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San Francisco Bay Area Network Freshwater Quality Monitoring Protocol

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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

Mary A. Cooprider (Water Quality Specialist) and Rob G. Carson (Water Quality Specialist)
Inventory and Monitoring Program
San Francisco Bay Area Network (SFAN)
Golden Gate National Recreation Area
Fort Cronkhite
Sausalito, CA 94965

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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

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.

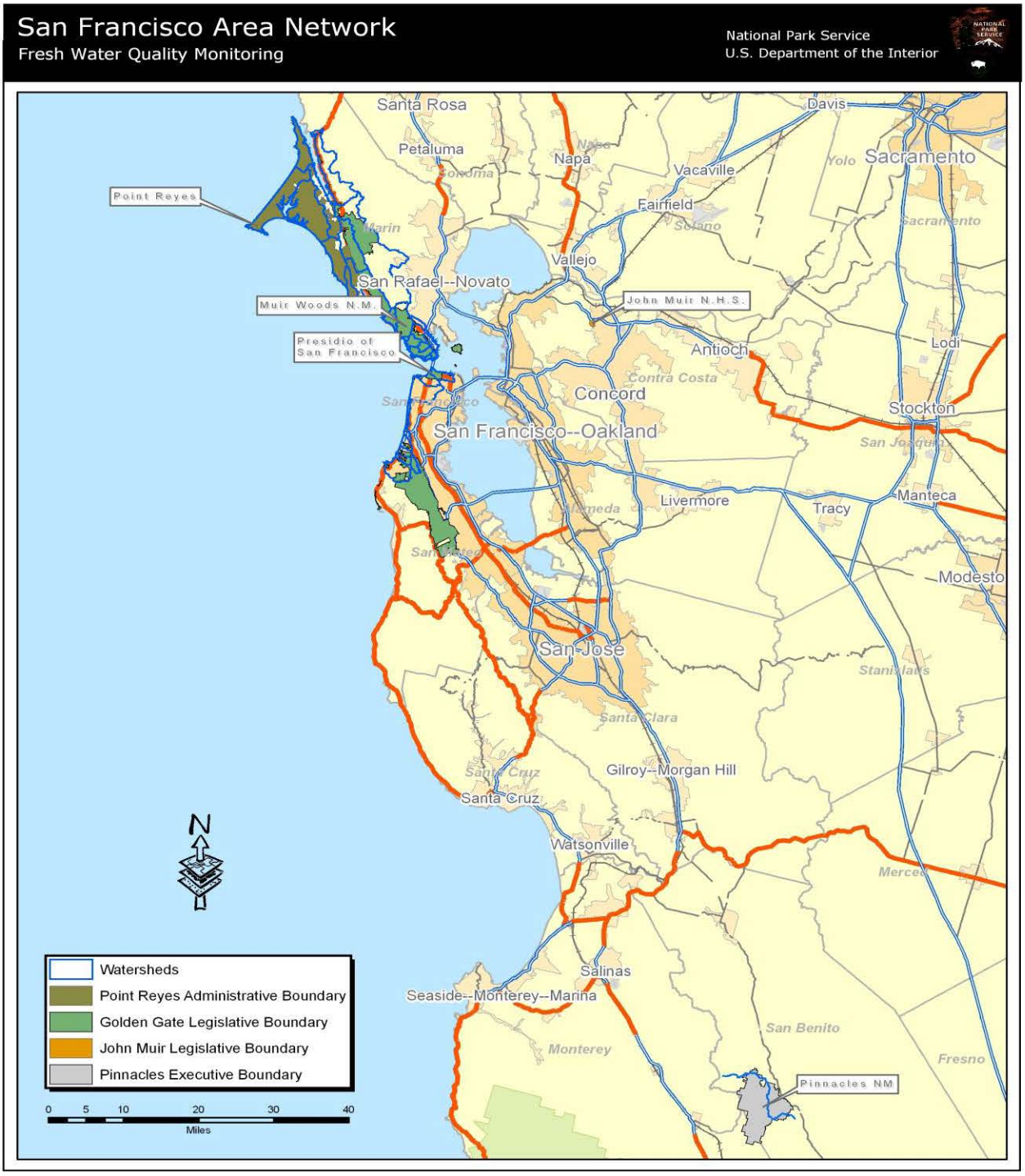

Figure 1. Map of San Francisco Bay Area Network Parks (created by Jason Herynk, National Park Service, 2005).

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 Upstream* of Carquinez bridge: 7.0 mg/L minimum
Dissolved oxygen (non-tidal waters)	Cold water habitat 7.0 mg/L minimum 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) 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		
$^{\phi}$Turbidity	25 NTU		1.30 NTU	2.34 NTU

∗Total suspended solids are listed in milligrams per liter (mg/L)
$^{\phi}$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 90^{th} percentile < 4000	
Shellfish harvesting (SHELL)	Median < 14 90^{th} percentile < 43	Median < 70 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 **v**arious 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:

<u>Only listed as impaired by diazinon (no other Category 1 or 2 characteristics):</u>
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.

<u>Lacking baseline data:</u>
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.

Notes on Table 14:

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). • Systematic verification of data in the database, as well as periodic review of stated procedures and included documentation (SOP's). • 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. • 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. • All methods used for laboratory samples will follow Standard Methods using APHA/AWWA/WEF methods or comparable EPA methods. • 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). • 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). • For Lab Measurements: Duplicate analysis of 10% of samples. Report the Relative Percent Difference (RPD).
Bias	• Maintain consistent personnel and methodology where possible. • 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. • Analyze such overlapping samples to determine the contribution of bias (if any) to any variance in the data. • Control bias by: Use and analysis of "blank" samples (Field, Trip or Lab Blanks) to determine contamination by methodology. • 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 18-20 FIB samples	**72-96** **(108-144 FIB samples)**	**PORE**	**FY07-FY08** 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_α= Z coefficient for type I error rate
  - Z_β= 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: 1) A Project must have been created, 2) One or more Stations must have been established, and 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. - Archive old data and document monitoring activities -Describe current condition of the resources -Document changes in the monitoring protocol -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. - Determine patterns and trends -Discover correlations among resources being monitored -Analyze data to determine the level of change that can be detected using the existing sampling scheme -Provide context, interpret data for the park within a multi-park, regional, or national context -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 -Review of protocol design and product to determine if changes are needed -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

Broad tasks for Network Coordinator

- 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

Tasks for Network Data Manager

- 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 $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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Appendix A. Beneficial Uses of the SFAN Water Bodies

Beneficial Uses of individual the SFAN water bodies as determined by the San Francisco Bay RWQCB (with modifications/additions by the SFAN staff in an April 2003 Memo to the RWQCB) are listed in the table below. Sets of water bodies grouped together with similar shading are located within the same greater watershed. Chalone Creek is located within the jurisdiction of the Central Coast Regional Water Quality Control Board; however, it is not included in there list of streams. Potential beneficial uses are indicated by "P", existing beneficial uses are indicated by "E".

