POINT REYES NATIONAL SEASHORE

WATER QUALITY MONITORING REPORT

MAY 1999 – MAY 2001

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Water Quality Monitoring Report

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ABSTRACT

Point Reyes National Seashore possesses extremely diverse, valuable, and sensitive water-related resources that are dependent upon the water quality in the park's streams, lakes, bays, lagoons, estuaries and wetlands. Enabling legislation charges the Seashore with the preservation of both natural and cultural resources, including ranching and dairying, that contribute substantially to the cultural landscape (PL87-657). The Seashore is committed to protecting the quality of all surface and ground waters consistent with the 1987 Clean Water Act and other federal, state, and local laws (NPS 1991).

Beginning in WY2000, Point Reyes National Seashore initiated surface water quality monitoring at 23 stream locations and three recreational ponds, and aquatic bioassessment at 12 locations. Monitored water quality parameters include nitrate, nitrite, ammonia, orthophosphate, fecal/total coliform, total suspended sediment, temperature, conductivity, dissolved oxygen, and pH. Macroinvertebrate samples were collected from Olema Creek and three coastal watersheds draining to Drakes Estero for a long-term biologic trend analysis.

Information is reported by ambient stream sites, recreational use sites, and macroinvertebrate monitoring sites. Results indicate distinct differences in monitored water quality parameters between dairy, beef, and wilderness watersheds. Implemented in conjunction with fisheries monitoring efforts, the water quality program is focused on identifying water quality impacts to the aquatic ecosystems within the Seashore. Biweekly monitoring of recreationally used ponds resulted in the posting of a health warning on Hagmaier Pond. Management actions stemming from the water quality monitoring program have been implemented at pastoral sites within the Seashore.

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The implementation of the Point Reyes National Seashore Water Quality Monitoring Program has involved a great deal of effort on the part of Water Resource and Restoration Program Staff. Most importantly David Press, who took the workplan and brought it to life. He also developed the highly functional Water Quality Monitoring Database (See Appendix A). The program has also had a great deal of assistance from current and former Coho Salmon and Steelhead Trout Restoration Project Staff: Greg Brown, Jesse Wechsler and Ken Kundargi.

The cooperation of all the agricultural operators in the Seashore has allowed for fair sampling and the ability to address concerns in a timely manner.

Comments or questions regarding this report should be submitted to Brannon Ketcham, Water Resource and Restoration Branch Chief at (415) 464-5192 or brannon_ketcham@nps.gov

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EXECUTIVE SUMMARY

Point Reyes National Seashore (PRNS) is charged through its enabling legislation and subsequent amendments with balancing the need to protect the water related components of the National Seashore with the need to preserve agricultural operations as a cultural resource. Ranch and dairy operations continue to operate within the Seashore boundary as part of the cultural landscape. The Seashore contains a variety of aquatic habitats supporting threatened and endangered species, including coho salmon, steelhead trout, and the California red-legged frog.

In 2000, the San Francisco Bay Regional Water Quality Control Board identified Tomales Bay and Lagunitas Creek as impaired by sediment, nutrients, and pathogens. The Seashore is an active participant in local committees including the Tomales Bay Watershed Council and Tomales Bay Shellfish Technical Advisory Committee which have major emphasis in the issues of water quality.

Point Reyes National Seashore initiated a water quality monitoring program in 1999 to inventory the condition of water resources throughout the managed area. Three monitoring strategies, including ambient stream monitoring, recreational use monitoring, and aquatic bioassessment make up the water quality program. From the outset, this program has been intended to provide information allowing resource managers to be responsive in their management decisions.

Ambient Monitoring Program

The ambient stream monitoring program is focused on water bodies not designated for recreational use. The Seashore program is intended to determine the extent of source areas and identify workable solutions that will be incorporated into future management. The Seashore Ambient Water Quality Program will continue to monitor sites where restoration actions have been taken in order to quantify response. Based on this evaluation, it is recommended that ambient monitoring be performed at quarterly intervals, collecting samples from all sites in a single day. Additional winter sample events will focus on watersheds where water quality conditions have been determined to be most degraded.

More than 235 samples were collected from over thirty locations within the Seashore since 1999. This program has revealed degraded water quality conditions below most of the dairy operations within the Seashore, and from two tributaries in Olema Creek. Based upon the monitoring parameter characteristics, this program identified fecal coliform and toxic ammonia as primary indicators of water quality degradation. Secondary indicators of water quality degradation include conductivity and Total Suspended Solids.

Federal and state fecal coliform standards for non-contact recreation are not to exceed a geometric mean (based on a minimum of five samples within a thirty day period) of 2,000 most probable number of colonies per 100 milliliters (MPN/100 ml) with the 90th percentile not to exceed 4,000 MPN/100ml. Fecal coliform samples within the Seashore ranged from <2 to greater than 1,600,000 MPN/100ml. Of 235 fecal coliform samples, 33% (78 samples) exceeded the non-contact recreational limit or 2,000 MPN/100 ml, 25% (59 samples) exceeded 4,000 MPN/100ml, and 20% (47 samples) exceeded a level of 10,000 MPN/100ml. It is important to acknowledge that exceedence levels are high, because nearly all samples targeted storm runoff events.

Ammonia toxicity directly affects survival of aquatic species. Of 163 ammonia samples, 3.1% (5 samples) were associated with toxic conditions. This rate of toxicity is actually lower than observation through other local monitoring programs (CDFG 1995-2001). Monitoring of Total Suspended Solids has shown high levels of background sediment input within the Olema Creek watershed. Most other water quality parameters have not been indicative of degraded water quality.

Depending upon which analytical criteria is used, there are between 3 and 14 sites that show some levels of impact. This report has identified nine sites (8 sub-watersheds) as severely degraded and in immediate need of management attention. Discussions to improve conditions within many of these watersheds are ongoing. While additional monitoring sites have shown exceedence of fecal coliform standards, these sites are downstream of the degraded sites, and the higher readings are a result of the pollutant persistence in the water column.

Table 1. Water monitoring locations with degraded conditions

		Pollutants of concern	
Station	**Watershed**	**PRIMARY**	**SECONDARY**
PAC2	North Kehoe Creek	• Fecal Coliform	• Conductivity
PAC2a	North Kehoe at Ranch	• Fecal Coliform	• Conductivity
PAC1	South Kehoe Creek	• Fecal Coliform	• Conductivity
ABB1	Abbotts Perennial	• Fecal Coliform	
ABB2	McClure Drainage	• Fecal Coliform	
DBY3	A-Ranch Drainage	• Fecal Coliform • Toxic Ammonia	
DBY2	B-Ranch Drainage	• Fecal Coliform • Toxic Ammonia	
OLM2	Giacomini Creek	• Fecal Coliform	
OLM4	Quarry Gulch	• Fecal Coliform	

The ambient monitoring program was intended to, and has revealed the effectiveness of management practices reducing access of livestock to stream channels, and has been responsive enough to allow for implementation of management changes during the winter season. Cooperation among the agricultural operators has resulted in projects to exclude cattle from John West Fork, Cheda Creek, Olema Creek, and Randall Gulch. This has also resulted in modification of existing runoff management operations to better contain contaminated material on site, rather than allowing for discharge to the stream channel.

Recreational Monitoring Program

While the Seashore has not designated water bodies specifically for recreational use, sampling for fecal and total coliform was performed at three of the most heavily used sites during summers 1999 and 2000. Results indicate that water bodies not influenced by cattle grazing, remained far below any level of concern for contact recreation. Monitoring at Hagmaier Pond, a cattle stock pond, indicated short-term spikes of fecal coliform associated with the presence of cattle. Of 29 samples collected over two summers at Hagmaier Pond, 14% (4 samples) exceeded contact recreational standards (400 MPN/100ml). The duration of these fecal coliform spikes is known to be less than one week. In response the Seashore posted warning signs at the pond, and access points, indicating the use of the pond by livestock, and associated risks.

Recreational monitoring will continue at Hagmaier Pond with a new location established at Kehoe Beach. Monitoring frequency at Bass Lake and Vision Pond will be reduced.

Aquatic Bioassessment Program

Sampling of the aquatic macroinvertebrates was initiated to determine biotic response to different land use within Seashore watersheds. Sampling of six sites within Olema Creek, and three paired-watershed samples in the Drakes Estero watershed was performed in fall of 1999 and spring 2000. Evaluation and reporting of the results was contracted to a specialist in the field.

Results indicate even in areas where biotic indices are highest, macroinvertebrate condition is only moderate when compared to reference indices representative of the Russian River. To some extent this may be attributed to stream size, but for the most part it indicates that Seashore streams are still recovering from land use practices imparted on these systems for more than a century. Within Olema Creek species diversity is limited, likely due to high background sediment loading associated with flow along the San Andreas Fault Zone. Even in Muddy Hollow Creek, a wilderness watershed, cumulative impacts of the past land use and the 1995 Mount Vision fire are indicative of rather impaired conditions for support of the macroinvertebrate community.

Monitoring did show a degrading trend from upstream to downstream areas consistent with accumulated land use impacts. It is recommended that potential reference streams within the Seashore be identified to determine if the perceived impairment in comparison to the Russian River Index of Biological Indicators does not fairly evaluate conditions within the Seashore. Future sampling should evaluate streams such as Coast Creek, North Kehoe Creek, and White Gulch for broader comparison of the aquatic macroinvertebrate condition.

Operational Costs

Operation of the water quality monitoring program includes staff, analytical cost, and equipment. To date, the operational costs have been $35,000 annually. Staffing and laboratory costs (49% and 43% respectively) make up the bulk of the budget, with operational expenses (vehicle, equipment, overtime) covering the final 8%. Continued support through ONPS base and rangeland fee revenues is important to the overall success of this program.

In the past year, the San Francisco Bay Network of NPS units has received a base increase of $70,000 to implement a large scale water quality inventory and monitoring program. While this will assist in quarterly sampling within the Seashore, it will in no way meet the detailed monitoring requirements that will likely be necessary on most watersheds within the pastoral zone.

INTRODUCTION AND BACKGROUND

OBJECTIVES

- To document water quality condition within Point Reyes National Seashore.
- To develop management recommendations addressing impacts specific to agricultural and recreational operations and use.
- To identify a long-term monitoring strategy to track the trends, enabling the park to identify and address future problems.

BACKGROUND

Point Reyes National Seashore (PRNS) is charged through its enabling legislation and subsequent amendments with balancing the need to protect the water related components of the National Seashore with the need to preserve the agricultural operations, including ranching and dairying, which contribute substantially to the cultural landscape. The Seashore contains a variety of aquatic habitats supporting threatened and endangered species, including coho salmon, steelhead trout, and the California red-legged frog, within the pastoral lands.

The Pastoral Management Zone includes twenty thousand acres (nearly 25% of the lands administered by the park) that are leased to private operators through Agricultural Special Use Permits (SUP). Seven dairies, one riding stable, and a number of beef cattle ranches are operated under such lease agreements. The leases occur within some of the most sensitive watersheds including Drakes and Limantour Estero, Abbotts Lagoon, Olema Creek, Pine Gulch Creek, and the Tomales Bay.

The Monitoring Program area includes the entirety of Point Reyes National Seashore and the North District Lands of the Golden Gate National Recreation Area. A complete inventory of the water quality within this area has never been performed. The Seashore is in the process of developing the General Management Plan (GMP) by 2003. An understanding of how existing management impacts watershed and water quality conditions is of great importance as the GMP initiative moves forward.

The preservation of cultural resources within Point Reyes will likely include some levels of dairy and cattle operations. The Seashore water quality monitoring program is intended to assist land managers with the identification of at-risk watersheds and help make informed management decisions.

In 2000, the San Francisco Bay Regional Water Quality Control Board identified Tomales Bay and Lagunitas Creek as impaired by sediment, nutrients, and pathogens. In the fall of 2000, the County of Marin declared fish consumption advisories on certain marine species due to bioaccumulation of mercury. The community and regulatory agencies have been active in establishing a protection and oversight role in the area. Assessing and addressing pollutant contributions from National Park Service lands is consistent with the initiative to preserve and protect coastal waters, including Tomales Bay.

The Seashore participates in a variety of forums, including the Tomales Bay Watershed Council, Tomales Bay Advisory Council, Tomales Bay Shellfish Technical Advisory Committee, Marin Municipal Water District – Lagunitas Creek Sediment and Riparian Management Plan Technical Advisory Committee, and many others. This reflects the commitment and value of monitoring within the Seashore. Results of this program may be incorporated as part of the Regional Water Quality Control Board (RWQCB) – Surface Water Ambient Monitoring Program (SWAMP). The Seashore also cooperated with the Regional Board in the winter 2000-2001, assisting in the Tomales Bay Watershed pathogen time series monitoring program (RWQCB 2001).

Many of the Seashore's biologic resources are dependent upon good water quality. The Seashore supports freshwater, estuarine, and ocean environments and is of national significance for offshore marine productivity. It contains four threatened or endangered aquatic species, including the coho salmon (*Oncorhynchus kisutch*), steelhead trout (*Oncorhynchus mykiss*), California freshwater shrimp (*Syncharis pacifica*) and the California red-legged frog (*Rana aurora draytonii*).

The unique ecological environment and mix of wilderness and agricultural land use within these coastal watersheds requires monitoring to determine how the existing land management practices within the Seashore affect the quality of water and aquatic resources. The watersheds within the PRNS management area drain to state and federal protection areas including the Gulf of the Farallones and Cordell Banks National Marine Sanctuaries, and the Estero de Limantour and Point Reyes Headlands California Areas of Biological Significance. The area is also part of the UNESCO Man-in-the-Biosphere Golden Gate Biosphere Reserve. Beneficial uses of these waterbodies include designated areas of biological significance, cold water habitat, contact and non-contact recreation and shellfish production.

The Seashore is committed to land management techniques that not only meet established water quality criteria for humans, but for all aquatic species of concern. The existing uses, including intensive agricultural production add to the difficulty of achieving these objectives. The Seashore monitoring program intends to determine existing water quality conditions, and implement practices that will address the pollution source areas and minimize the levels of pollutants delivered to the aquatic systems within the Seashore Management Area.

Map 1. Point Reyes National Seashore

GENERAL SOURCES OF POLLUTION

Human activities can negatively impact surface water quality, even when the activity is far removed from the waterbody. With proper management of wastes and land use activities, these impacts can be minimized. Pollutants that enter waters fall into two general categories: *point sources* and *nonpoint sources*.

Point Sources

Point sources are typically piped discharges and are controlled through regulatory programs administered by the state. All regulated point source dischargers in California must apply for and obtain a National Pollutant Discharge Elimination System (NPDES) permit from the state Regional Water Quality Control Board. Depending upon size, confined animal operations may require an NPDES permit. At this time, none of the Seashore dairies are of a size requiring this permit.

> ***Point Sources***
>
> **Piped discharges from:**
> - Municipal wastewater treatment plants
> - Industrial facilities
> - Small package treatment plants
> - Large urban and industrial stormwater systems

Nonpoint Sources

Nonpoint sources are from a broad range of land use activities. Nonpoint source pollutants are typically carried to waters by rainfall, runoff or snowmelt. Sediment and nutrients are most often associated with nonpoint source pollution. Other pollutants associated with nonpoint source pollution include fecal coliform bacteria, oil and grease, pesticides and any other substance that may be washed off the ground or deposited from the atmosphere into surface waters.

Nonpoint pollution sources are diffuse in nature and occur intermittently, depending on rainfall events and land disturbance. Given these characteristics, it is difficult and resource intensive to quantify nonpoint contributions to water quality degradation in a given watershed. While nonpoint source pollution control often relies on voluntary actions, there are many programs designed to reduce nonpoint source pollution. While any one activity may not have a dramatic effect on water quality, the cumulative effect of land use activities in a watershed can have a severe and long-lasting impact.

> ***Nonpoint Sources***
>
> - Roads, parking lots and rooftops
> - Forest Practices
> - Agricultural lands
> - Rural residential development
> - Septic systems
> - Mining

Pollution sources within the Seashore watersheds are primarily nonpoint source. Agricultural operations including dairies and beef cattle, roads and trails (both maintained and abandoned), and minor development are normally described as nonpoint sources of pollution.

It is important to distinguish that many large areas discharge to a single point. In these cases, whether agriculture or trails, the pollution may be treated as if it is a point source discharge. Treatment of such source areas may be made at a single location. Primary means of addressing nonpoint source pollution involves a change in land management strategies. Whether agricultural or urban areas, changes in the manner that land and facilities are managed may make a marked difference with regard to pollutant sources or delivery to a stream.

APPLICABLE LAWS, REGULATIONS, AND POLICIES

NPS actions must comply with a suite of laws, regulations and policies, including the NPS Organic Act, enabling legislation for PRNS and GGNRA, NPS Management Policies (revised in 2001), Director's Orders 12 (regulations for implementing the National Environmental Policy Act), the PRNS General Management Plan, Resource Management Plan, and other planning and policy documents.

Enabling Legislation. Congress established Point Reyes National Seashore on September 13, 1962 "to save and preserve, for purposes of public recreation, benefit and inspiration, a portion of the diminishing seashore of the United States that remains undeveloped (Public Law 87-657)." An amendment to Public Law 94-544 (passed in 1976) states that the Seashore is to be administered "…without impairment of its natural values, in a manner which provides for such recreational, educational, historic preservation, interpretation and scientific research opportunities as are consistent with, based upon, and supportive of the maximum protection, restoration and preservation of the natural environment within the area." In addition, the NPS Organic Act and its amendments (16 U.S.C. 1 et seq.) require all units of the NPS to both conserve park resources and values, and to "leave them unimpaired for the enjoyment of future generations."

Congress established Golden Gate National Recreation Area by Public Law 92-589 "in order to preserve for public use and enjoyment certain areas of Marin and San Francisco Counties, California. In addition to providing for recreation and educational opportunities consistent with sound principles of land use planning and management, the NPS also was instructed to "preserve the recreation area, as far as possible, in its natural setting, and protect it from development and uses which would destroy the scenic beauty and natural character of the area."

Coastal Zone Act. This act was enacted to protect coastal environments. While this act transfers regulatory authority to the States and excluded federal installations from the definition of the "coastal zone," it requires that federal actions be consistent with state coastal management plans. Activities taking place within the coastal zone under the definition established by the California Coastal Management Plan require a federal consistency determination.

Coastal Zone Act Reauthorization Amendments (CZMA Section 6217). The 1990 reauthorization of the Coastal Zone Act significantly increased nonpoint source control measures associated with activities within the coastal zone. A series of management measures for nonpoint sources of pollution to coastal waters were identified for states to address. The guidelines associated with the Section 6217 mandate have been adopted into the California Nonpoint Source Program Strategy and Implementation Plan, 1998-2013 (SWRCB & CCC 2000).

Endangered Species Act of 1973, as amended, PL 93-205, 87 Stat. 884, 16 USC §1531 et seq. The Endangered Species Act (ESA) protects threatened and endangered species, as listed by the U.S. Fish and Wildlife Service (USFWS), from unauthorized take, and directs federal agencies to ensure that their actions do not jeopardize the continued existence of such species. Section 7 of the act defines federal agency responsibilities for consultation with the USFWS and requires preparation of a Biological Assessment to identify any threatened or endangered species that is likely to be affected by the proposed action.

Federal Water Pollution Control Act (i.e., the Clean Water Act) of 1977 (33 USC 1251 et seq.) and 1987 Amendments. The Clean Water Act provides for restoration and maintenance of the physical, chemical, and biological integrity of the nation's waters. Section 404 of the act prohibits the discharge of fill material into navigable water of the United States, including wetlands, except as permitted under separate regulations by the U.S. Army Corps of Engineers and U.S. Environmental Protection Agency.

The Clean Water Act transfers regulatory authority to the States for management and implementation of all water quality related programs. The 1987 amendments upgraded the program, significantly enhancing concentration on nonpoint sources of pollution.

Executive Order 11988: Floodplain Management. This Executive Order requires federal agencies to avoid, to the extent possible, adverse impacts associated with the occupancy and modification of floodplains, and to avoid development in floodplains whenever there is a practical alternative. If a proposed action is found to be in the applicable regulatory floodplain, the agency shall prepare a floodplain assessment, known as a Statement of Findings.

Executive Order 11990: Protection of Wetlands. This Executive Order established the protection of wetlands and riparian systems as the official policy of the federal government. It requires all federal agencies to consider wetland protection as an important part of their policies and take action to minimize the destruction, loss or degradation of wetlands, and to preserve and enhance the natural and beneficial values of wetlands.

National Environmental Policy Act (NEPA) of 1970 and implementing regulations. PL 91-190, 83 Stat. 852, 42 USC §4341 et seq. and 40 CFR Parts 1500-1508. The NEPA process is intended to help public officials make decisions that are based on understanding of environmental consequences, and take actions that protect, restore, and enhance the environment. In addition to regulations implementing NEPA set forth by the Council on Environmental Quality (CEQ), PRNS is guided by regulations that further direct the Department of the Interior and NPS. These regulations establish the process by which PRNS must implement the NEPA, including requirements for this EIS.

LOCAL WATER QUALITY PROGRAMS

San Francisco Bay Regional Water Quality Control Board - Water Quality Control Plan

The State of California Water Resources Control Board (SWRCB) is responsible for ensuring that waters of the state are "fishable and swimmable" as set forth through the Clean Water Act. The SWRCB has designated nine regions within the state to implement and administer water quality management programs. The 1995 San Francisco Bay Region Water Quality Control Plan is the master policy document for the San Francisco Bay Region. This plan identifies beneficial use designations for most water bodies, water quality objectives to protect those beneficial uses, and a strategy to achieve designated water quality objectives.

Point Reyes National Seashore is located within the Marin Coastal Basin of the San Francisco Bay Regional Water Quality Control Board (RWQCB) area. The Basin includes all coastal drainages from Rodeo Creek, north to Walker Creek. Significant surface water and wetland areas within the Basin are identified along with their designated beneficial uses. The Plan contains some serious hydrologic and use designation omissions for areas within the Seashore. Beneficial use criteria are described for each of the monitored watersheds.

A list and description of beneficial uses is included in Appendix C.

California Department of Health Services – Management Plans for Commercial Shellfish Growing Areas

Tomales Bay and Drakes Estero are two of the few remaining commercial shellfish growing areas within the State of California. Maricultural leases for submerged waters within the state of California are administered through the Department of Fish and Game (CDFG). Shellfish harvest standards are established through the National Shellfish Sanitation Program (NSSP) and implemented through the Department of Health Services (CDHS). The CDHS is responsible for developing and implementing the water quality monitoring program associated with shellfish harvest. Through this program, a significant number of Tomales Bay and Drakes Estero surface water samples have been taken over the past decade to characterize how these waters respond to storm runoff events (CDHS 1992-2000).

Annual evaluation of the growing area classifications and rainfall closure standards is required through the NSSP Model Ordinance Chapter IV (1999). The latest shellfish management plans, maps of the Tomales Bay and Drakes Estero maricultural leases, growing areas, and sampling points are included in Appendix D of the report.

All of the leases within Tomales Bay and Drakes Estero are conditionally approved, meaning that they are subject to either seasonal or rainfall induced closure. All closures are established and adjusted based upon the surface water quality results collected from standardized locations. Closure thresholds are established for areas within the shellfish production leases thresholds and are based upon a 24-hour period of rainfall at an established monitoring location. Primary closure thresholds for Tomales Bay range from 0.4” to 0.5” and secondary closure thresholds are 0.67”. In Drakes Estero, closure thresholds are 0.70” for inner Schooner Bay and 0.75” for the remainder of the conditionally approved shellfish production areas. When the secondary rainfall closure threshold is exceeded in Tomales Bay, the mandated period of closure is extended by one day. Mandated closures typically last from three to seven days after the rainfall event.

Clean Water Action Plan

The Clean Water Action Plan, released on February 19, 1998, requests that States and Tribes, with assistance from federal agencies and input from stakeholders and the public, convene a collaborative process to develop a Unified Watershed Assessment (UWA) to guide allocation of new federal resources for watershed protection. Using the USGS 8-digit Hydrologic Units as the spatial framework for defining its watershed assessment categories and targeting the watersheds, states were required to identify their restoration priorities. California developed a priority list by Hydrologic Unit from aggregated database information. The Tomales – Drakes Bay Hydrologic Unit (18050005) is identified as a high priority watershed for restoration.

Clean Water Act - Section 303 (d) listing

As mandated by Section 303 (d) of the Clean Water Act, states are required to list impaired water bodies on a biannual basis. Within the Tomales – Drakes Bay Hydrologic Unit, watersheds draining to Tomales Bay are of particular interest. The following areas have been determined by the San Francisco Bay Regional Water Quality Control Board to not meet their designated beneficial use and are listed as impaired by the following constituents.

- Tomales Bay – sediment, nutrients, pathogens, and mercury
- Lagunitas Creek – sediment, nutrients, and pathogens
- Walker Creek – sediment, nutrients, mercury (pathogens to be added)

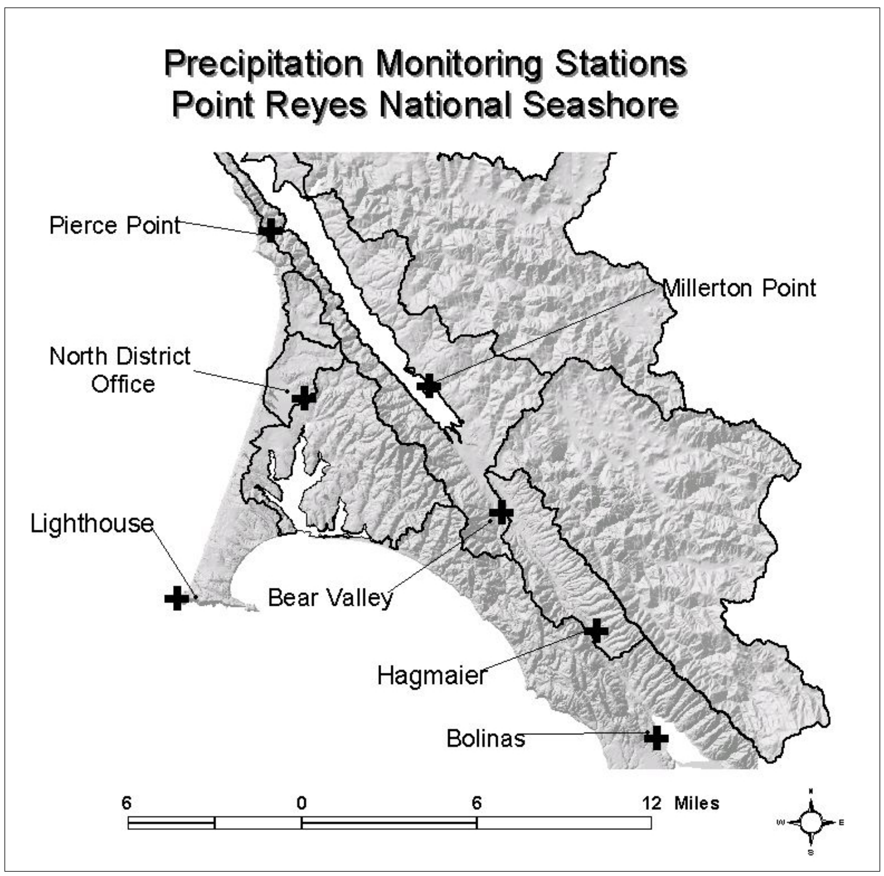
States are required to develop a timeline for addressing watersheds listed on the 303(d) list. It is likely for each of the impaired waterbodies, that management strategies and or Total Maximum Daily Loads (TMDLs) will be developed for each of the listed pollution parameters. A schedule for TMDLs has been established by the RWQCB and is included as part of Appendix C. Actions to reduce pollutants and pollution within the Seashore, and specifically Lagunitas and Tomales Bay watersheds, will contribute directly to State restoration efforts.

CLIMATE

The coastal Mediterranean climate of the study area is characterized by cool wet winters and warm dry summers, often affected by low-lying fog and strong sea breezes. A major feature is the lack of extreme temperatures, which rarely exceed 90° or drop below 40° F. Thick local fogs are common during summer. The temperatures change rapidly with proximity to the ocean and with topography. The ocean temperature averages 55° year-round, and the cold water and low fog mitigate the summer heat of eastern Marin County, which frequently approaches 95°. Thus, as one moves away from the coast the climate often becomes warmer and drier, especially in the summer.

Ninety-one percent of the annual precipitation falls between October and March of the water year. Precipitation amounts at the Lighthouse or near the pacific shore may be less than half of those on the ridge or to the east in Olema and Inverness. The 1,000 to 1,500 foot ridgeline provides an orographic effect, wringing the clouds of their moisture. Rainfall averages range from 25 inches west of Inverness Ridge up to 40 inches at Bear Valley.

The summer months are prone to fog as the moist marine air is pushed inland by the onshore breezes. Fog drip is most



Map 2. Rainfall Monitoring Locations

prevalent at the higher elevations where wind blows the saturated air over the ridgeline and into the Olema Valley. The needles of Douglas-fir and Bishop pine trees capture moisture, which accumulates and drops to the soil below. Research shows that fog drip is proportional to the surface area of the individual trees. It is possible in this region that 20 inches of precipitation are extracted from the fog by individual trees, with that water supporting the lush understory and growth of the woody vegetation. Fog drip augments the groundwater supply, reducing stress on the aquifers, and possibly increasing the baseflow of the streams.

Fall weather patterns are typically dryer, with onshore high pressure resulting in an offshore flow. This is the driest season of the year with high fire danger.

Much of the nonpoint source pollution is driven by precipitation events. Rainfall monitoring stations are shown in Map 2. The longest continuous period of record is the Bear Valley Weather station (1965 to present) located adjacent to the Bear Valley Headquarters. In 1998, additional recording precipitation gages were installed at the Lighthouse, Pierce Point Ranch, and Hagmaier Ranch. In addition, other recording rainfall gages are located at Millerton Point and the Coast Guard station. The Seashore is cooperating with the California Department of Health Services – Preharvest Shellfish Sanitation Unit for operation of a real-time recording weather station at the old North District Ranger office.

Monthly and daily rainfall records for Bear Valley and Hagmaier are included in Appendix E.

THREATENED AND ENDANGERED SPECIES

The Seashore supports a variety of threatened and endangered species. Description of aquatic species and their habitat requirements are adapted from the draft California red-legged frog Recovery Plan (USFWS 2000) and presented below.

Coho salmon (*Oncorhynchus kisutch*) –Threatened

The general biology of coho salmon is described in detail in Shapovolov and Taft, 1954. The coho salmon is an anadromous species. The salmon generally return to natal streams after spending two years in the ocean. The spawning migrations begin after heavy late-fall or winter rains breach the sandbars at the mouth of coastal streams allowing the fish to move upstream. Spawning occurs in small to medium sized gravel at aerated sites, typically near the head of the riffle (Moyle 1976). These streams have summer temperatures seldom exceeding 21 degrees Centigrade (70 degrees Fahrenheit). Emergent fry use shallow near-shore areas, whereas optimal habitat conditions for juveniles and sub-adults are deep pools associated with rootwads, woody debris, and boulders in shaded stream sections. The distribution and habitat of coho juveniles partially overlaps with that of the steelhead trout and California red-legged frog.

Because of dramatic declines in population numbers, the National Marine Fisheries Service (NMFS) was petitioned to list this species coastwide (NMFS 1997). Several runs were listed along the central California coast. Causes of coho salmon declines in California include incompatible landuse practices such as logging and urbanization, loss of wild stocks, introduced diseases, over harvesting, and climactic changes.

The National Marine Fisheries Service has noted that within the central California coast Evolutionarily Significant Unit (ESU), the decision to list coho salmon as threatened may have been overly optimistic and concludes that the ESU population is presently in danger of extinction (NMFS 2001). It has been noted, through personal communication, that the Lagunitas Creek Watershed population is the largest south of the Noyo River and may represent a much larger percentage of the remaining wild coho in the ESU, than the 10% quoted in the 1997 listing.

Coho salmon are known to exist in watersheds including Lagunitas and Olema Creek. Additional watersheds including Walker Creek and Pine Gulch Creek historically support coho salmon. Through the National Park Service Coho Salmon and Steelhead Trout Restoration Project (CSRP), assessment of habitat and condition of these species has significantly improved the knowledge of this resource, resulting in management changes to protect these species.

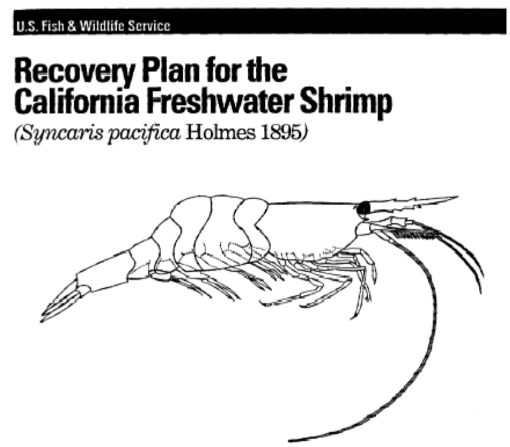
Steelhead trout (*Oncorhynchus mykiss*) – Threatened

Steelhead trout are anadromous rainbow trout; adult steelhead typically spawn in gravel riffles in the spring, from February to June. Optimum temperatures for growth range from 13 to 21 degrees Centigrade (55 to 70 degrees Fahrenheit) (Moyle 1976). It is also noted that steelhead may persist in a broad range of pH (from 5.8 to 9.6) but prefer a pH between 7 and 8 (Moyle

1976). Steelhead fry reside in near-shore areas. Steelhead juveniles tend to use riffles and pool margins, potentially overlapping with California red-legged frog tadpoles. Because of dramatic declines in population numbers, the National Marine Fisheries Service (NMFS) was petitioned to list this species throughout much of the California coast (NMFS 1998a).

Steelhead trout are known to exist in most perennial watersheds within Point Reyes National Seashore.

California freshwater shrimp (*Syncharis pacifica*) - Endangered



The California freshwater shrimp is endemic to perennial streams in Marin, Napa, and Sonoma counties and is the only existing species in the genus *Syncharis*. The species is adapted to the freshwater environments and has not been found in brackish or estuarine environments. The shrimp is found in low elevation (less than 16 meters (52 feet)) and low gradient (less than 1 percent) streams where the banks are structurally diverse with undercut banks, exposed roots, overhanging woody debris, or overhanging vegetation (Eng 1981, Serpa 1986). The shrimp is threatened by several types of human activities (e.g., urbanization, in-stream gravel mining, overgrazing, agricultural development and activities, impoundments, water diversions, water pollution, and introduced predators). Many of these threats operate synergistically and cumulatively with each other and with natural disturbances such as floods and droughts (US Fish and Wildlife Service 1997a).

Distribution of the California freshwater shrimp occurs in Walker Creek and Lagunitas Creek. Recent monitoring on Olema Creek identified a small population of the shrimp in 1997. Field surveys in 1999 did not reveal any individual shrimp. This is likely related to significant habitat changes in the lower watershed of Olema Creek associated flooding and sediment deposition in the primary habitat area.

California red-legged frog (*Rana aurora draytonii*) – Threatened

The California red-legged frog is identified as threatened by the US Fish and Wildlife Service (USFWS 2000a, 2001). Habitat requirements for the RLF include breeding, non-breeding, and migration. Breeding and tadpole rearing habitat is provided in impoundments and/or slow-moving water. Frogs lay their eggs between November and April. Eggs hatch within 8 to 16 days. Tadpoles rear in the same body of water before molting.

California red-legged frogs are sensitive to high salinity, which often occurs in coastal lagoon habitats. When eggs are exposed to salinity levels greater than 4.5 parts per thousand (ppt), 100% mortality occurs (Jennings and Hayes 1990). Larvae die when exposed to salinity levels greater than 7 ppt. (M Jennings *in litt*. 1993). Observations at Horseshoe Pond at Point Reyes National Seashore indicate that frogs may occur in waters with salinity exceeding 10 ppt. In addition, RLF tadpoles have been captured at salinities exceeding 8 ppt in this same locality (D. Press pers. comm. 2001).

Nussbaum et. al. (1983) state that early embryos of northern red-legged frogs are tolerant of temperatures only between 9 and 21 degrees Celsius (48 and 70 degrees Fahrenheit). Both the upper and lower lethal limits are the most extreme known for any North American ranid frog. Data specific to the California red-legged frog are not available although field observations indicate that the RLF is absent when temperature exceeds 22 degrees Celsius (70 degrees Fahrenheit), particularly when the temperature throughout a pool is this high and there are no cool, deep portions (S Bobzein pers. comm. 1998).

The factors associated with declining populations of the frog include degradation and loss of its habitat through agriculture, urbanization, mining, overgrazing, recreation, timber harvesting, non-native plants, impoundments, water diversions, degraded water quality, and introduced predators.

Tomales asellid (*Caecidotea tomalensis*) – Species of Concern

The asellid, an aquatic sowbug, inhabits moist soils or water bodies with perennial flows although it has been found in seasonal wetlands (Shinomoto and Fong 1997). In general, freshwater isopods such as the Tomales asellid, are associated with shallow waters less than one meter (three feet) deep, and are found under rocks, vegetation, and debris (Serpa 1991). The Tomales asellid is known from just 11 sites within California, from Mendocino County to San Mateo County (Serpa 1991).

RANGELAND MANAGEMENT

PRNS contains approximately 20,300 acres zoned for traditional agricultural uses, and manages an additional 11,700 acres for such use in the North District of Golden Gate National Recreation Area (See Map 1). Together these lands contain roughly 30 historic ranch sites on which active beef or dairy ranching was taking place at the time of purchase for inclusion in the two National Park units, and on which such activities continue today.

As agricultural lands were purchased by the NPS, sellers were allowed to continue dairying, beef ranching, or equestrian activities under one of two arrangements. They could retain a Reservation of Possession (ROP), under which they would forego a portion of the purchase amount in exchange for the right to continue ranching activities for up to 25 years. Alternately, they could sell outright and enter into Special Use Permits (SUP) of up to 5 years with the park. Some sellers retained an ROP on part of their land, and entered into SUP agreements for the rest, while others have entered into more than one SUP agreement with the Park.

Between them the 25 ranchers currently operating within the project area currently hold 12 ROPs and 32 SUPs, and another 5 SUPs have become vacant in the last few years (Table 2). Most of the ROPs will be expiring in the next decade. It has been the policy of PRNS in the past to allow ranchers whose ROP terms expire to continue ranch operations under SUPs. If this policy is maintained, the number of grazing permits managed by PRNS will increase to a maximum of 49. Together these permittees and ROP holders support approximately 6350 cattle on a year-round basis.

Through the permitting process, the National Park Service has established appropriate stocking rates, described in Animal Unit months (AUMs) for beef grazing operations.

Table 2. Livestock operations under management by PRNS.

Operator Name / Ranch Name[a]	Total Acres	Grazed Acres	# of Animals Authorized	# of AUMs Authorized	Watershed
Cheda Ranch ROP	914	570	44	(ROP)	Cheda
D Ranch	1092	922	*vacant*		Drakes Bay
D Ranch / North Headland	32	32	*vacant*		Drakes Bay
D Ranch / South Headland	59	49	*vacant*		Drakes Bay
Gallagher / F Ranch	1510	1346	175	2100	Drakes Estero
Genazzi Ranch ROP	438	361	55	660	Lagunitas
Giacomini, Ralph	1832	810	95	1140	Olema
Giacomini, Rich/Waldo	570	570	ROP Dairy	ROP Dairy	Lagunitas
Giacomini, Robert	320	229	35	420	Lagunitas
Grossi, A. / H Ranch	1033	785	280	3360	Drakes Estero
Grossi, A. / H – Abbotts Lagoon	71	71	5	60	Pacific
Grossi, A. / K Ranch	710	685	72	864	Pacific
Grossi, R. / M Ranch	1193	986	175	2100	Pacific
Kehoe / J Ranch ROP	615	289	836	dairy	Pacific
Kehoe / J SUP	415	285	37	444	Pacific
Lunny / G Ranch	1151	665	95	1140	Drakes Estero

Lupton Ranch	834	442	75	900	Olema
Martinelli Ranch ROP	259	236	40	480	Tomales Bay
McClure / I Ranch	1320	600	976	dairy	Pacific
McDonald / N Ranch	925	580	90	1080	Drakes Estero
McFadden Ranch ROP	335	244	35	420	Olema
McFadden SUP	6	6	7	35	Olema
McIsaac Tocaloma Ranch ROP	1065	650	not specified	(ROP)	Lagunitas
McIsaac SUP	530	258	45	540	Lagunitas
Mendoza / B Ranch	1242	916	850	dairy	Drakes Bay
Mendoza / L Ranch	1126	716	430	dairy	Pacific
Murphy / Home Ranch	3045	2360	318	3816	Drakes Estero
Murphy / Home Ranch ROP	20	16	horses only		Drakes Estero
Niman Ranch ROP	206	198	not specified	(ROP)	Bolinas Mesa
Niman / Commonweal	575	513	66	792	Bolinas Mesa
Niman / Mesa Ranch	90	70	9	108	Bolinas Mesa
Nunes / A Ranch	771	607	480	dairy	Drakes Bay
Nunes / A Ranch headlands	96	96	10	120	Drakes Bay
Nunes / E Ranch	1010	692	175	2100	Drakes Estero
Nunes / E-Creamery Bay	329	98	13	156	Drakes Estero
Nunes / E-North Beach	36	36	cultivated		Pacific
Percy Ranch ROP	240	78	20 sheep	(ROP)	Lagunitas
Percy SUP	443	206	25	240	Lagunitas
Rogers, C. Ranch ROP	219	207	30	(ROP)	Olema
Rogers, C. SUP	10	10	1	12	Olema
Rogers, D. Ranch	398	342	66	792	Drakes Bay
Spaletta / C Ranch	709	630	430	dairy	Drakes Bay
Stewart Stables ROP	18	18	horses only		Olema
Stewart Ranch SUP	885	784	50	600	Olema
Stewart / Truttman Ranch	1128	873	140	1680	Olema
Stewart / Olema East	95	95	63/3 mo.	189	Olema
Stewart / Olema West	200	200	63/9 mo.	567	Olema
Tacherra Bros.	516	325	35	420	Bolinas Mesa
Wilkins Ranch	1382	359	25	300	Bolinas Lagoon
Zanardi Ranch ROP	573	329	45	540	Lagunitas
Total Authorized Animals	**30534**	**20976**	**6350**		

a/ Unless designated otherwise, ranches are Special Use Permits or leases.

Seven of the ranches are dairies, which differ from beef ranches in a number of ways. Dairies have many more cattle on each ranch than do beef ranches, and approximately two-thirds of the livestock on PRNS-administered lands are on dairies. Because they are milked twice daily, milk cows are kept near dairy headquarters and maintained on high-nutrition feeds. Dairies with more than 700 milking cows are considered Confined Animal Feeding Operations (CAFOs) by the Environmental Protection Agency (EPA). They produce large quantities of manure wastes and must have a National Pollution Discharge Elimination System (NPDES) permit in hand. None of the operations in the Seashore operate at a level to require a NPDES permit, but they still must manage operations to avoid pollution of nearby streams by excess nutrients and coliform bacteria.

