).

The partial correlations approach was implemented using the SAS statistical software package. Partial correlations (denoted as ρ) were calculated for each of the land-use category percentages – water quality parameter pair and are given in table 4.4. Scatter plots for variable pairs that had significant partial correlations are shown in Appendix 3.
Nitrate had a significant negative correlation with forest/shrubs (ρ = -0.49) and positive correlations with cultivated areas (ρ = 0.28), orchards/vineyards (ρ = 0.36), and bare/transitional land-uses (ρ = 0.26). Ammonia had significant negative relationships with forest/shrubs (ρ =-0.29) and grasslands (ρ = -0.48); and significant positive relationships with the developed (ρ = 0.31), bare/transitional (ρ = 0.21), and orchards/vineyards (ρ = 0.21). Total Suspended Solids (TSS) was positively correlated with bare/transitional (ρ = 0.29) and with the cultivated (ρ = 0.33) land-use category. Ph was negatively related to the developed land-use category (ρ = -0.37) and positively related to grasslands (ρ= 0.31). Fecal coliform and orthophosphate had no significant relationships with any particular land-use category.

Table 4.4 Partial correlations between land-use category percentages and selected key water quality parameters (* p ≤ 0.001, ** p ≤ 0.01, * p ≤ 0.05)**

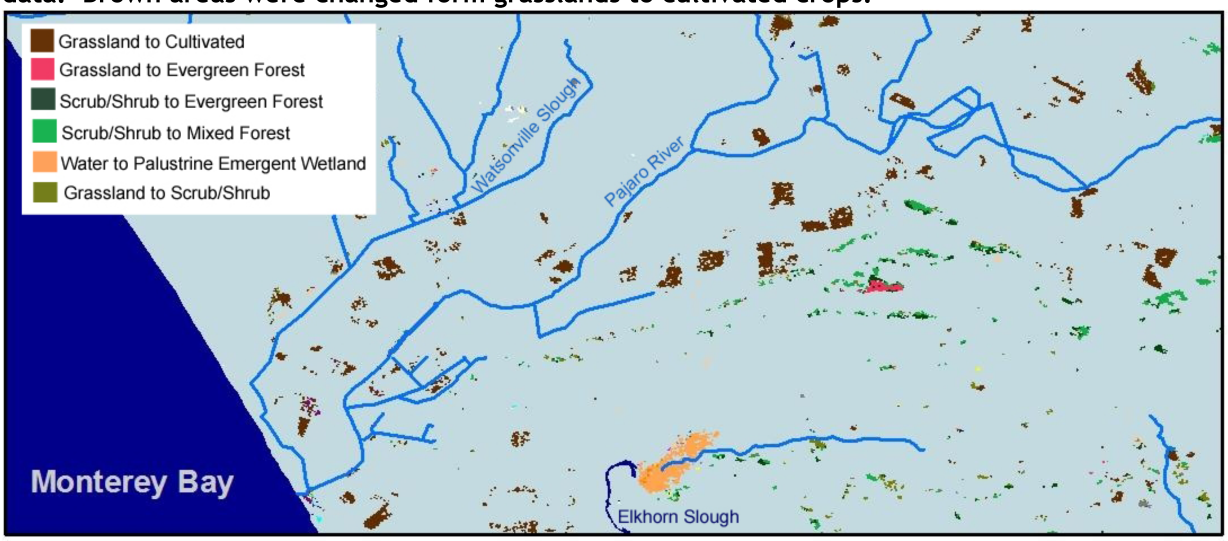
	Nitrate	Ammonia	TSS	Fecal Col	OrthoP	pH
Developed	-0.03	0.31**	-0.03	0.15	0.17	-0.37***
Bare/trans	0.26*	0.21*	0.29**	0.19	0.17	0.16
Forest/Shrubs	-0.49***	-0.26**	-0.19	-0.18	0.06	0.10
Cultivated	0.28**	0.13	0.33**	-0.03	0.05	0.22
Grasslands	-0.27	-0.48***	-0.17	-0.20	-0.16	0.31***
Wetlands	0.10	0.07	0.11	0.19	0.12	-0.01
Orch/Vinyard	0.36***	0.21*	0.11	0.10	-0.13	-0.06

4.3.5 Discussion and limitations

The results in table 4.4 demonstrate that land-use can be quantitatively associated with water quality parameter measurements in some cases. The strongest relationships that were identified were negative correlations between grasslands and woodlands and either nitrate or ammonia, which indicates that a high proportion of a natural land-uses is associated with lower nutrient concentrations in a watershed. The positive association between nitrate and both cultivated and orchards/vineyards land-use corresponds with the conclusions of Andersen et al. (2003) who found that high nutrient concentrations occurred where crops were irrigated upstream. However, Andersen et al. (2003) identified associations between irrigated crops and nitrate, ammonia, and orthophosphate; while this analysis only revealed significant correlations between irrigated land-uses and nitrate. The results shown in table 4.4 also indicate that developed areas may be an important source for ammonia. The lack of correlations between fecal coliform and land-use concurs with the results of Hager et al. (2004) who found that no single land-use could be identified as the source of pathogens in the Watsonville Sloughs.

All of the correlations that were identified can be described as either weak or moderate. The plots in Appendix 3 demonstrate that in most cases very little of the variance in the water quality variables is explained by associations with land-use category percentages. The unexplained variance is probably due to a number of factors including the errors in the land-use data set, the influence of climatic variability, and differences in spatial and temporal land-use patterns within watersheds. The 1992 land cover dataset contained in the NHD was used primarily because it was a very time efficient way of extracting the land-use data for the various watersheds. If land-use conditions changed in the years between land cover mapping and water quality measurements, they may not have accurately reflected the land cover conditions at the time water quality measurements were taken. For example, figure 4.5 shows land-use changes that occurred in the lower Pajaro watershed between 1995 and 2000 based on the NOAA Coastal Change Analysis Project (C-CAP) data. Such changes in land-use have been shown to affect water quality in streams (e.g. Tsegay et al., 2006; Schoonover et al., 2006). The land-use changes that occurred may also explain positive correlations that were observed between the bare/transitional land-use category and nitrate, ammonia, and TSS measurements (see table 4.4). Testing the hypothesis that land use changes such as those shown in figure 4.5.1 affected the land use-water quality relationship will require development of an efficient method to extract watershed land use that incorporates more up-to-date land use data than the NHD currently contains.

Figure 4.5 Land-use changes in the lower Pajaro watershed 1995-2000 from NOAA C-CAP data. Brown areas were changed form grasslands to cultivated crops.



Some of the weakness of the correlations observed between water quality and land use may have been due to the water quality data from some sites being more or less representative than others. The number of water quality measurements varied depending on the parameter and the station, so that some of the values were based on different amounts of information. If seasonal climatic and hydrologic fluctuations were represented at some stations and not at others, this may have obscured relationships between water quality measurements and land-use.

The spatial arrangement of land-use within a watershed and the watershed size also may affect relationships between land use and water quality conditions. The land-use that is closest to a sampling station can have a greater influence on the water quality at that station than those land uses further away. A distance weighting approach, where the land-use is weighted more strongly in areas that are nearer to the water quality sampling station may be a useful technique for dealing with this issue (e.g. King et al., 2005). Since the size of a watershed has an important influence on characteristics of its streamflow regime, a complete analysis would explore how the land-use – water quality relationship changed at different watershed scales. The SAM database would be a valuable resource for implementing more sophisticated analysis of relationships between land-use and water quality conditions on the Central Coast.

4.4 Are there statistically significant temporal trends for water quality variables?

4.4.1 Critical issues for testing water quality trends

Detection of trends in water quality data is necessary to determine whether water quality conditions are getting better or worse and the rate at which change may be occurring. Such fundamental knowledge may be important for decision making related to water quality policies and determination of priorities for where and how measures to improve water quality should be implemented. Methods to determine trends may involve qualitative comparisons over time, inspection of graphical plots, and different types of statistical tests. This section reports the results of using statistical procedures to test for trends over time in water quality data sets and an analysis of the adequacy of existing data sets for identifying trends.

The outcome of a statistical test for trends is a decision to either reject the null hypothesis or not to reject the null hypothesis. The null hypothesis is that there is no trend. Failing to reject the null hypothesis does not mean that no trend exists. Rather, it means that the evidence available is not sufficient to conclude that there is a trend. Critical issues for this type of analysis include the type of trend that will be tested, the type of method, the type of data, and data manipulations.

Two basic types of trends that can be tested are step-trends and monotonic trends.
The step-trend tests the hypothesis that data collected before a specific time are significantly different from those collected at another time, e.g. a t-test of two means. This type of test is more specific in that it requires an a-priori hypothesis about the time that a change occurred (Hirsch et al., 1982). Since such a hypothesis does not exist for the ambient water quality data used in this study, a test for monotonic (one-directional) change that will identify linear and non-linear trends is more appropriate (Helsel and Hirsch, 2002)

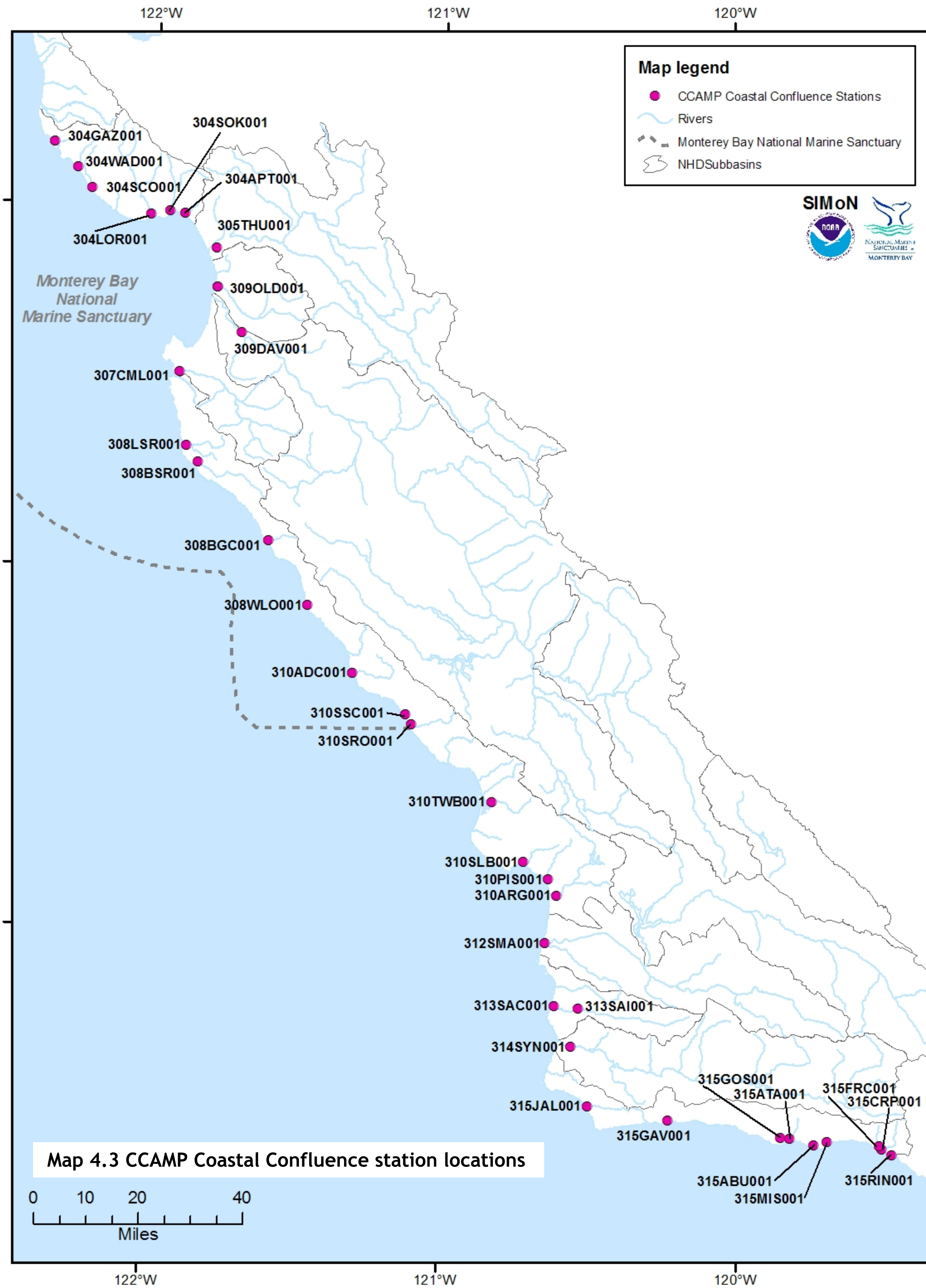
The selection of the method to use is based on the type of trend that is being tested. For testing monotonic trends, both parametric and non-parametric methods are available. A choice between the two should depend on the statistical power, efficiency, and the assumptions that are required for each test. Efficiency is a measure of estimation error. Power is the probability of correctly rejecting the null hypothesis given a particular magnitude of trend. An important assumption for maximum power and efficiency of parametric procedures, such as linear regression, is that the residuals are normally distributed. Since water quality data are commonly skewed resulting in non-normal distributions of residuals (Hirsch et al.,1982), non-parametric procedures, such as the Mann-Kendall test, are often substantially more powerful with large sample sizes (e.g. Helsel and Hirsch, 1988). Additionally, it has been demonstrated that non-parametric methods have only marginal disadvantages when data are normally distributed (Hirsch et al., 1991).

If concurrent streamflow and concentration data are available, the choice can be made to test either concentration or flux (load), depending on whether the question of interest relates to the ambient water quality in the stream or the amounts of material that are transported through the stream. The availability of streamflow data also permits adjustments of concentration data to account for changes over time in concentration measurements that may be explained by hydrologic variability. In the analysis that is described in the following sections, concentration measurements were used without adjustment using streamflow data.

4.4.2 Water quality data

Data were subset from the SAMdb to apply tests for trends over time in the previously identified key water quality parameters: ammonia, nitrate, orthophosphate, dissolved oxygen, pH, temperature, TSS, fecal coliform, and *E. coli*. The toxicity data did not have enough samples, and may not be appropriate for this type of analysis, so it was not included. The CCAMP network of 'Coastal Confluence' stations was selected as the primary data source for a number of reasons. First, the thirty-five stations are located along the coast in a manner that has good geographic coverage for the Central Coast, and sample the runoff from approximately 95% of the watershed area that drains to the ocean. Second, most of the stations have 4-5 years of recent monthly samples for many of the key parameters of interest. Thirdly, the CCAMP data are sufficiently high quality to satisfy the standards for California Surface Water Ambient Monitoring Program (SWAMP). The locations of the CCAMP coastal confluence stations are shown in map 4.3.

Two groups of stations were used for two different types of trend tests. The first was performed using only data from the CCAMP Coastal Confluence stations. The second set of trend tests used the CCAMP Coastal Confluence stations in combination with data from nearby stations that were monitored by various other organizations. These are referred to as Coastal Confluence Plots. The data were combined using a statistical procedure that is explained in section 4.4.3. The objective for combining data sets was to enhance the utility of the individual data sets for detecting changes over time by increasing the sample size. The study period for both sets of tests was determined by the length of the CCAMP coastal confluence stations' record which was from 2001 to 2006. The number of samples for the CCAMP stations varied somewhat between individual stations and from parameter to parameter.



Map 4.3 CCAMP Coastal Confluence station locations

4.4.3 Statistical tests

To test for changes over time in water quality parameters, a set of Mann-Kendall statistical tests was employed. The Seasonal Mann-Kendall test is a distribution free, non-parametic test that is modified from the original Mann-Kendall test (Helsel and Hirsch, 1992). Kendall's Tau (τ) is a rank correlation statistic that measures the strength of dependence between two variables and was first used to test for trends in time by Mann (1945). Because of their robust statistical properties and relative simplicity, Mann-Kendall tests are frequently used in the environmental sciences. The test is valid for non-normal data, and handles missing values and values below a detection limit well. The value of τ is calculated by computing Kendall's S statistic which is the number of matching ranks of two variables. If we consider two variables x and y, the total number of pairings of equal ranks possible between the two is n(n-1)/2. *S* is the difference between the number of matching pairs (n_{mp}) and the number non-matching pairs (n_{np}):

$$S = n_{mp} - n_{np}$$

τ is related to *S* by:

$$\tau = \frac{S_i}{n(n-1)/2}$$

The test accounts for seasonality by comparing the relative ranks of data from each season and computing Kendall's S_i statistic for a specified number of seasons (*k*) and summing the results to obtain an overall value (S_k).

$$S_k = \sum_{i=1}^{m} S_i$$

No comparisons are made across different seasons. The test of significance for trend is based the τ value that is computed from S_k. The significance that is attained (p-value) is the probability of incorrectly rejecting the null hypothesis of no trend when a trend does not actually exist. This test is much more sensitive than using the individual seasonal statistics because it is based on a sample that is much larger, approximately multiplied by the number of seasons.

While Kendall's Tau is used to test the significance of a correlation with time, the Sen slope estimator is used to denote the magnitude of the change over time. It is computed using the method of Sen (1968) and is expressed as the rate of change per year for the original units (usually mg/L). For the Seasonal Kendall test, a slope is calculated for each season and the overall slope is the median of those slopes.

On the Central Coast there are many monitoring stations that are in very close proximity to one another and are measured by different monitoring programs (see map 2.1, Chapter 2). The Mann-Kendall test can be used to combine measurements taken at more than one monitoring station for a regional test (Lettenmaier, 1988). The regional Mann-Kendall test works precisely the same way as the seasonal Mann-Kendall except that the values of *S* are summed over different locations in addition to different seasons. The result is a spatial lumping of data to test for a plot or regional level trend that preserves the unique characteristics of individual data sets for comparisons over time. This is preferable to combining data sets from different monitoring programs directly for a single test, since this approach may result in measuring differences between program characteristics, such as sampling or analytical procedures, rather than changes in the environment.

4.4.4 Data Censoring

Some of the water quality parameters that were included in the trend analysis have analytical detection limits associated with their measurement. Values below the detection limit are commonly dealt through some type of 'censoring', such as substitution or exclusion from the time series. The problem can be exacerbated if more than one detection limit exists for the data time series that is being tested for trends since a change in a detection limit may be interpreted as a change in the parameter concentration (Smith et al., 1996).

When dealing with censored data, some methods for testing trends are precluded. For example, the use of ordinary least squares (OLS) regression techniques should not be used because the regression parameters cannot be calculated without substituting values for the censored observations which can produce coefficients that are strongly dependent on the values that are substituted (Hensel, 2005). Kendall's rank correlation Tau, however, can be computed when censored variables exist provided that the censored values make up less than 20% of the total time series (Hensel, 2005).

For the Kendall rank correlation tests that were performed in this analysis, data values below the detection limit were 'tied' to the same rank that was set at one-half the value of the detection limit. Therefore, the trend was determined only based on the data that exceeded the detection limit. For data time series that had more than one detection limit, the highest detection limit was used to determine the value of the rank at which all non-detect values were tied.

4.4.5 Implementation

The Seasonal/Regional Mann-Kendall tests were implemented using a Visual Basic script created by Libiseller and Grimvall (2002) that runs in a Microsoft Excel Spreadsheet. The program allows the use of multiple monitoring stations and incorporation of covariates such as weather or streamflow conditions that may influence the water quality time series. A separate script also created by Libiseller and Grimvall (2002) was used to calculate Sen's slope estimator.

4.4.6 Temporal trends results for CCAMP Coastal Confluence stations

The results of the temporal trends analysis for nine of the key water quality parameters, arranged by station, are presented in Appendix 4, which shows the number of samples, the overall Tau, S_k, p-value, and Sen's slope estimator for each station and each parameter at each of the 34 Coastal Confluence stations. A 0.05 alpha level (two tailed test) was used as the threshold to determine significance of trends which are shown in Appendix 4. The sign of the calculated Tau and Sen values indicate the direction of the trend, so that a negative sign denotes a decreasing trend and a positive sign denotes an increasing trend. The results for *E. coli* are not reported because there were insufficient data to perform the test (3 years is required). Similarly, Coastal Confluence station 304SOK001 had less than 3 years of data for all parameters and the results are not reported.

Of the 264 tests that were performed, there 24 trends were detected. Time series plots for each of the significant trends are presented in Appendix 5. The trend lines that are plotted are 4 month moving averages. Ammonia had a downward trend at 313SAC001 (figure A5.1, Appendix 5); Nitrate showed increasing trends at stations 304LOR001, 308LSR001, 309OLD001, and 310TWB001 (figures A5.2 – A5.5, Appendix 5). Orthophosphate showed an increasing trend at 309OLD001 and decreasing trends at 304GAZ001, 313SAC001, 315ABU001, 315FRC001, and 315MIS001 (figures A5.6-A5.11, Appendix 5). There were negative trends for dissolved oxygen at station 304LOR001, 309DAV001, 310SRO001, 310ARG001, and 313SAC001 (figures A5.12-A5.16, Appendix 5). pH decreased at 304APT001 and 309OLD001 (figures A5.17-A5.20, Appendix 6). There were significant temperature decreases at 304APT001 and 310SSC001 (figures A5.19 and A5.20, Appendix 5). TSS levels showed an increase at 304SCO001, and decreases at 313SAC001 and 315ATA001 (figures A5.21-A5.23, Appendix 5). Station 308BGC001 showed a decrease in fecal coliform (figure A5.24, Appendix 5).

There are a number of important considerations to the interpretation of the water quality trends that were detected. Examination of the graph for the upward nitrate trend at station 308LSR001 (figure A5.3) reveals that the trend detected was probably due to changes in detection limits over time. Care should be taken in the interpretation of the dissolved oxygen and temperature trends, since the diurnal variation of both of these parameters is much greater than the magnitude of the trends that were detected. Such trends may simply reflect changes in the time of sample collection from one time period to another. Another important consideration is that increasing trends do not necessarily indicate an immediate problem, especially when the rate of increase is very low and all of the measurements show low concentrations.

Four trends were detected at stations 313SAC001 which had three years of data only the month of February (see figures A5.1, A5.8, A5.16, and A5.22 in Appendix 5). Consequently, the test for significance of the trend was based only on the three measurements that were acquired in February. The small sample size reduces confidence in the trend results from this station; since it has less data were used than is normally recommended for the Mann-Kendall test. However, these results indicate that it may be worthwhile to test for trends that occur only in certain months or seasons. Even though this analysis made no cross month comparisons in testing for overall trends, seasons or months with the strongest trends over time may be 'diluted' by other months or seasons in which the water quality variables were more strongly influenced by year to year variations in climatic or hydrologic conditions. Three trends that were detected at station 309OLD001 had a greater number of samples for most parameters than any other station. The greater sample size likely increased the statistical power of the trend test for this station.

4.4.7 Temporal trends results for CCAMP Coastal Confluence plots

A set of tests for trends was performed using data from the CCAMP Coastal Confluence stations combined with nearby stations that were monitored by other organizations using the Regional Mann-Kendall test that is described in section 4.4.3. The U.S.EPA uses a 200 m threshold to consider that water quality monitoring stations are close enough to be considered essentially the same location (SWRCB, 2007). For this analysis, stations that were within 300 m of the Coastal Confluence stations were considered to be within the same plot. The wider buffer included a substantial number of additional Coastal Confluence stations that had 'complementary' stations within this range. Fourteen of the Coastal Confluence stations had complementary stations that were within the 300 m radius that made up the Coastal Confluence Plots and are listed in table 4.5. The increase in sample size that resulted from combining the stations was variable, but sometimes increased the plot level number of samples to many times the number that was used in the individual coastal Confluence stations analysis.

The results of the trend tests at the Coastal Confluence plots are given in Appendix 6 and the time-series plots are shown in Appendix 7. Sen's slope estimator was not calculated for the plots due to computational limitations associated with calculations that summed over multiple seasons in addition to multiple stations. There were 7 significant trends detected from the 126 tests that were performed. Orthophosphate had a significant downward trend at the 304GAZ001

Table 4.5 Coastal Confluence Plots

CCAMP Coastal Confluence Station	Complementary Station
304APT001	304APT_CCL
	304-APTOS-22
	304-APTOS-24
	304APV_SCC
	304VAL_SCC
	304-VALEN-22
304GAZ001	202-GAZOS-11
304LOR001	304SLU_SCC
	304SNL_CCL
304SCO001	304SCB_SCC
	304SCM_SCC
	304-SCOTT-25
	304SCT_CCL
304SOK001	304-CSD-01
	304-SOQUE-21
304WAD001	304WAD_CCL
305THU001	305PAJ_CCL
	305-PAJAR-21
307CML001	307CAR-HWY
	307-CARME-38
	307CML_CCL
308BGC001	308-BIGCR-31
308BSR001	308-BIGSU-31
308WLO001	308-WILLO-31
309DAV001	309SAL-DAV
	309-SALIN-32
	309SLR_CCL
309OLD001	309OLS-MON
	309OSRMDW
	309PIP-MOL
	309-TEMBL-31
	309TEM-MOL
313SAI001	313SAA_USGS

plot and an increase at 309OLD001 plots (figures A7.1 and A7.2, Appendix 7). Dissolved oxygen showed decreasing trends at plots 304APT001 and 304LOR001 (figures A8.3 and A8.4, Appendix 8). Downward trends for pH occurred at plots 304APT001, 304LOR001, and 304SOK001 (figures A7.5-A7.7, Appendix 7).

Combining the data resulted in a sufficient number of samples for tests to be performed at the 304SOK001 plot, which had insufficient data at the station level. Similarly the increase in the number of *E. coli* measurements allowed tests at most plots that were not possible at the individual station level. There were 3 trends that were detected using the Coastal Confluence plots that were not detected using the Coastal Confluence stations. These were the pH measurements for the plots and 304LOR001 and 304SOK001 (see figures A7.6 and A7.7, Appendix 7) and the dissolved oxygen measurements at plot 304APT001 (see figure A7.3, Appendix 7).

While combining the data sets often greatly increased the number samples that was used in the tests, trends were detected less often by combining data sets than they were using data from single data stations. The fact that trends were detected at 5.5% of the plots compared to 9% of the stations points to some important limitations of the procedure of combining data from multiple stations. Monitoring programs sample at different frequencies or have missing years of data. In many instances, the stations that were combined did not have similar amounts of data, which can be problematic for applying the Regional Mann-Kendall test. Often programs sampling in the same area have different detection limits associated with their analytical methods. In order to combine the data, all of the values that were below a detection limit were adjusted relative to the highest detection limit, which often resulted in a loss of information from measurements with lower detection limits.

The Coastal Confluence station 309OLD001 at Old Salinas Road on the Salinas River showed a significant upward trend in nitrate. When combined with other data sets, there was no trend detected. Figure 4.6 illustrates that combining the Coastal Confluence data (blue dots) with other data sets can increase in the degree of scatter in the data so that a trend is not apparent at the plot level. Differences between monitoring programs that contribute to differences in the measurements include the locations of monitoring stations and the analytical methods that were used.

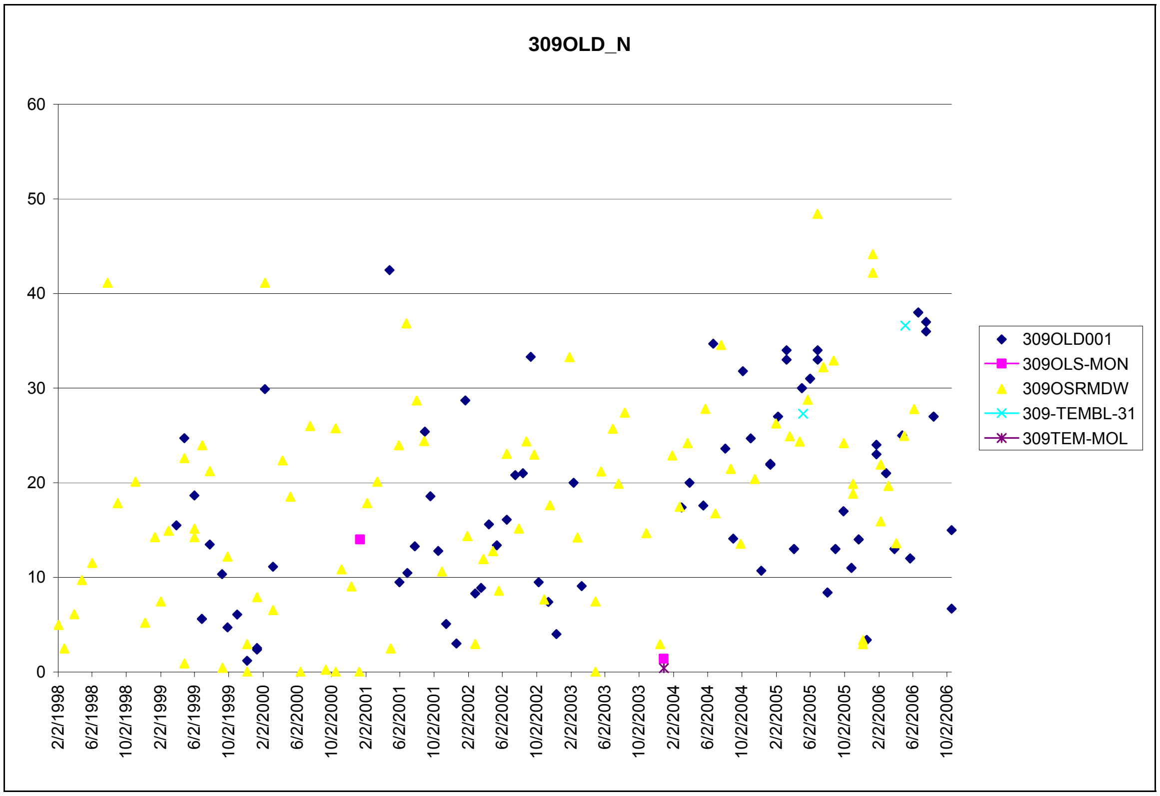


Figure 4.6. 309OLD001 Coastal Confluence plot data

4.4.8 Statistical power of the tests

A key question associated with analysis of water quality data is whether or not the data that exist are sufficient to assess changes in water quality conditions. In the preceding analysis a significance level of 95% was used, which means that on average, a trend will be detected in 5% of the cases that is due to chance alone. Since trends were detected at 9% of the Coastal Confluence stations and 5.5% of the Coastal Confluence plots, some of the trends that were detected could simply have been chance occurrences. One possibility to explain the lack of trends in the data is that the water quality conditions are not changing substantially at most of the Coastal Confluence locations. Another possibility is that the data that were used were not adequate to detect whether or not trends existed.