	Park	AGR	COLD	COMM	EST	FRSH	GWR	IND	MAR	MIGR	MUN	NAV	PROC	RARE	REC1	REC2	SHEL	SPWN	WARM	WI
Tomales Bay	PORE GOGA	E	E	E	E		E			E	E	E		E	E	E	E	E		E
Lagunitas Creek	GOGA	E	E				E			E	E			E	E	E		E	E	E
Bear Valley Creek	PORE		E							E				E	P	E		E		E
Haggerty Gulch	PORE		E							E				E		E		E		E
Olema Creek	PORE	E	E				E							E	E	E		E	E	E
Pacific Ocean	PORE GOGA			E				E	E	E		E		E	E	E	E	E		E
Santa Maria Creek	PORE		E							E				E	P	E		E	E	E
Coast Creek	PORE		E							P				P	E	E		E		E
Alamere Creek	PORE														P	E		E		E
Crystal Lake	PORE														P	E		E	E	E
Arroyo Hondo	PORE		E							P				E	P	E		E		E
Limantour Estero	PORE		E	E	E				E	E				E	P	E	E	E		E
Glenbrook Creek	PORE		E	E	E				E	E				E	P	E		E		E
Muddy Hollow	PORE		E	E	E				E	E				E	P	E		E		E
Kehoe Lagoon	PORE														E	E			E	E
Abbott's Lagoon	PORE								E						E	E			E	E
Drakes Estero	PORE		P	E	E				E	E				E		E	E	E		E
East Schooner Ck.	PORE		P							P				P				P		E
Home Ranch Creek	PORE		E							E				E		E		E		E
Bolinas Lagoon	GOGA			E					E	E		E		E	E	E	E	E		E
Pine Gulch	PORE		E							E				E		E		E		E
McKinnan Gulch	GOGA		E							E				E		E		E		E
Morses Gulch	GOGA		E							E				E		E		E		E
Pike County Gulch	GOGA		E							E				E		E		E		E
Stinson Gulch	GOGA		E				E			E	E			E		E		E		E
Easkoot Creek	GOGA		E							E	E			E		E		E		E
Webb Creek	GOGA		E								E							E		E
Lone Tree Creek	GOGA																			E
Redwood Creek	GOGA	E	E				E			E	E			E	E	E		E		E
Tennessee Valley	GOGA	E	E							E						E		E		E
Rodeo Lagoon	GOGA				E									E		E		E	E	E
Rodeo Creek	GOGA		E											E		E		E		E
Nyhan Creek	GOGA															E			E	E
San Francisco Bay	GOGA			E	E			E	E	E		E	E	E	E	E	E	E		E
West Union Creek	GOGA		E				E			E				E		E		E		E
Lobos Creek	PRES						P			P	E					E		E	E	E
Mountain Lake	PRES						P									E			E	E
San Pedro Creek	GOGA		E							E	E					E		E		E
Alhambra Creek	JOMU		P							P	E			P	P	E		E	E	E

Definitions of Beneficial Uses are included below. These are defined by the San Francisco Bay Regional Water Quality Control Board at http://www.waterboards.ca.gov/sanfranciscobay/basinplan/web/BP_CH2.html Accessed July 20, 2005

AGRICULTURAL SUPPLY (AGR)

Uses of water for farming, horticulture, or ranching, including, but not limited to, irrigation, stock watering, or support of vegetation for range grazing.
The criteria discussed under municipal and domestic water supply (MUN) also effectively protect farmstead uses. To establish water quality criteria for livestock water supply, the Regional Board must consider the relationship of water to the total diet, including water freely drunk, moisture content of feed, and interactions between irrigation water quality and feed quality. The University of California Cooperative Extension has developed threshold and limiting concentrations for livestock and irrigation water. Continued irrigation often leads to one or more of four types of hazards related to water quality and the nature of soils and crops. These hazards are (1) soluble salt accumulations, (2) chemical changes in the soil, (3) toxicity to crops, and (4) potential disease transmission to humans through reclaimed water use. Irrigation water classification systems, arable soil classification systems, and public health criteria related to reuse of wastewater have been developed with consideration given to these hazards.

AREAS OF SPECIAL BIOLOGICAL SIGNIFICANCE (ASBS)

Areas designated by the State Water Resources Control Board.
These include marine life refuges, ecological reserves, and designated areas where the preservation and enhancement of natural resources requires special protection. In these areas, alteration of natural water quality is undesirable. The areas that have been designated as ASBS in this region are depicted in Figure 2-1. The state Ocean Plan (see Chapter 5) requires wastes to be discharged at a sufficient distance from these areas to assure maintenance of natural water quality conditions.

COLD FRESHWATER HABITAT (COLD)

Uses of water that support cold water ecosystems, including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates.
Cold freshwater habitats generally support trout and may support the anadromous salmon and steelhead fisheries as well. Cold water habitats are commonly well-oxygenated. Life within these waters is relatively intolerant to environmental stresses. Often, soft waters feed cold water habitats. These waters render fish more susceptible to toxic metals, such as copper, because of their lower buffering capacity.

OCEAN, COMMERCIAL, AND SPORT FISHING (COMM)

Uses of water for commercial or recreational collection of fish, shellfish, or other organisms in oceans, bays, and estuaries, including, but not limited to, uses involving organisms intended for human consumption or bait purposes.
To maintain ocean fishing, the aquatic life habitats where fish reproduce and seek their food must be protected. Habitat protection is under descriptions of other beneficial uses.

ESTUARINE HABITAT (EST)

Uses of water that support estuarine ecosystems, including, but not limited to, preservation or enhancement of estuarine habitats, vegetation, fish, shellfish, or wildlife (e.g., estuarine

mammals, waterfowl, shorebirds), and the propagation, sustenance, and migration of estuarine organisms.
Estuarine habitat provides an essential and unique habitat that serves to acclimate anadromous fishes (salmon, striped bass) migrating into fresh or marine water conditions. The protection of estuarine habitat is contingent upon (1) the maintenance of adequate Delta outflow to provide mixing and salinity control; and (2) provisions to protect wildlife habitat associated with marshlands and the Bay periphery (i.e., prevention of fill activities). Estuarine habitat is generally associated with moderate seasonal fluctuations in dissolved oxygen, pH, and temperature and with a wide range in turbidity.

FRESHWATER REPLENISHMENT (FRSH)

Uses of water for natural or artificial maintenance of surface water quantity or quality.

GROUNDWATER RECHARGE (GWR)

Uses of water for natural or artificial recharge of groundwater for purposes of future extraction, maintenance of water quality, or halting saltwater intrusion into freshwater aquifers.
The requirements for groundwater recharge operations generally reflect the future use to be made of the water stored underground. In some cases, recharge operations may be conducted to prevent seawater intrusion. In these cases, the quality of recharged waters may not directly affect quality at the well field being protected. Recharge operations are often limited by excessive suspended sediment or turbidity that can clog the surface of recharge pits, basins, or wells. Under the state Antidegradation Policy, the quality of some of the waters of the state is higher than established by adopted policies. It is the intent of this policy to maintain that existing higher quality to the maximum extent possible.
Requirements for groundwater recharge, therefore, shall impose the Best Available Technology (BAT) or Best Management Practices (BMPs) for control of the discharge as necessary to assure the highest quality consistent with maximum benefit to the people of the state. Additionally, it must be recognized that groundwater recharge occurs naturally in many areas from streams and reservoirs. This recharge may have little impact on the quality of groundwater under normal circumstances, but it may act to transport pollutants from the recharging water body to the groundwater. Therefore, groundwater recharge must be considered when requirements are established.

INDUSTRIAL SERVICE SUPPLY (IND)

Uses of water for industrial activities that do not depend primarily on water quality, including, but not limited to, mining, cooling water supply, hydraulic conveyance, gravel washing, fire protection, and oil well repressurization.
Most industrial service supplies have essentially no water quality limitations except for gross constraints, such as freedom from unusual debris.