Livestock-related activities

Dairy waste capture and disposal
Because large numbers of cows are confined to small areas near milking facilities on dairies, manure must be collected and disposed of. Small pastures in which cows are held between milkings are typically scraped by tractor and the manure stockpiled. On most of the dairies, cows are kept in barns during the winter. The barns, milking parlors, and travel lanes between them are cleaned by washing manure into ponds, where the manure slurry is stored during the winter. Stored manure is spread as fertilizer on rangelands and silage fields during the dry season, as discussed below. Facilities for holding runoff from animal concentration areas on the dairies are not adequate to capture all runoff from the calculated 25-year, 24-hour rainfall event. In some cases, runoff from concentration areas is not diverted to holding ponds, and enters nearby creeks. Dairy runoff does not enter streams used by anadromous fish, but it does affect water quality in Drakes Bay and offshore waters of northern Point Reyes. PRNS is currently working with these ranches to improve dairy facilities and management to correct these problems.

Fertilizing with Animal Manure
Dairies dispose of accumulated animal manure by spraying it on fields from trucks or pumping it through pipes that drain waste out onto fields. Pipes are moved periodically to distribute manure. In some cases the waste is plowed into fields during the fall before silage crops are planted. Such disposal takes place in upland areas so plants will take up nutrients in the manure before they reach creeks.

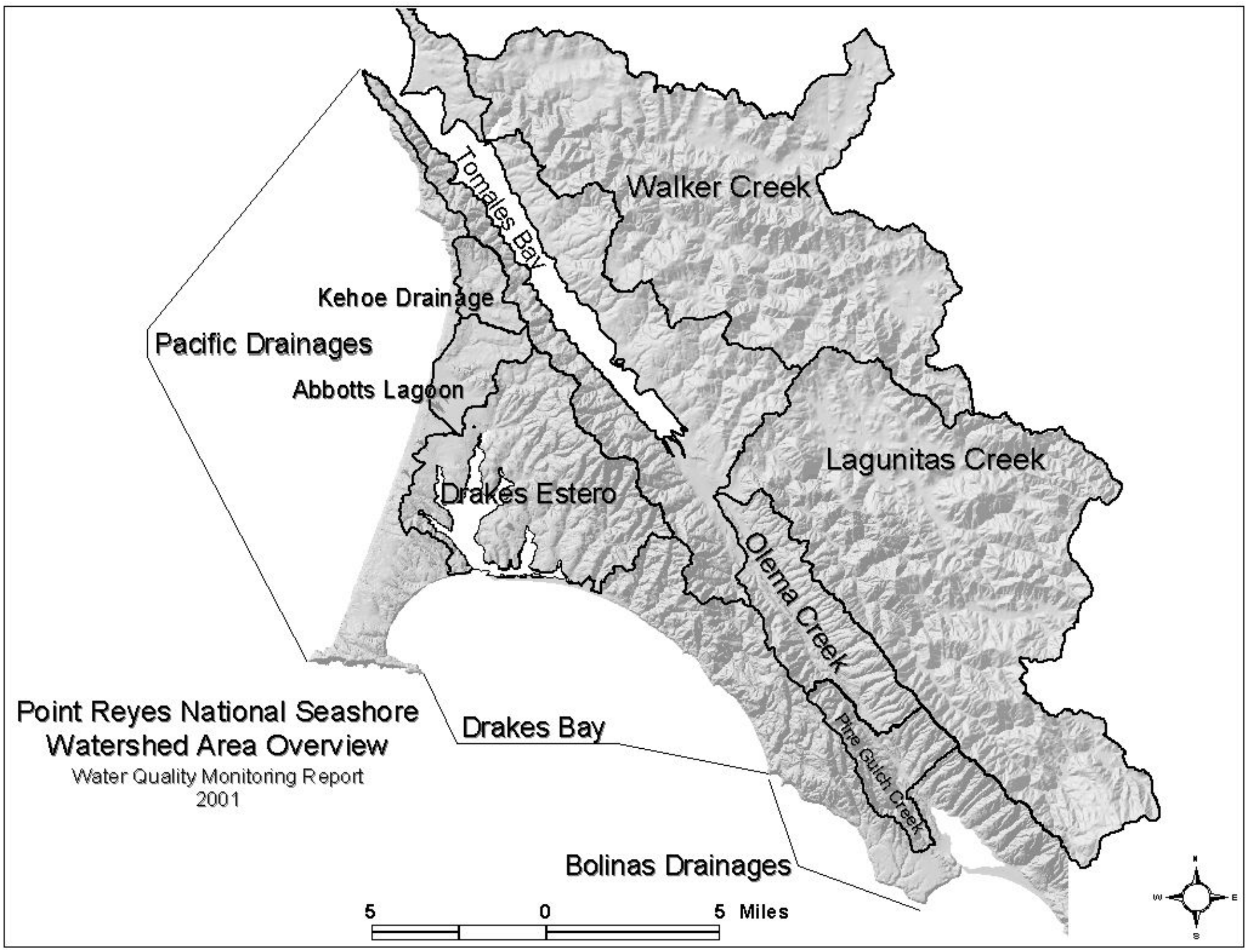
Silage production
Five of the permittees, including three of the dairies, are allowed to raise grass crops on a total of 1,420 acres to provide silage for feeding their livestock. Non-native annual grasses, such as Italian ryegrass (*Lolium multiflorum*) and oat grass (*Avena sativa*) are typically planted. Permittees who raise silage are required to leave adequate crop residues to protect the soil from erosion.

Horse stables
Several of the ranches keep horses for use in livestock management and two also board horses. One of the ranches in the Olema Valley keeps up to 30 boarded and privately-owned horses.

AMBIENT STREAM MONITORING PROGRAM

The ambient stream monitoring program began with 23 stream sampling sites distributed among 12 watersheds in the Seashore Management Area. The sample locations were selected based upon location, accessibility, and land use within the watershed. Concentrated monitoring on Olema Creek (12 sites) was performed to characterize different land use practices, cumulative impact, and the effect of restoration practices initiated within the watershed. Based upon results, the program has been expanded and currently includes a total of 28 monitoring sites, including sites downstream of all Seashore dairy operations. The monitoring sites are included in the Kehoe, Abbotts, Drakes Estero, Drakes Bay, Olema and Lagunitas Creek watersheds.

Map 3. Watershed Area Overview



Sample results have been compiled within the Point Reyes National Seashore Water Quality Monitoring Database (See Appendix A). This database is a Microsoft Access program allowing for provision of reports, accounting of sample analysis, and export to a spreadsheet format.

WATER QUALITY SAMPLE REGIME

Ideally, storm samples are collected on the rising limb of the hydrograph, as pollutants are flushed from the land surface. Sampling based on storm event poses logistical difficulties related to distance between sample locations, operations of commercial laboratories, and small watershed size. Monitoring results in this report are rather conservative, due to sampling constraints, but are indicative of the general water quality conditions.

Original protocol focused water quality collection around storm events. Sampling based on storm events posed significant logistical difficulties related to distance between sample locations, operations of commercial laboratories, and response time between peak rainfall and peak flow (small watershed size). Six events (fall, first flush, three winter, and one spring) were to be sampled annually. This proved difficult as only two of the six sample events could be planned.

In the first year, no more than 10 to 15 samples could be collected in a given day. This limited the ability to effectively compare watershed conditions across the Seashore, as they were sampled on different days or different weeks.

Future Collection Strategy

The sample collection has been modified to regular quarterly sampling plus two unscheduled winter events (first flush and one other storm). Additional collection in specific areas during specific storm events will be planned to identify specific sources.

In FY2000, additional field equipment was purchased to allow for two groups to perform field collection at the same time. This resulted in the ability, with pre-preparation and an early start, to collect samples from all 23 base monitoring stations in a given day.

Single day sample collection requires advance notification of the laboratory and pre-planning. Two teams of two can sample all sites and deliver samples to the lab.

All quarterly and storm based sample events should be done in a single day. This technique was also used effectively to sample all of the dairy drainages where long access hikes are required.

Sample Events

Fall Quarter Base Flow (October)

The fall base flow sample is focused on the lowest flow period of the year, prior to the period of time where deciduous trees reduce water uptake and stream flows begin to rebound. Many of the Olema Creek tributaries are intermittent and are dry for the base flow sample.

High pollutant levels observed during the fall base flow are attributed to direct access to water or persistent sources (septic systems) as pollutants stored on the land surface are not delivered until the first flush. Fecal coliform is not expected to be high during this sample period unless there is direct access by the cattle to the stream.

First Flush (weather dependent – December/January)

The first flush event occurs after soils are saturated and precipitation begins to accumulate on the surface and flow to rivulets and channels. This is the event that washes nonpoint sources of pollution accumulated on the land during the summer and fall into the stream. The normal rainfall patterns would result in saturated soil conditions (approximately 6 to 9 inches of rain within a 30-day period) by mid December. Coincidentally, this can also correspond to the first ‘freshet’ that brings coho salmon into the watershed.

Winter Runoff Events (weather dependent - December- March)
Once saturated in the winter, the precipitation to runoff ratio is markedly increased. The intent of the winter samples is to detect pollution sources that prove to be persistent, even with relatively short pollution accumulation periods between runoff events. Based on operations in 2001, focused sampling allowed for better identification of source areas, and immediate treatment.

These sample events should focus on specific land uses (all dairy drainages), or areas of concern (subwatersheds or project specific focus). For each sample day, one baseline watershed (an area without the land use that is the subject of the collection event) should be sampled. Laguna Creek or Muddy Hollow Creek are the best sites if agricultural lands are being samples. If sediment levels are the main parameter of concern, Bear Valley Creek should be used.

Winter Quarter Sample Event
In future years, it is recommended that instead of three, only one mid-winter sample be collected from all base sites in a given day.

Table 3. Sample Event Matrix

	Fall	**First Flush**	**Winter**	**Storm samples**	**Spring**	**Summer**
When	October	Weather dependant Nov-Jan	Weather Dependant December-March	December – March	April	July
Where	All sites	All Sites	All Sites	Dairy district, degraded subwatersheds	All Sites	All Sites
Sample Objective	Fall base flow Temperature and DO	Initial pollutant load from upland areas – nutrients, pathogens, & sediment	Winter discharge, nutrients, sediment, and pathogens	Site specific sampling for pathogens, sediment, nutrients and ammonia.	Spring baseflow-nutrients and pathogens	Summer flow, identify low flow conditions. Temperature and DO
Collection type	Single Day	Single day	Single Day	Single Day	Single Day	Single Day
Planning	Advance notice to Lab	Unplanned – 24 hour notice to lab	Unplanned – 24 hour notice to lab	Unplanned - 24 hour notice to Lab	Advance notice to Lab	Advance notice to Lab
Staffing	4 people	4 people	4 people	2-4 people	4 people	4 people

Spring Quarter Sample Event (April)
Unlike areas with hydrology dominated by snowfall, the spring flow event is meant to capture runoff while many of the intermittent tributaries are still flowing. While many of the perennial streams have been excluded to livestock, the intermittent tributaries are areas accessible to

livestock that might be contributing to the spring flow. Sampling is not tied to actual storm events, but rather the declining April flows.

Summer Quarter Sample Event (July)
Summer flow sampling was not part of the original protocol. After evaluating this program, it is important that summer water quality conditions are identified.

SAMPLE PARAMETERS

Sampling parameters for the Point Reyes National Seashore water quality monitoring program are categorized between field and laboratory parameters.

Field Parameters
Field parameters are collected using standard field probes. This allows extensive collection without additional analytical cost. Field collected parameters include temperature, pH, dissolved oxygen, percent oxygen saturation, conductivity, and salinity.

Temperature
Temperature is critical for maintaining suitable habitat for aquatic organisms. Thermal tolerance ranges for coho salmon are 12-19 degrees centigrade, while steelhead trout can handle warmer conditions, ranging from 13-21 degrees centigrade. The levels of dissolved oxygen in water are strongly correlated to temperature. The higher the temperature, the lower the ability of the water to store dissolved oxygen. In streams critical to the protection of coho salmon and steelhead trout the CSRP is conducting long-term temperature monitoring with data loggers to characterize the diurnal variations and thermal range.

Temperature also plays a minor role in the speciation of ammonia with higher temperatures resulting in higher amounts of toxic un-ionized ammonia. Temperatures are measured using any of the YSI hand-held probes.

pH
pH is a measurement of a water's acidity. Low pH, commonly a result of acid rain, can cause the death of aquatic biota directly or indirectly. One common indirect consequence of low pH is the liberation of highly toxic aluminum from surrounding soils. pH also plays a large role in ammonia chemistry. The relative amount of charged and uncharged ammonia is mainly a function of pH. The Regional Water Quality Control Board (RWQCB) water quality objective for pH is between 6.5 and 8.5. Typical pH levels observed in this region are from 7 to 8.5. Waterproof Oakton pH meters are calibrated regularly for use in the field.

Dissolved Oxygen
DO is critical for respiring aquatic biota such as fish, fish eggs and benthic invertebrates. RWQCB DO water quality objectives for warm and cold water habitat are 5.0 and 7.0 mg/L, respectively. Dissolved oxygen can be measured using the YSI-55 or YSI-85.

RWQCB Criteria - 1995 Basin Plan	
Dissolved Oxygen	
Cold water habitat	7.0 mg/l minimum
Warm water habitat	5.0 mg/l minimum

The equipment allows for analysis of dissolved oxygen from 0 to 20 mg/l. Dissolved oxygen is of concern in the summer as temperatures rise and flow drops. In stream systems, low dissolved oxygen has been observed in association with isolated pools due to low flow. Salmonids have been observed surviving in isolated pools with dissolved oxygen levels less than 3 mg/l.

Conductivity, Specific Conductance, Salinity

Conductivity is a measurement of the ability of ions in an aqueous solution to carry electrical current. Thus, it is an estimate of the amount of dissolved ionic "pollution" in a sample.

Common ions effecting conductivity

Na^{+}, K^{+}, NH_4^{+}, Ca^{2+}, Mg^{2+}, Cl^{-}, HCO_3^{-}, NO_3^{-} and SO_4^{2-}

Conductivity is measured using YSI-30 and YSI-85 handheld probes. These units are designed for field use, and are calibrated on a regular basis. The probes collect conductivity, specific conductance (temperature corrected conductivity to 25 C), and salinity.

Monitoring Criteria for Conductivity

Specific Conductance	850 uS/cm
Conductivity	750 uS/cm
Becomes lethal to fish	~1,700 uS/cm

Recommendation per Michael Rugg - CDFG

The measure of conductive material within the liquid (conductivity) is reported as a flux, microSiemens per centimeter (uS/cm). Specific conductance is the conductivity standardized to a 25 degrees Centigrade. The unit also converts information into a salinity reading in parts per thousand (ppt).

Conductivity is indicative of a significant salt source. Background levels in coastal watersheds are higher than in inland areas. All freshwater fish (warm and cold water) are intolerant of salts. As they absorb water through osmosis, the higher salinity levels reduce their ability to bring water into their system.

For the purpose of this report, conductivity is used as a secondary indicator of impaired conditions. Sample sites with simple mean conductivity above 850 uS/cm are considered impacted by land use activity. Existing land use likely impacts sites with simple mean conductivity between 500uS/cm and 850 uS/cm. Conductivity monitoring should be continued.

Laboratory Parameters

The threats based water quality monitoring program is designed to help determine the ambient pollutant levels of Total Suspended Solids (TSS), nitrate, nitrite, orthophosphorus, ammonia, and coliform at each of the sites. Through the first year of sampling the Seashore has made determinations as to the need for continued sampling of certain parameters in the future.

One gross generalization based upon our results is that nutrient concentrations are significantly diluted by winter flows. In the smaller watersheds or close to source areas, nutrient concentrations have been measurable. The fact that we see dilution in most cases is indicative of limited pollutant source areas within the monitored watersheds. In Olema Creek, for example, some tributaries have shown raised levels of nutrient concentrations, but in the mainstem, levels have been below detection. This has required that other pollutant parameters, such as fecal coliform are used to trace back towards source areas.

Nitrate and Nitrite

Nitrate and nitrite are chemical constituents essential to biotic production. When too much Nitrogen is available, productivity may exceed normal levels. Depending on the system, either nitrogen or phosphorus is the limiting nutrient. In either case, excess nutrient loading will lead to increased production of algae or other aquatic plants. Where algal blooms occur, the increased plant respiration leads to supersaturated levels of oxygen in the water and high levels of dissolved oxygen. Following the boom in aquatic production is the bust. Decay of this excessive biomass leads to consumption of nearly all the dissolved oxygen in the system. In many cases algal blooms are followed by fish kills, associated with the low levels of oxygen in the water.

Levels of nitrate and nitrite are responsive to runoff. They are mobilized by water with accumulation in depositional (sink) areas. Within the Seashore these areas are often ponds or lagoons. Monitoring of nitrate and nitrite has proven difficult, as the levels are often below detectable limits due to dilution by water.

Following one year of sampling it is clear that at most ambient stream sites, levels of nitrate and nitrite were below detectable limits (0.2 mg/l).

Ammonia, Un-ionized Ammonia

In aquatic systems, ammonia is generally in its ionized or charged form NH_4^+. However, a small fraction occurs in the un-ionized, or uncharged form NH_3. It is the un-ionized form of ammonia that is toxic to aquatic species.

RWQCB Criteria - 1995 Basin Plan	
Un-ionized Ammonia	
Toxic	0.025 mg/l
Lethal	0.12 mg/l

The relative amount of charged and uncharged ammonia is mainly a function of pH. Higher pH results in a higher fraction of ammonia in its un-ionized toxic form. For example, at a temperature of 15 °C only 0.3% of total ammonia is in its un-ionized form at a pH of 7.0. However, at a pH of 9.0, the fraction of un-ionized ammonia increases nearly 100 fold to 21%.

The EPA has established criteria for maximum ammonia concentrations in surface water based on danger to aquatic organisms such as fish. These criteria vary with acidity and water temperature, which affect both the toxicity of ammonia and the form in which it occurs. In most natural surface waters, total ammonia concentrations greater than about 2 mg/L exceed the chronic exposure criteria for fish. In alkaline water at high temperature, the criteria can be exceeded by total ammonia concentrations less than 0.1 mg/L. The natural conversion of ammonia to nitrate in streams removes oxygen from water and, therefore, can also adversely affect fish (USGS 1999).

The EPA water quality objective for the protection of aquatic life is 0.025 mg-N/L un-ionized ammonia. At levels of 0.08 mg-N/L, un-ionized ammonia is toxic to all aquatic species. For the purposes of this report, all un-ionized levels of ammonia >0.025 are reported as toxic.

Orthophosphate

Orthophosphate is a proxy used to indicate levels of phosphorus delivered to a sink area. In most cases, the phosphorus is bound to sediment particles delivered downstream and to the water body. Like Nitrogen, it is a pollutant of accumulation, rather than performance. The impact to aquatic systems occurs not upon delivery of phosphorus, but with accumulation and reaction of phosphorus with other chemicals.

Orthophosphorus monitoring through the entire year did not provide any information linking monitoring to pollution sources. Though loading of orthophosphorus can occur at low levels, the combination of low concentration and low flows has made this parameter of limited utility in determining pollution sources through this program.

Fecal and Total Coliform

Coliform are rod-shaped bacteria that grow in the intestinal tract of mammals. Humans discharge hundreds of billions of fecal coliform each day. Some coliform bacteria also can grow in soils. For the most part, coliform are harmless. The organisms are easily tested for and, as a result, are used as an indicator organism. The presence of coliform, fecal coliform in particular, are an indication that a sample has been contaminated with fecal matter and that other pathogenic, disease-producing organisms may likely present. Because it is an indirect measure of potential threat to human health, it is widely acknowledged that this is an inadequate water quality standard. Until the USEPA or RWQCB establishes a new standard, the Seashore will continue sampling for this parameter.

Based upon the array of pollutant parameters tested at the Seashore, fecal coliform has actually turned out to be a dependable indicator of pollutant sources. This is because the pollutant is more persistent than other nutrient parameters sampled (is not as easily diluted). Because of the observed levels of detection, it is also a parameter that we expect to see a response in based upon site specific treatments.

It is important to acknowledge that nearly all of the sampled sites in the Seashore have fecal coliform levels in excess of recommended non-contact recreational standards. Much of the reason for these elevated levels is that the sampling protocol has been performed when water quality is expected to be at its worst. RWQCB surface water objectives for total and fecal coliform are shown in Table 4. All of these regulatory standards are based upon a minimum of 5 consecutive samples equally spaced over a 30-day period. The Seashore sampling protocol is not intended to meet this rigorous standard. Often, only a single sample per site is collected per storm event. This is done at a number of sites across the watershed and provides a very good spatial representation of water quality conditions in a watershed.

For effective analysis staff must determine expected fecal coliform levels prior to sampling in order to request proper analytical dilutions. Analytical levels should be predicted based upon past experience and confirmed upon sampling in the field. This will reduce the number of times results are returned with results greater than the analytical ceiling.

Through the Tomales Bay Pathogen Study, time series sampling was performed a few locations to characterize watershed response on the temporal scale. Samples were collected at regular intervals for the duration of a storm event to monitor pollutant response through the discharge event. This information can be used to make more detailed loading estimates in these areas.

The Seashore has identified FC as a useful parameter to identify pollutant source areas because of its persistence in the water column, even with high levels of in-stream dilution. While this persistence has allowed managers to find source areas miles upstream, it has also resulted in elevated FC levels at multiple monitoring locations emanating from the same source. FC is used to identify degraded condition, not impairment. Monitored FC results are indicative of conditions that occur in watersheds less than 5% of the time.

Table 4. Water Quality Objectives for Coliform Bacteria[a]

BENEFICIAL USE	FECAL COLIFORM (MPN /100ML)	TOTAL COLIFORM (MPN/100ML)
Water Contact Recreation	log mean < 200 90th percentile < 400	median < 240 no sample > 10,000
Shellfish Harvest[b]	Median < 14 90th percentile < 43	median < 70 90th percentile < 230[c]
Non-contact Water Recreation[d]	Mean < 2,000 90th percentile < 4,000	
Municipal Supply: - Surface Water[e] - Groundwater	log mean < 20	log mean < 100 < 1.1[f]

NOTES:
a. Based on a minimum of five consecutive samples equally spaced over a 30-day period.
b. Source: National Shellfish Sanitation Program.
c. Based on a five-tube decimal dilution test or 300 MPN/100 ml when a three-tube decimal dilution test is used.
d. Source: Report of the Committee on Water Quality Criteria, National Technical Advisory Committee, 1968.
e. Source: DOHS recommendation.
f. Based on multiple tube fermentation technique; equivalent test results based on other analytical techniques, as specified in the National Primary Drinking Water Regulation, 40 CFR, Part 141.21(f), revised June 10, 1992, are acceptable.

Because most samples were collected during storm events and not at intervals close enough to calculate the geometric mean, ambient site evaluation FC simple means are categorized for comparison at 2,000 MPN/100ml, 4,000 MPN/100ml, and 10,000 MPN/100ml. The result of this organization strategy is used to prioritize the worst sites for immediate management concentration. The reported numbers should be interpreted with the caveat that sampling targeted runoff conditions.

Total Suspended Solids

TSS is made up of sediment and other materials suspended in flowing creek water. Measurement of TSS is a method of monitoring direct watershed performance.

1995 RWQCB Basin Plan

"Waters shall be free of changes in turbidity that cause nuisance or adversely affect beneficial uses."

Recommended Criteria

Total Suspended Solid levels of concern <50mg/l
<100 NTU

High TSS in stream water is common during times of flooding. Suspended sediment can impact fish on two levels. Extremely high levels of sediment, on the order of 2,000 to 3,000 mg/l can injure fish by clogging their gills or cover gravel beds where fish spawn. In streams that are highly impacted it takes a long time for water to clear, or the turbidity levels to drop. Turbidity impacts the ability of fish to feed. The Regional Board will be using this type of criteria, assessing days of high turbidity levels as they begin to assess the Lagunitas Creek watershed for sediment. A strategy to monitor this effect will be devised in conjunction with the Regional Board.

TSS is sampled using a standard one-liter bottle. TSS samples are separated in the laboratory by NPS staff. The samples are analyzed at the Golden Gate National Recreation Area (GGNRA) wet lab. The GGNRA has the equipment necessary to filter, dry and weigh the sediment sample.

The sample is vigorously shaken and then 300 ml poured into a clean holding container. Results for suspended sediment are determined at mg/100ml and reported in milligrams per liter (mg/l).

Turbidity, an indirect measure of suspended solids is measured using Nephelometric Turbidity Units. The Seashore will have access to a portable turbidity meter that will be employed in the upcoming sample events.

Operational Costs

Operation of the water quality monitoring program comprises two major cost elements. Staff to perform the sampling has thus far been supplied through the Coho Salmon and Steelhead Trout Restoration Project. The Water Resource Branch has hired a hydrologic technician that will assist in the planning and implementation of the water quality monitoring program in the coming year. It is estimated that this will require at least 10 pay periods of a GS-07 hydrologic technician (equivalent to $17,000). Because this is an ongoing issue, the position should have some funding through ONPS base operations. Because most of the water quality monitoring issues are related with the agricultural lease operations, some of this position could be funded through this source.

The cost of sampling all five analytical parameters is $114 per site. Recommendations to drop orthophosphorus and nitrite will reduce that cost to $83 per site. Five planned sample events on 30 sites will cost approximately $12,500. An additional $2,500 should be allowed for sampling around the dairy operations winter 2001-02. Given existing staffing levels, continuation of the FY01 water quality budget of $15,000 is adequate to meet the recommended water quality monitoring needs for FY02.

To this point there has been no accommodation for overtime pay associated with water quality sampling. It is important to note that more than 100 hours of time outside of normal hours were committed to monitoring in FY2001. In order to expect sampling during weekends or at night, authorization and support of overtime should be committed. Future requests for authorization of 20 hours of overtime will be included in budget requests. Costs including vehicle support, equipment, and overtime are $3,000. Annual operations cost for the water quality monitoring program is $35,000.

Through the National Park Service – Natural Resources Challenge the San Francisco Bay Network has received $70,000 beginning in FY 2001 for implementation of a regional water quality monitoring program. The network is developing a workplan for the implementation of this program, which will likely include a network based water quality specialist to perform quarterly monitoring. This is not a substitute, but a supplement to the Seashore water quality monitoring program.

AMBIENT WATER QUALITY MONITORING PROGRAM RECOMMENDATIONS

Sample collection

The Point Reyes National Seashore Water Quality Monitoring Program has been successful at identifying source areas to environmentally sensitive waters. Adjustment of the sample regime from mostly winter samples, to quarterly sampling will increase efficiency and effectiveness of sampling. The sample collection protocol has been modified to include regular quarterly sample events plus two unscheduled winter events (first flush and one other storm). Additional collection in specific areas during specific storm events (i.e. subwatershed scale or dairy drainages) will be planned for more focused surveys. Single day sample events should be planned for all quarterly sample runs. This will improve the ability of managers to interpret water quality conditions throughout the Seashore on a given day.

The Seashore has acquired equipment to allow for two sample collection teams to sample all sites during a single day. This requires coordination with the lab prior to the sampling date, and an early start. Sampling should occur between 0700 and 1300, for delivery to the laboratory by 1500.

Field Parameters

It is recommended that pH, temperature, DO, conductivity and salinity measurements are included in any future water quality monitoring program. pH and temperature are required to calculate the fraction of ammonia in the toxic un-ionized form. All measurements are readily collected in the field. Equipment should be calibrated regularly for use in the field.

Laboratory Parameters

It has been determined that not all of the laboratory analyzed parameters are essential to this monitoring program. It is recommended that orthophosphorus and nitrite are dropped from the revised sample protocol. This will leave coliform, nitrate, and ammonia as the laboratory analyzed parameters. The Seashore staff will continue collecting total suspended solids (TSS) and analyzing samples at the GGNRA Fort Cronkhite wet lab. It will also incorporate use of the portable turbidometers for transition to that monitoring parameter.

The sampling protocol also includes collection of a variety of other parameters using portable probes, flow measurements, and general observations. As technology advances, there are portable means for analyzing a variety of parameters currently sent for laboratory analysis. In the long-term it will be most cost effective to adopt procedures that allow for use of field probes to make many of the water quality measurements.

Total Suspended Solids

The Seashore will incorporate use of a Turbidometer in order to reduce processing time and effort. Turbidity measurements will be collected in the field for all sample sites. For the next year this will be performed in conjunction with collection and processing of TSS at the GOGA wet lab.

Through the San Francisco Bay Network Water Quality Monitoring Program, the NPS has acquired permanent turbidity sampling probes. One probe will be installed on Olema Creek for long term monitoring. Turbidity Threshold Sample protocols developed at the Redwood Sciences Laboratory in Arcata, California will be implemented.

New sampling locations

These sites are identified and described in the Watershed and Site Reports section below. The Program will continue sampling the base sites in the coming year, with additional sites sampled as appropriate. New sites including DBY1, DBY2, DES1, ABB2, ABB3, PAC2a, OLM4a, and OLM 18 will be included in quarterly samples. In addition OLM2a, and OLM2b should be sampled next winter to determine the effectiveness of the adjustments implemented on the Ralph Giacomini ranch site.

Coordination

The Seashore monitoring program will be coordinated with the San Francisco Bay Network Water Quality Monitoring Position. This will facilitate broader collection and more focused investigations. The Network position will also maintain some of the recording stations that will provide new water quality information related to suspended solids and other chosen parameters.

Coordination with the Regional Water Quality Control Board regarding fecal coliform and sediment monitoring will continue. The Seashore will seek information as to appropriate field equipment to initiate turbidity monitoring and investigate the availability of a probe to monitor ammonia in the field. The Seashore will continue to work with the RWQCB and ranch operators to integrate milestones for water quality improvements into the lease agreements.

Information collected through this or other programs will be maintained in the Point Reyes National Seashore Water Quality Monitoring Database and summarized in an annual report.

WATERSHED AND SITE REPORTS

All monitoring sites showed strong seasonal variation in pollutant levels. Winter runoff is the primary driver of pollutant levels. Summer samples showed few results indicative of direct pollution, indicating that most pollutant sources are runoff derived. Primary pollutants presented in the watershed site evaluations include sediment, fecal coliform, temperature, pH, and conductivity. These parameters are most indicative of trends and conditions at each site. While not reported in the narrative, most monitored nutrient and ammonia levels were normally below limits of detection due to factors of dilution. Specific sampling information is included in site reports presented as Appendix A.

The Water Quality Monitoring Program Database is used to manage the Seashore water quality information. The Database is designed to allow users to print out full reports of information by watershed, sample location, sample year, or for comparison of seasonal samples.

The Seashore monitoring protocol is conducive to the spatial evaluation of water quality information. Significant effort has been put in to collecting samples from all sites within a relatively short period of time (6 to 8 hours). This is a very effective means of showing spatially where source areas are located, and how they rank comparatively between all sample sites.

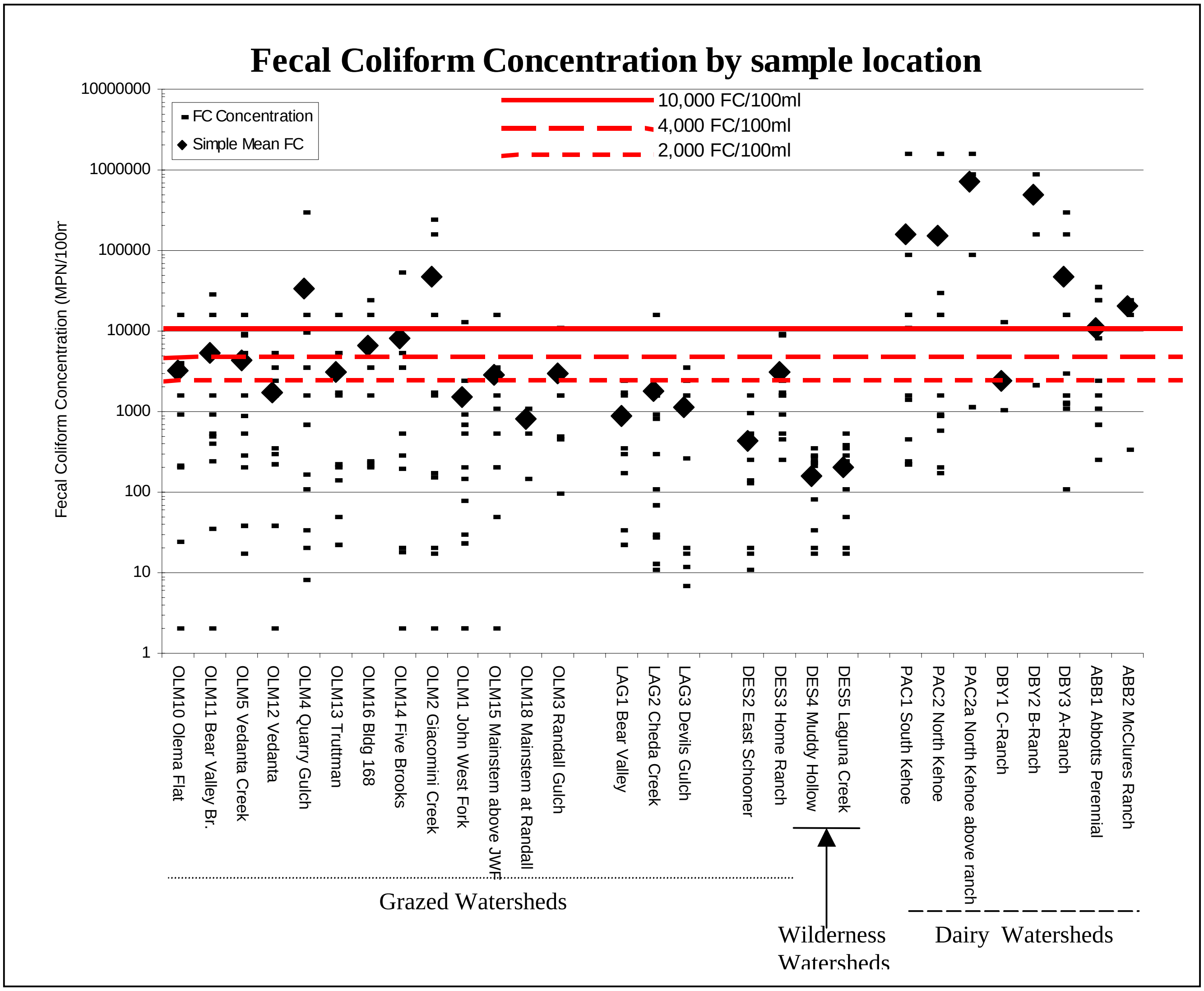
General Overview

Based upon the monitoring parameter characteristics, this program identified fecal coliform and toxic ammonia are used as primary indicators of water quality degradation. Secondary indicators of water quality degradation include conductivity and total suspended solids (TSS). The statistical evaluation of fecal coliform (FC) has been problematic when evaluating the results against existing contact and non-contact recreation water quality standards. It should be noted that none of the monitored sites are intended for recreational use. For most sites, 60% of the samples were taken during a storm event. The sampled flow events are representative of conditions that occur less than 5% of the year. Using a simple mean evaluation, one high data point can easily raise the average above levels of concern.

Fecal coliform sample concentrations and simple mean information are shown in Figure 1. Individual samples show the range of FC concentrations at each site, and the FC simple mean is used to focus on which sites prove to have the most impaired conditions with relation to fecal coliform.

The sample program included two wilderness watersheds (DES4 & DES5). The FC simple mean concentrations for each site were less than 200 FC MPN/100ml with a range of 17 to 540 FC MPN/100ml. In grazed watersheds, the simple mean ranges from approximately 1,000 to 46,000 FC MPN/100ml. Sites monitored in association with dairy operations had a mean fecal coliform range between 2,400 to 710,000 FC MPN/100ml. During the reporting period, 235 stream FC samples were collected. Evaluation of individual samples indicates that 33% (78 samples) exceeded the non-contact recreational limit or 2,000 MPN/100ml, 25% (59 samples) exceeded the level of 4,000 MPN/100ml, and 20% (47 samples) exceeded a level of 10,000 MPN/100ml. One sample collected during winter 2000-2001 exceeded 1.6 million MPN/100ml.

Figure 1. Fecal Coliform Concentration by Monitoring Location



Sampling was primarily performed in response to rainfall runoff events (first flush, winter storms, and spring rainfall). Of the 28 monitored sites, 46% (13 sites) had a simple mean of fecal coliform greater than 4,000 MPN/100ml. Of these 13 sites, 9 of them had a simple mean of fecal coliform greater than 10,000 MPN/100 ml. Though no standard is established for the FC level of 10,000 MPN/100ml it is used in this program for spatial comparison of water quality conditions. Nine sites exceeded an average of 10,000 MPN/100ml, seven are within dairy watersheds while the other two are grazed tributaries in Olema Creek. These are considered severely degraded and in need of water quality management and protection (see Table 5).

Most telling regarding impact to aquatic species is toxic ammonia. Of 163 ammonia samples, 3.1% (5 samples) were associated with toxic conditions. Four of these readings were collected below two dairy operations, and the fifth off of a horse pasture in the Olema Valley. The California Department of Fish and Game - Marin-Sonoma Agricultural Runoff Influence

Investigation reported toxic ammonia events in 12% of the samples in 1998-99 and 4.7% of the samples during the 1999-2000 monitoring period CDFG 1999, 2000).

Mean specific conductivity levels for most of the monitored sites are less than 850 uS/cm. Exceedence of these criteria occurred in four watersheds (PAC2a, DBY1, DBY2, and DBY3), all containing dairy operations. Throughout the rest of the monitoring sites, the conductivity readings by watershed were very consistent, relating to assumed background levels of conductive ions coming from the watershed.

Table 5. Water monitoring locations with degraded conditions

		Pollutants of concern	
Station	**Watershed**	**PRIMARY**	**SECONDARY**
PAC2	North Kehoe Creek	• Fecal Coliform • 90th percentile 147,000 MPN	• Conductivity
PAC2a	North Kehoe at Ranch	• Fecal Coliform • 90th percentile 1,380,000 MPN	• Conductivity
PAC1	South Kehoe Creek	• Fecal Coliform • 90th percentile 153,000 MPN	• Conductivity
ABB1	Abbotts Perennial	• Fecal Coliform • 90th percentile 26,200 MPN	
ABB2	McClure Drainage	• Fecal Coliform • 90th percentile 23,200 MPN	
DBY3	A-Ranch Drainage	• Fecal Coliform • 90th percentile 160,000 MPN • Toxic Ammonia – 2 events	
DBY2	B-Ranch Drainage	• Fecal Coliform • 90th percentile 819,000 MPN • Toxic Ammonia – 2 events	
OLM2	Giacomini Creek	• Fecal Coliform • 90th percentile 176,000 MPN	
OLM4	Quarry Gulch	• Fecal Coliform • 90th percentile 44,400 MPN	

Based upon the monitoring results, the Seashore considers conditions at nine sites (8 sub-watersheds) as degraded. Discussions to improve conditions within these watersheds are ongoing. Additional monitoring sites have shown exceedence of fecal coliform standards. In most cases, these sites are downstream of the degraded sites, and the higher readings are a result pollutant persistence in the water column.

TOMALES BAY WATERSHED

Description

Tomales Bay and its tributary watersheds are significant habitat for a variety of threatened and endangered aquatic species. The Bay is also home to a number of oyster production operations accounting for nearly 15% of the oyster production in the state of California.

Because of identified water quality impacts to ecological and commercial values, Tomales Bay is currently listed as impaired by the RWQCB for pathogens, sediment, nutrients, and mercury. Interest in taking action to monitor and protect the Bay is high. A report of water quality sampling efforts in 1995 was recently completed showing marked differences (in orders of magnitude) between fecal coliform contributions from the east, south, and west sides of the Bay (see below).

The watersheds monitored within the Tomales Bay drainages should meet cold water criteria as defined by the San Francisco Bay Regional Water Quality Control Board. This is determined by the fact that these streams have or do support populations of steelhead trout (*Oncorhynchus mykiss*).

Specific sampling has been performed in Olema and Lagunitas Creek watersheds. The results are presented separately.

Tomales Bay Pathogen Study - 1995-96 (TBSTAC 2001)

In the winter 1995-96, CDHS and RWQCB staff, under the auspices of the Tomales Bay Shellfish Technical Advisory Committee conducted an intensive study of bacteriological and pathogen studies in Tomales Bay and contributing watersheds. The study consisted of 40 sampling stations throughout the Bay and watersheds, collected during two dry season and four wet season events.

Fecal coliform loadings were estimated for number of FC per day contributed by watershed. The loading results were greatest from the eastern watersheds, followed by the Lagunitas/Olema Creek watershed and lowest from the western watersheds. The report concluded that the majority of the fecal coliform delivered to the Bay came from the eastern and southern parts of the watershed. Degradation of the Bay water quality coincided with the pulses of fecal contamination from the watershed after rainfall. As a result of the study, rainfall closure levels were reduced for all areas of Tomales Bay.

Tomales Bay Pathogen Study 2000-2001 (RWQCB 2001)

Staff supported implementation of the San Francisco Regional Water Quality Control Board - Tomales Bay Pathogen Study by assisting with field collection at two designated time series sample locations. The time series is intended to document the response of *e. coli* levels in relation to the monitored hydrograph. For the Tomales Bay Pathogen Study, 25 stations were sampled during the sample events. At most sites one or two samples were collected in a given day. NPS staff collected water quality samples from the sample sites listed below at a rate of one sample every one to four hours for the duration of the event (up to four days).

- Olema Creek – Bear Valley Road Bridge (OLM11)
- USGS Point Reyes gauging station at Lagunitas Creek (11460600)

Collection was spread across the rising and falling limb of the hydrograph to determine pathogen delivery response in relation to the stream flow. The resulting information was used to develop a pathogen loading determination from each of the monitored watersheds.

Results

Based upon extensive evaluation of the water quality information, it was shown that the Olema Creek watershed had one of the lowest Fecal Coliform (FC) loadings to the Bay. This result was the same for Olema Creek's contribution of e. coli to the Bay. Loading results from Lagunitas Creek indicated that it was a larger contributor of FC an e. coli to the Bay, but by no means the largest. In collecting samples Lagunitas FC concentration levels were always lower than Olema, but due to streamflow, the loading from Lagunitas was actually higher than loading from Olema.

The report concludes that agricultural sources are certainly major contributors of FC and e. coli to the Bay, but high levels of these pollutant parameters observed in San Geronimo Creek and from the Point Reyes Station stormdrains indicates that developed areas cannot be discounted as a source. All of the pollution observed was associated with storm runoff events (two dry season sample events were conducted).

The complete report is available through the San Francisco Bay Regional Water Quality Control Board.

LAGUNITAS CREEK WATERSHED

Description

Lagunitas Creek drains to the head of the Tomales Bay. The 88 square mile watershed is the major contributor of freshwater to the Bay. It is also the major supplier of water to most of Marin County through the Marin Municipal Water District. Within the watershed, four dams with storage in excess of 60,000 acre-feet have significantly altered both the hydrology and condition of anadromous populations. Once the cradle of significant coho salmon and steelhead trout populations, the damming of Lagunitas Creek and Nicasio Creek has eliminated nearly two thirds of the spawning and rearing habitat of these threatened populations.

