**National Park Service**
**U.S. Department of the Interior**

**Natural Resource Program Center**
**Fort Collins, Colorado**

# San Francisco Bay Area Network Freshwater Quality Monitoring Protocol

*Version 2.11 October 2006*

Natural Resource Report NPS/SFAN/NRR—2006/016

**ON THE COVER**
Watercourses in the San Francisco Bay Area Inventory and Monitoring Netowork
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# San Francisco Bay Area Network Freshwater Quality Monitoring Protocol

Natural Resource Report NPS/SFAN/NRR—2006/016

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U.S. Department of the Interior
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## Change History

| Prev. Version # | Revision Date | Author | Changes Made | Reason for Change | New Version # |
|---|---|---|---|---|---|
| 1.00 | 2-16-05 | Mary Cooprider | Added stream miles table for GPRA goals, addressed comments from WRD on QA/QC, added SOP 1 | Clarification of existing information, minor edits | 1.01 |
| 1.01 | 5-13-05 | Mary Cooprider | Incorporated comments from internal peer view. Several small changes; sampling design change; QAPP changes | Clarification of existing information, addition of information, refining methods and parameters | 2.0 |
| 2.0 | 7-29-05 | Mary Cooprider | Added abstract and maps; updated tables; incorporated comments from technical peer review | Finalizing draft for formal peer review | 2.01 |
| 2.01 | 3/9/06 | Rob Carson | Edits to text and tables | Addressing peer reviewer comments | 2.02 |
| 2.02 | 9/28/06 | Rob Carson | Addresses Sampling Design Issues & Data Management Section | Addressing peer reviewer concerns | 2.1 |
| 2.1 | 10/12/06 | Rob Carson | Minor clarification of Table 2.5, the discussion of table 2.9, and some text in section 2.4 | Suggestions from WRD prior to approval | 2.11 |

1. "Version numbers increase incrementally by hundredths (e.g. version 1.01, version 1.02 …etc) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0 …). Record the previous version number, date of revision, author of the revision, identify paragraphs and pages where changes are made, and the reason for making the changes along with the new version number" (Peitz et al., 2002).

2. Notify the SFAN Lead Data Manager of any changes to the Protocol Narrative or SOP so that the new version number can be incorporated in the Metadata of the NPSTORET database. The Data Manager will then edit the database per any changes to the Protocol Narrative and SOPs.

3. Post new versions on the internet and forward copies to all individuals with a previous version of the Protocol Narrative or SOP.

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# Acronyms and Abbreviations

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|---|---|
| ASBS | Area of Special Biological Significance |
| AWAG | Alhambra Watershed Action Group, Martinez, CA |
| BMP | Best Management Practice |
| BO | Biological Opinion |
| BU | Beneficial Use |
| CALM | Consolidated Assessment and Listing Methodology (EPA) |
| CCCR | Central California Coast Biosphere Reserve |
| CCSF | City and County of San Francisco |
| CDFG | California Department of Fish and Game |
| COE | Army Corps of Engineers |
| CSRP | Coho and Steelhead Restoration Project |
| CWA | Clean Water Act |
| DDT | Dichloro-Diphenyl-Trichloroethane |
| DHS | California Department of Health Services |
| DMMO | Dredged Materials Management Office |
| DO | Dissolved Oxygen |
| EBRPD | East Bay Regional Park District |
| ENSO | El Niño Southern Oscillation |
| EPA | (United States) Environmental Protection Agency |
| EUON | Eugene O'Neill National Historic Site |
| FDA | (United States) Food and Drug Administration |
| FIB | Fecal Indicator Bacteria |
| FOPO | Fort Point National Historic Site |
| GFNMS | Gulf of the Farallones National Marine Sanctuary |
| GMA | General Minerals Analysis |
| GOGA | Golden Gate National Recreation Area |
| GPRA | Government Performance and Results Act |
| HI | Headlands Institute |
| HUC | Hydrologic Unit Code |
| I&M | Inventory & Monitoring |
| IPM | Integrated Pest Management |
| IQR | Interquartile Range (statistical value) |
| MDL | Method Detection Limit |
| MMC | Marine Mammal Center, Sausalito, CA |
| MMWD | Marin Municipal Water District |
| MPA | Marine Protected Areas |
| MPN | Most Probable Number (of bacteria) |
| MQO | Measurement Quality Objective |
| ML | Minimum Level of Quantitation |
| MUWO | Muir Woods National Monument |
| NAWQA | National Water Quality Assessment (USGS Program) |
| NFM | National Field Manual (USGS) |
| NMFS | National Marine Fisheries Service |
| NOAA | National Oceanic and Atmospheric Administration |

## Acronyms and Abbreviations (continued)

| | |
|---|---|
| NPSTORET | National Park Service version of EPA's STORET database |
| ONRW | Outstanding Natural Resource Water |
| PCB | Polychlorinated Biphenyls |
| PINN | Pinnacles National Monument |
| PORE | Point Reyes National Seashore |
| PQL | Practical Quantitation Limit |
| PRBO | Point Reyes Bird Observatory |
| PRES | Presidio of San Francisco |
| QAPP | Quality Assurance Project Plan |
| QA/QC | Quality Assurance/Quality Control |
| RWQCB | Regional Water Quality Control Board |
| SBWD | Stinson Beach Water District |
| SCCWRP | Southern California Coastal Water Research Project |
| SFAN | San Francisco Bay Area Network |
| SFEI | San Francisco Estuary Institute |
| SFRWQCB | San Francisco Bay Regional Water Quality Control Board |
| SOP | Standard Operating Procedure |
| SSC | Suspended Sediment Concentration |
| STORET | Storage and Retrieval (EPA's Water Quality database) |
| SWAMP | Surface Water Ambient Monitoring Program |
| SWRCB | State (CA) Water Resources Control Board |
| TBAG | Tomales Bay Agricultural Group |
| TBSTAC | Tomales Bay Shellfish Technical Advisory Committee |
| TBWC | Tomales Bay Watershed Council |
| T&E | Threatened and Endangered Species |
| TKN | Total Kjeldahl Nitrogen |
| TMDL | Total Maximum Daily Load |
| TSS | Total Suspended Solids |
| TTS | Turbidity Threshold Sampling |
| UCB | University of California-Berkeley |
| UCCE | University of California Cooperative Extension |
| UNESCO | United Nations Educational, Scientific, and Cultural Organization |
| USGS | United States Geological Survey |
| UWP | Urban Watershed Project |
| WRD | Water Resources Division (National Park Service) |
| WTP | Water Treatment Plant |

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## Abstract

The National Park Service Inventory and Monitoring (I&M) Program measures long-term changes in the condition of natural resources throughout the National Park System. As part of this effort, the San Francisco Bay Area Network (SFAN), which encompasses Eugene O'Neil National Historic Site, Fort Point National Historic Site, Golden Gate National Recreation Area, John Muir National Historic Site, Muir Woods National Monument, Pinnacles National Monument, Point Reyes National Seashore, and the Presidio of San Francisco, has developed a detailed water quality monitoring plan. The plan consists of three sections: 1) a protocol narrative, 2) standard operating procedures (SOPs), and 3) supplementary materials. The *protocol narrative* summarizes the significance of aquatic resources in the SFAN with a focus on beneficial uses of freshwater streams. The narrative also discusses the SFAN waters listed as impaired under the Clean Water Act section 303d and describes associated Total Maximum Daily Load (TMDL) projects. The narrative defines the network's water quality criteria and monitoring questions and discusses the use of a rotating basin design and a decision table for selecting streams and monitoring sites. The protocol narrative addresses all aspects of data management and storage and provides an overview of water quality data analysis. Finally, the narrative discusses the expected program budget and personnel qualifications. Specific *SOPs* prescribe personnel training procedures, methods of protocol revision, field equipment preparations, quality assurance/quality control, data analysis and reporting, and monitoring site establishment. Additional SOPs address procedures for sampling specific parameters including core water chemistry (temperature, pH, dissolved oxygen, and conductivity), bacteria, nutrients, sediment, and stream flow. The protocol narrative and SOPs follow techniques outlined by the U.S. Geological Survey (USGS), the State Water Resources Control Board Surface Water Ambient Monitoring Program, and the U.S. Environmental Protection Agency's Western Pilot Study Field Manual for Wadeable Streams. *Supplementary materials* include a preliminary water quality status report for the SFAN, the USGS National Field Manual (on CD), and a USGS tutorial (on CD) for taking flow measurements. The comprehensive collection of information in the protocol narrative, SOPs, and supplementary materials is intended to standardize water quality monitoring and ensure that methods and data are comparable and effective in the long-term.

# 1.0 Background and Objectives

## 1.1 Introduction & Purpose

Ecosystem vital signs are key to the National Park Service's (NPS) Inventory and Monitoring Program (I&M). A vital sign is a physical, chemical, or biological component of the air, water, or land. It is rarely possible to monitor all components, or indicators, of ecosystem health; therefore, vital signs are chosen since they are the most representative of the ecosystem as a whole and/or are most critical to ecosystem function. A goal of NPS Vital Signs Monitoring is to report ecosystem status and trends and to document how much confidence there is in the results. A good summary of vital signs monitoring is provided in An Overview of Vital Signs Monitoring and its Central Role in Natural Resource Stewardship and Performance Management (Fancy, 2005). It states that:

> Knowing the condition of natural resources in national parks is fundamental to the National Park Service's ability to manage park resources. Vital signs monitoring is a key component in the Service's strategy to provide scientific data and information needed for management decision-making and education. Vital signs monitoring also contributes information needed to understand and to measure performance regarding the condition of watersheds, landscapes, marine resources, and biological communities.

Through the NPS I&M program, 270 national park units were organized into 32 networks. In order to improve efficiency and reduce costs, parks were organized into networks that share similar geographic and natural resource characteristics. These networks share funding and a core professional staff to conduct long-term ecological monitoring (Fancy, 2005). The San Francisco Bay Area Network (SFAN) includes Eugene O'Neill (EUON) and John Muir (JOMU) National Historic Sites in Contra Costa County, Fort Point National Historic Site (FOPO) and the Presidio of San Francisco (PRES) in San Francisco County, and Muir Woods National Monument (MUWO) and Point Reyes National Seashore (PORE) in Marin County. Golden Gate National Recreation (GOGA) is located in Marin, San Francisco, and San Mateo Counties. Pinnacles National Monument (PINN) is located southeast of Monterey in San Benito County. Figure 1.1 shows the location of each of the parks.

Freshwater quality monitoring was funded through a NPS Water Resources Division (WRD) initiative and was also recognized as significant at the network level. The significance of water resources within SFAN is reflected in the network's ranking of freshwater quality as 3rd among all of the potential vital signs identified and prioritized by the SFAN. Freshwater quality has *direct* impact on several other indicators including: marine water quality, stream threatened and endangered (T&E) species and fish assemblages, T&E amphibians and reptiles, riparian habitat, wetlands, and aquatic macroinvertebrates. Freshwater quality has *indirect* impacts on all plant and animal life as well as human consumption, recreation, and enjoyment (i.e., the intrinsic value of water). Much of what is on the land is transferred to water via surface runoff, subsurface flow, and base flow (groundwater). Therefore, not only is water quality an indicator of the health of aquatic systems, but it is an important indicator of overall ecosystem health.


Figure 1. Map of San Francisco Bay Area Network Parks (created by Jason Herynk, National Park Service, 2005).

SFAN has many unique aquatic resources that are significant in an ecological and socio-economic context. Aquatic resources in the SFAN include streams, bays, estuaries, lagoons, lakes, reservoirs, freshwater and estuarine marshes, seeps, and springs. The combination of marine and freshwater aquatic systems within the network supports a variety of federal and state listed threatened and endangered aquatic species including the California freshwater shrimp (*Syncharis pacifica*), coho salmon (*Oncorhynchus kisutch*), steelhead trout (*Oncorhynchus mykiss*), the California red-legged frog (*Rana aurora draytonii*), tidewater goby (*Eucyclogobius newberryi* ), Tomales roach (*Lavinina symmetricus ssp 2*), and northwest pond turtle (*Clemmys marmorata mormorata*). Commercial operations include a significant herring fishery in Tomales Bay and San Francisco Bay, oyster growing/harvesting in Tomales Bay and Drakes Estero, and clam and mussel operations in Tomales Bay. Oysters have not been commercially harvested in San Francisco Bay since 1910.

Watershed conditions vary from coastal watersheds in wilderness areas to an urbanized watershed managed as public water supply. Lobos Creek in the Presidio of San Francisco is the only free-flowing (above ground) creek in the city and is the public water supply for the Presidio. Land uses within the more rural watersheds include agricultural and commercial operations (e.g., beef and dairy cattle ranching, vegetable farming, viticulture, oyster harvesting, and equestrian use) as well as predominantly wilderness areas.

The Mediterranean climate of the San Francisco Bay Region creates wet winters followed by dry summers. The resulting hydrology is flashy, with high runoff in the winter, and very low to intermittent flow dominating summer conditions. In response to flashy hydrologic conditions and the highly active geologic processes associated with the San Andreas Fault system, most stream channels are geomorphically dynamic. Chalone Creek in PINN includes a highly mobile sand bed that typically dries in the summer months. Watersheds within JOMU and the developed portions of GOGA are highly altered by development and urbanization. These systems are highly confined/constrained, with many natural processes engineered out of the stream systems. Within the Marin and San Mateo Counties portions of GOGA, as well as PORE, watersheds are fairly stable and support threatened coho salmon and steelhead trout. Although generally unaltered, stream systems in these areas have been impacted by historic and current agricultural activities as well as more dispersed development including roads and trails.

Several NPS efforts to improve water resources within SFAN are underway. The Redwood Creek watershed (GOGA/MUWO) is currently the focus of a variety of activities including watershed planning, transportation planning, water quality and water rights evaluations, sensitive species monitoring, aquatic system and riparian restoration, invasive non-native plant removal and habitat restoration, and GIS mapping of all watershed features. Similar activities are occurring throughout the network. Several stream restoration projects are on-going at PORE including bank stabilization, dam removal, and culvert removal projects. Restoration efforts for Chalone Creek (PINN) and its floodplain have also been initiated. Streambank restoration (including removal of invasive plants, erosion control, and bank stabilization) is proposed along Franklin Creek (JOMU), as well as a dam removal project in the Strentzel Creek (JOMU) watershed. Tidal wetland restoration efforts are on-going at PORE, GOGA, and PRES. Wetlands inventories and functional assessments are being conducted at GOGA (funded by the I&M program), as well as PORE (funding through NPS-WRD). In addition, a watershed project aimed at "daylighting" Tennessee Hollow Creek (PRES) and improving its ecological integrity is underway. Restoration efforts have primarily focused on the protection and restoration of natural physical processes, habitat known to benefit T&E aquatic species, and water quality.

The purpose of this Protocol Narrative is to address all of the significant issues that need to be considered when developing a long-term monitoring plan for freshwater quality. It documents the decision making processes involved in prioritizing streams, selecting sites, and selecting parameters to monitor and associated methods. The Protocol Narrative also provides a summary of monitoring methods, data management and reporting, and staff and budget considerations. This document provides a brief summary of SFAN water resources and an overview of water quality monitoring efforts. A more thorough review of surface hydrology and water resources, water quality monitoring efforts, and water quality issues and priorities is included in the "SFAN Preliminary Water Quality Status Report" (Cooprider, 2004). Details related to sampling methods, including safety and quality assurance/quality control (QA/QC) are included in individual Standard Operating Procedures (SOP) on each water quality parameter or group of parameters.

Many of the SOPs in the SFAN Freshwater Quality Protocol rely heavily on State and Federal protocols such as those published by the California State Water Resources Control Board (SWRCB), U.S. Geological Survey (USGS), and the U.S. Environmental Protection Agency (EPA). In most cases, when protocols differed among agencies, the State protocol was followed since they are most involved in monitoring on park lands. Other I&M network protocols were also consulted for consistency in protocol format and content. Ultimately, protocols were chosen based on the monitoring objectives. "Parks are encouraged to use or modify standard protocols and partner with existing programs wherever possible to allow comparability and synthesis of data at multiple scales, but the primary use of the data is at the park level for management decisions" (Fancy, 2005).

### *1.1.1 Beneficial Uses*

All of the park units except PINN are regulated by the San Francisco Bay Regional Water Quality Control Board. There are nine Regional Water Quality Control Boards ("Regional Boards") that are part of the California State Water Resources Control Board, a department of the California Environmental Protection Agency. Pinnacles NM is within the Central California Coast Regional Water Quality Control Board. Management criteria for water bodies within the state of California are established by the Regional Boards. Through their water quality control plans (also referred to as basin plans), the Regional Boards established beneficial uses for streams and set numeric and narrative criteria to meet those surface water use objectives.

The primary water quality issues within SFAN relate to whether or not streams are supporting the beneficial uses established by the Regional Boards. Table 1 includes the beneficial uses of all SFAN water bodies combined (streams, Pacific Ocean, etc). The beneficial uses of SFAN water bodies are numerous and this is a testament to the significance of water resources within the network. A list of beneficial uses for individual SFAN water bodies is included in Appendix A. The full definitions of beneficial uses are also included in Appendix A.

Table 1. Collective beneficial uses of SFAN water bodies.

| Acronym | Definition |
|---|---|
| AGR | Agricultural Supply |
| COLD | Cold Freshwater Habitat |
| COMM | Commercial and Sport Fishing |
| EST | Estuarine Habitat |
| FRSH | Freshwater Replenishment |
| GWR | Groundwater Recharge |
| IND | Industrial Service Supply |
| MAR | Marine Habitat |
| MIGR | Fish Migration |
| MUN | Municipal Supply |
| NAV | Navigation |
| PROC | Industrial Process Supply |
| RARE | Preservation of Rare and Endangered Species |
| REC1 | Contact Water Recreation |
| REC2 | Non-contact Water Recreation |
| SHELL | Shellfish Harvesting |
| SPWN | Fish Spawning |
| WARM | Warm Freshwater Habitat |
| WILD | Wildlife Habitat |

### *1.1.2 Water Quality Criteria*

Water quality standards are key components of the water quality-based control program mandated by the Clean Water Act (CWA). Designated use classifications and numerical and/or narrative water quality criteria are two types of water quality standards. The CWA requires all States to establish use classifications for all water bodies within the State. These beneficial uses were discussed in Section 1.1.1. Water quality criteria are numeric descriptions of the physical, chemical, and biological characteristics of waters necessary to support these designated beneficial uses.