MARINE HABITAT (MAR)

Uses of water that support marine ecosystems, including, but not limited to, preservation or enhancement of marine habitats, vegetation such as kelp, fish, shellfish, or wildlife (e.g., marine mammals, shorebirds).
In many cases, the protection of marine habitat will be accomplished by measures that protect wildlife habitat generally, but more stringent criteria may be necessary for waterfowl marshes and other habitats, such as those for shellfish and marine fishes. Some marine habitats, such as important intertidal zones and kelp beds, may require special protection.

FISH MIGRATION (MIGR)

Uses of water that support habitats necessary for migration, acclimatization between fresh water and salt water, and protection of aquatic organisms that are temporary inhabitants of waters within the region.

The water quality provisions acceptable to cold water fish generally protect anadromous fish as well. However, particular attention must be paid to maintaining zones of passage. Any barrier to migration or free movement of migratory fish is harmful. Natural tidal movement in estuaries and unimpeded river flows are necessary to sustain migratory fish and their offspring. A water quality barrier, whether thermal, physical, or chemical, can destroy the integrity of the migration route and lead to the rapid decline of dependent fisheries.

Water quality may vary through a zone of passage as a result of natural or human- induced activities. Fresh water entering estuaries may float on the surface of the denser salt water or hug one shore as a result of density differences related to water temperature, salinity, or suspended matter.

MUNICIPAL AND DOMESTIC SUPPLY (MUN)

Uses of water for community, military, or individual water supply systems, including, but not limited to, drinking water supply.

The principal issues involving municipal water supply quality are (1) protection of public health; (2) aesthetic acceptability of the water; and (3) the economic impacts associated with treatment- or quality-related damages.

The health aspects broadly relate to: direct disease transmission, such as the possibility of contracting typhoid fever or cholera from contaminated water; toxic effects, such as links between nitrate and methemoglobinemia (blue babies); and increased susceptibility to disease, such as links between halogenated organic compounds and cancer.

Aesthetic acceptance varies widely depending on the nature of the supply source to which people have become accustomed. However, the parameters of general concern are excessive hardness, unpleasant odor or taste, turbidity, and color. In each case, treatment can improve acceptability although its cost may not be economically justified when alternative water supply sources of suitable quality are available.

Published water quality objectives give limits for known health-related constituents and most properties affecting public acceptance. These objectives for drinking water include the U.S. Environmental Protection Agency Drinking Water Standards and the California State Department of Health Services criteria.

NAVIGATION (NAV)

Uses of water for shipping, travel, or other transportation by private, military, or commercial vessels.

INDUSTRIAL PROCESS SUPPLY (PROC)

Uses of water for industrial activities that depend primarily on water quality.

Water quality requirements differ widely for the many industrial processes in use today. So many specific industrial processes exist with differing water quality requirements that no meaningful criteria can be established generally for quality of raw water supplies. Fortunately, this is not a serious shortcoming, since current water treatment technology can create desired product waters tailored for specific uses.

PRESERVATION OF RARE AND ENDANGERED SPECIES (RARE)

Uses of waters that support habitats necessary for the survival and successful maintenance of plant or animal species established under state and/or federal law as rare, threatened, or endangered.

The water quality criteria to be achieved that would encourage development and protection of rare and endangered species should be the same as those for protection of fish and wildlife habitats generally. However, where rare or endangered species exist, special control requirements may be necessary to assure attainment and maintenance of particular quality criteria, which may vary slightly with the environmental needs of each particular species. Criteria for species using areas of special biological significance should likewise be derived from the general criteria for the habitat types involved, with special management diligence given where required.

WATER CONTACT RECREATION (REC1)

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.

Water contact implies a risk of waterborne disease transmission and involves human health; accordingly, criteria required to protect this use are more stringent than those for more casual water-oriented recreation.

Excessive algal growth has reduced the value of shoreline recreation areas in some cases, particularly for swimming. Where algal growths exist in nuisance proportions, particularly blue green algae, all recreational water uses, including fishing, tend to suffer.

One criterion to protect the aesthetic quality of waters used for recreation from excessive algal growth is based on chlorophyll a.

NONCONTACT WATER RECREATION (REC2)

Uses of water for recreational activities involving proximity to water, but not normally involving contact with water where water ingestion is reasonably possible. These uses include, but are not limited to, picnicking, sunbathing, hiking, beachcombing, camping, boating, tide pool and marine life study, hunting, sightseeing, or aesthetic enjoyment in conjunction with the above activities.

Water quality considerations relevant to noncontact water recreation, such as hiking, camping, or boating, and those activities related to tide pool or other nature studies require protection of habitats and aesthetic features. In some cases, preservation of a natural wilderness condition is justified, particularly when nature study is a major dedicated use.

One criterion to protect the aesthetic quality of waters used for recreation from excessive algal growth is based on chlorophyll a.

SHELLFISH HARVESTING (SHELL)

Uses of water that support habitats suitable for the collection of crustaceans and filter-feeding shellfish (e.g., clams, oysters, and mussels) for human consumption, commercial, or sport purposes.

Shellfish harvesting areas require protection and management to preserve the resource and protect public health. The potential for disease transmission and direct poisoning of humans is of considerable concern in shellfish regulation. The bacteriological criteria for the open ocean,

bays, and estuarine waters where shellfish cultivation and harvesting occur should conform to the standards described in the National Shellfish Sanitation Program, Manual of Operation.
Toxic metals can accumulate in shellfish. Mercury and cadmium are two metals known to have caused extremely disabling effects in humans who consumed shellfish that concentrated these elements from industrial waste discharges. Other elements, radioactive isotopes, and certain toxins produced by particular plankton species also concentrate in shellfish tissue. Documented cases of paralytic shellfish poisoning are not uncommon in California.

FISH SPAWNING (SPWN)

Uses of water that support high quality aquatic habitats suitable for reproduction and early development of fish.
Dissolved oxygen levels in spawning areas should ideally approach saturation levels. Free movement of water is essential to maintain well-oxygenated conditions around eggs deposited in sediments. Water temperature, size distribution and organic content of sediments, water depth, and current velocity are also important determinants of spawning area adequacy.

WARM FRESHWATER HABITAT (WARM)

Uses of water that support warm water ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates.
The warm freshwater habitats supporting bass, bluegill, perch, and other panfish are generally lakes and reservoirs, although some minor streams will serve this purpose where stream flow is sufficient to sustain the fishery. The habitat is also important to a variety of non-fish species, such as frogs, crayfish, and insects, which provide food for fish and small mammals. This habitat is less sensitive to environmental changes, but more diverse than the cold freshwater habitat, and natural fluctuations in temperature, dissolved oxygen, pH, and turbidity are usually greater.

WILDLIFE HABITAT (WILD)

Uses of waters that support wildlife habitats, including, but not limited to, the preservation and enhancement of vegetation and prey species used by wildlife, such as waterfowl.
The two most important types of wildlife habitat are riparian and wetland habitats. These habitats can be threatened by development, erosion, and sedimentation, as well as by poor water quality. The water quality requirements of wildlife pertain to the water directly ingested, the aquatic habitat itself, and the effect of water quality on the production of food materials. Waterfowl habitat is particularly sensitive to changes in water quality. Dissolved oxygen, pH, alkalinity, salinity, turbidity, settleable matter, oil, toxicants, and specific disease organisms are water quality characteristics particularly important to waterfowl habitat. Dissolved oxygen is needed in waterfowl habitats to suppress development of botulism organisms; botulism has killed millions of waterfowl. It is particularly important to maintain adequate circulation and aerobic conditions in shallow fringe areas of ponds or reservoirs where botulism has caused problems.