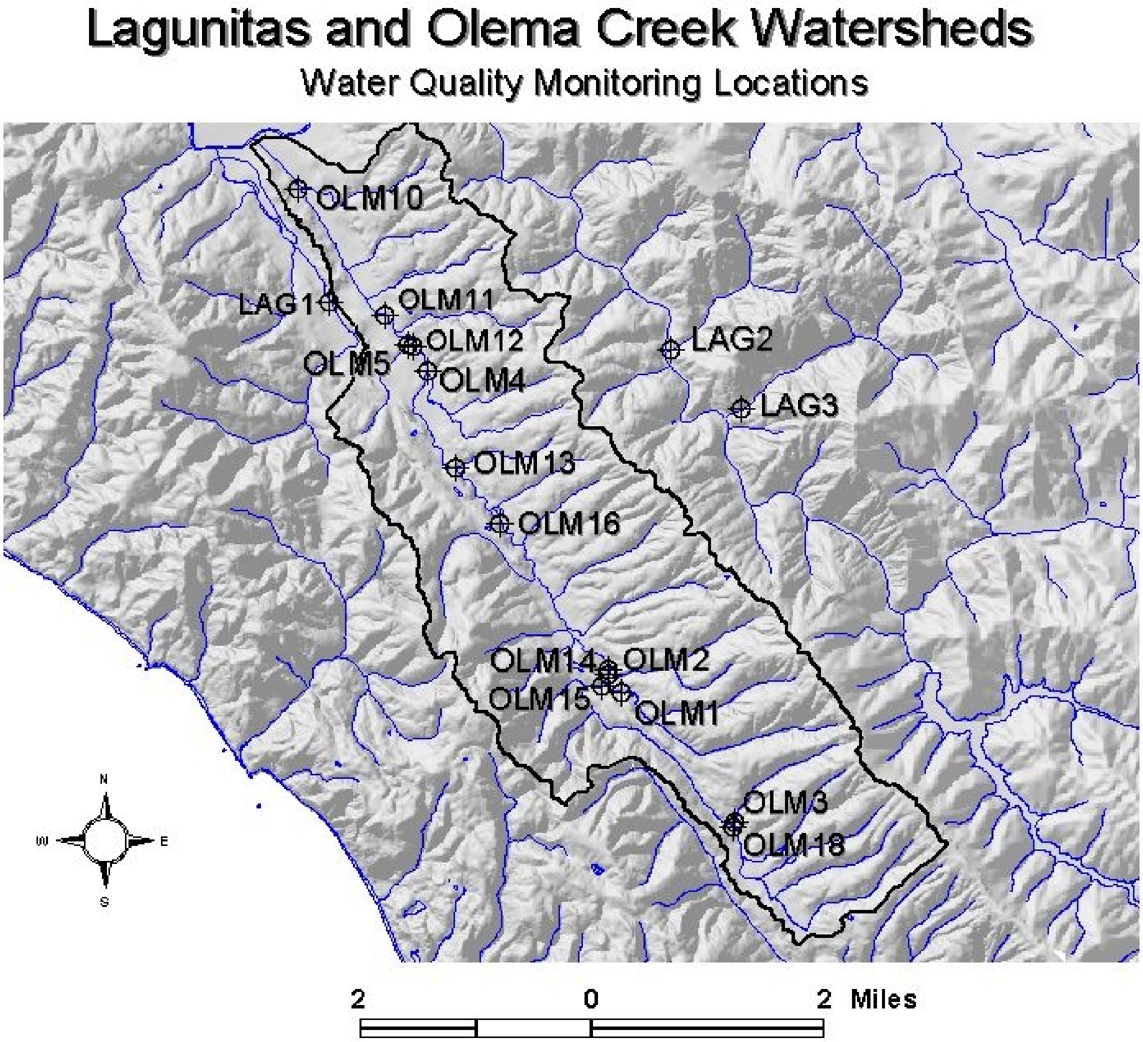
Lagunitas Creek has been identified by the RWQCB as impaired by sediment, nutrients, and pathogens. While sedimentation is the most talked about pollutant parameter in the Lagunitas basin, mainly due to impacts on the fisheries habitat, there are a number of small communities spread throughout the area which operate septic systems. The major undammed tributaries heading upstream include Bear Valley Creek, Olema Creek, McIsaac Gulch, Cheda Creek, Devils Gulch, and San Geronimo Creek. The watershed is significant as it supports viable populations of federally threatened coho salmon, steelhead trout, California red-legged frog and the California freshwater shrimp.

The watersheds monitored within the Lagunitas Creek drainages should meet cold water criteria as defined by the San Francisco Bay Regional Water Quality Control Board. This is determined by the fact that all three subwatersheds support anadromous species of fish.

Sample Locations - See Map 4

- LAG1 – Bear Valley Creek – below NPS headquarters
- LAG2 – Cheda Creek
- LAG3 – Devil's Gulch

Bear Valley Creek is sampled downstream of all potential source areas associated with the PRNS headquarters. Cheda Creek is sampled 50 meters upstream of Sir Francis Drake Road. The site is representative of a grazed watershed without riparian protection (completion of riparian protection fence is expected by summer 2001). Devils Gulch is sampled 300 meters upstream of Sir Francis Drake Road. Originating on developed and grazed land, Devils Gulch enters the Samuel P Taylor State Park and flows nearly 2 miles to the monitoring station.



Map 4. Lagunitas and Olema Creek Watershed Monitoring Sites

Analysis

The three monitoring sites, Bear Valley, Cheda, and Devils Gulch are tributaries of Lagunitas Creek. Cheda and Devils Gulch support populations of coho salmon and steelhead trout, while Bear Valley supports steelhead trout. Results of the monitoring are included in Table 6.

Field Parameter Observations

The mean conductivity levels observed are below the level of concern. Readings are consistent and not indicative of problems.

Laboratory Analysis Results

All three Lagunitas Creek monitoring sites have mean fecal coliform levels below that of significant concern. None of the sites showed detectable levels of ammonia until the spring 2001 sample, when levels remained very low. Of the three sites, Cheda Creek showed the highest mean levels of fecal coliform and sediment. There has been one sample of nine collected at Cheda that exceeded 16,000 MPN/100 ml. The Seashore has recently completed riparian exclusion fencing from approximately 2.5 kilometers of the stream. This is expected to enhance conditions observed within the watershed.

Table 6. Lagunitas Watershed Sites – Mean collected information

Site**	Sample Events	Water Temp C	pH	Specific Conductance @ 25 C	Toxic Ammonia Events	Mean Fecal Coliform ^ (MPN/100 ml)	Maximum Fecal Coliform (MPN/100 ml)	90th Percentile FC #	Mean TSS (mg/l)	Max TSS (mg/l)	90th Percentile TSS
LAG1 Bear Valley	9	12	8.2	299	0	888	1840	1,700	26	95	61
LAG2 Cheda Creek	12	12.6	8.3	295	0	1,776	>16,000	**>16,000**	29.5	180	68
LAG3 Devils Gulch	9	11.1	8.3	262	0	1,145	2730	3,500	13.7	36	29

** See Map 4 for site locations
Non-Contact Human Health Standards

^ mean <2,000 MPN/100ml
#90th percentile <4,000 MPN/100ml

Future Monitoring within Lagunitas Creek Watershed

The listing of Lagunitas Creek (including Olema Creek) as impaired by nutrients, fecal coliform, and sediment, will result in coordination with the Regional Water Quality Control Board and Tomales Bay Watershed Council for water quality monitoring to continue. Any changes to the Seashore sampling regime will be associated with monitoring programs of the RWQCB.

OLEMA CREEK WATERSHED

Description

Olema Creek is the largest undammed tributary of Lagunitas Creek. The 14.5 square mile watershed flows north through the Olema Valley, the landward expression of the San Andreas Fault Zone (SFZ). It's confluence with Lagunitas Creek lies at the head of the ecologically significant Tomales Bay. The watershed supports viable populations of coho salmon, steelhead trout, California red-legged frog and the California freshwater shrimp.

Because it is the centerpiece of fisheries management within Point Reyes National Seashore, Olema Creek is the subject of extensive monitoring to determine the effectiveness of various stream protection measures – including riparian exclusion fencing and habitat restoration. Data gathered within the watershed will help with ongoing efforts to monitor and control contributions of fecal coliform to Tomales Bay.

Currently, 35% of the Olema Creek watershed is managed for beef cattle grazing. The Stewart Horse Stable is located in the central portion of the watershed. The watersheds monitored within the Olema Creek drainages all should meet cold water criteria as defined by the San Francisco Bay Regional Water Quality Control Board. This is determined by the fact that Olema Creek supports anadromous species of fish.

Sample Locations (See Map 4)

- OLM1 – John West Fork
- OLM2 – Giacomini Gulch
- OLM3 – Randall Gulch
- OLM4 – Quarry Gulch
- OLM5 – Vedanta Creek
- OLM10 – mainstem, below Stewart flat
- OLM11 – mainstem @ Bear Valley Road Bridge
- OLM12 – mainstem above Vedanta Bridge
- OLM13 – mainstem @Truttman Gulch
- OLM14 – mainstem @ Five Brooks Bridge (north)
- OLM15 – mainstem above John West Fork confluence
- OLM16 – mainstem at NPS Quarters 168
- OLM17 – mainstem at Five Brooks Bridge (south)
- OLM18 – mainstem above Randall Gulch confluence

*Note: 1-5 are tributaries, 10-18 are mainstem samples

Analysis

Olema Creek, because of its proximity and its hosting of coho salmon and steelhead trout, was sampled intensively to determine overall ambient water quality condition, evaluate effectiveness of riparian exclosures, and to identify and treat source areas of pollution.

John West Fork - January 11, 2001 1630

John West Fork - January 12, 2001 0730

The information shows that for the most part, Olema Creek is in good condition. While specific source areas requiring treatment have been identified, it is clear that actions to enhance fisheries will result in improved water quality conditions.

Giacomini Creek 2001

The largest magnitude source area in 2001 originated at Giacomini Creek, with a recognizable 'plume' extending downstream two miles to the sampling location at the Quarters 168. Based on this initial event, staff met with the operator and identified solutions to treat this problem, including moving horses off a specific pasture and diverting runoff into a waste pit to settle out sediment. The pit was cleared and horses moved within two weeks of sampling, thanks to the willingness of the rancher to adjust his operation.

Field Parameter Observations

Mean conductivity and pH indicates that all sites are stable with very little fluctuation between sites within the watershed. Mean conductivity increases from 97 uS/cm at Randall Gulch to 238 uS/cm at the Bear Valley Bridge. Though below any level of concern, it does show the accumulation of conductive ions from upstream to downstream. During winter sampling, we have not found dissolved oxygen or temperature to be a concern. This is more readily a concern during the summer. The CSRP is monitoring temperature and DO in isolated pools of the John West Fork associated with the drying of pools and fish mortality. A thorough report of this information will be included in the Olema Creek Watershed Assessment and Recommendations.

Laboratory Analysis Results

The laboratory sampled parameters show that nutrients and ammonia are not a concern in this watershed. Nearly all of the mainstem samples, and most of the tributary samples were below limits of detection. These low levels are associated with dilution. No toxic ammonia events were observed in the mainstem or tributaries, but a single sample collected from pasture runoff in the Giacomini tributary was toxic. In this specific case, this toxic ammonia was assimilated, diluted, or volatilized as the sample location 50 meters below this input (OLM2) did not show detectable levels of ammonia.

Table 7. Olema Creek Sites – Mean collected information*

Site**	Sample Events	Water Temp C	pH	Specific Conductance @ 25 C	Toxic Ammonia Events	Mean Fecal Coliform ^ (MPN/100 ml)	Maximum Fecal Coliform (MPN/100 ml)	90th Percentile FC #	Mean TSS (mg/l)	Max TSS (mg/l)	90th Percentile TSS
OLM10 Olema Flat	9	12.2	7.9	216	0	3,194	>16,000	6,000	78	247	188
OLM11 Bear Valley Bridge	11	11.7	7.9	238	0	5,340	28,000	17,200	83	256	204
OLM5 Vedanta Creek	10	12.6	7.8	280	0	4,290	16,000	9,880	32	79	78
OLM12 Vedanta	8	11.7	7.9	225	0	1,699	5,400	4,070	75	176	168
OLM4 Quarry Gulch	***11***	***11.5***	***8.1***	***163***	***0***	***33,147***	***300,000***	***44,400***	***81***	***294***	***216***
OLM13 Truttman	8	11.1	7.9	225	0	3,139	16,000	8,580	68	250	175
OLM16 Bdg. 168	7	10.8	7.8	209	0	6,539	24,000	19,200	62	129	120
OLM14 Five Brooks	8	10.9	7.9	198	0	7,970	54,000	19,980	70	155	127
OLM2 Giacomini Creek	***9***	***10.7***	***8***	***156***	***0***	***46,612***	***240,000***	***176,000***	***161***	***660***	***517***
OLM1 John West Fork	12	11.2	8.2	148	0	1,493	13,000	2,252	6	32	14
OLM15 Mainstem @ John West Fork	8	11	8	202	0	2,874	16,000	7,250	87	337	231
OLM3 Randall Gulch	7	11.7	7.6	97	0	3,032	11,000	7,240	14	46	32
OLM18 Mainstem @ Randall	5	9	8.2	148	0	820	1,100	1,044	10	23	19

** See Map 4 for site locations
Non-Contact Human Health Standards

^ mean <2,000 MPN/100ml
#90th percentile <4,000 MPN/100ml

Two parameters indicative of watershed condition and land use activities are sediment and fecal coliform. After a year of working out details with the laboratory, sampling was able to capture the upper limits of fecal coliform in January 2001. The results show that Giacomini Creek and Quarry Gulch carried the highest concentrations of fecal coliform runoff (Figure 1, Table 7) in the watershed. On the mainstem, higher fecal coliform levels have been observed downstream of these tributaries. Minor spikes have been identified with relation to other source areas. The Seashore plans to address the largest magnitude source areas first.

Sediment is the other major pollutant of concern in Olema Creek. The source areas are much more widespread. Results suggest that many of these source areas are not related to current agricultural operations, but include impacts associated with past land use practices, and stream alignment along the San Andreas Fault Zone.

Future Monitoring in the Olema Creek Watershed

Monitoring on Olema Creek is important for a variety of reasons. Existing levels of effort will be continued in order to quantify restoration efforts in the watershed. Water quality information, including DO, temperature and conductivity will be collected during the summer juvenile fish monitoring. The Coho and Steelhead Restoration Project does have some temperature monitoring locations.

During winter storm events, concentrated sampling efforts should be focused around potential source areas to determine the degree of impact from small, but potentially potent sources. Future monitoring on Olema Creek will include continued sampling of nitrate, ammonia, fecal coliform and sediment.

A detailed report on the response of the Olema Creek watershed to storm events is included as Appendix B.

Five Brooks Road drainage to Olema Creek Mainstem

John West Fork (foreground) confluence with Olema Creek (background)

COASTAL WATERSHEDS

The watersheds on the west side of Inverness Ridge are grouped into four organizational drainages: 1) Drakes Bay; 2) Drakes Estero; 3) Pacific Ocean; and 4) Abbotts Lagoon (See Map 3). The geologic framework of these watersheds is made up of marine sedimentary deposits of the Monterey and Purisima formation (primarily mudstone, siltstone, and sandstone) underlain by granitic bedrock. The watersheds are generally small, though inclusive of significant topographic changes. Water quality concerns in these watersheds are primarily related to agricultural operations within the Pastoral Zone. Two of the watersheds within the monitoring program are within the wilderness area and are not subject to livestock operations. Results observed at these sites are considered natural background for areas within the Seashore.

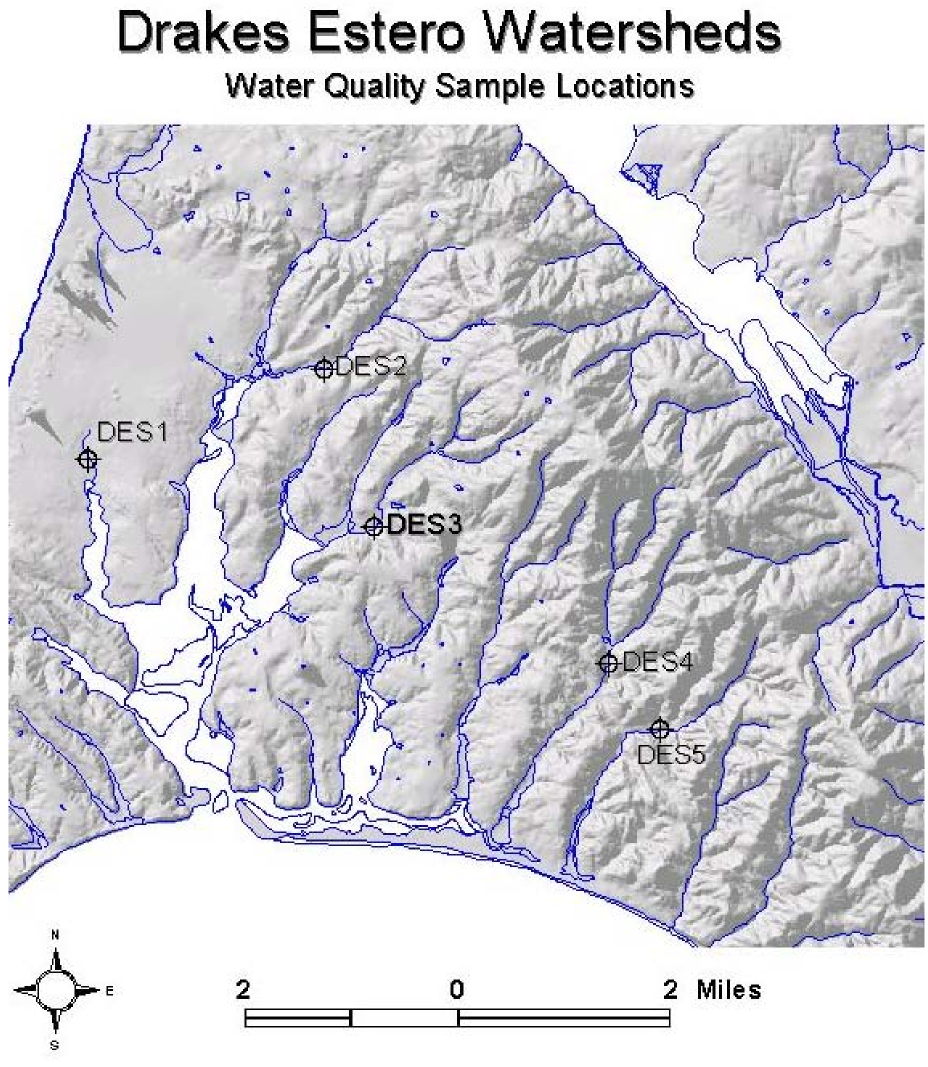
Drakes Estero and Headlands - Photo by Marty Knapp

DRAKES ESTERO WATERSHEDS

Description

Drakes Estero and the Estero de Limantour comprise a complex estuarine system capturing flow from more than 13.5 square miles of land. Major watersheds contributing to this system are Laguna, Muddy Hollow, Glenbrook, Home Ranch, East and North Schooner Creek, and Creamery Bay Creek. Minor watersheds flowing to the system are Limantour Creek, North Home Ranch, and Barries Bay Creek. Winter runoff from Laguna Creek bypasses the Estero complex through a breach in the dunes. Obstruction of stormwater runoff, combined with heavy surf, acts to breach the dune line allowing for at least seasonal connection to Drakes Bay. Home Ranch, Muddy Hollow, and Laguna Creeks were heavily impacted by the 1995 Mt. Vision Fire.

The watersheds monitored within the Drakes Estero drainages all should meet cold water criteria as defined by the San Francisco Bay Regional Water Quality Control Board. This is determined by the fact that these streams have or do support small populations of *Oncorhynchus mykiss*.



Map 5. Drakes Estero Watershed Sample Locations

Sample Locations

- DES1 – Creamery Bay Creek
- DES2 – East Schooner Creek
- DES3 – Home Ranch Creek
- DES4 – Muddy Hollow Creek
- DES5 – Laguna Creek

Analysis

E-Ranch view down Berries Bay and the mouth of Drakes Estero

The Drakes Estero watersheds are split between grazing and wilderness management. Distinct differences in fecal coliform are related to existing land use, while the sediment levels are indicative of longer term impact to these watersheds. While the Laguna watershed is primarily wilderness, the sampling location is downstream of the Clem Miller Education Center and two park residences. Muddy Hollow and Laguna Creeks have shown results that are significantly lower than all other watersheds for nutrients and pathogens. The exception to this rule is sediment. Neither of these sites can be considered a sediment monitoring control site, because of past land use and the Mount Vision fire.

Field Parameter Observations

None of the field indicators show any problem sites within this area. It is interesting to note that the conductivities are far higher than Olema Creek, likely due to proximity to the ocean. The highest conductivities observed are in Laguna Creek.

Laboratory Analysis Results

Fecal coliform is most telling between these sites. The Home Ranch sample location is downstream of the ranch operation, with direct access by livestock to approximately two kilometers of the channel. During the April 2001 sample event, Home Ranch had fecal coliform levels of 9,000 MPN/100ml. These higher levels unassociated with storm runoff events are indicative of direct access by livestock to the channel. The mean fecal coliform levels are an order of magnitude higher at Home Ranch Creek, as compared to any of the other Drakes Estero watersheds.

Table 8. Drakes Estero Watershed Sites – Mean collected information

Site**	Sample Events	Water Temp C	pH	Specific Conductance @ 25 C	Toxic Ammonia Events	Mean Fecal Coliform ^ (MPN/100 ml)	Maximum Fecal Coliform (MPN/100 ml)	90th Percentile FC #	Mean TSS (mg/l)	Max TSS (mg/l)	90th Percentile TSS
DES2 East Schooner	9	11	8	246	0	430	>1,600	1,080	27	138	63
DES3 Home Ranch	9	12.8	7.9	248	0	3,047	**9,200**	9,040	15	61	32
DES4 Muddy Hollow	9	12.1	7.8	281	0	161	350	286	17	104	38
DES5 Laguna Creek	9	10.7	8.1	381	0	204	540	388	58	388	143

** See Map 5 for site locations
Non-Contact Human Health Standards

^ mean <2,000 MPN/100ml,
#90th percentile <4,000 MPN/100ml

Future Monitoring in the Drakes Estero Watersheds

Existing monitoring efforts (all field parameters, fecal coliform, and TSS) should be continued at all sites. Ammonia and Nitrate sampling will continue at all four sampling sites. Staff has identified Creamery bay Creek (DES1) for future water quality sampling. The watershed includes much of the historic F-Ranch area and drains to the head of Creamery Bay. The land grazed by beef cattle, and the perennial stream has no protection from the livestock. While the watershed is not large enough to support salmonids, the stream is a potential source of pollutants to Creamery Bay. The sample site is located at the Bull Point Trail crossing and may be accessed by vehicle.

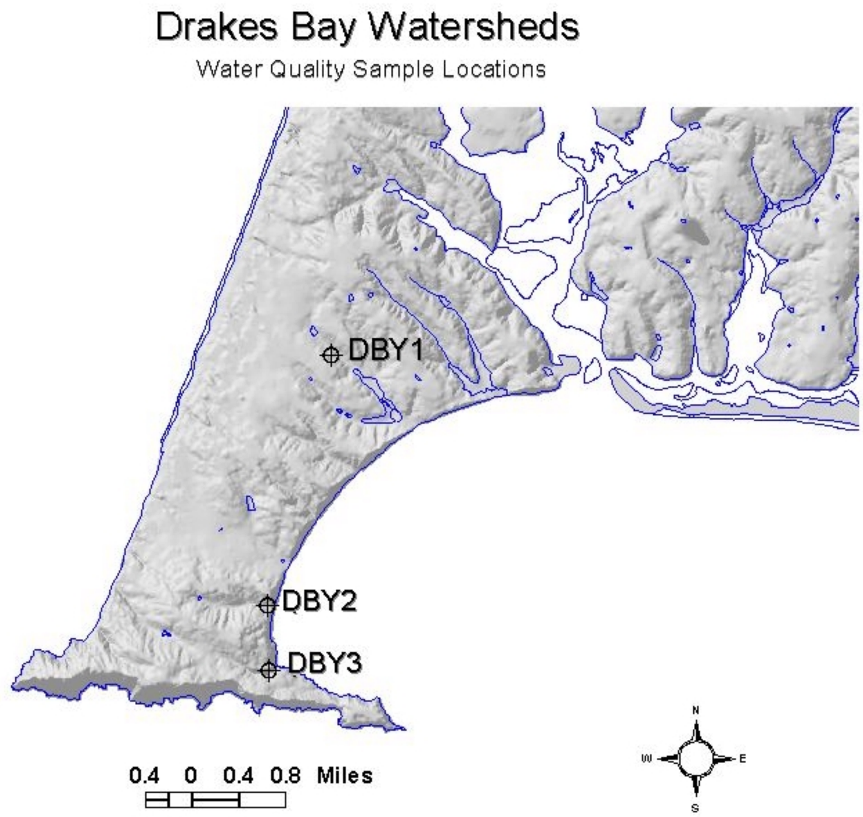
Additional monitoring and management efforts should be made around Home Ranch and the direct access of livestock to more than two kilometers of stream habitat. This issue is identified in the Biological Assessment for grazing activities at Point Reyes National Seashore.

The Drakes Estero watershed is slated for major restoration work in the next five years through the Coastal Watershed Restoration Project. Continued monitoring of sediment and other parameters is essential to helping concentrate restoration to reduce sediment loading to the Estero.

DRAKES BAY WATERSHEDS

Description

All of the watersheds represe instances, the wave action forms a seasonal lagoon at the mouth of the stream, while others maintain constant connection with the Bay. The primary watersheds south of Drakes Estero include Coast Camp, Santa Maria (Machado), Coast, Wildcat, and Alamere Creeks. Minor watersheds include Elk Gulch, Woodward Valley, and Kelham. Watersheds east of the Estero include Horseshoe (D Ranch), Drakes Beach, C Ranch, B Ranch, and A Ranch.



Map 6. Drakes Bay Monitoring Locations

The watersheds monitored within the Drakes Bay drainages are mixed between cold and warm water criteria as defined by the San Francisco Bay Regional Water Quality Control Board. Watersheds draining directly from Inverness Ridge may be classified as cold water criteria watersheds, while other drainages closer to the headlands are more likely warm water streams. The three streams currently monitored in this area are considered warm water streams. Each watershed contains a single dairy operation.

Sample Locations – See Map 6

- DBY1 – C-Ranch drainage
- DBY2 – B-Ranch drainage
- DBY3 – A-Ranch perennial stream

Analysis

Watersheds draining from A-Ranch, B-Ranch, and C-Ranch were targeted for sampling due to the intensive land use impacts associated with dairy operations. It is important to note that these are relatively small watersheds discharging directly to the beach. Sample locations are sited at the lower end of the operations, allowing for the rancher to use the land as part of the treatment process (Map 6). Despite this conservative monitoring approach, significant levels of pollution were monitored below these operations. Monitoring began initially on the A-Ranch Perennial stream because of concern regarding the elephant seal colony on the beach at the outflow of the stream.

Spaletta Management at C-Ranch

In the past few years, the operators of the historic C-Ranch, Ernie and Nicola Spaletta have significantly improved the water quality management on their dairy. Though operating a dairy built in the 1800s, they have made improvements to cattle holding areas and the infrastructure. Expansion of their pond south of the dairy complex allows for runoff to be captured prior to discharging downstream to the Ken Patrick Visitor Center parking lot. Sampling shows dramatic reduction in water borne pollutant levels due to the settling action of the pond. The investment by the Spaletta Dairy shows significant environmental benefit.

Drainages DBY1 and DBY 2 were not originally sampled as they are intermittent. After significant pollutant levels were measured below other dairy drainages within the Seashore in January 2001, it was determined that a dairy sample run should also include DBY1 and DBY2. Results from these two sites include only winter runoff samples, and are not inclusive of spring sample events. These intermittent streams are dry in the summer and fall. Overall sampling indicates severely degraded conditions within watersheds downstream of the A-Ranch and B-Ranch dairy operations. Through this process, the Seashore has identified specific practices that work, or should be implemented to improve containment and reduce discharge of pollutants to Drakes Bay during the winter.

Field Parameter Observations

Compared to specific conductivity levels of 100 to 300 uS/cm (0.1 to 0.2 ppt) in most other monitored watersheds, each of the DBY sites has a mean conductivity level of greater than 1,000 uS/cm (0.5 to 1.1 ppt). This increase in the level of conductive ions in the water is indicative of heavy impact associated with the dairy operations. The high levels observed below C-Ranch indicate that conductivity might also be related to leaching from past conductive ion accumulation.

B-Ranch Sample Location – 100 meters from beach

Laboratory Analysis Results

More telling of the degraded conditions at these sites are the fecal coliform levels and toxic form of ammonia. Mean levels of fecal coliform are an order of magnitude higher than most other sites (See Figure 2). In addition, the maximum levels observed below A-Ranch and B-Ranch were excessive (up to 900,000 MPN/100ml). While fecal coliform is only an indicator, toxic ammonia levels are interpreted as the most serious issue related to stream condition and function. Measured levels of unionized ammonia are lethal not only to fish but also to aquatic macroinvertebrates, amphibians, etc. A-Ranch had one toxic event in January 2000, and again in January 2001. These events occurred following extended dry periods during the winter. It is not clear how long these toxic conditions persisted. B-Ranch has only been sampled on two occasions, and on both, un-ionized ammonia levels were toxic. Samples were collected within six weeks of each other with some rainfall occurring between sample events. It is likely that conditions at B-Ranch remained toxic between sample periods.

Table 9. Drakes Bay Watershed Sites – Mean collected information

Site **	Sample Events	Water Temp C	pH	Specific Conductance @ 25 C	Toxic Ammonia Events	Mean Fecal Coliform ^ (MPN/100 ml)	Maximum Fecal Coliform (MPN/100 ml)	90th Percentile FC #	Mean TSS (mg/l)	Max TSS (mg/l)	90th Percentile TSS
DBY1 C-Ranch	2	11	7.7	**1,048**	0	2,400	13,000	11,940	18	23	22
DBY2 B-Ranch	***2***	***11.8***	***7.9***	***2,134***	***2***	***495,000***	***900,000***	***819,000***	***88***	***95***	***94***
DBY3 A-Ranch	***11***	***11.9***	***8.3***	***1,220***	***2***	***46,974***	***300,000***	***160,000***	***28***	***113***	***66***

** See Map 6 for Site Locations ^ mean <2,000 MPN/100ml
Non-Contact Human Health Standards #90th percentile <4,000 MPN/100ml

Future Monitoring of Drakes Bay Watersheds

While the results of the monitoring are discouraging, it provides a baseline as the Seashore moves towards more proactive dairy operation management through the Special Use Permit (SUP) process. The Seashore met with operators at B-Ranch and was able to adjust operations. Though this did not solve the problems fully, they were willing to make the effort. Ranch operation and manure management plans to control runoff from dairy facility and pasture areas are necessary for each of the dairies. On A-Ranch and B-Ranch, the cattle are housed in the winter, but there is significant contribution to the stream from adjacent pastures. Actions to contain manure and runoff from cement runways may help reduce such occurrences. On C-Ranch the cattle are not housed, but the containment facilities, smaller herd size, and location of the herd in the winter (near South Beach Parking Lot) relieves downstream runoff conditions.

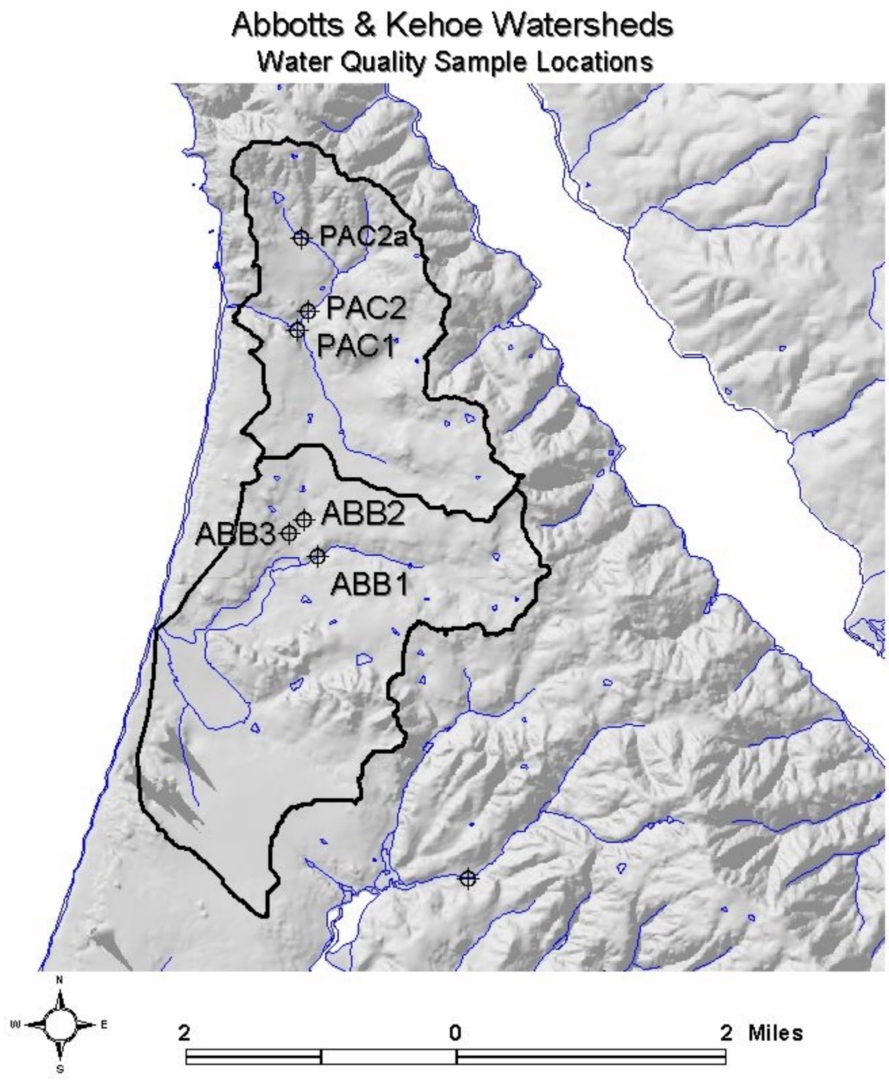
Continued monitoring is recommended downstream of all dairy operations. Cooperative monitoring of water quality conditions could be developed as part of the SUP process, so that the Seashore and operators may begin quantifying change in condition associated with manure management adjustments.

PACIFIC OCEAN WATERSHEDS – KEHOE AND ABBOTTS

For the purposes of this and other PRNS documents, these watersheds drain to the west and north of Drakes Bay (See Map 3). The primary watersheds from the north are McClures, Kehoe North, Kehoe South, E Ranch and Lighthouse. There are a significant number of drainages north of Kehoe beach that drain to the ocean including Elk Fence, White Gulch east, and others. There are a number of dune watersheds that are not included in this list but occasionally drain to the ocean across the ten-mile beach.

Description

The Pacific drainage water quality monitoring sites are limited to Abbotts and Kehoe watersheds (See Map 7). Three dairies operate within these watersheds. Kehoe Ranch is located within the North Kehoe Creek watershed (PAC2 & PAC2a). The L Ranch Dairy drains to South Kehoe Creek (PAC1) and also is within the upper portions of the Abbotts perennial watershed (ABB1). The McClure Dairy drains to Abbotts Lagoon via small unnamed tributaries. The Abbotts Lagoon monitoring sites (ABB1 and ABB2) are not directly downstream of the operation's impact areas. PAC1, PAC2, and ABB1 have been sampled for the duration of the monitoring program. Additional stations (PAC2a and ABB2) were established in winter 2000-01 to help narrow potential source areas.



Map 7. Abbotts and Kehoe Watershed Sample Sites

The watersheds monitored within the Pacific Ocean drainages should meet warm water criteria as defined by the San Francisco Bay Regional Water Quality Control Board. Though stream temperature may be low, the primary habitat area for the fish is in the lower portions of the watershed, where residence time of the water is very high.

In addition, most of these drainages form lagoons at their outlet, and are subject to ponding during the summer and flow in the winter. Until more comprehensive fisheries surveys are conducted on these watersheds, the management strategy should be to meet the minimum warm water quality standards.

The Abbotts Lagoon watershed is unique, in that the watershed drains across gently sloping terrain and into a unique lagoon environment. The lagoon itself has three chambers sometimes connected at the surface. A man-made pond, and dual chambered lagoon separated by a bedrock sill provide a unique combination of brackish and freshwater environments in a system that often has the same surface water elevation. Another unique feature is that the lagoon does not breach regularly. In recent years the Lagoon has remained closed for years at a time (Lightheiser 1998).

The watershed is the topic of a special water quality study through a partnership with the USGS and the National Park Service to assess inputs to the lagoon from different areas within the watershed. The impact area to the southwest of the McClure facility drains to Abbotts Lagoon. Two of the swales draining from the dairy were sampled as part of the Abbotts Lagoon USGS water quality investigation. Nutrient loading information was developed for the watershed (Kratzer 1999). Table 10 identifies the percent loading of specific nutrient parameters from the entire watershed. The 188-acre area draining to ABB2 and ABB3 is equivalent to 6.1% of the Abbotts Lagoon Watershed. Referring to Table 10, this area is the primary source of all monitored nutrient parameters delivered to the Lagoon.

Table 10. Watershed loading to Abbotts Lagoon (from Kratzer 1999)

Source Area (sample sites)	% load Ammonia (NH4)	% load Nitrate (NO3)	% load Total Nitrogen (TN)	% load Ortho-phosphorus	% load Total Phosphorus
Abbotts Perennial (ABB1)	5	10	25	8	20
McClure Impact Area (ABB2 & ABB3)	85	50	40	85	65
Evans beef grazing areas (T4, T5, and T6)	5	30	20	5	5
Lunny Dunes (T7)	5	10	15	2	10

No FC monitoring occurred in association with the USGS report. The operator has proposed construction of a loafing facility and waste management system. Though the barn will significantly reduce the contributions of nutrients, sediment, and pathogens from the dairy operation to the Lagoon, the staff will assist the operator with compliance requirements by expanding monitoring to quantify the response.

Sample Locations – See Map 7

- ABB1 – Abbotts perennial drainage
- ABB2 – I Ranch perennial
- ABB3 – McClure Impact Yard
- PAC1 – South Kehoe
- PAC2 – North Kehoe
- PAC2a – Upper North Kehoe

Analysis

Field Parameter Observations

Sampling locations PAC1 and PAC2 are at least two kilometers downstream of ranch operations while PAC2a is near the center of the Kehoe Dairy operation (upstream of waste lagoon and loafing barn). The mean conductivity level at downstream sample locations was near the 500 uS/cm level in the Kehoe watershed sites, but only half of that at the two Abbotts Lagoon watershed sites.

Laboratory Analysis Results

Results indicate significant fecal coliform source areas in drainages originating near Kehoe Dairy and the L-Ranch Dairy (Table 11). Site PAC2a was established upstream of the Pierce Point Road to determine if the waste lagoon could be a problem site. Extremely high levels of fecal coliform monitored at all three sites indicate that source areas are both persistent and abundant.

Even up to two kilometers downstream from the source area, fecal coliform levels were at or above 1.6 million MPN/100ml. It is assumed that the levels observed at PAC2a are highest due to the proximity of the sample location to the operation. As with most pollutants, dilution and breakdown of material along the stream channel reduces pollutant levels over distance.

There is a clear distinction between conditions in the Kehoe drainages and those sites sampled in the Abbotts Lagoon drainages. Though orders of magnitude lower, the observed fecal coliform levels at ABB1 and ABB2 are still above the 10,000 MPN/100ml criteria.

Sediment levels in the Kehoe drainages are greater than those observed in the Abbotts drainages. The TSS levels sampled at these sites are indicative of significant erosion, which is visible from the road. The gullies observed in the Kehoe watershed are the largest in terms of scale, exceeding 20 feet wide and 15 feet deep. Gullies are common throughout the Seashore but those observed in the Kehoe watershed are largest, likely a combination of soil type and land use practice.

Table 11. Kehoe and Abbotts Lagoon Watershed Site Information

Site**	Sample Events	Water Temp C	pH	Specific Conductance @ 25 C	Toxic Ammonia Events	Mean Fecal Coliform ^ (MPN/100 ml)	Maximum Fecal Coliform (MPN/100 ml)	90^{th} Percentile Fecal Coliform #	Mean TSS (mg/l)	Max TSS (mg/l)	90^{th} Percentile TSS
PAC1 South Kehoe	***12***	***11.5***	***7.6***	***453***	***0***	***158,079***	***>1,600,000***	***153,000***	***113***	***716***	***271***
PAC2 North Kehoe	***12***	***11.5***	***7.8***	***582***	***0***	***154,058***	***1,600,000***	***147,000***	***138***	***471***	***317***
PAC2a North Kehoe within in dairy complex	***3***	***11.3***	***7.9***	***1,126***	***0***	***710,000***	***1,600,000***	***1,380,000***	***171***	***292***	***266***
ABB1 Abbotts Perennial	***9***	***10.6***	***7.6***	***252***	***0***	***10,878***	***35,000***	***26,200***	***26***	***56***	***43***
ABB2 McClures	***2***	***11.9***	***7.3***	***342***	***0***	***20,000***	***24,000***	***23,200***	***19***	***20***	***20***

**See Map 7 for site locations
Non-Contact Human Health Standards

^ mean <2,000 MPN/100ml
#90^{th} percentile <4,000 MPN/100ml

Future Monitoring in the Kehoe and Abbotts Lagoon Watersheds

It is clear that the North and South Kehoe Creek watersheds are significantly impacted by the dairy operations. Existing levels of monitoring should be continued in future years. As opposed to the Drakes Bay situation, low levels of ammonia are allowing for significant aquatic productivity. The lower portions of these streams are highly productive marsh systems, likely driven by nutrient loading from the operations. The Recreational Water Quality Monitoring Program will begin sampling the beach interface during summer 2001.

The McClure dairy plans to construct a loafing barn to house nearly all of the milking herd during the winter. The California Coastal Commission has requested that water quality improvements are quantified. The Seashore staff will assist with monitoring to quantify pollutant levels currently leaving the impact areas, and will monitor the same locations once the loafing barn and waste management systems are completed.

RECREATIONAL USE MONITORING PROGRAM

WATER QUALITY MONITORING OBJECTIVES FOR RECREATION

The Point Reyes National Seashore has not formally designated any water bodies for recreational use. However, there are a number of water bodies that are heavily used by swimmers and sunbathers. The recreational monitoring program has identified three locations where recreational use is the highest for water quality monitoring.

The RWQCB has established water quality objectives for contact and non-contact recreational use. Contact recreation is defined as the use of water for recreational activities involving body contact with water where ingestion of water is reasonably possible. These uses include, but are not limited to, swimming, wading, water-skiing, skin and scuba diving, surfing, whitewater activities, fishing, and uses of natural hot springs (RWQCB 1995). Non-contact recreation is defined as the use of water for recreational activities involving proximity to water, but not normally involving contact with water where water ingestion is reasonably possible. These uses include, but are not limited to, picnicking, sunbathing, hiking, beach combing, camping, boating, tide pool and marine life study, hunting, sightseeing, or aesthetic enjoyment in conjunction with the above activities (RWQCB 1995).

METHODS

Three recreational ponds were monitored every other week between May and October 1999 and 2000. A schedule was established for collection of recreational samples during the high use period of May through October. Samples were collected from a pond every other Tuesday for the duration of this period. Pathogen samples were delivered to the park water quality refrigerator in the morning for afternoon pickup by the laboratory courier.