The RWQCB Basin Plans include numeric and narrative water quality objectives for surface water. General water quality objectives for estuarine and marine waters are also included. However, a separate document, the Ocean Plan, was produced by the California SWRCB to regulate ocean waters (California State Water Resources Control Board, 2001).

Table 2 lists general numeric objectives for all inland surface waters, enclosed bays, and estuaries in the San Francisco Bay Area (San Francisco Bay Regional Water Quality Control Board, 1995). These general objectives can be used to determine whether water bodies are meeting specific beneficial uses. For example, un-ionized ammonia levels above the water quality objective would hinder the ability of a stream to support healthy aquatic life (e.g., fish spawning). This would then trigger a management action to reduce the inputs of nitrogen to the streams. It may also dictate more frequent sampling of nutrients, pH, and temperature – factors that affect the amount of ammonia in a stream.

Some of the water quality objectives for inland surface waters, enclosed bays, and estuaries within the Central Coast Regional Water Quality Control Board where PINN is located are slightly different than those listed in Table 2. For example, the numeric objective for pH is 7.0 to 8.5. The general objective for dissolved oxygen is $\geq$ 5.0 mg/L (Central Coast Regional Water

Quality Control Board, 1998). However, for the specific beneficial uses COLD and SPWN, the objective is 7.0 mg/L.

Table 2. General numeric objectives for physical parameters in surface waters in the San Francisco Bay Area (from San Francisco Bay Regional Water Quality Control Board, 1995).

| **Parameter** | **Water Quality Objective** |
|---|---|
| Dissolved oxygen (tidal waters) | Downstream of Carquinez bridge: 5.0 milligrams per liter (mg/L) minimum<br>Upstream* of Carquinez bridge: 7.0 mg/L minimum |
| Dissolved oxygen (non-tidal waters) | Cold water habitat 7.0 mg/L minimum<br>Warm water habitat 5.0 mg/L minimum |
| pH | Less than 8.5 and greater than 6.5 |
| Un-ionized ammonia | Annual Median 0.025 mg/L as nitrogen (N) (freshwater)<br>Maximum Central San Francisco Bay 0.16 mg/L (N) (estuarine) |

* A more stringent minimum objective is desirable for the northern reach of the Bay for the protection of cold water fish habitat as well as protection of the migratory corridor running through Central Bay, San Pablo Bay, and upstream reaches.

Several other parameters that are important to the SFAN water quality monitoring program do not have ambient surface water quality objectives established by the Regional Boards. In these cases, Tables 3 and 4 can be consulted. Table 3 lists nutrient criteria and recommendations from several different sources.

The numbers are based on both human health criteria and overall aquatic health. Chronic human toxicity for nitrate occurs at 10 mg/L (San Francisco Bay Regional Water Quality Control Board, 1995). However, this may not be stringent enough for aquatic life (San Francisco Bay Regional Water Quality Control Board, 2003b). Chronic toxicity to aquatic life, especially fish and amphibian eggs, can occur at 1.1 mg/L (Kincheloe et al., 1979; Crunkilton, 2000). Nutrient levels at which algal growth limitation begins are less than 0.5 mg/L for total nitrogen and 0.1 mg/L for total phosphorus (Bowie et al., 1985).

Recent EPA criteria are based on *Ambient Water Quality Criteria Recommendations* for Ecoregions across the country (U.S. Environmental Protection Agency, 2000). A map of the ecoregions can be found at**:** http://www.epa.gov/waterscience/criteria/nutrient/ecomap.html**.** During the development of nutrient criteria for the ecoregions, several sources of data were consulted including historical and recent nutrient data and reference sites. Ecoregion III (Xeric West) covers PINN and JOMU while Ecoregion II (Western Forested Mountains) covers PORE and GOGA. Recommended criteria for Ecoregions II and III are listed in Table 3. These are not regulations but are intended to be "starting points" for states and tribes developing water quality standards (U.S. Environmental Protection Agency, 2000a). The EPA Ecoregion values in Table 3 represent nutrient levels that are generally protective of nutrient over enrichment. However, "States and Tribes should evaluate the information in light of the specific designated uses that need to be protected" (U.S. Environmental Protection Agency, 2000a). Conversely, overly stringent criteria may actually fall below levels of nutrient loading that naturally occur. The EPA encourages the states to develop more refined criteria through the use of local data.

There are also various recommendations for the sediment parameters total suspended solids and turbidity (Table 4). Similarly, nutrient levels can be compared to several different thresholds until targets or Total Maximum Daily Loads (TMDL) are set. SFAN will utilize this “multiple thresholds” concept for data analysis. The effects of nutrients and sediment on water quality are discussed further in standard operating procedures in Appendix H.

Table 3. Recommended criteria for nutrients.

| **Parameter** | **EPA Quality Criteria for Water (1986)** | **EPA Aggregate Ecoregion II Criteria (2000b)** | **EPA Aggregate Ecoregion III Criteria (2000a)** | **Kincheloe et al., 1979; Crunkilton, 2000** | **Bowie et al., 1985** |
|---|---|---|---|---|---|
| Total Phosphorus (P) | 0.1 mg/L | 10 ug/L | 21.88 ug/L | | 0.1 mg/L |
| Total Phosphates as P | 50 ug/L | | | | |
| Total Nitrogen | | 0.12 mg/L | 0.38 mg/L | | 0.5 mg/L |
| Nitrate | 10 mg/L | | | 1.1 mg/L | |

Table 4. Recommended criteria for sediment.

| | **Sigler et al., 1984** | **Newcomb and Jensen, 1996** | **EPA Aggregate Ecoregion II Criteria (2003)** | **EPA Aggregate Ecoregion III Criteria (2003)** |
|---|---|---|---|---|
| ∗Acute Total Suspended Solids | | > 50 mg/L | | |
| ∗Chronic (>6 days) Total Suspended Solids (TSS) | | > 10 mg/L | | |
| [ϕ]Turbidity | 25 NTU | | 1.30 NTU | 2.34 NTU |

∗Total suspended solids are listed in milligrams per liter (mg/L)
[ϕ]Turbidity is listed as nephelometric turbidity units (NTU)

Only three beneficial uses within SFAN have specified bacterial objectives. These include contact recreation, non-contact recreation, and shellfish harvesting (Table 5). Many water bodies in SFAN meet the definition of non-contact recreation and some meet the definition for contact recreation (see Appendix A for complete list). The Regional Boards define contact recreation (REC1) as:

> Uses of water for recreational activities involving body contact with water where ingestion of water is reasonably possible. These uses include but are not limited to,

swimming, wading, water-skiing, skin and scuba diving, surfing, whitewater activities, fishing, and uses of natural hot springs." Non-contact water recreation (REC2) is defined as: "Uses of water for recreational activities involving proximity to water, but not normally involving contact with water where ingestion is reasonably possible. These uses include but are not limited to, picnicking, sunbathing, hiking, beachcombing, camping, boating, tide pool and marine life study, hunting, sightseeing, or aesthetic enjoyment in conjunction with the above activities.

*San Francisco Bay Regional Water Quality Control Board, 1995*

Additional detailed criteria specifically for contact recreation are relevant for SFAN lakes, freshwater lagoons, and some streams where swimming or other contact recreation occurs (Table 6). The California SWQCB's use total and fecal coliforms as criteria for determining whether waters are in compliance with beneficial uses, while the US EPA has established criteria using *E. coli* and *Enterococcus* as fecal indicator bacteria (FIB). Studies have suggested that *E. coli* and *Enterococci* have a much more significant correlation to the occurrence of swimming-related gastrointestinal illness (USEPA, 1986). *Enterococcus* typically has greater survival in marine waters and is therefore a better indicator of fecal contamination in coastal areas. *E. coli* is a subset of the fecal coliform group, and is judged to be a better indicator of pathogenic bacterial contamination in freshwaters. Also, analytical methods for these two indicator bacteria are often more efficient and cost effective than those for fecal coliforms alone.

Consecutive sampling (e.g., five consecutive weeks) to obtain a 30-day geometric mean is a necessary component of any monitoring scheme related to the REC1 beneficial use.

Table 5. U.S. EPA bacteriological criteria for contact recreation (REC1).

| **Fecal Indicator Bacteria** | **Bacterial Colonies/100mL (MPN)** |
|---|---|
| Total Coliform | |
| Single Day Sample | 10,000 |
| *30 Day Geometric Mean | 1,000 |
| Fecal coliform | |
| Single Day Sample | 400 |
| *30 Day Geometric Mean | 200 |
| *E. Coli*** | |
| Single Day Sample | 235 |
| *30 Day Geometric Mean | 126 |
| *Enterococcus*** | |
| Single Day Sample | 61 |
| *30 Day Geometric Mean | 33 |

* Geometric mean of five consecutive weeks
**These bacteriological tests are considered "ancillary" for the SFBRWQC; however the EPA has adopted *E. Coli* as the primary test for freshwater recreational uses, and *Enterococcus* testing for marine water recreational uses because they have determined that these tests correlate more closely with contact-related illnesses.

Tomales Bay and Drakes Bay support commercial shellfish harvesting. The State Department of Health Services (DHS) tests these waters for compliance with the National Shellfish Sanitation Program. Since the U.S. Food and Drug Administration (FDA) regulates shellfish consumption based on fecal coliforms, they are used instead of other fecal indicator bacteria (FIB) such as *Escherichia coli (E. coli).*

Table 6. Water quality objectives for coliform bacteria (from San Francisco Bay Regional Water Quality Control Board, 1995).

| **Beneficial Use** | **Fecal Coliform (MPN/100mL)** | **Total Coliform (MPN/100mL)** |
|---|---|---|
| Non-contact recreation (REC2) | Mean < 2000<br>$90^{th}$ percentile < 4000 | |
| Shellfish harvesting (SHELL) | Median < 14<br>$90^{th}$ percentile < 43 | Median < 70<br>$90^{th}$ percentile < 230 |

### *1.1.3 Significant Waters*

Some water bodies have been specifically designated as significant due to a variety of factors including: biodiversity, ability to support a unique habitat or species, or status as relatively undisturbed. There are several significant and unique coastal waters within the San Francisco Bay Region. Recognizing the extraordinary significance and exposure to threats in the region, United Nations Educational, Scientific, and Cultural Organization (UNESCO) Man in the Biosphere program designated the Golden Gate Biosphere Reserve in 1988. This reserve encompasses six of the eight SFAN parks and includes coastal waters. The California coast is only one of five areas of eastern boundary coastal upwelling oceanic currents worldwide and the only one in North America.

The State Water Resources Control Board established Areas of Special Biological Significance (ASBS) in 1974. Five of these are within the legislative boundaries of the SFAN parks. These include the Point Reyes Headlands, Bird Rock, Double Point, Duxbury Reef, and the James Fitzgerald Marine Preserve. These areas were chosen through a nomination process based primarily on habitat quality and limited to coastal areas. The ASBS are all coastal areas since inland areas have not yet been assessed. Although this protocol focuses on freshwater quality, it is critical to know the significance of coastal "receiving waters" for the freshwater streams within SFAN. The procedure for this nomination process is outlined in the California Ocean Plan (2001) developed by the State Water Resources Control Board. A Southern California Coastal Water Research Project (SCCWRP) report to the State Water Resources Control Board addresses issues related to current and potential discharges into these ASBS (SCCWRP, 2003). In 2000, the California Department of Fish and Game drafted a Marine Protected Area (MPA) plan that proposed including ASBS as primary reserve areas. In January 2003, legislation took effect that incorporated previously-designated Areas of Special Biological Significance (ASBS) into an established system of State Water Quality Protection Areas (SWQPA). ASBS/SWQPA are designated as no discharge zones and the SWRCB has established a program to enforce the no discharge requirements.

A state publication detailing the location and included resources of State Water Quality Protection Areas / Areas of Special Biological Significance can be found at: http://www.waterboards.ca.gov/plnspols/oplans/docs/asbs_swqpa_publication03.doc. Maps of the five ASBS that are within the legislative boundaries of SFAN parks can be viewed

electronically on the SWRCB website at:
http://www.waterboards.ca.gov/plnspols/asbs_info.html

In addition to the above designations and associated marine protection, several marine sanctuaries are located offshore of PORE and GOGA. These include the Gulf of the Farallones National Marine Sanctuary, Cordell Bank National Marine Sanctuary, and Monterrey Bay National Marine Sanctuary.

### *1.1.4 Clean Water Act Section 303d Impaired Waters*

The EPA requires that States submit a list of water bodies that fail to meet water quality standards. These lists are referred to as "303(d) lists" after the section of the CWA which contains the requirement. The EPA approves the list only if it meets applicable requirements. Water bodies on an approved 303(d) list require the establishment of a total maximum daily load (TMDL). A TMDL specifies the amount of a particular pollutant that may be present in a water body, allocates allowable pollutant loads among sources, and provides the basis for attaining or maintaining water quality standards.

Water bodies within and adjacent to NPS lands have specifically been identified as impaired by the San Francisco Bay Water Quality Control Regional Board and in some cases, the EPA. Table 8 lists these water bodies. The Regional Board has established a timeline for development of Total Maximum Daily Loads (TMDLs) associated with the highest priority impairment listings (Table 9). Not all impaired (Section 303d listed) water bodies currently have TMDL projects. For a complete listing of impaired water bodies and a map of current projects see Regional Board's website at:
http://www.waterboards.ca.gov/sanfranciscobay/TMDL/303dlist.htm
The list of impaired miles of water bodies in Table 7 is taken from the NPS Water Resources Division (WRD) website http://www1.nrintra.nps.gov/wrd/dui/. It is based on GIS coverage of the Section 303d listed water bodies. It is important to note that tributaries of listed water bodies are also impaired even though the tributaries themselves may not be listed. Tributary miles are not included in the table. In addition, PORE manages the north district GOGA lands that include the impaired Lagunitas Creek. The numbers listed in the table below reflect management divisions between GOGA and PORE (i.e. north district GOGA lands are included in the PORE totals).

The SFBRWQCB listed all SF Bay area urban streams as impaired by diazinon, although these creeks are not specifically listed by name and the presence of this contaminant has not been verified. The NPS is currently coordinating with the USGS to conduct baseline monitoring for pesticides in these urban creeks. So, while these streams (which include streams in JOMU, PRES and GOGA) are potentially impaired, they are not included in 303(d) impaired stream miles in the table below.

1.1.4.1 Sediment, Nutrients, and Pathogens: The San Francisco Bay Regional Water Quality Control Board has identified Tomales Bay and its tributaries Lagunitas Creek and Walker Creek as impaired by fecal coliform, sediment, and nutrients (Table 1.8). Health concerns have arisen due to contamination of shellfish with pathogenic bacteria. SFAN and PORE staffs have

Table 7. Stream and shoreline miles of impaired waters within SFAN.

| | Total Stream Miles (intermittent/perennial) | 303(d) Impaired Stream Miles | Lakes and Reservoirs Acres | 303(d) Impaired Acres | Sea/Ocean Shoreline Miles | 303(d) Impaired Shoreline Miles |
|---|---|---|---|---|---|---|
| FOPO* | 0 | 0 | 0 | 0 | 0.37 | 0.37 |
| GOGA† | 33.44 | 0.73 | 43.53 | 0 | 53.99 | 22.54 |
| JOMU | 0.28 | 0 | 0 | 0 | 0 | 0 |
| MUWO* | 2.07 | 0 | 0 | 0 | 0 | 0 |
| PINN | 90.98 | 0 | 1.18 | 0 | 0 | 0 |
| PORE† | 153.56 | 3.45 | 559.79 | 0 | 113.12 | 27.89 |
| PRES* | 0.71 | 0 | 5 | 0 | 3.2 | 3.2 |

*These park units are, in part, managed by GOGA, and their miles and impaired mile numbers are included within the GOGA numbers in this table.

†The totals listed for both GOGA and PORE reflect management boundaries rather than legislative boundaries. This means that GOGA north lands that are managed by PORE are included in the PORE numbers.

collaborated with the Regional Board regarding monitoring of indicator bacteria in Olema Creek, a tributary to Lagunitas. The Regional Board recently completed a final TMDL project report for pathogens in Tomales Bay (San Francisco Bay Regional Water Quality Control Board, 2005). Implementation of monitoring (by NPS and others) for the Tomales Bay Pathogen TMDL program includes monthly monitoring plus five consecutive weeks of monitoring during both the winter and summer. NPS has also monitored sediment (total suspended solids and turbidity) and nutrients (nitrates and ammonia) in Olema Creek. Sediment and nutrient TMDL projects have not yet been completed for Tomales Bay (see Table 1.8 for completion dates). The Regional Board developed a conceptual approach for developing sediment TMDLs in San Francisco Bay Area streams (San Francisco Bay Regional Water Quality Control Board, 2003a). A conceptual approach was also developed for nutrient TMDLs in San Francisco Bay area water bodies (San Francisco Bay Regional Water Quality Control Board, 2003b). These reports provide background information about the pollutant and preliminary plans for monitoring.

A portion of the San Francisquito Creek watershed is located within GOGA’s Phleger Estate in San Mateo County. This creek is listed as sediment impaired. The type and extent of impairment is unknown at this point. SFAN recently began baseline water quality monitoring (including sediment) in West Union Creek, one of the San Francisquito Creek tributaries.