PRESENT AND POTENTIAL BENEFICIAL USES

SURFACE WATERS

Surface waters in the region consist of freshwater rivers, streams, and lakes (collectively described as inland surface waters), estuarine waters, and coastal waters. Estuarine waters are comprised of the Bay system from the Golden Gate to the regional boundary near Pittsburg and the lower portions of streams flowing into the Bay, such as the Napa and Petaluma rivers in the north and Coyote and San Francisquito creeks in the south.

Inland surface waters support or could support most of the beneficial uses described above. The specific beneficial uses for inland streams include municipal and domestic supply, agricultural supply, industrial process supply, groundwater recharge, water contact recreation, non-contact water recreation, wildlife habitat, cold freshwater habitat, warm freshwater habitat, fish migration, and fish spawning. The San Francisco Bay Estuary supports estuarine habitat, industrial service supply, and navigation in addition to all of the uses supported by streams. Coastal waters' beneficial uses include water contact recreation; non-contact water recreation; industrial service supply; navigation; marine habitat; shellfish harvesting; ocean, commercial and sport fishing; and preservation of rare and endangered species. In addition, the California coastline within the San Francisco Bay Basin is endowed with exceptional scenic beauty. Beneficial uses of each significant water body have been identified and are organized according to the seven major watersheds within the region (Figure 2-2). The maps locating each water body (Figures 2-3 through 2-9) and tables keyed to each map (Tables 2-1 through 2-7) describing associated present and potential beneficial uses were produced using a geographical information system (GIS) at the Regional Board. More detailed representations of each location can be created using this computerized version.

The beneficial uses of any specifically identified water body generally apply to all its tributaries. In some cases a beneficial use may not be applicable to the entire body of water, such as navigation in Calabazas Creek or shellfish harvesting in the Pacific Ocean. In these cases, the Regional Board's judgment regarding water quality control measures necessary to protect beneficial uses will be applied.

Appendix B. Water Quality Monitoring Stages

Monitoring Stages of All Water Bodies Within Legislative Boundaries

	Immediate Watershed	Limited Monitoring	Baseline Monitoring	Adaptive Monitoring	Management Action	Restoration
White Gulch	Tomales Bay					
Bear Valley Creek	Lagunitas Creek		NPS			
Haggerty Gulch	Tomales Bay	NPS				
Olema Creek	Lagunitas Creek		NPS	NPS	NPS	NPS/Other
Cheda Creek	Lagunitas Creek		NPS			
Devil's Gulch	Lagunitas Creek		NPS			
Lagunitas	Tomales Bay	SFBRWQCB	USGS			
Tomales Bay*	Tomales Bay	NPS	Other/NPS		Other	
Bass Lake	Pacific Ocean		NPS			
Hagmaier Pond	Olema Creek		NPS			
Vision Pond	Drakes Bay		NPS			
Pelican Lake	Pacific Ocean					
Wildcat Lake	Pacific Ocean					
Pacific Ocean*			NOAA			
Santa Maria Creek	Drakes Bay					
Coast Creek	Drakes Bay					
Alamere Creek	Pacific Ocean					
Arroyo Hondo	Pacific Ocean					
Crystal Lake	Alamere Creek					
Glenbrook Creek	Limantour Estero	NPS				NPS
Muddy Hollow	Limantour Estero		NPS			NPS
Laguna Creek	Drakes Bay		NPS			
Limantour Estero*	Drakes Bay					
McClure's Creek	Pacific Ocean					
Kehoe Creek	Pacific Ocean		NPS			
Abbott's Creek	Pacific Ocean		NPS			
East Schooner Ck.	Drakes Estero		NPS	NPS		
Home Ranch Creek	Drakes Estero		NPS	NPS		
Creamery Creek	Drakes Estero		NPS			
Drakes Estero*	Drakes Bay	NPS	DHS			
Drakes Bay*	Pacific Ocean	NPS	DHS, others			
A Ranch Perennial	Drakes Bay		NPS			
B Ranch	Drakes Bay		NPS			
C Ranch	Drakes Bay		NPS			
Pine Gulch	Bolinas Lagoon	NPS	Others, SFBRWQCB			
McKinnan Gulch	Bolinas Lagoon	NPS	SFBRWQCB			
Pike County Gulch	Bolinas Lagoon					

	Immediate Watershed	Limited Monitoring	Baseline Monitoring	Adaptive Monitoring	Management Action	Restoration
Audubon Canyon	Bolinas Lagoon		SFBRWQCB			
Morses Gulch	Bolinas Lagoon	NPS				
Stinson Gulch	Bolinas Lagoon					
Laurel Creek	Bolinas Lagoon					
Black Rock Creek	Bolinas Lagoon		SBWD			
Fitzhenry Creek	Bolinas Lagoon		SBWD			
Easkoot (Table Rock) Creek	Bolinas Lagoon	NPS/Other	SBWD			NPS
Webb Creek	Pacific Ocean	UCB	SFBRWQCB			
Lone Tree Creek	Pacific Ocean	UCB				
Cold Stream	Pacific Ocean	UCB				
Redwood Creek	Pacific Ocean		NPS, UCB, USGS, SFBRWQCB	NPS	NPS	NPS/Other
Green Gulch	Redwood Creek		NPS, SFBRWQCB	NPS		
Kent Creek	Redwood Creek					
Fern Creek	Redwood Creek	USF				
Bootjack Creek	Redwood Creek	USF				
Tennessee Valley	Pacific Ocean		NPS, SFBRWQCB		NPS	NPS
Rodeo Lagoon*	Pacific Ocean	NPS, UCB	HI, SFBRWQCB			
Rodeo Creek	Rodeo Lagoon	NPS, UCB	SFBRWQCB	NPS	NPS	
Gerbode Creek	Rodeo Creek	UCB				
Nyhan Creek	Coyote Creek	NPS				
Oakwood Valley	Nyhan Creek	NPS				
Coyote Creek	Richardson Bay					
San Francisco Bay*			SFEI, many others			SFEI, others
Franklin Creek	Alhambra Creek	NPS/Other				
Strentzel Creek	Alhambra Creek	NPS				NPS
Crissy Marsh	San Francisco Bay		NPS	NPS		NPS
Lobos Creek	Pacific Ocean		NPS, UWP, Presidio Trust, SFBRWQCB			
El Polin Spring	Sam Francisco Bay	NPS				

	Immediate Watershed	Limited Monitoring	Baseline Monitoring	Adaptive Monitoring	Management Action	Restoration
Dragonfly Creek	San Francisco Bay		NPS			NPS/Presidio Trust
Tennessee Hollow	San Francisco Bay	NPS	Presidio Trust			
Mountain Lake	Pacific Ocean		NPS/Other			NPS/Presidio Trust
Milagra Creek	Pacific Ocean	NPS/Other				
Calera Creek	Pacific Ocean	NPS, other				
Sanchez Creek	Pacific Ocean	NPS				
Laguna Salada	Pacific Ocean					
San Pedro Creek	Pacific Ocean	Other				
San Mateo Creek	San Francisco Bay		SFBRWQCB			
Pilacartos Creek	San Francisco Bay		SFBRWQCB			
Pilacartos Lake	San Francisco Bay		SFBRWQCB			
Stone Dam Reservoir	San Francisco Bay		SFBRWQCB			
San Andreas Lake	San Francisco Bay		SFBRWQCB			
Lower Crystal Springs Reservoir	San Francisco Bay		SFBRWQCB			
Upper Crystal Springs Reservoir	San Francisco Bay		SFBRWQCB			
West Union Creek	San Francisquito Creek	NPS	others			
McGarvey Gulch	San Francisquito Creek	NPS				
Sandy Creek	Chalone Creek		NPS			
Bear Gulch Reservoir	Bear Gulch	NPS				
Bear Gulch	Chalone Creek		NPS			
Chalone Creek	Salinas River		NPS			NPS