Sample Parameters

Recreational sites were sampled for only some of the parameters evaluated at the stream sites. Temperature and pH were sampled in the field, and fecal coliform samples were collected and transported to the laboratory for evaluation.

RECREATIONAL MONITORING SITES

Bass Lake

A natural lake formed of a depression associated with coastal sliding, Bass Lake is a well known swimming destination in the bay area. A two mile hike from the Palomarin Trailhead, the lake is a primary destination for many visitors during the summer months. A number of access points to the lake provide for contact recreation.

Hagmaier Pond

Hagmaier Pond, built in the 1950s as an agricultural water source, is a well known destination. The pond is located in a pasture used by cattle throughout the summer. The pond is a water source for the cattle and the dam and slopes around the pond are well used by visitors. The

Hagmaier Pond dam is one of seven Point Reyes National Seashore dams on the National Park Service – Dam Inventory. Annual inspections of dam and spillway condition are performed in coordination with the NPS and PRNS dam safety officers.

Vision Pond

Vision Pond, constructed in the mid-1950s for agricultural operations lies within the Philip Burton Wilderness Area. The pond is used for swimming and sunbathing.

RESULTS

Summer 1999

Results of the Summer 1999 sample period indicate even when human use is heavy, the fecal coliform levels remained within the adequate use levels. A single sample result from Hagmaier Pond in July read very high, most likely due to cattle activity adjacent to the pond (it is within the pastoral zone and managed for grazing). Seashore staff notified the administration, posted warning signs, and initiated additional samples once high result was received. Subsequent samples returned to an acceptable level for contact recreation.

Table 12. Recreational Water Quality Results for Summer 1999

Site	Sample Events	Water Temperature	pH	Mean Fecal Coliform	90th Percentile Fecal Coliform	Median Total Coliform	> 10,000 MPN	Contact Violation	Non-contact Violation
Bass Lake	7	18.1	8.5	8.8	21.8	37.6	no	0	0
Hagmaier Pond	12	18.3	8.7	**161.0**	**444.0**	**399.5**	no	**1**	0
Vision Pond	13	18.1	8.2	23.6	50.4	207.7	no	0	0

Source data is included in Appendix G

Summer 2000

Results of the Summer 2000 sample period supports indications that fecal coliform levels remained within the adequate use levels if only human use existed. In two of the three water bodies, Bass Lake and Vision Pond, mean water quality values (except for total coliform) were lower than in 1999. This trend was not maintained in Hagmaier Pond, where the mean fecal coliform level was 207 MPN/100ml, up from 167 MPN/100ml in 1999.

At Hagmaier Pond, three readings (18%) in excess of contact recreational use standards were observed. Following the first high fecal coliform reading, the staff initiated weekly sampling of Hagmaier Pond. In conjunction with information from 1999, continued weekly monitoring observed dramatic response, both up and down in only a week's time. This further supports the premise that presence of cattle at the pond is correlated with high fecal coliform levels.

Table 13. Recreational Water Quality Results for Summer 2000

Site	Sample Events	Mean Water Temperature C	Mean pH	Mean Fecal Coliform	90th Percentile Fecal Coliform MPN/100ml	Median Total Coliform MPN/100ml	> 10,000 MPN/100ml	Contact Violation	Non-contact Violation
Bass Lake	11	19.0	8.6	8.9	23	215.4	no	0	0
Hagmaier Pond	17	19.1	8.2	207.6	768	550.0	no	3	0
Vision Pond	12	18.2	8.2	11.6	42.2	217.5	no	0	0

Source data is included in Appendix G

At Hagmaier Pond, the cumulative total of 4 violations in 29 samples results in an exceedence 14% of the time. In August, staff worked with the Maintenance Division to install permanent warning signs indicating the designated use of the pond as a stock watering facility, and potentially high fecal coliform levels in the pond.

RECOMMENDATIONS

Hagmaier Pond

Continued monitoring on a weekly basis is recommended for Hagmaier Pond for the summer 2001. Posting of the warnings has not reduced recreational use of the area around the pond, but may be effective at keeping visitors from actually swimming in the pond. Staff has only received one phone call inquiring about the effects of fecal coliform.

Bass Lake and Vision Pond

Based upon two seasons of monitoring for fecal coliform, it is clear that Bass Lake and Vision Pond consistently meet contact recreational use criteria. It is recommended that sampling is cut to once every 6 weeks at these two locations.

Kehoe Marsh

The staff has identified the Kehoe Marsh for sampling in summer 2001. The marsh runs along a heavily used trail and is contained behind a sand bar for the duration of the summer. Recreational use of the area is heavy, and it is likely that there is some use of the marsh for wading. Upstream sources of pollution include North and South Kehoe Creeks, which are well documented to carry excessive levels of fecal coliform in the winter runoff events. Monitoring every other week will also help quantify how much the marsh is actually used for recreation.

AQUATIC BIOASSESSMENT PROGRAM

AQUATIC BIOASSESSMENT REPORT ABSTRACT

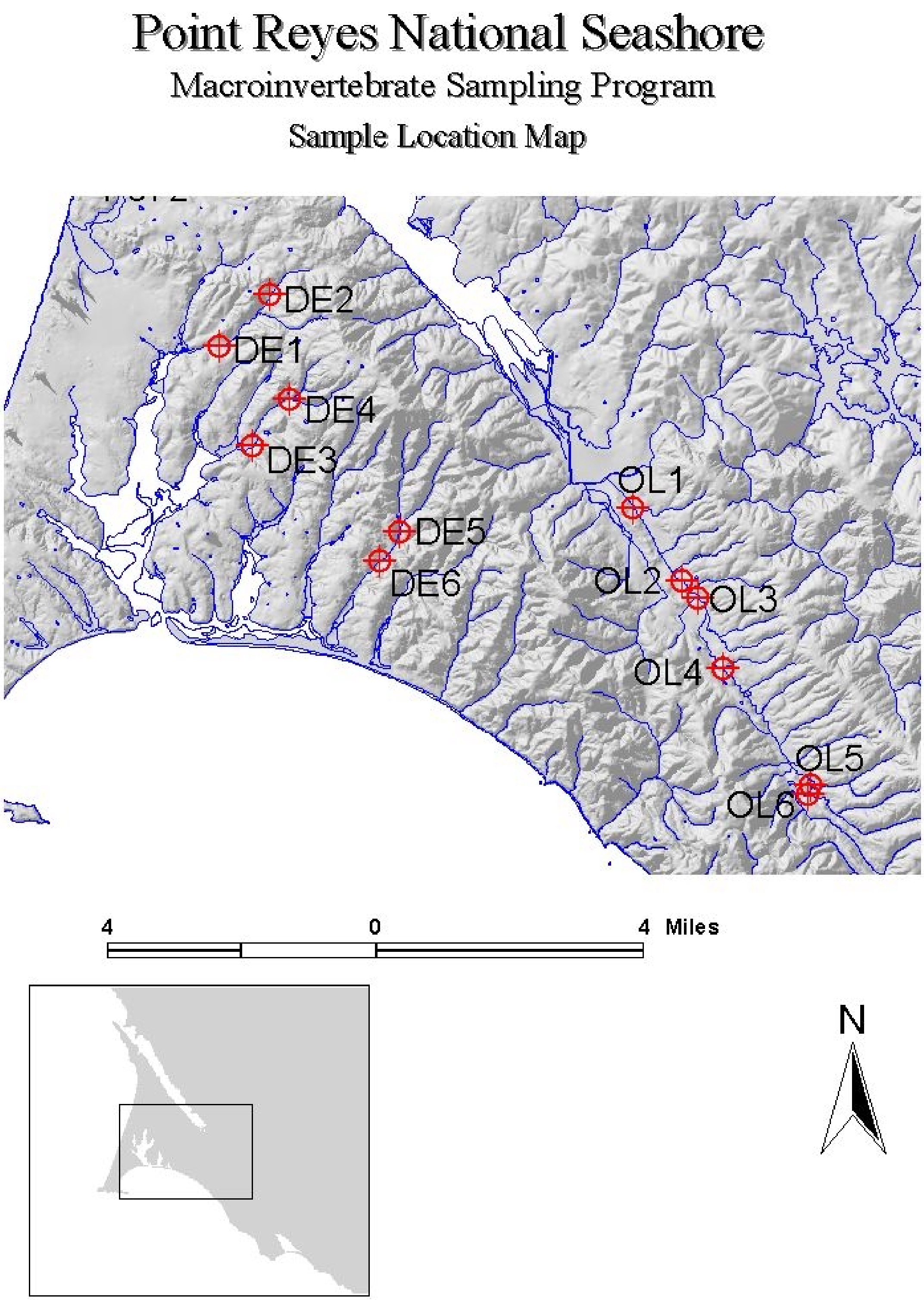
Thirty-six benthic macroinvertebrate samples were collected from twelve stream sites in Point Reyes National Seashore. Sample collection, laboratory processing, and taxa determination followed the California Stream Bioassessment procedure for point source pollution. Six biological metrics (Taxa Richness, EPT Taxa richness, Modified EPT index, Percent Dominant Taxon, Tolerance Value, and Shannon's Diversity Index) were used for the analysis. Metric scores for the Olema Creek sample sites were compared individually while metric scores from the remaining sample sites were compared in pairs, above and below a disturbance. Metric scores were moderate to low for the sample sites evaluated. Metric scores suggest greater impairment at many of the downstream sites in comparison to upstream sites.

RECOMMENDATIONS

A spring sample collected in 2000 was delivered to Jon Lee consulting for evaluation this summer. Comparison of these seasonal collections will be used to determine the best time of year to sample.

If benthic macroinvertebrate communities in this area differ naturally from the Russian River watershed, development of an Index of Biological Integrity for Point Reyes National Seashore may be warranted. It may be worth investigating whether a reference stream exists within Point Reyes National Seashore. A reference stream would be an effective comparison for metrics which were generated from samples collected within the Seashore.

The complete macroinvertebrate report is included as Appendix H.



Map 8. Macroinvertebrate Sample Locations

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APPENDIX A

SAMPLING PROTOCOL
AMBIENT STATION REPORTS

Point Reyes National Seashore

Ambient Water Quality Site Report for Bear Valley

Station	Location	Date	Water Temp. C	Specific Conductance	Salinity	pH	DO	Nitrate (mg/L)	Orthophosphorous (mg/L)	Ammonia (mg/L)	Total Suspended Solids (mg/L)	Total Coliform (MPN)/100ml	Fecal Coliform
LAG1	Bear Valley												
		5/18/99	12.9	312.2	0.2	8.2	10.4				10	50	22
		9/13/99	16.5	325.1	0.2	9.3	8.6				26	1,600	34
		1/24/00	11.1	267.6	0.1	8.1	8.1	1.4	0.45	< 0.1	95	> 1,600	1,600
		2/23/00	10.0	242.2	0.1	8.5		1	0.33	< 0.1	13	2,200	1,700
		3/8/00	10.3	234.6	0.1	8.1		0.76	0.4	< 0.1		920	920
		5/8/00	13.1	297.8	0.1	7.7	9.2	0.56	0.36	< 0.1	2	800	800
		10/23/00	10.3	332.2	0.2	8.1	9.6	0.43	0.33	< 0.2		900	170
		1/11/01	9.5	339.5	0.2	7.9	10.3	0.8	0.4		8	2,200	350
		4/24/01	13.9	338.7	0.2	7.8	10.2	0.58		0.3		2,400	2,400
Average		**9**	**12.0**	**299**	**0.2**	**8.2**	**9.5**	**0.79**	**0.4**	**0.2**	**25.7**	**1,408**	**888**
Maximum			16.5	340	0.2	9.3	10.4	1.40	0.5	0.3	95.0	2,400	2,400
Minimum			9.5	235	0.1	7.7	8.1	0.43	0.3	0.1	2.0	50	22

Point Reyes National Seashore

Ambient Water Quality Site Report for Cheda Creek

Station	Location	Date	Water Temp. C	Specific Conductance	Salinity	pH	DO	Nitrate (mg/L)	Orthophosphorous (mg/L)	Ammonia (mg/L)	Total Suspended Solids (mg/L)	Total Coliform (MPN)/100ml	Fecal Coliform
LAG2	Cheda Creek												
		5/10/99	12.5	320.9	0.2	8.6	10.5				8		
		5/24/99	12.7	340.6	0.2	8.7	8.2					110	70
		6/8/99	13.3	349.1	0.2	8.5	8.0				3	22	11
		7/13/99	18.6	356.5	0.2	8.4	8.2	0.26	0.08	< 0.2		110	110
		8/10/99	15.8	358.0	0.2	8.0	7.0	< 0.2	0.07	< 0.2		80	30
		9/13/99	16.3	371.1	0.2	8.9	7.3				0	80	27
		1/16/00	9.9	257.0	0.1	8.4	11.0	1.4	0.29	< 0.1	20	> 1,600	> 1,600
		2/23/00	9.8	134.7	0.1	7.6		0.24	0.08	< 0.1	19	1,100	920
		3/8/00	9.7	131.3	0.1	7.9		< 0.2	0.2	< 0.1		> 1,600	> 1,600
		5/8/00	13.1	299.4	0.1	8.3	9.6	0.25	0.1	< 0.1	2	1,300	800
		10/23/00	11.8	394.3	0.2	7.8	7.7	< 0.2	0.08	< 0.2		30	13
		1/11/01	8.7	177.5	0.1	8.2	11.0	1.8	0.53		180	> 16,000	> 16,000
		4/24/01	11.5	343.7	0.2	8.0	10.7	0.23		0.2	4	130	130
Average		**13**	**12.6**	**295**	**0.2**	**8.3**	**9.0**	**0.53**	**0.2**	**0.1**	**29.5**	**1,847**	**1,776**
Maximum			18.6	394	0.2	8.9	11.0	1.80	0.5	0.2	180.0	16,000	16,000
Minimum			8.7	131	0.1	7.6	7.0	0.20	0.1	0.1	0.0	22	11

Point Reyes National Seashore

Ambient Water Quality Site Report for Devil's Gulch

Station	Location	Date	Water Temp. C	Specific Conductance	Salinity	pH	DO	Nitrate (mg/L)	Orthophosphorous (mg/L)	Ammonia (mg/L)	Total Suspended Solids (mg/L)	Total Coliform (MPN)/100ml	Fecal Coliform
LAG3	Devil's Gulch												
		5/10/99	11.4	322.1	0.2	8.8	11.1				9	33	7
		9/13/99	15.6	348.1	0.2	8.9	9.5				0	500	12
		1/16/00	10.0	228.5	0.1	8.5	11.1	1.3	0.24	< 0.1	26	> 1,600	> 1,600
		2/23/00	10.0	154.1	0.1	7.7		0.36	0.08	< 0.1	17	4,600	3,500
		3/8/00	9.7	168.2	0.1	7.8		0.24	0.18	< 0.1		> 1,600	> 1,600
		5/8/00	12.7	301.5	0.1	8.2	9.6	0.08	0.08	< 0.1	5		
		10/23/00	10.9	365.1	0.2	8.2	10.4	< 0.2	0.27	< 0.2		30	17
		1/11/01	8.8	181.3	0.1	8.3	11.5	1.2	0.18		36	> 16,000	2,400
		4/24/01	10.6	291.5	0.1	8.0	10.9	0.29		< 0.2	3	500	< 20
Average		**9**	**11.1**	**262**	**0.1**	**8.3**	**10.6**	**0.52**	**0.2**	**0.1**	**13.7**	**3,108**	**1,145**
Maximum			15.6	365	0.2	8.9	11.5	1.30	0.3	0.2	36.0	16,000	3,500
Minimum			8.8	154	0.1	7.7	9.5	0.08	0.1	0.1	0.0	30	7

Point Reyes National Seashore

Ambient Water Quality Site Report for Olema Creek - below Stewart's Pasture

Station	Location	Date	Water Temp. C	Specific Conductance	Salinity	pH	DO	Nitrate (mg/L)	Orthophosphorous (mg/L)	Ammonia (mg/L)	Total Suspended Solids (mg/L)	Total Coliform (MPN)/100ml	Fecal Coliform
OLM10	Olema Creek - below Stewart's Pasture												
		8/10/99	16.2	299.5	0.1	8.0	6.0	< 0.2	0.18	< 0.2		300	< 2
		9/27/99	14.8	313.6	0.2	8.0	9.1				7	> 1,600	24
		1/24/00	11.9	116.9	0.1	7.7	10.1	1.2	0.34	< 0.1	106	> 1,600	> 1,600
		2/10/00	12.1	118.2	0.1	7.8		0.5	0.51	< 0.1	247	> 16,000	> 16,000
		2/29/00	11.1	41.7	0.0	7.7		0.3	0.19	< 0.1	149	3,500	3,500
		5/15/00	13.7	192.1	0.1	7.9	10.2	< 0.2	0.19	< 0.1	1	1,300	200
		10/24/00	9.5	336.3	0.2	8.4	9.5	< 0.2	0.2	< 0.2		920	920
		1/11/01	8.3	266.2	0.1	7.9	10.8	0.99	0.26		11	5,400	3,500
		4/24/01	12.6	262.5	0.1	7.8	10.6	< 0.2		< 0.2	22	3,000	3,000
Average		**9**	**12.2**	**216**	**0.1**	**7.9**	**9.5**	**0.47**	**0.3**	**0.1**	**77.6**	**3,736**	**3,194**
Maximum			16.2	336	0.2	8.4	10.8	1.20	0.5	0.2	247.0	16,000	16,000
Minimum			8.3	42	0.0	7.7	6.0	0.20	0.2	0.1	1.0	300	2

Point Reyes National Seashore

Ambient Water Quality Site Report for Olema Creek - Bear Valley Bridge

Station	Location	Date	Water Temp. C	Specific Conductance	Salinity	pH	DO	Nitrate (mg/L)	Orthophosphorous (mg/L)	Ammonia (mg/L)	Total Suspended Solids (mg/L)	Total Coliform (MPN)/100ml	Fecal Coliform
OLM11	Olema Creek - Bear Valley Bridge												
		8/10/99	16.0	306.7	0.1	7.9	8.9	< 0.2	0.17	< 0.2		500	2
		9/27/99	15.0	326.1	0.2	7.9	8.5				3	> 1,600	35
		1/24/00	11.8	115.5	0.1	7.7	10.6	1.3	0.3	< 0.1	170	> 1,600	1,600
		2/10/00	11.8	106.9	0.1	7.8		0.5	0.44	< 0.1	256	> 16,000	16,000
		2/29/00	11.0	94.6	0.0	7.6		0.3	0.17	< 0.1	140	5,400	5,400
		5/15/00	13.2	188.9	0.1	7.9	10.4	0.2	0.18	< 0.1	2	2,200	400
		10/24/00	9.9	347.6	0.2	8.1	9.7	< 0.2	0.15	< 0.2		540	540
		1/3/01	9.1	372.2	0.2	8.6	12.1						
		1/11/01	8.3	262.6	0.1	8.0	11.3	1.1	0.24		9	1,700	920
		1/25/01										35,000	28,000
		4/24/01	11.1	262.9	0.1	7.9	10.8	0.21		< 0.2	0	800	500
Average		**11**	**11.7**	**238**	**0.1**	**7.9**	**10.3**	**0.50**	**0.2**	**0.1**	**82.9**	**6,534**	**5,340**
Maximum			16.0	372	0.2	8.6	12.1	1.30	0.4	0.2	256.0	35,000	28,000
Minimum			8.3	95	0.0	7.6	8.5	0.20	0.1	0.1	0.0	500	2

Point Reyes National Seashore

Ambient Water Quality Site Report for Vedanta Creek

Station	Location	Date	Water Temp. C	Specific Conductance	Salinity	pH	DO	Nitrate (mg/L)	Orthophosphorous (mg/L)	Ammonia (mg/L)	Total Suspended Solids (mg/L)	Total Coliform (MPN)/100ml	Fecal Coliform
OLM5	Vedanta Creek												
		6/8/99	14.0	277.2	0.1	8.2	6.3				4	> 1,600	17
		7/13/99	16.6	303.6	0.1	8.5	4.8	< 0.2	0.28	< 0.2		900	900
		9/21/99	16.0	341.0	0.2	7.8	8.4				2	300	38
		1/24/00	11.2	254.6	0.1	7.7	7.5	2.2	0.58	< 0.1	78	> 1,600	> 1,600
		2/10/00	12.0	237.0	0.1	7.4		0.97	0.5	< 0.1	48	> 16,000	16,000
		2/29/00	12.2	172.6	0.1	7.2		0.75	0.75	< 0.1	79	17,000	5,400
		5/15/00	14.1	248.1	0.1	7.3	9.3	< 0.2	0.32	< 0.1	3	700	200
		10/24/00	9.4	371.1	0.2	8.2	10.2	< 0.2	0.17	< 0.2		920	540
		1/11/01	8.6	310.9	0.1	7.7	10.5	1.1	0.43		36	> 16,000	9,200
		4/24/01	12.1	283.5	0.1	7.6	9.7	0.28		0.2	5	16,400	9,000
Average		**10**	**12.6**	**280**	**0.1**	**7.8**	**8.3**	**0.74**	**0.4**	**0.1**	**31.9**	**7,142**	**4,290**
Maximum			16.6	371	0.2	8.5	10.5	2.20	0.8	0.2	79.0	17,000	16,000
Minimum			8.6	173	0.1	7.2	4.8	0.20	0.2	0.1	2.0	300	17

Point Reyes National Seashore

Ambient Water Quality Site Report for Olema Creek - above Vedanta Bridge

Station	Location	Date	Water Temp. C	Specific Conductance	Salinity	pH	DO	Nitrate (mg/L)	Orthophosphorous (mg/L)	Ammonia (mg/L)	Total Suspended Solids (mg/L)	Total Coliform (MPN)/100ml	Fecal Coliform
OLM12	Olema Creek - above Vedanta Bridge												
		9/27/99	16.0	318.2	0.2	7.9	9.2				1	> 1,600	38
		1/24/00	11.8	112.2	0.1	7.7	10.3	1.2	0.33	< 0.1	176	> 1,600	1,600
		2/10/00	11.8	103.0	0.1	7.8		0.46	0.31	< 0.1	163	> 16,000	5,400
		2/29/00	11.0			7.6		0.28	0.16	< 0.1	156	4,600	3,500
		5/15/00	13.1	183.1	0.1	7.9	10.9	< 0.2	0.18	< 0.1	8	2,300	< 2
		10/24/00	10.2	341.1	0.2	8.1	9.0	< 0.2	0.14	< 0.2		350	350
		1/11/01	8.2	255.0	0.1	8.1	11.5	1.1	0.22		19	2,400	2,400
		4/24/01	11.6	262.5	0.1	7.8	10.6	< 0.2		0.2	1	500	300
Average		**8**	**11.7**	**225**	**0.1**	**7.9**	**10.2**	**0.52**	**0.2**	**0.1**	**74.9**	**3,669**	**1,699**
Maximum			16.0	341	0.2	8.1	11.5	1.20	0.3	0.2	176.0	16,000	5,400
Minimum			8.2	103	0.1	7.6	9.0	0.20	0.1	0.1	1.0	350	2

Point Reyes National Seashore

Ambient Water Quality Site Report for Quarry Gulch

Station	Location	Date	Water Temp. C	Specific Conductance	Salinity	pH	DO	Nitrate (mg/L)	Orthophosphorous (mg/L)	Ammonia (mg/L)	Total Suspended Solids (mg/L)	Total Coliform (MPN)/100ml	Fecal Coliform
OLM4	Quarry Gulch												
		5/10/99	11.4	170.2	0.1	8.7	11.3				10	500	33
		6/8/99	11.6	192.2	0.1	9.1	8.8				0	44	8
		7/13/99	15.6	216.8	0.1	8.6	3.5	< 0.2	0.08	< 0.2		900	110
		1/24/00	11.7	117.6	0.1	8.0	8.5	1.9	0.27	< 0.1	131	> 1,600	> 1,600
		2/10/00	12.5	101.1	0.0	7.7		0.68	0.33	< 0.1	197	> 16,000	> 16,000
		2/29/00	11.5	96.8	0.0	7.6		0.52	0.18	< 0.1	71	14,000	9,500
		5/15/00	15.1	173.8	0.1	7.8	9.8	< 0.2	0.07	< 0.1	3	220	700
		10/24/00											
		1/11/01	7.9	208.7	0.1	8.0	10.9	< 0.2	0.26		27	9,200	3,500
		1/25/01	7.6	154.2	0.1	7.7	10.5				294	300,000	300,000
		4/24/01	10.3	197.5	0.1	7.9	10.2	< 0.2		< 0.2	0	1,300	20
Average		**11**	**11.5**	**163**	**0.1**	**8.1**	**9.2**	**0.56**	**0.2**	**0.1**	**81.4**	**34,376**	**33,147**
Maximum			15.6	217	0.1	9.1	11.3	1.90	0.3	0.2	294.0	300,000	300,000
Minimum			7.6	97	0.0	7.6	3.5	0.20	0.1	0.1	0.0	44	8

Point Reyes National Seashore

Ambient Water Quality Site Report for Olema Creek - Truttman Gulch

Station	Location	Date	Water Temp. C	Specific Conductance	Salinity	pH	DO	Nitrate (mg/L)	Orthophosphorous (mg/L)	Ammonia (mg/L)	Total Suspended Solids (mg/L)	Total Coliform (MPN)/100ml	Fecal Coliform
OLM13	Olema Creek - Truttman Gulch												
		9/27/99	13.7	326.4	0.2	7.9	9.3				3	350	22
		1/24/00	11.7	109.5	0.1	7.7	10.3	1.1	0.28	< 0.1	125	> 1,600	> 1,600
		2/10/00	11.6	101.2	0.0	8.0		0.44	0.33	< 0.1	250	> 16,000	16,000
		2/29/00	11.0			7.6		0.24	0.15	< 0.1	86	5,400	1,700
		5/15/00	12.6	179.3	0.1	7.9	10.3	0.2	0.18	< 0.1	0	700	200
		10/24/00	10.0	350.0	0.2	8.1	9.7	< 0.2	0.24	< 0.2		79	49
		1/11/01	8.3	250.1	0.1	8.1	12.7	1.1	0.44		9	9,200	5,400
		4/24/01	10.0	260.5	0.1	7.8	10.7	< 0.2		< 0.2	1	800	140
Average		**8**	**11.1**	**225**	**0.1**	**7.9**	**10.5**	**0.50**	**0.3**	**0.1**	**67.7**	**4,266**	**3,139**
Maximum			13.7	350	0.2	8.1	12.7	1.10	0.4	0.2	250.0	16,000	16,000
Minimum			8.3	101	0.0	7.6	9.3	0.20	0.1	0.1	0.0	79	22

Point Reyes National Seashore

Ambient Water Quality Site Report for Olema Creek - Building 168

Station	Location	Date	Water Temp. C	Specific Conductance	Salinity	pH	DO	Nitrate (mg/L)	Orthophosphorous (mg/L)	Ammonia (mg/L)	Total Suspended Solids (mg/L)	Total Coliform (MPN)/100ml	Fecal Coliform
OLM16	Olema Creek - Building 168												
		1/24/00	11.7	107.9	0.1	8.0	10.3	1.1	0.21	< 0.1	110	> 1,600	1,600
		2/10/00	11.4	118.2	0.1	7.8		0.48	0.62	< 0.1	129	> 16,000	> 16,000
		2/29/00				7.0		0.24	0.14	< 0.1	90	3,500	3,500
		5/15/00	12.6	176.4	0.1	7.8	10.3	0.21	0.18	< 0.1	6	2,300	200
		10/24/00	10.4	333.0	0.2	8.1	10.5	< 0.2	0.29	< 0.2		240	240
		1/11/01	8.5	254.2	0.1	8.1	11.2	1.4	0.33		36	92,000	24,000
		4/24/01	9.9	263.9	0.1	8.0	10.4	0.22		< 0.2	0	500	230
Average		**7**	**10.8**	**209**	**0.1**	**7.8**	**10.5**	**0.55**	**0.3**	**0.1**	**61.8**	**16,591**	**6,539**
Maximum			12.6	333	0.2	8.1	11.2	1.40	0.6	0.2	129.0	92,000	24,000
Minimum			8.5	108	0.1	7.0	10.3	0.20	0.1	0.1	0.0	240	200

Point Reyes National Seashore

Ambient Water Quality Site Report for Olema Creek - Five Brooks

Station	Location	Date	Water Temp. C	Specific Conductance	Salinity	pH	DO	Nitrate (mg/L)	Orthophosphorous (mg/L)	Ammonia (mg/L)	Total Suspended Solids (mg/L)	Total Coliform (MPN)/100ml	Fecal Coliform
OLM14	Olema Creek - Five Brooks												
		9/27/99	14.7	320.1	0.2	7.4	6.8				2	80	18
		1/24/00	11.5	104.1	0.1	7.9	7.6	0.86	0.19	< 0.1	94	1,600	540
		2/10/00	11.2	122.1	0.1	8.0	9.8	0.44	0.26	< 0.1	98	> 16,000	5,400
		2/29/00	10.6	90.6	0.0	7.6		< 0.2	0.12	< 0.1	70	3,500	3,500
		5/15/00										1,700	< 2
		10/24/00	10.1	310.0	0.1	8.0	9.4	< 0.2	0.14	< 0.2		280	280
		1/11/01	8.6	215.8	0.1	8.1	11.0	1.1	0.44		155	54,000	54,000
		4/24/01	9.7	224.2	0.1	8.0	10.7	0.21		0.2	2	60	20
Average		**8**	**10.9**	**198**	**0.1**	**7.9**	**9.2**	**0.50**	**0.2**	**0.1**	**70.2**	**9,653**	**7,970**
Maximum			14.7	320	0.2	8.1	11.0	1.10	0.4	0.2	155.0	54,000	54,000
Minimum			8.6	91	0.0	7.4	6.8	0.20	0.1	0.1	2.0	60	2

Point Reyes National Seashore

Ambient Water Quality Site Report for Giacomini Gulch

Station	Location	Date	Water Temp. C	Specific Conductance	Salinity	pH	DO	Nitrate (mg/L)	Orthophosphorous (mg/L)	Ammonia (mg/L)	Total Suspended Solids (mg/L)	Total Coliform (MPN)/100ml	Fecal Coliform
OLM2	Giacomini Gulch												
		5/10/99	11.2	171.9	0.1	8.6	9.4				3	170	170
		9/21/99	14.4	277.3	0.1	7.6	6.5				1	110	17
		1/18/00	10.0	123.1	0.1	8.3	9.9	1.4	0.11	< 0.1	6	> 1,600	> 1,600
		2/10/00	11.2	99.1	0.0	8.3	10.9						
		2/10/00	11.3	89.4	0.0	7.8		0.57	0.5	< 0.1	150	> 16,000	> 16,000
		2/29/00	10.5	77.9	0.0	7.7		0.26	0.12	< 0.1	7	9,200	1,700
		5/15/00	12.0	146.5	0.1	7.8	10.6	0.46	0.12	< 0.1		400	< 2
		1/11/01	8.9	184.9	0.1	8.1	11.5	1.8	1		457	> 160,000	> 160,000
		1/25/01	8.2	123.2	0.1	8.0	11.1	0.54	2.2	< 0.2	660	540,000	240,000
		4/24/01	9.5	203.7	0.1	8.1	10.5	0.64		0.4	3	220	< 20
Average		**10**	**10.7**	**150**	**0.1**	**8.0**	**10.0**	**0.81**	**0.7**	**0.2**	**160.9**	**80,856**	**46,612**
Maximum			14.4	277	0.1	8.6	11.5	1.80	2.2	0.4	660.0	540,000	240,000
Minimum			8.2	78	0.0	7.6	6.5	0.26	0.1	0.1	1.0	110	2

Point Reyes National Seashore

Ambient Water Quality Site Report for John West Fork

Station	Location	Date	Water Temp. C	Specific Conductance	Salinity	pH	DO	Nitrate (mg/L)	Orthophosphorous (mg/L)	Ammonia (mg/L)	Total Suspended Solids (mg/L)	Total Coliform (MPN)/100ml	Fecal Coliform
OLM1	John West Fork												
		5/10/99	10.6	133.4	0.1	9.0	9.8				2	50	23
		6/8/99	11.6	136.3	0.1	8.8	9.4				0	70	30
		8/10/99	15.1	196.6	0.1	7.9	5.4	0.29	< 0.06	< 0.2		17	2
		9/21/99	14.0	213.9	0.1	7.7	5.2				1	23	2
		1/18/00	10.3	130.5	0.1	8.0	9.8	1.3	0.1	< 0.1	9	> 1,600	920
		2/10/00	11.2	103.6	0.1	8.5	10.6	0.52	0.09	< 0.1	6	16,000	2,400
		2/29/00	10.6	80.6	0.0	7.6		0.27	0.1	< 0.1	7	920	540
		5/15/00	12.6	129.1	0.1	7.6	10.2	0.22	0.06	< 0.1	5	700	200
		10/24/00	10.3	205.8	0.1	8.0	5.4	< 0.2	< 0.06	< 0.2		79	79
		1/11/01	9.0	163.5	0.1	8.2	10.7	1.5			1	16,000	700
		1/25/01	8.9	132.1	0.1	8.2	10.7				32	17,000	13,000
		4/24/01	10.1	144.9	0.1	8.3	9.6	< 0.2		0.2	0	270	20
Average		**12**	**11.2**	**148**	**0.1**	**8.2**	**8.8**	**0.56**	**0.1**	**0.1**	**6.3**	**4,394**	**1,493**
Maximum			15.1	214	0.1	9.0	10.7	1.50	0.1	0.2	32.0	17,000	13,000
Minimum			8.9	81	0.0	7.6	5.2	0.20	0.1	0.1	0.0	17	2

Point Reyes National Seashore

Ambient Water Quality Site Report for Olema Creek - above John West Fork

Station	Location	Date	Water Temp. C	Specific Conductance	Salinity	pH	DO	Nitrate (mg/L)	Orthophosphorous (mg/L)	Ammonia (mg/L)	Total Suspended Solids (mg/L)	Total Coliform (MPN)/100ml	Fecal Coliform
OLM15	Olema Creek - above John West Fork												
		9/27/99	15.3	315.5	0.2	8.0	8.9				0	80	50
		1/24/00	11.3	107.3	0.1	7.8	7.6	0.67	0.22	< 0.1	161	> 1,600	1,600
		2/10/00	11.1	136.6	0.1	8.0	9.6	0.34	0.45	< 0.1	81	> 16,000	16,000
		2/29/00	10.5	93.6	0.0	7.6		< 0.2	0.14	< 0.1	25	9,200	3,500
		5/15/00	12.1	157.3	0.1	7.8	10.4	< 0.2	0.14	< 0.1	7	700	200
		10/26/00	9.9	312.0	0.1	8.1	9.9	< 0.2	0.19	< 0.2		7	2
		1/11/01	8.3	258.1	0.1	8.3	11.4	0.73	0.52		337	1,700	540
		4/24/01	9.4	239.0	0.1	8.2	10.9	< 0.2		0.2	0	1,700	1,100
Average		**8**	**11.0**	**202**	**0.1**	**8.0**	**9.8**	**0.36**	**0.3**	**0.1**	**87.3**	**3,873**	**2,874**
Maximum			15.3	316	0.2	8.3	11.4	0.73	0.5	0.2	337.0	16,000	16,000
Minimum			8.3	94	0.0	7.6	7.6	0.20	0.1	0.1	0.0	7	2

Point Reyes National Seashore

Ambient Water Quality Site Report for Randall Gulch

Station	Location	Date	Water Temp. C	Specific Conductance	Salinity	pH	DO	Nitrate (mg/L)	Orthophosphorous (mg/L)	Ammonia (mg/L)	Total Suspended Solids (mg/L)	Total Coliform (MPN)/100ml	Fecal Coliform
OLM3	Randall Gulch												
		1/24/00	11.5	92.8	0.0	7.5	9.6	1.1	0.17	< 0.1	46	> 1,600	> 1,600
		2/10/00	11.2	97.2	0.0	7.9		0.54	0.66	< 0.1	10	16,000	460
		2/29/00	10.8	82.3	0.0	7.3		0.26	0.06	< 0.1	6	1,600	1,600
		5/1/00	15.8	101.2	0.1	6.9	10.5	< 0.2		< 0.1		500	500
		5/15/00						0.44	0.09	< 0.1	6		
		10/24/00											
		1/25/01	9.4	112.9	0.1	8.3	10.2				3	22,000	11,000
Average		**7**	**11.7**	**97**	**0.0**	**7.6**	**10.1**	**0.51**	**0.2**	**0.1**	**14.2**	**8,340**	**3,032**
Maximum			15.8	113	0.1	8.3	10.5	1.10	0.7	0.1	46.0	22,000	11,000
Minimum			9.4	82	0.0	6.9	9.6	0.20	0.1	0.1	3.0	500	460

Point Reyes National Seashore

Ambient Water Quality Site Report for Olema Creek - Randall

Station	Location	Date	Water Temp. C	Specific Conductance	Salinity	pH	DO	Nitrate (mg/L)	Orthophosphorous (mg/L)	Ammonia (mg/L)	Total Suspended Solids (mg/L)	Total Coliform (MPN)/100ml	Fecal Coliform
OLM18	Olema Creek - Randall												
		1/24/00									23		
		2/10/00									14		
		5/15/00									6		
		1/11/01	8.1	167.4	0.1	8.0	9.8	0.55	0.08		4	5,400	540
		4/24/01	9.9	128.6	0.1	8.4	8.2	< 0.2		< 0.2	2	1,100	1,100
Average		**5**	**9.0**	**148**	**0.1**	**8.2**	**9.0**	**0.38**	**0.1**	**0.2**	**9.8**	**3,250**	**820**
Maximum			9.9	167	0.1	8.4	9.8	0.55	0.1	0.2	23.0	5,400	1,100
Minimum			8.1	129	0.1	8.0	8.2	0.20	0.1	0.2	2.0	1,100	540

Point Reyes National Seashore

Ambient Water Quality Site Report for East Schooner

Station	Location	Date	Water Temp. C	Specific Conductance	Salinity	pH	DO	Nitrate (mg/L)	Orthophosphorous (mg/L)	Ammonia (mg/L)	Total Suspended Solids (mg/L)	Total Coliform (MPN)/100ml	Fecal Coliform
DES2	East Schooner												
		5/18/99	11.1	219.1	0.1	8.2	10.5				11	80	11
		9/13/99	14.1	277.2	0.1	9.5	9.4				3	900	17
		1/16/00	10.0	270.5	0.1	8.0	6.5	1.1	0.2	< 0.1	31	> 1,600	> 1,600
		2/14/00	12.3	157.2	0.1	7.3		1.6	0.14	< 0.1	138	16,000	460
		4/18/00	10.7	190.8	0.1	7.3	10.6	0.6	0.12		10	3,500	950
		5/22/00	12.4	224.6	0.1	7.5	10.0	< 0.2	0.12	< 0.1	4	500	20
		10/17/00	9.7	290.8	0.1	8.3	9.7	< 0.2	0.15	< 0.2		950	540
		1/11/01	8.9	318.1	0.2	8.3	11.1	1.5	0.1		17	920	130
		4/24/01	10.2	262.7	0.1	7.9	11.1	< 0.2		0.2	3	500	140
Average		**9**	**11.0**	**246**	**0.1**	**8.0**	**9.9**	**0.77**	**0.1**	**0.1**	**27.1**	**2,772**	**430**
Maximum			14.1	318	0.2	9.5	11.1	1.60	0.2	0.2	138.0	16,000	1,600
Minimum			8.9	157	0.1	7.3	6.5	0.20	0.1	0.1	3.0	80	11

Point Reyes National Seashore

Ambient Water Quality Site Report for Home Ranch

Station	Location	Date	Water Temp. C	Specific Conductance	Salinity	pH	DO	Nitrate (mg/L)	Orthophosphorous (mg/L)	Ammonia (mg/L)	Total Suspended Solids (mg/L)	Total Coliform (MPN)/100ml	Fecal Coliform
DES3	Home Ranch												
		5/11/99	16.3	202.4	0.1		12.1				11	1,600	1,600
		9/13/99	16.3	300.2	0.1	9.1	7.0				3	1,600	1,600
		1/16/00	11.0	256.7	0.1	7.8	6.1	0.22	0.16	< 0.1	11	> 1,600	540
		2/14/00	12.1	144.2	0.1	7.5		0.6	0.09	< 0.1	61	16,000	460
		4/18/00	12.5	171.8	0.1	7.0	10.3	< 0.2	0.1		8	9,200	2,400
		5/22/00	16.3	217.0	0.1	7.7	10.5	< 0.2	0.11	< 0.1	2	1,700	1,700
		10/17/00	10.8	334.2	0.2	8.0	8.0	0.38	0.13	< 0.2		2,200	920
		1/11/01	8.9	336.9	0.2	8.2	9.8	0.48	0.22		12	16,000	9,200
		4/24/01	11.4	270.3	0.1	7.5	9.7	< 0.2		0.3		>= 16,000	9,000
Average		**9**	**12.8**	**248**	**0.1**	**7.9**	**9.2**	**0.33**	**0.1**	**0.2**	**15.4**	**7,322**	**3,047**
Maximum			16.3	337	0.2	9.1	12.1	0.60	0.2	0.3	61.0	16,000	9,200
Minimum			8.9	144	0.1	7.0	6.1	0.20	0.1	0.1	2.0	1,600	460

Point Reyes National Seashore

Ambient Water Quality Site Report for Muddy Hollow

Station	Location	Date	Water Temp. C	Specific Conductance	Salinity	pH	DO	Nitrate (mg/L)	Orthophosphorous (mg/L)	Ammonia (mg/L)	Total Suspended Solids (mg/L)	Total Coliform (MPN)/100ml	Fecal Coliform
DES4	Muddy Hollow												
		5/11/99	11.9	244.2	0.1	8.1	10.8				6	110	80
		9/21/99	14.3	303.0	0.1	7.8	9.8				2	280	17
		1/16/00	11.0	306.8	0.1	7.9	8.6	< 0.2	0.06	< 0.1	7	540	240
		2/14/00	12.3	180.9	0.1	7.5		0.7	0.09	< 0.1	104	5,400	230
		4/18/00	12.4	229.9	0.1	7.3	10.3	<0.02	< 0.06		5	110	33
		5/22/00	15.1	260.5	0.1	7.6	9.9	< 0.2	< 0.06	< 0.1	2	1,300	20
		10/17/00	11.6	331.6	0.2	7.9	10.8	< 0.2	< 0.06	< 0.2		700	210
		1/11/01	9.1	348.6	0.2	8.1	10.7	< 0.2	0.06		9	1,700	350
		4/24/01	10.9	321.7	0.2	7.7	10.8	< 0.2		0.2	0	1,700	270
Average		**9**	**12.1**	**281**	**0.1**	**7.8**	**10.2**	**0.25**	**0.1**	**0.1**	**16.9**	**1,316**	**161**
Maximum			15.1	349	0.2	8.1	10.8	0.70	0.1	0.2	104.0	5,400	350
Minimum			9.1	181	0.1	7.3	8.6	0.02	0.1	0.1	0.0	110	17