1.1.4.2 Metals, Pesticides, and Other Chemicals: Tomales Bay is also listed as impaired by mercury due to an abandoned mercury mine in the Walker Creek watershed. In 2000, Marin County announced a fish consumption advisory for Tomales Bay due to mercury bioaccumulation. San Francisco Bay is also impaired by mercury in bedded sediments that are a legacy of historical mercury and gold mining activities. Current TMDL projects in the Bay include mercury and polychlorinated biphenyls (PCBs). Potential sources of mercury include industrial and municipal point sources, resource extraction, and atmospheric deposition. Sources of PCBs are unknown (non-point sources). Other pollutants listed by the Regional Board include exotic species and selenium; EPA has also added several pollutants to the list including the pesticides chlordane and dichloro-diphenyl-trichloroethane (DDT).

All urban creeks in the San Francisco Bay area are considered impaired by diazinon. Potential for contamination by this pesticide exists in all urban areas. The most urbanized areas within NPS lands include water bodies in the Presidio (Lobos Creek, Dragonfly Creek, Tennessee Hollow Creek), JOMU (Franklin Creek), and GOGA (Milagra Creek, Calera Creek, Sanchez Creek, and San Pedro Creek). With the exception of the Presidio creeks, significant portions of these watersheds are located outside NPS land. City water treatment plants monitor diazinon; data is available from the Baker Beach Treatment Plant that tests Lobos Creek. Recent data from the treatment plant has not indicated contamination of Lobos Creek by diazinon. A *Final Project Report for Diazinon and Pesticide-Related Toxicity in Bay Area Urban Creeks* was also completed by the San Francisco Bay Regional Water Quality Control Board (2004). More recently, the Regional Board has turned its focus to pyrethroid based pesticides since they are replacing the phased-out diazinon based pesticides. Information on pyrethroids in the San Francisco Bay Area can be found in *Pesticides in Surface Water: Annual Research and Monitoring Update 2005* (TDC Environmental, 2005).

Table 8. Impaired water bodies in the SFAN.

| **Water body (Watershed)** | **Park Unit** | **Pollutant** |
|---|---|---|
| Coyote Creek (Richardson Bay) | GOGA | Diazinon |
| Lagunitas Creek (Tomales Bay) | PORE, GOGA | Pathogens, Sediment, Nutrients |
| Richardson Bay* | GOGA | High Coliform, Mercury, PCBs, Pesticides, Exotic Species |
| San Francisco Bay* | GOGA, PRES | Mercury, PCBs, Nickel, Pesticides, Exotic Species, Dioxin, Selenium |
| San Francisco Bay Urban Creeks | GOGA, PRES, JOMU | Diazinon |
| San Francisquito Creek (SF Bay) | GOGA | Diazinon, Sediment |
| San Pedro Creek (Pacific Ocean) | GOGA | High Coliform |
| Tomales Bay | PORE, GOGA | Pathogens, Sediment, Nutrients, Mercury |

*See Appendix A of the *SFAN Preliminary Water Quality Status Report* (Cooprider, 2004) for details on pollutants

Table 9. San Francisco Bay Regional Water Quality Control Board TMDL Project Timeline as of June 2005.

| **Water body** | **Park Unit** | **Pollutant** | **Project Report Completion** | **Regional Board Adoption Date** |
|---|---|---|---|---|
| San Francisco Bay | GOGA, PRES | Mercury | June 2003 | Sept. 2004 |
| San Francisco Bay | GOGA, PRES | PCBs | Jan. 2006 | Mar. 2006 |
| Tomales Bay | GOGA, PORE | Pathogens | April 2005 | June 2005 |
| SF Bay Urban Creeks | GOGA, PRES, JOMU | Diazinon | Aug. 2005 | Oct. 2005 |
| San Francisco Bay | GOGA, PRES | Nickel | Dec. 2004 | Aug. 2005 |
| San Francisquito Creek | GOGA | Sediment | Dec. 2005 | Dec. 2006 |
| Tomales Bay | GOGA, PORE | Mercury | Aug. 2006 | Dec. 2007 |
| San Francisco Bay | GOGA, PRES | Pesticide Toxicity | Oct. 2006 | Aug. 2007 |
| Lagunitas Creek | PORE, GOGA | Sediment | Dec. 2006 | Feb. 2008 |
| San Francisco Bay | GOGA, PRES | Legacy pesticides | Dec. 2007 | Dec. 2008 |
| Tomales Bay | GOGA, PORE | Sediment | Dec. 2007 | Dec. 2008 |

### 1.1.5 Water Quality Monitoring History

A summary of water quality issues, monitoring activities, and data is provided in the *SFAN Preliminary Water Quality Status Report* (Cooprider, 2004). Section 1.1.5.1 below provides a summary of water quality issues. Refer to the water quality status report for a review of hydrology and location water bodies in the network, and for an analysis of past data. SFAN parks and water bodies are in various stages of monitoring. While some watersheds are in need of comprehensive baseline data, others are in need of more strategic data focused on suspected pollution sources. A summary of water quality monitoring activities for the major water bodies within the network is included in a table in Appendix B.

1.1.5.1 SFAN Land Uses and Related Water Quality Issues:
Golden Gate National Recreation Area (GOGA) and Muir Woods National Monument (MUWO).

Muir Woods NM is located within the legislative boundary of GOGA. Therefore, although the two parks were established separately (i.e., by different enabling legislation), they are often included together. In addition, MUWO is located entirely within the Redwood Creek watershed and GOGA encompasses much of the lower part of this watershed. GOGA manages a large area but very few complete watersheds. Many of the lands have been managed and altered through agricultural and military uses. Due to the size and nature of the park including high visitor use, proximity to the urban interface, and multitude of recreation and land uses, there are several water quality related issues. Accelerated erosion due to roads, trails, and other uses and developments threatens the sediment balance and ecological health of several watersheds. Cattle grazing is no longer allowed on GOGA managed lands (National Park Service, 1999) but some of the impacts remain. Bacteria and nutrient inputs from equestrian operations, pet waste, agricultural operations, sewer and septic systems can impact wildlife and public health as well as the overall ecological balance of water resources. Channel alteration such as dams and culverts impacts the ecological health of park watersheds. Many park water quality issues are related to facilities and structures. Water quality issues occur to varying extents within multiple park watersheds.

John Muir National Historic Site (JOMU)
Potential or existing issues in the JOMU sub-watersheds include impacts of flooding and pollution by fecal coliforms, nutrients, and sediment. Potential sources of pollutants in Franklin Creek include illegal garbage dumping (including appliances, tires, etc.), highway runoff, equestrian operations, a nursery, and residential septic systems. Due to excessive erosion and the associated reduction of channel capacity, flooding frequently occurs in the Strentzel Lane neighborhood adjacent to the park and erosion is a major concern at the John Muir gravesite within JOMU.

Pinnacles National Monument (PINN)
Pinnacles NM shares some of the same water quality issues as other SFAN parks; however, due to drier conditions, groundwater issues are a proportionally larger concern at PINN than in the coastal parks. Reduction and contamination of groundwater and elevated levels of sediment, bacteria, and nutrients in surface waters are current issues. Due to past land uses (particularly a former landfill site), threats of heavy metal contamination are also a concern. Some of these concerns are not well documented; therefore, one goal of a long-term monitoring plan is to clearly identify threats to water quality in order to better understand the extent of contamination so that it can be addressed.

Point Reyes National Seashore (PORE)
There are several water quality issues within PORE. These issues relate to the beneficial uses of fish migration and spawning, shellfish harvesting, and contact recreation. Sediment, pathogens, and nutrients are the most significant issues which can affect these beneficial uses. Erosion due to the presence of a major earthquake fault, cattle grazing, roads, culverts, and trails threatens the sediment balance and ecological health of several watersheds. Excess sediment has detrimental

effects on salmonids including clogging of their gills, embedding of gravel beds used for spawning, and reduced visibility leading to an inability to locate food sources. Due primarily to the significant acreage of pastoral land within park boundaries, bacterial contamination is also a very serious and prevalent issue. Bacteria inputs are primarily dairy and beef cattle operations, but pet waste, particularly at beaches, stable operations, and septic systems may also be contributing.

Presidio of San Francisco (PRES)
Freshwater quality issues within the Presidio are related to pesticides, other chemicals, landfills, hazardous waste, heavy metal contamination, nutrient inputs, public health (contact recreation), sanitary sewers, and storm drains. One of the main threats to Lobos Creek is leaky storm and sanitary sewer lines that cross the creek. There is also a landfill above the source of Lobos Creek. Ground disturbance and contamination are potential issues with this landfill. Lobos Creek also has had high bacteria numbers at the Baker Beach outfall. Warning signs have been posted at Baker Beach due to water samples exceeding the criteria for contact recreation. Heavy metal contamination problems are prevalent throughout the Presidio; metals are mainly a concern in sediments. At Mountain Lake high levels of lead have been found in the sediments. Remediation plans are underway to address the sediment contamination issue. Also, nutrients from waterfowl waste have caused excessive algal growth in the lake.

## 1.2 Rationale for Selecting this Resource to Monitor

Freshwater quality has high ecological, management, and legal significance within SFAN parks. Freshwater systems within the network support a variety of threatened and endangered species including California freshwater shrimp (*Syncharis pacifica*), coho salmon (*Oncorhynchus kisutch*), steelhead trout (*Oncorhynchus mykiss*), California red-legged frog (*Rana aurora draytonii*), and northwest pond turtle (*Clemmys marmorata mormorata*). Beneficial uses of freshwater bodies include contact recreation and non-contact recreation, fish spawning, agricultural water supply, and wildlife habitat (see Section 1.1.1). Some streams do not support, or only partially support, these beneficial uses due to impairment. For watersheds that are located primarily on parklands, significant tangible management actions can be taken to improve water quality of these impaired streams. Implementation of this monitoring protocol will provide park management with the data necessary to make effective decisions to ameliorate poor water quality and maintain good water quality of SFAN water bodies.

### *1.2.1 Measurable Objectives*

1. Determine the variability and long-term trends in water quality through monthly summaries of select parameters (water temperature, pH, conductivity, dissolved oxygen, flow, *E. coli*, fecal and total coliforms, nitrate, ammonia, and total nitrogen) at selected sites in priority streams within SFAN.

2. Determine the existing ranges and diurnal variability of water temperature, pH, conductivity, and dissolved oxygen at selected sites in priority streams within SFAN.

3. Determine the extent that selected sites in priority streams within SFAN meet federal and state water quality criteria for fecal indicator bacteria, un-ionized ammonia, dissolved

oxygen, and pH through monthly sampling.

4. Determine the annual, seasonal, and 30-day mean fecal coliform load to Tomales Bay (an impaired water body) from Olema Creek as required by the San Francisco Bay Regional Water Quality Control Board's Tomales Bay Pathogen TMDL program.

Specific objectives or criteria for chemical and biological parameters are listed in Section 1.1.2 (Water Quality Criteria). These numeric objectives will be used to determine when waters are outside their natural range and whether or not they meet federal and state water quality criteria. They will also be used to inform local park staff of potential areas warranting management actions, or source differentiation sampling.

### *1.2.2 Overall Monitoring Questions*

- ♦ What are the existing chemical and biological ranges in water quality at selected sites within priority SFAN streams?
- ♦ What are the long-term trends in water quality at selected sites in priority SFAN streams?
- ♦ Is the water quality of priority SFAN streams in compliance with designated beneficial uses?
- ♦ What are the point and non-point pollution sources within the watersheds?
- ♦ Are specific management actions reducing pollution loads?

Specific monitoring questions for each site and parameter are discussed in Chapter 2 (Sampling Design). Questions will also be augmented and refined during the protocol testing phase. Also, as this protocol is implemented it will become clearer what the I&M program can provide to park managers and what specific issues the parks may need to address individually. In other words, the I&M program will help provide a link between broad monitoring and source differentiation/effectiveness monitoring for management practices. For source differentiation a longer time period and greater sampling frequency is needed. The I&M program can make recommendations to park management but may not necessarily cover all source differentiation monitoring from a budget and staff perspective.

### *1.2.3 Other Regional Water Quality Monitoring Programs*

Within the SFAN, several monitoring programs have existed or are on-going. Water quality programs developed by the parks include a comprehensive (i.e., park-wide) water quality monitoring program at PORE and stables and stormwater monitoring projects at GOGA. Other NPS monitoring programs include the Coastal Wetland Restoration at Lower Redwood Creek (GOGA), Giacomini Marsh (PORE/GOGA), and Crissy Marsh (PRES). The *SFAN Preliminary Water Quality Status Report* provides a more thorough review of the monitoring conducted by NPS staff (Cooprider, 2004).

Several other agencies are monitoring aquatic resources (water quality, stream flow monitoring, and fish) within SFAN watersheds. The Tomales Bay Watershed Council (in and to which NPS staff participates and provides technical expertise) has developed a water quality monitoring plan for their watershed which includes PORE and GOGA lands. The I&M water quality monitoring protocol will be implemented, where possible, in conjunction with the Tomales Bay Watershed

Council's Water Quality Monitoring Plan. Other agencies associated with SFAN watersheds, either through water quality monitoring or land management activities include:

Alhambra Watershed Action Group (AWAG)
California Department of Fish and Game (CDFG)
California Department of Health Services (CDHS)
California State Parks
(California) State Water Resources Control Board
Central Coast Regional Water Quality Control Board
City and County of San Francisco (CCSF)
Contra-Costa County
County of Marin
Friends of Alhambra Creek
Headlands Institute
Marin County Resource Conservation District (RCD)
Marin Municipal Water District (MMWD)
Muir Beach Community Services District (MBCSD)
San Francisco Bay RWQCB Surface Water Ambient Monitoring Program (SWAMP)
San Francisco State University (SFSU)
San Francisquito Creek Watershed Council
San Jose State University (SJSU)
Salmon Protection and Watershed Network (SPAWN)
Stinson Beach County Water District
Tomales Bay Agricultural Group (TBAG)
Tomales Bay Watershed Council (TBWC)
University of California-Berkeley (UCB)
University of California Cooperative Extension (UCCE)
University of San Francisco (USF)
Urban Watershed Project (UWP)
U.S. Geological Survey (USGS)

### 1.3 Measurable Results and Deliverables

Data will be summarized annually by the water quality specialist and every three to five years to evaluate trends and to conduct more intensive data analysis including comparison of data to relevant benchmarks (guidelines, criteria and objectives.) Reports will be provided to each park unit and the I&M coordinator. A completed NPSTORET database as well as a summary report will be provided to the NPS Water Resources Division (WRD) in Fort Collins annually. In the more detailed trend report, recommendations will be provided to parks regarding management actions to improve water quality including any additional monitoring that the individual parks could conduct (efforts outside the means or scope of the I&M monitoring program). See Table 22 in section 24 for a complete summary of reporting and communication products.

The SFAN aquatics group, consisting of water resources professionals from all of the SFAN parks, as well as the Network Coordinator will meet quarterly to discuss progress and provide guidance for the freshwater quality monitoring program. More formal water quality planning meetings catering to park management staff will be held during the summer. These meetings will include a discussion of water quality monitoring results for each park and will provide a forum for discussing and recommending management practices related to water quality issues. These meetings will also provide an opportunity to receive suggestions on refining protocols. In addition, the meetings will help foster a relationship between I&M program staff and park staff to ensure that parks obtain needed data and feedback, and that the I&M program receives necessary information and support from parks.

# 2.0 Sampling Design

## 2.1 Rationale For Selecting This Sampling Design Over Others

An appropriate sampling design ensures that specific monitoring questions will be answered with the data gathered and the subsequent statistical analysis. A sampling design needs to enable us to detect changes that are statistically significant and ecologically significant although these are not always identical (Irwin, 2004). The process of developing an overall sampling design requires knowledge of management objectives, associated monitoring objectives (Ch.1), and specific monitoring questions. A logical process for developing specific monitoring questions is: 1) Develop monitoring questions for each objective, 2) Determine site locations based on monitoring questions, 3) Determine specific questions for each site location, and 4) Determine specific questions for each parameter.

### *2.1.1 Sampling Design Types*

One approach to sampling design suggests three options for monitoring designs (EPA, 2002). These options include *census* (monitoring every water body), *judgmental* or *targeted* (specific water bodies and locations are targeted based on what is known), and *statistical surveys* (probability-based). EPA's Environmental Monitoring and Assessment Program (EMAP) utilizes probability sampling.

States will often utilize more than one sampling design to meet monitoring objectives but they do not typically use census monitoring. However, monitoring all waters of a particular type (e.g., recreational waters) is sometimes utilized. Although not commonly used, many states are adding some component of probability-based surveys to their monitoring programs. These designs "ensure that sample units represent the target population and are statistically unbiased" ((U.S. Environmental Protection Agency, 2002). Judgment is a major component of any water quality monitoring design and most states primarily utilize judgmental (non-random) designs that are focused on answering a specific management question. The USGS National Water Quality Assessment (NAWQA) program is an example of a judgmental (i.e. targeted) design (U.S. Environmental Protection Agency, 2002).

Other sampling designs include a *rotating basin* component targets certain basins in a state for intensive and/or probability-based monitoring. The basins that are monitored change each year so that over a period of time (typically five years), the entire state is monitored (e.g., all lakes in the state). *Fixed station* networks monitor the same sites over a long period of time. These are often used to establish long-term trends in water quality at these sites. *Intensive survey* designs incorporate a large number of sites in an area (e.g., a watershed) for a specified period. This design may take the form of an intensive basin/watershed survey or a site-specific study. These designs may be used in conjunction with each other.

### *2.1.2 Sampling design for the SFAN*

Previously, parks within the SFAN have typically utilized judgmental designs for short-term projects (e.g., before and after a restoration project or implementation of a management practice) or source differentiation. Due to the proximity of water bodies to stables and dairies, monitoring has consisted largely of source differentiation rather than baseline or trend data. In addition, sampling has been opportunistic, rather than scheduled, in order to capture pollutant loads during storm events.  However, more recent monitoring efforts have centered on scheduled sampling events with some flexibility built in for storm sampling.