DHS-California Dept. of Health Services
HI – Headlands Institute
NOAA – National Oceanic and Atmospheric Association
NPS – National Park Service
SBWD – Stinson Beach Water District
SFBRWQCB – San Francisco Bay Regional Water Quality Control Board
SFEI – San Francisco Estuary Institute
SWRCB – State Water Resources Control Board
UCB – University of California, Berkeley
USF – University of San Francisco
USGS – U.S. Geological Survey
UWP – Urban Watershed Project

Definitions of Monitoring Stages:
No monitoring – all columns are blank; no monitoring has been conducted or information is not available

Limited Monitoring – annual monitoring only; past or current sporadic monitoring, few data points
Baseline Monitoring – seasonal/quarterly or monthly monitoring for at least one year
Adaptive Monitoring – past data has shown elevated levels; source area monitoring was initiated
Management Action - BMPs such as buffer strips and fencing have been implemented
Restoration – past or on-going restoration (e.g., channel or habitat improvement) has occurred or the planning process is underway.

Appendix C. Selection Criteria of the SFAN “Target” Water Bodies

Selection criteria of the SFAN target water bodies within NPS legislative boundaries based on WRD Category 1 and Category 2 water bodies and other criteria. Only wadeable streams are included as target water bodies.

		CATEGORY 1	CATEGORY 2				OTHER	
	Park Unit	On section 303d list?	Lacking Baseline Data?	Established Threat?	Subject to ecological impairment?	Vital Signs Link?	Managed by NPS?	Other agencies/entities currently monitoring?
White Gulch	PORE	X*	X				Yes	
Bear Valley Creek	PORE	X*			X		Yes	
Haggerty Gulch	PORE	X*	X				Partial	
Olema Creek	PORE	X*		X	X	X	Yes	
Cheda Creek	GOGA	X*		X		X	Yes	
Devil's Gulch	GOGA	X*		X		X	Yes	
Lagunitas Creek	PORE GOGA	X		X		X	Partial	USGS, SPAWN, and others
Santa Maria Creek	PORE		X				Yes	
Coast Creek	PORE		X				Yes	
Alamere Creek	PORE		X				Yes	
Arroyo Hondo	PORE		X				Yes	
Glenbrook Creek	PORE		X				Yes	
Muddy Hollow	PORE						Yes	
Laguna Creek	PORE						Yes	
McClure's Creek	PORE		X				Yes	
Kehoe Creek	PORE			X			Yes	
Abbott's Creek	PORE			X			Yes	
Home Ranch Creek	PORE			X			Yes	
Creamery Creek	PORE			X			Yes	
A Ranch Perennial	PORE			X			Yes	
B Ranch Creek	PORE			X			Yes	
C Ranch Creek	PORE			X			Yes	
Pine Gulch	PORE				X	X	Yes	
McKinnan Gulch	GOGA		X				Yes	
Pike County Gulch	GOGA		X				Yes	
Audubon Canyon	GOGA		X				No	
Morses Gulch	GOGA		X				Yes	
McKinnan Gulch	GOGA		X				Yes	
Stinson Gulch	GOGA		X				Yes	
Laurel Creek	GOGA						Partial	
Black Rock Creek	GOGA						Partial	
Fitzhenry Creek	GOGA						Partial	
Easkoot Creek	GOGA					X	Partial	Stinson Beach Water Agency
Lone Tree Creek	GOGA		X				Yes	
Cold Stream	GOGA		X				Yes	

	Park Unit	CATEGORY 1	CATEGORY 2				OTHER	
		On section 303d list?	Lacking Baseline Data?	Established Threat?	Subject to ecological impairment?	Vital Signs Link?	Managed by NPS?	Other agencies/entities currently monitoring?
Webb Creek	GOGA						Minimal	
Redwood Creek	GOGA			X		X	Yes	
Green Gulch	GOGA			X		X	Partial	
Kent Creek	GOGA				X	X	Partial	
Fern Creek	GOGA				X	X	Partial	
Bootjack Creek	GOGA				X		Partial	
Tennessee Valley	GOGA			X		X	Yes	
Rodeo Creek	GOGA			X		X	Yes	
Gerbode Creek	GOGA			X		X	Yes	
Nyhan Creek	GOGA	X*			X		Partial	
Oakwood Valley	GOGA	X*					Yes	
Coyote Creek	GOGA	X	X				Minimal	
Franklin Creek	JOMU	X**		X		X	Minimal	Friends of Alhambra Creek
Strentzel Creek	JOMU		X		X		Partial	
Lobos Creek	PRES	X**		X			Yes	City/County of San Francisco
El Polin Spring	PRES						Yes‡	
Dragonfly Creek	PRES	X**					Yes‡	
Tennessee Hollow	PRES	X**			X		Yes‡	
Milagra Creek	GOGA	X**	X		X		Minimal	
Calera Creek	GOGA	X**	X		X		Minimal	
Sanchez Creek	GOGA	X**	X		X		Minimal	
San Pedro Creek	GOGA	X		X		X	No	San Pedro Creek Watershed Coalition
San Mateo Creek	GOGA						No	CA Water Resources Control Board
Pilacartos Creek	GOGA						No	CA Water Resources Control Board
West Union Creek	GOGA	X*	X		X	X	Partial	San Francisquito Creek Watershed Council
Chalone Creek	PINN	X*			X	X	Yes	
Sandy Creek	PINN			X			Yes	
Bear Gulch	PINN					X	Yes	

** All urban creeks are impaired by diazinon according to the San Francisco Bay Regional Water Quality Control Board

* These water bodies are tributaries of or adjacent to impaired waters but are not themselves listed as impaired

‡ These Presidio water bodies are owned by the Presidio Trust but jointly managed by the Presidio Trust and NPS

Category 1 and Category 2 Definitions

Section 303d List – on the Clean Water Act's Section 303d list of impaired water bodies (impaired due to one or more pollutants)

Lacking Baseline Data – no data has been collected for the stream or data is very limited and does not provide enough information to know the baseline condition

Established Threat – monitoring has shown that water quality is compromised due to one or more pollutants

Subject to Ecological Impairment – monitoring has not been conducted or has not shown poor water quality due to pollutants; however, there is potential for impairment

Vital Signs Link- the creek provides habitat for one or more threatened or endangered species (salmonids, CA red-legged frog, San Francisco Garter Snake, CA freshwater shrimp)

Managed by NPS (Category Definitions):

Yes – watershed is located entirely or mostly within park boundaries and is managed by NPS

No – watershed is located within legislative boundary but is managed by other entities

Partial – watershed is partially located within parklands and/or is managed by multiple agencies (e.g., Lagunitas Creek Watershed is managed by NPS, CA State Parks and the Marin Municipal Water District)

Minimal – watershed is primarily located outside parklands

Appendix D. Specific Monitoring Questions and Related Sample Location and Monitoring Questions for Each Stream