Point Reyes National Seashore

Ambient Water Quality Site Report for Laguna Creek

Station	Location	Date	Water Temp. C	Specific Conductance	Salinity	pH	DO	Nitrate (mg/L)	Orthophosphorous (mg/L)	Ammonia (mg/L)	Total Suspended Solids (mg/L)	Total Coliform (MPN)/100ml	Fecal Coliform
DES5	Laguna Creek												
		5/11/99	10.4	351.8	0.2	8.6	10.7				12	50	50
		9/21/99	13.4	390.0	0.2	8.2	9.9	< 0.2	0.25	0.2	0	900	17
		1/16/00	10.2	414.8	0.2	8.2	5.8	0.66	0.31	< 0.1	10	1,600	540
		2/14/00	12.0	207.7	0.1	7.6		1.4	0.28	< 0.1	388	9,200	20
		4/18/00	11.4	305.9	0.1	7.7	10.7	0.36	0.25		8	2,400	280
		10/17/00	11.6	481.7	0.2	8.3	10.5	< 0.2	0.28	< 0.2		540	350
		1/11/01	8.8	456.3	0.2	8.2	10.9	0.55	0.4		5	210	110
		1/26/01	8.5	380.0	0.2	7.9	11.0	1.3	0.29		38	500	240
		4/24/01	10.4	439.4	0.2	8.2	11.1	< 0.2		< 0.2	6	600	230
Average		**9**	**10.7**	**381**	**0.2**	**8.1**	**10.1**	**0.61**	**0.3**	**0.2**	**58.4**	**1,778**	**204**
Maximum			13.4	482	0.2	8.6	11.1	1.40	0.4	0.2	388.0	9,200	540
Minimum			8.5	208	0.1	7.6	5.8	0.20	0.3	0.1	0.0	50	17

Point Reyes National Seashore

Ambient Water Quality Site Report for C Ranch

Station	Location	Date	Water Temp. C	Specific Conductance	Salinity	pH	DO	Nitrate (mg/L)	Orthophosphorous (mg/L)	Ammonia (mg/L)	Total Suspended Solids (mg/L)	Total Coliform (MPN)/100ml	Fecal Coliform
DBY1	C Ranch												
		1/26/01	9.2	1,006.0	0.5	8.0	9.6	0.86	0.48		23	9,200	2,400
		3/6/01	12.8	1,089.0	0.5	7.4	9.5	2.9	2.7	2	13	24,000	13,000
Average		**2**	**11.0**	**1,048**	**0.5**	**7.7**	**9.5**	**1.88**	**1.6**	**2.0**	**18.0**	**16,600**	**7,700**
Maximum			12.8	1,089	0.5	8.0	9.6	2.90	2.7	2.0	23.0	24,000	13,000
Minimum			9.2	1,006	0.5	7.4	9.5	0.86	0.5	2.0	13.0	9,200	2,400

Point Reyes National Seashore

Ambient Water Quality Site Report for B Ranch

Station	Location	Date	Water Temp. C	Specific Conductance	Salinity	pH	DO	Nitrate (mg/L)	Orthophosphorous (mg/L)	Ammonia (mg/L)		Total Suspended Solids (mg/L)	Total Coliform (MPN)/100ml	Fecal Coliform
DBY2	B Ranch													
		1/26/01	8.3	2,941.0	1.5	8.2	6.1	6.6	28	5.6	Toxic	95	900,000	900,000
		3/6/01	15.3	1,327.0	0.7	7.7	3.2	< 0.2	16	8.5	Toxic	81	160,000	90,000
Average		**2**	**11.8**	**2,134**	**1.1**	**7.9**	**4.7**	**3.40**	**22.0**	**7.0**		**88.0**	**530,000**	**495,000**
Maximum			15.3	2,941	1.5	8.2	6.1	6.60	28.0	8.5		95.0	900,000	900,000
Minimum			8.3	1,327	0.7	7.7	3.2	0.20	16.0	5.6		81.0	160,000	90,000

Point Reyes National Seashore

Ambient Water Quality Site Report for A Ranch Perennial

Station	Location	Date	Water Temp. C	Specific Conductance	Salinity	pH	DO	Nitrate (mg/L)	Orthophosphorous (mg/L)	Ammonia (mg/L)	Total Suspended Solids (mg/L)	Total Coliform (MPN)/100ml	Fecal Coliform
DBY3	A Ranch Perennial												
		5/18/99	12.8	978.0	0.5	8.4	10.6				8	1,600	1,600
		9/13/99	15.1	1,185.0	0.6	9.7	6.3				1	500	110
		1/16/00	9.8	1,693.0	0.9	8.3	10.2	8.5	11	4.3	Toxic 42	> 1,600	> 1,600
		2/14/00	15.2	672.0	0.3	7.8		9.4	3.1	0.5	113	> 16,000	16,000
		4/18/00	11.2	977.0	0.5	8.1	10.6	3.5	3.1	< 0.1	5	>= 16,000	>= 16,000
		5/22/00	15.1	1,060.0	0.9	8.1	9.5	< 0.2	1	< 0.1	2	3,000	1,300
		10/17/00	12.2	1,317.0	0.7	8.0	6.3	< 0.2	0.47	< 0.2		> 16,000	> 16,000
		1/11/01	8.9	1,912.0	1.0	8.7	10.8	8.5	6.1	< 0.2	35	> 160,000	> 160,000
		1/26/01	7.7	1,501.0	0.8	8.6	12.2	11	12	1.7	Toxic 61	1,600,000	300,000
		3/6/01	12.1	879.0	0.4	8.0	10.3	5.9	2.9	0.6	12	7,000	3,000
		4/24/01	10.8	1,247.0	0.6	7.9	9.5	< 0.2		0.5	5	5,000	1,100
Average		**11**	**11.9**	**1,220**	**0.7**	**8.3**	**9.6**	**5.27**	**5.0**	**0.9**	**28.4**	**166,064**	**46,974**
Maximum			15.2	1,912	1.0	9.7	12.2	11.00	12.0	4.3	113.0	1,600,000	300,000
Minimum			7.7	672	0.3	7.8	6.3	0.20	0.5	0.1	1.0	500	110

Point Reyes National Seashore

Ambient Water Quality Site Report for South Kehoe

Station	Location	Date	Water Temp. C	Specific Conductance	Salinity	pH	DO	Nitrate (mg/L)	Orthophosphorous (mg/L)	Ammonia (mg/L)	Total Suspended Solids (mg/L)	Total Coliform (MPN)/100ml	Fecal Coliform
PAC1	South Kehoe												
		5/18/99	12.8	403.7	0.2	7.7	2.1				14	1,600	220
		7/13/99	14.3	445.7	0.2	8.1	2.0	< 0.2	0.46	< 0.2		> 1,600	240
		9/21/99	14.5	464.0	0.2	7.4	2.0				3	> 1,600	220
		1/18/00	10.1	480.5	0.2	7.9	3.7	1.4	0.94	< 0.1	40	> 1,600	> 1,600
		2/14/00	12.2	297.7	0.1	7.3		2.4	2.1	0.6	61	> 16,000	> 16,000
		2/23/00	9.3	321.4	0.2	6.9		1.2	1.2	1.2	30	> 16,000	> 16,000
		5/8/00	13.4	424.2	0.2	7.5	4.0	1.7	1.1	< 0.1	15	90,000	90,000
		10/17/00	12.3	500.0	0.2	7.6	6.1	4.1	0.51	< 0.2		16,000	1,400
		1/11/01	8.4	593.0	0.3	7.7	7.4	2.3	0.92	< 0.2	716	> 160,000	> 160,000
		1/26/01	7.3	623.0	0.3	7.6	6.9	1.6	0.48		222	> 1,600,000	> 1,600,000
		3/6/01	11.2	439.8	0.2	7.6	4.9	2.2	1.1	0.9	14	11,000	11,000
		4/24/01	12.0	448.0	0.2	7.4	7.7	1		0.6	16	5,600	270
Average		**12**	**11.5**	**453**	**0.2**	**7.6**	**4.7**	**1.81**	**1.0**	**0.5**	**113.1**	**160,083**	**158,079**
Maximum			14.5	623	0.3	8.1	7.7	4.10	2.1	1.2	716.0	1,600,000	1,600,000
Minimum			7.3	298	0.1	6.9	2.0	0.20	0.5	0.1	3.0	1,600	220

Point Reyes National Seashore

Ambient Water Quality Site Report for North Kehoe

Station	Location	Date	Water Temp. C	Specific Conductance	Salinity	pH	DO	Nitrate (mg/L)	Orthophosphorous (mg/L)	Ammonia (mg/L)	Total Suspended Solids (mg/L)	Total Coliform (MPN)/100ml	Fecal Coliform
PAC2	North Kehoe												
		5/18/99	13.7	537.0	0.3	7.8	9.3				20	> 1,600	170
		7/13/99	13.8	626.0	0.3	8.2	8.3	0.2	0.19	< 0.2		900	900
		9/21/99	13.5	615.0	0.3	7.8	8.3				9	900	900
		1/18/00	9.9	705.0	0.3	7.8	4.5	1.2	6.4	1	151	> 1,600	> 1,600
		2/14/00	12.3	339.3	0.2	7.6		3.7	1.5	< 0.1	471	> 16,000	> 16,000
		2/23/00	10.6	350.5	0.2	7.4		2.4	1.8	0.3	248	> 16,000	> 16,000
		5/8/00	13.5	440.0	0.2	7.8	9.4	0.37	0.78	< 0.1	30	50,000	30,000
		10/17/00	11.7	590.0	0.2	7.9	8.2	0.24	0.17	< 0.2		920	920
		1/11/01	8.8	816.0	0.4	7.8	9.3	3	1.3	< 0.2	82	> 160,000	> 160,000
		1/26/01	8.0	812.0	0.4	7.8	9.9	3.6	0.75		300	> 1,600,000	1,600,000
		3/6/01	10.8	478.0	0.2	7.7	10.1	2.8	0.87	0.9	47	5,000	200
		4/24/01	11.6	681.0	0.3	7.6	8.1	0.29		2	21	50,000	22,000
Average		**12**	**11.5**	**582**	**0.3**	**7.8**	**8.5**	**1.78**	**1.5**	**0.6**	**137.9**	**158,577**	**154,058**
Maximum			13.8	816	0.4	8.2	10.1	3.70	6.4	2.0	471.0	1,600,000	1,600,000
Minimum			8.0	339	0.2	7.4	4.5	0.20	0.2	0.1	9.0	900	170

Point Reyes National Seashore

Ambient Water Quality Site Report for North Kehoe Ranch (farm)

Station	Location	Date	Water Temp. C	Specific Conductance	Salinity	pH	DO	Nitrate (mg/L)	Orthophosphorous (mg/L)	Ammonia (mg/L)	Total Suspended Solids (mg/L)	Total Coliform (MPN)/100ml	Fecal Coliform
PAC2A	North Kehoe Ranch (farm)												
		1/26/01	8.3	1,910.0	1.0	8.3	10.8	9	3		292	> 1,600,000	1,600,000
		3/6/01	11.2	538.0	0.1	7.9	10.4	1.5	0.96	0.6	60	900,000	500,000
		4/24/01	14.3	929.0	0.5	7.5	7.4	3.4		0.9	161	90,000	30,000
Average		**3**	**11.3**	**1,126**	**0.5**	**7.9**	**9.5**	**4.63**	**2.0**	**0.8**	**171.0**	**863,333**	**710,000**
Maximum			14.3	1,910	1.0	8.3	10.8	9.00	3.0	0.9	292.0	1,600,000	1,600,000
Minimum			8.3	538	0.1	7.5	7.4	1.50	1.0	0.6	60.0	90,000	30,000

Point Reyes National Seashore

Ambient Water Quality Site Report for Abbotts Perennial

Station	Location	Date	Water Temp. C	Specific Conductance	Salinity	pH	DO	Nitrate (mg/L)	Orthophosphorous (mg/L)	Ammonia (mg/L)	Total Suspended Solids (mg/L)	Total Coliform (MPN)/100ml	Fecal Coliform
ABB1	Abbotts Perennial												
		1/16/00	10.8	326.7	0.2	7.7	5.6	< 0.2	0.2	< 0.1	29	> 1,600	> 1,600
		2/14/00	12.1	162.3	0.1	7.4		< 0.2	0.11	< 0.1	26	9,200	1,100
		2/23/00	9.9	171.1	0.1	6.9		0.36	0.08	< 0.1	22	700	700
		5/8/00	13.2	211.1	0.1	7.4	8.7	< 0.2	0.13	< 0.1	17	24,000	8,000
		10/17/00	10.3	252.2	0.1	8.0	8.8	1.4	0.19	< 0.2		1,700	1,100
		1/11/01	8.6	359.7	0.2	8.1	10.6	0.37	0.13		56	92,000	35,000
		1/26/01	7.7	264.5	0.1	7.8	11.1	0.24	0.17		37	24,000	24,000
		3/6/01	10.8	228.7	0.1	7.7	10.4	< 0.2	0.08		11	24,000	24,000
		4/24/01	11.9	291.2	0.1	7.6	10.3	0.21		0.3	7	2,400	2,400
Average		**9**	**10.6**	**252**	**0.1**	**7.6**	**9.4**	**0.38**	**0.1**	**0.2**	**25.6**	**19,956**	**10,878**
Maximum			13.2	360	0.2	8.1	11.1	1.40	0.2	0.3	56.0	92,000	35,000
Minimum			7.7	162	0.1	6.9	5.6	0.20	0.1	0.1	7.0	700	700

Point Reyes National Seashore

Ambient Water Quality Site Report for McClures Ranch

Station	Location	Date	Water Temp. C	Specific Conductance	Salinity	pH	DO	Nitrate (mg/L)	Orthophosphorous (mg/L)	Ammonia (mg/L)	Total Suspended Solids (mg/L)	Total Coliform (MPN)/100ml	Fecal Coliform
ABB2	McClures Ranch												
		3/6/01	11.3	384.2	0.2	7.3	7.2	3.9	1.8		20	50,000	16,000
		4/24/01	12.5	299.0	0.1	7.2	7.6	3		0.2	18	24,000	24,000
Average		**2**	**11.9**	**342**	**0.2**	**7.3**	**7.4**	**3.45**	**1.8**	**0.2**	**19.0**	**37,000**	**20,000**
Maximum			12.5	384	0.2	7.3	7.6	3.90	1.8	0.2	20.0	50,000	24,000
Minimum			11.3	299	0.1	7.2	7.2	3.00	1.8	0.2	18.0	24,000	16,000

Appendix B

Olema Creek Watershed Water Quality Response Report

DETAILED ANALYSIS OF OLEMA CREEK WATERSHED RESPONSE

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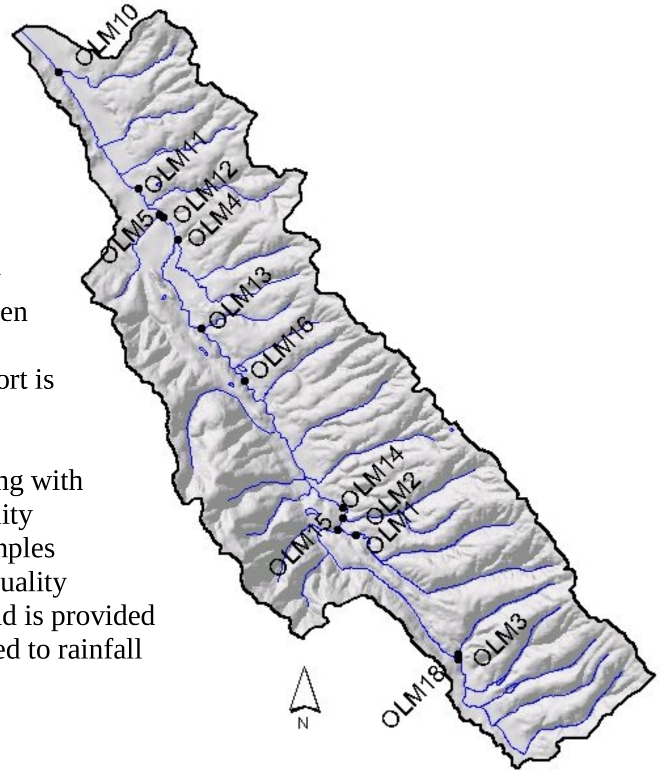


Supporting four federally threatened aquatic species, the 14.5 square mile Olema Creek watershed is the focal point of hydrologic, water quality, and fisheries monitoring within Point Reyes National Seashore. Since 1997, Seashore staff have maintained a stream gage at the Bear Valley Bridge (OLM11). The Seashore has also been working with related to fecal coliform time series monitoring. The objective of this report is to document water quality and hydrologic response within the watershed, including collaborative time-series pathogen monitoring with the San Francisco Bay Regional Water Quality Control Board and single day watershed samples conducted through the Point Reyes Water Quality Monitoring Program. Watershed background is provided to detail the overall response of the watershed to rainfall and pollutant loading.

Physical Setting

Olema Creek's hydrologic response is inextricably linked to the San Andreas Fault and Mediterranean climate. East of the fault, intermittent tributaries flow from the serpentine bedrock and thin soils of Bolinas Ridge and across the alluvial valley bottom. Perennial tributaries draining the deep marine sedimentary deposits of Inverness Ridge to the west follow much steeper stream gradients before joining the mainstem of Olema Creek.

Tributaries providing the most significant fisheries habitat and watershed area are the intermittent Bolinas Ridge drainages. Tributaries supplying the important summer base flow to the mainstem are derived from Inverness Ridge. The majority of the aquatic habitat is located within the mainstem of Olema Creek. Of the 39 inches annual rainfall at Bear Valley, 95% of this precipitation falls between November and May.

Historic Context

The Olema Valley has a rich and varied land management history. Beginning in the early 1800s land use was converted from traditional hunting and burning by the Coast Miwok to intensive livestock production. The first major Mexican land grants included livestock and sheep grazing as well as extractive uses such as logging. In the later 1800s production converted primarily to dairy operations, and western Marin County became one of the state leaders in dairy production. The dairy business lost appeal in the mid-1900s with many of the operations converting to beef cattle production.

The Olema Valley was the site of a surface rupture trending to the northwest during the 1906 San Francisco earthquake. With offsets of up to 20 feet, it is not suprising that the watershed remains relatively unstable. Acquisition of the land in the Olema Valley by the National Park Service's Point Reyes National Seashore and Golden Gate National Recreation Area began in the mid 1970s. Currently, 35% of the Olema Creek watershed is within the designated Pastoral Zone and managed for beef cattle (see Map 2). Agricultural land use is primarily limited to the east side of Olema Valley and the Bolinas Ridge. The exception are the areas downstream on the private lands operated by the Vedanta Society.

Map 2. Olema Creek Watershed Land Use

Watershed Condition

A fisheries and water quality assessment of the Olema Creek watershed indicate that the effects of past land-use practices (logging, agriculture, and grazing) have changed the condition of the watershed, altering its ability to support fish populations at their historic levels. Although land-use activities have been greatly reduced and upgraded to a more environmentally sustainable land-use ethic, present land-use continues to influence water quality conditions within the watershed. Loss of native perennial vegetation, soil compaction and loss, hillside trailing, gullying, and incision of swales and meadows have changed the runoff patterns and reduced the capacity of the watershed to attenuate pollutant loading and surface runoff.

Hydrologic Response

Within the Olema Creek system, hydrologic response is rapid and short-lived. In this Mediterranean climate, the flow of Olema Creek ranges from less than 0.5 cubic feet per second (cfs) in the summer to more than 2,500 cfs in the winter. An indicator often used to describe stream channel condition is the bankfull or effective discharge. This is a flow that occurs approximately on a two-year repeat interval and is calculated at approximately 500 cfs (Dunne & Leopold 1979). The 14.5 square mile watershed is quite linear with a measured lag time between peak rainfall and runoff at the Bear Valley Bridge on the order of three to four hours. The rainfall-runoff response time in most tributaries is between 15 to 45 minutes, depending on watershed size.

Past land use has altered the hydrologic response of Olema Creek. Incision through meadow and floodplain features has reduced the lag time and increased peak flows within the watershed. The result of these physical alterations and increased winter discharge is a reduced groundwater storage capacity in the tributary floodplains and meadows. The alterations to the wetland systems has resulted in a greater range of flow between winter and summer.

Seven to nine inches of cumulative rainfall are required to initiate significant response and connectivity of the entire system. If this rainfall is spread across more than 60 days, additional precipitation is necessary to saturate the watershed. Once tributaries are connected to the mainstem, runoff response Bear Valley Bridge increases dramatically.

This event is considered the first flush water quality event, delivering accumulated sediment and pollutants from land-based source areas. This runoff event often coincides with the initial upstream migration by coho salmon. into the stream system. Until most tributaries are surficially connected, response in the main channel is not adequate to accommodate fish passage to most of the spawning habitat within the system.

The most significant tributaries with regard to water, habitat, and fish are the John West Fork, Quarry Gulch, Giacomini Creek, Randall Gulch, and Boundary Gulch. These tributaries provide some perennial habitat sections in the upper and middle portions of the channel, while going intermittent as the creek stretches across the alluvial valley bottom. Habitat within these streams is viable for both coho salmon and steelhead trout .

Tributaries draining Inverness Ridge are perennial, and are significant contributors to the summer base flow. In normal years the upper 30% of the Olema mainstem, lacking connection to Inverness Ridge, is intermittent. Beginning just south of five Brooks and progressing north, these steep tributaries join the mainstem. While ripe with water supply, most of these steep drainages provide little to no habitat. Where there is habitat, it primarily fits the needs of steelhead trout for both access and rearing (riffle dominated). Most significant of these watersheds are Davis/Boucher and Vedanta Creeks.

Olema Creek Hydrologic Monitoring Station

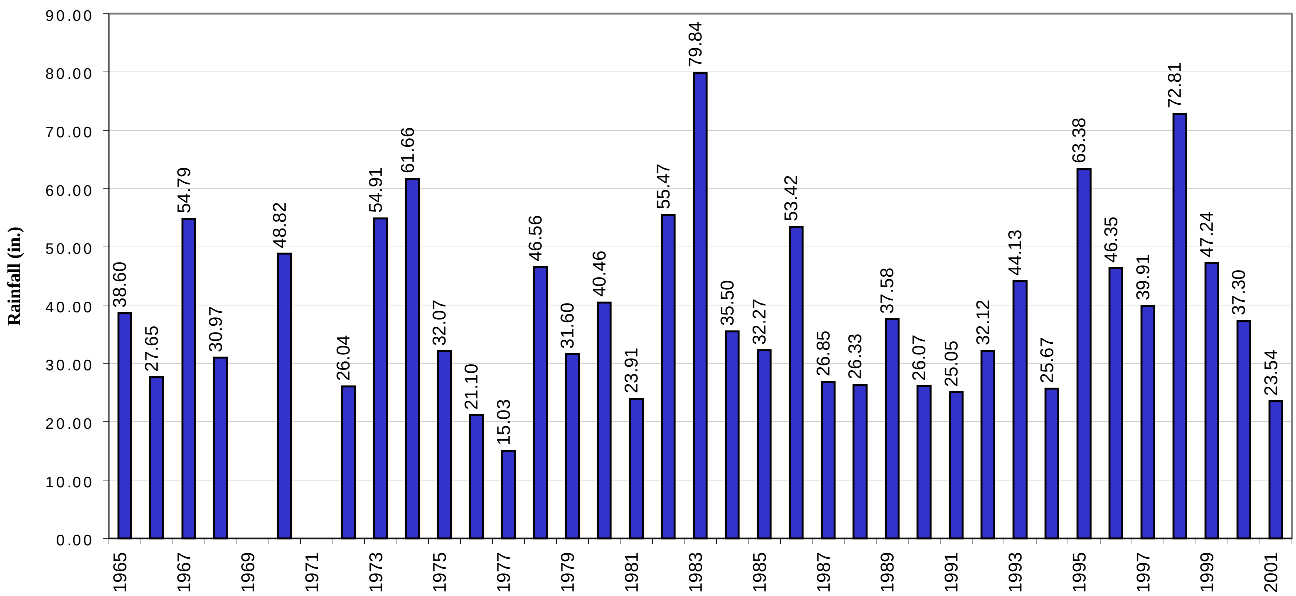
Olema Creek has the most complete set of discharge information within the Seashore. The site is located at the Bear Valley Road Bridge, and has been modified since original installation (PWA 1996). This station is located at the same point as monitoring was performed between 1986 and 1989 during a sediment investigation contract (Questa Engineering 1990).

The Olema cross-section is rather stable. Scour changes the low-flow cross-section from year to year, but at higher flows the water is confined between the bridge abutments. The rating curve is good at high flows, but must be modified each year for the lower flows. Since 1996 the range of flows observed at the monitoring station is 0.5 cfs to 2,500 cfs. The associated rainfall data for this station is collected at the Bear Valley Headquarters. Daily discharge and rainfall tables for WY1998-WY2001 are included at the end of this report.

Rainfall Information

Daily rainfall totals have been recorded at the Bear Valley Headquarters since 1968. In 1997, the Seashore installed a weather station to collect and compile hourly weather information. Annual rainfall for the period 1968 to the present is 39.30 inches at Bear Valley headquarters, with approximately 95% of that occurring between November and April. Of the past 36 years, 15 have exceeded the rainfall normal. Since 1998, additional watershed rainfall has been collected at Hagmaier Ranch, in the upper end of the watershed.

Annual Rainfall Totals at Bear Valley, Point Reyes National Seashore



	Total	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	July	Aug	Sept
Average	**39.30**	**2.10**	**5.68**	**6.27**	**8.65**	**6.69**	**5.64**	**2.42**	**1.07**	**0.20**	**0.09**	**0.14**	**0.34**
Max	79.84	5.74	18.20	16.09	22.39	24.68	24.28	6.60	6.35	1.02	2.58	1.82	2.54
Min	15.03	0.00	0.61	0.01	0.40	0.47	0.24	0.00	0.00	0.00	0.00	0.00	0.00

Table 1. Annual Rainfall Monthly Averages at Bear Valley, 1965-2001

A Century of Physical Extremes

The landforms observed throughout western Marin County have been formed by a combination of extreme climactic events and plate tectonics. While the geologic setting and climate have been described, it is the extremes associated with these conditions that have played the greatest role in shaping the valley, stream channel, and habitat for the anadromous fisheries known to prefer this watershed. The Olema Valley was the site of a surface rupture trending to the northwest following the 1906 San Francisco earthquake. In many other ways, the fault zone has resulted in very unusual geomorphic features, including parallel streams flowing opposite directions within the same valley (Olema and Pine Gulch Creek).

Discounting the cumulative impacts of human alteration and ocean conditions, and assuming that anadromous fish populations were relatively strong in the mid 1960s as the NPS began acquiring land, it is the extreme climactic events that have impacted the habitat and ultimately populations of coho salmon and steelhead trout.

The last thirty years have been marked by two major droughts (1976-77 and 1985-90), two El Nino events (1983 and 1998), and a 500 year storm event (1982). While the drought weakened fish populations throughout the coastal watersheds, it was the 500 year flood followed the next year by the first documented El Nino event that severely impacted habitat and fish populations for 2/3 of the coho salmon year class. The major storm events resulted in catastrophic debris flows and delivery of sediment to the channel. In some areas we are still observing major sediment deposition resulting from the mobilization of materials deposited in the channels in 1982 and 1983. In addition to these issues, abandoned road facilities within the Seashore persist as sources of sediment to the stream.

Historic Channel Conditions (discussion adapted from Niemi and Hall 1996)

Like many of the watersheds in coastal California, there are a series of periods bounded by regional shifts in resource extraction. Within the Olema Valley major land use shifts, alterations to the channel, and climactic events are connected to the geomorphic character of the existing stream channel and habitat condition. The discussion of the historic channel conditions and alignments is best illustrated in Figure 2.

Prior to European influence on the Olema Valley, it is likely that the east side drainages deposited most of their bed load and sediment on alluvial fans (Dietrich 1997). Disconnection of these tributary channels to the mainstem was effective at metering sediment into the main channel. The tributaries were likely prime spawning areas with extensive and well conditioned spawning gravels. Post disturbance these tributary channels incise through the alluvial fans and are directly connected to the mainstem. Aside from the instability in the mainstem, the tributaries are a new source of sediment to the system. If the disconnected alluvial fans were the norm it is likely that the east side drainages have always been intermittent.

Between 1860 and 1918, land use consisted primarily of logging and intensive agricultural production. The lower section of the stream channel meandered across a floodplain beginning south of Olema and covering the entire valley bottom. Sediment entrainment and transport to the head of Tomales Bay contributed to the progradation of the tidal marsh more than one kilometer to the northwest.

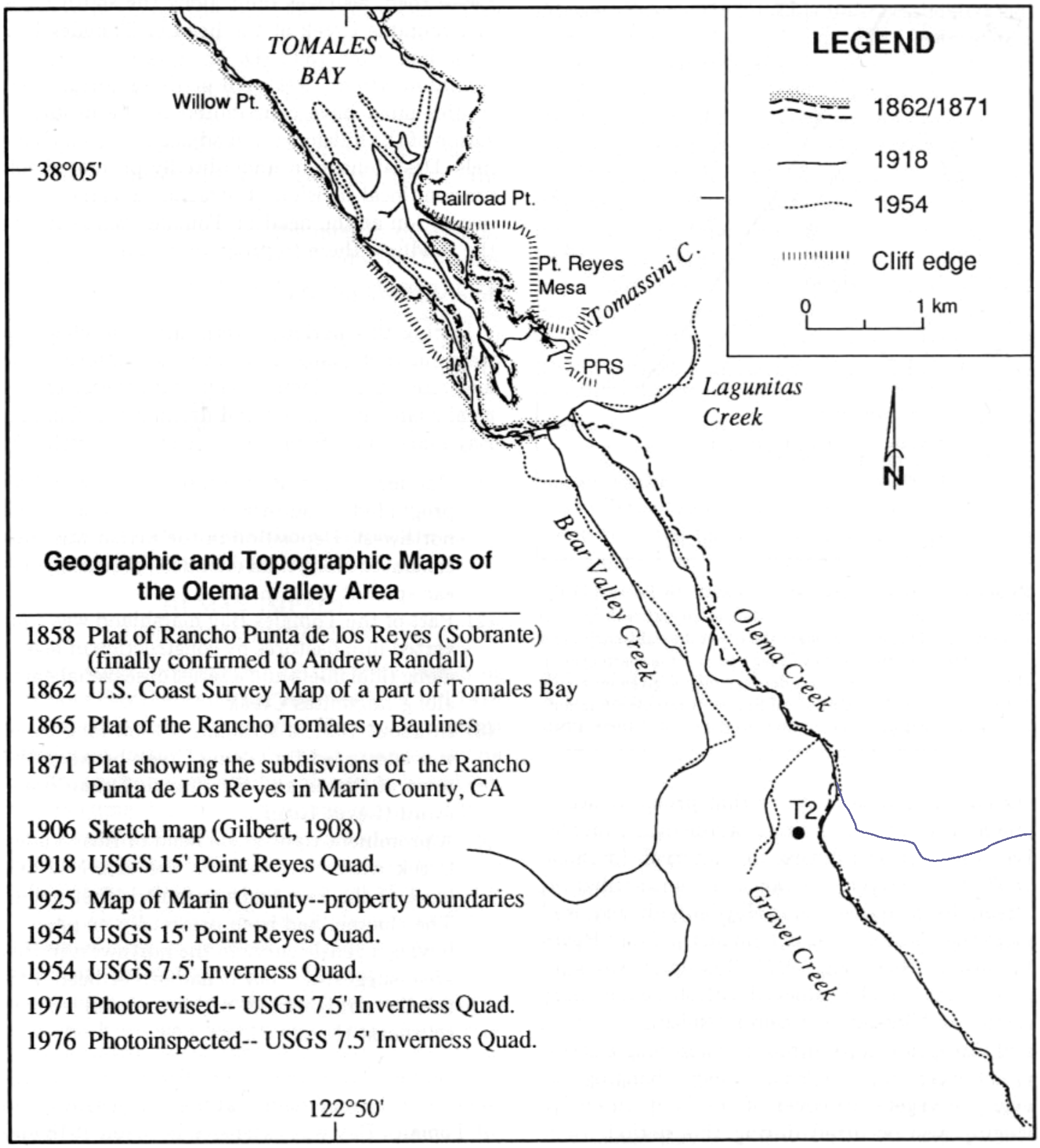


Figure 2. Comparison of the 1862/1871, 1918, and 1954 maps of Tomales Bay and the northern reach of Olema Creek (adapted from Niemi and Hall 1996).

In 1921 a canal was excavated between Sir Francis Drake Boulevard and the town of Olema. This area, adjacent Highway 1 between Olema and Point Reyes Station (currently referred to as the Olema Pasture) was once a willow thicket regularly flooded by stormflow events. Clearing of the willows for charcoal and dredging to an estimated depth of two to three meters below the floodplain significantly altered the channel within Olema Creek. Aside from initiating a process of incision and instability to the lower reach of the stream, loss of connectivity to the floodplain resulted in increased the sediment transport to the head of Tomales Bay.

Several pre-1920s historical accounts noted the “Arroyo Olemus Lake” (Livingston 1991). Besides the 1982 flood event, this area did not begin flooding again regularly until 1995 when a combination of major storms, restored riparian corridor (woody debris) and sediment deposition resulted in the avulsion of Olema Creek and the regular formation of the Olema Lake. The process that resulted in the reconnection of this section of the channel to its floodplain is prevalent in many of the coastal watersheds within the Point Reyes National Seashore. Excessive sediment mobilized during episodic rainfall conditions is deposited in the lower reaches of a channelized and/or leveed stream channel. Accumulation of these sediments is now allowing many of these channels to reoccupy the former floodplains, enhancing the quality and condition of the stream channel and estuarine system downstream.

The 1921 channelization initiated the development and migration of a knickpoint within the system. While the section of channel that was dredged remains relatively straight, the section of the channel beginning at the Bear Valley Bridge is characterized by entrenched meanders and extreme bank instability (as observed following El Nino 1998). Fieldwork completed by Niemi and Hall in 1992 indicated that the knickpoint was migrating upstream. The knickpoint currently lies approximately 200 meters upstream of the confluence with Quarry Gulch. It is a site of extreme streambank instability, high energy within the channel, and a major source of sediment to the channel downstream. Besides impacting the mainstem of Olema Creek, migration of this knickpoint past the Quarry Gulch resulted in bifrication of the impact, with the incision and instability transferred to the tributary.

In the 1940s Waldo Giacomini constructed a series of levees at the head of Tomales Bay in order to operate a major dairy operation. Besides eliminating more than 500 acres of estuarine and freshwater marsh habitat, construction of the levees changed the hydrologic circulation of the Laginitas, Olema, Bear Valley estuary. In larger events, the levees act as a dam to pond waters of the smaller tributaries, Olema and Bear Valley Creek.

Throughout the rest of the watershed logging and intensive dairying continued their prominence until the middle of the century. As most of the accessible trees were logged and the dairy economy changed, much of the watershed was converted to beef grazing operations. Though still intensive, the actions were much less impacting than those of the later 1800s and early 1900s.

Beginning in the 1960s and 1970s, with the establishment of Point Reyes National Seashore and Golden Gate National Recreation Area, the intensity of land use has been greatly reduced. Currently less than 40% of the watershed is managed for grazing activities.

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TIME SERIES ANALYSIS

In cooperation with the Tomales Bay Shellfish Technical Advisory Committee Water Quality Subcommittee and the San Francisco Bay Regional Water Quality Control Board, Seashore staff sampled four storm events during the winter of 2000-2001 to quantify pathogen loading for the duration of a runoff event. The objective was to identify lag times between peak runoff and peak pollutant delivery, and to identify how the pollutant loading drops off on the falling limb of the hydrograph. In cooperation with the Environmental Protection Agency laboratory in Richmond , CA, samples were collected and analyzed for *e. coli*. The Richmond lab used the quanti-tray analytical method, providing the time-series analytical services for no charge. Fifty six samples were collected during four separate events for the time-series analysis. Samples were delivered to the Richmond Lab with a maximum holding time of 24 hours.

One dry season event and three winter events were sampled. The dry season event was sampled on January 3, 2001. The first flush storm event was sampled on January 10-11, 2001. The second storm event was sampled on January 25-26, 2001, with the final event spanning four days, February 8-12, 2001. The Olema stream gage was not performing well during January and February. Storm hydrographs are developed based upon field visit information and extrapolation during the time of the sample period. This is a disadvantage to determining actual lag time. Despite these technological problems, the information is significant.

The results of the time series showed major patterns associated with an increase in cumulative rainfall:

- Peak *e. coli* levels were reduced, though still significant, indicating persistent nonpoint sources;
- The lag time between peak discharge and peak *e. coli* loading was reduced, indicating increased runoff and connectivity of pollutant sources to the stream with saturation;
- Within storm events, each peak rainfall would have an associated increase in *e. coli*.

Each of the sampled events, including cumulative rainfall, hourly runoff, and the $\log_{10}$ results of sampled *e. coli* are presented below.

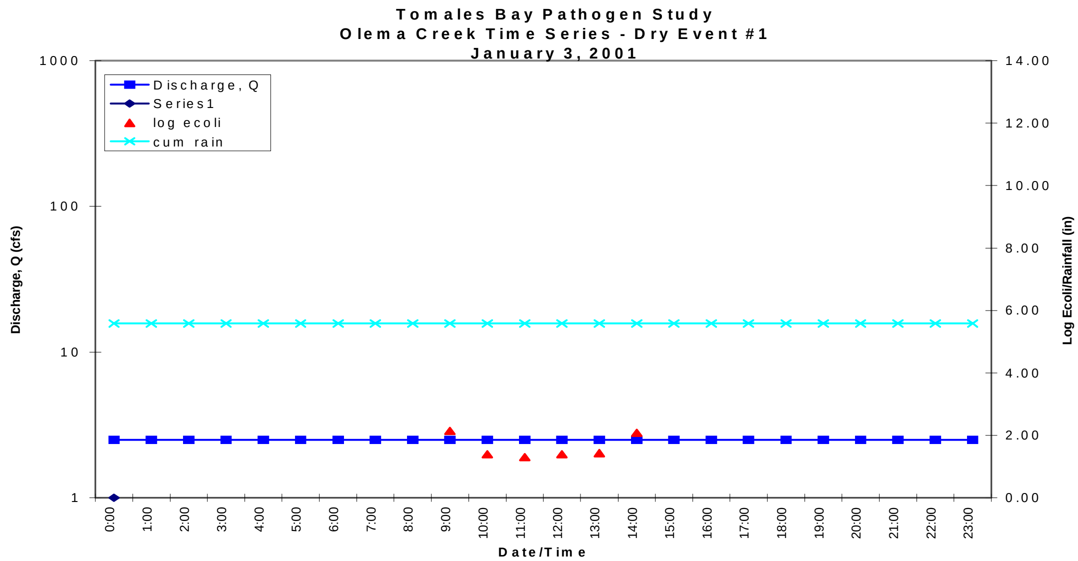


Figure 3. Storm Event 1

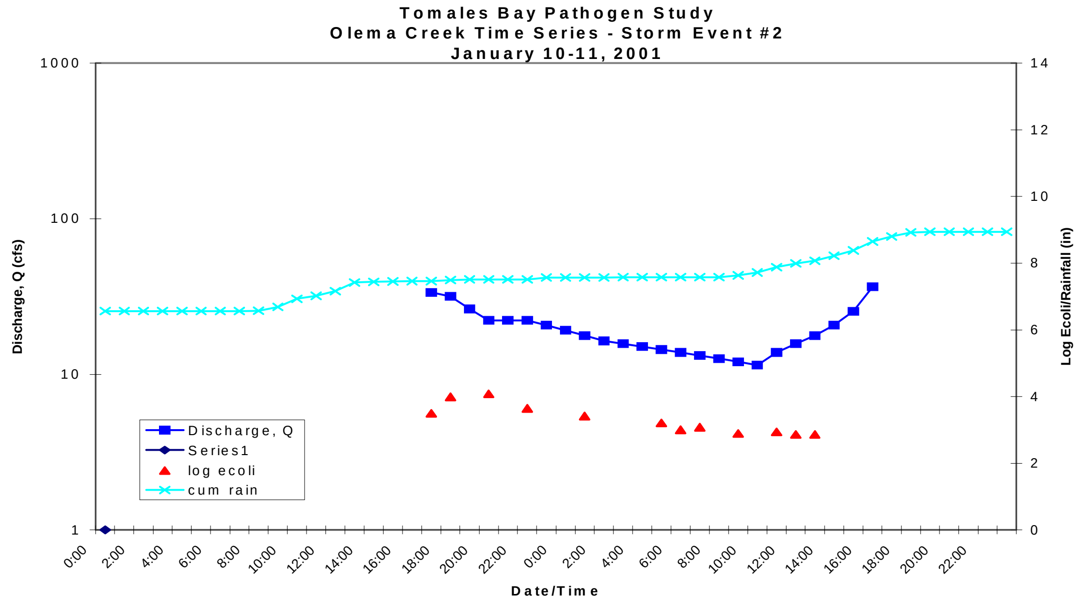


Figure 4. Storm Event 2

Lag time between peak discharge and peak *e. coli* level was 2 hours during the first flush storm event. *E. coli* levels declined through the duration of the storm, even during a second runoff peak during the day of January 11.

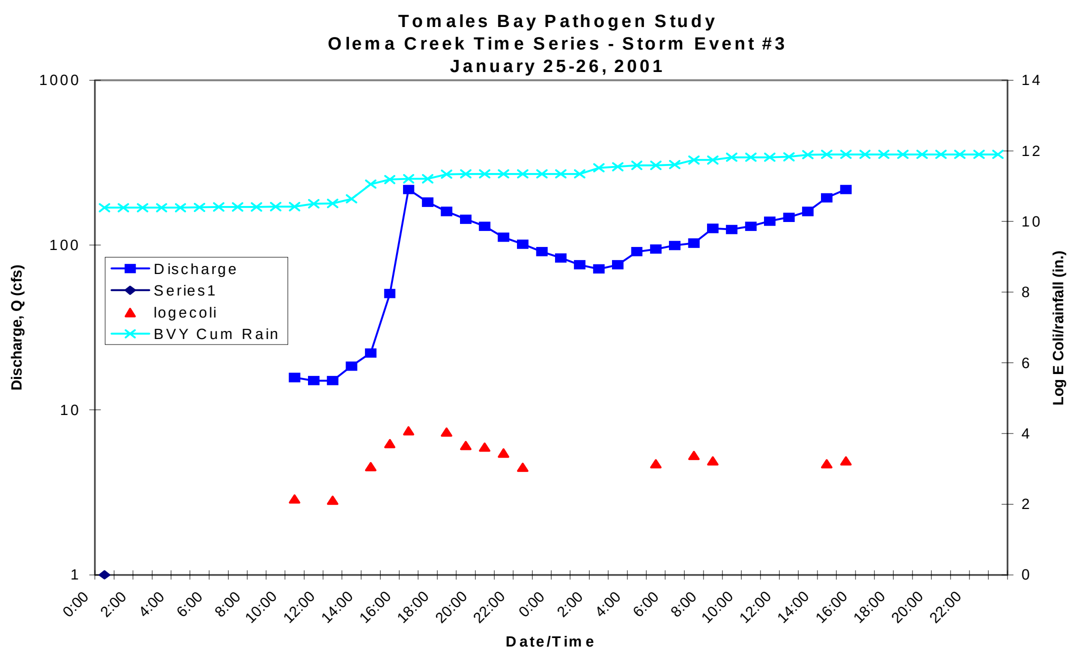


Figure 5. Storm Event 3

The peak e. coli level lag time was approximately 2 hours. As with the first flush event, *e. coli* levels remained low even with a rise in flow during the second peak. Likely sampling was discontinued prior to pollutant response.