Data characteristics that affect the ability to detect a certain level of change in water quality time series using a particular statistical test include the length of record, completeness of the record, and the precision of the measurements. The power of a statistical test measures the probability of correctly failing to reject an incorrect null hypothesis of no trend. In other words, a statistical procedure that has power of 0.80 has an 80% chance of detecting a trend when a trend actually exists. The estimation of statistical power is useful for experimental design and for answering questions such as: What was the chance of actually detecting a trend in the data that were analyzed? or How many samples would be required to detect a 20% change in nitrate?

Mann-Kendall's Tau value reflects the correlation between water quality variables and time, and will tend to increase in value as the variance in the data decreases. Figure 4.7a is a plot of the 80% theoretical power curve with Kendall's Tau on the x-axis and power on the y-axis at an alpha level of 0.05. The curve is drawn for a sample size of 50 which was typical sample size for many of the Coastal Confluence data sets that were used (see appendix 4). For both the Coastal Confluence stations and plots, the highest Tau values achieved (calculated from the S value given in appendices 4 and 6) were around 0.37 and the lowest were 0.035. Assuming a sample size of 50, which was typical for Coastal Confluence stations, for the range of Tau values there is a range of statistical power from approximately 10% to 95%. The statistical power for a certain parameter at a certain location depends on the variance in the data and how much of a change occurred. Since there is a wide range of variance and degrees of change in the data sets from one station/parameter to another, there is a substantial range of ability to detect trends from one station/parameter to another shown by the blue arrow in figure 4.7a.

Since Tau is affected by the level of variance in the data which is dependent on the number of samples, it is helpful to examine how many samples would be required for the data sets with lowest Tau values to achieve an acceptable power. Figure 4.7b shows the relationship between sample size and Tau for an alpha of 0.05 for a test with 80% power. The stations with the lowest Tau values would need approximately 80 samples to achieve a power of 80%, given the current degree of change that is observed in those stations (see figure 4.7b). The Coastal Confluence plots increased the sample size above that for individual stations. The reason that they did not improve the statistical power has to do with the apparent increases in data variance coupled with decreases in consistent directions of change due to combining data from different monitoring programs and sampling stations. Detection of trends at many individual Coastal Confluences stations, such as those with subtle degrees of change and high data variability, with good level of power (e.g. 80%) will require several more years of monthly sample data to be made available. This does not necessarily indicate how many samples will be required to detect a trend at these stations, since the level of association between water quality parameter measurements and time, measured by Tau, will change with the number of samples collected. A procedure to address this issue in a more rigorous manner is discussed in section 5.5.

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Figure 4.7a Theoretical curve showing the relationship between Tau and Power

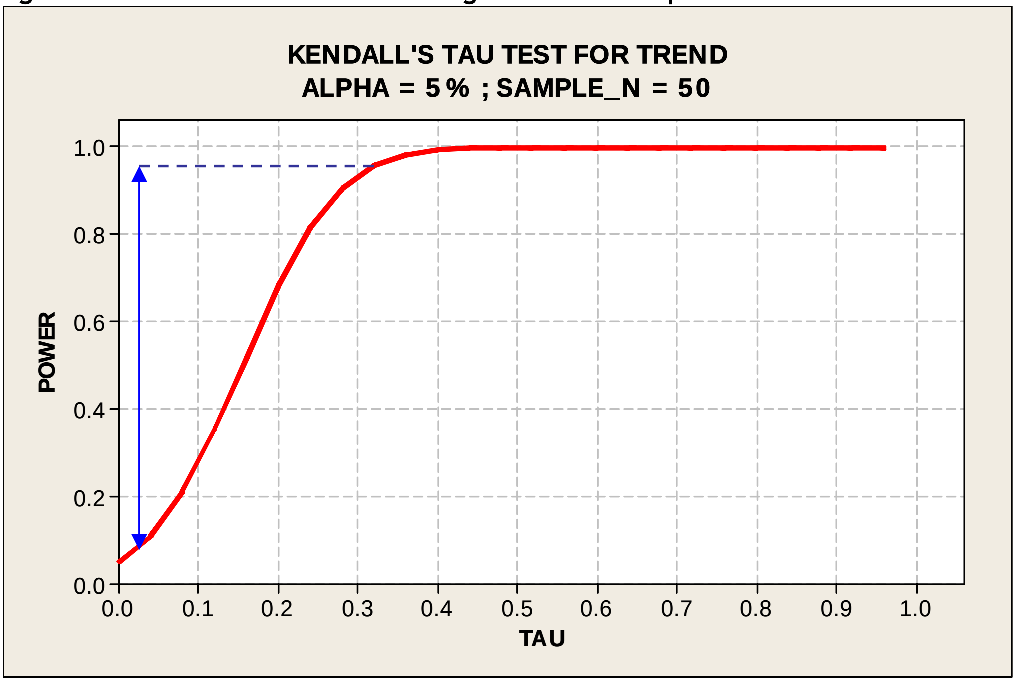
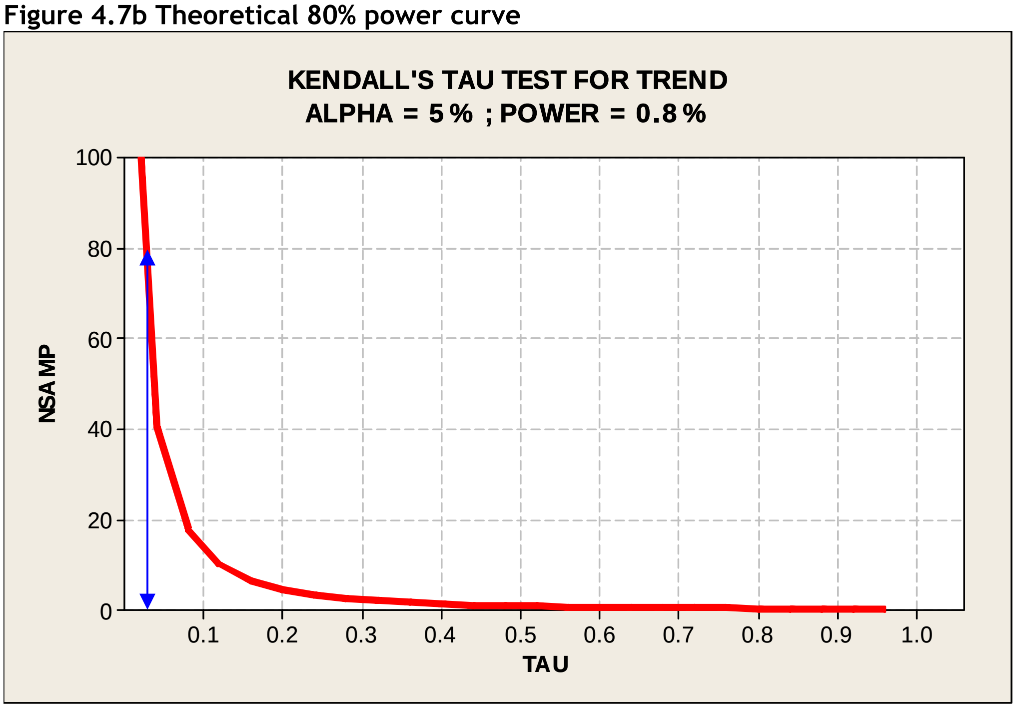


Figure 4.7b Theoretical 80% power curve



Individual stations with more complete and longer data records are more likely to indicate water quality changes over time. Data sets such as the 15 year record that has been established by a monitoring program in the Elkhorn Slough have been shown to be very useful for tracking changes over time. For example, the MaLoHAM program found highly significant trends ($p < 0.0001$) for turbidity in 100% of the stations that were tested using these data [7]. Monitoring program data sets with similar characteristics to the Elkhorn Slough record may be required to detect temporal trends at other locations on the Central Coast. Other data sets with similar length and completeness to the Elkhorn Slough record include the County of Santa Cruz, the U.S. Geological Survey, and the MaLoHAM programs. None of these programs have the region-wide geographic coverage of the CCAMP program.

4.5 Is there evidence that better management practices have been effective in improving ambient water quality conditions?

4.5.1 Linking water quality trends with land-use changes

The type of land-use and the management practices that are used within a watershed affect the amounts of NPS pollution that enters waterways. To reduce the amount of NPS pollution associated with a certain land-use, land management practices must be altered. On the Central Coast, there have been a number of efforts to implement better agricultural and urban management practices that have the aim of reducing NPS pollution.

Documentation of water quality improvements from changes in land management is essential to provide feedback to national, state, and regional policy makers. This information can help to identify practices that are most efficient at reducing discharges of NPS pollutants from watersheds with specific topographic, soils, geologic, and climatic characteristics. Additionally, demonstration that implementations of management practices are effective in improving water quality conditions will tend to increase political and economic support for future implementation of NPS pollution control measures.

The task of linking water quality improvements to changes in land-use practices has historically been difficult, partially due to the lack of well-designed water quality monitoring and land-use practice monitoring schemes (Gale et al., 1993). The two elements that are generally required are: 1) detection of significant trends in both water quality and land-use practices and 2) an association between water quality trends and land-use practice trends (Gale et al., 1993). The adequacy of the existing monitoring designs and available data for drawing causal relationships between land management changes and water quality is dependent on these two data analysis elements.

[7] http://home.csumb.edu/l/loshuertosmarc/world/documents/ElkhornTurbidity.pdf

4.5.2 Management practice implementation data sources

Detection of spatial or temporal trends in land management practices (e.g. BMP implementations) requires that land use practices be quantified in a consistent manner over time and from one location to another. Otherwise, changes in the way that practices are measured may be interpreted as spatial patterns or trends over time. The specific type of land-use management, the target pollutant, timing of implementation, its precise location, and spatial extent are measurement characteristics that would be desirable for comparison with water quality data.

Sources of data describing land management changes on the Central Coast are diffuse and vary in their content and formats. They include reports from federal, state, and local agencies, scientific institutions, non-profit organizations, private consulting firms, and peer reviewed academic papers. For this analysis, information was reviewed from the Central Coast Resource Conservation Districts (RCD), Regional Water Quality Control Board (RWQCB), Kestrel Consulting, the County of Monterey, Central Coast Watershed Studies at California State University, Monterey Bay (CSUMB), and the Natural Resource Projects Inventory (NERPI). Data sources varied in their level of precision for specifying the type, extent, timing, or location of management practice implementations. For example, one data source may give a latitude and longitude for a project, while another may indicate the Salinas watershed as the location, making these two types of information very difficult to compare.

Synthesizing information from the data sources mentioned above for comparison over time and across the region will require identifying data elements and a level of information content that is common to a sufficient number of them, discarding those which do not satisfy some minimum requirements, and either degrading data that contained more precise information or only comparing locations/times with a similar level information content. For this analysis, only one data source was used that measured the level of agricultural land management improvement. A survey performed by the RWQCB was selected as the data source because it satisfied important requirements for a meaningful comparison with water quality data including a uniform system of spatial referencing across the region.

4.5.3 Quantification of agricultural management practices

The RWQCB Management Practice Checklist is a survey that is designed to determine the level of implementation for four types of farm water quality management practices: pesticide management, irrigation water management, erosion and sediment management, and nutrient management (RWQCB, 2007). There were 1,040 growers that responded to the survey.

The data were used to determine a gross indicator of the level of implementation of water quality management practices by lumping all of the responses together rather than analyzing individual questions. This approach was taken partly due to the absence of knowledge as to the relative importance of individual questions for indicating the overall level of management practice implementation. Another consideration was the relative levels of uncertainty and error associated with individual questions. A number of sources of error associated with the survey were reported by the RWQCB (2007) which included:

- The checklist asked growers the level of implementation for each management practice, not the amount of acreage associated with each level of implementation.
- The response to a particular management practice was assumed to apply to the entire area of a grower's fields.
- The checklist was a self-assessment survey; the responses may vary based on the growers' interpretation of the questions and understanding of the management practices.

Each respondent to the survey had a permit ID number that was joined to crop data, which are available from county offices, and allowed spatial analysis and representation of the survey data. Watersheds and sub-watersheds are logical spatial units to aggregate the survey data for comparison with water quality data. Crop data from the County of Monterey were used to spatially join the survey data to a hydrologic planning watersheds layer from the CalWater dataset. The County of Monterey crop layer covers a large portion of the Salinas subbasin, the Alisal-Elkhorn subbasin, the lower portion of the Pajaro subbasin, and the northern portion of the Central Coastal subbasin.

The Management Practice Checklist results were quantified to represent each grower's level of management practice implementation scaled by the area that their fields occupied within a watershed. The Management Practice Checklist included four possible responses to questions about whether or not management practices had been implemented: yes; no, planned within 3 yrs; no, not planned; not applicable. These responses were categorized in a binary fashion simply as implemented or not implemented. The percentage of positive responses (implemented) to all of the questions (positive response rate) was calculated for each grower. For each hydrologic planning watershed, the positive response rate (P) was weighted by the total area occupied by each grower's fields (A_f). All of the area-weighted response rates for each hydrologic planning watershed were summed and divided by the total cultivated area (A_c) within the planning watershed to create an indicator (I_{pw}) of the relative level of management practice implementation for each planning watershed:

$$I_{pw} = \frac{\sum P(A_f)}{A_c}$$

The indicator variable (I_{pw}) is similar to the 'percent representative acreage' metric that was calculated by the RWQCB (2007); the difference being that they calculated it on a question-by-question basis and normalized by the total field area for the entire Central Coast.

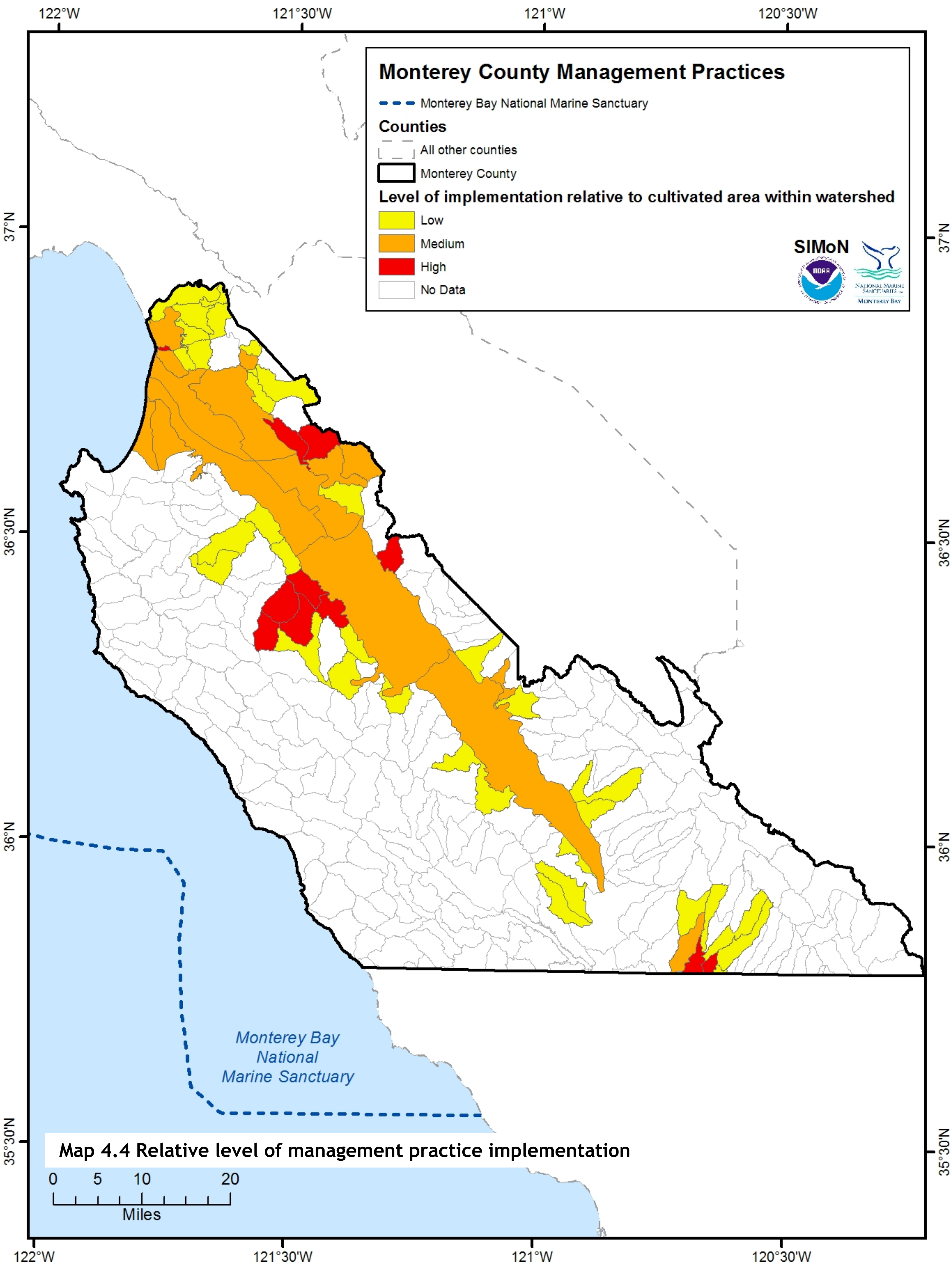
Map 4.4 shows the calculated indicator (I_{pw}) for each hydrologic planning watershed placed into categories: low, medium, and high. Watersheds with no data either have areas where there are no growers or where no growers responded to the survey. The I_{pw} for each watershed was calculated using only the data from growers who responded to the survey. Therefore, the calculation is biased by the number/field size of the respondents in each watershed.

The combined lower, middle, and upper portions of the Salinas Valley shows a medium relative level of implementation, while the smaller watersheds that drain to the valley often show relatively high or low levels of implementation. While the map does not provide information about changes in management practice implementations over time, it indicates potential areas to examine relationships between management practice implementations and changes in water quality conditions. Watersheds that are colored red have the highest relative level of management practice implementation in Monterey County. That is, according to the survey data, these areas have a relatively high number of management practices implemented and/or a large proportion of the cultivated area within the watershed with management practices implemented.

4.5.4 Comparing water quality data and management practice implementation data

A number of factors make it difficult to compare the survey data with water quality data to determine whether or not management practices have been effective. The survey data that were used were a snapshot of recently implemented management practices and do not allow quantification of changes in management practice implementations over time. Additionally, the majority of monitoring data are collected near the bottom of large watersheds, including the stations that were tested for temporal trends (see section 4.3), which receive runoff from the entire watershed. To test the hypothesis that expanding management practices are related to improving water quality would require analysis of either spatial or temporal covariance of management practice implementations and water quality variables. Such an analysis is not possible on a region-wide scale using the data that is currently available.

The trends that were detected at the Costal Confluence stations and plots in section 4.3 in the Salinas and Pajaro watersheds do not provide evidence to support the hypothesis that water quality conditions are improving. In fact, at station 309OLD001 in the Allisal-Elkhorn subbasin, nitrate and orthophosphate both showed significant increasing trends (see figures A5.4 and A5.6, Appendix 5). In general, the data that were used in this analysis were not adequate to draw conclusions about relationships between water quality conditions and changes to agricultural land management practices upstream.



Map 4.4 Relative level of management practice implementation

5.0 DATA GAPS AND RECCOMENDATIONS

A number of critical programmatic, resource, and information gaps have been illuminated through the course of this investigation. This chapter outlines deficiencies that were identified related to water quality monitoring, data integration, and data reporting; and provides recommendations on how they can be addressed to answer non-point source pollution questions in a more rigorous and complete manner in the future. Each section is structured with a summary of the 'gaps' that were discovered followed by a list of recommendations.

5.1. Water Quality Data Integration

5.1.1 Data integration gaps

Learning precisely how individual monitoring programs store information in order to unify data structures, formats, and notation takes a tremendous amount of time. Additionally, when a person external to a monitoring program who was not involved in data collection or data management performs such tasks, it increases the chance of introducing errors to data sets. A uniform set of formats would be beneficial for any type of region-wide analysis that used water quality data and also allowed data flow to higher level storage systems at the state (e.g. CEDEN) and national (e.g. EPA STORET) levels.

Primary obstacles to having a region-wide universal format for water quality data is the diversity of resources and objectives of monitoring programs. Different monitoring objectives and data management resource limitations are reflected in the way that data are entered and stored at individual organizations in the same way that the geographic extent, number of stations, or monitoring parameters are defined by those objectives and resources. For example, two programs may store information in a database field called '*sample type'* that stores entirely different types of information. One program may record in this field whether the sample was a single '*grab*' sample or a '*replicate*', while another program use such a field to identify whether the sample was water or sediment, while another program may specify the water quality parameter that was measured. Similarly, some programs may denote a non-detect value with the numerical detection limit value itself with a text qualifier, while others record a different value, such as '*0'* or '*ND'*. A system that does not store the detection limit with the other data requires review of documentation for data analysis, since even calculation of descriptive statistics generally requires knowledge of the detection limits. In this way, different levels of information that are stored reflect the needs of individual programs.

A system that permits seamless data integration will free up resources for data analysis and reporting; and facilitate monitoring coordination between organizations. With such a system in place, greater resources could be put toward regulatory assessments and allow development of more sophisticated data analysis and water quality health assessment techniques. Regionally standardized methods could be developed for investigating and reporting the status and trends of water pollutants. Identification of water quality data gaps and redundancies requires that data be in comparable formats. If coordination between monitoring organizations is to be the mechanism to create a more efficient region-wide monitoring system, staff at one organization will need to access, understand, and use data from another organization nearly as easily as if they had collected the data themselves.

5.1.2 Data integration recommendations

It is unlikely that regional data storage approaches will be fully adopted by monitoring organizations if there are aspects that are not optimal for meeting the objectives of individual organizations. Some programs in the region have already migrated or partially migrated toward database structures, formats, or notation that facilitate integration and movement toward regional and statewide data nodes. The recommendations below reflect some of the work that is currently ongoing within the SWAMP and CCAMP organizations and requires extension to a wider audience in the data collection community.

- An essential set of common fields, types of information that should be contained in those fields, and notation that is to be used, should be established that are compatible with the SWAMP data storage conventions and can be adopted by monitoring organizations.

- A regional data node should be established for collation of data sets from monitoring organizations; as well as application and dissemination of data formats translation tools. Data transformation activities should be gradually transferred to data managers at the monitoring organization to enhance the information content of tables and reduce the potential for errors. The data upload system developed by the CCAMP program [8] has already been established as a useful tool for data delivery, notation transformation, and data validation and should continue as a model for region-wide integration.

- Data integration should be expanded from the currently collected types of water chemistry and toxicity to other data types including sediments, mussel tissue, bioassessment, and biostimulation and additional monitoring programs.

[8] http://www.ccamp.org/Organizations.htm

5.2 Water Quality Monitoring Coordination

5.2.1 Monitoring Data Gaps

In Chapter 3, the level of monitoring effort, quantified as the number of measurements over the last five years, was compared across the Central Coast for a set of key parameters: ammonia, nitrate, orthophosphate, dissolved oxygen, pH, temperature, TSS, *E. coli*, fecal coliform, water toxicity, metals and POPs. Monitoring effort for all of the parameters that were considered is clustered around the Monterey Bay Area, in lower portions of Salinas and Pajaro subbasins, the Alisal-Elkhorn subbasin, and the San Lorenzo subbasin. Water toxicity and POPs were measured less frequently than any other parameters on the Central Coast, which is related to the analytical methods and costs that are required for these measurements. There are relatively few measurements in upland watersheds away from main river stems or watershed outlets. Large sections of the Salinas subbasin had relatively few measurements for many of the key parameters. Other than bacteria and physical parameters, there are relatively few stations with regular measurements in nearshore environments.

Some of the data gaps that were identified are related to data access rather than the level of monitoring effort. There may be substantial data sets collected by organizations that were not accessible for a number of reasons including the lack of digital storage. Some data collected recently by the CCAMP program and Ag Waiver Network were not available due to limited data processing resources. Toxicity measurements were taken by the First Flush program in 2005 and 2006, but were not available because they did not have a data storage system to accommodate these measurements at the time of data collection. These examples demonstrate the need for programs to increase the resources that they allocate to data management and indicate that enhanced data management support from the state and regional levels would be beneficial.

Water toxicity and POPs were measured less frequently than any other parameters on the Central Coast. Much of the toxicity and POP data that is collected is in the form of sediment and tissue analyses that were not include in this evaluation, however, including these data, the amount of toxicity and POP data would still be small compared to other parameters. Important emerging pollutants such as pyrethroid pesticides and pharmaceuticals are not measured by ambient monitoring programs on the Central Coast.

In general, monitoring effort is focused in the areas where there is evidence that water quality problems exits. The data indicates that certain areas located in the San Francisco Coastal South subbasin, the Carmel subbasin, and the northern portion of the Central Coastal subbasin, have high quality waters. These locations have the potential to be sampled less frequently (spatially or temporally) if both the water quality data and information on land-use activities indicate that there is not high potential for rapid change of water quality conditions. Efforts could be redirected to other areas such as upland sub-watersheds in the Santa Maria, Pajaro, or the upland Salinas subbasins where land-use activities indicate potential problems and less water quality data exist.

Many of the monitoring questions that were addressed in this analysis would be amenable to loads (flux) data in addition to concentration data. Only the CCLEAN program calculates loads from concentration data, and very few programs collect flow measurements along with the concentration measurements. Exceptions to this rule included data collected by the CCOWS program, and at some of the USGS and Santa Cruz County stations.

In areas around the Monterey Bay, water quality stations are often located in very close proximity to one another and are often monitored by more than one organization that may collect data on different parameters and/or at different times. Both the large number of stations and the limited spatial extent or temporal frequency of some data sets may be related to the funding sources for water quality monitoring programs. Monitoring projects often have short-term or unstable funding sources, so that new stations may be created with new projects that have different objectives. For ongoing programs, limited funding can result in a reduction in the number of monitoring sites, or a reduction in the frequency of data collection. For example the CCAMP monitoring strategy for watershed characterization calls for dividing the Region into five watershed rotation areas and conducting sampling each year in one of the areas. Other examples include discontinued USGS monitoring stations, a funding related one-year gap in the CCAMP data set, and recent elimination of CCLEAN river sampling stations.

5.2.2 Monitoring coordination gaps

Lack of coordination between monitoring organizations results in wasted resources and important data gaps. Overlaps in data collection reduce the ability to understand water quality conditions within a regional context compared to a more efficient system with a high level of coordination between programs. Unique characteristics of monitoring programs can serve as barriers to having a high level of regional monitoring coordination. For example, even if two monitoring organizations were measuring the same thing at the same place at the same time, it would be difficult to get one of them to monitor at different locations if the organizations had different metadata requirements, parameter notation conventions, data storage systems, or reporting objectives and timeframes. Thus, unique characteristics of monitoring programs such as their monitoring objectives and data management resources make data sharing and monitoring coordination challenging.

The design of a monitoring network often depends on the objectives of a program which may include measuring ambient conditions over a large geographic area, education and community outreach, long-term trends identification, source tracking, comparison with regulatory standards, loading calculations, hypothesis testing, or measuring overall ecological health. Many of the Central Coast monitoring programs share one or more of these objectives, however, the order of prioritization may differ from one monitoring program to another. If all of the Central Coast monitoring program resources were considered collectively, an optimal design could be created for the entire region based on a set of objectives. Such a design would more efficiently allocate the limited monitoring resources that exist on the Central Coast.

Statistical methods such as analysis of variance (ANOVA) or Spearman's Rank Correlation test could be applied to all Central Coast stations to determine the degree of independence for each station. Elimination of redundant stations or reduction in measurement frequency, however, would strongly depend on a high level of coordination, free flow of data, and adequate technical understanding between monitoring programs. For example, if one program stopped monitoring at an overlapping station to fill a gap elsewhere, but still required data at that station, it may necessitate that the objectives, parameters, methods, and data storage systems of the two programs to be very similar to one another. This degree of coordination also would require that new programs be developed within the context of existing programs and that cooperating programs could assure the others that their funding sources were secure enough for everyone to rely on.

Competing study design requirements and their mutual incompatibility will make a comprehensive level of monitoring coordination very difficult in the near future. For example, determining the percentage of a watershed that is impaired and detecting trends over time have different optimal study designs. One is based on probabilistic sampling and the other on targeted sampling. A less comprehensive approach to monitoring coordination is feasible at the present time that would have substantial regional benefits. Currently, there is not a regional venue with the purpose of having water quality investigators present the activities and findings of their programs. Such a venue would facilitate coordination of programs in terms of station locations, measurement parameters, and data analysis at a level that would be manageable given the current diversity of program objectives and resources. Such a venue could also include training sessions to unify data formats and facilitate the flow of information between organizations.

5.2.3 Data collection and monitoring coordination recommendations

- Given the direct ecological relevance of measuring toxicity and POPs (e.g. Hunt et al., 1999), it should be a priority to continue ongoing programs and to expand POP and toxicity monitoring to new areas where potential problems are identified. Emerging pollutants of concern should also be prioritized for monitoring at the regional level.