Specific Monitoring Questions and Related Sample Location

	Monitoring question	Habitat	Frequency/Timing*
1	How long does turbidity remain in a stream after a peak storm event?	Riffle/Run	S
2	What percentage of pH observations for each station fall within the numerical objective range of 6.5 – 8.5?	Pool and Riffle/Run	M, C
3	What percentage of all samples exceeds the recommended criteria of 0.025 mg/L for ammonia?	Pool and Riffle/Run	M
4	Do the seasonal median concentrations of dissolved oxygen at each station fall below the recommended criteria of 7.0 mg/L (San Francisco Bay Region) or 5.0 mg/L (Central Coast Regional)?	Pool and Riffle/Run	M, C
5	Based on the median of seasonal values, what percentage of stations meets the fecal coliform criteria for non-contact recreation (2000 MPN/100mL)?	Pool and Riffle/Run	M
6	What is the seasonal and annual variability in pH, D.O., conductivity, and temperature based on monthly samples over a year?	Pool and Riffle/Run	M
7	What is the diel, seasonal, and annual variability in pH, D.O., conductivity, and temperature based on continuous 15-minute readings over a year?	Pool	C
8	Is there a significant relationship between turbidity and Total Suspended Solids or Suspended Sediment Concentration during a storm event?	Pool and Riffle/Run	M, S
9	Is there a significant relationship between conductivity and fecal coliforms annually and during each season?	Pool and Riffle/Run	M
10	What is 30-day average flow-weighted fecal coliform load to Tomales Bay during the winter?	Riffle/Run	M, W
11	Does the 30-day average log mean fecal coliform concentration exceed 200MPN/100mL (criteria for contact recreation) based on five consecutive weeks of sampling in the summer or winter?	Pool and Riffle/Run	M, W
12	What percentage of samples exceeds the log mean total coliform concentration of 1000MPN/100mL (criteria for contact recreation) seasonally and annually?	Pool and Riffle/Run	M
13	What is the average annual and seasonal fecal coliform load contribution from each tributary?	Riffle/Run	M
14	What is the maximum fecal coliform concentration at each monitoring station?	Pool and Riffle/Run	M
15	What are the existing nutrient levels and how do they compare to recommended criteria for nitrate, ammonia, and Total nitrogen?	Pool and Riffle/Run	

M=monthly, W=weekly, C=continuous, S= storm event

*The storm event (first, second third; early/mid/late season) will be established during the first year of monitoring. The time of day that sampling takes place 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.

Monitoring Questions for Each Stream

This table includes priority and alternative streams as well as proposed and alternate sites. For all streams, question #'s 1-5, 12, and 14-15 from the "Specific Monitoring Questions and Related Sample Location" will be addressed. The table denotes additional questions to be addressed at each stream.

Stream/Watershed	Monitoring question	# Proposed Sites	# Alternate Sites*
Olema mainstem	6,7,8,9,10, 11	4	
John West Fork	11, 13	1	
Davis Boucher	11, 13	1	
Quarry Gulch	11, 13		1
Giacomini Gulch	11, 13		1
Home Ranch Creek	9,11		1
East Schooner Creek	9,11		1
Pine Gulch	6, 7	3	
Bear Valley Creek	10,11, 13	1	
Cheda Creek	13	1	
Devils Gulch	13	1	
Green Gulch	13	1	1
Golden Gate Dairy Trib	13	1	
Redwood Mainstem	6,7,8,9	3	
Banducci Creek	13		1
Kent Creek	13	1	
Camino del Canyon	13	1	
Fern Creek	6, 13	1	1
Bootjack Creek	6, 13	1	
Gerbode Creek	13	1	
Rodeo Creek	6, 7, 9	1	1
Tennessee Creek	6, 7, 9	2	1
Nyhan Creek			1
Oakwood Creek			1
Sandy Creek	13	2	2
Bear Gulch	13	1	
Chalone mainstem	7	2	1
Franklin Creek	6, 7	1	
Strentzel Creek	8		5
West Union Creek	6, 8	2	3
Total # of sites		**33**	**22**

*Proposed sites will be monitored; alternate sites are important but may not be a part of the long term plan (i.e., they may be monitored for a short period and then discontinued). Identification of proposed and alternate sites may change as data are analyzed and/or as the water quality program evolves. For some alternate sites, short term monitoring is planned or being conducted by other entities

Appendix E. Water Quality Monitoring Site Location and Access and Site History and Site ID Selection

Site Location and Access Table

Park/ Owner	Stream	Site ID	UTM N	UTM E	Elevation	Access/Directions	Topo Quad (7.5-minute)	Stream Type	Site Type	Permission & Access Notes
PORE	Olema creek	OLM 18	4203441	523220	320 ft	Hwy. 1 MP 21.06; mainstem Olema above Randall Gulch, park in pull-out east of Hwy. 1 near white house	Bolinas	intermittent (perennial pools)	Proposed	
PORE	Olema creek	OLM 14	4205596	521507	200 ft	Northernmost Five Brooks bridge across from park residence; park in large pull-out west of Hwy. 1 adjacent to bridge	Double Point	perennial flow	Proposed	
PORE	Olema creek	OLM 11	4210501	518436	40ft	Upstream of Bear Valley Rd. Bridge; park in pull-out on north side of Bear Valley Rd. (west of creek)	Inverness	perennial flow	Proposed	
PORE	Olema creek	OLM 10B	4212695	516882	20 ft	Below residence #530 (Olema Marsh); park at residence, walk downhill east towards creek (look for path through vegetation towards the left (north); avoid trees and shrubs)	Inverness	perennial flow	Proposed	
PORE	John West Fork	OLM 1	4205293	521706	200 ft	Upstream of Hwy. 1 culvert at MP 22.67; park at pull-out on west side of Hwy. 1 (south of Five Brooks and Ralph Giacomini Ranch), sample at staff gauge	Double Point	perennial flow	Proposed	
PORE	Davis Boucher Creek	OLM 6A	4206897	520260	160 ft	Park at Stewart's Ranch behind barns (northwest side of ranch); follow horse trail and cross Olema; continue along trail (don't cross the footbridge) and cross Davis Boucher; sample above horse trail (50 m upstream of trail bridge)	Inverness	perennial flow	Proposed	Coordinate with park re: private property
PORE	Quarry Gulch	OLM 4	4209737	519021	40 ft	just above confluence with Olema; park at pull-out on west side of Hwy. 1 after cemetery	Inverness	intermittent	Alternate	
PORE	Giacomini Gulch	OLM 2	4205548	521513	200 ft	Hwy. 1 MP 22.78; park at pull-out west of Hwy.1 near John West Fork; sample upstream of culvert	Double Point	intermittent	Alternate	
Private	Pine Gulch	PNG 1	4196963	527051	0 ft	Hwy. 1 to Bolinas Rd., turn left into driveway to sample downstream of road bridge; cross footbridge and access site near stream gauge	Bolinas	perennial flow	Proposed	Coordinate with park re: private property
PORE	Pine Gulch	PNG 2	4199638	524985	120 ft	Park at Olema Valley Trail pull-out on west side of Hwy.1 just north of Dogtown; follow trail then veer off to the west on undesignated trail around north end of wetland, cross the creek, then follow the creek a short distance; sample near stream bend before entrance to the gorge (sample near fish index reach).	Bolinas	perennial flow	Proposed	Contact park hydrologist or fishery biologist for assistance in locating site
PORE	Pine Gulch	PNG 3	4200800	524775	200 ft	Hwy. 1 to Texiera Ranch; enter gate and follow road to the end (past the residence); walk west to the Olema Valley Trail, follow trail, cross the creek twice; sample upstream of horse trail crossing (2nd crossing)	Bolinas	perennial flow	Proposed	Gate key required