In the SFAN protocol development process, it was determined that ideally, a hybrid sampling plan would be developed that includes both 1) targeted sites to answer site-specific pollutant or management issues or other limited inference questions and 2) probability-selected sites that allow for broader inferences to larger areas of the park or watershed as a whole.  The monitoring objectives and questions in section 1 can be addressed by these different, but complementary sampling designs.  Once specific monitoring objectives and monitoring questions were formulated, a process was begun to develop the network's monitoring program.  Table 10 provides examples by which particular questions, and appropriate sampling designs and data analyses that best address those questions.  This table served as a point of reference for SFAN to select sites and the overall sampling design.

The key monitoring questions identified for SFAN (see section 1.2.2) fall into the lower tier questions (the last three monitoring questions).  There are a number of factors, including: TMDL's, land-use, or interaction with T&E species that provided the impetus for individual park units to be able to assess their compliance with beneficial use criteria, pollution monitoring and the effectiveness of specific management actions.  The selection of the current list of sampling sites, and initial sampling plan were tailored to address those needs, relied heavily on consultation with park managers, and resulted in a judgmental or targeted sampling design.

Table 10. Choosing a sampling design based on monitoring questions.

| **Monitoring Question** | **Site/Sampling Location** | **Overall Sampling Design & Analysis** |
|---|---|---|
| What are the natural chemical and biological ranges in water quality within the freshwater systems of SFAN? | Random | Analyze data from randomly chosen upstream and/or control sites or reference streams; analyze annual, seasonal, and daily data for each station and each group of stations in a stream or watershed. |
| What are long-term trends in water quality in SFAN water bodies? | Random | Analyze data from randomly chosen sites in the upper, middle, and lower reaches.  Analyze annual and seasonal data for each station and for each group of stations in a stream or watershed. |
| Is the water quality of SFAN water bodies in compliance with beneficial uses? | Random and judgmental | Focus on sites known to be impaired; analyze data for each site for each group of stations (collectively) in a stream. Compare reference reach range with impacted reach range. |
| What are the pollution sources within the watersheds? | Judgmental | Compare data from individual sites from one sampling event to another; also compare data from multiple sites within a stream. Analyze annual and seasonal data for each station and for each group of stations in a stream or watershed. Compare variability in reference reaches with variability in impaired reaches. |
| Are specific management actions reducing pollution loads? | Judgmental | Compare data from individual sites from one sampling event to another; also compare data from multiple sites within a stream. Analyze annual and seasonal data for each station and for each group of stations in a stream or watershed. |

Judgmental sites will continue to be used in the long-term because 1) all of the SFAN parks have used this sampling design for the collection of legacy data, and many sites have been previously monitored, 2) sites can be co-located with monitoring sites for other vital signs, and 3) this design often provides more immediately useful data for park management, and 4) funding is limited and some portions of target streams are difficult to access due to their remote location, or the necessity to gain access through private property.

Potential water quality monitoring sites for a judgmental design include: 1) where a stream leaves the park, 2) where a stream enters the park, 3) upstream reference sites near the stream source, 4) the mouth of a stream or tributary, and 5) upstream and downstream of known pollutant sources.

Existing programs, such as the pathogen TMDL monitoring required by the RWQCB, have utilized similar site selection processes. The result is that sites in the upper, middle, and lower reaches are included.

Drawbacks to a judgmental design are that assumptions are made regarding the stream locations and their relative levels of pollutants. For example, we generally assume that the most upstream site, the reference site near the stream sources, is probably the most natural site since there are fewer opportunities for contamination. We also assume (based on knowledge of past data) that we know where the most polluted sites or sources are. While a probabilistic design allows broad conclusions to be drawn about the percentage of water impacted by a particular parameter, it offers little information for management actions if a water body is *already known* to be impaired. However, a probabilistic design does not make assumptions and could potentially reveal previously unknown areas of compromised water quality. Such a design would also allow for a statistically-unbiased representation of the target population which allows for broad watershed-level inferences about water quality.

However, the upper tier questions: (1) What are the natural chemical and biological ranges in water quality within the freshwater systems of SFAN? and (2) What are long-term trends in water quality in SFAN freshwater systems? are identified as important for addressing the objectives of I&M Vital Signs program, and require a statistically un-biased sampling design to support inferences from sampling site to whole watershed. Incorporating a sampling design element to address these monitoring questions in SFAN parks is crucial and will be considered in the future. This could be accomplished through the development and integration of probability-based sampling sites that will assure geographic coverage which will complement the initial sampling design and selected sites.

Due to the judgmental or targeted nature of the current sampling design, we cannot currently make statistically-supported inferences about the percentage of impaired miles in priority watersheds based on sampling at targeted locations. However, many of our streams are short compared with some other parks around the country. With long-term data from sites at various levels of the watershed including a reference or upper watershed site and a site at the bottom of a watershed, we can make educated guesses about some of the intervening sections, but no definitive statistical inferences can be made. Integration of probability-based sampling sites for priority freshwater streams in the San Francisco Bay Area Network (SFAN) would allow our network to address the first two monitoring questions from Table 10 without restricting conclusions and trends to the specific sites in priority freshwater streams.

Although the site selection presented in the current protocol narrative will primarily be judgmental, elements of randomness will be added at the levels of habitat and sampling point. For example, even though the selection of target streams and sites was not probabilistic, the particular pool or riffle that is sampled will be chosen randomly if more than one pool or riffle is present. The type of habitat sampled differs based on the type of stream (perennial or intermittent) and the monitoring questions (see Table 15(a,b) for a discussion of the targeted sampling habitat). In addition, the sampling spot within the habitat will also be chosen randomly. Temporal randomization (i.e., sampling at different times of the day) is another strategy for adding randomization to a sampling design. However, the SFAN water quality specialist will follow the same site order for each sampling event with the idea of sampling at approximately the same time every day for each site (within a two-hour window, where possible). Some parameters such as dissolved oxygen, temperature and pH can vary significantly within a 24 hour period. For example, dissolved oxygen can rise by several mg/L from early morning (lowest DO) to mid-afternoon (highest DO); and pH generally rises to its highest level in mid afternoon as photosynthesis removes carbon dioxide faster than it can be replaced by aeration in the riffles. Methods of cross-calibrating such measurements for temporal variation will be discussed further in SOP #5.

A rotating basin scenario will be implemented in order to monitor the maximum number of water bodies of concern. The number of streams rotated and the rotation interval will depend on funding and staff constraints. This will enable monitoring of more water bodies on a fixed budget. It also allows sufficient time for comprehensive water quality data reporting. USGS NAWQA protocols recommend a minimum of two years of consecutive monthly monitoring (Gilliom et al., 2001) for rotating basin designs. A phasing-in approach (gradually adding more watersheds over time) will also be considered depending upon funding. This would allow longer-term data sets for trends, without two-year gaps. It also allows time to explore additional funding opportunities, partnerships, and ways of streamlining the monitoring program and enabling it to be more comprehensive.

## 2.2 Site Selection

### *2.2.1 Identification of Target Population, Study Boundaries, & Sample Units*

For the SFAN, the target population of measurements is from a select group of priority water bodies. The EPA's Consolidated Assessment and Listing Methodology (CALM) provides examples of stratification for rivers/streams, lakes, wetlands, and estuaries (EPA, 2002). Rivers/streams are stratified into perennial/intermittent and wadeable/non-wadeable (deep river). Most streams within the SFAN fall into the categories of perennial or intermittent and wadeable with a few ephemeral streams. Ephemeral drainages are not typically monitored since they are only flowing during storm events and the SFAN hydrologic systems are very flashy. These types of drainages are also often hidden in deep brush (including poison oak) and/or located on steep or otherwise difficult to access terrain. The sampled population for the SFAN, at least for the first five years of protocol testing and refining, will primarily include perennial and intermittent, wadeable streams within priority target watersheds. For the purposes of this monitoring plan, these are streams that are safely wadeable except in heavy storm or flood conditions. The target population is all water column parameter values and ranges from the selected areas of priority streams within the limited temporal collection index periods.

Additional surface water strata (e.g., lagoons, lakes, marshes) may be added as protocols are updated and refined, and as funding permits. Although wetlands and marine/estuarine waters are significant resources within the SFAN, they are not included as target water bodies yet since these indicators were lower priority for the SFAN. However, protocols will be developed in the future as funding permits. All Areas of Special Biological Significance (ASBS) within the SFAN are in coastal waters and will be covered in a protocol for marine water quality.

2.2.1.1 Data representativeness/sampling constraints: Assuring representativeness of the data will be accomplished by using methods used by the USGS (collector sites, cross-section checks, sampling from the centroid of flow, etc.). A combination of assuring representativeness, plus selecting sites upstream of bridges and culverts (as detailed in Standard Operating Procedure (SOP #12, Site Selection & Documentation)), and randomly selecting where to start sampling the midpoints and cross-sections upstream will assure both reasonable representativeness of the target population while still maintaining good data comparability with regional USGS data. To help ensure that inferences from a single site visit (sample population) to chemical and biological ranges at selected sites in priority streams (target population) are appropriate, continuous monitors will be deployed. Data from these instruments will help gain an understanding of seasonal and diurnal (daily) variability. This data, where available for a particular site, will also allow us to broaden the target population definition to include all water quality parameter values and ranges from the selected areas of priority streams, (without the caveat of the limited temporal collection periods). These types of variability occur in many water quality parameters and will be discussed in greater detail in the SOPs and in subsequent versions of this protocol.

Some constraints to sampling representatively include difficult or unsafe site access, particularly during storm events, lack of staff availability during the winter holidays when major storm events often occur, and laboratory constraints such as sample hold time, and hours of operation or holiday closures. Other constraints to sampling representatively are that sites will primarily be located within park boundaries and will not necessarily represent the larger watershed. This will not be a significant concern for the SFAN since parks encompass several watersheds in their entirety. However, watersheds with significant portions located outside park boundaries may not be sampled in some cases due to access issues, relative lack of management options, or other limitations.

2.2.1.2 Selection of target streams: The SFAN watersheds are identified and described in the San Francisco Area Network Preliminary Water Quality Status Report (Cooprider, 2004). The target population was chosen based on: 1) Data trends from review of WRD Water Quality Data Inventory and Analysis Reports and a UC Berkeley report (Stafford and Horne, 2004) including recent data from PORE, GOGA, and PINN, 2) Results of water quality planning meetings in 2002 and 2003, and 3) Criteria for Selection Table (Appendix C) for the SFAN Target Water Bodies.

The selection criteria table in Appendix C provides the major information needed to prioritize target watersheds. This prioritization is essential to reducing the number of water bodies monitored due to staff, time, and funding constraints. The table takes into account Category 1 and 2 water bodies as defined by the NPS Freshwater Work Group Subcommittee (Rosenlieb et al., 2002). Category 1 water bodies are listed as impaired by the Clean Water Act Section 303d. Category 2 water bodies have one or more of the following characteristics: lack baseline data, have an established threat, are subject to ecological impairment or are linked to another vital sign (e.g., stream T&E and fish assemblages). Other characteristics used to prioritize target water bodies include a high proportion of the watershed within park boundaries (higher priority) and whether other entities are monitoring a particular water body (lower priority).

There are three levels of prioritization: high, medium, and low priority. Category 1 (303d listed) water bodies are high priority for monitoring followed by water bodies having two or more of the Category 2 characteristics. Low priority water bodies have only one or none of the Category 2 characteristics. Medium priority water bodies often had a combination of characteristics. Water bodies generally excluded from the priority list have one or more of the follow characteristics:

Only listed as impaired by diazinon (no other Category 1 or 2 characteristics):
The San Francisco Bay Regional Water Quality Control Board listed all San Francisco Bay Area urban streams as impaired by diazinon. These creeks are not specifically listed by name and it has not been verified that all of these streams contain elevated levels of diazinon. However, all urban creeks are considered to be potentially impaired by diazinon and are automatically included. Many SFAN streams (Franklin, Lobos, Dragonfly, Tennessee Hollow, Milagra, Calera, Sanchez, and Coyote Creek) are included.

Diazinon has now been phased out as a commercially available pesticide. Consequently, pyrethroid based pesticides have replaced diazinon as the Regional Board's primary pesticide of concern. Pesticides are not currently monitored in park streams but planning is underway to address pesticide issues through the WRD Level 1 Inventory Project with the USGS. The SFAN is currently coordinating with the USGS to conduct baseline monitoring for pesticides in these urban creeks.

Lacking baseline data:
Water bodies that lack baseline data are not appropriate for Water Quality Vital Signs funding since there is separate funding through WRD for Level 1 Water Quality Inventory Program (R. Irwin, personal communication, 18 September 2004). Also, streams that lack baseline data are often lower priority for park management. This is illustrated by the fact that many of the streams lacking baseline data are not subject to ecological impairment. After baseline data is obtained

for these water bodies, they will be added to the protocol if results indicate that there is an established threat.

Streams primarily located off parklands:
Water bodies with only small portions on park property are often located in urban areas where local watershed groups are active. This greatly improves the potential for parks to work with volunteers who, in many cases, are already been conducting monitoring activities. This also includes water bodies that are located within the park legislative boundary but not managed by the park (and particularly areas where NPS staff access is restricted).

Adequate monitoring by other entities:
Water bodies consistently monitored by other entities (e.g., Stinson Beach County Water District monitors Easkoot Creek (GOGA)) need not be monitored. It is appropriate and fiscally responsible not to monitor these streams if the parks have access to the data and the data meets the needs of the monitoring program.

To provide an example of how the criteria for selection table and the above exceptions can be used to prioritize water bodies, consider Haggerty Gulch. It flows into Tomales Bay, a Section 303d water body. However, it is primarily located off parklands. In addition, it lacks baseline data and may qualify for a separate monitoring program through WRD.

Franklin Creek has some conflicting characteristics in the criteria for selection table. It has several low priority characteristics including: 1) only a small portion located on parklands, 2) only diazinon impaired, and 3) a local group conducting monitoring. However, it also has some high priority characteristics including 1) it has an established threat (high fecal coliform) and 2) is linked to the freshwater dynamics (stream hydrology) vital sign and 3) has the potential to support Federally threatened steelhead. It is also a highly visible resource for the park since it is located behind the John Muir historic house.

Strentzel Creek has a somewhat more complex set of decision-making factors. It is ephemeral, only half of the watershed is located on NPS property (JOMU), and it lacks baseline data. These are factors that would exclude it from the priority list. However, it is subject to ecological impairment and it is the only significant watershed within JOMU. Also, erosion and sedimentation in this watershed are highly significant management issues for that park. Therefore, it is included on the priority list. Strentzel Creek is actually a higher priority for JOMU than Franklin Creek since JOMU owns half of this small watershed and manages only a few hundred meters of Franklin Creek. However, because of the proximity of these two streams it makes sense to monitor both if possible. Strentzel Creek is ephemeral and there may be opportunities to coordinate local volunteers to monitor water quality (particularly sediment) during storm events.

West Union Creek is also a complex example of utilizing the table in appendix C. The stream is only partially located on parklands but in this case, that does not reduce its priority since the headwaters are located on parklands. Also, the San Francisquito Creek Watershed Council and other groups are monitoring the creek further downstream but data is very limited for the upstream portion of the creek on parklands. Reasons to include it as priority stream in this monitoring plan are that it has a vital signs link (supports salmonids and possibly California red-legged frogs) and is subject to ecological impairment from erosion, landslides and potentially high coliform levels from equestrian use. It is also located within the sediment-impaired San Francisquito Creek watershed.

The examples above illustrate the point that the criteria for selection table provides a significant amount of information to guide decision making but it is not always straightforward. The purpose of the table is to guide decision making through a review of all issues that need to be considered and to document the decisions. Despite efforts to categorize water bodies and follow a logical process, professional judgment and park management also play a role and the decision-making process can be complex. The SFAN Preliminary Water Quality Status Report provides information about water quality priorities for each park (Cooprider, 2004).

The proposed priority water bodies were primarily chosen because they have an established threat and link to another vital sign. Olema Creek and Lagunitas Creek are also heavily weighted because they are considered impaired and this has been verified by baseline data. Chalone Creek is included because nearly all of PINN is part of the Chalone Creek watershed. Additional (alternative) streams are those that have established threats (i.e., monitoring has shown high levels of pollutants) or are subject to ecological impairment (i.e., streams are suspected to be contaminated in the future) but are primarily priority for individual parks. Alternative streams could potentially be monitored if funding were available.

Table 11. High priority streams.

| **Stream** | **Park** |
|---|---|
| Lower Redwood Creek and tributaries | GOGA |
| (Green Gulch, Kent, Banducci, Camino del Canyon) | MUWO |
| Upper Redwood Creek and tributaries | GOGA |
| (Bootjack and Fern Creek) | MUWO |
| Rodeo Creek and tributary | GOGA |
| (Gerbode Creek) | |
| Tennessee Valley Creek | GOGA |
| Chalone Creek and tributaries | PINN |
| (Sandy Creek, McCabe Canyon, Bear Gulch) | |
| Olema Creek and tributaries | PORE/GOGA |
| (John West Fork, Davis Boucher Creek) | (managed by PORE) |
| Lagunitas Creek tributaries | PORE/GOGA |
| (Bear Valley Creek, Devil's Gulch, and Cheda Creek) | (managed by PORE) |
| Pine Gulch Creek | PORE |
| West Union Creek and upper tributaries | GOGA |

Table 12. Medium priority streams.

| Stream | Park |
|---|---|
| Strentzel Creek | JOMU |
| Franklin Creek | JOMU |
| Nyhan Creek | GOGA |
| Oakwood Creek | GOGA |

Table 13. Low Priority Streams.

| Stream | Park |
|---|---|
| Additional Olema Creek tributaries (Quarry Gulch, Giacomini Gulch) | PORE |
| Webb Creek | GOGA |
| El Polin Spring (Creek) | PRES |
| Tennessee Hollow Creek | PRES |
| East Schooner Creek | PORE |
| Home Ranch Creek | PORE |
| Creamery Creek | PORE |
| A Ranch Perennial Creek | PORE |
| B Ranch Creek | PORE |
| C Ranch Creek | PORE |
| Kehoe Creek | PORE |
| Abbotts Creek | PORE |
| Muddy Hollow Creek | PORE |

### 2.2.2 Site selection criteria, stratification, and randomization

Examples of stratification in water quality sampling sites include broad stream type (perennial, intermittent, ephemeral), watershed size, stream pattern (straight, meandering, braided) or other channel characteristics. Sampling can also be stratified by time (e.g., by varying the order of sampling sites). For the SFAN, since the streams are mostly small coastal streams with similar substrate and channel type, watershed size, and hydrologic conditions, a stream classification scheme was not used to decide on monitoring locations. No stratification was used to determine current site locations.