- Other types of monitoring that provide integrative metrics such as bioassessments, periphyton, and wetlands assessments should be prioritized.

- Additional nearshore monitoring efforts could compliment the CCLEAN program and expand the spatial or temporal sampling frequency. Such monitoring would play an important role for understanding interactions between anthropogenic activities in coastal watersheds and nearshore marine ecosystems.

- Small upland watersheds within large drainage basins such as the Pajaro and the Salinas could be targeted for monitoring based on land-use, management practice implementation data.

- The CCAMP program is the only network that spans the Central Coast region with a monthly-frequency sampling program. It may be beneficial for tracking trends over time to have the CCAMP stations serve as a framework for spatially integrating stations from other programs. This would simply mean that if a station is very near to a CCAMP station, it could shift to the precise location of the CCAMP station and have this information be reflected in the data storage. Such an approach could help to fill in some data gaps that result from the CCAMP program's annual watersheds rotation.

- Objectives should be precisely identified that are common to multiple programs. This would help facilitate a coordinated monitoring optimization strategy that could be modeled after the U.S. Environmental Protection Agency's Data Quality Objectives Process (U.S. EPA, 1994) and robust statistical analyses.

- The high variability associated with concentration data can be dealt with by standardizing the data. One data standardization method that should be considered, particularly for evaluating loads, is to include streamflow in the standard suite of measurements.

- A regional culture of collaboration needs to be developed that includes willingness by investigators to develop their individual programs with the context of other ongoing programs. Two things that would help to promote this culture would be: (1) a regularly updated clearinghouse of information on all the exiting programs and (2) annual water quality conferences in the region that would help raise the visibility and value of monitoring coordination efforts.

5.3 NPS Questions 1 and 2:

What is the extent of impaired, threatened, and high quality water bodies on the Central Coast?

How do water quality limitations that derive from non-point sources compare to those from point sources?

5.3.1 NPS Questions 1 and 2 gaps

The SWRCB has created a well documented approach for assessing whether or not water bodies should be added or removed from the 303d list of water quality limited segments (SWRCB, 2007). Listing or de-listing of a water body is tied to the specific methods of the 303d process and assessment and comparison of water quality status based on the number of impaired or threatened water bodies is constrained by the methods of the 303d listing process. Since the approach is geared toward the regulatory objectives of the SWRCB, applying the results of these analyses to other objectives such as determining how the extent of water quality impairment has changed over time or identifying spatial patterns would be problematic.

The use of subjective methods for determining the extent of water quality limitation restrict its usefulness as a metric to categorize and compare water quality conditions in different locations or over time. Determination of impairment extent is accomplished by best professional judgment, which may be applied differently by different individuals or at different times and locations. Moreover, a certain length or area portion of a water body is often listed without specifying where that portion is located on the water body. Imprecise identification of the extent of water quality limitation can lead to inaccurate spatial representation of threatened and impaired water bodies on the Central Coast. Currently, there is no method to spatially join the unit of analysis used in 303d assessment ‘water body’ with a field in the most current set of hydrographic data – the National Hydrography Dataset (NHD).

Indication of pollution sources on the 303d list is based on a professional judgment that may cause differences in the way these sources are described across the region or over time. Additionally, the most prevalent sources that are cited on the 303d list are ‘unknown source’ and ‘unknown non-point source’.

5.3.2 NPS Questions 1 and 2 recommendations

- Increase resources to facilitate data flow from monitoring organization to the RWQCB in order to increase the information available for water body assessment.

- Develop a standardized method for delineating extent of impairments and pollutant source specification.

- Reconcile the water body names used in 303d assessment with data fields in the NHD.

- An alternative to using regulatory categorizations as a means to report and compare water quality status over time and space should be investigate. Such an approach could employ a different unit of analysis (other than water body) and a different categorization scheme and could still be based on exceedences of water quality criteria.

5.4 NPS Question 3:

Are there relationships between land-use and water quality parameters?

5.4.1 NPS Question 3 gaps

Land-use -water quality relationships were quantified at the regional scale for 6 parameters using a partial correlations analysis that was applied at a regional scale. More stations, spread more evenly across the region, with the same amount and type of water quality data would allow a larger sample size for the analysis and a greater diversity of land-use proportion combinations within the watersheds. An obvious deficiency of this analysis was that the land-use data contained in the NHD was from 1992. However, it is difficult to judge whether or not such factors limited the ability to address relationships between land-use and water quality conditions.

Limitations encountered were primarily technical or related to time constraints. A more complete analysis would use more up-to-date land-use data and employ a more sophisticated approach such as a distance weighting technique. Additionally, the influences of watershed size and climatic/hydrologic regimes on the land-use - water quality relationship could be explored. Such an analysis may yield additional significant relationships or correlations with less residual variance than was observed.

5.4.2 NPS Question 3 recommendations

- Develop a method to efficiently delineate watersheds from a monitoring station point using the NHD and current land-use data
- Identify the most relevant scale of study (e.g. regional or otherwise) and perform additional correlation/regression based analysis or explore alternatives for quantifying relationship between land-use and water quality, such as the distance weighting approach outlined in section 4.3.6.
- Build the geographic data synthesis infrastructure and allocate sufficient data analysis resources for future land-use water quality investigations.

5.5 NPS Question 4:

Are there statistically significant trends over time for water quality parameters?

5.5.1 NPS Question 4 gaps

5.5.1.1 Sample size and statistical power

Statistical trends were detected at a small percentage of the Coastal Confluence Stations (9%) and the Coastal Confluence Plots (5.5%). For most locations there were approximately 4-5 years of monthly data available. For most locations, especially those with subtle changes and more variable measurements, years of additional data will probably be required to reliably detect changes in parameter concentrations. It appears that the most effective means of detecting trends is to maintain stations with static locations and consistently applied analytical methods. Recent work suggests that approximately 10 years of data may be required to detect trends in water quality data (e.g. Hunt et al., 2006). Few programs currently maintain stations with a continuous data record of this length (see table 3.1). In terms of sample collection frequency, a high degree of temporal autocorrelation limits the ability to obtain truly independent samples when sampling effort is increased over a shorter time period (Hunt et al., 2006).

In general, the power of any procedure for detecting trends will be improved if the variance in the data can be decreased (Hensel and Hirsch, 2002). To estimate how statistical power changes with the length of the record, or how many samples would be required to detect a change of a particular magnitude, it is required to know how the variance for different parameters would change over time with increasing sample sizes. The steps involved in such an analysis would include fitting a mixed model to the water quality time series data and simulating monitoring data for a specified monitoring design. The steps for such an analysis using the Mann-Kendall test are outlined by Hunt et al. (2006):

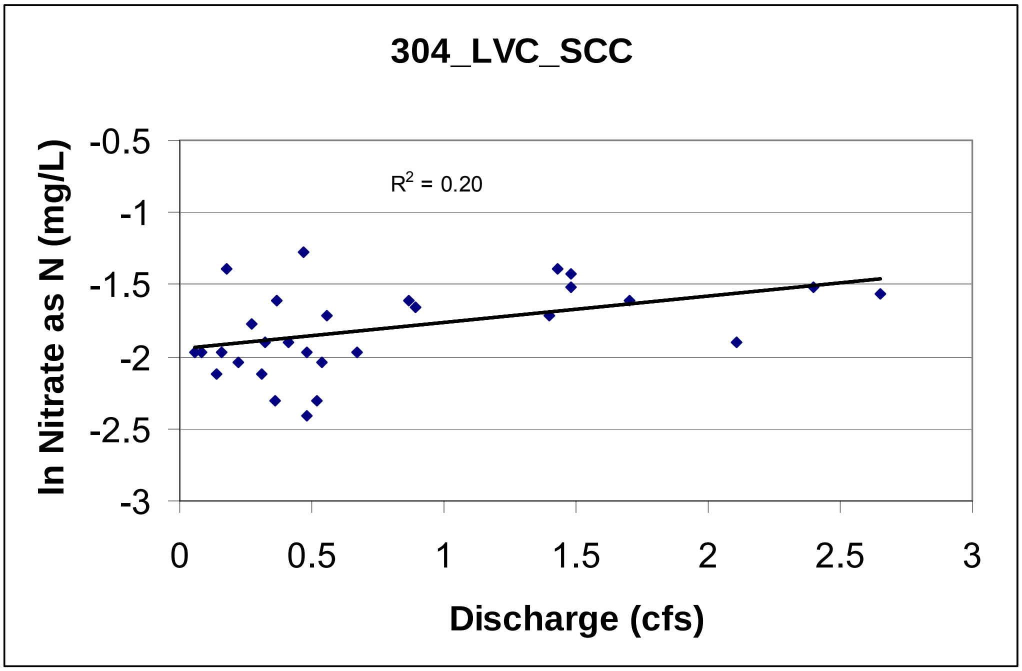
- Fit a statistical model to the characteristics of the data set of interest to support a Monte-Carlo based power analysis procedure.
- Generate multiple replicate simulated water quality time series data sets.
- Perform a Mann-Kendall trend analysis procedure for each simulated time series data set.
- Estimate the annual proportional change in water quality parameter values that would be detectable at a desire level of statistical power and significance level.

Such an analysis would be useful prior to a establishing a monitoring network that had the expressed goal of detecting changes in water quality conditions over time.

5.5.1.2 The influence of hydrologic variability

In general, temporal and spatial variability of watershed characteristics makes it difficult to detect changes within time spans that are useful for adaptive land-use management (Loftis et al., 2001). Unwanted sources of variation in water quality data can be due to random, natural processes such as rainfall, temperature variations, and streamflow. Different water quality constituents may have a direct or inverse relationship with streamflow discharge, or the relationship can be more complex and depend on antecedent hydrologic conditions, land use dependent activities, and watershed characteristics (USGS, 2000). For example, a positive relationship between nitrate (NO3 as N) and streamflow discharge was observed at a Santa Cruz County sampling station at Love Creek in the San Lorenzo-Soquel subbasin. A scatter plot of the relationship is shown in figure 5.1. In contrast to this example, Los Huertos et al. (2003) demonstrated that nitrate concentrations are generally higher in low flow years in the Pajaro River.

Figure 5.1. Nitrate - discharge relationship in Love Creek



Removal of external or 'exogenous' sources of variability in water quality data can reduce the uninteresting background variability to improve the ability to detect a change in water quality conditions. Options for dealing with covariation of discharge and parameter concentrations include flow adjustment of concentration measurements and using flow as an explanatory variable in tests for trends. Lisbiseller and Grimvall (2002) demonstrated that inclusion of flow as an explanatory variable in the Seasonal Mann-Kendall test for trends substantially improved the power of the test. It can be beneficial to include streamflow as an explanatory variable even with weak correlations between streamflow and a water quality variable of interest, and the ability to detect change can increase non-linearly as the correlation increases (Loftis, et al., 2001).

Including discharge variables in trends analysis is dependent on the availability of streamflow data at the same time and place as water quality sampling. There are very few permanent streamflow gauges on the Central Coast. An alternative approach would be to use statistical or process based modeling approach to estimate streamflow at specific locations.

5.5.2 NPS Question 4 recommendations

- Maintain commitments to sustain long term monitoring stations such as the CCAMP Coastal Confluences stations.

- Investigate modeling alternatives for estimating discharge at a select group of water quality stations.

- Develop an approach for incorporating flow measurements into trend tests.

- Encourage measurement of flow as a regular part of water quality monitoring and/or adjustment of water quality monitoring stations to locations with measured stream flows.

- Maintenance and expansion of USGS streamflow gauges. In the 1990's operation of a number of Central Coast USGS streamflow gauges was terminated by the agency. The lack of flow data is a substantial data gap that is critical to understanding changes in pollution problems over time.

5.6 NPS Question 5:

> *Is there evidence that better management practices have been effective in improving ambient water quality conditions?*

5.6.1 NPS Question 5 gaps

There are not sufficient data to test the hypotheses related to relationships between ambient water quality conditions and changes in management practices on a regional scale at this time. The data deficiencies fall under two categories: those related to water quality measurement, and those related to management practice implementation measurement. Year to year variability in water quality parameter measurements may require that several years of pre- and post-implementation monitoring data is collected at stations to demonstrate a consistent water quality change following management practice changes (Gale, 1993; Hunt et al., 2006). Stations maintained by Santa Cruz County and the Elkhorn Slough National Estuarine Research Reserve (ESNERR) have data record lengths that are the most amenable to investigating relationships between land use management and water quality conditions the Central Coast.

The data sources that were reviewed for measuring the implementations of management practices were not optimal for comparison with water quality data. The main deficiencies were related to imprecise location data for projects and the variability of information types and reporting formats across the region and over time. A database created from a review of articles and reports that used a common set of fields to describe projects in a region would be a useful tool for tracking spatial and temporal patterns of management practice implementations (e.g. Rice, 1998; Yagow, 2002) and investigating relationships between management practices and pollutant levels.

In the future, obtaining information on management practice implementation would be facilitated by close cooperation with stakeholders such as growers, Resource Conservation Districts (RCDs), and cities. One important obstacle to cooperation and data sharing would be confidentiality agreements that are often required for work to be done on growers' private property. However, without good information about the types and locations of management practices that are implemented it will not be possible to make direct comparisons with ambient water quality conditions.

Ideally, an experimental design could be established to demonstrate linkages between land management practice changes and water quality conditions. A design should be able to remove the effects of the land management changes from land-use and climatic fluctuations that may affect water quality. Such designs include: paired watersheds (e.g. Clausen and Spooner, 1993); an upstream/downstream approach (Spooner et al., 1985); or a before/after design (Spooner et al., 1985). Both the upstream/downstream approach (Harris et al., 2005) and the paired watersheds approach (CCRWQCB, 2002) have been successfully applied on the Central Coast.

Water quality changes that are due to management practice improvements are more likely to be detected in small watersheds (Gale et al., 1993). A system of small sub-watersheds throughout the region would be a more appropriate design compared to using stations at the bottom of very large watersheds such as the Salinas and the Pajaro. Such a system of watersheds could include upland watersheds as well as those which drain directly to the coast. Watersheds could be chosen based on land-use, abundance of management practice implementations; water quality and discharge data availability; and watershed climatic/hydrologic regimes.

5.6.2 NPS Question 5 recommendations

- Develop a management practice database with a common system of quantitative units that reflects the level of management practice implementation. The database should be easily updatable, useful for organizations such as the RCD's to track projects and funding, and coupled to the National Hydrography Dataset (NHD) to facilitate watershed based analyses. Such a database could draw on previous efforts such as the Natural Resources Projects Inventory (NERPI).

- Develop a region-wide monitoring design with the express purpose of evaluating water quality changes that are due to changes in land-use management activities at multiple watershed scales. Such a design should utilize current ongoing monitoring program stations such as the CCAMP coastal confluence stations.

- Encourage cooperation of watershed stakeholders to share information on management practice implementations that will be useful for comparison with water quality data.

- A statistical or numerical modeling approach could be used in concert with a targeted monitoring design that would serve to organize spatial and time series data into a single framework; and provide a means for testing hypotheses based on heuristic scenarios (e.g. Ice et. al., 1998). A modeling approach may also avoid the need for precise locations of management practices and could use water quality data and spatially lumped management practice information for model calibration and validation procedures.

5.7 Water quality data reporting

5.7.1 Current SAM data users

Compiling water quality data and metadata in for the entire region has resulted in useful collaborations with a number of different organizations. Table 5.1 lists the organizations and the activities for which SAM data and data products have been used during 2007 and 2008. The widespread interest, outcomes, and direction of the SAM effort point to the need for this type of synthesis work to continue and for the capacity to report water quality information and disseminate data to be increased.

Table 5.1 SAM Project data users

Organization	**SAM Collaborative Activity**
Central and Northern California Ocean Observing Systems (CeNCOOS)	Coastal management data products
Central Coast Water Quality Preservation Inc. (CCWQP)	Monitoring efficiency and Identification of management practice effectiveness
Monterey Bay Aquarium Research Institute (MBARI)	Nutrients and bacterial pathogen indicators data provided for two independent research projects.
Sanctuary Integrated Monitoring Network (SIMoN)	Water quality expertise for the Sanctuary Integrated Monitoring Network (SIMoN) and the Sanctuary Wide Integrated Monitoring (SWIM) Report
Regional Water Quality Control Board (RWQCB)	Data provided for impaired water bodies assessment.
NOAA National Marine Fisheries Service (NMFS)	Data provided for steelhead trout habitat suitability tool development
Santa Cruz County	Comments provided on water quality and management practice implementations data management system development

5.7.2 A system for water quality data reporting

A number of organizations in the region have expressed interest in synthesizing environmental data for integrated ecosystem assessments and for understanding interactions between anthropogenic activities on land and nearshore dynamics. There is no single location to access the abundance of water quality data that is collected on the Central Coast that would invariably be an integral part of such an assessment. Programs, station locations, and types of measurements change over time based on the funding and monitoring objectives that can change as new information becomes available. The dynamic nature of water quality monitoring programs further complicates the situation for the general data user.

A regional node for water quality data integration and reporting could serve to track the changes in monitoring programs, facilitate ongoing data integration, and develop a standardized system for ongoing analysis and reporting. Data could be served up in a multi-tiered way that would be appropriate for a wide spectrum of data users. For a general user, a user friendly 'report card' style report that would communicate water quality data using maps and graphics and be published on-line or in hard copy. Such a report could communicate both water quality studies by research organizations in the region as well as analysis of a multi-program integrated data set. Such a report could be structured to address some of the non-point source pollution questions that were dealt with in this report. A number of good models exist for integrated water quality data reporting including the San Francisco Estuary Institute's (SFEI) 'Pulse of the Estuary'. Such a reporting scheme would require a high level of coordination between organizations and could facilitate monitoring design coordination that optimized the goals of more than a single organization.

Access to raw water quality data could be accomplished with the development of the SAM database or improved movement of data from individual monitoring organizations to a central location such as the California Environmental Data Exchange Network (CEDEN) system.

5.7.3 Water quality data reporting recommendations

- Prioritize non-point source monitoring questions that would be most useful to address in an ongoing fashion and identify solutions to fill common information/resource needs.

- Identify the optimal spatial scale at which to address individual questions given available resources.

- Develop a standardized approach for evaluating water quality data and a reporting method that would be useful for reporting water quality conditions at regular intervals.

- Decide on the level of data access that will be provided to data users.

- Develop the regional data node. The SAM project should be viewed as a pilot project for a more comprehensive effort of regional water quality data synthesis and reporting.

LIST OF REFERENCES

Ahearn D.S., Sheibley, R.W., Dahlgren, R.A., Anderson, M., Johnson, J., Tate, K.W., 2005. Land use and land cover influence on water quality in the last free-flowing river draining the western sierra Nevada, California. Journal of Hydrology 313; 234-247.

Anderson B.S., Hunt, J.W., Phillips, B.M., Nicely, P.A., de Vlaming, V., Conner, V., Richard, N., Tjeerdema, R.S., 2003. Integrated assessment of the impacts of agricultural drainwater in the Salinas River (California, USA). Environmental Pollution 124: 523-532.

Anderson B.S., Phillips, B.M., Hunt, J.W., Worcester, K., Adams, M., Kapellas, N., Tjeerdema, R.S., 2006. Evidence of pesticide impacts in the Santa Maria River watershed. Environmental Toxicology and Chemistry Vol 25, 4:1160-1170.

Banks, K.E., Wachal, D.J., 2007. Water quality and land use; analyzing relationships among multiple watersheds using contingency analysis. Stormwater. January 2007.

Central Coast Regional Water Quality Control Board (CCRWQCB), 1984. Basin Plan. State Water Resources Control Board. http://www.swrcb.ca.gov/rwqcb3/BasinPlan/Index.htm

Central Coast Regional Water Quality Control Board (CCRRQCB), 2002. Morro Bay National Monitoring Program: Non-point Source Pollution and Treatment Measure Evaluation for the Morro Bay, Final Report. 60 p.

Central Coast Regional Water Quality Control Board (RWQCB), 2007. 2006 Management practice checklist update summary report. 60 p.

Clausen, J.C. and J. Spooner. 1993. *Paired Watershed Study Design*. Office of Water, U.S. Environmental Protection Agency, Washington, DC. EPA 841-F-93-009. 8 p.

Gale, J.A., D.E. Line, D.L. Osmond, S.W. Coffey, J. Spooner, J.A. Arnold, T.J. Hoban, and R.C. Wimberley. 1993. *Evaluation of the Experimental Rural Clean Water Program*. National Water Quality Evaluation Project, NCSU Water Quality Group, Biological and Agricultural Engineering Department, North Carolina State University, Raleigh, NC, EPA-841-R-93-005. 559 p.

Gerrodette, T., 1987. A power analysis for detecting trends. Ecoloty 68(5): 1364-1372

Hager, J., Watson, F., Bern, A., 2003. Chualar creek pilot project water quality monitoring March 2001 –December 2002. The Watershed Institute, CSU Monterey Bay, Seaside, CA 93955.Report WI-2003-08. Prepared for Central Coast Regional Water Quality Control Board, contract #: 9-168-130-0. http://science.csumb.edu/~ccows/pubs/reports/CCoWS_ChualarPilot_031113.pdf

Hager, J., Watson, F., Le, J., Olson, B., 2004. Watsonville Sloughs pathogen problems and sources. CSU Monterey Bay Watershed Institute. 116 p. http://science.csumb.edu/~ccows/ccows/pubs/reports/CCoWS_Wville_Pathogen_Final_040714.pdf

Hamill, K.D., McBride, G.B., 2003. River water quality trends and increased dairying in Southland, New Zealand. New Zealand Journal of Marine and Freshwater Research. 37: 323-332.

Harris, K., Larson, J., Watson, F., 2005. Agricultural Management Practices and Treatment Wetlands on the Gabilan Watershed: Monitoring Plan. California State University, Monterey Bay, Report No.

Helsel, D.R., 2005. Nondetects and Data Analysis. Wiley. p. 268.

Helsel, R. D., Hirsch, R. M., 1988. "Applicability of the t-test for detecting trends in water quality" by Robert H. Montgomery and Jim C. Loftis. Journal of American Water Resources Association 24 (1), 201–204.

Helsel, D.R., Hirsch, R.M., 1992. Statistical Methods in Water resources. Elsevier, New York

Hirsch, R.M., Alexander, R.B., Smith, R.A. 1991. Selection of methods for detection and estimation of trends in water quality. Water Resources Research 27: 803-813.

Hirsch, R.M., Slack, J.R., smith, R.A., 1982. Techniques or trend analysis for monthly water quality data. Water Resources Research 18:107-121.

Hunt et al., 2006. Surface Water Quality Monitoring Network Optimization Comprehensive Report to the South Florida Water Management District. # C-15968-WO04-11.

Hunt, J.W., Anderson, B.S., Phillips, B.M., Nicely, P.N., Tjeerdema, R.S., Puckett, H.M., Stephenson, M., Worcester, K., De Vlaming, V., 2002. Ambient Toxicity Due to Chlorpyrifos and Diazinon in a Central California Coastal Watershed. Environmental Monitoring and Assessment 82: 83-112, 2003.

Hunt, J.W., Anderson, B.S., Phillips, B.M., Tjeerdema, R., R.S., Puckett, H.M., De Vlaming, V., 1999. Patterns of aquatic toxicity in an agrigulturally dominated coastal watershed in California. Agric. Ecosyst. Environ, 75: 75-91.

Ice, G., Whittemore, R., 1998. Alternatives for Evaluating Water Quality and BMP Effectivenes at the Watershed Scale. National Water Quality Monitoring Conference Proceedings http://www.nwqmc.org/98proceedings/Papers/08-ICE.html

King, R.S., Baker, M.E., Whigham, D.G., Weller, D.E., Jordan, T.E., Kazyak, P.F., Hurd, M.K., 2005. Spatial conciderations for linking watershed land cover to ecological indicators in streams. Ecological Applications 15(1): 137-153.

Kolowski D., Watson, F., Angelo, M., Larson, J. 2004. Monitoring chlorpyrifos and diazinon in impaired surface waters of the lower Salinas region. CSU Monterey Bay Watershed Institute. Report to the Central Coast Regional Water Quality Control Board. Agreement 9-168-130-0. http://www.cdpr.ca.gov/docs/emon/surfwtr/contracts/cacoastrpt.pdf

Lettenmaier, D.P., 1988. Multivariate tests for trend in water quality. Water Resources Research 27: 505-512.

Lisbester, C. Grimball, A., 2002. Performance of partial Mann-Kendall tests for trend detection in the presence of covariates. Environmetrics 13: 71-84.

Loftis, J.C., MacDonald, L.H., Streett, S., Iyer, H.K., Bunte, K., 2001. Detecting cumulative watershed effects: the statistical power of pairing. Journal of Hydrology, 251, 49-64.

Los Huertos, M., Gentry, L., Shennan, C. 2003. Land Use and Water Quality on California's Central Coast: Nutrient Levels in Coastal Waterways. UCSC News Brief #2

Mann, H.B., 1945. Non-parametric tests against trend. Econometrica 13: 245-259

Monterey Bay Sanctuary, 2006. Draft Management Plan. pp. 425

Moyle, P.B., 1976. Inland Fishes of California. University of California Press, Berkeley.

Rice, J.M, Spooner, J., Cook, M.G., Stone, K.C., Coffey, S.W., Humenik, f.J., Hunt, P.G., 1998. *In: Proceedings of the 1998 National Water Quality Monitoring Conference.*

San Jose State University (SJSU) - Department of Civil Engineering and Applied Mechanics, Merritt Smith Consulting 1994. The Establishment of Nutrient Objectives, Sources, Impacts, and Best Management Practices for the Pajaro River and Llagas Creek. Prepared for California State Water Resources Control Board – Division of Water Quality, Regional Water Quality Control Board – Central Coast Region. Contract No. 0-212-253-0. (Also known as: Williamson et al., 1994)

Schoonover, J.E., Lockaby, B.G., 2006. Land Cover impacts on stream nutrients and fecal coliform in the lower Piedmont of West Georgia. Journal of Hydrology, 331: 371-382.

Sen, P.K., 1968 estimates of the regression coefficient based on Kendall's Tau. Journal of the American statistical Association, V. 63, p. 1379-1389.

Smith, D. G., McBride, G. B., Bryers, G. G., Wisse, J., Mink, D. F. J., 1996. Trends in New Zealand's National River Water Quality Network. *New Zealand Journal of Marine and Freshwater Research 30:* 485-500.

Spooner, J., Maas, S.A., Dressing, Smolen, M.D., Humenik, F.J., 1985. Appropriate Designs for documenting Water Quality Improvements from NPS Control Programs. *In: Perspectives on Nonpoint source Pollution.* EPA 440/5-85-001. pp 30-34

Spooner, J., Line D.E., Coffey, S.W., Osmond, D.L., Gale, J.A., 1995. Linking Water Quality Trends with Land Treatment Trends. http://www.bae.ncsu.edu/programs/extension/wqg/brochures/ten.html

State Water Resources Control Board (SWRCB), 2007. 303(d) Listing Policy Training Course.

Tsegaye, T., Sheppard, D., Islam, K.R., Johnson, A., Tadesse, W., Atalay, A., Marzen, L., 2006. Development of chemical index as a measure of in stream water quality in response to land-use and land cover changes. Water, Air, and soil Pollution, 174: 161-179.

United States Environmental Protection Agency (U.S. EPA), 1994. Guidance for the data quality objectives process. EPA QA/G-4 http://www.hanford.gov/dqo/project/level4/Epaqag4.pdf

United States Environmental Protection Agency (U.S. EPA), 2000. Ambient Water Quality Criteria Recommendations; Rivers and Streams in Nutrient Ecoregion III. http://www.epa.gov/waterscience/criteria/nutrient/ecoregions/rivers/rivers_3.pdf

United States Geological Survey, 2000. Trends in Surface-Water Quality During Implementation of Best Management Practices in Mill Creek and Muddy Run Basins, Lancaster County, Pennsylvania. USGS Fact Sheet 168-99 http://pa.water.usgs.gov/reports/fs168-99.pdf

Van Sickle, J., 2003. Analyzing correlations between stream and watershed attributes. Journal of the American Water Resources Association 39: 717-726.

Worcester, K., Kolb, H., Paradies, D., Adams, M., Berman, D., 1998 revised 2003. Pajaro River Watershed Characterization Report 1998 – Revised 2003. Prepared for Central Coast Regional Water Quality Control Board.