Park/ Owner	Stream	Site ID	UTM N	UTM E	Elevation	Access/Directions	Topo Quad (7.5-minute)	Stream Type	Site Type	Permission & Access Notes
PORE	Bear Valley Creek	LAG 1	4210696	517655	40 ft	Behind PORE Bear Valley headquarters; adjacent to Roads & Trails yard (downstream of bridge); obtain flow measurement above bridge	Inverness	perennial flow	Proposed	
GOGA	Cheda Creek	LAG 2	4210036	522385	120 ft	upstream of Sir Francis Drake Blvd. MP 19.17	San Geronimo	perennial flow	Proposed	
SPTSP	Devil's Gulch	LAG 3	4209214	523361	120 ft	upstream of Sir Francis Drake Blvd., below Devils Gulch trail (Samuel P. Taylor State Park); access creek past dog walking sign	San Geronimo	perennial flow	Proposed	
Private	Green Gulch	GG 1	4190636	537523	< 40 ft	Hwy 1 to Pacific Way; Lower Green Gulch (north), next to horse pasture	Point Bonita	intermittent	Proposed	Coordinate with park re: private property
Private	Green Gulch	GG 2	4191394	538455	160 ft	Hwy.1 to Green Gulch Zen Center; Upper Green Gulch (above Zen Center); near parking lot	Point Bonita	intermittent	Alternate	Coordinate with park re: private property
GOGA	Golden Gate Dairy	GGD	4190940	537395	40 ft	Hwy. 1 across from Muir Beach entrance road (Pacific Way); 5-10 m upstream of Hwy.1 culvert	Point Bonita	intermittent	Proposed	Coordinate with park re: private property
MTSP	Banducci	BAND 1	4191563	536541	< 40 ft	Hwy. 1 to Redwood Creek bridge; take road along Redwood Creek to sample upstream of Banducci culvert (above Redwood Confluence)	Point Bonita	intermittent	Alternate	
MUWO	Redwood Creek	RDW 1	4193545	538056	120 ft	Hwy. 1 to Frank Valley Rd.; Muir Woods concrete bridge above CDC 2, below Muir Woods	San Rafael	perennial	Proposed	
GOGA	Redwood Creek	RDW 2	4191053	537084	40 ft	Above Hwy. 1 bridge (below Banducci)	Point Bonita	perennial; pools in summer	Proposed	
GOGA	Redwood Creek	RDW 3	4190393	537396	< 40 ft	Hwy.1 to Pacific Way; just upstream of Muir Beach Pedestrian Bridge	Point Bonita	perennial; pools in summer	Proposed	
MTSP	Kent Creek	KC 1	4192716	537205	120 ft	Frank Valley Rd. to approximately 50 ft above Redwood Creek confluence (above Kent Creek culvert)	San Rafael	intermittent	Proposed	
MUWO	Camino del Canyon	CDC 2	4193508	538100	120 ft	Frank Valley Rd. to Camino del Canyon/Redwood confluence (CDC 1 is above slide)	San Rafael	intermittent	Proposed	
MUWO	Fern Creek	FC 1	4194958	537077	200 ft	Frank Valley Rd. to Muir Woods parking lot; take main trail past Cathedral Grove; follow Fern Creek Trail; sample above the Fern Creek/Redwood Creek confluence near MUWO/MTSP boundary	San Rafael	intermittent	Proposed	

Park/ Owner	Stream	Site ID	UTM N	UTM E	Elevation	Access/Directions	Topo Quad (7.5-minute)	Stream Type	Site Type	Permission & Access Notes
MTSP	Fern Creek	FC 2	4196588	536615	1000 ft	Panoramic Hwy. MP 3.22; Fern Creek above Panoramic Hwy. culvert in Mt. Tamalpais State Park	San Rafael	intermittent	Alternate	Notify State park, obtain permit
MTSP	Bootjack Creek	BJC 1	4195822	534960	1440 ft	Bootjack Camp above Panoramic Highway in Mt. Tamalpais State Park	San Rafael	intermittent	Proposed	Notify State park, obtain permit
GOGA	Gerbode Creek	GERB1	4187657	542339	< 40 ft	Hwy. 101 to 1st exit north of Golden Gate Bridge (Sausalito/Alexander Ave.); follow Bunker Rd. west towards Fort Cronkhite; access from Bobcat Trail after road bridge; sample above confluence with Rodeo Creek	Point Bonita	perennial	Proposed	
GOGA	Rodeo Creek	RC 1	4187316	542493	< 40 ft	Bunker Rd. to unmaintained road across from Presidio stables; access site through willows; site is upstream of Miwok trail bridge and downstream of stables (stable tributary convergence), approximately 420 m upstream of Gerbode/Rodeo Creek confluence)	Point Bonita	perennial	Proposed	
GOGA	Rodeo Creek	RC 2	4188095	544009	200 ft	Follow Bunker Rd. to park housing just southwest of tunnel; site is approximately 30m upstream of Capehart housing	San Francisco North	perennial	Alternate	
GOGA	Tennessee Creek	TV 1	4190335	541262	260 ft	Hwy. 1 to Tennessee Valley Rd. to end (trailhead parking); 100 m upstream of Old Springs Trails crossing; above Gabino's house, above Miwok stables	Point Bonita	intermittent	Alternate	Coordinate with park re: private property
GOGA	Tennessee Creek	TV 2	4190212	540670	160 ft	Below Miwok stables, 330 meters upstream of Tennessee Valley/Haypress tributary confluence	Point Bonita	intermittent	Proposed	Gate combination required
GOGA	Tennessee Creek	TV 3	4189337	540597	80 ft	2 meters downstream of Backdoor (tributary to Tenn. Valley); access from Tenn. Valley trail	Point Bonita	intermittent	Proposed	Gate combination required
GOGA	Nyhan Creek	NYH 1	4191465	541504	40 ft	Tennessee Valley Rd.; park at pull-out across from Oakwood Valley sign. Sample above Oakwood confluence, below footbridge.	Point Bonita	perennial	Alternate	
GOGA	Oakwood Creek	OAK 1	4191470	541561	40 ft	Above culvert near confluence with Nyhan	Point Bonita	intermittent	Alternate	
GOGA	West Union Creek	WU 1	4144676	562565	640 ft	Hwy. 280 South towards Redwood City; Woodside Rd. exit; Woodside west then veer right onto Kings Mountain Rd. to Huddart County park; park at Zwierlein Picnic area, Crystal Springs Trail, cross McGarvey Gulch, right onto Miramontes Trail. Site is on the mainstem in Phleger Estate 1/4mi down the trail from Huddart Co. Park boundary	Woodside	ponded in summer	Proposed	Notify ranger at entrance station