In consultation with park resource managers, sites were chosen based on the following criteria: 1) evidence or suspicion of contamination at a particular site (e.g., faulty septic systems, agricultural use, pet waste, outfall pipe), 2) human or aquatic health issue (e.g., there is a swimming area in the receiving water of a stream, 3) presence of a stream gauge or other permanent hydrologic monitoring equipment (linkage to freshwater dynamics vital sign), and 4) linkage to other aquatic vital signs (e.g., stream fish assemblages). Co-locating water quality sites with past or current macroinvertebrate or fish monitoring sites helps ensure data that has been used for trend analysis and management decisions in the past, continue to be comparable with the current monitoring program. All sites within a given watershed will be sampled on the same day (or even around the same time) or during the same storm event. Sites should represent inputs from all areas of the watershed (i.e., all major tributaries), capture the most downstream site within NPS property, and be permanent long-term sites (considering access). When choosing the number of sites within a watershed, we wanted to be as comprehensive as possible in representing the watershed while choosing a number of sites that is practical (considering laboratory and staff costs and logistics).

Where present, a particular tributary within a watershed may be suitable as a “reference reach”. This stream would be most similar to other streams in the watershed in geology and be the most natural (unaltered geomorphology and land use). These reference sites may be in wilderness areas with little disturbance, if available, or they may be located in the uppermost reaches of a particular priority stream, many of these sites are included in the site list as “alternate” sites. These reference sites are included in the sampling design not only to ensure monitoring of the state of “wilderness” or “pristine” water on park lands, but also to provide data for a comparison with sites in a particular priority stream more significantly impacted by environmental stressors. In this way, water quality data from the selected sites in SFAN priority streams will serve to better inform management decisions of land-use issues or to support broader watershed-level inferences.

After identifying specific monitoring questions that were to be addressed by sampling, efforts were made to determine if existing or previously-sampled sites could be used to answer these questions. If so, these sites were chosen for inclusion to enable data continuity and linkages. For example, there are six monitoring sites on Olema Creek that will be used. These are pre-established monitoring sites for the Regional Board’s pathogen TMDL project. The selection of water quality sites and site IDs was based to a large extent on existing or past water quality monitoring sites and park input. In some cases, the former site ID was initially used so that past and future data could be easily recognized as comparable.

A more simplified, logical naming convention is used in this protocol. A site ID history table explains when former sites were chosen as long-term monitoring sites, and when their ID’s were changed. This table accompanies the site location and access table in Appendix E. Site locations are shown on maps in Appendix F.

### 2.3 Selection of parameters and protocols

The EPA Western Pilot Field Operations Manual for Wadeable Streams (Peck et al., 2001) and the National Field Manual (USGS, various dates) protocols will be followed for field methods. USGS protocol for stream discharge measurements will be followed (Rantz, 1982). The USDA Forest Service Redwood Sciences Laboratory protocol for turbidity and sediment sampling will be followed at the turbidity threshold sampling station on Olema Creek (U.S. Forest Service, 2002). Table 13 includes a broad overview of field methods. Laboratory methods for fecal indicator bacteria (FIB), nutrients, and total suspended solids (TSS) will follow “Standard Methods” (American Public Health Association, et al., 1998) or comparable EPA method. The SOPs will describe more protocol details not covered in this table. Summaries of the SOPs are provided in Section 3.0 of this protocol. The SOPs will rely heavily on local programs such as the State Water Resources Control Board’s Surface Water Ambient Monitoring Program (SWAMP) and the associated Quality Assurance Management Plan (Puckett, 2002).

Water quality varies over space and time in still waters. Rivers and streams are generally well mixed. Therefore, depth integrated sampling may not be needed except in the dry season where only pools may be present. The USGS National Field Manual (NFM) discusses depth-integrated sampling further. The study objectives need to be considered when determining sample collection procedures. For example, if analyte discharge measurements are desired, the USGS National Field Manual recommends that depth and width integrating sampling be conducted (Wilde et al., 1998).

Another reason that the USGS recommends depth-integrated sampling is that some forms of nutrients and bacteria are often associated with sediment particles. The San Francisco Bay Regional Water Quality Control Board does not use depth-integrated sampling for bacteria or nutrient TMDL monitoring. The Regional Board's Surface Water Ambient Monitoring Program (SWAMP) does not collect depth-integrated samples for bacteria. Regardless, in many cases with the SFAN streams, there is not sufficient depth, except during storm events, to obtain a meaningful depth-integrated sample. In order to maintain consistency at all of the sites and throughout the sampling season, a "grab" or "hand-dipped' sample will be obtained at a uniform depth (typically 4-8 inches) from the centroid of flow. During periods of low or no flow, where water is isolated in pools, a randomly-selected pool will be sampled, grab samples will be obtained as stated, but a profile of core parameters will be obtained that includes a surface-level sample (~ 4 inches) and a sample from near the bottom will be collected.

Nitrate, ammonia, and total nitrogen will be monitored regularly for long-term trend detection and for short-term, localized toxic or eutrophic events. Ammonia transforms to different nitrogen species very quickly. In the winter there may be high levels of total ammonia, but low levels of the toxic, unionized ammonia. Also, even though a sample may have no unionized ammonia in one section of a stream there may be a toxic event in another section. Therefore, it is important to target certain areas of the watershed; this is achieved through a judgmental design.

EPA's recommended parameters for nutrient assessment are total phosphorous, total nitrogen, chlorophyll-a, and some measure of water clarity (e.g. turbidity for rivers and streams) (U.S. Environmental Protection Agency, 2000a). Nitrogen and phosphorous are the main causal agents of enrichment, while the two response variables, chlorophyll-a and water clarity are early indicators of system over-enrichment for most waters. However, it is generally agreed that Bay Area streams (i.e., freshwater systems) are nitrogen limiting, not phosphorus limiting. Therefore, any addition of nitrogen would impact aquatic growth and/or toxicity to organisms (Stafford and Horne, 2004).

Table 14. Target streams, parameters, and protocols to be monitored.

| Stream | Park | Parameters | Frequency | Personnel | Protocols |
|---|---|---|---|---|---|
| Olema Creek | PORE | Core parameters, flow, FIB, nutrients, sediment, water level | Monthly; weekly for 5 weeks in summer and winter; continuous at one site; one storm event | SFAN Water Quality Specialist | National Field Manual (USGS, various dates); Rantz , 1982 ; Peck et al., 2001; APHA et al., 1992; State Water Resources Control Board (Puckett 2002); U.S. Forest Service, 2002. |
| Lagunitas Creek tributaries | PORE GOGA | Core parameters, flow, FIB, nutrients, sediment | Monthly, plus one storm event continuous* at one site | SFAN Water Quality Specialist | National Field Manual (USGS, various dates); Rantz , 1982 ; Peck et al., 2001; APHA et al., 1992; State Water Resources Control Board (Puckett 2002); U.S. Forest Service, 2002. |
| Pine Gulch | PORE | Core parameters, flow, water level, FIB, nutrients | Monthly; continuous* at one site | SFAN Water Quality Specialist | National Field Manual (USGS, various dates); Rantz, 1982 ; Peck et al., 2001; APHA et al., 1992; State Water Resources Control Board (Puckett 2002) |
| Lower Redwood Creek | GOGA MUWO | Core parameters, flow, FIB, nutrients, sediment, water level | Monthly plus one storm event; one site continuous* | SFAN Water Quality Specialist | National Field Manual (USGS, various dates); Rantz, 1982 ; Peck et al., 2001; APHA et al., 1992; State Water Resources Control Board (Puckett 2002) |
| Upper Redwood Creek | GOGA MUWO | Core parameters, flow, FIB, nutrients, sediment | Monthly plus one storm event; continuous* at one site | SFAN Water Quality Specialist | National Field Manual (USGS, various dates); Rantz, 1982 ; Peck et al, 2001; APHA et al., 1992; State Water Resources Control Board (Puckett, 2002) |
| Rodeo Creek | GOGA | Core parameters, flow, FIB, nutrients, sediment | Monthly plus one storm event; continuous* at one site | SFAN Water Quality Specialist | National Field Manual (USGS, various dates); Rantz, 1982 ; Peck et al., 2001; APHA et al., 1992; State Water Resources Control Board (Puckett 2002) |
| Tennessee Creek (GOGA) | GOGA | Core parameters, flow, FIB, nutrients | Monthly plus one storm event; continuous* at one site | SFAN Water Quality Specialist | National Field Manual (USGS, various dates); Rantz, 1982 ; Peck et al., 2001; APHA et al., 1992; State Water Resources Control Board (Puckett 2002) |
| Nyhan Creek | GOGA | Core parameters, flow, FIB, nutrients | Monthly | SFAN Water Quality Specialist | National Field Manual (USGS, various dates); Rantz , 1982 ; Peck et al, 2001, APHA et al., 1992; State Water Resources Control Board (Puckett, 2002) |
| Oakwood Creek | GOGA | Core parameters, flow, FIB, nutrients | Monthly | SFAN Water Quality Specialist | National Field Manual (USGS, various dates); Rantz , 1982 ; Peck et al, 2001; APHA et al., 1992; State Water Resources Control Board (Puckett, 2002) |

| Stream | Park | Parameters | Frequency | Personnel | Protocols |
|---|---|---|---|---|---|
| West Union Creek | GOGA | Core parameters, flow, FIB, nutrients, sediment | Monthly during winter and spring | SFAN Water Quality Specialist | National Field Manual (USGS, various dates); Rantz , 1982 ; Peck et al, 2001; APHA et al., 1992; State Water Resources Control Board (Puckett 2002); U.S. Forest Service, 2002. |
| Franklin Creek | JOMU | Core parameters, flow, water level, FIB, nutrients | Monthly; continuous* at one site | SFAN Water Quality Specialist; assistance from local volunteers | National Field Manual (USGS, various dates); Rantz, 1982 ; Peck et al, 2001, APHA et al., 1992; State Water Resources Control Board (Puckett 2002) |
| Strentzel Creek | JOMU | Core parameters, flow, sediment | Storm events | SFAN Water Quality Specialist; assistance from local volunteers | National Field Manual (USGS, various dates); Rantz, 1982 ; APHA et al., 1992; State Water Resources Control Board (Puckett 2002); U.S. Forest Service, 2002. |
| Chalone Creek | PINN | Core parameters, flow, FIB, nutrients, sediment | Monthly during winter and spring; continuous* at one site; one storm event | SFAN Water Quality Specialist with park staff assistance as available | National Field Manual (USGS, various dates); Rantz, 1982 ; Peck et al., 2001; APHA et al., 1992; State Water Resources Control Board (Puckett 2002) |

*The continuous probe will be moved from watershed to watershed on a rotating basis (remaining in each watershed for at least two weeks, each season) for Olema, Pine Gulch, Redwood, Tennessee Valley, Rodeo, Franklin, and Chalone Creeks.

**<u>Notes on Table 14:</u>**

1. Ideally each priority stream would have a continuous monitoring data set that would represent the diurnal and seasonal conditions in that stream. Logging multiparameter instruments (e.g., datasondes) collecting continuous data can be rotated between watersheds for two-week deployments.
2. Storm event sampling will be opportunistic. but will be consistent for each site from year to year (i.e., an early/mid/late winter season storm will always be sampled).
3. In order to consider the potential of using field kits rather than laboratory analyses for nutrient parameters, field kits can be used in conjunction with laboratory sampling and the results can be compared.
4. (Ward et al., 1990) recommend reducing sampling frequency to once a quarter, unless looking for regulatory violations, to reduce serial correlation. However, there are often other variables of interest which change on a shorter time scale. If the same data is used for long-term trends and short-term exceedences measured values can be averaged over each quarter, so that there is just one value per quarter.
5. Maps of these water bodies are located in Appendix F.
6. Core parameters will be monitored continuously at sites on a rotating basis. Newly-revised USGS continuous monitoring protocols (Wagner et al, 2006) will be followed as appropriate. Water level is monitored continuously at sites where automatic recording stream gauges are located.

7. For streams that will be sampled during a storm event, the same general storm event will be monitored every year (i.e., first flush, mid, or late-season storm; 3rd storm event, etc.)

Key to Table 14

- Core parameters*: dissolved oxygen (D.O.), specific conductance, pH, and temperature
- Flow (quantitative) or Flow Severity Index* (estimated or qualitative)
- Water Level
- FIB (fecal indicator bacteria): Fecal/Total Coliforms, *E. coli*,
- Nutrients: Total nitrogen, ammonia, nitrate/nitrite,
- Sediment: Turbidity and total suspended solids (TSS) or suspended sediment concentration

* Minimum collection parameters for each station visit

### *2.3.1 Data Comparability*

Significant measures will be taken not only to ensure that our data is comparable with other agencies, but also to encourage universities, watershed councils and other volunteer groups conducting monitoring to document sufficient metadata to gauge the comparability of their data with ours. The network water quality specialist coordinates with all entities involved in monitoring on parklands in order to optimize data sharing. Representatives from the agencies/entities listed in section 1.2.3 above will be contacted, data comparability issues will be discussed and a metadata checklist will be distributed (see Ch. 4, Data Handling, Analysis and Reporting). SOP 4 (QAPP) details the efforts to provide maximum data comparability with federal, state, and other monitoring agencies. This protocol provides the minimum standards and guidelines that SFAN should utilize, with strong encouragement to use more stringent criteria and to adopt methodologies that improve upon these minimum standards. The SFAN QAPP (SOP 4), and Field method SOP's (SOPs #3-9) detail the procedures that will ensure that we have representative, comparable, accurate and precise data that can be shared statewide and nationwide, to the extent possible.

One of the central ways the SFAN freshwater quality monitoring protocol will insure the comparability of their data to outside groups is to follow some basic information quality guidelines by integrating a high degree of transparency about data and methods used to generate the data, including quantifying the limits of Measurement Quality Objectives (MQO's - See Table 9 in the QAPP (SOP4)) specifications for precision, bias and sensitivity.

Table 15. Overview of SFAN Data Quality Assurance.

| Data Comparability Issue | SFAN Data Quality Assurance |
|---|---|
| Sufficiency of Metadata | • Metadata requirements of NPSTORET are comprehensive, ensuring that methods, analyses and handling of both samples and data are documented in the same place as the data itself (including the attachment of the protocol and SOP documents themselves).<br>• Systematic verification of data in the database, as well as periodic review of stated procedures and included documentation (SOP's).<br>• The Protocol Narrative and SOP's will thoroughly document all field and laboratory methods, including QA/ QC measures. |
| Field Methods | • Standard USGS or SWQCB (SWAMP) protocols will be followed, as explained in the SOP's.<br>• Documentation of equipment calibration frequency and acceptance criteria. |
| Lab Methods | • All laboratories analyzing SFAN samples will be NELAP (or CA-ELAP) certified for the parameter and analysis being conducted.<br>• All methods used for laboratory samples will follow Standard Methods using APHA/AWWA/WEF methods or comparable EPA methods.<br>• Laboratory QC measures will include matrix spikes, method blanks, calibration standards, lab and field-duplicated samples. |
| Sensitivity | • For lab parameters: Calculation of both Method Detection Limit (MDL) and Minimum Level of Quantitation (ML).<br>• For field or "core" parameters: Quarterly collection of seven replicate samples or measurements in order to calculate the Alternative Measurement Sensitivity (AMS). |
| Precision | • For Field Measurements: Duplicate at least one measurement, or 10% of a days' samples (whichever is larger).<br>• For Lab Measurements: Duplicate analysis of 10% of samples. Report the Relative Percent Difference (RPD). |
| Bias | • Maintain consistent personnel and methodology where possible.<br>• Overlap* a minimum of seven (7) measurements when personnel changes, thirty (30) when a method or equipment changes, and fifty (50) when replacing surrogate estimators like FIB.<br>• Analyze such overlapping samples to determine the contribution of bias (if any) to any variance in the data.<br>• Control bias by: Use and analysis of "blank" samples (Field, Trip or Lab Blanks) to determine contamination by methodology.<br>• For control of measurement bias, certified reference materials and/or spikes will be analyzed once every 20 samples and % difference shall not be more than the values listed in Table 10 of SOP#4 (QAPP). |
| "Accuracy" | • For the purposes of this protocol, the term "accuracy" should be taken to be the "uncertainty in accuracy" and is a combination of random error (precision) and systematic error (bias) components that are due to sampling and analytical operations. Measurement uncertainty will be controlled quantitatively through calculations of sensitivity, precision and bias. |

*Overlap: old and new methods (i.e. old and new equipment, old and new personnel) will each be used to collect data from a site for a minimum number of times (a number of visits to different stations, or repeated measurements at a single site).

### 2.4 Sampling Frequency and Replication

There are many points to consider when determining when to collect a water sample and take field measurements. Ideally, dissolved oxygen would be measured in the early morning (just before dawn) when D.O. is expected to be lowest. This would capture the worst-case scenario and help determine whether the D.O. range meets the established criteria. The same holds true for pH – if they occur, we want to capture the pH's that are outside the criteria range of 6.5-8.5. However, we don't yet know enough about the creeks to make decisions about when D.O. and pH levels would be most detrimental to aquatic life. These answers can be obtained over time. It is more realistic to answer these types of questions with continuous monitoring than with monthly monitoring. A continuous probe will be moved from watershed to watershed on a rotating basis for Olema, Pine Gulch, Redwood, Tennessee Valley, Rodeo, Franklin, and Chalone Creeks to facilitate the collection of this important data.