Yagaw, G., Dillaha, T., Pease, J., Kibler, D., Bosch, D., 2002. A BMP Database for Nutrient Reduction. *In: Total Maximum Daly Load (TMDL) Environmental Regulations: Proceedings of the 2002 Conference. pp. 250-255.*

APPENDIX 1. Parameter category divisions

Physical	**Nutrients**	**Inorganics**
Air Temperature	Ammonia as N	Boron
Color	Ammonia as N, Total	Boron, dissolved
Discharge	Ammonia as N, Unionized	Calcium
Oxygen, Dissolved	Ammonia as NH3	CarbonDioxide
Oxygen, Saturation	Ammonia as NH4	Chloride
pH	Ammonia + organic nitrogen	Chlorine
Riparian Corridor Shading	Nitrate	Chlorophyll a
Salinity	Nitrate + Nitrite as N	Chlorophyll b
SpecificConductivity	Nitrate as N	Detergent
Stage	Nitrate as NO3	Dissolved Solids, Fixed
Temperature	Nitrite as N	Dissolved Solids, Volatile
Tide Staff	Nitrogen, Organic	Hardness
Transparency	Nitrogen, Total	Hardness as CaCO3
Turbidity	Orthophosphate as P	Nitrogen, Total Kjeldahl
WaterClarity	OrthoPhosphate as PO4	Noncarbonate hardness as CaCO3
	Phosphate as P	Oil and Grease
Biological	Phosphorus as P	Phosphate, total as P
% Algal Cover	Urea as N	Sand 0.0625 to <2.0 mm
% algal Cover, filamentous		Silica
% algal Cover, periphyton	**Organics**	Silt 0.0039 to <0.0625 mm
Bank Plant Cover	Chlordanes	Silt > 0.0063 mm
Phytoplankton	Chlorpyrifos APC	Silt 0.0017 to < 0.0063 mm
	Chlorpyrifos BPC	Sodium
Bacteria	Chlorpyrifos SPCM	Solids, Volatile
Coliform	Dacthal	Sulfate
Coliform, Fecal	DDD	Suspended Solids, Fixed
Coliform, Total	DDE	Suspended Solids, Volatile
E. coli	DDT	Total Dissolved Solids
Enterococcus	Diazinon APC	Total Hardness as CaCO3
Streptococcus	Diazinon BPC	Total Organic Carbon
	Diazinon SPCM	Total Suspended Solids
Metals	Dieldrin	
Magnesium	Endosulfans	
Lead	HCHs	
Copper	Hi-PAHs	
Zinc	Lo-PAHs	
	PCBs	
	Phenol	

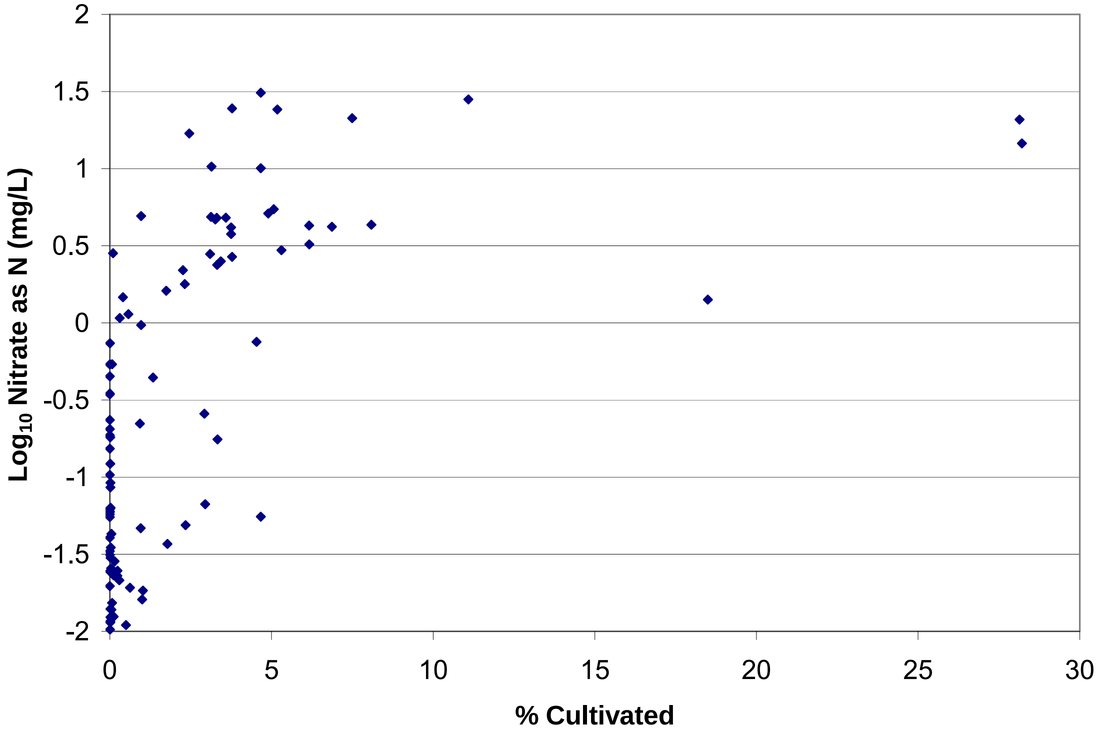
APPENDIX 2. Water quality variables (log_{10} values) used for partial correlations analysis

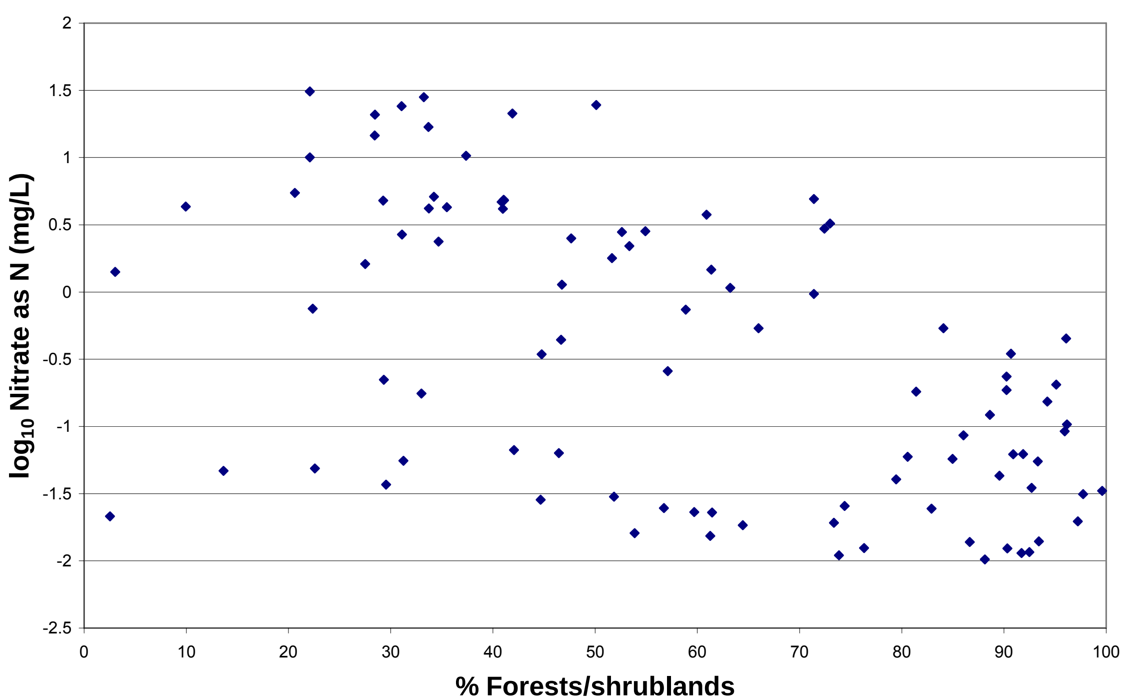
StationCode	Nitrate as N (mg/l)	Ammonia as N, Total (mg/l)	TSS (mg/l)	Fecal Coliform (mpn/100ml)	OrthoP as P (mg/l)	pH
304APS001	-1.48	-1.42	0.89	1.76	-0.88	0.92
304APT001	-0.74	-1.53	0.68	2.83	-0.80	0.91
304ARA001	-0.46	-1.13	0.68	2.70	-0.75	0.88
304BEP001	-1.21	-1.67	0.42	2.36	-1.18	0.91
304BH9001	-0.69	-1.59	0.65	2.04	-1.51	0.90
304BRA001	-0.27	-1.49	0.56	2.49	-0.88	0.88
304GAZ001	-1.26	-1.63	0.74	1.97	-1.52	0.89
304LOR001	-0.73	-1.44	0.79	2.69	-0.96	0.89
304RIV001	-0.63	-1.58	0.67	2.09	-0.97	0.91
304SCM001	-1.71	-1.61	0.15	1.27	-1.64	0.88
304SCO001	-1.37	-1.65	0.44	2.10	-1.34	0.88
304SL9001	-0.82	-1.59	0.52	2.30	-1.21	0.91
304SLB001	-0.46	-1.50	0.59	2.43	-0.95	0.90
304SLE001	-0.99	-1.52	0.57	2.57	-1.12	0.90
304SOK001	-1.24	-1.44	0.57	2.49	-1.05	0.91
304SOQ001	-1.61	-1.75	0.46	2.47	-1.00	0.91
304SOU001	-1.21	-1.42	0.76	1.95	-1.15	0.91
304VAL001	-0.35	-1.35	1.22	3.15	-0.73	0.91
304WAD001	-1.50	-1.58	0.53	1.68	-1.58	0.89
304ZAY001	-0.27	-1.44	0.51	2.52	-0.64	0.90
305BRI001	-1.64	-1.66	1.34	2.76	-2.15	0.93
305CAN001	0.69	-1.35	0.91	2.57	-1.26	0.89
305CHI001	0.69	-1.41	1.89	2.43	-1.09	0.91
305COR001	0.45	-1.41	1.01	2.52	-0.97	0.90
305COR200	-1.23	-1.34	0.69	2.25	-1.20	0.91
305FRA001	-1.26	-1.25	1.97	2.57	-1.43	0.92
305FUF001	1.49	-1.11	1.32	2.92	-0.81	0.90
305HAR001	-1.55	-0.96	1.75	3.04	-1.35	0.87
305HOL001	0.68	-1.37	0.71	2.46	-1.96	0.89
305LLA001	1.00	-1.22	1.13	2.65	-1.59	0.87
305MUR001	0.67	-1.51	1.65	2.32	-1.16	0.91
305PAC001	0.06	-1.52	0.72	2.40	-1.70	0.89
305PAJ001	0.71	-1.42	1.78	2.42	-1.26	0.90
305PJP001	0.68	-1.46	1.36	2.27	-1.00	0.91
305SAN001	-0.36	-1.48	1.69	2.87	-1.63	0.91

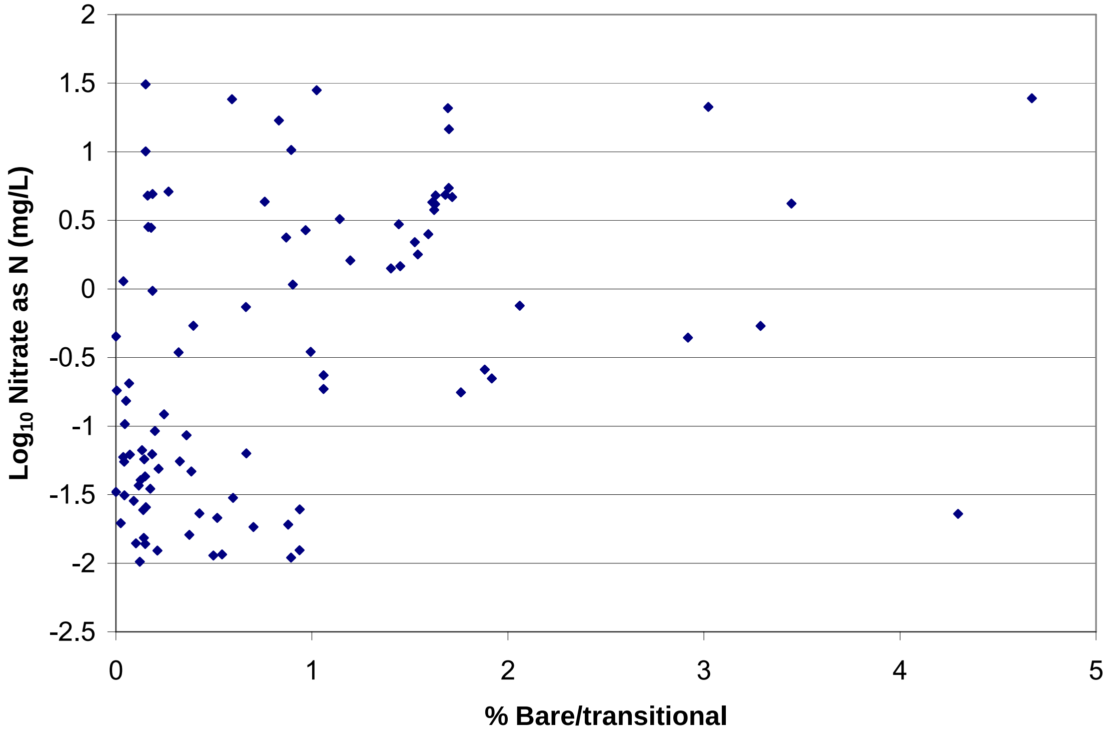
305SJN001	1.45	-1.32	0.85	3.00	-0.65	0.90
305STL001	-1.67	-0.86	0.91	1.89	-0.54	0.85
305THU001	0.62	-1.34	1.41	2.32	-1.40	0.90
305TRE001	-0.65	-1.53	1.33	2.56	-1.71	0.92
305UVA001	-0.01	-1.58	0.82	2.23	-1.80	0.90
305WSA001	0.15	-0.87	1.60	2.54	-0.38	0.86
307CMD001	-1.96	-2.25	-0.03	1.43	-2.10	0.90
307CML001	-1.72	-1.73	0.26	1.72	-1.85	0.88
307CMU001	-1.90	-2.17	-0.11	1.36	-2.01	0.90
307TUL001	-1.61	-2.12	0.68	2.61	-0.74	0.90
308BGC001	-1.46	-1.67	0.14	1.07	-2.17	0.92
308BSR001	-1.94	-1.66	0.02	1.51	-2.24	0.91
308BSU001	-1.94	-2.13	-0.11	1.03	-2.15	0.92
308GAR001	-1.04	-2.16	0.53	1.72	-1.74	0.90
308LIM001	-0.91	-2.17	-0.02	0.96	-2.24	0.92
308LSR001	-1.91	-1.79	0.30	1.26	-2.17	0.91
308MIL001	-1.07	-2.11	0.05	1.12	-2.23	0.91
308WLO001	-1.85	-1.71	-0.11	0.76	-2.18	0.92
309DAV001	0.62	-1.30	1.39	2.23	-1.43	0.90
309OLD001	1.16	-0.90	2.02	2.83	-0.69	0.91
309TDW001	1.32	-0.90	2.05	2.79	-0.47	0.91
310ADC001	-1.39	-1.70	0.04	1.77	-2.16	0.88
310AGB001	0.17	-1.84	0.68	2.18	-0.57	0.88
310AGF001	0.25	-1.78	0.55	2.55	-0.53	0.92
310AGS001	0.34	-1.79	0.73	2.29	-0.60	0.92
310ARG001	0.40	-1.53	0.66	2.58	-0.55	0.91
310BER001	0.63	-1.61	0.28	2.36	-0.39	0.88
310CAN001	0.43	-1.78	0.62	2.63	0.01	0.91
310CAY001	-1.33	-1.95	0.77	2.33	-1.71	0.91
310COO001	-1.86	-2.19	0.45	1.62	-0.38	0.91
310PCO001	-1.59	-2.01	0.04	1.55	-2.11	0.91
310PIS001	-0.75	-1.29	0.53	2.53	-0.06	0.89
310PRE001	1.38	-1.80	0.80	2.27	-0.78	0.88
310SCN001	0.21	-1.85	0.37	2.68	-1.05	0.91
310SCP001	-1.99	-2.12	-0.11	1.02	-2.30	0.89
310SLB001	1.01	-1.21	0.60	2.62	0.21	0.90
310SLC001	-1.52	-1.87	0.04	2.18	-0.96	0.90
310SLM001	-1.20	-1.93	-0.07	3.24	-0.91	0.92
310SLV001	1.23	-1.34	0.45	1.86	0.41	0.87
310SRO001	-1.43	-1.71	0.39	2.00	-1.69	0.91
310SRU001	-1.18	-2.01	0.76	2.25	-1.75	0.91

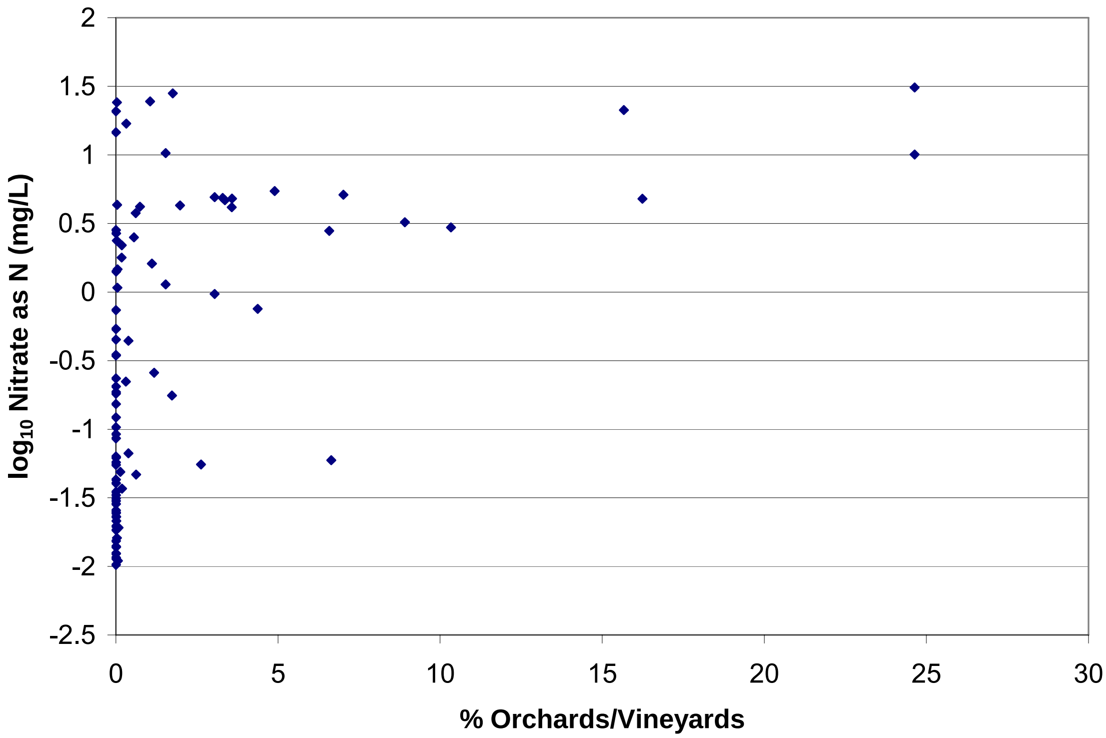
310SSC001	0.45	-1.63	0.26	1.95	-0.66	0.88
310SSU001	-1.82	-2.08	0.07	2.12	-2.23	0.91
310TOR001	-1.79	-2.19	0.37	2.60	-1.21	0.90
310TUR001	0.64	-1.77	1.43	2.54	-1.74	0.87
310TWB001	0.38	-1.47	0.44	2.17	-0.38	0.91
310VIA001	-1.31	-1.93	0.64	2.85	-1.68	0.92
312SMA001	1.39	-0.73	1.97	2.91	-0.43	0.89
313SAC001	-0.12	-1.20	1.03	1.81	0.15	0.87
313SAI001	0.74	-0.19	1.19	2.41	-0.03	0.89
314SYN001	0.58	-0.96	1.07	2.26	-0.03	0.89
315ABU001	0.03	-1.08	0.82	2.63	-1.40	0.88
315ATA001	-0.59	-1.41	0.79	2.42	-0.96	0.89
315CRP001	0.47	-1.46	0.62	2.33	-1.61	0.88
315FRC001	1.33	-1.46	0.83	2.92	-1.06	0.92
315GAV001	-1.64	-1.58	0.77	2.23	-1.59	0.90
315JAL001	-1.74	-1.61	0.69	2.11	-0.95	0.91
315MIS001	-0.13	-1.42	0.65	3.20	-1.39	0.89
315RIN001	0.51	-0.83	0.94	2.30	-1.61	0.89

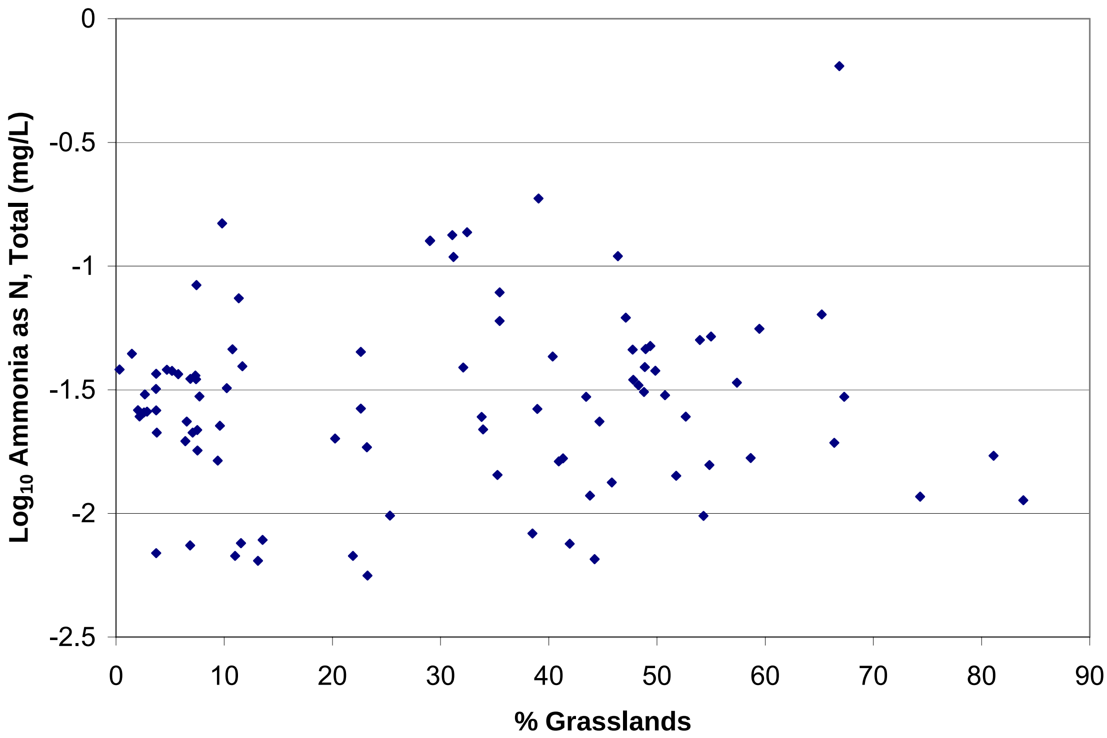
APPENDIX 3. Scatter plots for significant correlations between land use and water quality variables



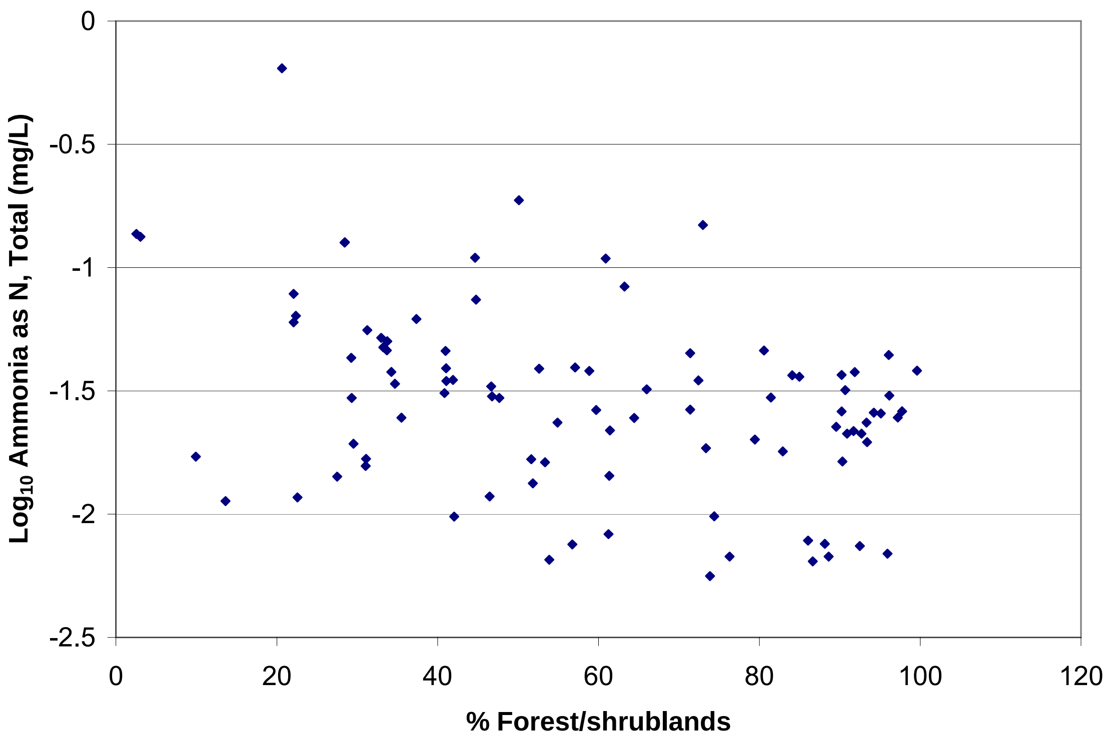



Log10 Nitrate as N (mg/L)
% Bare/transitional
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
0
1
2
3
4
5

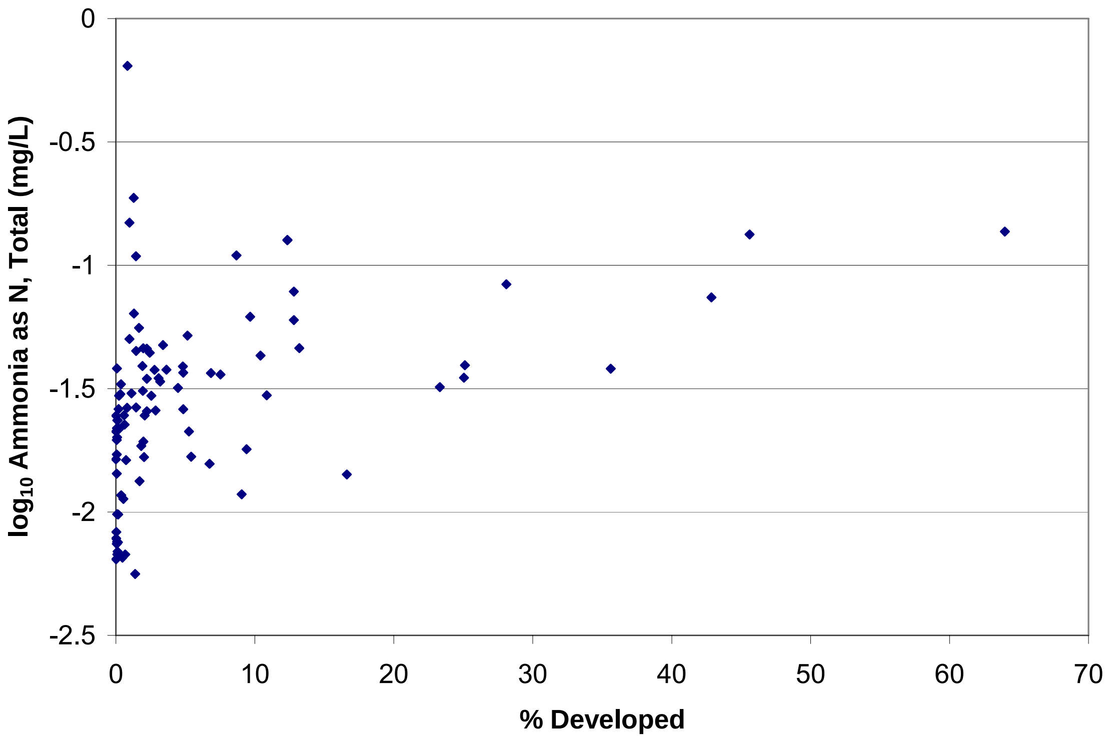

log10 Nitrate as N (mg/L)
% Orchards/Vineyards
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
0
5
10
15
20
25
30