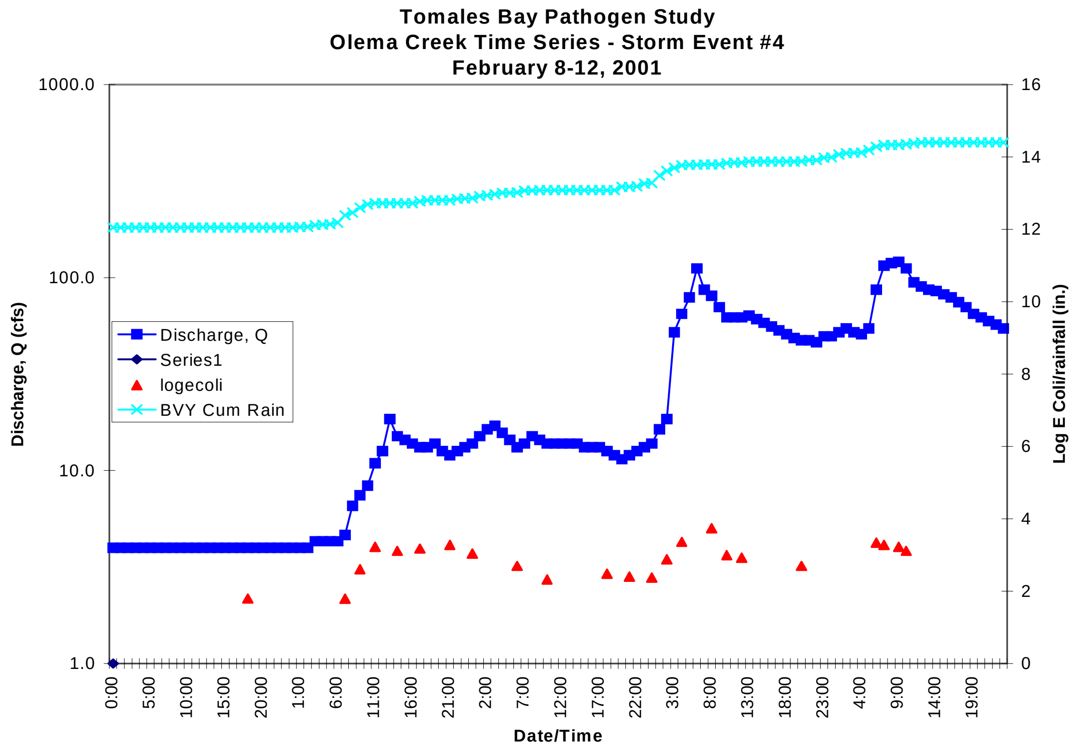


Figure 6. Storm Event 4

During this February event, pollutant response was much closer to the actual peak runoff. Due to the duration of monitoring, four days, there is a clear response to each peak event. Higher *e. coli* levels are related to increased saturation and connection to upland source areas. Pollutant response over the last peak in the hydrograph is not significantly different from other peaks during the storm event.

Conclusion

The results from *e. coli* time series sampling revealed concentrations in Storm event 4 significantly lower than in storm event 3. Though reduced, these *e. coli* concentrations were still far above background levels indicating that sources of nonpoint pollution within the watershed are persistent. As saturation occurred, the lag time between peak runoff and peak pollutant concentration was reduced. With saturated conditions, it takes less rainfall and runoff to flush and deliver pollutants downstream.

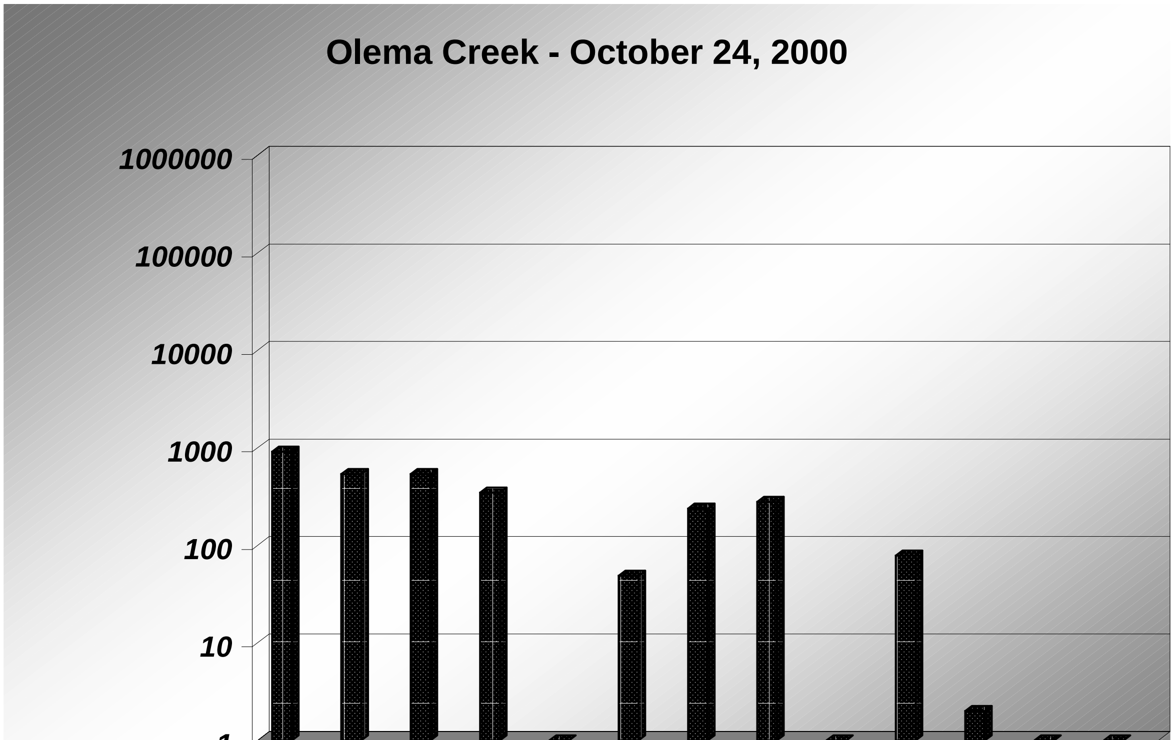
Continuation of such a program may be worthwhile within Olema Creek as long as monitoring equipment is operating properly. Other time-series monitoring type equipment, including an ISCO sampler will be used to evaluate other parameters, such as TSS.

OLEMA CREEK WATER QUALITY SAMPLE EVENT DISCUSSION

Fall Event – October 24, 2000

The fall sample run occurred in late October following the first major cold spell of the season. Dry conditions persisted with cumulative rainfall less than 2 inches for the season. Four sample locations OLM18, OLM2, OLM3, and OLM4 were all dry. Fecal coliform levels were very low and TSS was not sampled. Other parameters monitored, including specific conductance did not show a significant change from upstream to downstream.

Figure 7. Olema Creek Chart - Fall Sample Event



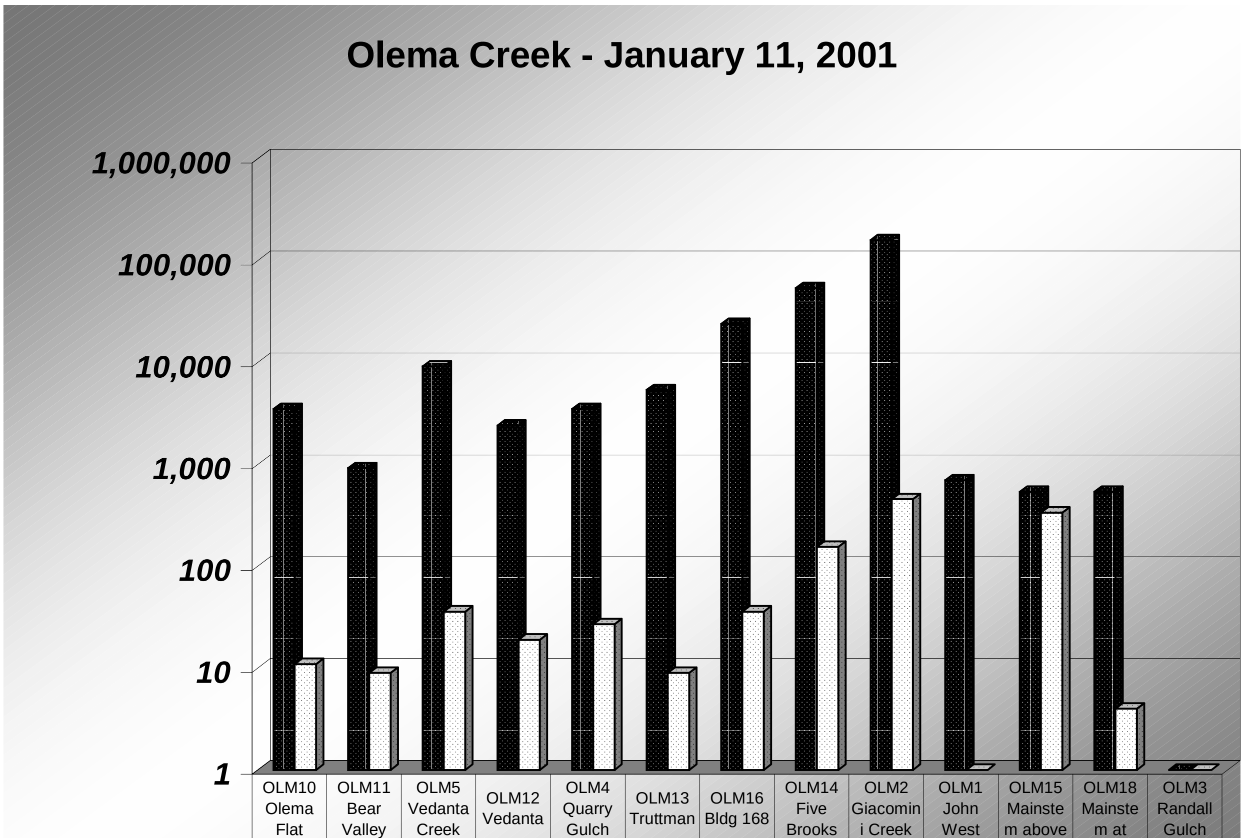
	OLM10 Olema Flat	OLM11 Bear Valley	OLM5 Vedanta Creek	OLM12 Vedanta	OLM4 Quarry Gulch	OLM13 Truttman	OLM16 Bldg 168	OLM14 Five Brooks	OLM2 Giacomini Creek	OLM1 John West	OLM15 Mainstem above	OLM18 Mainstem at	OLM3 Randall Gulch
■ Fecal Coliform (MPN/100ml)	920	540	540	350	0	49	240	280	0	79	2	0	0
□ Total Suspended Solids (mg/l)													

First Flush - January 11, 2001

On January 10, 2001 rainfall saturated the land to the point where most, but not all of the intermittent tributaries began to flow. The Seashore staff performed a monitoring event on the Olema watershed on January 11 to quantify water quality conditions. This event happened to correspond with the upstream migration of coho salmon and provided unique insight into the conditions faced by these salmonids on their way back to spawning. Figure 8, in conjunction with the watershed on the first page provides the most descriptive details. Two streams that did not connect to their upper watersheds during this event were Randall Gulch (OLM3) and Quarry Gulch (OLM4). OLM3 was dry at the sample location, while OLM4 had runoff from only the lower kilometer of the watershed.

The chart depicts fecal coliform and suspended sediment as the pollutant parameters of comparison. Focusing only on the fecal coliform, it is clear that the primary source area during the initial runoff event was OLM2, with FC levels actually in excess of 160,000 MPN/100ml.

Figure 8 – Olema Creek Chart – First Flush 2001



	OLM10 Olema Flat	OLM11 Bear Valley	OLM5 Vedanta Creek	OLM12 Vedanta	OLM4 Quarry Gulch	OLM13 Truttman	OLM16 Bldg 168	OLM14 Five Brooks	OLM2 Giacomini Creek	OLM1 John West	OLM15 Mainstem above	OLM18 Mainstem at	OLM3 Randall Gulch
■ Fecal Coliform (MPN/100ml)	3,500	920	9,200	2,400	3,500	5,400	24,000	54,000	160,000	700	540	540	0
□ Total Suspended Solids (mg/l)	11	9	36	19	27	9	36	155	457	1	337	4	0

This pollutant load persisted downstream two miles to the sample location at building 168. The fecal coliform was persistent, remaining above non-contact recreational standards (2,000 MPN/100 ml) until the sample location at Bear Valley Bridge. A similar decline is observed in the levels of total suspended solids. Of interest with this pollutant parameter is the high levels observed emerging from the relatively pristine upper watershed with a TSS of 337 mg/l on the mainstem above John West Fork (OLM15). A second major sediment input is the Giacomini Creek (OLM2). TSS levels like the FC do not drop to relatively background levels until nearly two miles downstream.

The monitored TSS levels in the mainstem (OLM15) and at the John West Fork (OLM1) likely played a role in the coho salmon spawning distribution during WY 2001. At the time fish approached the John West Fork confluence flows were relatively equal, but the TSS load in the mainstem was approximately 300 times higher than observed in the tributary. Approximately 40% of the fish chose the tributary with the clean water rather than the turbid mainstem. More telling of this choice is that no coho salmon smolts were observed leaving this tributary for this year class (spring 1999).

Synoptic winter event – January 25, 2001
Based upon the results of the January 11 samples, a more focused collection was organizeded for the storm event of January 25. The primary sampling effort was focused around Giacomini Creek and Quarry Gulch in the Olema Valley. Samples were also taken at John West Fork, Randall Gulch, and Bear Valley. A downpour around noon was the trigger to initiate this round of sampling.

Giacomini Gulch
Giacomini Gulch was identified as a priority for this sample event based upon high fecal coliform and sediment levels observed during the January 11 event. Staff walked the site and identified a discharge point suspected to be the main source of sediment and fecal coliform to the stream and planned a simple sample regime to isolate the source and determine its impacts.

- Giacomini Gulch upstream of the source (OLM2A),
- Discharge from the horse paddock (OLM2B), and
- Giacomini Gulch at our normal sample location (OLM2).

All three sites are within 100 meters of each other. The regular Giacomini site is downstream of the highway 1 culvert, allowing for complete mixing of the water.

Table 2. Giacomini Tributary Results, January 25, 2001

OLM2A **Giacomini Gulch above source** Fecal Coliform – 3,000 MPN/100 ml Total Suspended Solids – 115 mg/l Ammonia - <0.2 mg/l Estimated flow ~ 10 cfs	
↓	← **OLM2B** **Discharge from horse paddock** Fecal Coliform - 900,000 MPN/100ml Total Suspended Solids – 7,788 mg/l Ammonia – 13 mg/l Estimated flow ~ 0.5 cfs
OLM2 **Giacomini Gulch (regular site)** Fecal Coliform – 240,000 MPN/100ml Total Suspended Solids – 660 mg/l Ammonia - <0.2 mg/l Estimated flow ~ 11 cfs	

Water discharging from the horse paddock area, while approximately 5% of the total flow, delivered 99% of the total observed fecal coliform observed downstream. Unfortunately we did not sample the mainstem of Olema below this site to carry on the comparison, but it is clear that this small pasture was a major source of pollutant loading to the watershed.

Regarding Total Suspended Solids (TSS), the discharge from the horse paddock, again only 5% of the flow increased the TSS observed in Giacomini Gulch by 570%. The ammonia results are also presented to portray the fate and transport of different pollutants. Though the ammonia delivered to the stream from OLM2B qualified as toxic, the process of dilution and mixing resulted in a non-detectable level of ammonia just 50 meters downstream at OLM2. While the dilution factor for fecal coliform, TSS, and ammonia may be similar, the ability of the laboratory analyses to quantify these relationships leaves us with FC and TSS to provide managers with quick and somewhat reliable information.

Quarry Gulch
Quarry Gulch is a known source of sediment and is likely the most fully impacted tributary in the Olema watershed. Prior to the January 25 storm, the upper part of the watershed had not connected to the mainstem of Olema Creek (dry at highway 1 crossing). On the 25th we sampled at the Highway 1 crossing (OLM4A), and at our normal sample site 50 meters upstream of the Olema confluence.

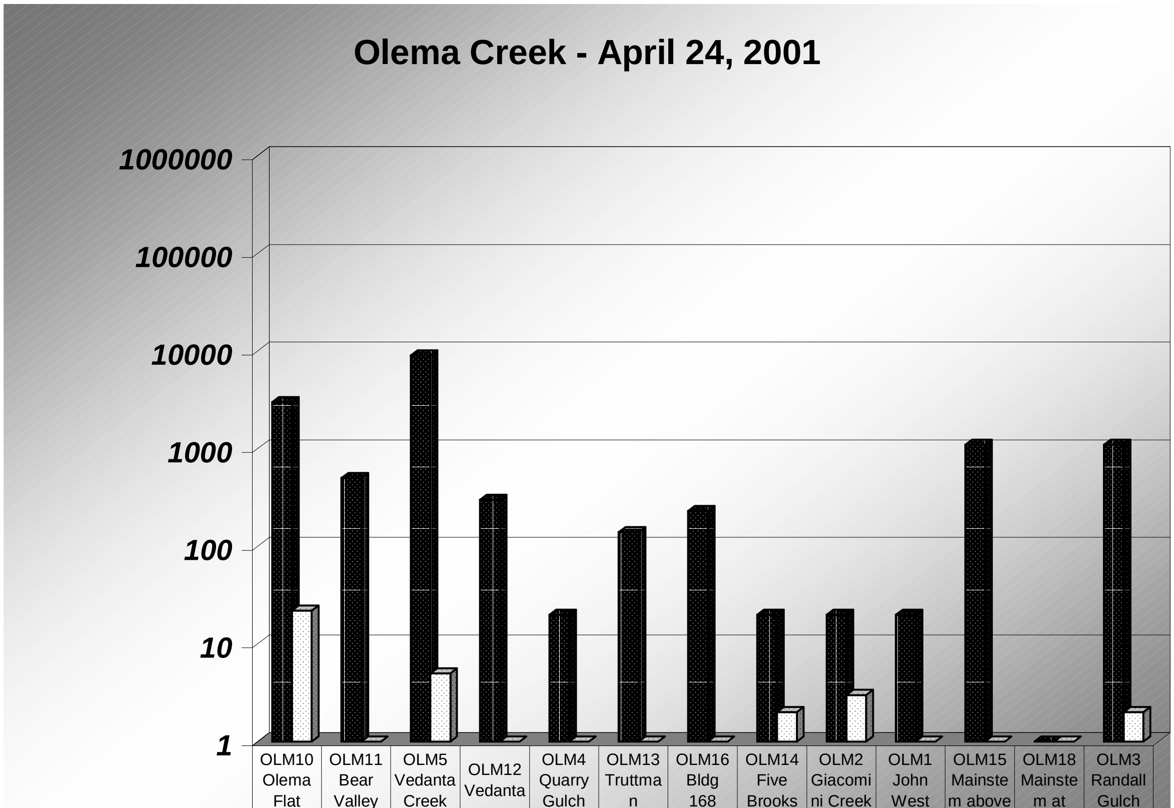
Table 3. Quarry Gulch Results, January 25, 2001

OLM4A **Quarry Gulch above Highway 1** Fecal Coliform – 350,000 MPN/100 ml Total Suspended Solids – 1,348 mg/l Estimated flow ~ 5 cfs
OLM4 **Quarry Gulch @ Olema Confluence** Fecal Coliform - 300,000 MPN/100ml Total Suspended Solids – 248 mg/l Estimated flow ~ 7 cfs

Results from this event indicate that most of the sediment and fecal coliform load is coming from the upper watershed. The flat adjacent to Highway 1 seems to be an area of heavy concentration livestock in the fall and winter months but attenuated some of the sediment and fecal coliform concentrations within the channel.

Spring Sample Event – April 24, 2001
The last watershed sample for this reporting period was April 24, 2001 (see Figure 8). This spring sample event was conducted under calm conditions, more than two weeks from previous rains. As the WY2001 was unusually dry, Randall Gulch (OLM3) was again dry, and Quarry Gulch (OLM4) was again disconnected at the Highway 1 crossing (OLM4A). As there was no major flow event, TSS levels were very low, except for the lowest site below the Stewart Flat (OLM10). The fecal coliform levels were all below the non-contact recreational standard (2,000 MPN/100ml), except for the Vedanta tributary (OLM5) and the Stewart Flat site (OLM10). These two elevated FC levels are not related as the Bear Valley Bridge site (OLM11) was far below either reading.

Figure 8. Olema Creek Chart – Spring 2001



	OLM10 Olema Flat	OLM11 Bear Valley	OLM5 Vedanta Creek	OLM12 Vedanta	OLM4 Quarry Gulch	OLM13 Truttman	OLM16 Bldg 168	OLM14 Five Brooks	OLM2 Giacomini Creek	OLM1 John West	OLM15 Mainstem above	OLM18 Mainstem at	OLM3 Randall Gulch
Fecal Coliform (MPN/100ml)	3000	500	9000	300	20	140	230	20	20	20	1100	0	1100
Total Suspended Solids (mg/l)	22	0	5	1	0	1	0	2	3	0	0	0	2

Conclusion

- The major source areas within the tributary remain Quarry Gulch and Giacomini Gulch. Fencing on John West Fork, Randall, and Vedanta have played some role in reducing pollutant loading from these areas.
- While most pollutant parameters, including FC and TSS showed similar dilution effects, the TSS and FC levels, allow for detection, even with dilution 10, 100, or 1000 times the concentration. The use of nutrient loads has not proven useful due to the effect of dilution.
- Quarterly sampling should allow for more effective comparison of watershed condition over time. Comparison will allow for tracking of progress or new source areas within the watershed.

Olema Creek Water Year 1998 Daily Average Discharge (cfs)
@ Bear Valley Rd. bridge

	Oct-97	Nov-97	Dec-97	Jan-98	Feb-98	Mar-98	Apr-98	May-98	Jun-98	Jul-98	Aug-98	Sep-98
1	0.5	0.90	51.2	3.5	525.5	48.9	30.8	11.7	16.4	4.2	2.1	1.3
2	0.50	0.90	36.7	30.9	1199.3	44.4	27.0	11.4	14.6	4.1	2.1	1.3
3	0.50	0.90	38.2	40.6	1339.6	39.9	50.2	10.1	13.3	3.9	2.1	1.2
4	0.50	0.90	41.8	86.3	203.8	35.2	50.7	9.9	12.2	3.8	1.9	1.1
5	0.50	0.90	59.4	45.2	593.8	36.7	36.8	9.9	11.1	3.7	1.8	1.0
6	0.50	1.00	42.6	38.4	818.7	34.1	40.5	10.2	10.4	3.6	1.7	1.0
7	0.50	1.00	93.5	48.4	733.6	31.1	38.2	10.3	10.2	3.5	1.8	0.9
8	*3.00*	1.00	87.0	37.6	283.2	28.9	30.8	9.7	9.5	3.4	1.7	1.0
9	*5.00*	1.00	51.7	42.7	154.9	24.7	31.4	9.7	8.9	3.4	1.7	1.1
10	*3.00*	2.79	34.6	171.7	162.0	22.9	30.4	9.7	8.5	3.4	1.6	1.1
11	*1.00*	2.19	24.3	423.1	154.1	21.6	28.6	10.0	8.3	3.2	1.5	1.1
12	*1.00*	1.78	18.8	608.5	137.2	23.4	27.1	15.2	8.1	3.0	1.5	1.0
13	*1.00*	8.19	15.5	191.0	127.4	38.3	49.3	13.5	7.6	3.0	1.4	0.9
14	*1.00*	5.81	57.6	579.8	346.4	29.0	32.2	12.0	7.1	3.0	1.4	0.9
15	*1.00*	13.0	42.5	663.0	176.9	24.6	30.1	11.1	6.7	2.8	1.4	1.0
16	*1.00*	13.1	32.2	275.8	223.6	23.4	25.3	10.8	6.4	2.7	1.5	0.8
17	*1.00*	9.5	27.2	178.8	168.0	22.1	21.9	10.2	6.0	2.7	1.5	0.8
18	*1.00*	9.2	22.3	285.8	107.5	21.3	19.9	9.7	5.8	2.6	1.5	0.7
19	*1.00*	61.7	17.9	207.4	938.4	21.0	18.2	9.3	5.6	2.5	1.5	0.7
20	*1.00*	14.4	15.3	118.6	285.8	20.1	15.0	8.8	5.4	2.5	1.5	0.6
21	*1.00*	10.7	13.0	87.4	563.6	19.4	14.5	8.3	5.3	2.6	1.4	0.6
22	*1.00*	9.3	10.6	76.5	288.7	18.6	13.6	7.9	5.3	2.8	1.3	0.6
23	*1.00*	16.7	8.9	70.3	341.7	48.4	15.3	7.6	5.3	2.8	1.3	0.4
24	*1.00*	13.0	7.7	66.4	209.3	63.8	13.9	7.4	5.1	2.7	1.3	0.4
25	*1.00*	12.4	6.6	60.2	131.6	48.7	12.3	7.2	4.9	2.5	1.3	0.6
26	*0.90*	207.6	5.6	134.3	93.7	34.6	11.5	7.0	4.7	2.4	1.4	0.8
27	*0.90*	96.9	5.2	164.5	70.5	28.8	10.7	8.8	4.5	2.3	1.3	0.7
28	*0.90*	46.2	4.9	98.5	55.2	27.3	9.9	30.9	4.4	2.3	1.3	0.8
29	*0.90*	50.0	4.4	158.8		24.9	9.3	28.6	4.4	2.3	1.3	0.8
30	*0.90*	116.1	3.8	99.0		22.9	8.9	26.0	4.3	2.4	1.3	0.9
31	*0.90*		3.4	136.1		39.0		19.5		2.3	1.3	
TOTAL	**34.9**	**729.3**	**884.6**	**5229.3**	**10434.1**	**967.9**	**754.3**	**372.5**	**230.3**	**92.3**	**47.8**	**26.0**
MEAN	**1.13**	**24.3**	**28.5**	**168.7**	**372.6**	**31.2**	**25.1**	**12.0**	**7.7**	**3.0**	**1.5**	**0.9**
MAX	**5.0**	**207.6**	**93.5**	**663.0**	**1339.6**	**63.8**	**50.7**	**30.9**	**16.4**	**4.2**	**2.1**	**1.3**
MIN	**0.5**	**0.9**	**3.4**	**3.5**	**55.2**	**18.6**	**8.9**	**7.0**	**4.3**	**2.3**	**1.3**	**0.4**
AC-FT	**29**	**1501**	**1599**	**10631**	**16516**	**1935**	**1503**	**748**	**456**	**183**	**95**	**52**
PEAK FLOW		**401**	**174**	**1525**	**2503**	**149**	**149**	**80**	**18**	**5**	**2**	**1**
CAL YR												
WTR YR	**35248**											

values in italics calculated from estimated water level data

Olema Creek @ Bear Valley HQ — Water Year 1998 — Daily Total Rain (in.)

	Oct-97	Nov-97	Dec-97	Jan-98	Feb-98	Mar-98	Apr-98	May-98	Jun-98	Jul-98	Aug-98	Sep-98
1	0.34	0.01	0.01	0.34	1.26	0	0.01	0.64	0	0	0	0
2	0.02	0.01	0.01	0.74	3.48	0.08	0.14	0.19	0.02	0	0	0
3	0.01	0	0.62	0.63	2.01	0	0.97	0.08	0	0	0	0
4	0	0	0.06	0.33	0.32	0	0	0.05	0	0	0	0
5	0	0	0.43	0.01	1.91	0.49	0	0.86	0	0	0	0
6	0.01	0.04	0.02	0	2.45	0.01	0.33	0	0	0	0	0
7	0	0.03	1.12	0.18	2.32	0.19	0.01	0	0.03	0	0	0
8	1.34	0.01	0.16	0.00	0.32	0	0.04	0	0	0	0	0
9	0.92	0	0.01	0.67	0.01	0	0.21	0	0	0	0	0
10	0.12	0.91	0.01	0.98	0.87	0.01	0.06	0	0	0	0	0
11	0	0.04	0	2.17	0.11	0	0	0.15	0	0	0	0
12	0	0.01	0	1.34	0.50	0.35	0.45	0.69	0.01	0	0	0
13	0	1.62	0.02	0.15	0.08	0.55	0.63	0.01	0	0	0	0
14	0	0.37	0.90	3.11	1.40	0	0.17	0	0	0	0	0
15	0	1.35	0	1.35	0.08	0	0	0	0	0	0	0
16	0.01	0.74	0.02	0.24	1.06	0.01	0	0.02	0	0	0	0
17	0.01	0.29	0	0.12	0.11	0	0.01	0.01	0	0	0	0
18	0	0.80	0	1.45	0.11	0.01	0	0	0	0	0	0
19	0	0.29	0	0.32	3.14	0	0	0	0	0	0	0
20	0	0.01	0.05	0.09	0.01	0	0	0	0	0	0	0
21	0	0.04	0	0	1.80	0.08	0	0	0	0	0	0
22	0	0.37	0	0.01	0.06	0.03	0	0	0	0	0	0
23	0	0.01	0.01	0.36	1.25	1.16	0.54	0	0	0	0	0
24	0.01	0.17	0	0.04	0.01	0.37	0	0.01	0	0	0	0
25	0	0.44	0	0.34	0	0	0	0.01	0	0	0	0.05
26	0	1.61	0	0.03	0	0	0	0	0	0	0	0
27	0	0.03	0.01	0.02	0	0.22	0	0.36	0	0	0	0.03
28	0	0.01	0.01	0.03	0.01	0.07	0	1.38	0	0	0	0
29	0	0.99	0	0.87		0	0	0.73	0	0	0	0
30	0.01	0.12	0	0.01		0.10	0.02	0	0	0.03	0	0
31	0.04		0	0.56		0.82		0		0	0	
TOTAL	**2.84**	**10.32**	**3.47**	**16.49**	**24.68**	**4.55**	**3.59**	**5.19**	**0.06**	**0.03**	**0.00**	**0.08**
MEAN	**0.09**	**0.34**	**0.11**	**0.53**	**0.88**	**0.15**	**0.12**	**0.17**	**0.00**	**0.00**	**0.00**	**0.00**
MAX	**1.34**	**1.62**	**1.12**	**3.11**	**3.48**	**1.16**	**0.97**	**1.38**	**0.03**	**0.03**	**0.00**	**0.05**
MIN	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Max 1hr												

WTR YR TOTAL	**71.30**

Olema Creek Water Year 1999 Daily Average Discharge (cfs)
@ Bear Valley Rd. bridge

	Oct-98	Nov-98	Dec-98	Jan-99	Feb-99	Mar-99	Apr-99	May-99	Jun-99	Jul-99	Aug-99	Sep-99
1	1.0	1.6	61.7	10.2	65.2	64.7	21.4	12.2	5.9	0.8	0.8	1.2
2	1.0	1.3	63.1	10.1	46.4	59.2	19.5	12.2	4.9	0.8	0.8	1.2
3	0.8	1.3	132	10.0	38.7	87.9	17.2	13.1	4.9	0.8	0.8	1.3
4	0.8	1.6	54.1	9.9	33.5	69.5	15.8	12.4	5.0	0.8	0.8	1.4
5	1.0	1.6	42.0	10.0	28.0	60.8	20.5	13.9	4.9	0.8	0.9	1.2
6	1.0	1.8	46.8	10.4	25.9	53.7	17.5	14.3	4.4	0.8	1.1	1.1
7	1.0	4.9	29.6	11.1	*500*	47.8	15.3	13.6	4.3	0.8	1.0	1.4
8	1.3	3.2	23.7	11.1	125	72.2	31.1	12.5	4.9	0.9	0.9	1.5
9	1.3	2.3	18.2	10.6	253	89.2	24.6	10.9	2.6	0.9	0.9	1.7
10	1.0	2.2	14.6	10.2	106	68.3	29.4	9.6	2.4	0.8	1.0	1.8
11	1.0	2.3	12.7	10.5	69.3	59.5	181	9.9	2.2	0.8	1.2	1.9
12	1.3	1.8	10.7	10.8	53.6	54.1	66.5	9.6	2.0	0.6	1.0	2.0
13	1.3	1.7	10.8	11.0	45.9	48.0	43.1	8.2	1.9	0.4	0.9	*1.9*
14	1.0	1.8	16.1	11.2	40.7	51.5	32.2	7.3	1.9	0.5	0.9	*1.8*
15	0.9	1.9	14.8	12.7	36.5	49.5	26.3	6.7	1.7	0.6	0.8	*1.7*
16	1.2	2.0	13.6	19.8	282	44.6	22.6	6.3	1.6	0.6	0.8	*1.6*
17	1.1	2.6	13.2	20.0	311	41.7	19.3	6.0	1.5	0.6	0.8	*1.5*
18	1.1	1.9	12.4	147	151	40.5	17.6	5.7	1.4	0.5	0.9	*1.5*
19	1.3	1.8	11.7	124	105	42.4	16.5	5.9	1.3	0.6	1.0	*1.4*
20	1.2	1.8	11.8	218	128	40.2	15.7	5.2	1.2	0.7	0.9	*1.3*
21	1.1	2.1	10.7	138	150	38.8	15.0	4.8	1.1	0.7	0.9	*1.2*
22	1.1	2.9	10.7	94.8	99.1	38.1	14.5	4.3	1.0	0.6	0.9	*1.3*
23	1.1	8.3	10.4	183	75.8	45.3	13.8	4.3	0.8	0.6	1.0	*1.3*
24	4.1	6.7	10.1	93.6	71.7	75.6	13.6	4.7	0.8	0.6	1.0	*1.3*
25	2.2	4.3	9.9	64.2	108	149	13.4	4.8	0.7	0.6	0.9	*1.3*
26	1.6	4.2	10.0	63.1	73.6	79.2	13.1	5.5	0.7	0.6	0.9	*1.4*
27	1.5	4.3	10.6	47.0	61.8	54.4	12.5	5.3	0.7	0.7	0.9	*1.4*
28	1.6	3.6	10.6	38.1	64.5	42.1	12.4	5.4	0.7	0.7	1.0	*1.5*
29	1.5	71.6	10.3	33.4		34.5	12.2	5.3	0.7	0.6	1.0	*1.5*
30	1.3	140	10.6	32.2		30.7	12.1	4.6	0.8	0.7	1.1	*1.5*
31	1.3		10.6	160		26.6		5.1		0.8	1.1	
TOTAL	**39.9**	**289**	**728**	**1636**	**3150**	**1759**	**786**	**250**	**68.9**	**21.2**	**29.0**	**44.1**
MEAN	**1.3**	**9.6**	**23.5**	**52.8**	**112.5**	**56.8**	**26.2**	**8.1**	**2.3**	**0.7**	**0.9**	**1.5**
MAX	**4.1**	**140**	**132**	**218**	**500**	**149**	**181**	**14.3**	**5.9**	**0.9**	**1.2**	**2.0**
MIN	**0.8**	**1.3**	**9.9**	**9.9**	**25.9**	**26.6**	**12.1**	**4.3**	**0.7**	**0.4**	**0.8**	**1.1**
AC-FT												
PEAK FLOW	**9.1**	**227**	**210**	**330**	**851**	**240**	**343**	**15.5**	**6.0**	**1.7**	**1.5**	**2.2**

values in italics calculated from estimated water level data

Olema Creek @ Bear Valley HQ   Water Year 1999   Daily Total Rain (in.)

	Oct-98	Nov-98	Dec-98	Jan-99	Feb-99	Mar-99	Apr-99	May-99	Jun-99	Jul-99	Aug-99	Sep-99
1	0	0.05	0	0.01	0	0	0.05	0	0.01	0	0	0
2	0	0	1.10	0	0.01	0.50	0	0.04	0	0	0	0
3	0	0.01	0.41	0.01	0	0.26	0.01	0.06	0.04	0	0	0
4	0	0	0	0	0	0	0.01	0.02	0	0	0	0
5	0	0	0.70	0.01	0.01	0	0.37	0.01	0	0	0	0
6	0	0.14	0	0	3.76	0	0.29	0.01	0	0	0.03	0
7	0	1.16	0	0	2.45	0	0.01	0	0	0	0	0
8	0.01	0.31	0	0.01	0.19	1.09	0.56	0	0	0	0	0.01
9	0	0.01	0	0	1.17	0.41	0	0	0	0	0	0
10	0	0.11	0	0	0.01	0	0.62	0	0	0	0	0
11	0	0.01	0	0.01	0.01	0.02	1.29	0	0	0	0.03	0
12	0	0.01	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0.12	0	0	0	0	0	0	0
14	0	0.01	0	0.01	0	0.43	0.01	0	0	0	0	0
15	0.01	0.08	0	0.69	0.01	0.02	0	0	0	0	0	0
16	0	0	0	0.08	3.43	0	0	0	0	0	0	0
17	0	0.11	0	0.76	0.39	0	0	0	0	0	0	0
18	0	0.01	0	1.06	0.71	0	0	0	0	0	0	0
19	0	0.02	0	1.01	0.01	0.23	0	0	0	0	0	0
20	0	0	0	0.59	1.25	0.02	0	0	0	0	0	0
21	0	0.32	0	0.02	0.31	0	0	0	0	0	0	0
22	0	0.02	0	1.04	0.20	0	0	0	0	0	0	0.04
23	0	1.35	0	0.31	0	0	0	0	0	0	0	0
24	1.36	0.01	0	0.01	0.66	0.70	0	0	0	0	0	0
25	0	0	0	0	0.32	1.01	0	0	0	0	0	0
26	0	0.34	0	0.40	0	0.02	0	0	0	0	0	0
27	0	0.01	0	0	0	0	0	0	0	0	0	0
28	0	0.01	0	0.01	0.59	0.05	0	0	0	0	0	0
29	0	2.17	0	0.01		0	0	0	0	0	0	0
30	0	1.21	0	0.45		0	0	0	0	0	0	0
31	0		0	1.16		0		0		0	0	
TOTAL	**1.38**	**7.48**	**2.21**	**7.66**	**15.61**	**4.76**	**3.22**	**0.14**	**0.05**	**0.00**	**0.06**	**0.05**
MEAN	**0.04**	**0.25**	**0.07**	**0.25**	**0.56**	**0.15**	**0.11**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
MAX	**1.36**	**2.17**	**1.10**	**1.16**	**3.76**	**1.09**	**1.29**	**0.06**	**0.04**	**0.00**	**0.03**	**0.04**
MIN	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Max 1hr												

WTR YR TOTAL	**42.62**

Olema Creek Water Year 2000 Daily Average Discharge (cfs)
@ Bear Valley Rd. Bridge

	Oct-99	Nov-99	Dec-99	Jan-00	Feb-00	Mar-00	Apr-00	May-00	Jun-00	Jul-00	Aug-00	Sep-00
1	*1.5*	*1.7*	*2.4*	*1.2*	41.7	104	7.1	7.2	3.8	1.2	0.9	0.8
2	*1.5*	*1.6*	*2.2*	*1.3*	36.9	77.2	6.8	7.0	3.6	1.2	1.1	0.9
3	*1.4*	*1.6*	*2.1*	*1.3*	37.7	57.9	6.7	6.7	3.5	1.2	1.2	0.5
4	*1.4*	*1.6*	*2.0*	*1.4*	35.5	67.6	6.6	6.5	3.4	1.1	1.2	0.5
5	*1.4*	*1.5*	*1.8*	*1.5*	45.7	103	6.4	6.3	3.3	1.0	1.0	0.8
6	*1.4*	*1.5*	*1.7*	*1.5*	45.0	63.1	6.2	6.3	3.1	1.1	0.6	0.9
7	*1.6*	*3.7*	*1.6*	*1.5*	36.5	53.0	6.1	8.3	3.1	1.1	0.7	0.8
8	*1.3*	*4.1*	*1.5*	*1.5*	30.9	92.5	5.9	12.5	3.6	1.1	0.8	1.2
9	*1.3*	*2.7*	*3.7*	*1.5*	40.8	106	5.6	8.7	3.0	1.1	0.8	1.2
10	*1.3*	*2.1*	*1.9*	*2.9*	128	67.7	5.3	7.8	2.7	1.1	0.7	1.1
11	*1.3*	*1.8*	*2.4*	*4.7*	189	51.5	5.0	7.2	2.6	1.3	0.8	1.0
12	*1.5*	*1.6*	*1.9*	6.7	258	39.3	5.2	6.8	2.5	1.2	0.7	0.8
13	*1.2*	*1.5*	*1.4*	6.4	777	32.3	6.6	6.5	2.3	1.3	0.7	1.8
14	*1.2*	*1.5*	*2.3*	6.3	347	26.6	7.5	11.7	2.1	1.3	0.8	1.6
15	*1.2*	*1.5*	*2.0*	5.3	100	23.3	6.1	16.4	1.9	1.4	0.7	1.5
16	*1.4*	*2.1*	*1.7*	14.6	64.0	20.5	15.0	13.4	2.1	1.4	0.7	1.7
17	*1.2*	*1.5*	*2.1*	*28.8*	47.0	18.5	125	11.4	2.1	1.4	0.8	1.6
18	*1.1*	*1.5*	*2.2*	47.4	34.4	16.7	40.1	10.0	2.1	1.4	0.8	1.5
19	*1.1*	*4.5*	*2.3*	21.0	25.4	15.1	24.7	8.8	1.9	1.5	0.7	1.2
20	*1.1*	*3.0*	*2.0*	22.3	25.9	14.1	18.8	7.8	1.8	1.5	0.7	1.2
21	*1.1*	*2.4*	*1.9*	*66.1*	34.7	13.3	15.8	7.1	1.7	1.4	1.0	1.3
22	*1.3*	*2.0*	*1.8*	*132*	55.0	12.2	13.8	6.5	1.6	1.4	0.8	1.5
23	*1.0*	*1.9*	*1.7*	*207*	103	11.1	11.9	6.0	1.7	1.4	0.8	1.1
24	*1.0*	*1.8*	*1.6*	278	60.0	10.6	10.8	5.8	1.6	1.5	0.8	1.0
25	*1.0*	*1.7*	*1.5*	68.8	55.7	9.8	9.9	5.6	1.5	1.4	1.1	1.2
26	*1.0*	*1.6*	*1.4*	51.1	197	9.1	9.1	5.4	1.4	1.3	0.8	1.3
27	*1.2*	*1.6*	*1.3*	36.7	313	8.6	8.7	5.0	1.3	1.3	0.9	1.1
28	*1.8*	*1.5*	*1.9*	32.6	131	8.3	8.2	4.7	1.2	1.3	0.4	1.3
29	*2.7*	*2.1*	*1.2*	28.0	178	7.8	7.7	4.5	1.3	1.2	0.2	2.1
30	*1.8*	*3.0*	*1.1*	48.7		7.4	7.5	4.3	1.3	1.0	0.4	2.1
31	*1.7*		*1.1*	44.5		7.2		4.1		1.0	0.8	
TOTAL	**42.2**	**61.9**	**58.0**	**1173**	**3474**	**1155**	**420**	**236**	**68.8**	**39.0**	**24.4**	**36.5**
MEAN	**1.4**	**2.1**	**1.9**	**37.8**	**120**	**37.3**	**14.0**	**7.6**	**2.3**	**1.3**	**0.8**	**1.2**
MAX	**2.7**	**4.5**	**3.7**	**278**	**777**	**106**	**125**	**16.4**	**3.8**	**1.5**	**1.2**	**2.1**
MIN	**1.0**	**1.5**	**1.1**	**1.2**	**25.4**	**7.2**	**5.0**	**4.1**	**1.2**	**1.0**	**0.2**	**0.5**
AC-FT												
PEAK FLOW			**4.8**	***279**	**1305**	**256**	**227**	**25.0**	**5.0**	**3.2**	**6.4**	**7.4**

values in italics calculated from estimated water level data

*calculated from highest recorded water level-may not be true peak value (some data missing)

Olema Creek @ Bear Valley HQ   Water Year 2000   Daily Total Rain (in.)