Sites will be monitored at approximately the same time for each monthly sample event (i.e., sites will be monitored roughly every thirty days, within a two hour window to the extent possible). The time of day that sampling takes place will be established during the first year of monitoring. The storm event (first, second third; early/mid/late season) will also be established during the first year of monitoring. Subsequent sampling years will mimic the initial monitoring year with regards to storm event and time of day.

The specific monitoring questions determine how sites are selected and the type and number of habitat(s) (riffle, run or pool) sampled. Some reasons to sample pools include that they are often the most contaminated, they allow for sampling in intermittent streams where riffles/runs are absent part of the year, and they are important fish habitat. Reasons to sample riffles include transport, flow, and load–related concerns (e.g., sediment transport, fecal coliform load for TMDL monitoring). Information from riffles can also be used in conjunction with stream macroinvertebrate data.

The primary sampling objective is to sample and take stream measurements in the centroid of flow wherever possible (see SOPs #5-8). At the establishment of each sampling site, a stream cross-section of core parameters will be measured to ensure and confirm that sampling at the centroid of flow is representative for other parameter sampling purposes. This measure will be repeated seasonally to ensure that the method continues to be representative. In an effort to impart some randomization to the exact sampling location within a target reach, a random number generation method will be used to select the point (upstream or downstream) within the centroid of flow (and within the desired habitat (riffle, run or pool)) for sample collection. For intermittent streams with isolated pools in the summer/fall it is also important to take samples and measurements in these pools since they are areas of fish refuge and to allow for comparison of annual and season variability in site water quality. Toxic ammonia, low D.O., and high temperatures are potential threats to aquatic life. In intermittent streams with isolated pools during the summer/fall, a randomly-selected pool will be sampled, grab samples will be obtained as stated for laboratory analysis, but a profile of core parameters will be obtained that includes measurements at the a surface (~ 4 inches) and at a point near the bottom. Tables 16a and 16b provide a summary of habitat sampling differences for perennial and intermittent streams.

Following this sampling regime will allow SFAN to answer specific monitoring questions listed in Appendix D. SFAN will follow the rotating watershed schedule listed in Table 17.

Table 16. Habitat Sampling

A. Perennial Streams.

| **Parameter** | **Pool** | **Season** | **Riffle/Run** | **Season** |
|---|---|---|---|---|
| Core parameters | | | X | All |
| Bacteria | | | X | All |
| Nutrients | | | X | All |
| Sediment | | | X | Winter/spring |

B. Habitat Sampling in Intermittent Streams*

| **Parameter** | **Pool** | **Season** | **Riffle/Run** | **Season**** |
|---|---|---|---|---|
| Core parameters | X | All | X | Winter/spring |
| Bacteria | X | Summer/fall | X | Winter/spring |
| Nutrients | X | Summer/fall | X | Winter/spring |
| Sediment | | | X | Winter/spring |

* Some site on intermittent streams may have perennial flow

**There may be years when there is flowing water well into summer; in this case sample based on flow not season.

Table 17. General Water Quality Monitoring Schedule.

| **Stream** | **Park Unit** | **FY07** | **FY08** | **FY09** | **FY10** |
|---|---|---|---|---|---|
| Olema Creek | PORE | M, S, W | M, S, W | M,S, W | M,S,W |
| Lagunitas Creek | PORE/GOGA | | | M | M |
| Pine Gulch | PORE | M | M | | |
| Lower Redwood Creek | GOGA/MUWO | | | M ,S | M, S |
| Upper Redwood Creek | GOGA/MUWO | | | M | M |
| Rodeo Creek | GOGA | M, S | M, S | | |
| Tennessee Creek | GOGA | M, S | M, S | | |
| Nyhan Creek | GOGA | M, S | M, S | | |
| Oakwood Creek | GOGA | M, S | M, S | | |
| West Union Creek | GOGA | | | M | M |
| Franklin Creek | JOMU | M | M | | |
| Strentzel Creek | JOMU | S | S | | |
| Chalone Creek | PINN | M, S | M, S | | |

M monthly monitoring (winter and spring only for Chalone Creek and West Union Creek)
S monitoring during at least one storm event
W weekly monitoring (of core parameters and FIB only) for five weeks in winter and summer

Opportunities for phasing-in additional water bodies (e.g., Presidio streams) or eliminating the rotating basin approach will continue to be considered. Due to the current pathogen TMDL program monitoring on Olema Creek, it will continue to be monitored annually for the foreseeable future. Ideally, Lagunitas Creek tributaries would also be monitored annually since this stream is an impaired water body. However, a sediment TMDL monitoring program is not yet in place for this creek (expected by 2008). Lower Redwood Creek is currently being monitored through 2006 as part of the Big Lagoon Restoration project. This is a short-term monitoring program designed by a consultant and modified by GOGA (Stillwater Sciences,

2004) and will end before FY08; hence, it is recommended that I&M assume monitoring for the entire watershed (Upper and Lower Redwood Creek) at that time. USGS NAWQA protocols recommend a minimum of two years of consecutive monthly monitoring (Gilliom et al., 2001) for rotating basin designs. A phasing-in approach (gradually adding more watersheds over time) will also be considered depending upon funding. This would allow longer-term data sets for trends, without two-year gaps. Also, where annual monitoring is mandated by state TMDL project, then we *will* monitor every year and be able to analyze for long-term trends without two-year gaps (an example would be Olema Creek) Other options are to conduct monthly monitoring of core parameters on all streams so that if there are any major problems, parks can be alerted. Monitoring for nutrient and bacteria parameters could then be conducted only quarterly, or monthly on a rotating schedule.

Sample size is a critical element of the power of statistical analysis. Sample size is determined largely by sampling design, and is one of three critical elements including confidence level and power that determine our ability to detect a change in water quality. Sample sizes will vary slightly depending on annual rainfall patterns and other conditions affecting how long a stream holds water, but a summary of anticipated sample sizes is shown in Table 18, below.

Table 18. Sample Size Summary for SFAN Priority Streams.

| Stream | # of Sites* Proposed(Alt.) | # Samples /Site/Yr ** | # Samples *** /Watershed/Yr | Park | # Samples /Park/Yr |
|---|---|---|---|---|---|
| Olema | **6(2)** | 13<br>18-20 FIB samples | **72-96**<br>**(108-144 FIB samples)** | **PORE** | **FY07-FY08**<br>144-180 |
| Pine Gulch | **3** | **12** | **36** | **PORE** | FY09-FY10 |
| Lagunitas | **3** | **13** | **39** | **PORE / GOGA** | **147-183** |
| Rodeo | **2(1)** | **13** | **26-39** | **GOGA** | **FY07-FY08** |
| Tennessee | **2(1)** | **7** | **14-21** | **GOGA** | 52-104 |
| Nyhan/ Oakwood | **0(2)** | **7-10** | **14-20** | **GOGA** | FY09-FY10 |
| Redwood | **9(3)** | **7-13** | **117-156** | **GOGA/MUWO** | 129-204 |
| West Union | **2(3)** | **7-12** | **24-48** | **GOGA** | |
| Franklin | **1** | **12** | **12** | **JOMU** | **17-22** |
| Strentzel | **0(5)** | **2** | **10** | **JOMU** | |
| Chalone | **5(3)** | **7-13** | **35-104** | **PINN** | **65-104** |

* The number of sites listed per stream is the proposed # with the alternate # of sites in parentheses (i.e. 6(2) means six proposed sites, with two alternate sites).
** The number of samples per site per year depends on the presence of water in intermittent streams during the dry season.
*** The number of samples per watershed per year depends on the availability of funding to sample alternate as well as proposed sites.

Based on data from a limited number of sites for the past two years, SFAN has been able to approximate the minimum detectible differences (MDD) in mean parameter values from one year to the next, which we will be able to distinguish given the sample sizes in the current protocol (Table 19). These approximations were based on available data for core parameters from long-term sites on Olema Creek. Those parameters for which we are unable to estimate the variation of the parameters of the population due to lack of baseline data, have estimated power and MDD goals that will be re-evaluated and updated as data is collected.

Table 19. Minimum Detectable Differences for 1-year intervals of SFAN Sampling Design.

| | Confidence Level (1-α*100) | Power (1-β *100) | MDD (% change) |
|---|---|---|---|
| **Core Parameters** | 95% | 95% | 15% (20% for SC) |
| **Nutrients** | 95% | 90% | 30% |
| **Sediment** | 95% | 80% | 40% |
| **Bacteria** | 95% | 80% | 50% |

- This power analysis was conducted using paired samples and the equations to estimate sample size using the form $n=(s)^2(Z_\alpha + Z_\beta)^2/(MDC)^2$ where
    - s= Standard deviation of the difference between paired samples
    - $Z_\alpha$= Z coefficient for type I error rate
    - $Z_\beta$= Z coefficient for type II error rate
- Analysis was checked using MS Excel macro from Gerow (*In Press*) at http://www.statsalive.com/

Because we do not have consistent or complete past data for either nutrient or sediment parameters for sites in SFAN priority streams, we have set some general goals based on initial estimates using the sample sizes in the current protocol. Because both bacteria and sediment parameters have high variation in SFAN streams, we have set more reasonable goal of being able to detect a larger change with slightly less power. Through evaluation of collected data, we should be able to refine our power and MDD calculations for these parameters, resulting in greater power to detect smaller change.

The current sampling design should allow SFAN to detect the minimum difference in the mean for parameters shown in Table 19 on one-year intervals. Due to the rotating panel design, we will also be able to compare two-year periods every six years, with greater power to detect a smaller change. The same stations will be monitored during years one and two, and again during years five and year six. So, these two year periods can be compared to one another every six years. Because the sample size will be twice as large as for single-year comparisons, we should be able to detect a smaller change with greater power.

Due to the judgmental or targeted nature of the current sampling design, we cannot currently make statistically-supported inferences about the percentage of impaired miles in priority watersheds based on sampling at targeted locations. However, many of our streams are short compared to some other parks around the country. With long-term data from sites at various levels of the watershed including a reference or upper watershed site and a site at the bottom of a watershed, we can make educated guesses about some of the intervening sections, but no definitive statistical inferences can be made. With the integration of randomly-selected sites that will assure geographic coverage for SFAN watersheds, we will be able to integrate statistically-unbiased inferences of the percentage of impaired stream miles, as well as the natural ranges of water-quality and long-term trends for water quality in freshwater systems of SFAN.

# 3.0 Field and Laboratory Methods

Standard operating procedures (SOPs) cover field season preparations and equipment, sequence of events in the field, details of taking measurements (including example field forms), post-collection processing of samples (e.g., lab analysis), end-of-season procedures, quality assurance/quality control (QA/QC), and all other details of water quality monitoring. The bulk of information related to field methods is included in SOP 3, SOP 5, and SOP 9. Most of the laboratory related details are included in SOP 6, SOP 7, and SOP 8. SOP 4 covers the majority of details related to QA/QC.

## 3.1 Standard Operating Procedures

All aspects related to field and laboratory methods are included in Standard Operating Procedures. Methods follow existing national programs (EPA and USGS). Quality assurance and quality control methods follow California Water Resources Control Board EPA-approved guidelines for Quality Assurance Project Plans. Details of field methods and implementation are outlined in the SOP documents including:

SOP 1: Revising the Protocol
SOP 2: Personnel Training and Safety
SOP 3: Equipment and Field Preparations
SOP 4: QAPP (QA/QC SOP)
SOP 5: Field Methods For Measurement of Core Parameters
SOP 6: Field and Laboratory Methods for Fecal Indicator Bacteria
SOP 7: Field Methods For Sampling Nutrients
SOP 8: Field and Laboratory Methods For Sediment
SOP 9: Field Methods For Flow (Stream Discharge)
SOP 10: Data Analysis
SOP 11: Data Reporting
SOP 12: Site Selection and Documentation

### *SOP 1: Revising the Protocol*

This SOP refers to revisions to be made after the monitoring plan has been implemented in October 2006. Data analysis after the first year or two of monitoring will help determine whether the monitoring data collected adequately answers the stated questions and meets objectives. Revising the protocol to thoroughly answer the monitoring questions will be a top priority. Practical issues to be considered include: sampling frequencies, site selection and location, logistics of transporting samples to laboratory, and effectiveness of the protocol during storm events. It is essential to make these critical changes earlier in the implementation of the monitoring plan to ensure long-term effectiveness of the protocol. Therefore, it is expected that the majority of major changes (i.e., those having the most effect on sampling design and statistical analysis) to the protocol would be made in the first few years. Any changes to the protocol or SOPs will be documented in a revision history log. In addition, the SOP emphasizes the importance of overlap in equipment, methods, and staff when changes occur in order to document bias in the data.

### *SOP 2: Personnel Training and Safety*

At least two network or park individuals will be trained initially. This will help ensure continuity should one person leave a position or otherwise not be available for a particular sampling event. In addition, it will be mandatory that two field staff be present for sampling during storm events (see safety SOP) and it is recommended at other times as well. Staff will be trained through review of written guidance plus a series of consecutive sampling events. The overall project purpose, protocols, equipment manuals, and field maps will be reviewed before commencing fieldwork. The first sampling event (or first group of sites in an event) will be used to demonstrate the sampling process including QA/QC. The second sampling events or group of sites will give the trainees an opportunity to sample with guidance. The trainer (water quality specialist, hydrologist, or hydrologic technician) will periodically accompany the recently trained individuals to ensure that the protocol continues to be followed and to address any questions.

The safety SOP ensures that safety will be a priority in the short and long-term. The SOP will stress the importance of radio use, team communication (e.g., sign-out sheet or buddy system) and sound judgment. The SOP will also individually address potential safety hazards by focusing on the Job Hazard Analysis for this position. In addition, USGS standard safety protocols will be incorporated (Lane and Fay, 1997).

Sampling during storm events is of particular concern in Mediterranean climates. Most, if not all, of the streams in the SFAN have a rapid response time (hydrograph) with stage rising rapidly during a storm event. For example, individuals taking flow measurements in Chalone Creek (PINN) have had to end flow measurements since the stage rose to an unsafe level during the short time that the velocity measurements were being taken.

Other potential hazards to be considered at all parks include flowing logs and other debris, quicksand (particularly at PINN), falling trees, drowning, falling, back injuries from lifting/bending/falling, poison oak and stinging nettle, and (though rare) large predators such as mountain lions. Though some of these hazards are rare, it is important to be aware of all of them. A thorough list of hazards is particularly useful for staff that may not be familiar with the local weather and climate, topography, flora, or fauna.

### *SOP 3: Equipment and Field Preparations*

This SOP will follow guidelines provided by the manufactures (e.g., Oakton, YSI, Inc., Marsh-McBirney, Eureka Environmental, and Rickly Hydrologic) for equipment operation and maintenance including calibration methods and frequency, cleaning, changing pH electrodes, D.O. membranes, etc. In addition, recommendations from the WRD and USGS will be followed on pre-field mobilization and water quality instrument checks that include procedures for office/lab calibrations and error checks of each sensor to determine if acceptance criteria are met prior to conducting field work (P. Penoyer, NPS Hydrologist, Fort Collins, 2005, pers. comm). A field equipment checklist is included in the protocol. This lists all required and optional equipment to be carried with the field crew (or in the field vehicle) and all times. The checklist is provided for review before leaving the base park/office for each sampling event. This SOP also includes procedures for preparing and maintaining continuous monitoring equipment following USGS protocols (Wagner et. al., 2006). End-of-season procedures and preparation of equipment for short and long-term storage are also covered here.

### *SOP 4: Overall Quality Assurance Project Plan (QAPP)*

Following NPS guidance from (Irwin, 2004), the QAPP or QC SOP includes 1) QC objectives for measurement certainty (detection limits such as MDL (method detection limit) and PQL (practical quantitative limit), 2) QC objectives for measurement precision, 3) QC objectives for measurement systematic error (bias as percent recovery), 4) QC objectives for data completeness (including adequacy of planned sample sizes and statistical power), and 5) QC objectives for blank controls for lab measurements. Individual SOPs for parameters also includes discussion related to data comparability and selection of laboratories and protocols. SOPs are highly detailed (e.g., indicating how many duplicate samples will be collected for QC) so that other agencies can determine whether they can utilize SFAN data in conjunction with their own data). The California Department of Water Resources "Guidelines for Preparing Quality Assurance Project Plans" (1998) was followed.

### *SOP 5: Field Methods for Measurement of Core Parameters*

This SOP primarily focuses on the use of multiparameter probes for measuring basic water chemistry parameters. Specifically, the YSI 85 will be used for determining dissolved oxygen concentration and percent saturation, specific conductance, salinity, and temperature. Handheld, waterproof pH meters will be used in conjunction with the YSI 85. The SOP also discusses the use of continuous monitors for temperature, conductivity, pH, and dissolved oxygen. Details of this field SOP focus on the actual in-situ measurement (e.g., location of probe within sample site, location of probe in water column, proximity to streambank, differences in measurement techniques in pools versus riffles, etc.). Equipment use and preparations prior to fieldwork are discussed in the Equipment and Field Preparations SOP.

### *SOP 6 & 7: Field Methods for Sampling Bacteria and Nutrients*

Details of these field SOPs focus on the actual sampling (e.g., sterile technique to avoid contaminating a sample, location of sample in the water column, proximity to streambank). Details of sample bottle labeling, storage, and transport to laboratories (including chain of custody protocols) are discussed. Laboratory methods are also discussed.

### *SOP 8: Field and Laboratory Methods for Sediment*

This SOP discusses all aspects of monitoring sediment (i.e., total suspended solids and turbidity). This includes preparation of sample bottles, how to collect a sample in the field, laboratory analysis using the oven-dry weight method for TSS, and use of a Hach 2100 turbidimeter. Depth integrated sampling and use of in-site turbidity sensors are also discussed as well as integration of sediment monitoring with other vital signs monitoring (e.g., freshwater dynamics/stream hydrology). Operation and maintenance of the network's turbidity thresholds sampling unit is also introduced.