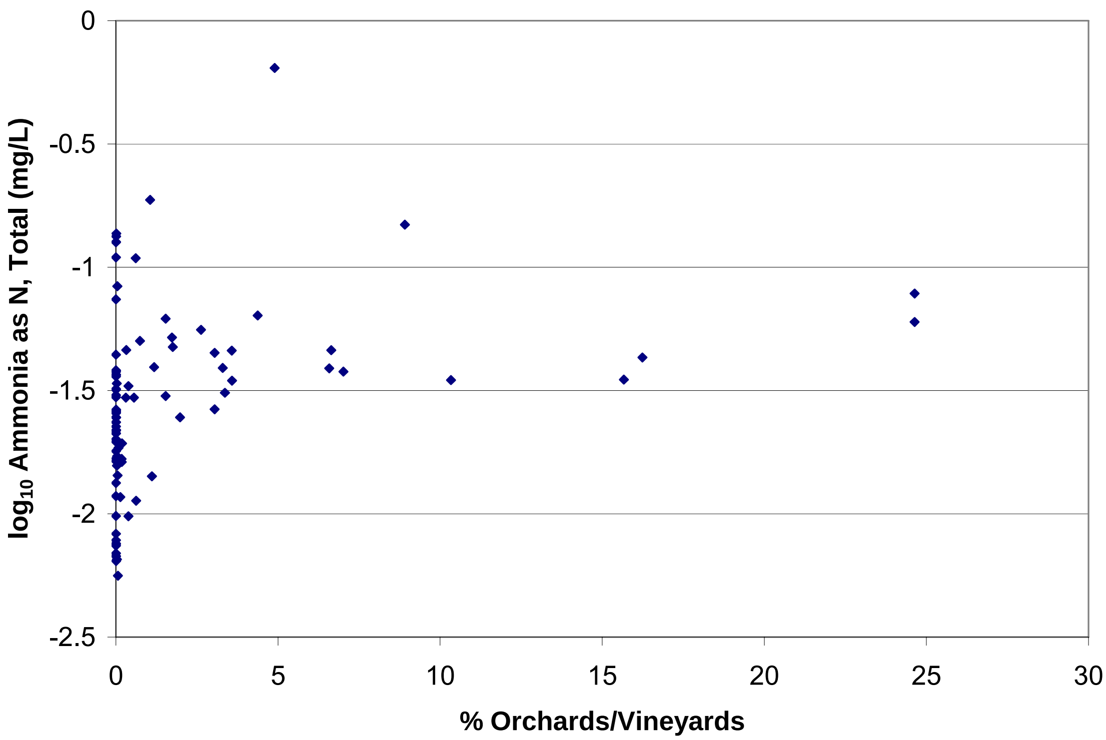


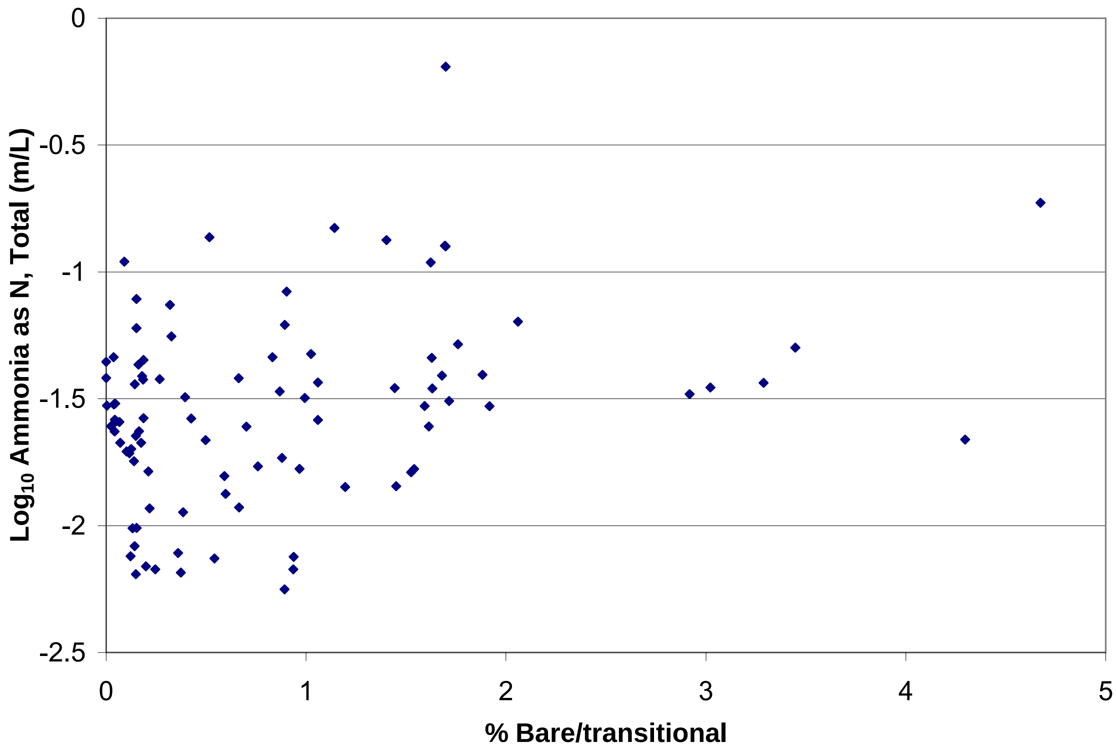
Log$_{10}$ Ammonia as N, Total (mg/L)
0
-0.5
-1
-1.5
-2
-2.5
0
10
20
30
40
50
60
70
80
90
% Grasslands

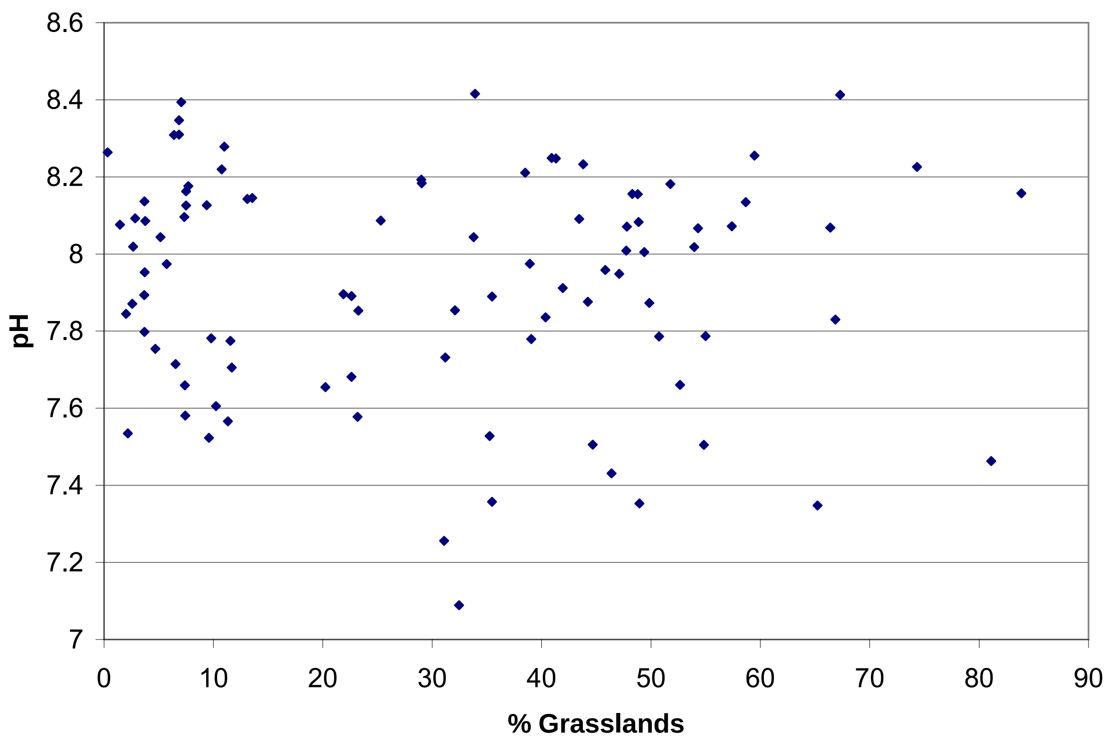


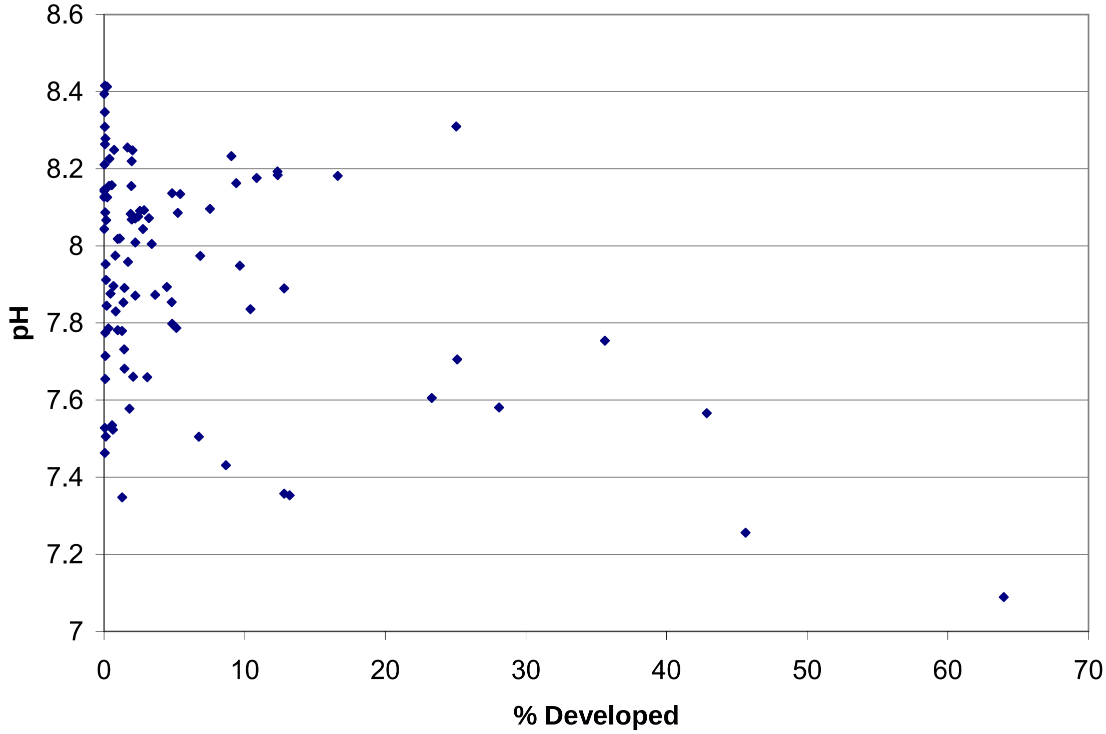
Log$_{10}$ Ammonia as N, Total (mg/L)
0
-0.5
-1
-1.5
-2
-2.5
0
20
40
60
80
100
120
% Forest/shrublands

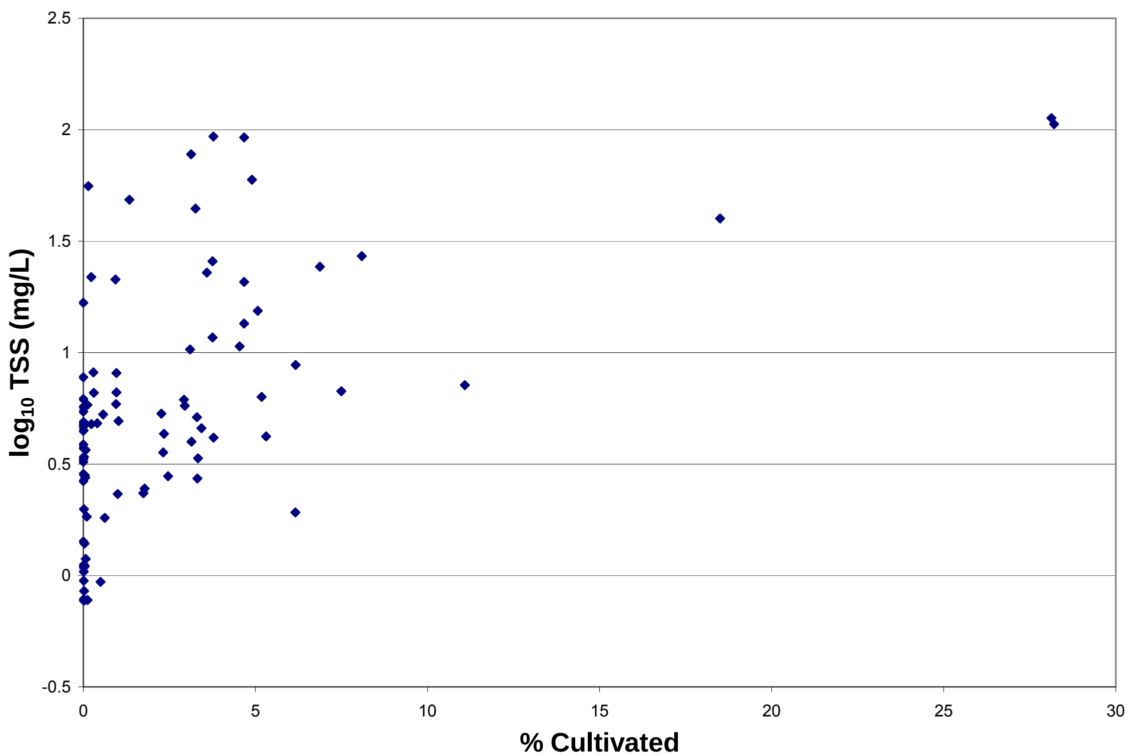

log10 Ammonia as N, Total (mg/L)
% Developed
0
-0.5
-1
-1.5
-2
-2.5
0
10
20
30
40
50
60
70

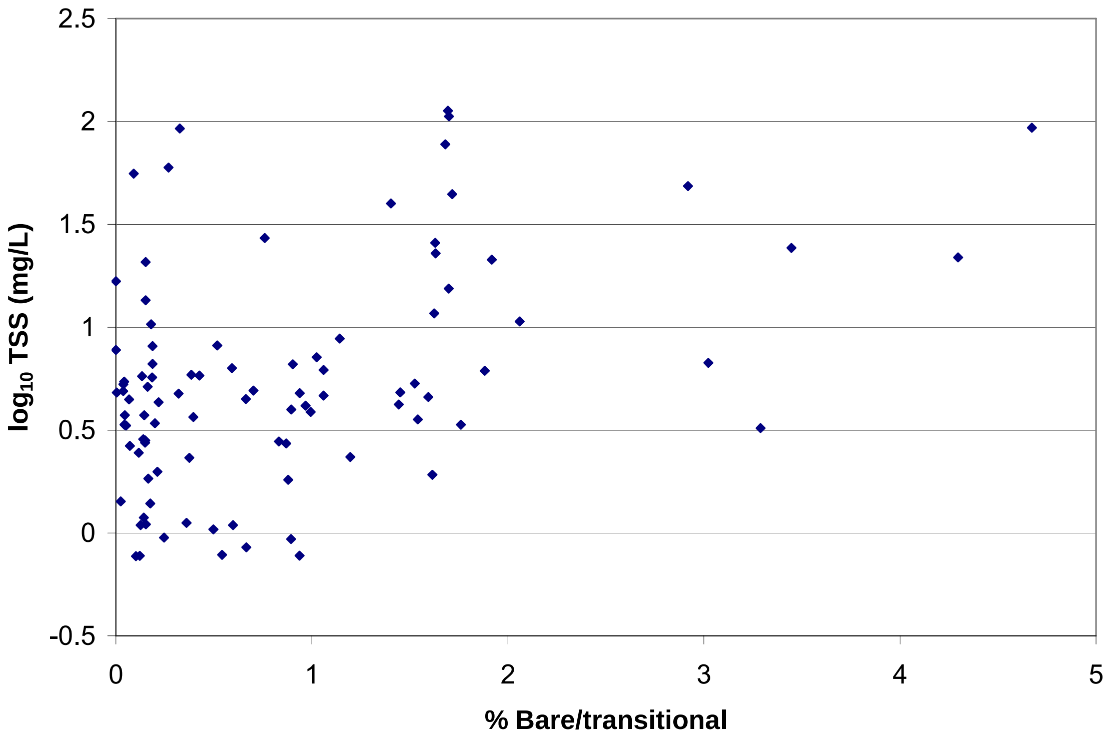

log10 Ammonia as N, Total (mg/L)
% Orchards/Vineyards
0
-0.5
-1
-1.5
-2
-2.5
0
5
10
15
20
25
30


Log10 Ammonia as N, Total (m/L)
0
-0.5
-1
-1.5
-2
-2.5
0
1
2
3
4
5
% Bare/transitional


pH
8.6
8.4
8.2
8
7.8
7.6
7.4
7.2
7
0
10
20
30
40
50
60
70
80
90
% Grasslands


8.6
8.4
8.2
8
7.8
7.6
7.4
7.2
7
pH
0
10
20
30
40
50
60
70
% Developed


2.5
2
1.5
1
0.5
0
-0.5
log10 TSS (mg/L)
0
5
10
15
20
25
30
% Cultivated



2.5
2
1.5
1
0.5
0
-0.5
$\log_{10}$ TSS (mg/L)
0
1
2
3
4
5
% Bare/transitional

APPENDIX 4 CCAMP Coastal Confluence stations trend results

Significant trends are shown in **bold** ($p < 0.05$, two tailed test). Units for Sen's slope estimator are the original measurement units per year - mg/L for total ammonia as N, nitrate as N , orthophosphate as P, dissolved oxygen (DO), and total suspended solids (TSS); °C for temperature, MPN/100 mL for fecal coliform)

Station	Value	Ammonia as N, total	Nitrate as N	OrthoP as P	DO	pH	Temp	TSS	Fecal Coliform
304APT001	Samples	33	33	33	33	**35**	35	33	32
	S	14	9	-9	-5	**-22**	-9	9	-3
	p-value	0.113	0.303	0.163	0.477	**0.046**	0.180	0.176	0.502
	Sen	0.019	0.038	-0.066	-0.028	**-0.066**	-0.381	0.575	-110.000
304GAZ001	Samples	44	44	**44**	31	46	46	43	43
	S	-7	-1	**-29**	-10	-11	-27	6	-22
	p-value	0.646	0.951	**0.023**	0.088	0.479	0.055	0.324	0.060
	Sen	-0.001	-0.002	**-0.007**	-0.298	-0.007	-0.346	0.556	-88.375
304LOR001	Samples	49	**49**	49	**133**	51	51	47	48
	S	14	**33**	8	**-138**	-3	-37	10	-8
	p-value	0.314	**0.023**	0.562	**0.010**	0.718	0.143	0.422	0.390
	Sen	0.000	**0.036**	-0.033	**-0.146**	-0.033	-0.750	0.555	-50.333
304SCO001	Samples	46	46	46	35	49	49	**44**	44
	S	7	36	-24	4	-7	-23	**14**	-10
	p-value	0.642	0.074	0.105	0.540	0.632	0.212	**0.050**	0.396
	Sen	0.004	0.009	0.002	0.188	0.002	-0.266	**0.300**	-13.750
304WAD001	Samples	48	48	48	33	51	51	46	47
	S	19	28	1	5	1	-13	31	27
	p-value	0.237	0.070	0.939	0.463	0.936	0.473	0.073	0.356
	Sen	0.003	0.009	-0.004	0.210	-0.004	-0.146	0.733	7.083
305THU001	Samples	60	60	60	45	61	61	59	56
	S	-19	31	43	3	15	7	-19	-36
	p-value	0.405	0.082	0.085	0.826	0.356	0.829	0.436	0.152
	Sen	-0.002	0.342	0.356	0.063	0.013	-0.001	-0.868	1.625
307CML001	Samples	27	27	27	20	27	27	27	27
	S	5	18	-2	2	-11	-17	10	-1
	p-value	0.687	0.099	0.759	0.681	0.247	0.126	0.249	0.898
	Sen	0.000	0.007	0.681	0.040	-0.055	-0.926	0.220	-5.450
308BGC001	Samples	50	50	50	37	52	52	48	**49**
	S	19	2	-15	-2	-23	-17	2	**-36**
	p-value	0.377	0.880	0.101	0.704	0.369	0.296	0.634	**0.026**
	Sen	0.004	-0.001	-0.369	0.080	-0.043	-0.102	0.100	**-9.250**

Station	Value	Ammonia as N, total	Nitrate as N	OrthoP as P	DO	pH	Temp	TSS	Fecal Coliform
308BSR001	Samples	50	50	50	37	52	52	49	49
	S	20	2	-7	-3	-11	-22	22	-20
	p-value	0.409	0.733	0.225	0.641	0.511	0.228		0.218
	Sen	0.004	0.000	-0.511	-0.057	-0.039	-0.308	0.293	-41.310
308LSR001	Samples	36	**36**	36	21	38	38	35	35
	S	11	**15**	-5	-3	-12	-6	11	-3
	p-value	0.317	**0.034**	0.077	0.066	0.296	0.478	0.088	0.730
	Sen	0.000	**0.003**	-0.077	-0.580	-0.039	-0.061	0.313	0.578
308WLO001	Samples	50	50	50	37	52	52	48	49
	S	14	7	-28	4	-13	-18	4	-11
	p-value	0.578	0.611	0.075	0.592	0.575	0.234	0.421	0.578
	Sen	0.002	0.000	-0.575	0.090	-0.030	-0.091	0.000	-0.167
309DAV001	Samples	57	57	57	**45**	62	61	55	58
	S	-17	-10	0	**-37**	-29	8	21	5
	p-value	0.330	0.519	1.000	**0.049**	0.350	0.560	0.303	0.654
	Sen	-0.003	0.000	0.000	**-0.609**	0.000	0.000	0.000	-1.800
309OLD001	Samples	60	**60**	**60**	144	**63**	64	58	57
	S	-4	**36**	**49**	109	**-55**	4	5	3
	p-value	0.695	**0.047**	**0.027**	0.203	**0.031**	0.767	0.777	0.874
	Sen	0.004	**1.568**	**0.031**	0.204	**-0.078**	-0.060	-0.383	-4.438
309TDW001	Samples	50	50	50	35	52	52	48	51
	S	8	5	19	-6	-26	6	-7	-11
	p-value	0.224	0.431	0.192	0.281	0.090	0.703	0.601	0.489
	Sen	0.013	-0.120	0.192	-0.295	-0.066	0.320	-5.050	2.356
310ADC001	Samples	36	36	36	25	36	36	35	36
	S	5	-10	-5	7	22	-4	9	0
	p-value	0.742	0.166	0.324	0.077	0.057	0.206		1.000
	Sen	0.000	-0.001	0.077	0.054	0.041	-0.213	0.113	-133.500
310ARG001	Samples	52	52	52	**34**	54	54	50	51
	S	0	48	25	**-17**	-15	-22	7	2
	p-value	1.000	0.109	0.064	**0.021**	0.397	0.313	0.711	0.846
	Sen	0.003	0.492	0.064	**-0.700**	-0.052	-0.262	0.091	-2.188
310PIS001	Samples	52	52	52	33	53	53	50	51
	S	7	9	-3	-17	9	-13	16	4
	p-value	0.722	0.734	0.897	0.054	0.607	0.089	0.344	0.808
	Sen	0.005	0.030	-0.607	-0.483	-0.003	-0.096	0.250	5.813

Station	Value	Ammonia as N, total	Nitrate as N	OrthoP as P	DO	pH	Temp	TSS	Fecal Coliform
310SLB001	Samples	53	53	53	35	55	55	51	52
	S	-26	-44	-33	4	16	-29	23	5
	p-value	0.173	0.080	0.213	0.718	0.240	0.066	0.129	0.605
	Sen	-0.005	-1.053	-0.240	0.130	0.011	-0.095	0.446	-2.188
310SRO001	Samples	49	49	49	**32**	51	**51**	49	47
	S	8	13	2	**-14**	-8	**-22**	-3	20
	p-value	0.616	0.194	0.793	**0.050**	0.676	**0.046**	0.428	0.088
	Sen	0.002	0.000	0.676	**-0.719**	0.007	**-0.297**	0.100	19.792
310SSC001	Samples	48	48	48	32	49	**49**	46	47
	S	1	1	-1	2	18	**-6**	5	-11
	p-value	0.947	0.912	0.901	0.749	0.296	**0.451**	0.735	0.214
	Sen	0.004	-0.111	0.749	-0.074	0.031	0.048	0.050	4.375
310TWB001	Samples	53	**53**	53	35	55	55	52	51
	S	-7	**49**	-54	0	-3	-17	-7	1
	p-value	0.691	**0.038**	0.105	1.000	0.913	0.354	0.603	0.923
	Sen	-0.002	**0.408**	0.913	0.144	-0.017	-0.194	-0.200	23.250
312SMA001	Samples	67	67	67	47	68	66	65	65
	S	33	41	8	15	-8	-24	-17	7
	p-value	0.158	0.158	0.932	0.233	0.824	0.500	0.381	0.336
	Sen	0.032	0.871	0.701	0.141	-0.038	-0.112	-1.125	-10.850
313SAC001	Samples	**21**	21	**21**	**21**	21	**21**	**19**	20
	S	**-6**	-2	**-8**	**-6**	0	**4**	**-7**	-1
	p-value	**0.002**	0.296	**0.000**	**0.002**	1.000	**0.037**	**0.000**	0.602
	Sen	**-0.052**	-0.105	**-0.002**	**-0.810**	0.050	**1.415**	**-16.10**	0.625
313SAI001	Samples	30	45	45	43	46	46	45	44
	S	2	31	10	29	-25	-41	-28	-16
	p-value	0.817	0.116	0.419	0.057	0.203	0.097	0.157	0.128
	Sen	0.010	0.688	0.203	0.196	-0.065	-1.103	-4.618	29.167
314SYN001	Samples	51	51	51	32	52	52	49	49
	S	-2	1	-3	-3	-14	-28	-6	7
	p-value	0.893	0.924	0.782	0.755	0.555	0.073	0.709	0.658
	Sen	0.000	0.279	0.755	-0.658	-0.028	-0.620	-0.860	-735.000
315ABU001	Samples	53	53	**52**	37	55	55	51	52
	S	-8	-1	**-34**	-12	10	-14	-25	-15
	p-value	0.617	0.958	**0.049**	0.324	0.687	0.596	0.196	0.253
	Sen	0.004	0.027	**-0.324**	-0.295	0.005	-0.206	-0.729	-119.875

Station	Value	Ammonia as N, total	Nitrate as N	OrthoP as P	DO	pH	Temp	TSS	Fecal Coliform
315ATA001	Samples	54	54	53	36	56	56	**52**	54
	S	24	16	1	-3	-26	-30	**-20**	-10
	p-value	0.22741	0.119	0.96668	0.61869	0.20635	0.10915	**0.0455**	0.572528
	Sen	0.011	0.025	0.619	-0.667	-0.042	-0.413	**-0.188**	6.979
315CRP001	Samples	55	55	54	37	57	57	53	55
	S	-6	-6	-36	-22	15	1	9	-2
	p-value	0.768	0.417	0.235	0.115	0.663	0.951	0.584	0.866
	Sen	0.000	-0.071	-0.144	-0.678	0.030	-0.166	0.263	-25.500
315FRC001	Samples	54	54	**53**	37	56	56	52	54
	S	-23	-22	**-50**	2	2	12	-10	-9
	p-value	0.324	0.283	**0.041**	0.801	0.922	0.531	0.325	0.460
	Sen	-0.007	-0.592	**-0.801**	-0.011	0.011	0.124	-0.780	-25.083
315GAV001	Samples	49	49	48	31	51	51	49	49
	S	15	-3	8	-11	0	25	-5	24
	p-value	0.424	0.799	0.443	0.226	1.000	0.358	0.695	0.073
	Sen	0.002	0.000	0.000	-0.303	-0.027	0.270	-0.340	10.125
315JAL001	Samples	33	33	32	21	34	34	33	32
	S	-2	1	-16	6	2	10	-1	3
	p-value	0.738	0.712	0.161	0.066	0.789	0.155	0.59	0.26
	Sen	-0.001	0.000	-0.010	0.164	0.005	0.478	-0.040	-100.000
315MIS001	Samples	55	55	**54**	37	57	57	53	55
	S	20	-5	**-41**	-6	-2	-3	21	-13
	p-value	0.196	0.810	**0.039**	0.586	0.937	0.899	0.139	0.519
	Sen	0.004	-0.010	**-0.007**	-0.415	0.007	0.100	0.367	26.700
315RIN001	Samples	55	55	54	37	57	57	53	55
	S	-1	16	-33	-18	4	5	-16	0
	p-value	0.962	0.307	0.131	0.055	0.903	0.843	0.369	1.000
	Sen	-0.007	0.220	-0.003	-0.321	-0.007	0.034	-1.162	15.667