	Oct-99	Nov-99	Dec-99	Jan-00	Feb-00	Mar-00	Apr-00	May-00	Jun-00	Jul-00	Aug-00	Sep-00
1	0	0.01	0.05	0	0.03	0	0	0	0	0	0	0.01
2	0	0.01	0.13	0	0	0.33	0	0	0	0	0	0.04
3	0	0	0.01	0.01	0.36	0	0	0	0	0	0	0.01
4	0	0	0.01	0.03	0	1.08	0	0	0	0	0	0
5	0.05	0	0	0.01	0.43	0.01	0	0	0	0	0	0
6	0.01	0	0.03	0.01	0.01	0	0	0.08	0	0	0.03	0
7	0.01	1.11	0.01	0	0	0.51	0	0.63	0.23	0	0	0
8	0	0.23	0	0	0.01	0.78	0	0.32	0.13	0	0	0
9	0	0.01	0.53	0	0.10	0.17	0	0	0	0	0	0
10	0	0.20	0.01	0.24	1.00	0.14	0	0.02	0	0	0.03	0
11	0	0.02	0.01	1.11	1.34	0.09	0	0	0	0	0	0
12	0.01	0	0	0.01	0.14	0.01	0.57	0	0	0	0	0
13	0	0	0.11	0.06	3.63	0	0.10	0	0	0	0	0
14	0	0.10	0.01	0.01	0.31	0	0.57	0.95	0	0	0	0
15	0	0.17	0	0.15	0.01	0.01	0.08	0	0	0	0	0
16	0.01	0.60	0.01	1.00	0.15	0	2.39	0	0	0	0	0
17	0	0.02	0	0.02	0.03	0	0.47	0	0	0	0	0
18	0	0	0.01	0.84	0	0	0.01	0	0	0	0	0
19	0	0.99	0	0.49	0.01	0	0	0	0	0	0	0
20	0	0.07	0.01	0.01	0.55	0	0	0	0	0	0	0
21	0	0.07	0	0.15	0.12	0	0	0	0	0	0	0.09
22	0.01	0.01	0.01	0.03	1.22	0	0.06	0	0	0	0	0.02
23	0	0	0	0.93	0.04	0	0	0	0	0	0	0
24	0	0.01	0.01	0.96	0.31	0	0	0	0	0	0	0
25	0	0	0	0.04	0.09	0	0	0	0	0	0	0
26	0.01	0	0.01	0	1.65	0	0	0	0	0	0	0
27	0.08	0.02	0	0	0.34	0	0	0	0	0	0	0
28	0.37	0	0	0.01	0.02	0	0	0	0	0	0	0
29	0.63	0.86	0.01	0	0.87	0	0	0	0	0	0	0
30	0.01	0.69	0	0.80		0	0	0	0	0	0	0
31	0.01		0.01	0.23		0		0		0	0	
TOTAL	**1.21**	**5.20**	**0.99**	**7.15**	**12.77**	**3.13**	**4.25**	**2.00**	**0.36**	**0.00**	**0.06**	**0.17**
MEAN	**0.04**	**0.17**	**0.03**	**0.23**	**0.44**	**0.10**	**0.14**	**0.06**	**0.01**	**0.00**	**0.00**	**0.01**
MAX	**0.63**	**1.11**	**0.53**	**1.11**	**3.63**	**1.08**	**2.39**	**0.95**	**0.23**	**0.00**	**0.03**	**0.09**
MIN	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Max 1hr												

WTR YR TOTAL	**37.29**

Olema Creek Water Year 2001 Daily Average Discharge (cfs)
@ Bear Valley Rd. Bridge

	Oct-00	Nov-00	Dec-00	Jan-01	Feb-01	Mar-01	Apr-01	May-01	Jun-01	Jul-01	Aug-01	Sep-01
1	1.7	*2.1*	*2.2*	*1.9*	*10.9*	33.8	5.4	2.3	1.2	1.0	0.6	0.6
2	1.6	*1.9*	*2.1*	*1.9*	*9.3*	30.0	5.2	2.1	1.3	0.9	0.6	0.5
3	1.7	*1.8*	*2.1*	*1.8*	*7.9*	28.9	5.0	1.9	1.1	0.8	0.6	0.5
4	1.6	*1.8*	*2.1*	*1.8*	*6.7*	64.3	4.8	1.9	1.2	0.8	0.6	0.5
5	1.7	*1.7*	*2.0*	*1.7*	*5.0*	68.5	4.6	1.9	1.0	0.7	0.6	0.4
6	1.7	*1.7*	*2.0*	*1.7*	*4.0*	50.2	5.8	1.8	1.0	0.8	0.6	0.4
7	1.5	*1.7*	*2.0*	*2.8*	*3.0*	39.2	5.8	1.6	1.0	0.7	0.6	0.5
8	1.8	*1.7*	*1.9*	*4.3*	*2.6*	30.9	4.8	1.7	1.0	0.7	0.6	0.7
9	2.5	*1.7*	*1.9*	*9.3*	*30.7*	25.1	4.4	1.8	1.0	0.8	0.7	0.7
10	3.1	*1.7*	*1.9*	*27.2*	*22.2*	23.1	4.2	1.6	1.0	0.8	0.7	0.7
11	1.8	*1.7*	*2.2*	*40.7*	*111*	20.1	4.0	1.6	1.0	0.8	0.7	0.6
12	1.5	*1.7*	*2.2*	*193*	*98*	17.6	3.8	1.7	1.0	0.8	0.9	0.7
13	1.6	*2.1*	*2.8*	*30.7*	*32.6*	15.7	3.7	1.7	1.0	0.8	0.8	0.8
14	1.9	*1.9*	*4.0*	*15.1*	*25.4*	14.3	3.7	1.7	0.9	0.8	0.6	0.7
15	2.1	*2.0*	*3.7*	*7.9*	*19.2*	13.3	3.6	1.6	0.9	0.8	0.6	0.7
16	1.9	*1.8*	*3.1*	*5.0*	*15.1*	12.2	3.4	1.5	0.8	0.8	0.6	0.8
17	1.8	*1.7*	*2.8*	*3.4*	*48.5*	11.3	3.3	1.5	0.8	0.8	0.9	0.8
18	2.1	*1.7*	*2.7*	*2.8*	49.1	10.5	3.4	1.5	0.7	0.7	0.8	0.8
19	2.6	*1.7*	*2.7*	*2.6*	101	9.9	3.3	1.5	0.7	0.7	0.8	0.8
20	2.4	*1.7*	*2.6*	*2.3*	104	9.2	4.0	1.4	0.7	0.7	0.9	0.9
21	2.4	*2.3*	*2.6*	*2.3*	423	8.9	3.8	1.4	0.7	0.7	0.9	0.9
22	2.4	*2.1*	*2.5*	*2.1*	330	8.4	3.2	1.4	0.7	0.6	0.8	1.0
23	2.0	*2.0*	*2.4*	*111*	255	8.0	3.1	1.5	0.8	0.6	0.7	1.0
24	2.1	*1.9*	*2.4*	*85.0*	271	8.1	2.9	1.5	0.8	0.6	0.8	1.1
25	4.4	*1.9*	*2.3*	*82.0*	180	8.3	2.8	1.5	0.9	0.6	0.8	1.3
26	5.0	1.8	*2.2*	*164*	58.7	7.5	2.8	1.6	0.9	0.6	0.7	1.4
27	3.0	*1.7*	*2.2*	*52.0*	60.6	7.0	2.4	1.7	2.0	0.6	0.7	1.4
28	4.3	*1.7*	*2.1*	*26.3*	44.5	6.6	2.4	1.5	1.9	0.6	0.7	1.3
29	6.1	*2.6*	*2.1*	*20.7*		6.4	2.3	1.5	1.2	0.6	0.8	1.4
30	2.9	*2.2*	*2.0*	*16.4*		6.0	2.3	1.2	1.1	0.6	0.8	1.6
31	2.0		*2.0*	*12.0*		5.6		1.0		0.6	0.8	
TOTAL	**75.2**	**55.2**	**73.7**	**932.7**	**2327.8**	**608.6**	**114.2**	**50.2**	**30.3**	**22.5**	**22.2**	**25.4**
MEAN	**2.4**	**1.8**	**2.4**	**30.1**	**83.1**	**19.6**	**3.8**	**1.62**	**1.01**	**0.73**	**0.72**	**0.85**
MAX	**6.1**	**2.6**	**4.0**	**193.4**	**423.1**	**68.5**	**5.8**	**2.3**	**2.0**	**1.0**	**0.9**	**1.6**
MIN	**1.5**	**1.7**	**1.9**	**1.7**	**2.6**	**5.6**	**2.3**	**1.0**	**0.7**	**0.6**	**0.6**	**0.4**
AC-FT												
PEAK FLOW	**10.0**	***5.2**	***7.1**	***213**	***423**	**129**	**25.4**	**2.6**	**11.4**	**2.0**	**18.8**	**3**

values in italics calculated from estimated water level data

*calculated from highest recorded water level-may not be true peak value (some data missing)

Olema Creek @ Bear Valley HQ | Water Year 2001 | Daily Total Rain (in.)

	Oct-00	Nov-00	Dec-00	Jan-01	Feb-01	Mar-01	Apr-01	May-01	Jun-01	Jul-01	Aug-01	Sep-01
1	0	0	0	0	0.01	0.08	0	0	0	0	0	0
2	0	0	0	0	0	0.26	0	0	0	0	0	0
3	0	0.01	0.01	0	0	0.24	0	0	0	0	0	0
4	0	0	0	0	0	1.07	0	0	0	0	0	0
5	0	0	0	0.01	0.01	0.16	0	0	0	0	0	0
6	0	0	0	0	0	0	0.55	0	0	0	0	0
7	0	0	0	0.09	0	0	0.09	0	0	0	0	0
8	0	0	0	0.55	0	0	0	0	0	0	0	0
9	0.34	0	0	0.33	0.80	0	0	0	0	0	0	0
10	0.04	0	0.01	1.01	0.41	0	0	0	0	0	0	0
11	0.01	0	0.36	1.37	0.72	0	0	0	0	0	0	0
12	0	0.01	0.03	0.01	0.42	0	0	0	0	0	0	0
13	0	0.29	0.33			0	0	0	0	0	0	0
14	0	0.01	0.42	0.16	0.01	0.01	0	0	0	0	0	0
15	0	0.11	0.04	0	0	0	0	0	0	0	0	0
16	0	0.02	0.01	0.01	0	0	0.08	0	0	0	0	0
17	0	0	0	0	0.81	0	0	0	0	0	0	0
18	0.01	0.01	0.01	0.01	0.04	0	0.04	0	0	0	0	0
19	0	0	0	0	0.66	0	0	0	0	0	0	0
20	0	0	0	0	0.19	0	0.32	0	0	0	0	0
21	0	0.56	0.05	0	0.93	0	0.01	0	0	0	0	0
22	0	0	0.01	0	0.94	0	0	0	0	0	0	0
23	0	0.01	0.01	1.14	0.10	0	0	0	0	0	0	0
24	0	0.03	0	0.12	0.86	0.27	0	0	0	0	0	0.1
25	0.54	0	0	0.96	0.29	0.01	0	0	0	0	0	0
26	0.47	0.01	0.01	0.55	0	0	0	0	0	0	0	0
27	0	0	0	0.01	0	0	0	0	1.01	0	0	0
28	1.21	0	0	0	0	0	0	0	0.01	0	0	0
29	0	0.46	0.01	0.12	0.87	0	0	0	0	0	0	0
30	0.11	0.01	0	0		0	0	0	0	0	0	0
31	0		0	0		0		0		0	0	
TOTAL	**2.73**	**1.54**	**1.31**	**6.45**	**8.07**	**2.10**	**1.09**	**0.00**	**1.02**	**0.00**	**0.00**	**0.10**
MEAN	**0.09**	**0.05**	**0.04**	**0.22**	**0.29**	**0.07**	**0.04**	**0.00**	**0.03**	**0.00**	**0.00**	**0.00**
MAX	**1.21**	**0.56**	**0.42**	**1.37**	**0.94**	**1.07**	**0.55**	**0.00**	**1.01**	**0.00**	**0.00**	**0.10**
MIN	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Max 1hr												

WTR YR TOTAL	**24.41**

APPENDIX C

REGIONAL WATER QUALITY CONTROL BOARD BASIN PLAN

BENEFICIAL USE DESIGNATIONS

TMDL TIMELINE

APPENDIX D

TRIENNIAL SANITARY SURVEY UPDATES FOR TOMALES BAY AND DRAKES ESTERO COMMERCIAL SHELLFISH GROWING AREAS

California Department of Health Services

APPENDIX E

POINT REYES NATIONAL SEASHORE RAINFALL INFORMATION

Bear Valley
Point Reyes National Seashore

MONTHLY TOTAL RAINFALL

E10 0572 00
38°02'38", 122°47'50", 50'

Average	**39.30**	**2.10**	**5.68**	**6.27**	**8.65**	**6.69**	**5.64**	**2.42**	**1.07**	**0.20**	**0.09**	**0.14**	**0.34**	**% Normal**
Max	79.84	5.74	18.20	16.09	22.39	24.68	24.28	6.60	6.35	1.02	2.58	1.82	2.54	
Min	15.03	0.00	0.61	0.01	0.40	0.47	0.24	0.00	0.00	0.00	0.00	0.00	0.00	
Count	35	37	36	36	36	36	37	37	37	37	37	37	37	
WYYear	**Sum**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	
1964														
1965	**38.60**	3.52	7.18	8.38	7.55	2.29	3.06	**6.60**	.01	.01	.00	.00	.00	98%
1966	**27.65**	.20	5.69	3.53	10.31	4.54	1.46	1.19	.12	.17	.01	.28	.15	70%
1967	**54.79**	.00	10.97	*12.00*	18.11	.49	7.16	5.10	.26	.67	.00	.00	.03	138%
1968	**30.97**	1.57	*4.00*	3.93	7.58	5.35	6.45	.75	.56	.00	.00	.68	.10	78%
1969		4.77	4.28	12.71			2.70	3.32	.17	.13	.00	.00	.00	0%
1970	**48.82**	3.58	2.04	12.49	21.80	3.92	4.27	.27	.06	.39	.00	.00	.00	123%
1971		2.90			1.64	.59	6.16	1.50	.97	.00	.00	.00	.00	0%
1972	**26.04**	.56	4.08	9.34	3.03	5.15	1.15	2.29	.06	.35	.00	.03	.00	66%
1973	**54.91**	5.74	9.10	5.78	16.76	9.90	5.98	.02	.10	.00	.00	.00	1.53	139%
1974	**61.66**	3.41	**18.20**	8.50	8.23	4.65	10.41	5.40	.03	.25	**2.58**	.00	.00	156%
1975	**32.07**	1.65	2.38	3.41	1.64	11.03	9.13	2.08	.15	.17	.34	.09	.00	81%
1976	**21.10**	5.29	2.92	1.62	.49	4.39	.62	3.17	.07	.01	.06	**1.82**	.64	53%
1977	**15.03**	.54	2.53	1.32	4.04	2.06	2.62	*.00*	*.00*	*.00*	.08	.00	1.84	38%
1978	**46.56**	1.16	5.34	8.00	12.51	7.52	6.73	3.99	.08	.04	.00	.08	1.11	118%
1979	**31.60**	.02	2.80	1.07	13.33	7.10	4.26	1.58	1.34	.04	.02	.00	.04	80%
1980	**40.46**	4.21	5.89	7.92	7.97	9.48	1.85	2.50	.46	.17	.00	.00	.01	102%
1981	**23.91**	.59	.61	4.26	7.90	2.55	6.68	.05	.73	.00	.01	.00	.53	60%
1982	**55.47**	3.61	9.19	14.06	13.30	6.01	7.12	1.50	.00	.05	.00	.00	.63	140%
1983	**79.84**	3.27	12.90	5.06	11.49	15.55	**24.28**	5.00	1.65	.00	.18	.43	.03	202%
1984	**35.50**	.65	11.14	12.80	.40	2.55	2.65	2.30	2.00	.67	.00	.13	.21	90%
1985	**32.27**	3.66	13.40	3.17	1.20	3.73	5.82	.17	.09	.09	.07	.00	.87	82%
1986	**53.42**	1.47	5.84	3.65	9.38	17.13	8.47	2.83	1.58	.53	.00	.00	**2.54**	135%
1987	**26.85**	.44	1.02	3.32	7.89	6.65	6.70	.79	.04	.00	.00	.00	.00	68%
1988	**26.33**	1.43	3.75	11.17	7.46	.54	.24	1.74	.00	.00	.00	.00	.00	67%
1989	**37.58**	.33	8.46	5.75	2.95	2.03	13.28	3.06	.19	.10	.00	.00	1.43	95%
1990	**26.07**	2.71	1.95	.01	7.62	4.25	2.26	.92	**6.35**	.00	.00	.00	.00	66%
1991	**25.05**	.00	.62	2.11	1.45	4.43	13.67	2.15	.62	.00	.00	.00	.00	63%
1992	**32.12**	4.91	1.98	4.65	3.19	9.53	6.09	1.73	.00	.00	.00	.04	.02	81%
1993	**44.13**	4.54	1.23	8.76	13.67	7.83	3.48	2.31	1.64	.67	.00	.00	.00	112%
1994	**25.67**	1.38	4.92	3.79	3.90	7.28	.60	2.35	1.26	.14	.00	.00	.05	65%
1995	**63.38**	.13	10.42	5.50	**22.39**	1.77	15.02	4.93	2.44	**.79**	.00	.00	.00	160%
1996	**46.35**	.00	.73	13.40	10.32	9.95	2.73	4.83	4.17	.08	.00	.00	.15	117%
1997	**39.91**	1.38	4.50	**16.09**	12.61	*.47*	1.09	1.11	.38	.45	.00	1.40	.43	101%
1998	**72.81**	2.84	10.31	3.48	17.99	**24.68**	4.56	3.59	5.19	.06	.03	.00	.08	184%
1999	**47.24**	1.38	7.48	2.21	7.66	15.61	4.76	3.22	4.76	0.05	0	0.06	0.05	119%
2000	**37.30**	1.21	5.2	0.99	7.15	12.77	3.13	4.25	2.01	0.36	0	0.06	0.17	94%
2001	**23.54**	2.73	1.54	1.31	6.45	7.2	2.1	1.09	0	1.02	0	0	0.1	59%
2002														
2003														
Average	39.57	2.10	5.68	6.27	8.65	6.69	5.64	2.42	1.07	.20	.09	.14	.34	
Stdev	15.32	1.73	4.25	4.43	5.88	5.36	4.85	1.71	1.61	.27	.43	.39	.61	
Rec Max	79.84	5.74	18.20	16.09	22.39	24.68	24.28	6.60	6.35	1.02	2.58	1.82	2.54	
Rec Min	15.03	.00	.61	.01	.40	.47	.24	.00	.00	.00	.00	.00	.00	
Z	2.52	4.02	5.17	3.70	3.84	6.49	8.18	4.33	12.51	10.41	70.58	31.70	18.99	
Yrs Rec	35	37	36	36	36	36	37	37	37	37	37	37	37	
CV	.387	.822	.748	.707	.680	.801	.859	.705	1.505	1.337	4.656	2.793	1.763	
Reg CV	.404	.431	.426	.424	.414	.414	.404	.398	.395	.390	.386	.385	.336	
Reg Skew	1.3	1.4	1.4	1.3	1.2	1.2	1.2	1.0	0.8	0.8	0.9	0.6	0.5	
FIC	1.14	1.07	1.04	1.02	1.01	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
RP 2	43.65	2.18	5.73	6.20	8.48	6.50	5.48	2.36	1.04	0.20	0.09	0.13	0.34	
RP 5	59.87	3.04	7.97	8.61	11.70	8.97	7.51	3.21	1.41	0.27	0.12	0.18	0.44	
RP 10	69.17	3.53	9.23	9.97	13.51	10.35	8.65	3.70	1.63	0.31	0.14	0.21	0.50	
RP 25	79.92	4.07	10.64	11.48	15.53	11.90	9.93	4.24	1.86	0.35	0.16	0.24	0.56	
RP 50	87.21	4.44	11.60	12.51	16.91	12.96	10.79	4.60	2.02	0.38	0.17	0.26	0.61	
RP 100	94.14	4.79	12.51	13.49	18.21	13.95	11.61	4.95	2.17	0.41	0.18	0.28	0.65	
RP 200	100.51	5.11	13.34	14.38	19.40	14.87	12.36	5.27	2.31	0.43	0.20	0.29	0.69	
RP 500	110.36	5.52	14.39	15.52	20.92	16.03	13.32	5.67	2.49	0.47	0.21	0.32	0.73	
RP 1000	114.55	5.81	15.15	16.33	22.01	16.86	14.01	5.96	2.62	0.49	0.22	0.33	0.77	
RP 10000	132.95	6.71	17.49	18.85	25.37	19.44	16.13	6.86	3.01	0.56	0.25	0.38	0.88	

Rainfall Depth-Duration-Frequency for Bear Valley-Point Reyes

11/26/01	DWR # E10 0572 00	Elev	Lat	Long
12:02 AM	Analysis By Jim Goodridge 916 345 3106	feet	dd.ddd	ddd.ddd
	Data From : Wm Shook, Nat Park Ser	50'	38.044	122.797

estimated

maximum **Maximum Rainfall For Indicated Number Of Concecutive Days**

WY	**1**	**2**	**3**	**4**	**5**	**6**	**8**	**10**	**15**	**20**	**30**	**60**	**W-YR**
1965	2.05	3.11	3.70	4.67	5.28	5.84	6.83	7.46	10.21	13.37	13.81	19.96	38.60
1966	6.00	7.72	7.90	7.98	8.61	8.79	10.15	11.58	12.29	12.29	12.53	17.64	27.65
1967	6.42	**9.83**	**10.58**	**10.58**	**12.31**	12.53	13.98	**16.33**	18.01	18.09	18.17	*30.11*	*59.61*
1968	2.91	3.54	3.66	3.68	4.75	4.77	4.98	5.47	5.80	6.30	8.00	14.84	*30.97*
1969													
1970	5.07	6.02	6.42	6.62	7.90	9.20	13.03	14.43	17.97	21.27	21.83	34.32	48.82
1971													
1972	2.22	3.05	3.56	3.83	4.67	4.78	4.78	4.86	6.82	7.90	10.60	13.55	26.04
1973	3.07	5.71	5.79	7.97	8.47	9.17	11.58	13.84	15.28	15.92	18.77	29.48	54.91
1974	3.88	4.72	5.97	6.03	7.63	9.39	11.94	12.21	15.51	16.77	19.22	28.73	61.66
1975	2.96	3.98	3.98	4.65	5.43	6.41	8.00	8.80	9.95	11.03	11.38	20.16	32.07
1976	2.00	2.08	2.08	2.61	3.12	3.12	3.12	3.13	3.32	4.63	5.91	8.44	21.10
1977	2.10	2.10	2.10	2.27	2.37	2.42	2.58	2.58	2.62	2.62	3.89	4.68	15.03
1978	*2.80*	*3.80*	4.75	6.03	6.35	7.70	8.36	8.73	11.47	12.51	15.56	24.48	46.56
1979	4.45	4.50	4.92	7.57	8.54	8.58	11.66	11.85	12.22	12.22	13.35	21.45	31.60
1980	3.05	4.22	5.53	6.03	6.50	7.05	7.63	7.95	9.48	10.89	11.07	18.25	40.46
1981	2.50	3.50	4.05	4.69	4.69	4.72	6.77	6.98	7.90	7.90	9.14	14.71	23.91
1982	**7.10**	7.60	8.85	8.85	8.95	10.28	11.90	12.45	13.88	21.70	23.92	33.21	59.93
1983	6.70	6.70	7.38	8.90	8.90	10.20	13.58	14.68	**19.73**	**26.03**	**31.28**	**46.02**	**79.84**
1984	5.50	5.50	6.80	6.80	6.80	6.80	6.80	6.80	9.00	11.40	12.80	23.94	35.50
1985	3.63	3.63	5.27	5.27	5.38	6.32	7.27	7.38	9.40	11.46	14.07	17.74	32.27
1986	4.05	6.85	9.25	9.95	11.10	**13.50**	**15.10**	15.58	15.60	16.98	19.58	32.62	53.42
1987	3.50	3.60	4.86	4.96	5.66	5.66	5.66	5.66	6.62	8.42	11.37	18.09	26.85
1988	2.26	2.96	3.40	3.63	4.44	5.24	5.93	7.84	8.56	9.91	11.17	19.41	*26.33*
1989	2.70	3.07	3.11	3.75	4.12	4.32	5.33	6.58	8.61	10.09	13.28	16.31	36.15
1990	2.37	3.87	4.07	4.16	4.29	4.32	6.16	6.38	6.98	7.05	9.01	12.51	27.50
1991	2.51	3.51	4.02	4.62	5.62	5.86	5.91	6.87	8.18	9.28	14.9	18.31	25.05
1992	4.5	4.51	4.51	4.86	4.87	5.11	6.11	7.13	8.94	9.33	11.48	16.63	32.08
1993	2.62	3.7	4.22	4.6	5.54	5.54	7.07	9.29	11.45	12.37	15.21	23.04	44.19
1994	1.95	3.05	3.55	3.63	4.07	4.5	4.5	4.7	6.2	7.34	9.88	11.18	25.62
1995	3.90	7.01	7.02	7.55	8.02	9.00	11.14	11.75	14.27	17.52	22.29	27.89	63.43
1996	4.86	8.26	8.29	8.59	9.16	9.16	9.42	9.42	10.25	12.52	13.55	26.13	46.20
1997	3.51	4.61	5.29	6.57	7.67	7.73	9.45	9.47	12.29	12.31	20.38	28.71	*38.23*
1998	4.19	5.55	6.81	7.72	10.19	12.51	14.33	14.95	17.6	22.1	29.04	42.68	72.81
1999	3.76	6.21	6.4	7.57	7.58	7.59	7.71	8.75	13.51	15	17.24	25.92	42.62
2000	3.63	3.94	5.11	6.11	6.42	6.52	6.68	6.97	8.86	11.83	14.85	22.74	37.29
2001	1.37	2.38	2.71	3.26	3.35	3.68	4.53	4.82	6.09	7.18	9	15.45	23.54

	1	2	3	4	5	6	8	10	15	20	30	60	W-YR
Average	3.60	4.70	5.31	5.90	6.54	7.09	8.28	8.96	10.71	12.39	14.79	22.27	39.65
Stdev	1.45	1.88	2.05	2.13	2.34	2.72	3.38	3.66	4.24	5.24	6.02	8.99	15.56
Rec Max	7.10	9.83	10.58	10.58	12.31	13.50	15.10	16.33	19.73	26.03	31.28	46.02	79.84
Rec Min	1.37	2.08	2.08	2.27	2.37	2.42	2.58	2.58	2.62	2.62	3.89	4.68	15.03
Z	2.40	2.54	2.33	1.87	2.13	2.18	2.04	2.07	2.13	2.82	2.89	2.77	3.02
Yrs Rec	35	35	35	35	35	35	35	35	35	35	35	35	35
CV	.403	.400	.386	.360	.358	.384	.408	.409	.396	.423	.407	.404	.392
Reg CV	.404	.431	.426	.424	.414	.414	.404	.398	.395	.390	.386	.385	.336
Reg Skew	1.3	1.4	1.4	1.3	1.2	1.2	1.2	1.0	0.8	0.8	0.9	0.6	0.5
FIC	1.14	1.07	1.04	1.02	1.01	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
RP 2	3.76	4.53	4.98	5.56	6.05	6.51	7.62	8.39	10.16	11.76	13.99	21.41	38.59
RP 5	5.30	6.56	7.19	7.93	8.60	9.24	10.73	11.67	14.01	16.15	19.18	29.12	50.44
RP 10	6.48	7.93	8.68	9.44	10.26	11.03	12.77	13.74	16.38	18.86	22.43	33.67	57.24
RP 25	7.61	9.64	10.54	11.30	12.31	13.23	15.28	16.24	19.13	22.00	26.32	38.90	65.10
RP 50	8.54	10.90	11.90	12.60	13.79	14.82	17.09	18.02	21.08	24.22	29.06	42.50	70.43
RP 100	9.43	12.11	13.22	13.91	15.21	16.35	18.83	19.73	22.94	26.35	31.68	45.93	75.49
RP 200	10.31	13.32	14.54	15.16	16.60	17.84	20.53	21.41	24.71	28.38	34.19	49.10	80.16
RP 500	11.46	14.88	16.23	16.76	18.41	19.78	22.74	23.59	27.00	30.98	37.50	53.30	87.35
RP 1000	12.34	16.07	17.53	17.94	19.75	21.22	24.38	25.12	28.65	32.87	39.84	56.21	90.41
RP 10000	15.12	19.91	21.69	21.79	24.12	25.92	29.74	30.22	33.98	38.95	47.49	65.56	103.87

Rainfall Depth-Duration-Frequency for Point Reyes Station

11/26/01
12:02 AM

DWR # E10 7088 20
Analysis By : Jim Goodridge   916 345 3106
Data From : Marin Co PWD

Elevation 31'
Latitude 38°04'
Longitude 122°48'

				Maximum	Rainfall	For Indicated	Number Of	Concecutive Minutes			
Year	5 Min	10 Min	15 Min	30 Min	1 Hr	2 Hr	3 Hr	6 Hr	12 Hr	24 Hr	W-Yr
1975	.23	.29	.33	.41	.57	.85	1.22	1.72	2.34	3.45	27.85
1976	.07	.09	.13	.25	.50	.82	1.05	1.33	1.66	1.88	15.13
1977	.14	.26	.34	.47	.52	.73	.78	.88	1.33	2.54	13.03
1978	.21	.30	.36	.45	.69	.90	1.28	1.97	3.66	5.97	41.61
1979	**.32**	**.38**	.40	.54	.65	.88	1.19	1.76	2.72	2.98	27.61
1980	.23	.31	.33	.43	.59	.83	1.08	1.92	2.23	2.93	34.82
1981	.12	.15	.20	.37	.65	.89	1.00	1.67	1.87	3.57	21.08
1982	.21	.38	**.44**	**.83**	**1.13**	**1.68**	**2.43**	**4.25**	**6.49**	**8.07**	50.51
1983	.15	.25	.38	.50	.82					2.96	**54.71**
1984	.17	.26	.34	.44	.56	.87	1.18	1.87	2.01	3.20	28.59
1985	.11	.19	.29	.45	.70	.95	1.10	1.18	2.32	3.07	27.92
1986	.14	.28	.31	.55	.93	1.61	1.81	2.01	3.18	4.84	47.63
1987	.08	.14	.20	.30	.52	.71	.88	1.50	2.60	3.37	22.04
1988	.17	.21	.22	.31	.50	.96	1.09	1.25	1.30	2.42	24.73
1989											
Average	.17	.25	.31	.45	.67	.98	1.24	1.79	2.59	3.66	31.23
Stdev	.07	.09	.09	.14	.18	.31	.43	.81	1.35	1.62	12.94
Rec Max	.32	.38	.44	.83	1.13	1.68	2.43	4.25	6.49	8.07	54.71
Yrs Rec	14	14	14	14	14	13	13	13	13	14	14
CV	.402	.344	.287	.312	.274	.314	.350	.454	.522	.444	.414
Reg CV	.404	.404	.404	.404	.404	.404	.404	.404	.404	.404	.336
Reg Skew	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	0.5
FIC	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
RP 2	.15	.23	.28	.41	.61	.89	1.13	1.64	2.37	3.35	30.39
RP 5	.22	.32	.39	.58	.86	1.26	1.60	2.31	3.35	4.73	39.73
RP 10	.26	.39	.48	.71	1.05	1.54	1.95	2.83	4.09	5.78	45.09
RP 25	.31	.46	.56	.83	1.23	1.81	2.29	3.32	4.80	6.78	51.28
RP 50	.35	.52	.63	.94	1.39	2.03	2.57	3.73	5.39	7.61	55.47
RP 100	.39	.57	.70	1.03	1.53	2.24	2.84	4.12	5.96	8.41	59.46
RP 200	.42	.63	.77	1.13	1.67	2.45	3.11	4.50	6.51	9.19	63.14
RP 500	.47	.70	.85	1.26	1.86	2.72	3.45	5.00	7.23	10.21	68.80
RP 1000	.50	.75	.92	1.35	2.00	2.93	3.72	5.39	7.79	11.00	71.22
RP 10000	.62	.92	1.12	1.66	2.45	3.59	4.56	6.60	9.55	13.48	81.82

APPENDIX F

POINT REYES NATIONAL SEASHORE WATER QUALITY MONITORING PLAN

STUDY PLAN

DOCUMENT IMPACTS OF GRAZING, AGRICULTURE, AND RECREATION ON KEY WATER RESOURCES

-REVISED DECEMBER 1999-

Point Reyes National Seashore

PORE-N-65.001

PROGRAM IMPLEMENTATION: APRIL 1998 - OCTOBER 2000
TOTAL WRD FUNDING: $46,000
TOTAL BUDGET: $77,600

PROJECT MANAGER

Brannon Ketcham
Hydrologist
National Park Service
Point Reyes National Seashore
Point Reyes Station, CA 94956

ABSTRACT

Point Reyes possesses extremely diverse, valuable, and sensitive water-related resources that are dependent upon the water quality in the park's streams, lakes, bays, lagoons, estuaries and wetlands. The park is also charged with preserving agricultural operations, including ranching and dairying, which contribute substantially to the cultural landscape. Nonpoint source pollution is both extensive and persistent in the 20,000-acre pastoral zone. The Seashore is committed to protecting the quality of all surface and ground waters consistent with the 1987 Clean Water Act and other federal, state, and local laws (NPS, 1991). This project will (1) document the impacts of grazing, agriculture and recreation on the park's water quality, (2) develop management recommendations to address these current impacts, and (3) initiate long-term monitoring to track trends and enable the park to identify and address future problems.

STATEMENT OF PROBLEM

The waters of the Point Reyes National Seashore (PORE) are recognized nationally as having some of the most intact estuarine systems. The Seashore also possesses extremely diverse, valuable, and sensitive water-related resources that are dependent upon the water quality in these systems. These resources include five federally listed threatened or endangered species: Coho salmon (*Oncorhynchus kisutch*), Steelhead trout (*Oncorhynchus mykiss*), California red-legged frog (*Rana aurora daytoni*), and the Pacific freshwater shrimp (*Syncharis pacifica*).

The park waters are also important recreational resources. Located less than 40 miles from the San Francisco Bay area, the park is visited by over 2.5 million people annually. Many of the beaches, estuaries, ponds, and lakes provide recreational opportunities ranging from birding and hiking to swimming, kayaking, and canoeing. In fact, the February 23, 1997 edition of the San Francisco Chronicle named Bass Lake as the number one place in the Bay Area to go swimming.

Grazing, agriculture, and recreational use of the Point Reyes National Seashore waters pose a substantial threat to these resources. The extent of the impacts of these activities needs to be thoroughly and systematically documented to enable the park to target its control of nonpoint sources toward the most acute problems. Once documented, the National Park Service can work cooperatively with the permittees to reduce water quality impacts.

Threats to Water Quality

Agriculture is recognized as a major source of sediment and nutrients into the nation's waters. Water quality monitoring of a few coastal watersheds identified a significant difference in pollutant concentrations between agricultural and wilderness watersheds (Hagar personnel communication). Grazing and direct access to water bodies are the most common types of nonpoint sources in the Seashore. Degraded riparian zones, unstable banks, and sediment producing gullies are common in the pastoral zone. Upland sources and gullies are also most likely to be sources of sediment and nutrient runoff during storm events. In the summer, direct access by cattle may be extremely detrimental in areas where base flow is very low.

Dairy and stable operations are defined as Confined Animal Operations (CAO)(RWQCB 1995). The minimum design and management standards, (California Code of Regulations, Title 23, Chapter 15, Article 6), prohibit the discharge of facility washwater, animal wastes, and stormwater runoff from animal confinement areas into the waters of the state. Within the park, all dairy operations have waste storage lagoons. In designated impact areas, best management practices have not been established to minimize runoff. These areas have the greatest potential for nonpoint source contributions. In pastures without exclusionary fencing, riparian degradation and direct livestock access to the stream corridor pose the greatest threats.

Increased recreational use of the water resources has raised concern over the impacts of access and pollution. The banks of these areas are both denuded of vegetation and subject to erosion. In addition, the lack of sanitary facilities in proximity to many of these areas increases the likelihood of human waste pollution.

Risk to Resources

Water quality degradation poses risks to the natural resources as well as the recreational users. As noted, four threatened or endangered aquatic species are found within the Seashore. The great number of recreational users increases the risk of human exposure to bacteriologic levels greater than allowable levels as determined by the California Regional Water Quality Control Board (RWQCB 1995). Over the years a number of cases involving skin irritation have been linked to the water, but the causes have not been identified.

This project will identify watersheds and water bodies which tend to have higher pollution levels than would be considered normal. Establishing long-term biological sampling sites will augment standard bacteriologic and nutrient testing. These will be used to track the ambient water quality condition in these areas managed for agriculture. By identifying the baseline water quality information, managers will better be able to quantify the risks to both humans and threatened wildlife species.

Objectives

Point Reyes National Seashore is charged in its enabling legislation and subsequent amendments with balancing the need to save and preserve the water related components of the National Seashore with the need to preserve the agricultural operations, including ranching and dairying, which contribute substantially to the cultural landscape. Twenty thousand acres (nearly 25% of the lands administered by the park) are leased to private operators under Agricultural Special Use Permits (SUP). Five dairies, one stable, and a number of beef cattle ranches are operated under such lease agreements. These leases are located on some of the most sensitive watersheds in the park, including Drakes and Limantour esteros, Abbotts Lagoon, Olema Creek, Pine Gulch Creek, and the Tomales Bay.

A complete inventory of the water quality within the park has never been performed. Neither has any sort of program been established to document the condition of and threats to the watersheds located within the Point Reyes National Seashore administrative area. The purpose of this project is:

* To document the impacts of grazing, agriculture, and recreation to the park's water quality.

* To develop management recommendations to address these current impacts.

* To initiate long-term monitoring to track the trends and enable the park to identify and address future problems.

Water quality testing will be performed within a number of watersheds throughout the park. Results of bacteriologic, nutrient, sediment, and biological analyses will provide the Seashore with a baseline of information in order to make more educated resource management decisions. Establishment of these sampling stations will be valuable for future monitoring and management, as well as potential research.

The preservation of cultural resources means that dairy and cattle operations will continue for the foreseeable future. With these legislative goals, the park should establish a long-term, threats-based water quality monitoring program to identify at-risk watersheds. Collection and analysis protocols established by this program will facilitate the implementation of a long-term monitoring program.

Background

Streams and water bodies within the Seashore, including Drakes Estero, Limantour Estero, and Abbotts Lagoon have been identified as high value water resources, yet the only regular water quality monitoring in these areas has been performed by the California Department of Health Services shellfish harvest testing programs (Gomsi 1996). Limited information is available for most other drainages.

In most National Park Service areas, water quality problems are often derived from activities outside of the park jurisdiction. Point Reyes National Seashore is unusual in that most of the affected watersheds lie almost entirely within the boundaries of the Seashore administrative area. The administration has the authority to alter agricultural/ranching operation SUPs to protect the park's natural resources once a threat is documented.

Given adequate information, the park has demonstrated its willingness and ability to act. Samples taken at the mouth of Olema Creek exceeded the non-contact recreational limit of 4,000 MPN, 33% (n=15) of the time. At a site two miles upstream, the limit was exceeded only 10% (n=20) of the time (RWQCB 1996; Vore 1996). Cattle grazing near the creek were identified as the source of this pollution and are being fenced out. This program, in concert with the Coho salmon and Steelhead trout Restoration Project (CSRP), will identify sites where prescriptive actions may be implemented to protect both water quality and aquatic habitat.

Recent national and local events illustrate both the responsibility of the park to monitor water quality, and possible legal liabilities. The lawsuit filed against the Channel Islands National Recreation Area and the 1 million-gallon sewage spill resulting in a three month closure of Tomales Bay to shellfish harvesting (NMWD 1996), are just two such examples.

PROJECT DESIGN

The project is designed to identify both the source and general condition of:

- ambient water quality (nutrient data, macroinvertebrate sampling)
- direct effects on aquatic species (nutrient data, turbidity, invertebrate sampling)
- aquatic habitat (sediment levels, riparian condition, macroinvertebrate sampling)
- human health (bacteriologic data)
- sensitive hydrologic systems (sediment levels, turbidity)

The park, in cooperation with the Water Resources Division and local water quality laboratories, has developed the protocol for sample collection and handling. It is designed to insure that all samples are handled in accordance with EPA approved standard methods.

Sample watersheds and sub-watersheds for sampling were identified based upon five criteria: the presence of a threatened of endangered species, the presence of pastoral activities, the degree of recreational use, the sensitivity of downstream ecosystems, and restoration potential. These sites were then broken down into three categories: recreational areas, streams, and ponds/impoundments.

Sample Collection

The monitoring program is broken down into stream sites (23), recreational use sites (3), and ponds/impoundments (15) (Map 1). Stream sites have been selected based upon watershed sensitivity and land use. Recreational use sites are those which are used mainly for recreational purposes including fishing and swimming. Pond sites will be monitored by the USGS – Biological Resources Division (BRD). A subset of watersheds has been identified for invertebrate trend analysis. These watersheds and sample sites are shown in Map 2.

The methods that will be used for the handling and analysis of samples are documented in the METHODS section (p. 7)

Stream Sites

A number of the streams within the pastoral zone either support, or have the potential to support endangered or threatened species. The potential for nonpoint source pollution is high in these areas where dairy and beef ranching is on-going. Mobilization of sediment and transport of nutrients and bacteria from these upland sources occurs during storm events. In watersheds where livestock have direct access to the stream, pollutant levels may also be abnormally high. Pollutants transported to the stream are often delivered to particularly sensitive marsh and estuarine systems.

Seventeen watersheds or sub-watersheds have been identified for this initial phase of monitoring, with a total of 23 separate sampling sites. They are spread throughout the park, in both pastoral and wilderness zones (Map 1). Sampling will be performed six times per year. Five winter flow, and one fall base flow sample will be collected at each site. Bacteriologic, nutrient and sediment levels will be analyzed for each of these sample events (Table 1). More detailed description of the analysis procedures and techniques are described in the METHODS section. The winter samples are designed to monitor pollutant response to storm runoff events. The fall base flow sample will be indicative of direct livestock access or other persistent pollution sources. Additional sediment and nutrient samples may be collected on a site-specific basis. All of the testing parameters will be correlated with field measurements of flow at each site.