### *SOP 9: Field Methods for Flow Measurements*

Flow will be measured quantitatively at stream gauges (pressure transducer water level monitors such as Global or Druck, Inc.) using the USGS method for measurement of stream discharge (Rantz, 1982). Quantitative stream flow will also be assessed at sites related to TMDL projects in order to calculate loads to a 303d listed water. Where time or storm conditions do not permit safely measuring flows, then a quantitative estimate (float method) will be provided. In addition, regardless of whether a flow measurement can be taken, a qualitative description of flow will also be provided.  This is often referred to as a flow severity value and has several categories. These categories include: no flow (pools present), dry, low, medium, high, flood. Other methods and instructions on when to use a particular method are discussed further in the SOP.  The use of automatic dataloggers to monitor stream flow is also recommended and these procedures will be detailed in the SFAN freshwater dynamics protocol.

### *SOP 10:  Data Analysis*
An overview of data analysis is covered in Ch. 4.  However, more details are provided in this SOP including coverage of summary statistics, comparing data to water quality criteria, and QA/QC measures such as calculating duplicate precision.  The data analysis SOP follows the Greater Yellowstone Network's (GRYN) SOP #9 for Data Analysis (O'Ney, 2005).   Also included in this SOP is a discussion of data analysis tools that have been integrated into NPSTORET.

### *SOP11:  Data Reporting*
This SOP provides details on reporting intervals, content, and format.  It closely follows other networks data reporting SOPs as well as the SFAN Data Management Plan.

### *SOP 12: Site Selection and Documentation*
This SOP discusses various permits or contacts required before commencing fieldwork. Access issues are covered such as obtaining keys or combinations for locks and being sensitive towards landowner concerns.  Other topics to be discussed include randomization to determine a sampling location within a sampling site.  Site documentation is also covered including photographic documentation (periphyton, gravel bars, riparian cover) and site naming conventions.

### *Data Collection and Management*
There is no established data collection SOP for Freshwater Quality.  However, the Network's overall Data Management Plan (Press, 2005) should be consulted.  Some of the suggested methods for data collection include: 1) using an established field data sheet instead of a field notebook, 2) using a handheld computer to enter data, 3) using a handheld tape recorder and later transcribing the data, 4) keeping a log of any decisions made, 5) ensure proper training for field crews. The third suggestion can be useful if there is only one person collecting field measurements, particularly flow measurements.

## 3.2 Field and Laboratory Methods Overview

Field and laboratory methods are covered in detail in the QAPP and SOPs. Field and lab documentation, sample handling, logistics, and measurement quality objectives for field and laboratory parameters are covered in the QAPP.  Only labs approved for the parameters of interest by the State and the National Environmental Laboratory Accreditation Program will be utilized.

Additional research was conducted to obtain information and comparative results from several labs prior to the establishment of a laboratory contract for the SFAN freshwater quality monitoring project. Laboratory detection limits must meet the specific guidelines outlined in the QAPP. Any change of labs should be thoroughly documented. Any change in methods or personnel should also be documented and overlap should be provided/conducted whenever possible.

# 4.0 Data Handling, Analysis and Reporting

Roles and responsibilities for data managers, project managers, and the Network Coordinator in relation to data management are outlined in the SFAN Data Management Plan (Press, 2005). The Data Management Plan also provides guidance on dealing with legacy data and non-programmatic data from internal (NPS) and external sources. The SFAN Water Quality Specialist will coordinate with internal and external monitoring programs regarding acquisition of legacy data and metadata.

## 4.1 Metadata Procedures

Metadata reporting is accomplished through the metadata template located on the main switchboard of the NPSTORET database. The metadata template consists of nine categories including:

1) Collection Procedures
2) Gear Configurations
3) Preserve/Transport
4) Analytical Procedures
5) Lab Sample Preparation
6) Characteristics
7) Laboratory Information
8) Staff and Roles
9) Citations

A metadata checklist (D. Tucker, personal communication, 5 December 2004) will be used and presented to all individuals conducting water quality data collection. The checklist is included in Appendix G of this document. Field data sheets will contain much of the metadata and the checklist will help ensure that additional metadata is documented and tracked by field and office personnel. Metadata will be checked at least twice by the SFAN Water Quality Specialist before submission of the yearly NPSTORET Database to WRD.

## 4.2 Overview of Database Design

The SFAN will be utilizing the NPSTORET database produced by WRD. This database is a modification of EPA's STORET (Storage and Retrieval) database. It is a relational Microsoft Access database with built-in tools for transferring data to WRD and ultimately to STORET. The long-term location of the master database is on the PORE network (U:\Natural_Water\NPS_STORET\NPSTORET). The SFAN Water Quality Specialist will be responsible for managing the master database. Satellite copies of the SFAN NPSTORET database will be located on servers at PINN and GOGA.

A description of database structure, goals, and a link to download a copy can be found at the WRD Website: http://www.nature.nps.gov/water/infoanddata/index.cfm A brief summary is included here, but a hard copy of this document as it appeared at the time of this protocol version is included in Appendix G.

Table 20. Overview of NPSTORET Database Structure.

| Elements | Description | SFAN Implementation |
| --- | --- | --- |
| **Organization** | Defines the owner of related data sets in NPSTORET | SFAN is defined as the overarching owner of all Network and Park project data. |
| **Projects** | Defines a project name, start date, duration, purpose, study area and contact info. Allows for defining relationships to particular stations, characteristics, personnel and supporting documentation. | Projects are defined to maintain data sets for network pilot data, SFAN long-term monitoring data, as well as various state, county or park-level monitoring of park water resources. |
| **Stations** | Defines the location of water quality data collection points. Allows the definition of lat./long., elevation, county, state, and depth of sampling point, as well as a narrative station description and travel direcitons. Allows for the association of picture files for documenting site location or variation of conditions at the station. | SFAN defines stations for all current and legacy sampling sites, including seasonal photos and site naming history if applicable. |
| **Metadata** | Defines the background information about the following elements: Field Sample Collection Procedures, Gear Configurations, Sample Preservation, Transport, and Storage Procedures, Field/Lab Analytical Procedures, Lab Sample Preparation Procedures, Characteristics(water quality parameters), Groups of characteristics, Laboratory information, Staff and roles, and Citations. Collection method, equipment, laboratory methods, preservation and transport. Uses the EPA's "official" STORET Characteristic list, and requires the definition of various details depending on the chosen element. | SFAN has defined characteristics by EPA STORET name and the method or equipment used to collect (e.g. "DO_YSI85" for Dissolved Oxygen as measured by the YSI 85 multiparameter probe). Different methods to collect the same general characteristic are defined independently to ensure appropriate statistical treatment. |

| Elements | Description | SFAN Implementation |
|---|---|---|
| **Results** | Contains the narrative and numerical data collected during site visits or other monitoring activities. In order to enter the results of monitoring activities:<br>1) A Project must have been created,<br>2) One or more Stations must have been established, and<br>3) Minimally defined Characteristics must have been created. | SFAN has defined Activities as the various characteristic groups 1) Field Parameters 2) Bacteriological Lab Analysis; 3) Sediment Field and Lab Analysis and 4) Nutrient Lab Analysis; QA replicate data is associated with a particular station visit, and is flagged as Quality Assurance sampling, as are the replicate samples for calculation of PQL |
| **Reports, Statistics, Graphs and Exports** | NPSTORET has the capability to generate a variety of reports, statistical analyses, graphics and data export options. List or detailed reports can be generated to document each database template. Any subset of data can be analyzed using built-in statistical tools that include options for dealing with censored (detection limit/quantification limit) data. Any subset of data can be graphed using a variety of formats including Time Series and Box-and-Whiskers. Graphs are generated in Microsoft Excel to they can be saved or customized. Exports of any database element or any subset of Results data can be made to Access, Excel and text formats. | SFAN will be generating graphs and statistical analyses using imbedded tools. As we gather data and begin to perform analyses, we will work closely with WRD to tailor reporting, analyses and graphic capabilities to match SFAN needs. Subsequent revisions of NPSTORET will reflect improvements in reporting and analytical tools. |

Because this database is still in development, and a full version release is not expected until later this year, some details of actual fields, requirements and capabilities are still changing. For a draft version of a data dictionary for NPSTORET, including a list of fields, their description and lists of acceptable values for each field can be found in the draft guidance document from the WRD (Tucker, 2004). This document is titled: “Draft Guidance on Data Reporting and Archiving in STORET” and can be found online at: http://www.nature.nps.gov/water/infoanddata/wqpartetest.pdf

A report from NPSTORET containing the field definitions for the SFAN I&M Freshwater Quality Monitoring Program is included in Appendix G for reference only. The most current version is accessible only through the active copy of NPSTORET on the PORE server.

Satellite databases will be created at the beginning of each water year. The water year is generally from October to September. Individuals entering data into satellite copies are responsible for verifying data. They should also create back-up copies of the database on a CD or zip drive or on a different server or computer. The satellite databases will be brought into the master database at the end of each water year.

Data storage templates for NPSTORET include projects, stations, metadata, and results. All data for this program will be entered under the project name: SFAN_I&M: SFAN Long-Term Water Quality Monitoring Program. NPSTORET will run under Microsoft Access 2002 or higher.

Notes to include in the SFAN version of NPSTORET include: 1) upstream and surrounding land usage 2) site observations even if normal, 3) indicated whether the station is a reference site or not, 4) indicate whether the stream is ephemeral, intermittent, or perennial, and 5) indicate the type of water body, e.g., stream mainstem, tributary, pond, lagoon, lake.

There is a SIM Export button in the NPSTORET that creates a data file that is easily transferable to WRD for inclusion in the overall version of NPSTORET and ultimately to EPA's STORET in Washington, D.C. Also, NPSTORET will export data in Microsoft Access, Microsoft Excel, or comma or space delimited Text format for further data analyses.

In addition, a copy of NPSTORET will be made available to the Tomales Bay Watershed Council (TBWC) for use as a database to store their water quality data. Advice and support will be provided to ensure that legacy data from the old TBWC database will be moved into NPSTORET. A unique feature of this previous TBWC database is that is has a hierarchical structure that denotes the location of every water body in relation to every other water body. The SFAN and PORE staffs have been coordinating with the TBWC over the past few years (including providing feedback on their database) and this is expected to continue in the future.

## 4.3 Data entry, verification and editing

### *4.3.1 Data Entry*

Data will be reviewed upon receipt from a laboratory and during and immediately after field measurements (this is also true of data from data loggers such as turbidity sensor or pressure transducer data). This helps identify potential equipment problems and/or presence of pollutants. Full data analysis is not necessary until a complete set of data is gathered (annual), but it is essential to preview data as it is gathered. This includes comparing site data to expected results. For example, a pH of 12 is outside the established range for the SFAN sites and the data reviewer would need to determine the source of error. Similarly, the NPSTORET database has functions that can detect errant values that are entered. For example, a pH of 15 is not possible since it is on a scale of 1-14, so the program would not allow "15" to be entered as a pH measurement. The individual reviewing the data should have a working knowledge of what would be expected for that stream or watershed in different seasons, etc.

Data will be reviewed within a week after each sampling event for inconsistencies related to field personnel, how well SOPs are followed and how timing and logistics of sample collection and transport to laboratories may be affecting sample data. Also, at this time, any field notes regarding broken equipment or other needs (calibration, batteries, or replacement) can be addressed in time for the next sampling event. The SFAN data managers will work with the SFAN water quality specialist to ensure that data is well-understood and entered into the proper fields in NPSTORET. This coordination will also help ensure that metadata is complete and accurate. Data will be entered into the SFAN NPSTORET database no less than once a month to ensure adequate interpretation of field notes and receipt of proper laboratory QA/QC information. Entering data soon after collection and receipt of data from the laboratory ensures that labs are providing the needed data (including MDL, PQL) and handling samples properly.

### *4.3.2 Data Verification*

The accuracy of digitized records should be verified with field and laboratory data sheets. Once data is entered into the database, a different individual verifies the datasheet information against the database. Field staff will verify each of the field sheets that are entered into the database. As a QA/QC measure, the project manager will verify approximately 10% of the data entered. See the QAPP for additional details.

### *4.3.4 Data Validation*

Data validation is the final step in assuring the accuracy of data transfer from raw to digital form. Questionable data are identified, reviewed, and corrected if necessary. Automatic validation that checks the data as it is entered is built into NPSTORET and will be modified, if necessary, for the SFAN version of NPSTORET. These automatic validations are programming elements that "censor" the data based on known ranges. Therefore the data manager would not be allowed to enter data that is invalid such as 16 for pH or a date in the future. Through this process, outliers are identified. Examples of common errors are missed decimal places, numerical data placed in the wrong field (for example, the database shows a pH of 12 when 12 is actually the water temperature). Outliers can be identified through simply graphing all observations for a given station and parameter or graphing all station data together if there is only low to medium variability.

## 4.4 Routine data summaries and statistical analyses to detect change

This section is intended to provide an overview of statistical analyses appropriate for water quality data. It addresses particular features of water quality data sets that are unique and discusses methods of dealing with these features. More detailed and specific data analysis techniques are included in SOP#10 – Data Analysis. This SOP also covers details of data representation including tabular and graphical data.

### *4.4.1 Characteristics of Water Quality Data*

Most traditional statistical methods are based on the assumption that the data being analyzed have originated from a population (of measurements) with a normal (symmetric) distribution. Classical statistics makes other assumptions including uncorrelated data and constant variance for populations being compared (Gilbert, 1987). However, water quality data typically has a non-normal distribution (due to a lower bound of zero, the presence of outliers, and positive skewness). Seasonality and autocorrelation are also common as well as covariance with other variables such as discharge (Helsel and Hirsch, 2002). All these factors are important in deciding types of analysis to use since the ability to detect trends is dependent upon the variability of the data, as well as the responsiveness of the indicators (parameters), and sample size (Irwin, 2004).

Water quality data is usually highly variable, both temporally and spatially. Temporal variability is caused by autocorrelation (serial correlation) and by seasonality. Ward et al. (1990), recommend reducing sampling frequency to once a quarter, unless looking for regulatory violations, to reduce serial correlation. However, there are often other variables of interest which change on a shorter time scale than three months. For example, if the same data is used for long-term trends and short-term exceedences, measured values can be averaged over each quarter, to provide just one value per quarter. This method could also be useful in analyzing large data sets with varying sampling frequencies (common with past water quality data). Seasonal variation can often be explained by variation in discharge. However, seasonality sometimes remains in the data set even after accounting for flow effects. In these cases, seasonal variation can be reduced by analyzing data grouped by season (Hirsch et al., 1982). See section 4.6 for more on seasonality and data analysis.

### *4.4.2 Preparing the Raw Data Set for Analysis*

4.4.2.1 Censored and missing data: In addition to the above characteristics, water quality data is commonly "censored" or reported as less than or greater than the detection limit (this has been common for ammonia and nitrate data within the SFAN as well as fecal coliform data). This data is considered outside the range of quantitation. In other words, it cannot be accurately quantified and represented as a numerical value). Data outside the range of quantitation will not be statistically analyzed. More information on dealing with censored data is included in the SOP#10 – Data Analysis. For more information on the range of quantitation, detection limits, etc. refer to SOP#4 – Quality Assurance Project Plan.

Uncensored data is particularly an issue with FIB data. Knowledge of the water quality patterns, with relation to location and storm event, is required in order to determine if a bacteria sample should be diluted and to what magnitude. Having an educated guess of what the dilution should be for a given sample is essential to limiting the number of results that are censored.

4.4.2.2 Replicates: Replicates from the raw data record should be averaged together and the single mean value used in their place for analysis, or else the median value should be used. The standard deviation or range of the replicates provides an estimate of the variability in the measurement technique (Stafford and Horne, 2004).

4.4.2.3 Data transformations: Data transformations can be utilized including logarithmic transformations and adjusting data for flow. Logarithmic transformations will be used particularly with FIB data since transforming allows for a more simple data analysis and graphical display of data with a range that often spans over several orders of magnitude. In addition geometric means, required for regulatory monitoring of FIB, are calculated after log transformations (see SOP #10).

Logarithmic and flow transformations can make the data more "normal" in distribution and increase the possibility of using parametric statistics which are slightly more powerful for determining statistical differences. An advantage of using the medians and interquartile ranges to describe central tendencies is that they remain the same even when the data is transformed whereas the mean and standard deviation change (Helsel and Hirsch, 2002). Data that is transformed for analysis will be back-transformed prior to reporting.

### *4.4.3 Data Analysis: Techniques & Issues*

Non-parametric statistical tests are more appropriate for non-normal data and are used to describe distributions in water quality data. The median and interquartile range (IQR) (middle 50% of data points) will used in addition to the mean and standard deviation typically used for normally distributed data (Hirsch et al., 1991). The median is particularly useful for water quality data since it is less sensitive to outliers than the mean (Zar, 1999).

Confidence intervals (95%) will be used to bound uncertainties in means and medians (Irwin, 2004). Summary statistics and correlation techniques will be used to quantify relationships between water quality parameters. To limit seasonal variability, statistical tests will be conducted for each of the different seasons.

Trend analyses will also be conducted following techniques discussed in "Statistical Methods in Water Resources" (Helsel and Hirsch, 2002). As WRD suggests (Irwin, 2004), traditional hypothesis tests will not be used. Modified hypothesis testing may be used for trend detection. Methods for long-term trend analysis (e.g., every 5 or 10 years) are discussed further in SOP#10.

Table 21 describes the broad types of data analysis for each monitoring question. For each monitoring question, individual station data will be summarized seasonally and annually. Data from all stations within each watershed will also be summarized seasonally and annually. Discrete and continuous data will be analyzed separately. However, data from the same days will be compared for quality control and to obtain a relationship between the datalogger readings and instantaneous monthly/weekly data. All data will be compared with water quality standards by graphing the data along with a "criteria line" on the graph that clearly shows which measurements fall above or below the standards. Within each watershed, data from stations upstream and downstream of a suspected pollution source or tributary will be compared. Summary tables, histograms, and box and whisker plots will be used to show median and interquartile ranges (non-parametric), mean and standard deviation (parametric), and 95% confidence intervals for means and medians.