APPENDIX 5 Plots for CCAMP Coastal Confluence Stations Significant Trends

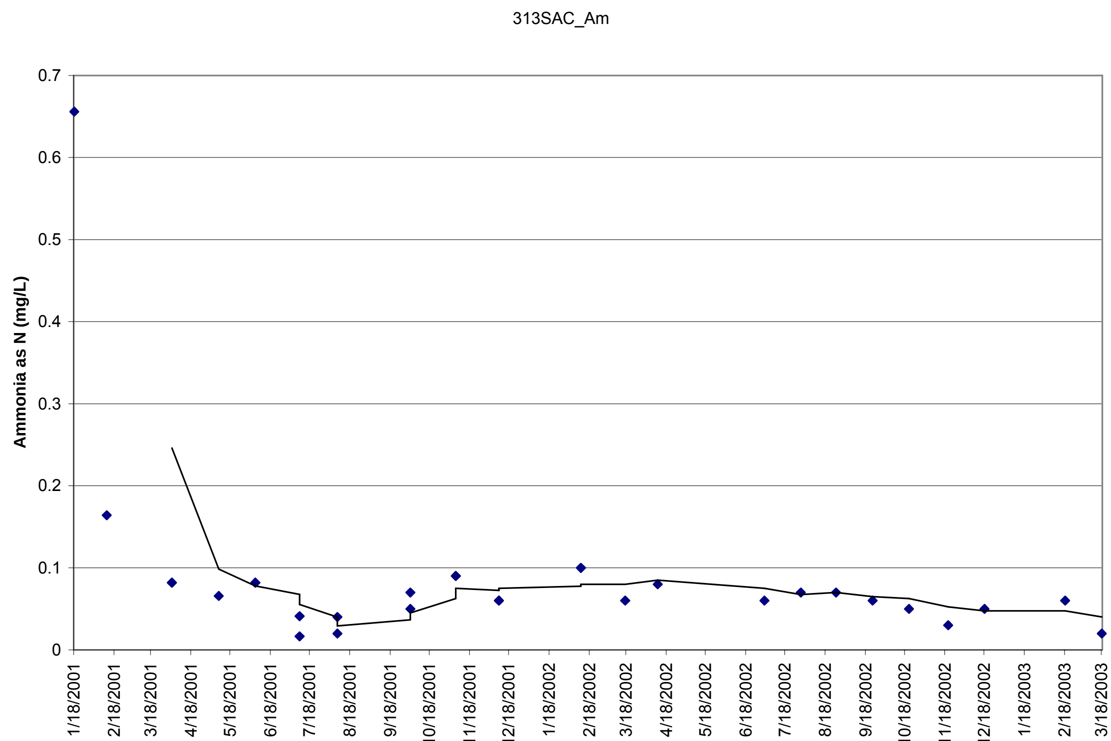


Figure A5.1

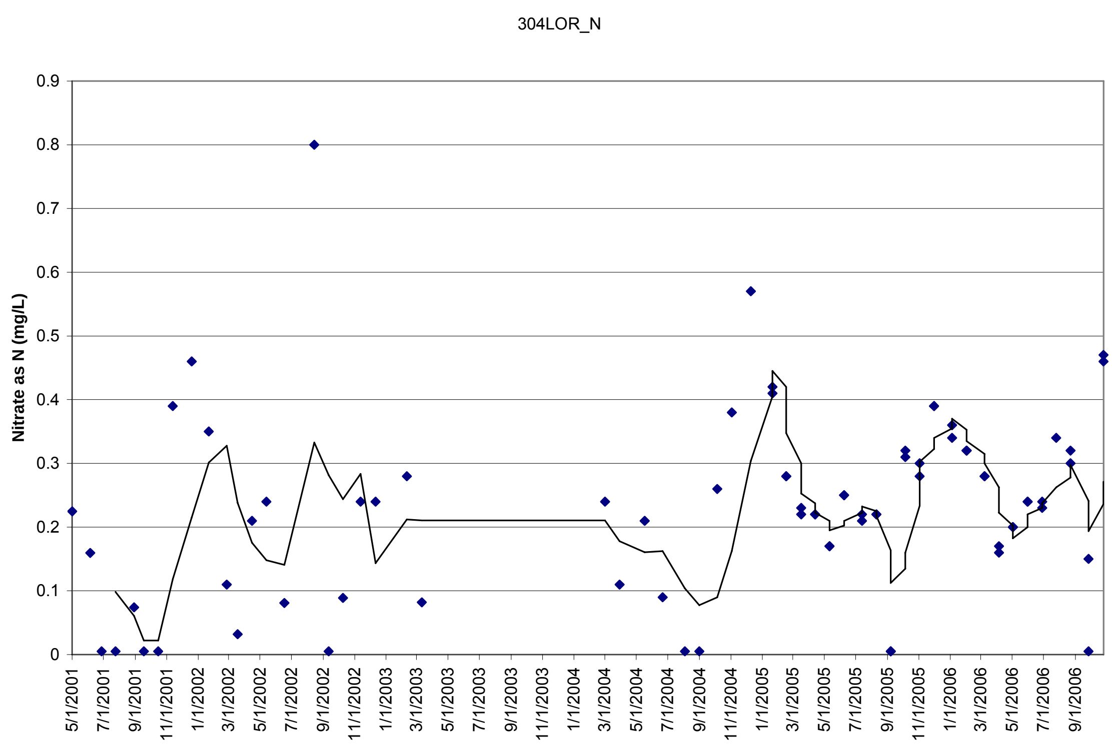


Figure A5.2

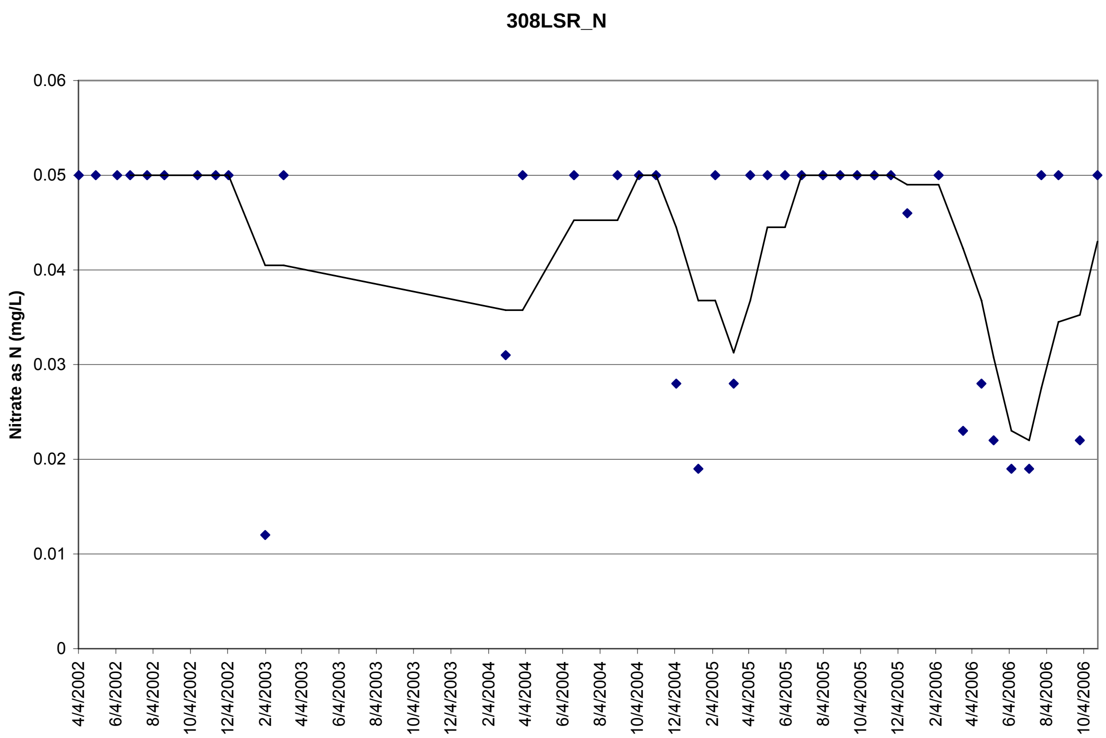


Figure A5.3

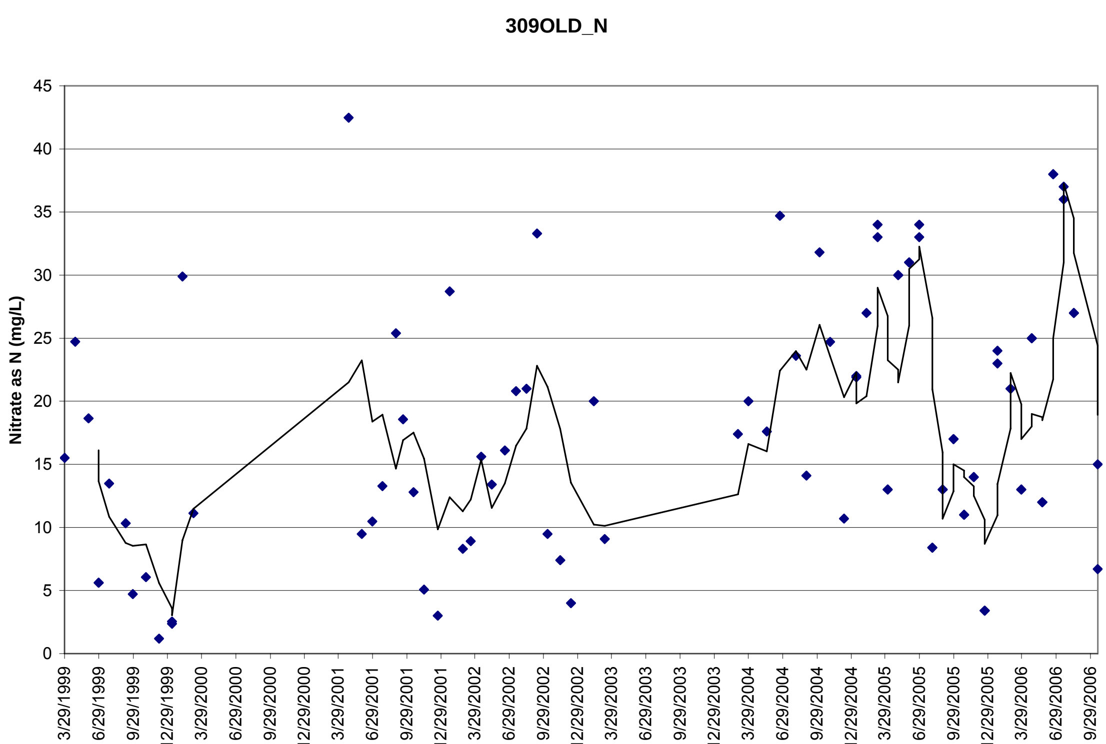


Figure A5.4

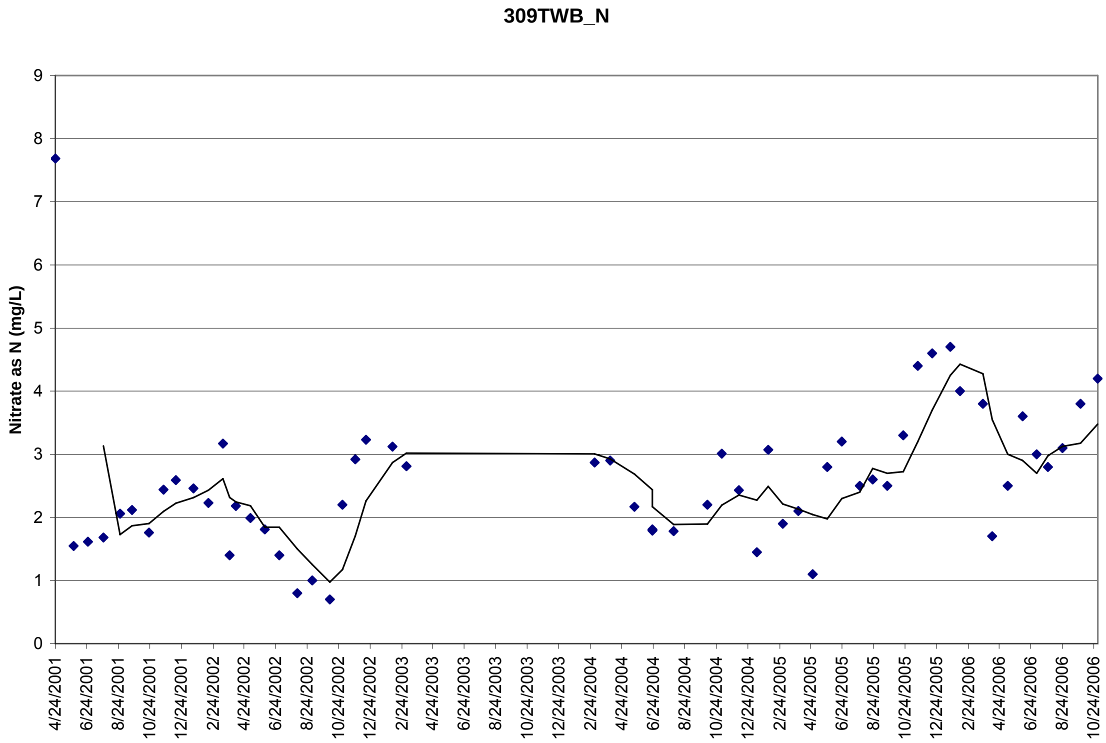


Figure A5.5

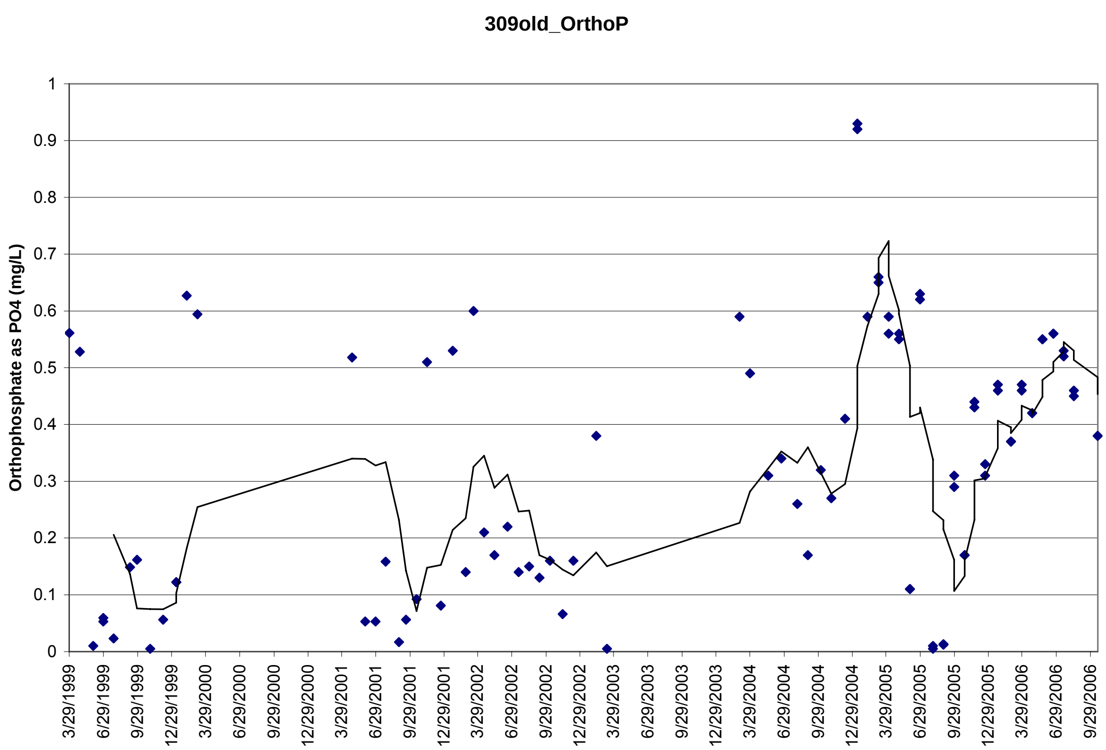


Figure A5.6

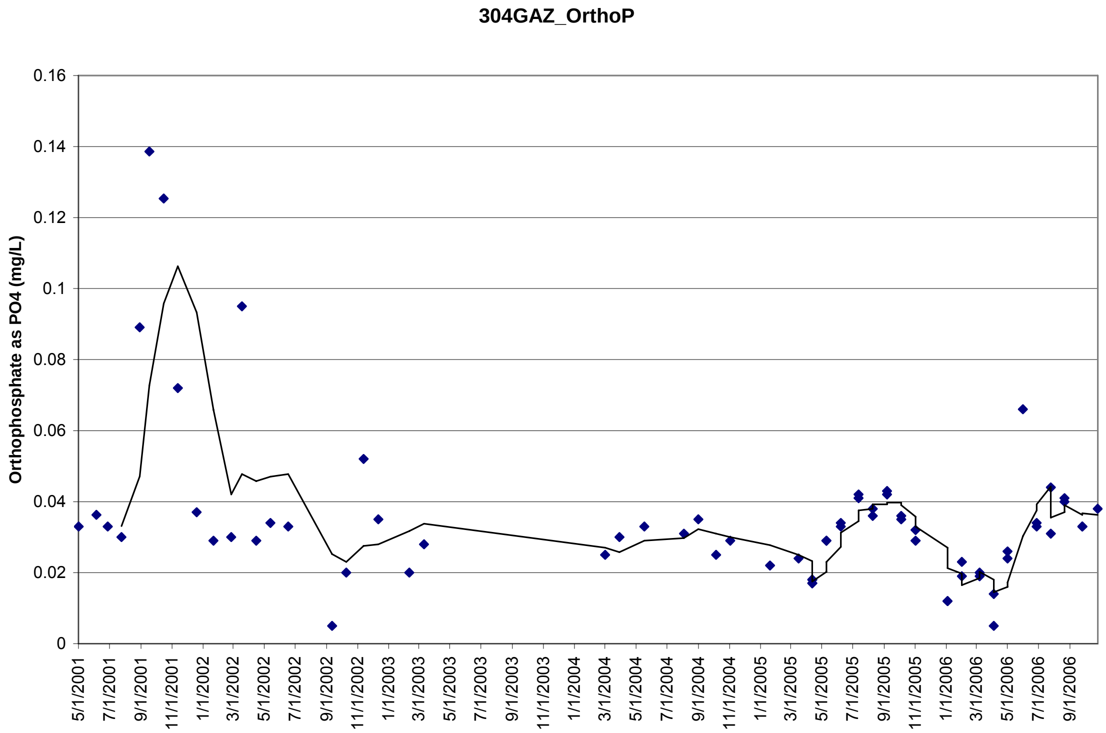


Figure A5.7

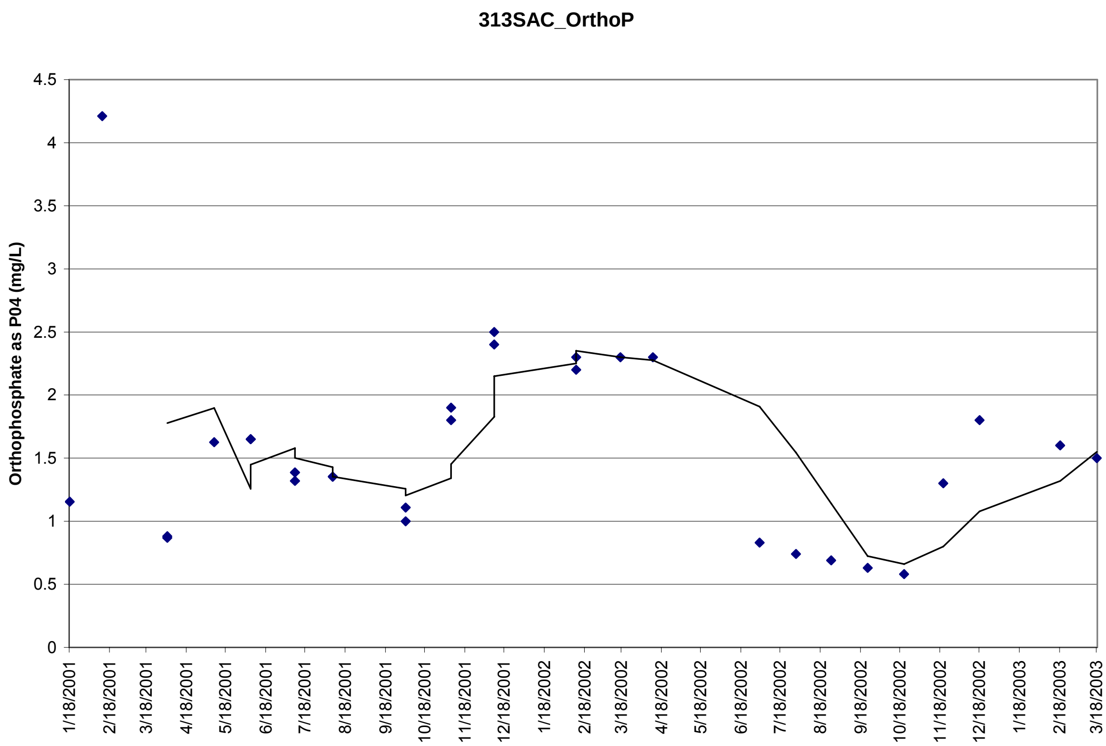


Figure A5.8

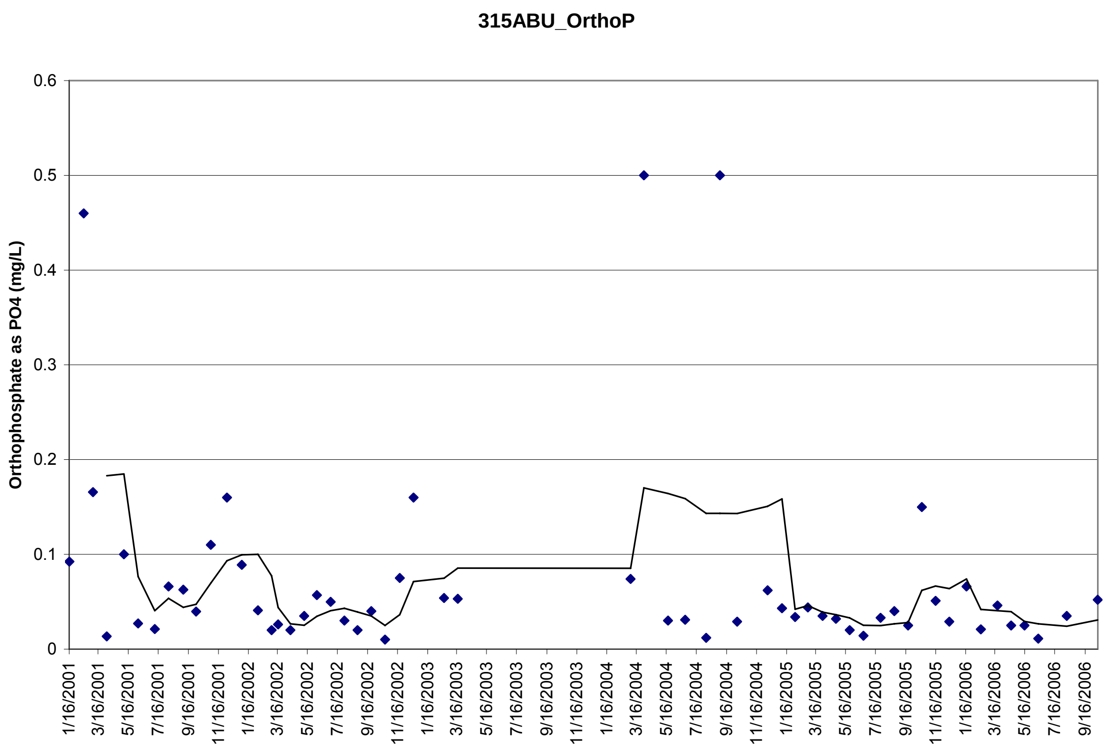


Figure A5.9

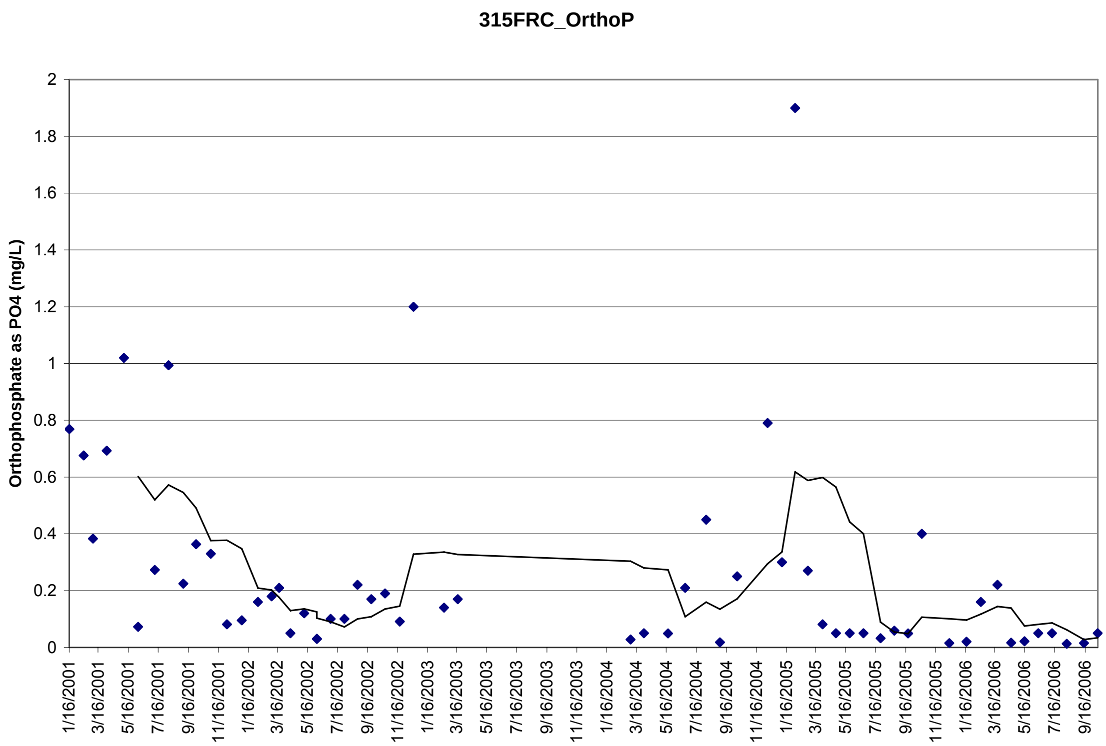


Figure A5.10

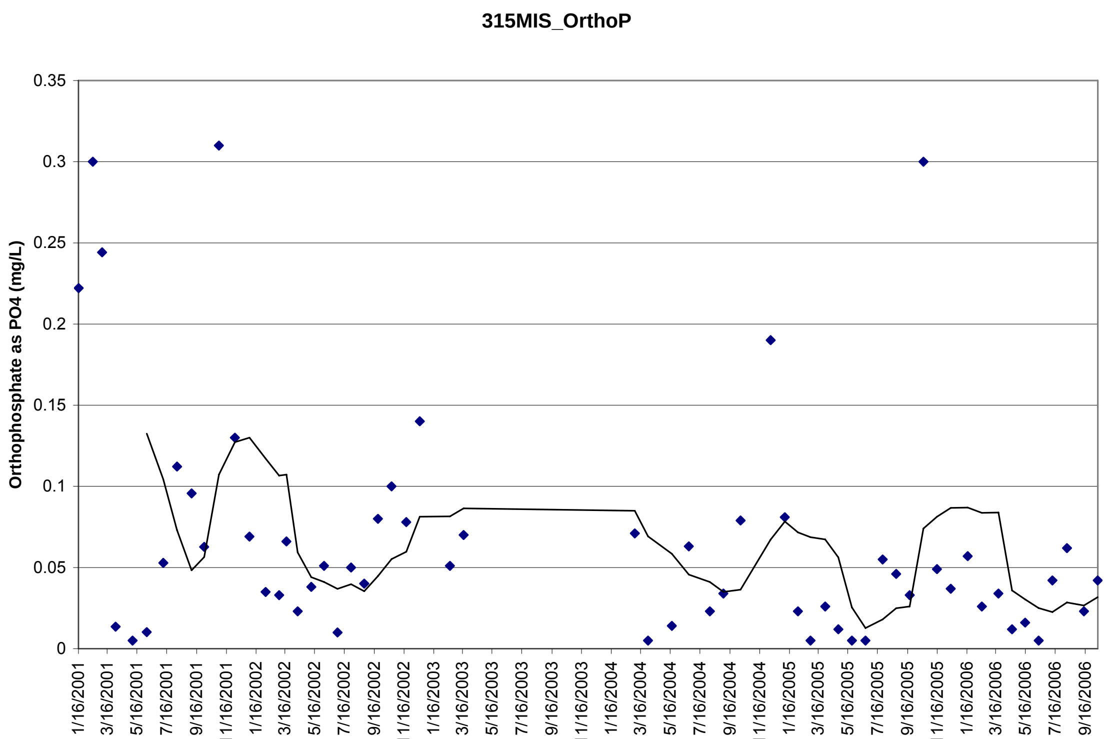


Figure A5.11

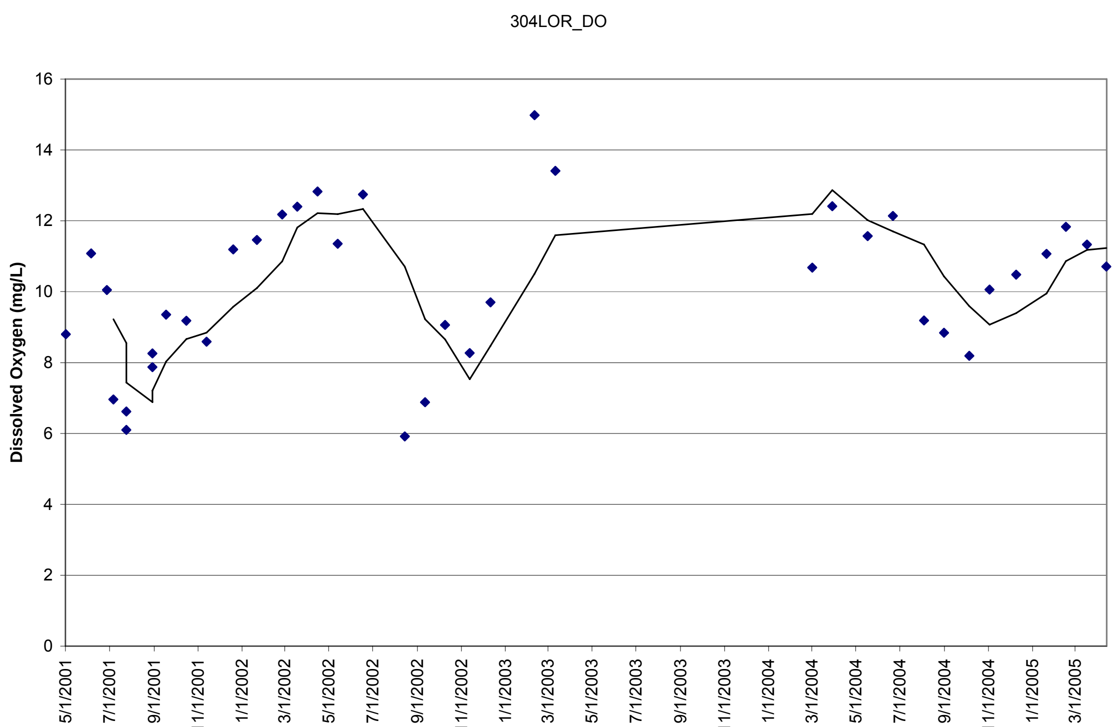


Figure A5.12

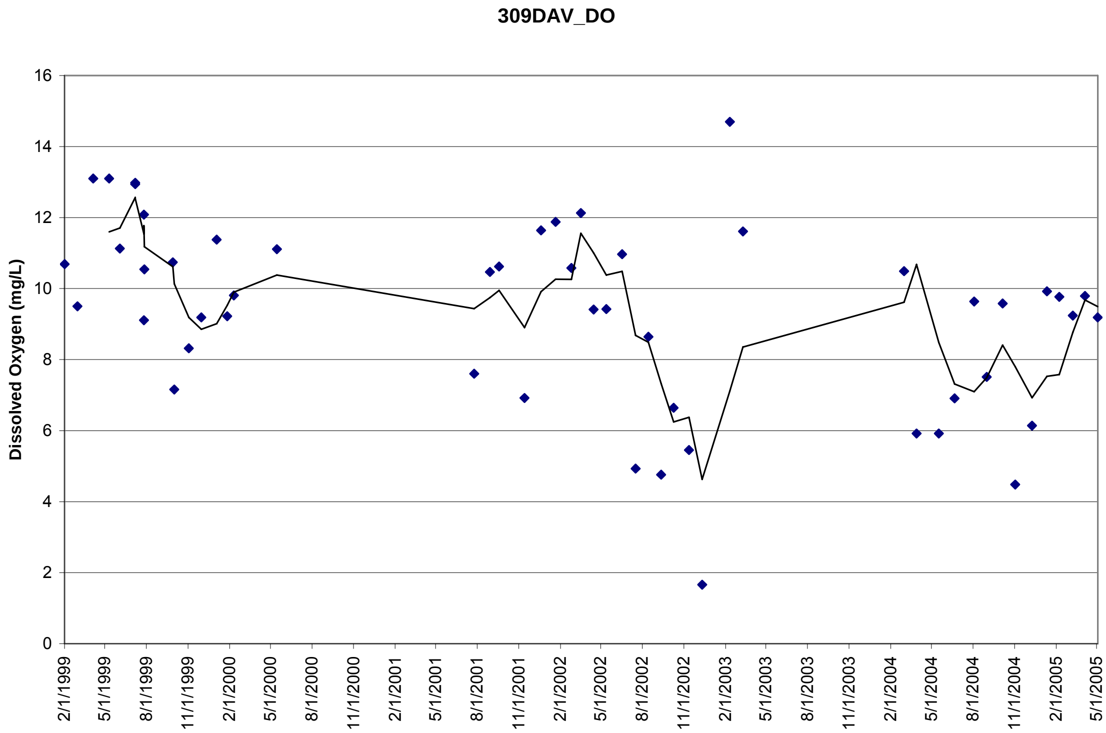


Figure A5.13

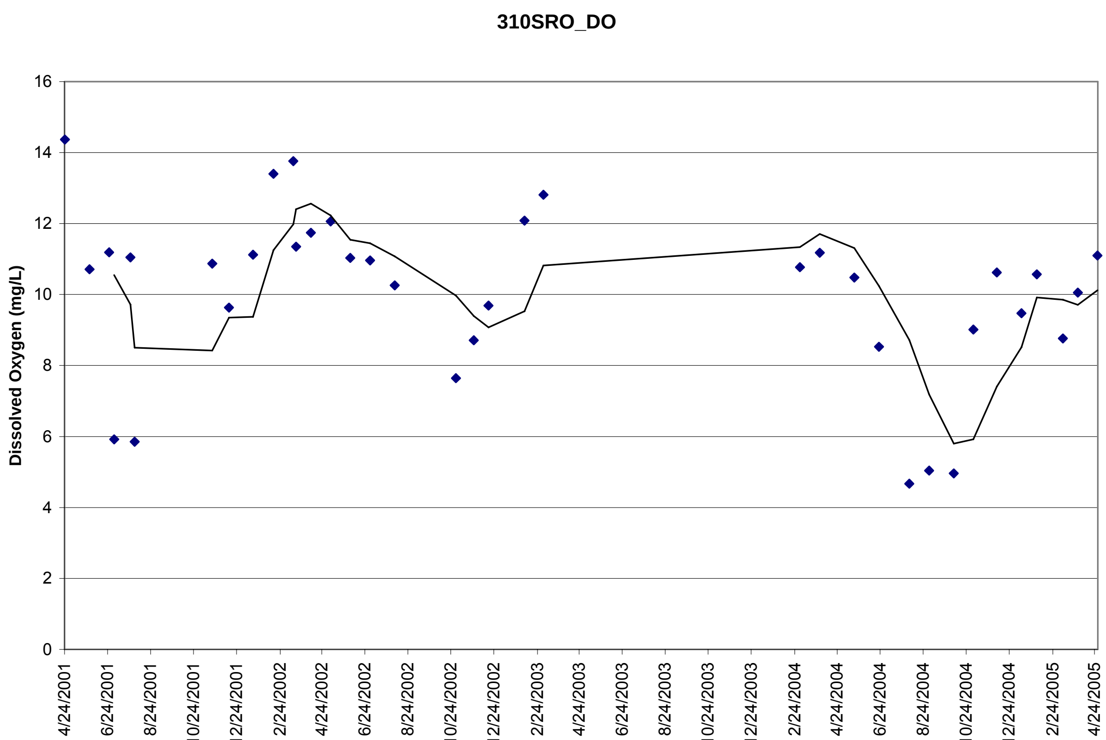


Figure A5.14

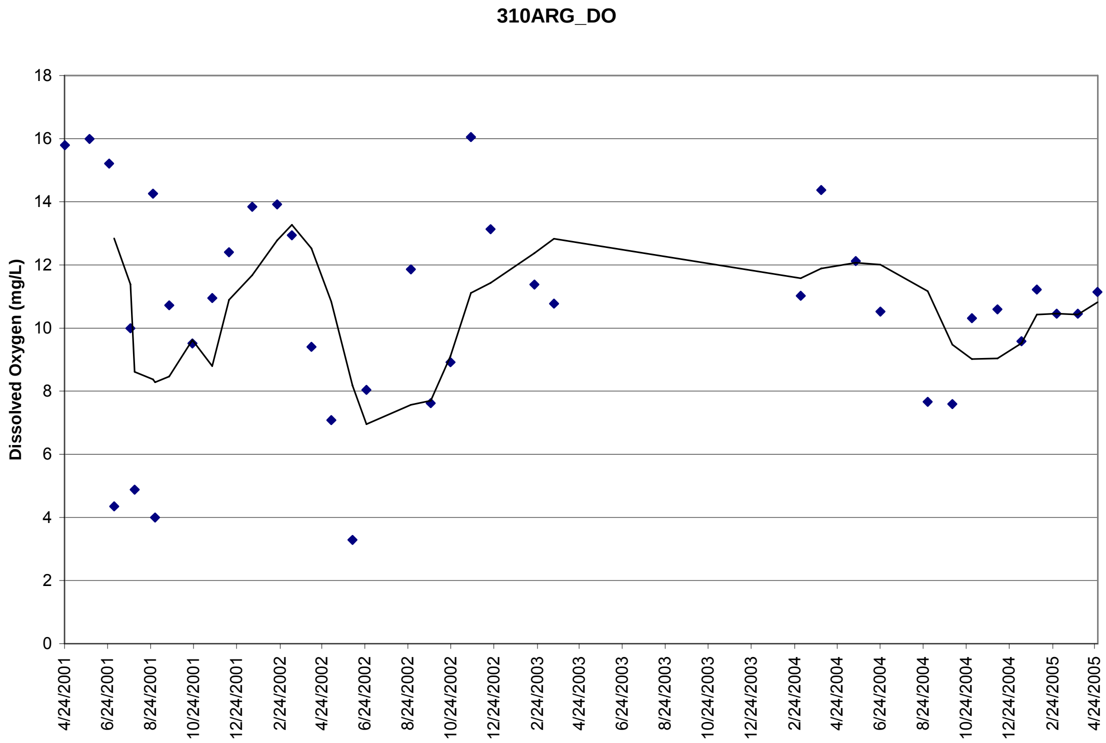


Figure A5.15