Twenty sites are located within pastoral watersheds with varying degrees of agricultural activities, and three sites are representative of wilderness watersheds. Monitoring will help identify differences in nonpoint source pollution based upon land-use activity. Data collection in this initial phase will provide information as to which watersheds have the most acute problems and where later surveys should be concentrated.

The park hydrologic technician and the range conservationist will be in charge of stream sample collection. The field collection protocol is described in Appendix A.

Recreational Use Sites

A number of ponds within the park administrative area are used regularly for recreation. Kayaking and canoeing is common on the lagoons and estuaries associated with both Tomales Bay and Drakes Bays, while swimming is popular in some of the lakes and ponds within the park. The park is obligated to monitor conditions for human health protection.

The State Regional Water Quality Control Board (Region 2) has set bacteriologic limits (most probable number of fecal coliform units) for contact and non-contact recreational use. For activities including swimming, 90% of the samples must be less than 400 MPN/100ml. For non-contact recreation, such as boating or fishing, the limit is an order of magnitude higher, or 4000 MPN/100ml.

Regular bacteriologic sampling will be performed to establish a reliable base of information. In the second year of testing there will be enough samples to enforce closures if these requirements are violated.

Three sites that will be sampled twice per month between May and October of each year (Table 2). Recreational use coincides with the hotter months, typically June through October. A member of the park's Visitor Protection Division will sample each of these sites. The sampling will be performed on a regular schedule to coincide with laboratory pick-up of drinking water quality samples. Samples will be delivered to the Brelje and Race Laboratories ice chest at the park headquarters for pick-up and analysis.

Assigned personnel will be provided with collection training, a pH meter, thermometer, an insulated carrier, blue ice, and sterilized sample bottles. A limited number of field parameters including water and air temperature, pH, and general conditions will be noted on a field collection data sheet. The sampling protocol and field sheet are shown in Appendix B. Samples will be collected in the morning and returned for pick-up prior to 2pm. The lab will perform the sample analysis, supply collection bottles, and report the results as necessary.

Macroinvertebrate Sampling

Spring and fall macroinvertebrate sampling will be performed to monitor the productivity of some selected watersheds within the park. Macroinvertebrate density and distribution is used in many states as an indicator of water quality conditions. The California Stream Bioassessment Procedure (CSBP) is a standardized protocol for assessing the biological and physical conditions of wadable streams in California. The CSBP is a regional adaptation of the national Rapid Bioassessment Protocols outlined by the U. S. Environmental Protection Agency (Plafkin et al. 1989). The State of California has adopted this method and the Department of Fish and Game is currently in the process of developing reference conditions. Sampling will be concentrated in four of the park watersheds (Table 3).

Selected watersheds will have at least two collection sites. Sites have been selected in areas where physical characteristics and substrate composition are similar. When these habitat characteristics are held constant, differences in invertebrate composition, diversity, and productivity are indicative of point or non-point source impacts to the stream.

Collection of field samples will be performed park staff. Separation and analysis of the invertebrate samples will be performed thorough a contractor.

The procedures for sample collection and site habitat assessment are included in Appendix C.

Ponds/Impoundments

Existing natural ponds and man-made impoundments are located in upland pastoral and wilderness areas. These closed systems are most sensitive to sediment and nutrient inputs. The long residence time and large surface area make the bodies highly susceptible to seasonal thermal changes.

Ponds and impoundments that are known to support the California red-legged frog will be monitored to identify potential correlation between population and water quality changes. Park scientists, working for the U. S. Geological Survey - Biological Research Division (BRD) have implemented this component of the program. Regular monitoring of bacteria, nutrient, and turbidity levels in these water bodies will provide detailed information regarding seasonal water quality change in these closed systems. Fifteen ponds and impoundments, located in both pastoral and wilderness areas, were selected based upon three years of BRD population monitoring.

Sample collection and analysis techniques are similar to those described for the stream sites.

METHODS FOR SAMPLE HANDLING AND ANALYSIS

Four samples will be collected at each stream site. One, a bacteriologic sample, will be collected in a sterilized bottle provided by the analytical laboratory. Two, 1-quart bottles will be collected for nutrient analysis by the analytical laboratory. Finally, a 1-liter bottle will be collected and separated at the park wet-lab for sediment analysis.

Bacteriologic samples will be delivered to the Marin County Public Health Laboratory or Brelje and Race Laboratories the afternoon of the collection date. Nutrient samples will be delivered to Brelje and Race Laboratory on the afternoon of the collection date as well. The holding time for the sediment samples will not exceed 7 days. Samples will be stored on blue-ice or in a refrigerator at all times.

At the time of collection, the following field measurements will be taken:

* water and air temperature -- standard hand-held thermometer
* pH -- Oakton pH meter
* conductivity -- YSI-30 probe
* dissolved oxygen -- YSI-55 probe or LaMotte DO test kit
* flow rate -- Marsh-McBirnie Flow-mate 2000 or pygmy meter depending upon flow

Detailed collection protocol and field sheets are shown in the appendices. Each collection site will be located in UTM coordinates using Global Positioning System technology. The documentation and photos of each site will be compiled and stored in the park hydrologic files.

Bacteriologic Sample Analysis

An agreement has been established between the Park and the Marin County Public Health Laboratory (MCPHL) and Brelje and Race Laboratories for bacteriologic sample analysis. Levels of total coliform and fecal coliform will be reported. The sample handling protocol has been taken from the MCPHL requirements. These samples will be collected, stored on blue-ice, and delivered to one of the labs on the day of collection. The labs will provide the project with sterilized containers for collection.

The contact person at the MCPHL is:

Kay Flink
Marin County Public Health Laboratory
920 Grand Avenue
San Rafael, CA 94901
(415) 499-6849
Laboratory hours: M-F 8am to 5pm

The contact person at Brelje and Race Laboratories is:

Ann Hill
Brelje and Race Laboratories
425 South E Street
Santa Rosa, CA 95404
(707) 544-8807
Laboratory hours: 8am to 5pm all week

Nutrient Sample Analysis

Nutrient analysis will be performed by Brelje and Race Laboratories. These include nitrate, nitrite, ammonia, and orthophosphate. Samples will be processed within 48 hours of collection.

Sediment Analysis

Sediment samples will be separated in the laboratory. The sample will be vigorously shaken and then 300 ml poured into a clean holding container. The samples will be analyzed at the Golden Gate National Recreation Area (GGNRA) wet lab. The GGNRA has the equipment necessary to filter, dry and weigh the sediment sample. Results for suspended sediment will be reported in mg/100ml. Turbidity will be analyzed using a Hach DR/800 colorimeter and will be reported in FAU.

Macroinvertebrate Sample Analysis

Baseline invertebrate sampling will be performed in a sub-set of streams to establish benchmark conditions (Map 2).

Kick samples will be collected at each site. These samples will be separated using the grid separation method and then preserved using 70% ethanol. Three hundred invertebrates will be picked from each sample for identification. A contractor will be hired to identify individuals to the lowest taxonomic level and perform statistical analysis of the population composition and density.

In conjunction with the invertebrate sample collection, an assessment of riparian habitat will be performed based upon the guidelines provided in the CSBP. The stream habitat characteristics are assessed using a ranking system ranging from optimal to poor condition. This rapid ranking system relies on visual evaluation and is inherently subjective. The CSBP provides instructions and procedures to standardize the individual observations and reduce differences in scores.

These data will add to the scope of hydrologic and water quality information collected at each of the long-term sample sites. Comparison of yearly data is important to identify trends to the water quality conditions.

QUALITY CONTROL AND QUALITY ASSURANCE

To avoid contamination, samples will be collected with gloved hands. In the field, probes will be rinsed in the pond or stream prior to the reading of parameter levels. Bacteriologic samples will be collected in sterilized bottles provided by the MCPHL, sealed upon collection, kept on blue-ice, and delivered within 8 hours for analysis. The analytical laboratory will be responsible for laboratory QA/QC checks.

The sediment samples will be analyzed in a wet lab at the park. Procedures will be taken directly from Standard Methods for the Examination of Water and Wastewater. Laboratory glass and equipment will be cleaned using de-ionized water and rinsed with a portion of the particular sample. For quality assurance in the park wet lab, 10% of the sediment samples will be replicated per testing session. Selections will be random.

Quality control of the macroinvertebrate sampling techniques is described in the CSBP protocol. These methods will be employed during the sample site selection and collection, sample processing, and identification.

DATA MANAGEMENT

Data management is an important component of this water quality monitoring program. It will be performed throughout the course of the study. In order to maintain, catalog and analyze the data, records will be entered into a Microsoft Access database. All raw data will be stored according to examples provided in a number of WRD Water Quality Analysis and Interpretation documents (Long, et. al., 1995) so that it may be archived in the EPA STORET database.

The park GIS facilities will be used extensively. Watershed scale impact matrices will be developed based upon various coverages available to the park. The park also has access to 1:4,800 scale digital orthophotos that will be used to identify pollution point sources and the physical condition in each watershed. The database will be geographically linked to the GIS system, and will be important in performing trend analysis.

Ultimately this water quality information will be used to identify areas requiring alternative water quality management practices, riparian protection, or restoration. Results from water quality testing will enable the Seashore to make management decisions which are in accordance with NEPA, the Clean Water Act, the Endangered Species Act, and National Park Service Policies. This study plan is consistent with the draft Point Reyes Water Resource Management Plan, NPS-77, the PORE Natural Resource Management Plan, and the PORE General Management Plan.

PERSONNEL

Project Manager
Brannon Ketcham
Hydrologist, PORE

David Press
Natural Resource Specialist, PORE

William Shook, PORE
Chief of Resource Management

Range Management Specialist

Principal Investigator for Pond/Impoundment sites:
Dr. Gary Fellers
USGS-BRD Scientist

DELIVERABLES

Implementation of a standardized water quality monitoring program will provide the park resource managers with the information:

* To identify and prioritize threats to water and natural resources.
* To implement prescriptive actions through the Range Division at priority sites.
* To perform water quality trend analyses for a number of sample sites.
* To develop and implement specific watershed management recommendations.
* To create GIS data layers and linked databases.
* To train park staff for a long-term monitoring program.

Annual progress reports will be delivered to the Water Resources Division in June of 1999 and 2000. Because of the timing of sample collection, and the fiscal year, sampling may not begin until the spring of 1999. The project calls for 5 wet and 1 dry sample. All of the wet samples should be taken during the same water year. For this reason, winter sampling will not be performed until WY 1999. A final timeline will be developed based upon the time of fund transfer, and consultation with the WRD.

The progress reports will include discussion of the sample sites, results, and subsequent management actions based on these results. It will discuss any problems encountered and changes made in the course of the study. It will also identify the steps to be taken in the subsequent year. All raw data will be stored according to examples provided in a number of WRD Water Quality Analysis and Interpretation documents (Long, et. al., 1995) so that it may be archived in the EPA STORET database.

Draft and final reports will be submitted to the park administration, the Pacific West Region Office, and the Water Resources Division by December of 2000. These reports will include complete data analysis, interpretation, and management response. The main focus of the report will be to identify problem watersheds, and protocol for more detailed monitoring in those areas. The report will also discuss the incorporation of a long-term, threats based monitoring program into the general resource management plan.

A significant amount of hydrologic, water quality, and biologic information will be collected for each sample site. These data will be of great use for internal management actions or external research. The results of pond/impoundment sampling and correlation with California red-legged frog populations will be reported by the USGS-BRD scientists separately.

BUDGET

Funding requirements are broken down by Point Reyes National Seashore base funds, Water Resource Division funding, and USGS - Biological Research Division support.

	FY1998		FY1999
A. WRD funding breakdown			
Personnel (Hydro Tech GS-07, 0.2 FTE)	$5,600		$5,600
Bacteriologic Analysis (190 samples)	$5,700		$5,700
Invertebrate sample analysis (24/yr)	$3,600		$3,600
Nutrient Analysis and Field Equipment	$7,600		$4,100
Transportation	$1,000		$1,000
Data Analysis	$1,000		$1,500
TOTAL WRD CONTRIBUTION	$24,500		$21,500
B. USGS - Biological Research Division funding			
BRD Personnel (GS-07, 0.1 FTE)	$2,800		$2,800
Bacteriologic analysis (12 mo @ 15 sites)	$5,400		$5,400
Transportation	$1,000		$1,000
Equipment	$2,500		$2,500
Total BRD Contribution	$11,700		$11,700
C. Point Reyes National Seashore support			
Personnel (Range Mgmt Tech GS-07,0.1 FTE)	$2,800		$2,800
Personnel (GIS Technician GS-07,0.1 FTE)	$2,800		$2,800
Total Park Contributions	$5,600		$5,600
D. Marin Municipal Water District analysis* * sample analysis donated in spring of 1997			
Bacteriologic and Nutrient Analysis	$1,000		
Total MMWD Contribution	$1,000		
GRAND TOTAL OF NON-WRD CONTRIBUTIONS	$18,300	(43%)	$17,300(50%)
TOTAL PROJECT BUDGET	**$42,800**		**$34,800**

COMPLIANCE

This project is categorically excluded from NEPA compliance, Departmental Categorical Exclusions, 516 DM, Chapter 2, Appendices 1 and 7, U.S. Department of the Interior. Compliance under Section 106 of the NHPA is likewise not required for this project. Changes in management practices undertaken as a result of this project may require compliance actions.

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Table 1 -- PORE Water Quality Monitoring Stations

Stream Sites

Station and location	Number of Monitoring Events		Contact permitee	Gage Reading/ Flow	Bacteriologic Samples	Nutrient Analysis*	pH	Cond.	Ammonia	Temp.	DO	TSS	Turb
	Dry	Wet											
1 – ABBOTTS LAGOON WATERSHED													
ABB1 Abbotts perennial	1	5	N	Y	X	X	X	X	X	X	X	X	X
2 – DRAKES BAY DRAINAGES													
DBY3 A Ranch perennial	1	5	N	Y	X	X	X	X	X	X	X	X	X
3 – DRAKES ESTERO WATERSHED													
DES2 East Schooner	1	5	N	Y	X	X	X	X	X	X	X	X	X
DES3 Home Ranch	1	5	Y	Y	X	X	X	X	X	X	X	X	X
DES4 Muddy Hollow	1	5	N	Y	X	X	X	X	X	X	X	X	X
DES5 Laguna	1	5	N	Y	X	X	X	X	X	X	X	X	X
4 – LAGUNITAS CREEK WATERSHED													
LAG1 Bear Valley	1	5	N	Y	X	X	X	X	X	X	X	X	X
LAG2 Cheda	1	5	N	Y	X	X	X	X	X	X	X	X	X
LAG3 Devil's Gulch	1	5	N	Y	X	X	X	X	X	X	X	X	x
5 – OLEMA CREEK WATERSHED													
OLM1 Blue Line	1	5	N	Y	X	X	X	X	X	X	X	X	X
OLM2 Giacomini Gulch	1	5	Y	Y	X	X	X	X	X	X	X	X	X
OLM3 Randall Gulch	1	5	N	Y	X	X	X	X	X	X	X	X	X
OLM4 Quarry Gulch	1	5	N	Y	X	X	X	X	X	X	X	X	X
OLM5 Vedanta Creek	1	5	N	Y	X	X	X	X	X	X	X	X	X
OLM10 Olema Creek - Stewart Pasture	1	5	N	Y	X	X	X	X	X	X	X	X	X
OLM11 Olema Creek - BV Bridge	1	5	N	Y	X	X	X	X	X	X	X	X	X
OLM12 Olema Creek - above Vedanta	1	5	N	Y	X	X	X	X	X	X	X	X	X
OLM13 Olema Creek - Truttman Gulch	1	5	N	Y	X	X	X	X	X	X	X	X	X
OLM14 Olema Creek – Five Brooks	1	5	N	Y	X	X	X	X	X	X	X	X	X
OLM15 Olema Creek – above Blueline	1	5	N	Y	X	X	X	X	X	X	X	X	X
OLM16 Olema Creek - Shook's House	1	5	N	Y	X	X	X	X	X	X	X	X	X
6 – PACIFIC DRAINAGES													
PAC1 South Kehoe	1	5	N	Y	X	X	X	X	X	X	X	X	X
PAC2 North Kehoe	1	5	N	Y	X	X	X	X	X	X	X	X	X

* includes unionized ammonia, nitrate, nitrite, and orthophosphorus

Table 2 -- PORE Water Quality Monitoring Stations

Recreational Sites

Station and location	Number of Monitoring Events	Contact permitee	General Field Conditions	Bacteriologic Samples	pH	Temp.
	May-October					
1 – BASS LAKE BAS1 Bass Lake	12	N	X	X	X	X
2 – HAGMAIERS POND HAG1 Hagmaiers Pond	12	N	X	X	X	X
3 – Vision Pond VIS1 Upper Vision Pond	12	N	X	X	X	X

Table 3 -- PORE Macroinvertebrate Monitoring Sites

Selected watershed	Station	Number of Monitoring Events		Contact permitee	Gage Reading/ Flow	pH	Cond.	DO
		Spring	Fall					
DRAKES ESTERO WATERSHED								
EAST SCHOONER (2)								
MP 32.93 Sir Frances Drake culvert	DE1	1	1	N	Y	Y	Y	Y
Near Mt. Vision Rd crossing	DE2	1	1	N	Y	Y	Y	Y
HOME RANCH (2)								
Home Ranch (DES3 site)	DE3	1	1	Y	Y	Y	Y	Y
Above bull pasture	DE4	1	1	Y	Y	Y	Y	Y
MUDDY HOLLOW (2)								
Muddy Hollow Stream Gage	DE5	1	1	N	Y	Y	Y	Y
At the Pump house	DE6	1	1	N	Y	Y	Y	Y
OLEMA CREEK WATERSHED (6)								
Lower end of Stewart Pasture	OL1	1	1	N	Y	Y	Y	Y
Below Bear Valley Road Bridge	OL2	1	1	N	Y	Y	Y	Y
At Vedanta Bridge	OL3	1	1	N	Y	Y	Y	Y
Below Truttman Gulch	OL4	1	1	N	Y	Y	Y	Y
Above North 5-Brooks Bridge	OL5	1	1	N	Y	Y	Y	Y
Above 22.67 inflow	OL6	1	1	N	Y	Y	Y	Y

APPENDIX A

STREAM SITE SAMPLING PROTOCOL

Introduction

Stream site samples will be collected during three to five, winter runoff events and fall base flow. The runoff events are those that occur after the soil has reached saturation. Post-saturation stream-flow response is considered to be significant, primarily due to the contribution from overland flow. The sample events and approximate time frame are shown below.

"first flush"	(November-December)
mid-winter	(December-January)
mid-winter	(December-January)
mid-winter	(December-January)
spring flow	(March-April)
fall base flow	(August-September)

Exactly when these events occur are difficult to predict. The hydrologist will monitor stream-flow and soil saturation to determine when the first flush event occurs. Other events will be sampled based upon available time, and individual storm events during the identified period of time.

All efforts should be made to sample the rising limb of the hydrograph. This is not always possible. Field conditions should help to determine whether the sample was taken on the rising or falling limb. This should be noted on the field collection data sheet.

Sample Plan Development

Depending upon the runoff event and personnel availability, not all of the sites may be sampled in a single day. In this case, the number and sampling route should be determined prior to leaving headquarters. This will simplify the collection process and insure that collected samples are delivered and analyzed within the required time frame.

Gearing Up

A number of steps should be taken at the office to insure that all of the equipment is in the vehicle.

1. Required Equipment

Sterile water sample bottles, with labels
Sterile 1-quart sample bottles, with labels
Sterile 1-liter sample bottles, with labels
Disposable rubber gloves
Field collection data sheet
Water sampling stick (broom handle with hose clamp on the end)
Thermometer
Conductivity Meter
DO Meter*
pH meter*
Ice Chest
Blue ice
Flow meter
Wading Rod
50m measuring tape

Chaining pin

* Calibrate at the start of each sampling day.

2. Notify the Marin County Public Health Lab and/or Brelje and Race Laboratories of the intent to sample. MCHL is open Monday-Friday (8am to 5pm) at (415) 499-6849. Authorization by those named on the purchase order is required. Ask to speak with Babs, Kris, or Kay. Let them know the type of water, number of samples, date, analysis to be performed, and the expected time of delivery to the lab. Try to get the samples to the lab by 3PM.
   Brelje and Race Laboratories are open seven days a week (9am to 5pm) at (707) 544-8807. Ask to speak with Anne Hill. Samples can be delivered to the B&U refrigerator by 2pm on Tuesdays, or to Brelje and Race Laboratories in Santa Rosa by 4pm. Take 101 N to HWY 12 East in Santa Rosa. Take the first exit off HWY 12 on to South E St. Turn left. 425 South E St., two blocks on the left. Parking lot in back.
   The Water Quality Monitoring Project Coordinator will determine which lab will be used for the sampling event.

3. Check that enough sterile bacteriologic sample bottles (supplied by the labs), 1-quart sample bottles (supplied by Brelje and Race) and 1-liter sample bottles, and labels are on hand. If there are not enough, whirl pack sample collection bags may be used as a substitute under low flow conditions.

In the Field

4. Upon arriving at the sample site, note the height of the water on the gage and general site conditions. Insure that the site can be safely sampled. Note the general field conditions including time of day, rain/no rain, rising/falling limb, water color, runoff conditions, etc.

5. Four water samples should be taken at each sampling site. A 1-liter bottle will be used for in-house sediment analysis. Two 1-quart bottles should be filled for nutrient analysis by Brelje and Race. A 125 ml bottle will be used for the bacteriologic sample. Use the following procedure to collect the bacteriologic, nutrient, and sediment samples.

   a. Insert empty bottle into hose clamp on the sampling stick.

   a. Carefully remove the cap and hold in one hand so that the inside surfaces of the cap and bottle are not touched or otherwise contaminated.

   b. Avoiding visible debris, dip the bottle underwater, mouth down, and with a slow forward sweeping motion turn bottle right side up and fill. The sample should be taken approximately six inches below the surface, but not deeper than one foot.

   c. Bring the bottle to the surface, tipping out a small air space.

   d. Carefully replace the cap, without contaminating the sample, and screw on tight. [NOTE: If the sample bottle accidentally becomes contaminated, DO NOT USE; sample with another bottle and return the contaminated bottle to the lab for re-sterilization.]

e. Record the station, date, time, and your name on the field sheet and the bottle label.

f. Place the sample bottle in an ice-chest. [NOTE: Use blue ice (provided), not wet ice to avoid possible contamination by contact with the melt water.]

g. NOTE – MUCH OF THIS MAY BE PERFORMED AT HIGH FLOW. BE SURE THAT THE BOTTLE IS SECURELY ATTACHED TO THE SAMPLING ROD, AND THAT YOU HAVE ANALYSED THE SAFETY OF THE SITUATION.

6. Record the water and air temperature at each site, to the nearest ½ degree centigrade. These temperatures should be read after 1 minute in the medium. DO NOT take the temperature from the collected water sample. Record the water temperature on all bottle labels.

7. Take the salinity, conductivity, and specific conductance using the YSI-30 probe. Insert the probe into the thalweg and allow it to equilibrate for 30 seconds. Be sure that the entire probe is below the surface. Record each reading. The mode button should be pressed to check different parameters. Note the temperature displayed on the probe.

8. Take the pH using the calibrated Oakton pH meter. Allow the level to stabilize before taking the reading. Record the pH on all bottle labels.

9. Take the dissolved oxygen (DO) level using the YSI-55 probe. The probe must be stirred rather vigorously to gain an accurate measurement. Once the fluctuation is less than .02 mg/l of oxygen then the reading should be taken. Note the temperature displayed on the probe. [NOTE: This should be calibrated at the beginning of each sampling day using the instructions provided in the manual.]

10. Record the height of the water on the staff gage.

11. The flow velocity will be taken using the Marsh-McBirnie flow-mate 2000. At road crossing sites, the water depth and average velocity at the center of the culvert should be taken. Manning's equation will be used to calculate flow at these sites. Flow at open channels will be determined by taking eight to ten flows at intervals across the channel. Be sure to take flows at all breaks in the gradient of the stream bottom and changes in flow velocity. At water levels below 2.5ft, a single flow measurement at 0.6 of the depth below the surface will be taken. Above 2.5ft, two points at 0.2 and 0.8 of the depth should be read. Collection personnel will be trained to collect stream-flow information. Measured flows will be used to develop a rating curve, which will be used to reduce future sample collection times.

12. These steps should be performed at each sampling site. The Field Collection Data Sheet should be completed on site. Feel free to add any additional observations regarding site conditions, etc.

13. Deliver the Field Collection Data Sheet to the Water Quality Monitoring Project Coordinator.

Field Collection Data Sheet
Stream Site

Station: ______________________________ Date: _______________
Location: ____________________________ Time: _______________
Sample Number: _______________________ Collected By: _______________

Field Parameters

Air Temperature (C)

Oakton pH Meter
pH

YSI 30

Temperature	C
Specific Conductance (flashing)	uS/cm
Conductivity (not flashing)	uS/cm
Salinity	ppt

YSI 55

Temperature	C
Dissolved Oxygen	mg/l
Oxygen %	

General Field Conditions
____
____

Flow Monitoring

Gage Height __________ft **Flow** __________cfs
Bed Level __________ft **Stream Width** __________ft

Flow Worksheet

Station	Depth	Velocity
REW:		
LEW:		

Channel Type (circle one)
Dimensions

Open Channel			
Box Culvert	Width	Height	Water Level
Round Culvert	Diameter	Surface R S	Water Level

(R) rough surface, (S) smooth surface

Sediment Analysis

		Date	Initials
TSS	mg/100ml		
TSS Duplicate	mg/100ml		

Water Quality Laboratory Sheet

Stream Site

Station: ______________________ Date Collected: ______________________
Location: ______________________ Time Collected: ______________________
Sample Number: ______________________ Collected By: ______________________

Field Parameters

Air Temperature (C)

Oakton pH Meter
pH

YSI 30

Temperature	C
Specific Conductance	uS/cm
Conductivity	uS/cm
Salinity	ppt

YSI 55

Temperature	C
Dissolved Oxygen	mg/l
Oxygen %	

Gage Height __________ft
Bed Level __________ft
Flow __________cfs
Stream Width __________ft

Lab Results

Nutrient Analysis

	Total (mg/L)	Date	Time	Initials
Nitrate				
Nitrite				
Orthophosphorous				
Ammonia				

Sediment Analysis

	Total	Date	Initials
TSS	mg/100ml		
TSS Duplicate	mg/100ml		
Turbidity	FAU		

Bacteriological Analysis
Marin County Health Laboratory

Lab Report #: ______________
Elapsed Time: ______________
Total Coliform: __________(MPN)
Fecal Coliform: __________(MPN)

Water Quality Field and Laboratory Sheet
Pond/Impoundment Site

Station: ___________________________ Date Collected: _______________________
Location: __________________________ Time Collected: _______________________
Sample Number: ____________________ Collected By: _______________________

Field Parameters

Air Temperature (C)

Oakton pH Meter pH

YSI 30

Temperature	C
Specific Conductance	uS/cm
Conductivity	uS/cm
Salinity	ppt

YSI 55

Temperature	C
Dissolved Oxygen	mg/l
Oxygen %	

General Field Conditions

____
____

Lab Results

Nutrient Analysis

	Total (mg/L)	Date	Time	Initials
Nitrate				
Nitrite				
Orthophosphorous				
Ammonia				

Sediment Analysis

Turbidity: ____________ FAU
Date: ________________
Initials: ________________

Bacteriological Analysis
Marin County Health Laboratory
(415) 499-6849

Lab Report #: __________________
Elapsed Time: __________________
Total Coliform: __________ (MPN)
Fecal Coliform: __________ (MPN)

APPENDIX B

RECREATIONAL USE SITE SAMPLING PROTOCOL

Required Equipment

4 sterile water sample bottles, with labels
Disposable rubber gloves
Field collection data sheet
Water sampling stick (broom handle with hose clamp on the end)
Thermometer
pH meter
Insulated pack
Blue ice

Water Sampling Procedure

1. Collect samples twice per month between April and October.

    a. Samples should be collected on a Tuesday morning and delivered to the B&U refigerator, **before 2pm**. The refrigerator is located in the B&U building across from John Ryan's office.

2. Collect a single sample from each of the sampling locations.

    a. **Bass Lake** – 1^{st} and 3^{rd} Tuesday of the month
    b. **Hagmaiers Pond** – 1^{st} and 3^{rd} Tuesday of the month
    c. **Vision Pond** – 2^{nd} and 4^{th} Tuesday of the month

3. Collect 1 water sample at each site using the following technique:

    a. Insert empty bottle into hose clamp on the sampling stick.

    b. Carefully remove the cap and hold in one hand so that the inside surfaces of the cap and bottle are not touched or otherwise contaminated.

    c. Avoiding visible debris, dip the bottle underwater, mouth down, and with a slow forward sweeping motion turn bottle right side up and fill. The sample should be taken approximately six inches below the surface, but not deeper than one foot.

    d. Bring the bottle to the surface, tipping out a small air space.

    e. Carefully replace the cap, without contaminating the sample, and screw on tight. [NOTE: If the sample bottle accidentally becomes contaminated, DO NOT USE; sample with another bottle and return the contaminated bottle to the lab for re-sterilization.]

    f. Record the station, date, time, and bottle number on the field sheet and the bottle label.

    g. Place the sample bottle in the insulated pack. [NOTE: Use blue ice (provided), not wet ice to avoid possible contamination by contact with the melt water.]

4. Record the water and air temperature at each site, to the nearest ½ degree centigrade. These temperatures should be read after 1 minute in the medium. DO NOT take the temperature from the collected water sample.

5. Take the pH using the calibrated pH meter. Allow the level to stabilize before taking the reading.

6. Complete the Field Collection Data Sheet for each site.

7. Deliver the Field Collection Data Sheet to the Water Quality Monitoring Project Coordinator.

Field Collection Data Sheet
Recreational Use Site

Sample Site: ______________________________
Sample Number: __________________________ Date: ________________
Collected By: _____________________________ Time: ________________

General Field Conditions

Temperature (C)

Air	Water

pH

Calibrated Today?	**Y N**
pH Reading	

Recreational Use

Describe the general appearance of the pond: ____
____

Water color _______________ Number of people using the water body ____________________

Time delivered to Brelje and Race ice chests: ______________________

Laboratory Results

Laboratory Log Number: __________________________

Parameter	Count	Health Violation Contact	Health Violation Non-Contact
Total Coliform			
Total Fecal Coliform			

RWQCB standards for recreational use: (MPN/100ml)

	TFC
Contact	400
Non-contact	4000

APPENDIX C

INVERTEBRATE SAMPLING PROTOCOL

Introduction

Invertebrate sampling will be performed in selected watersheds and sub-watersheds to detect point and nonpoint sources of pollution and to assess ambient water quality conditions. Samples will be taken once in the fall and once in the spring as recommended by the California Stream Bioassessment Procedure (CSBP). Collection and analysis protocols are taken directly from the latest CSBP version (March 1996).

Sample sites have been identified (Table 3), and are shown in Map 2. Selected sites are paired to compare conditions above and below impact areas. These sites have been selected in areas with similar geomorphic features.

The field component of the invertebrate sampling involves that actual sample collection and a riparian habitat assessment.

gearing up

Before heading out into the field, it is important to have all of the necessary sampling equipment.

Required Equipment

- D-shaped kick-net
- Standard size 35 sieve
- Wide mouthed plastic jars
- 100-meter measuring tape
- Map of sample sites
- Thermometer
- Conductivity meter
- DO meter
- Flow meter
- Chaining pin
- Gloves
- Water sprayer
- Wash bottle
- 95% ethanol
- Labels
- Random numbers table
- California Stream Bioassessment Procedure
- Macroinvertebrate Field Collection Data Sheet

in the field

Samples are to be collected from a single riffle.

1. Upon reaching the sampling site be careful not to walk on the riffle to be sampled. To select a transect, place the measuring tape along the bank of the entire riffle section. Three transect locations should be determined using the random number table. Make sure that at least one transect is located within the top third of the riffle. Record the locations of each transect with reference to the longitudinal tape.

2. Starting from the downstream transect, collect benthic macroinvertebrates from three locations along each transect using the D-shaped kick-net. As much as possible, the three locations should be the side margins and center of the stream. Collect macroinvertebrates by placing the kick-net on the substrate and disturbing a one by two-foot section of substrate upstream of the kick-net to approximately 4 to 6 inches in depth. Pick-up and scrub large rocks by hand under water in front of the net. Maintain a consistent sampling effort (approximately 1-3 minutes) at each site. Combine the three collections within the kick-net.

3. Using the water sprayer, wash the contents of the net to the bottom. Remove large organic material by hand after carefully washing of clinging organisms. Ring out the contents of the net as much as possible. Place a large mouthed jar in the sieve, and then invert the contents of the net into the jar. Whatever spills out of the net will collect on the sieve. Tilt the sieve and spray the contents to the bottom. Using the wash bottle filled with 95% ethanol, spray the contents of the sieve into the jar from the bottom side of the sieve out. Add an ample amount of 95% ethanol to the jar. Place labels on the inside and outside of the jar. If more than one jar is needed for the contents of the net, be sure to label the jars "Jar __ of __", etc.

4. Once the macroinvertebrate samples are collected, it is time to perform the Habitat Assessment. The CSBP provides a two sheet form which helps the observer rate the condition of instream cover, epifaunal substrate, embeddedness, channel alteration, sediment deposition, frequency of riffles, channel flow status, bank vegetative protection, bank stability, and riparian vegetative zone width. These sheets have descriptors which correspond with the ratings. The Habitat Survey should be completed on-site.

in the laboratory

5. Empty contents of the jar(s) into a tray with numbered grids (24, 2 sq. in.), and evenly distribute the contents on the bottom of the tray.

6. Choose five or more grid numbers using a random numbers table. Starting with the first grid, remove all of the material and place in a petri dish. With the dissecting microscope, remove, count, and place macroinvertebrates in a clean labeled vial filled with 70% ethanol. Using as many additional grids as necessary, remove a total of 300 macroinvertebrates from the sample. Record the number of macroinvertebrates counted on each grid. If all of the macroinvertebrates were not removed from the last grid, then place a "P" next to the number to signify that the last grid was partially processed to attain the required 300 organisms. Remove the remaining macroinvertebrates from the last grid and place in a separate, labeled vial containing 70% ethanol.

7. The debris from the processed grids should be put in a clean "remnant" jar and the remaining contents of the tray should be placed back in the sample jar. Both jars should be filled with fresh 70% ethanol, labeled, and returned to sample depository.

8. Macroinvertebrates will be identified to the lowest taxonomic level using identification keys. Identification will be contracted out as necessary.

Biological data analyses

The CSBP identifies a suite of metrics that should be calculated for each sample. These metrics include species richness, modified Hilsenhoff Biotic Index, percent contribution of dominant taxon, EPT index, community similarity indices, and the diversity index (Plafkin et al. 1989). Relative abundance should also be calculated by adding the number of organisms found in fully processed grids (do not include the last grid if marked by a "P"). Divide the total number by the number of grids used to collect the organisms and multiply by the number of grids in the pan.

Field Collection Data Sheet
Macroinvertebrate Sample Station

Station: ______________________________ Date: ________________
Location: ______________________________ Time: ________________
Location Description: ____________________ Collected By:________________
Sample Number: _________________________

Field Parameters

Air Temperature (C)

[ ]

Oakton pH Meter

pH [ ]

YSI 30

Temperature	C
Specific Conductance	uS/cm
Conductivity	uS/cm
Salinity	ppt

YSI 55

Temperature	C
Dissolved Oxygen	mg/l
Oxygen %	

General Field Conditions/Habitat Comments

____

____

Kick-net Samples

Riffle length: ________m

Transect	Location*	Width	Sample ID
1			
2			
3			

*Measured from pool tailout

Habitat Assessment*

Epifaunal Substrate/ Available Cover	
Embeddedness	
Velocity/ Depth	
Sediment Deposition	
Channel Flow	
Channel Alteration	
Frequency of Riffles	
Bank Stability	**L: R:**
Bank Vegetation	**L: R:**
Riparian Zone	**L: R:**

*Habitat assessment will follow CSBP protocol.

Flow Worksheet

Station	Depth	Velocity
REW:		
LEW:		

Gage Height __________ft
Bed Level ____________ft
Stream Width ________ft
Flow _______________cfs

APPENDIX G

RECREATIONAL WATER QUALITY
SITE REPORTS

Point Reyes National Seashore 1999
Recreational Site Water Quality Summary for Vision Pond

Location	Date	Water Temp.	pH	Total Coliform	Fecal Coliform	TFC Contact Violation	TFC Non-contact Violation
Vision Pond	5/11/99	17	8.6	33	11	N	N
Vision Pond	5/25/99	18.5		79		N	N
Vision Pond	6/8/99	17	8.3	79		N	N
Vision Pond	6/22/99	20	8.4	22		N	N
Vision Pond	7/6/99	18	8	240		N	N
Vision Pond	7/20/99	19	8.7	180	11	N	N
Vision Pond	8/3/99	17.5	8.4	110	2	N	N
Vision Pond	8/17/99	19	8.2	1600	120	N	N
Vision Pond	8/31/99	20.5	8.2	49	33	N	N
Vision Pond	9/14/99	18	8.1	26	2	N	N
Vision Pond	9/28/99	19	7.8	49	2	N	N
Vision Pond	10/12/99	16	7.6	220	23	N	N
Vision Pond	10/26/99	16	7.8	13	8	N	N
Station Summary							
Vision Pond	13	18.1	8.2	208	24	8	

Point Reyes National Seashore 2000

Recreational Site Water Quality Summary for Vision Pond

Location	Date	Water Temp.	pH	Total Coliform	Fecal Coliform	TFC Contact Violation	TFC Non-contact Violation
Vision Pond	4/25/00	15	9	33	5	N	N
Vision Pond	5/9/00	15.9	8.1	95	46	N	N
Vision Pond	5/23/00	20	7.9	23	5	N	N
Vision Pond	6/6/00	16.5	8.2	33	5	N	N
Vision Pond	6/20/00	18.5	8.7	23	8	N	N
Vision Pond	7/5/00	18	7.8	14	6	N	N
Vision Pond	7/18/00	18	7.7	< 2	< 2	N	N
Vision Pond	8/1/00	21	8	> 1600	1	N	N
Vision Pond	8/15/00	19	7.6	70	2	N	N
Vision Pond	8/29/00	19	8.1	13	2	N	N
Vision Pond	9/12/00	19	8.2	64	7	N	N
Vision Pond	9/26/00	18.2	8.5	540	49	N	N
Station Summary							
Vision Pond	12	18.2	8.2	209	12	49	

Point Reyes National Seashore 1999
Recreational Site Water Quality Summary for Hagmaier Pond

Location	Date	Water Temp.	pH	Total Coliform	Fecal Coliform	TFC Contact Violation	TFC Non-contact Violation
Hagmaier Pond	5/11/99	17	8.3	1600	920	Y	N
Hagmaier Pond	6/1/99	16.5	8.7	13		N	N
Hagmaier Pond	6/8/99	16	7.9	33		N	N
Hagmaier Pond	6/22/99	21	8.8	920		?	N
Hagmaier Pond	7/6/99	20.5	8.2	540		?	N
Hagmaier Pond	7/20/99	19.5	9.3	540	79	N	N
Hagmaier Pond	8/3/99	19		110	17	N	N
Hagmaier Pond	8/17/99	18.5	8.5	130	5	N	N
Hagmaier Pond	8/31/99	21	9	49	2	N	N
Hagmaier Pond	9/14/99	18	9.3	240	2	N	N
Hagmaier Pond	9/28/99	19	8.8	79	23	N	N
Hagmaier Pond	10/26/99	14	8.5	540	240	N	N
Station Summary							
Hagmaier Pond	12	18.3	8.7	400	161	240	

Point Reyes National Seashore 2000

Recreational Site Water Quality Summary for Hagmaier Pond

Location	Date	Water Temp.	pH	Total Coliform	Fecal Coliform	TFC Contact Violation	TFC Non-contact Violation
Hagmaier Pond	5/2/00	17.8	8.9	23	< 2	N	N
Hagmaier Pond	5/16/00	15	7.7	11	2	N	N
Hagmaier Pond	5/30/00	18	7.9	49	2	N	N
Hagmaier Pond	6/13/00	20	7.9	540	23	N	N
Hagmaier Pond	6/27/00	20	8	>= 1600	>= 1600	Y	?
Hagmaier Pond	7/11/00	18.5		49	8	N	N
Hagmaier Pond	7/25/00	20	8.5	1600	920	Y	N
Hagmaier Pond	8/1/00	20	7.7	1600	31	N	N
Hagmaier Pond	8/8/00	20	9.4	79	33	N	N
Hagmaier Pond	8/15/00	19	8.1	79	11	N	N
Hagmaier Pond	8/22/00	20	8.1	350	2	N	N
Hagmaier Pond	8/29/00	18	7.5	180	110	N	N
Hagmaier Pond	9/5/00	21	8.4	920	540	Y	N
Hagmaier Pond	9/12/00	16.8	7.9	1986	ecoli	N	N
Hagmaier Pond	9/19/00	23	9	220	33	N	N
Hagmaier Pond	9/26/00	19	7.7	31	2	N	N
Hagmaier Pond	10/3/00	18.1	8.1	33	< 2	N	N

Station Summary

Location	Date	Water Temp.	pH	Total Coliform	Fecal Coliform	TFC Contact Violation	TFC Non-contact Violation
Hagmaier Pond	17	19.1	8.2	550	208	2	

Point Reyes National Seashore 1999

Recreational Site Water Quality Summary for Bass Lake

Location	Date	Water Temp.	pH	Total Coliform	Fecal Coliform	TFC Contact Violation	TFC Non-contact Violation
Bass Lake	6/8/99	16	8.9	5		N	N
Bass Lake	6/22/99	20	8.7	33		N	N
Bass Lake	7/20/99	17	8.9	79	33	N	N
Bass Lake	8/17/99	18	8.5	9	5	N	N
Bass Lake	8/31/99	21	8.6	2	2	N	N
Bass Lake	9/14/99	17	7.7	5	2	N	N
Bass Lake	9/28/99	17.5	7.9	130	2	N	N
Station Summary							
Bass Lake	7	18.1	8.5	38	9	2	

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Recreational Site Water Quality Summary for Bass Lake

Location	Date	Water Temp.	pH	Total Coliform	Fecal Coliform	TFC Contact Violation	TFC Non-contact Violation
Bass Lake	5/2/00	17	9.3	33	23	N	N
Bass Lake	5/16/00	16	8.8	8	< 2	N	N
Bass Lake	5/30/00	18	9.3	180	5	N	N
Bass Lake	6/13/00	20	9	22	2	N	N
Bass Lake	6/27/00	17.5	9	220	23	N	N
Bass Lake	7/25/00	20	8.5	8	< 2	N	N
Bass Lake	8/8/00	21	8.4	14	< 2	N	N
Bass Lake	8/22/00	20	8.2	13	< 2	N	N
Bass Lake	9/5/00	20	8.1	> 1600	5	N	N
Bass Lake	9/19/00	21	8.1	170	26	N	N
Bass Lake	10/3/00	18.8	8.2	2	2	N	N
Station Summary							
Bass Lake	11	19.0	8.6	206	9	2	

APPENDIX H

MACROINVERTEBRATE SAMPLE REPORT
JON LEE CONSULTING