Table 21. Sampling Designs and Data Analysis Based on Monitoring Questions.

| **Monitoring Question** | **Overall Sampling Design & Analysis** |
|---|---|
| What are the existing chemical and biological ranges in water quality *at particular sites†* within SFAN priority freshwater streams? | Analyze annual, seasonal, and daily data for each station and each group of stations in a stream or watershed. |
| What are long-term trends in water quality *at particular sites†* in the SFAN priority streams? | Analyze data from sites in the upper, middle, and lower reaches if possible, or at the stream source and mouth. Analyze annual and seasonal data for each station and for each group of stations in a stream or watershed. |
| Is the water quality of the SFAN at particular sites in priority streams in compliance with beneficial uses? | Focus on sites known or suspected to be impaired; analyze data for each site for each group of stations (collectively) in a stream. Compare reference reach range with impacted reach range. |
| What are the pollution sources within the watersheds? | Compare data from individual sites from one sampling event to another; also compare data from multiple sites within a stream. Analyze annual and seasonal data for each station and for each group of stations in a stream or watershed. Compare variability in reference reaches with variability in impaired reaches. |
| *Are specific management actions reducing pollution loads? | Compare data from individual sites from one sampling event to another; also compare data from multiple sites within a stream. Analyze annual and seasonal data for each station and for each group of stations in a stream or watershed. |

† The caveat of limiting range and trend analyses to data from *particular sites* in priority streams will be eliminated with the integration of a probablistic monitoring element.
*Documenting effectiveness generally requires higher frequency sampling over more than two years (Dave Lewis, personal communication, 28 July 2005). Therefore, this may be a situation where the I&M program notifies parks of pollution sources so that parks can implement management practices and potentially augment existing I&M monitoring.

### 4.5 Reporting schedule and format

Reporting results is a critical component of long-term vital signs monitoring in order to ensure that information generated through the program is available to all levels of park management including planning, interpretation, maintenance, and law enforcement. An overall communication strategy is being developed and will be updated in the document: SFAN Communication and Outreach Strategy.

The overall strategy provides detailed information about required reports including 1) annual reports and 2) Analysis AND synthesis reports. Suggested formats are documented in the SFAN Data Management Plan – Appendix C (Press, 2005)

In order to complete the annual report, the SFAN Data Management Team will work with the water quality specialist to ensure that data from the network's version of NPSTORET is provided to WRD on an annual basis. An additional requirement for WRD is to provide a report that includes a paragraph summary for each parameter plus summary graphs of each site. In addition, summary paragraphs will be provided for each watershed including any proposed management activities related to water quality improvements. Recommendations for revising the protocol (changing monitoring intervals and timing, moving/adding sites, etc.) will also be proposed. These annual reports will also be provided to the SFAN parks, and can be used to report to GPRA and can be included in the AAWRP annual report to Congress.

A comprehensive data analysis and synthesis will be written every few years in addition to more simplified, general annual summaries. Having this extra time allows for more thorough data analysis and review of protocols and may give greater opportunity for adaptive management. More details on data reporting are included in the Data Reporting SOP (#11).

In addition, the Water Quality Specialist will be responsible for contributing to the Annual Administrative Report and Workplan required by each network along with additional outreach products summarized in Table 22.

Table 22. Summary of reporting and communication products.

| Communcaction Product | Lead | Audience | Schedule | Summary |
|---|---|---|---|---|
| Annual Report: | Water Quality Specialist | Park Resource Managers | Annually | Formatted as described in Data Management Plan – Appendix C.<br>- Archive old data and document monitoring activities<br>-Describe current condition of the resources<br>-Document changes in the monitoring protocol<br>-Increase communication within the park and network |
| Analysis and Synthesis Report | PORE Hydrologist | Park Resource Managers | 3-5 years | Formatted as described in Data Management Plan – Appendix C.<br>- Determine patterns and trends<br>-Discover correlations among resources being monitored<br>-Analyze data to determine the level of change that can be detected using the existing sampling scheme<br>-Provide context, interpret data for the park within a multi-park, regional, or national context<br>-Recommend changes to management practices |
| Program and Protocol Reviews | Network Coordinator | Program Lead, Water Quality Steering Committee, I&M Technical Steering Committee, Water Resource Division | 5 years | -Periodic formal reviews of operations and results<br>-Review of protocol design and product to determine if changes are needed<br>-Part of the quality assurance – peer review process |
| Executive Briefing | Water Quality Specialist | Program Managers, Superintendents, Front line interpretation staff | Annually (upon completion of annual report) | Two-page summary that lists monitoring objectives and questions, discusses annual results, and provides a regional context. |
| Vital Sign Report Card | Network Coordinator | Program Managers, Superintendents, Front line interpretation staff | 3-5 years (upon completion of Analysis and Synthesis Report | Two-page summary that aggregates trend data into an index. Provides |
| Web Site Intranet | Water Quality Specialist | Park Staff | Annually or as needed | Post all completed reports |
| Web Site Internet | Water Quality Specialist | Park Staff, General Public | Annually or as needed | Post all Executive Briefings, Report Cards, |
| Park Presentations | Water Quality Specialist | Park Staff | Annually | Provide a presentation to park staff during senior staff, all employee, or division meetings at each park upon request. Gives staff an opportunity to ask questions about the program. |

| Communcaction Product | Lead | Audience | Schedule | Summary |
|---|---|---|---|---|
| IM Update | Water Quality Specialist | Park Staff | Quarterly | This one-page monthly e-mail provides park staff with a short update on vital signs projects. Text should be no more than one paragraph. |
| Photos | Water Quality Specialist | For all reports and publication | Continuous | High quality publication quality photo are needed to support all communication products. For digital photos that means 300 pixels per inch resolution in a plain or compressed TIF format. Specialist should make every effort to document ongoing work, special incidents, site visits for communication purposes. |

## 4.6 Data archiving procedures

Electronic data archiving includes long-term storage and access through the network server. The NPSTORET database and all reports will be available electronically through the GOGA main server where all I&M files are stored. In addition original data sheets and copies of reports will be stored in GOGA archives with hard copies potentially available in the GOGA Resource Management building where many I&M program staff are located. Once data have been validated/verified and the appropriate QA/QC procedures conducted (see the QAPP), the SFAN Water Quality Specialist will notify the Network Data Manager that the dataset is ready to be archived. All archived data will be stored in the secure Archive folder on the network server. The suggested directory structure for archived project folders is in the SFAN Data Management Plan.

# 5.0 Personnel Requirements and Training

## 5.1 Roles and responsibilities

The GS-6/7 Water Quality Specialist will be responsible for implementing the SFAN Freshwater Quality Protocol. The position will be term subject-to-furlough for the immediate future. A permanent position may be considered in the future dependent on funding. The Network Water Quality Specialist will have a flexible schedule ("maxi-flex") due to the need for travel time and long hours in the field.

The Network Water Quality Specialist will be directly supervised by the PORE Hydrologist. Duty station will be at the PORE headquarters. There is currently a dedicated office space for the individual at the PORE. Office space will also be provided at GOGA (Fort Cronkhite) in the same location as the Network Coordinator, Lead Data Manager, and Vegetation Ecologist.

The Network Water Quality Specialist will be responsible for conducting fieldwork and all QA/QC measures, data management, data analysis, and reporting. The Network Coordinator will provide programmatic oversight for data management, analysis, and reporting. In addition, the Network Aquatic Professionals Group will meet quarterly in order to maintain communication and coordination among the parks and between the parks and I&M staff. Additional individuals will assist with field work and data validation/verification tasks. These may be network technicians or park staff.

The PORE Hydrologist, with assistance from the Network Water Quality Specialist, will coordinate all contract management activities related to the water quality monitoring program. These individuals will coordinate with resource management staff at the parks to ensure monitoring goals are being met, to keep parks informed of monitoring activities, and to pursue funding opportunities. Partnerships and coordination with other agencies/individuals will include the Tomales Bay Watershed Council, Marin County Environmental Health Services, and the Regional Water Quality Control Board.

The Network Water Quality Specialist will work closely with other SFAN staff to integrate weather and stream hydrology (freshwater dynamics) monitoring components with water quality monitoring thereby limiting travel, improving efficiency, and optimizing safety. Park and network staff will work together when possible, particularly during storm events. This is a safety measure as well as a QA/QC measure.

<u>The SFAN Aquatic Professionals Group will consist of:</u>
Network Water Quality Specialist (Group lead)
*Network Hydrologic/Weather Technician or Intern
GOGA Hydrologist
GOGA Aquatic Ecologist
Network I&M Coordinator (will represent JOMU and EUON as well as overall network)
Network Data manager
PINN Resource Manager
PORE Hydrologist

PWR Aquatic Ecologist (pending Technical Assistance request through WRD)

*These individuals may not participate in all meetings, particularly those related to management issues such as budget and personnel

Tasks for the SFAN Aquatic Professionals Group

- ♦ Conduct quarterly meetings to accomplish the following tasks:
- ♦ Provide input for the Stream T&E and Fish Assemblages, Freshwater Quality, Freshwater Dynamics, and Weather Monitoring programs
- ♦ Communicate network and park needs and work together to prioritize and resolve issues
- ♦ Make decisions regarding personnel hiring and program implementation
- ♦ Provide a forum to discuss monitoring results
- ♦ Review and approve workplans for network staff including the Water Quality Specialist and Hydrologic Technician
- ♦ Review technical reports (e.g., annual reports to WRD) and provide technical and programmatic oversight
- ♦ Assist Network Water Quality Specialist in recruiting field assistance among park and network staff
- ♦ Assist with coordination of aquatics group meetings
- ♦ Establish a MOU with state agencies conducting monitoring programs
- ♦ Participate in I&M Technical Steering Committee Meetings as a water resources representative (as needed)

Tasks for the SFAN Water Quality Specialist:

- ♦ Be well-versed in all aspects of the SFAN Freshwater Quality Protocol and conduct protocol revisions
- ♦ Coordinate logistics for field work and laboratory sample drop-off
- ♦ Coordinate field assistance for protocol implementation and provide training to field assistants
- ♦ Calibrate and maintain equipment in good working order and keep maintenance records
- ♦ Collect field data and implement field QA/QC measures
- ♦ Coordinate with laboratories regarding field sampling schedules and measurement quality objectives (QA/QC)
- ♦ Coordinate data entry, verification, and validation and consult with network data managers
- ♦ Perform statistical analyses on data; present and interpret results in technical reports
- ♦ Coordinate with PORE Hydrologist regarding staff and training needs, data analysis and data interpretation
- ♦ Coordinate with PORE Hydrologist regarding budget, vehicle, and equipment needs
- ♦ Assist with coordination of Aquatics Group Meetings
- ♦ Coordinate with USGS and WRD on Level 1 Water Quality Inventory
- ♦ Complete annual report and other communication products
- ♦ Provide regular updates to the aquatics group including a summary of data and related activities

Broad tasks for PORE Hydrologist

- ♦ Provide technical assistance and supervision for the SFAN Water Quality Specialist

- ♦ Develop and conduct performance review (to be reviewed by aquatic professionals group)
- ♦ Manage WRD Water Quality Monitoring Program budget
- ♦ Manage laboratory contracts for the SFAN Freshwater Quality Monitoring program
- ♦ Assist in coordination of Aquatic Professionals Group Meetings
- ♦ Provide or coordinate training for the SFAN Water Quality Specialist
- ♦ Conduct annual QA/QC field checks
- ♦ Participate in I&M Technical Steering Committee Meetings as a water resources representative

<u>Broad tasks for Network Coordinator</u>

- ♦ Participate in Aquatic Professionals Group meetings
- ♦ Coordinate guidance on data management, data analysis and reporting
- ♦ Provide information related to I&M program requirements including reporting requirements and deadlines
- ♦ Review technical reports and provide programmatic oversight

<u>Tasks for Network Data Manager</u>

- ♦ Provide assistance to the Network Water Quality Specialist regarding data management, archiving, reporting
- ♦ Assist with GIS needs
- ♦ Assist in coordinating with WRD regarding the NPSTORET database
- ♦ Assist with compilation of metadata for past and current monitoring programs; develop a scope of work for dealing with legacy water quality data throughout the network

## 5.2 Qualifications and training

See Section A8 of the QAAP for staff training/qualifications. Also, SOP 2 (training) and SOP 3 (safety) will include other details regarding staff requirements.

# 6.0 Operational Requirements

## 6.1 Annual workload and field schedule

A general monitoring schedule for the SFAN water bodies was presented previously in Table 12. Time commitments for the water quality specialist will be approximately 50% for field work and 50% for data management, analysis, and reporting. The field work load will be heavier in the winter. Since some parks or streams will not be monitored in the dry season (summer/fall), this is when the majority of the data analysis and reporting will occur. It is anticipated that data entry/management will be on-going in conjunction with the field work. Where possible, efforts will be made to obtain additional help for data entry. The project lead (water quality specialist) would then be more available for data validation and QA/QC measures. Also, where possible, the other park and network staff will assist with water quality monitoring in order to improve efficiency and safety.

## 6. 2 Key Partnerships and Access Requirements

A list of other regional water quality monitoring programs was offered in section 1.2.3 of this protocol. The SFAN Water Quality Specialist will maintain records of these and other groups or organizations monitoring water quality in or near SFAN parks. The person will also maintain contact information for project leaders of such programs. In addition, a data inventory for historic and current water quality data in SFAN parks will also be maintained with contact information, duration of monitoring and parameters monitored in order to facilitate data integration. As key partnerships are established with other monitoring agencies, the details of these partnerships will be included here. Refer to appendix C to determine what group, if any, is currently monitoring SFAN streams.

For some SFAN monitoring sites, access is restricted or controlled due to ownership or management of the site by private, or outside public entities. Please refer to the Site Location and Access Table in Appendix E for information and access recommendations for specific sites.

## 6.3 Facility and equipment needs

An inventory of all park and network equipment is included in SOP#3 – Equipment and Field Preparations. The SFAN Water Quality Monitoring Program has a dedicated YSI 85, pH meters, and a flow meter. Primary equipment costs will be related to purchase of continuous dataloggers for determining daily variability on water quality parameters. Another significant cost would be calibration of flow meters. Other anticipated costs include repair or replacement of old meters and purchasing supplies such as calibration kits, buffer solutions, batteries, gloves, etc. Equipment lists specific to each monitoring parameter are included in the SOPs.

Total suspended solids (TSS) analysis can be conducted “in-house” in the wet lab located at GOGA (Marin Headlands). The lab contains a balance, sink, vacuum, and drying oven used in TSS analyses. See SOP#8 – Field and Laboratory Methods for Sediment.

## 6.4 Startup costs and budget considerations

Table 23. Cost of laboratory analysis by parameter

| Analyte | Method Code | Method Name | *Cost per sample |
|---|---|---|---|
| Fecal/Total coliform | SM 9221B | /Multiple Tube Technique (MPN) | $30.00 |
| *E. coli*/Total coliform | SM 9223B | Quantitray† (MPN) | $20.00 @ offsite lab<br>$6.35 @ NPS lab |
| Total Kjeldahl Nitrogen | SM 4500 | Persulfate Method (oxidation to nitrate) | $50.00 |
| Ammonia | SM 4500F | Phenate Method (spectrophotometric) | $25.00 |
| Nitrate or Nitrite | SM 4500 | Colorimetric or cadmium reduction | $20.00 |
| Total suspended solids | SM 2540D | gravimetric | in-house lab |
| Suspended Sediment | SM 2540D | gravimetric | $35.00 |

*Approximate cost; prices will vary by laboratory

† SFAN has purchased an IDEXX Quantitray system for *E. coli*. The SFAN WQ lab will be set up in the Pacific Coast Science and Learning Center at PORE.

Table 24. Cost of laboratory analysis by stream for FY07-08 (update)

| Creek | All Sites | Proposed Sites Only |
|---|---|---|
| Chalone* | $7,523 | $4,975 |
| Olema* | $15,932 | $12,423 |
| Pine Gulch | $4,280 | $4,280 |
| Rodeo* | $5,855 | $4,100 |
| Tennessee* | $2,647 | $1,701 |
| Nyhan (A) | $1170 | |
| Oakwood (A) | $851 | |
| Franklin | $1,383 | $1,383 |
| Strentzel (A) | $385 | |
| | **$40,026** | **$28,861** |

*These are proposed creeks with at least one alternate site

A – These are alternate creeks

Table 25. Cost of laboratory analysis by stream for FY09-10

| Creek | All Sites | Proposed Sites Only |
|---|---|---|
| Lagunitas | $5,805 | $5,805 |
| Olema | $15,932 | $12,423 |
| Upper Redwood | $7,290 | $5,940 |
| Lower Redwood | $13,635 | $10,125 |
| West Union | $6,750 | $3,915 |
| | **$49,412** | **$38,208** |

Table 26. Estimated Budget

| Source of Funding or Expense | Budget | Expenses |
|---|---|---|
| WRD | $69,000 | |
| I&M (Freshwater Quality) | $20,000 | |
| Personnel GS-7/4 | | $45,000 |
| Vehicle | | $4,500 |
| Equipment and Supplies | | $4,500 |
| Travel | | $1,000 |
| Lab Contracts | | $34,000 |
| TOTAL | $89,000 | |

Personnel costs cover a GS-6/7 full time, term subject-to-furlough position. Travel covers local network travel, bridge tolls, and overnight stays for PINN. Equipment and supplies costs include the purchase of continuous loggers, replacement/repair of YSI 85 multiparameter probes and Oakton pH meters, and repair and calibration of existing flow meters. YSI 85 multiparameter probes generally last about 3 years and cost $1,200. Minisondes or datasondes that are deployed to determine diurnal variability are $3,000-$8,000 depending on the sensors that are attached. Sensors for basic core parameters are standard. Additional sensors for nitrate, ammonia, and turbidity add additional costs. These start-up equipment costs are significant for FY06.

Laboratory contracts will cover the cost of analyses for nutrients, fecal indicator bacteria, and potentially total suspended solids. Approximate costs for laboratory analyses are outlined in Table 23 for each parameter method. Further research into additional labs will determine if these costs are realistic for the desired detection limits (see SOP #4).

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