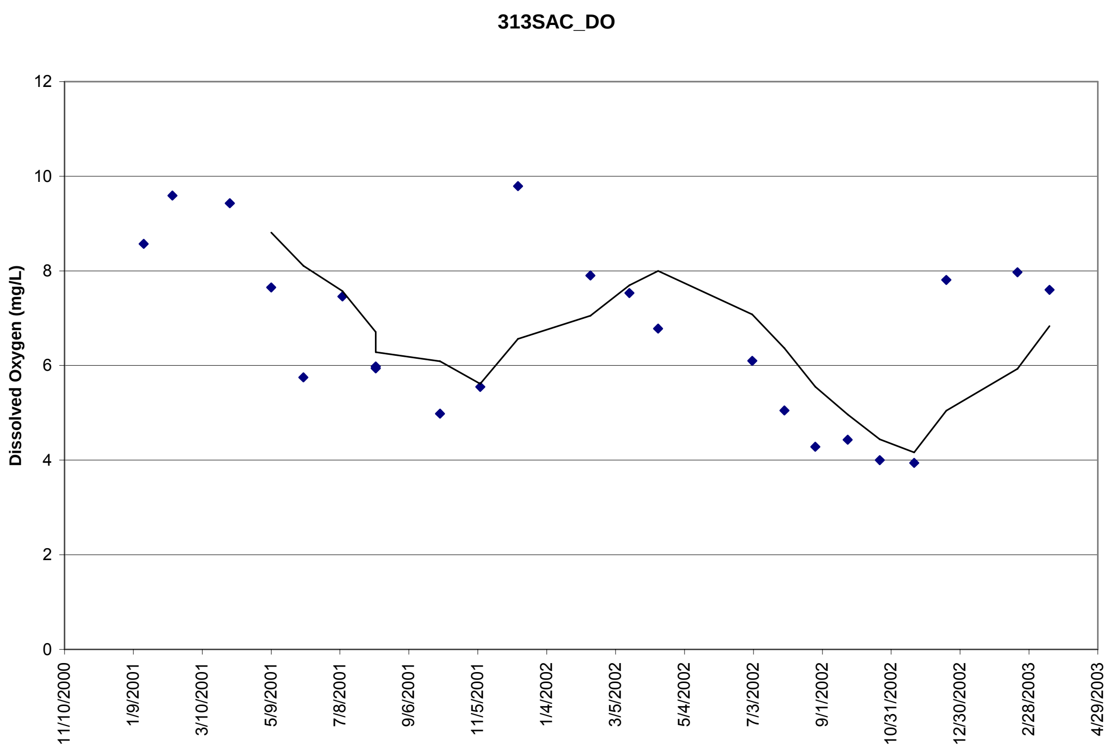


Figure A5.16

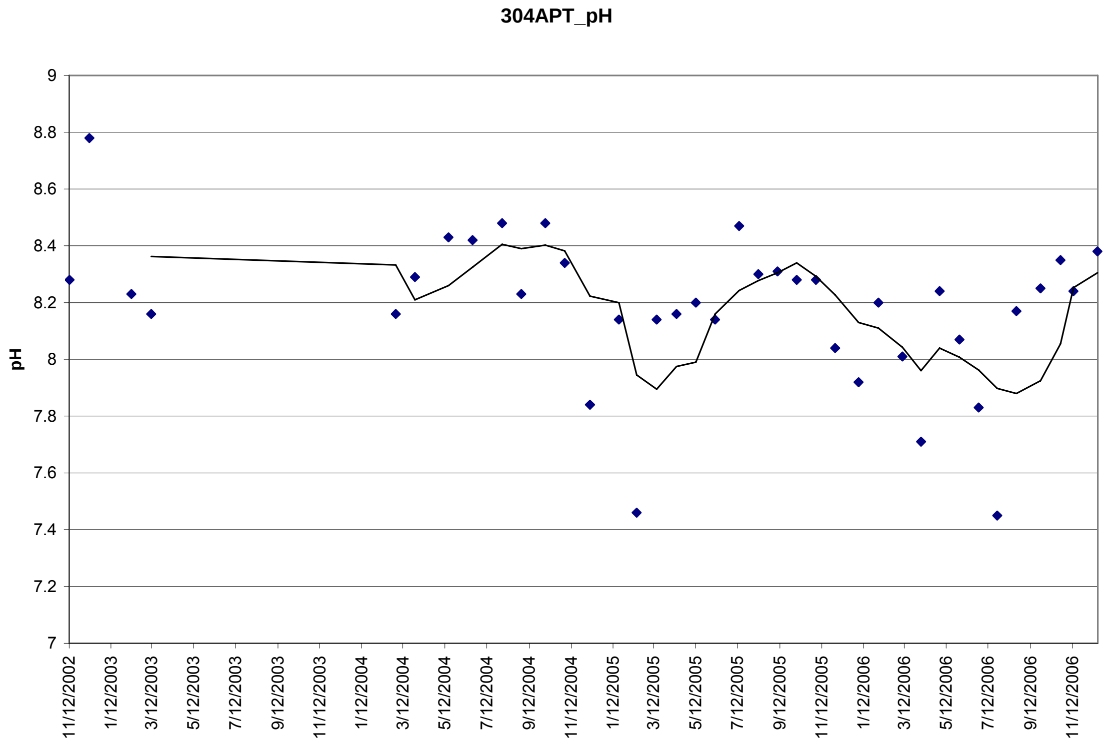


Figure A5.17

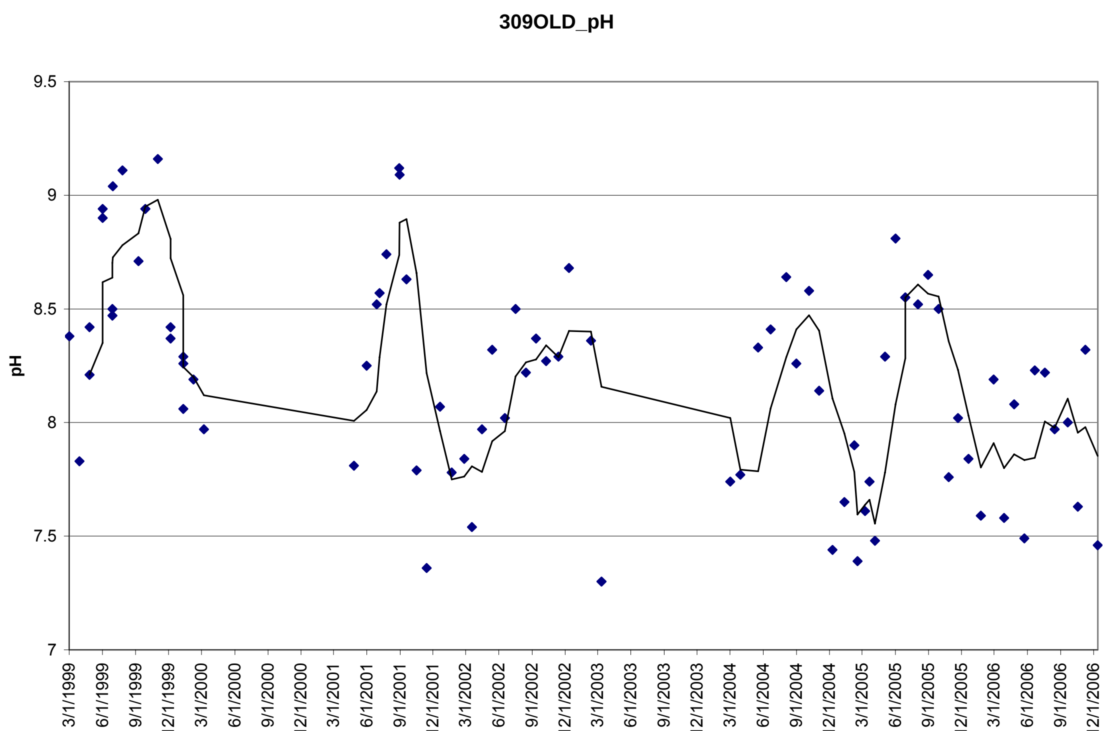


Figure A5.18

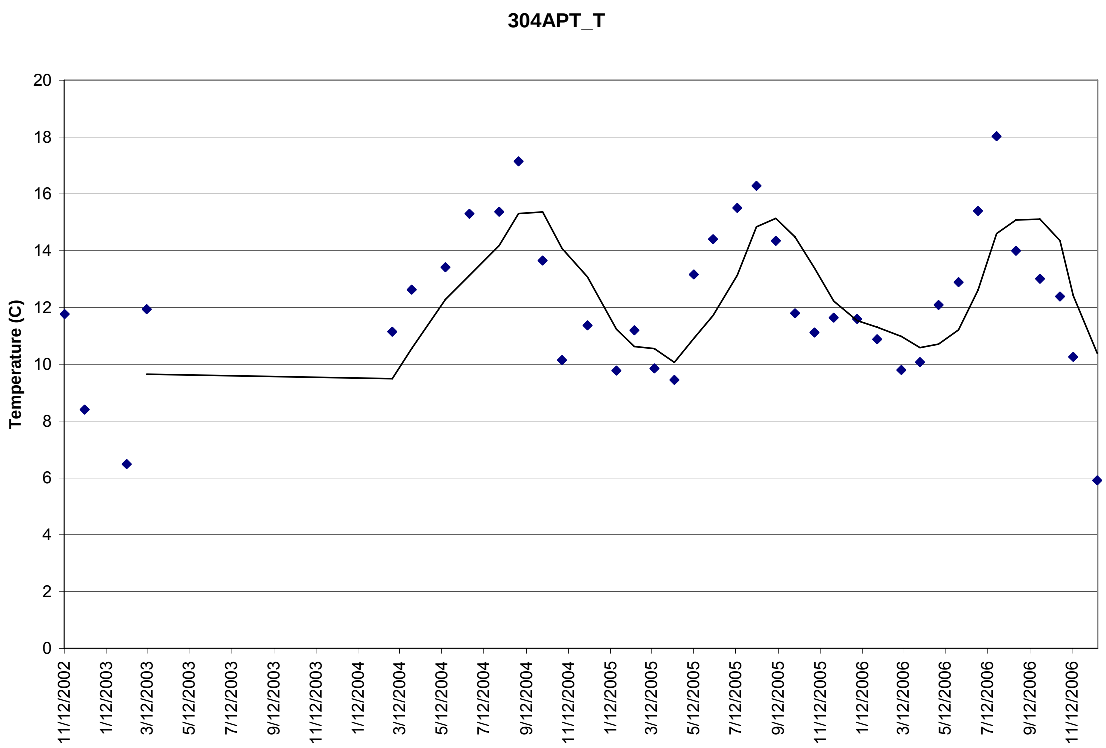


Figure A5.19

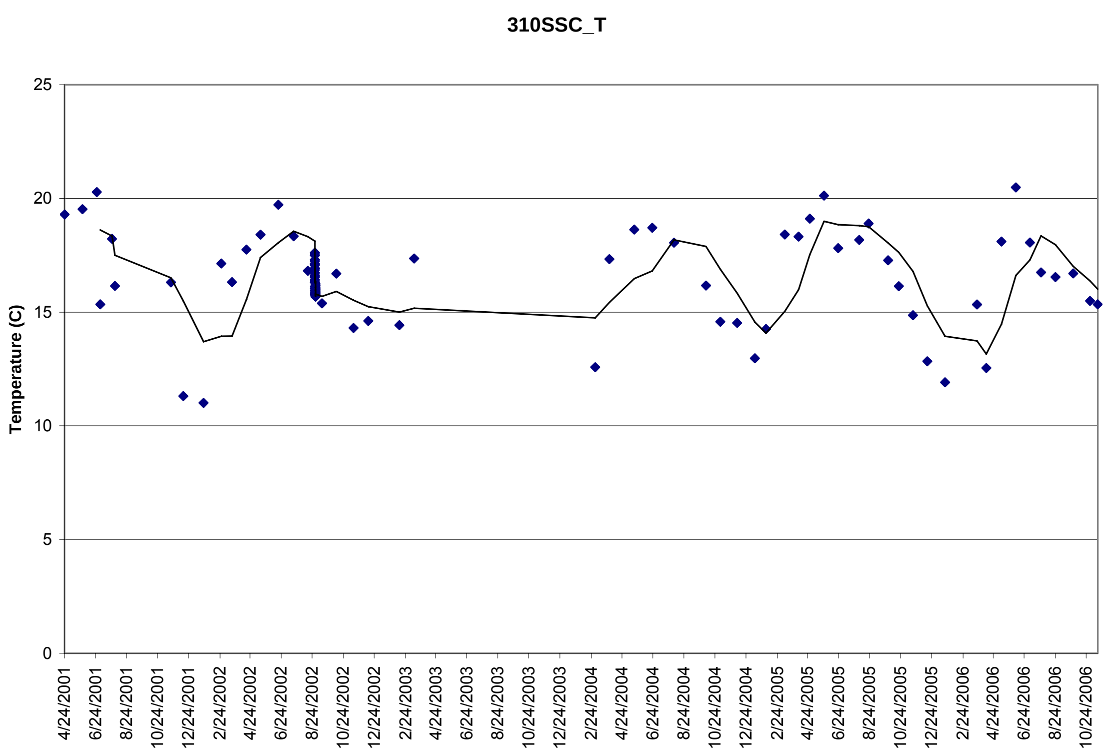


Figure A5.20

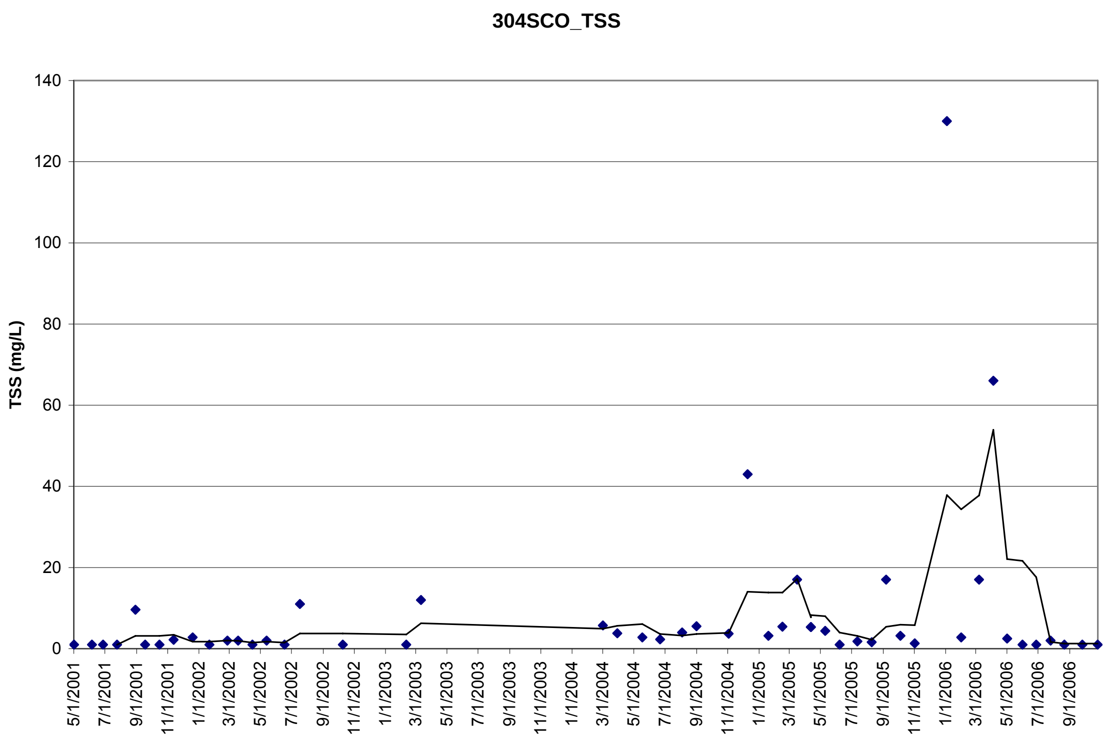


Figure A5.21

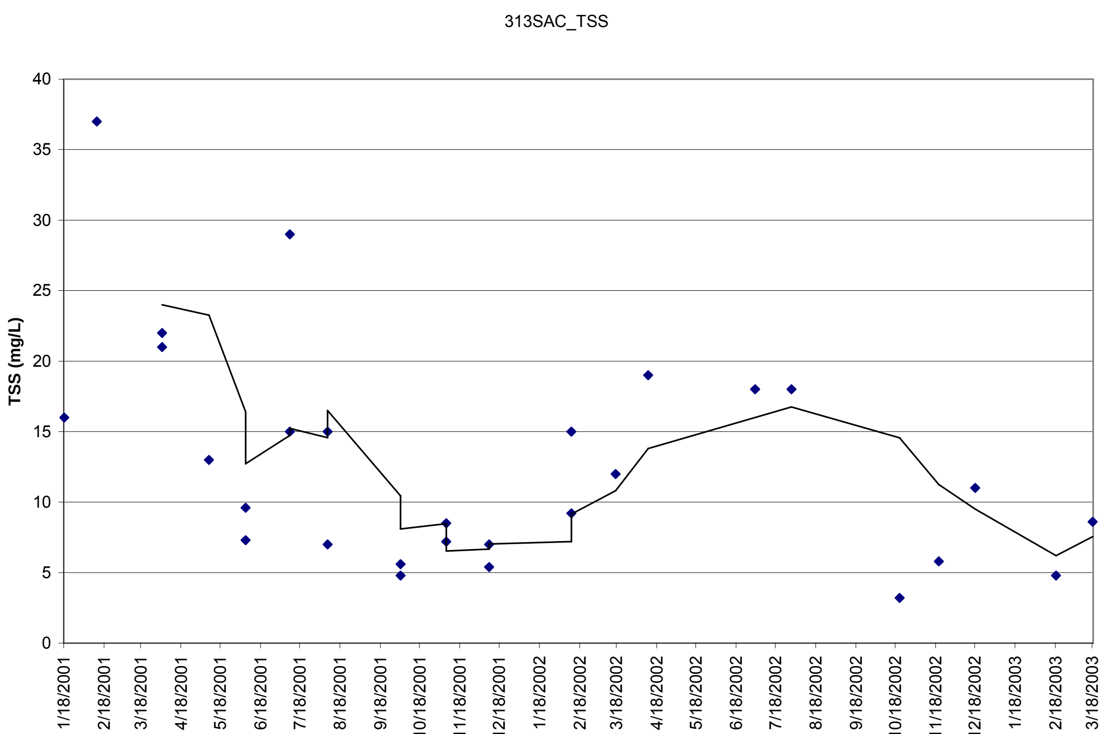


Figure A5.22

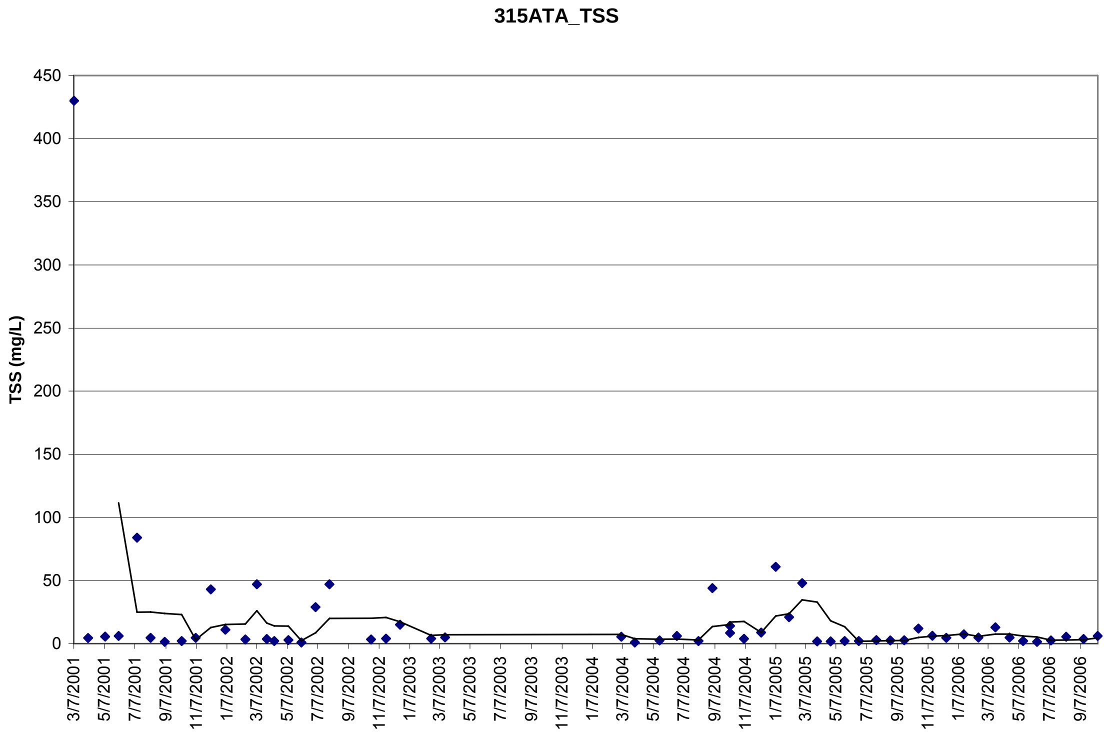


Figure A5.23

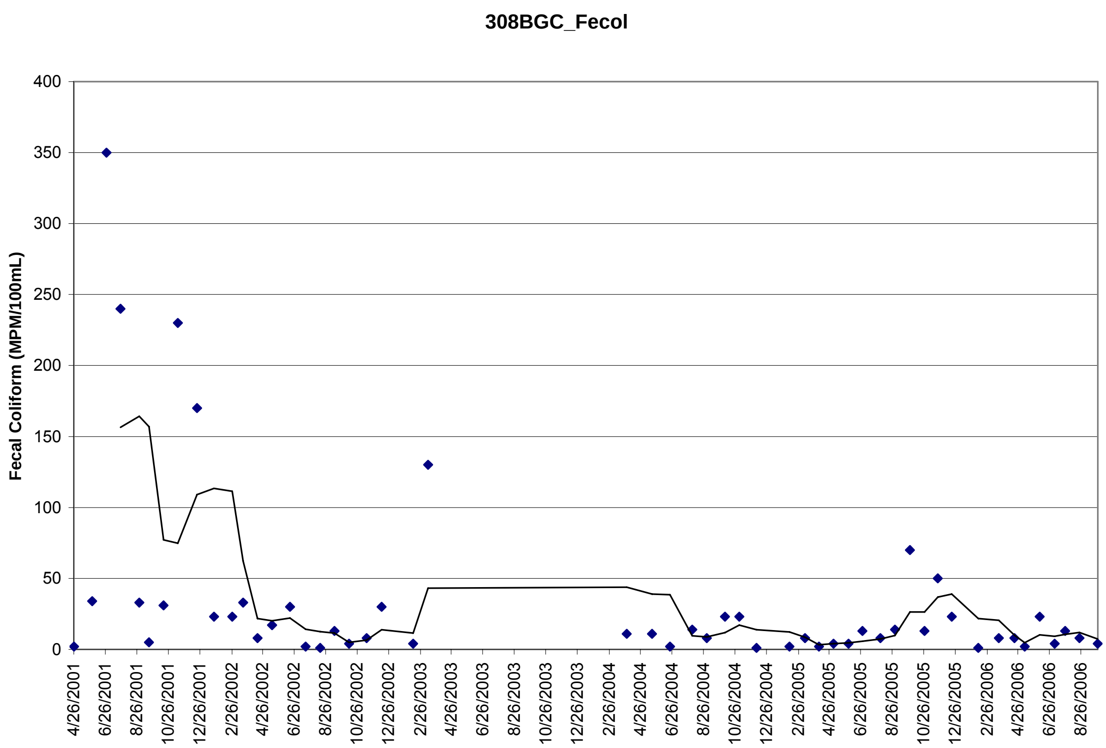


Figure A5.24

APPENDIX 6 CCAMP Coastal Confluence plots trend results

Significant trends are shown in **bold** (p <0.05, two tailed test). Units for Sen's slope estimator are the original measurement units per year - mg/L for total ammonia as N, nitrate as N , orthophosphate as P, dissolved oxygen (DO), and total suspended solids (TSS); °C for temperature, MPN/100 mL for fecal coliform). Dashes (--) indicate that a p-value could not be calculated.

Station	Value	Ammonia as N, total	Nitrate as N	OrthoP as P	DO	Temp	pH	TSS	Ecoli	FecCol
304APT001	Samples	28	97	54	**59**	35	**84**	71	79	206
	S	0	18	-12	**-8**	-9	**-36**	21	2	63
	p-value	--	0.166	0.063	**0.048**	0.180	**0.019**	0.091	0.894	0.130
304GAZ001	Samples	44	45	**44**	32	46	50	43	20	43
	S	-7	-3	**-29**	0	-27	-11	8	-1	-22
	p-value	0.646	0.853	**0.023**	1.000	0.055	0.426	0.459	--	0.063
304LOR001	Samples	21	224	70	**168**	51	**186**	85	78	183
	S	1	8	9	**-181**	-37	**-223**	12	13	-114
	p-value	--	0.915	0.515	**0.003**	0.143	**0.005**	0.406	0.373	0.140
304SCO001	Samples	20	93	67	38	49	57	82	63	131
	S	-1	40	-17	5	-23	-7	20	5	23
	p-value		0.070	0.251	0.102	0.212	0.632	0.112	0.567	0.472
304SOK001	Samples	22	26	25	8	23	**29**	25	26	21
	S	-8	7	4	1	1	**-6**	5	-3	-3
	p-value	--	--	--	0.718	--	**0.007**	--	0.117	--
304WAD001	Samples	20	86	69	33	51	51	84	57	47
	S	3	16	7	5	-13	1	25	20	27
	p-value	--	0.251	0.617	0.463	0.473	0.936	0.143	0.113	0.131
305THU001	Samples	21	99	81	45	61	65	97	62	56
	Tau	0.005	0.007	0.012	0.003	0.004	0.006	-0.002	0.006	-0.023
	S	1	36	40	3	7	12	-10	11	-36
	p-value	--	0.090	0.099	0.770	0.829	0.457	0.707	0.185	0.154
307CML001	Samples	10	52	38	22	27	31	51	41	27
	S	-2	2	-3	6	-17	-14	17	2	-1
	p-value	--	0.861	0.646	0.161	0.126	0.186	0.075	0.840	0.898
308BGC001	Samples	50	52	50	39	52	56	48	22	49
	S	19	3	-22	1	-17	-28	8	1	-36
	p-value	0.377	0.835	0.062	0.877	0.296	0.300	0.530	0.734	0.27

Station	Value	Ammonia as N, total	Nitrate	OrthoP	DO	Temp	pH	TSS	Ecoli	FecCol
308BSR001	Samples	50	52	50	39	52	56	49	23	49
	S	20	-6	-11	0	-22	-14	38	-1	-20
	p-value	0.409	0.583	0.142	1.000	0.228	0.440	0.43	0.734	0.218
308WLO001	Samples	50	52	50	39	52	56	48	22	49
	S	14	3	-37	11	-18	-18	20	1	-11
	p-value	0.578	0.829	0.053	0.209	0.234	0.462	0.212	0.734	0.587
309DAV001	Samples	18	94	73	47	61	66	94	59	58
	S	1	-30	2	-34	8	-32	44	3	5
	p-value	--	0.186	0.840	0.060	0.560	0.319	0.150	0.699	0.656
309OLD001	Samples	143	**208**	202	184	64	210	60	25	57
	S	69	**442**	86	174	4	-29	5	6	3
	p-value	0.206	**>0.0001**	0.374	0.057	0.767	0.763	0.777	0.030	0.874
313SAI001	Samples	20	45	105	44	46	313	45	22	44
	S	-14	31	2	9	-41	-312	-1.414	-2	-16
	p-value	0.083	0.116	0.938	0.230	0.097	0.182	0.157	0.260	0.128

APPENDIX 7. CCAMP Coastal Confluence plots significant trends graphs

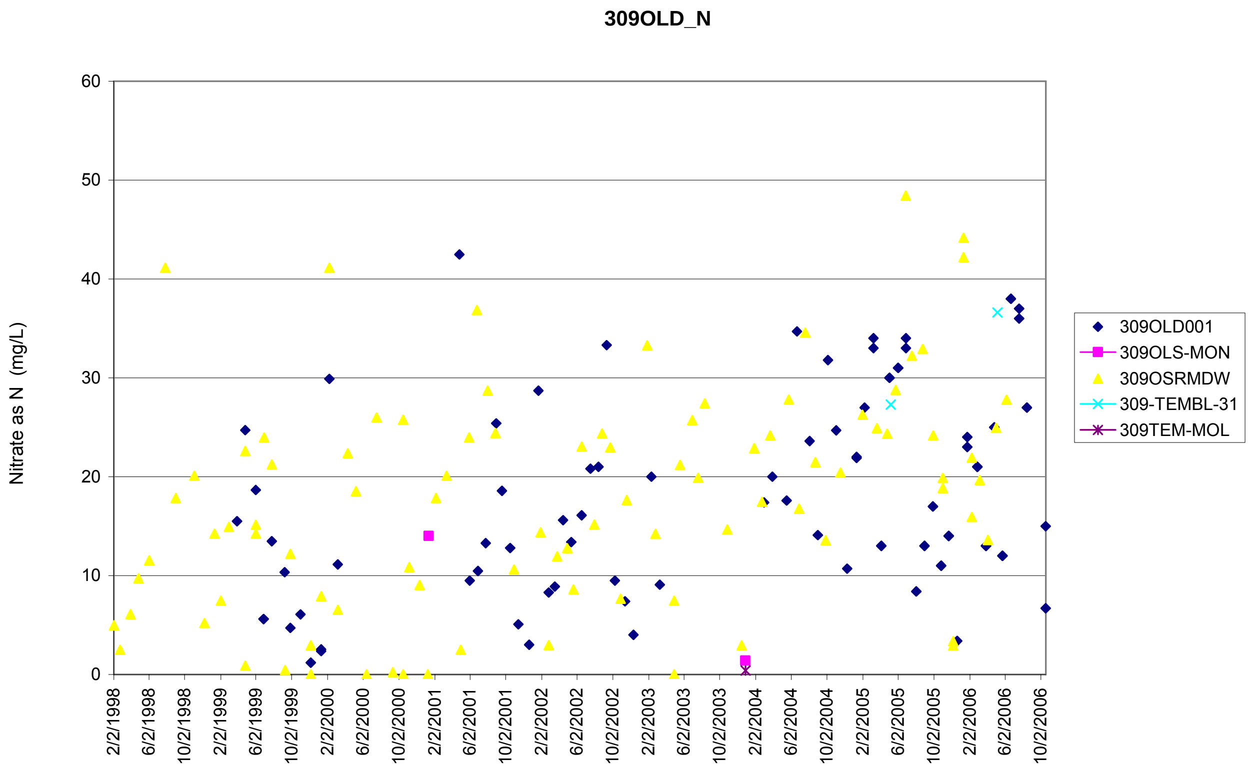


Figure A7.1

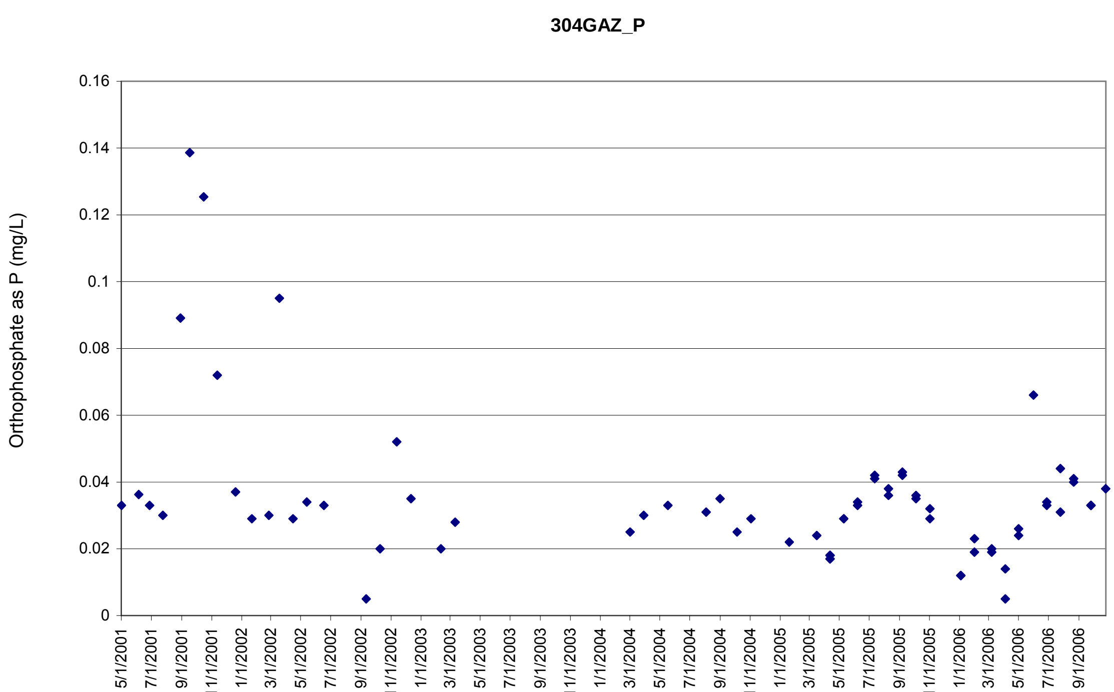


Figure A7.2

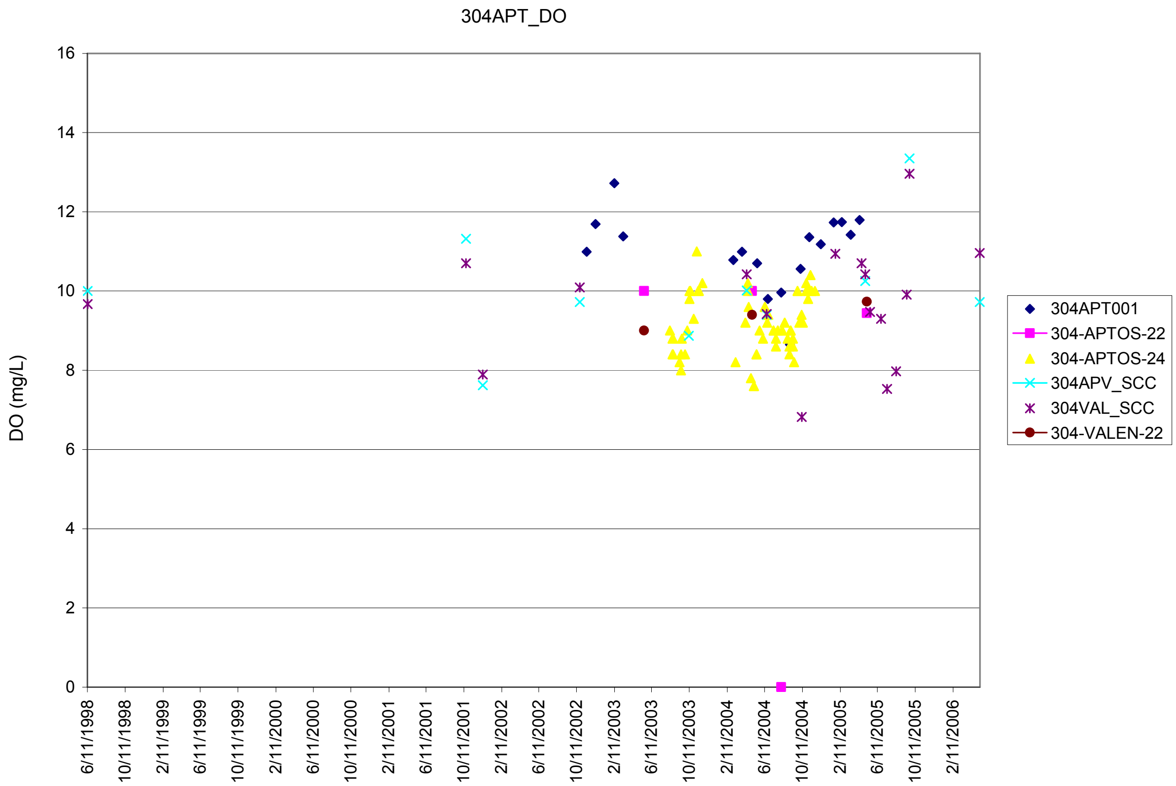


Figure A7.3

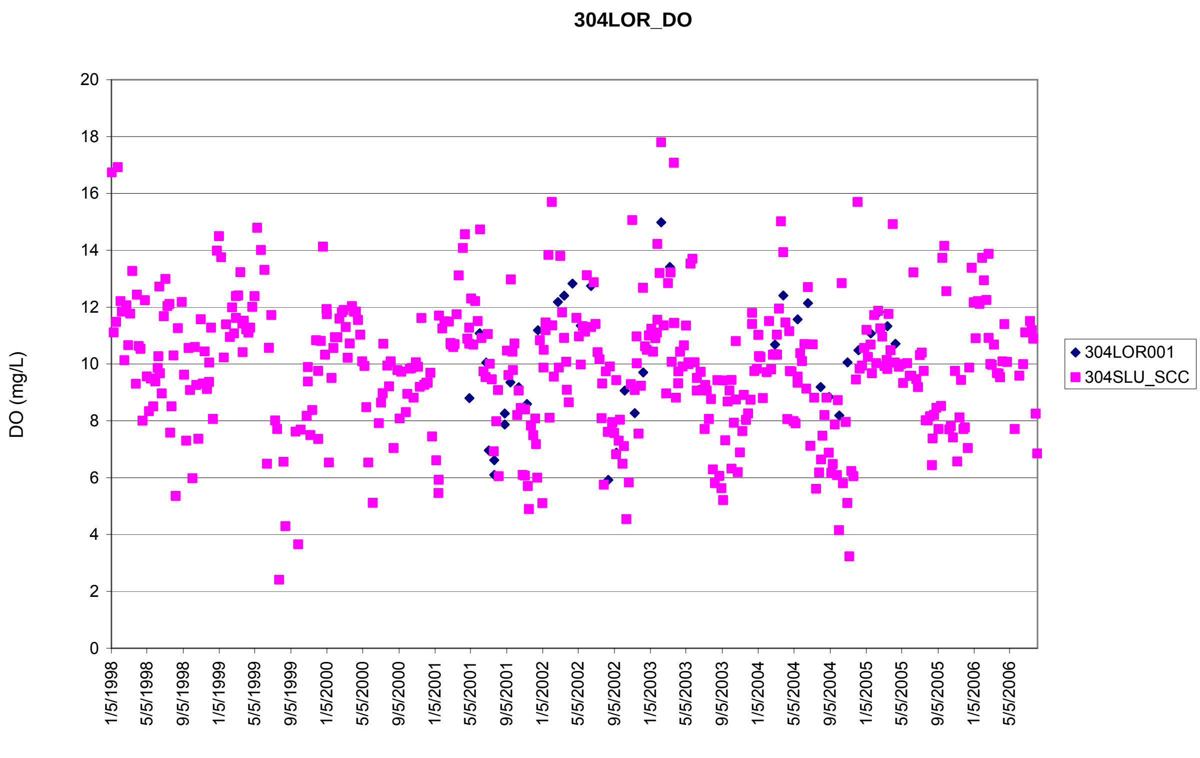


Figure A7.4

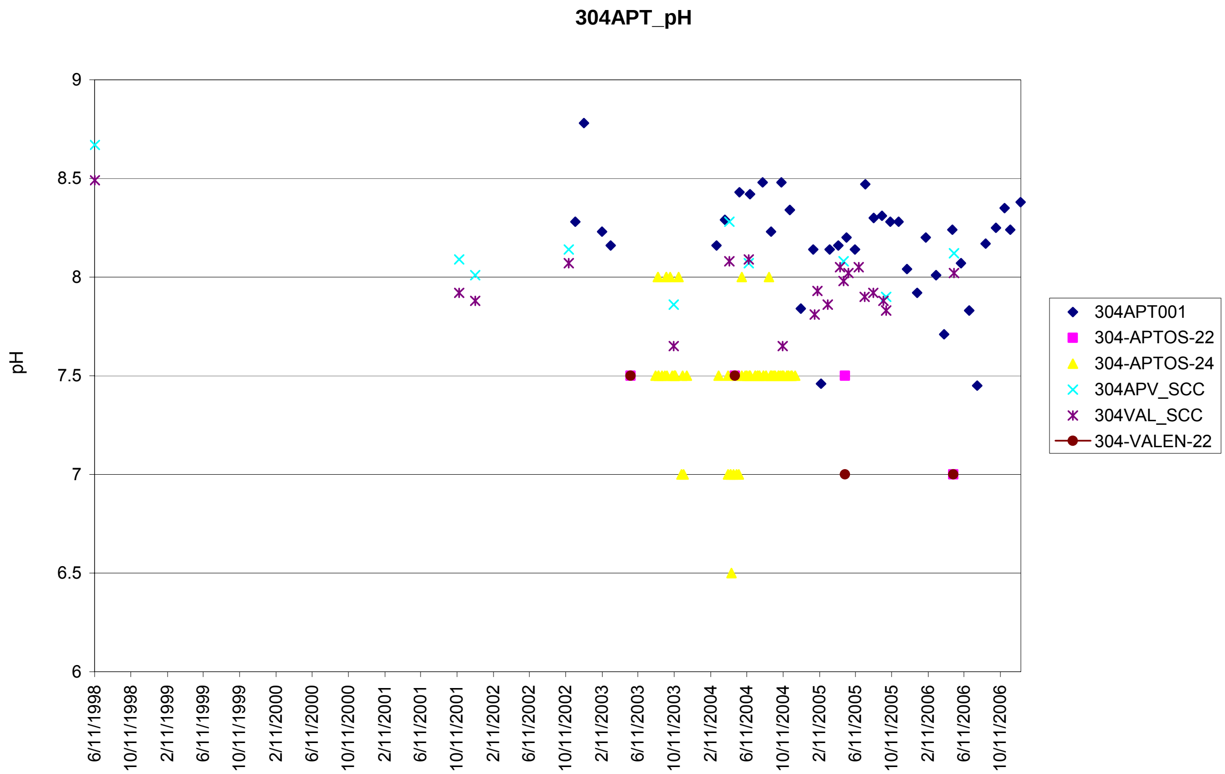


Figure A7.5

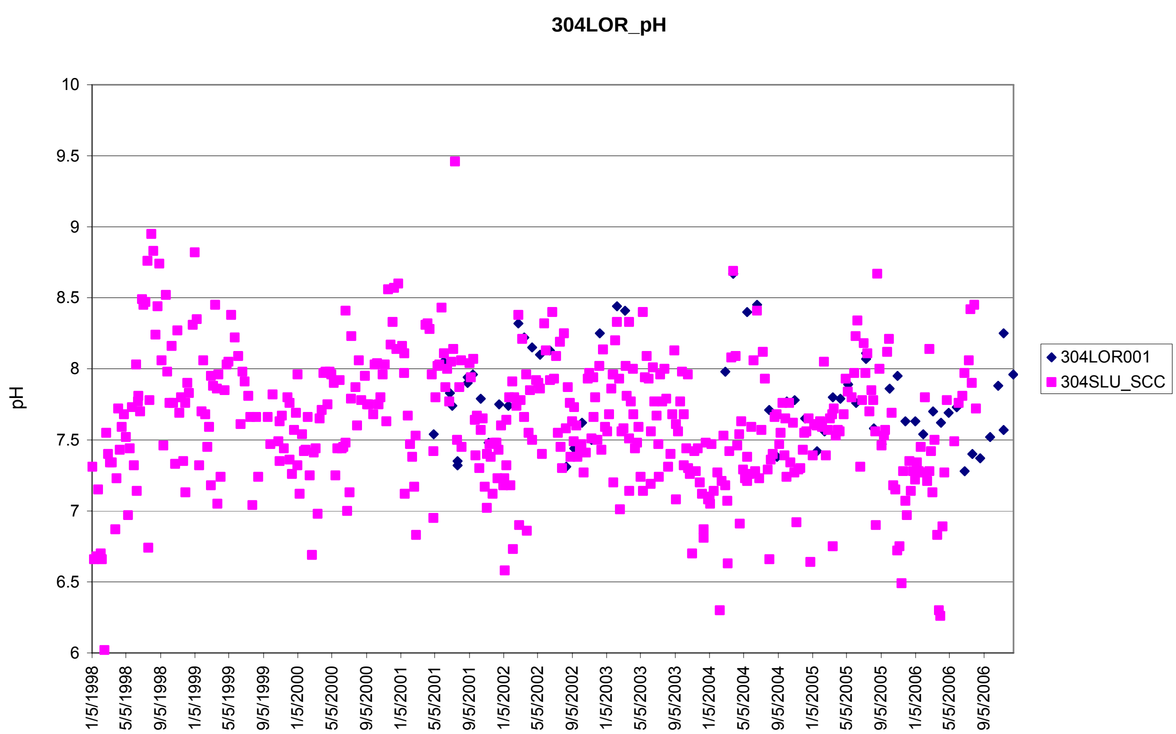
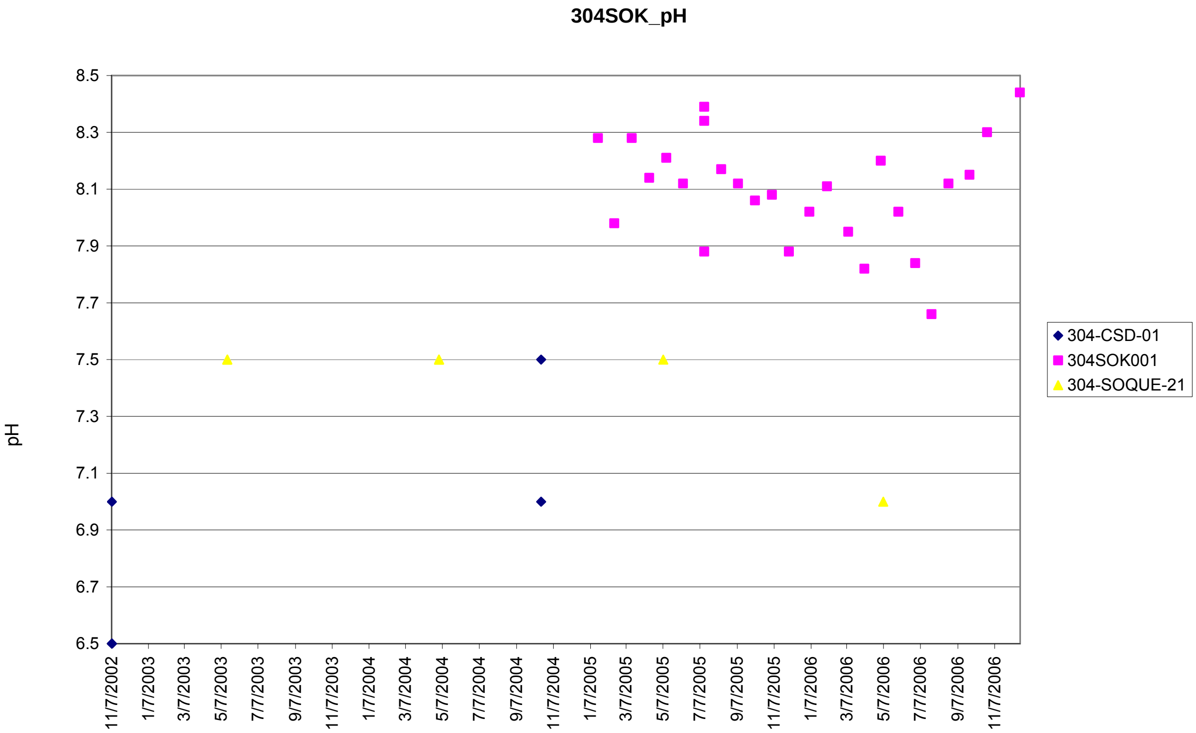


Figure A7.6


304SOK_pH
pH
8.5
8.3
8.1
7.9
7.7
7.5
7.3
7.1
6.9
6.7
6.5
11/7/2002
1/7/2003
3/7/2003
5/7/2003
7/7/2003
9/7/2003
11/7/2003
1/7/2004
3/7/2004
5/7/2004
7/7/2004
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7/7/2005
9/7/2005
11/7/2005
1/7/2006
3/7/2006
5/7/2006
7/7/2006
9/7/2006
11/7/2006
304-CSD-01
304SOK001
304-SOQUE-21

Figrue A7.7

APPENDIX 8. Ag Waiver Checklist Questions

Pesticide Management Questions

P_1) Is an integrated Pest Management program established?
P_2) Are pest populations assessed and pesticides applied based on scouting data, thresholds, and/or risk assessment models?
P_3) Are introduced or managed biological control agents utilized?
P_4) Does pesticide selection consider runoff or leaching potential?
P_5) Does pesticide selection consider toxicity to non-target organisms?
P_6) Is pesticide application equipment regularly inspected, maintained, and calibrated to ensure appropriate application rates and distributions?
P_7) Is yearly pesticide training provided for all pesticide handlers who apply, load, mix, transport, clean, and repair pesticide application equipment?
P_8) Do pesticide storage facilities have concrete pads and curbs for containment of spills?
P_9) Are pesticide mixing and loading areas located in such a manner to reduce the likelihood of a spill or overflow contaminating a water source?
P_10) Are production wells on elevated concrete bases upslope of pesticide storage and handling facilities?
P_11) Does wellhead protection consist of an elevated concrete seal, sump, or buffer area of 100' around the wellhead and a backflow prevention device?

Irrigation Water Management Questions

I_1) Is drip irrigation distribution uniformity maximized and maintained through regular system equipment and system pressure maintenance?
I_2) Is sprinkler and micro-sprinkler irrigation distribution uniformity maximized and maintained through regular system pressure maintenance and water application during low wind conditions?
I_3) Is furrow and flood irrigation distribution uniformity maximized and maintained by either managing furrow lengths, installing surge irrigation valves, installing irrigation field ditches, or using alternate row irrigation?
I_4) Is your irrigation system design optimized by matching sprinkler nozzle/drip applicator flow rates to the infiltration rate of the soil?
I_5) Are measured or published evapo-transpiration data (CIMIS) used to determine crop water use?
I_6) Is the soil water-holding capacity known?
I_7) Are records kept for each crop irrigated? (Records include the date, amount of each irrigation water applied, and the source of water used.)

I_8) Have all irrigators who apply irrigation water and maintain irrigation systems received training?
I_9) Has an irrigation mobile lab system evaluation been completed and the system been adjusted accordingly?

Erosion and Sediment Control Management Questions

E_1) Are cover crops used to protect bare soil from erosion during fallow cycles and to build up solid organic matter as a crop rotation?
E_2) Are hedgerows, trees, and shrubs established along field margins or between\ field blocks to reduce wind effects, and protect slopes from erosion?
E_3) Are farm access roads located and graded to minimize erosion potential?
E_4) Are farm access roads protected from concentrated runoff through the use of vegetative material, gravel, and/or mulch?
E_5) Are ditches and channel banks protected from concentrated flow through the use of grassed waterway, lined channels, and/or diversions?
E_6) Are field layout and row length designed to minimize erosion potential?
E_7) Are sediment basins constructed to intercept sediment-laden runoff in locations where erosion is expected and sediment is known to leave the farm?
E_8) Are water and sediment control basins used in locations where sediment and excess runoff may cause gullies or flooding problems downstream?
E_9) Are vegetative buffers implemented between cropped areas, along the lower edge of the farm, and along roadways? (*This practice is also effective in removing nutrients and pesticides from runoff*.)
E_10) Where streams cross or property, are riparian buffers established and maintained?
E_11) Are culverts properly sized and maintained?
E_12) Are implemented management practices evaluated for effectiveness? monitoring, water quality testing)?

Nutrient Management Questions

N_1) Are the crop's nutrient requirements known and are nutrient budgets established and recorded?
N_2) Do you test irrigation water for nitrogen content and incorporate that information into your fertilization program?
N_3) Is plant tissue analysis used to aid in fertilizer decisions?
N_4) Do you test your soil for residual nitrogen and incorporate that information into your fertilization program?

N_5) If fertigation is used, are measures in place to ensure that there is no backflow into wells or other water sources?
N_6) Do you regularly maintain and calibrate your fertilizer equipment?
N_7) Do field personnel receive nutrient management training?
N_8) Do fertilizer storage facilities include concrete pads and curbs for containment of spills and are they protected from weather?
N_9) Is mixing and loading performed on sites with low runoff hazard, over 100' down slope of wells?