Park/ Owner	Stream	Site ID	UTM N	UTM E	Elevation	Access/Directions	Topo Quad (7.5-minute)	Stream Type	Site Type	Permission & Access Notes
GOGA	West Union Trib. #1	WU 2	4144954	562339	640 ft	Tributary #1 (first tributary upstream of McGarvey Gulch), above Miramontes trail crossing	Woodside	dry in summer	Alternate	Notify ranger at entrance station
GOGA	West Union Trib. #2	WU 3	4145237	561550	640 ft	Tributary#2, (second tributary upstream of McGarvey Gulch); upstream of Raymundo trail bridge	Woodside	dry in summer	Alternate	Notify ranger at entrance station
GOGA	West Union Creek	WU 4	4145512	561055	720 ft	Mainstem; upstream of Trib. #2	Woodside	dry in summer	Alternate	Notify ranger at entrance station
Huddart County Park	McGarvey Gulch	MGG 1	4144415	562513	640 ft	Between trail crossing and confluence with West Union creek (accessible area above large boulders)	Woodside	ponded in summer	Proposed	Notify ranger at entrance station
JOMU	Franklin Creek	FRA 1	4205172	576184	120 ft	I-80 to Hwy. 4 to Martinez; Alhambra Ave (left), to JOMU visitor center; site is upstream of bridge near automatic stream gauge	Briones Valley	intermittent; pools in summer	Proposed	Gate key required for vehicle entry; separate gate combo for foot entry
JOMU	Strentzel Creek	STR 1	4203860	575809	260 ft	Alhambra Ave. south past Mt. Wanda, veer right, enter at Strain Ranch; site is just above confluence with 4th N. tributary (counting from east to west	Briones Valley	Ephemeral; small spring-fed tributary	Alternate	Key to Strain Ranch gate, coordinate with park contact re: private property
JOMU	Strentzel Creek	STR 2	4203819	575797	260 ft	4th north tributary (from east to west)	Briones Valley	ephemeral	Alternate	
JOMU	Strentzel Creek	STR 3	4203805	575781	260 ft	3rd south tributary (from east to west)	Briones Valley	ephemeral	Alternate	
JOMU	Strentzel Creek	STR 4	4203594	576341	260 ft	mainstem Strentzel Creek at fire road crossing near Strain Ranch	Briones Valley	ephemeral	Alternate	
JOMU	Strentzel Creek	STR 5	4203759	576711	220 ft	mainstem Strentzel Creek above Alhambra Ave. culvert	Briones Valley	ephemeral	Alternate	
PINN	Sandy Creek	SC 1	4039107	665268	920 ft	I-280 south to San Jose; 101 south to Hwy. 25 to Hollister; Hwy. 25 to PINN (Hwy. 146). Park at Hwy. 146 pull-out near air quality site; site is in creek opposite of air quality site	North Chalone Peak	intermittent	Proposed	
PINN	Sandy Creek	SC 2	4039516	665483	1000 ft	In Pinnacles Campground; near park boundary; far southwest side of campground, near restroom leachfield; sample upstream of culvert	North Chalone Peak	intermittent	Alternate	

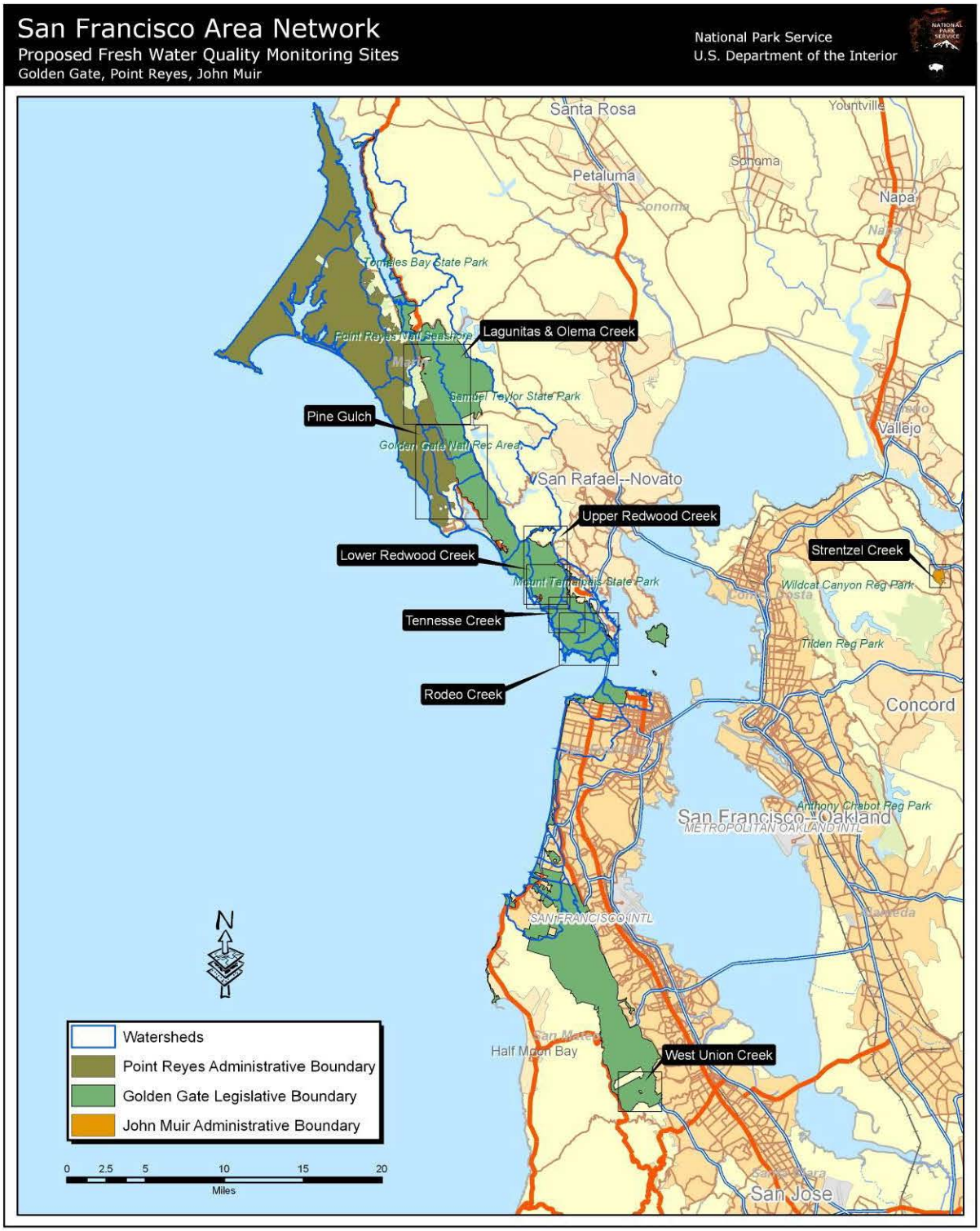
Park/ Owner	Stream	Site ID	UTM N	UTM E	Elevation	Access/Directions	Topo Quad (7.5-minute)	Stream Type	Site Type	Permission & Access Notes
PINN	Sandy Creek	SC3	4040202	666068	1000 ft	In Pinnacles campground near pump-out station and downstream of restroom (adjacent to leachfield); opposite side of campground as SC 2 (i.e., far north east end); upstream of tributary confluence	North Chalone Peak	intermittent	Alternate	
Private	McCabe Creek	MC1	4040066	665749	1000 ft	McCabe Canyon above Hwy. 146 culvert; across from Pinnacles campground	North Chalone Peak	intermittent	Proposed	Notify landowner (contact park), gate key required
PINN	Bear Gulch	BG 2	4038964	663073	1240 ft	Park at visitor center parking lot; walk to Resource Management bldg.; sample behind the building near footbridge	North Chalone Peak	intermittent	Proposed	
PINN	Chalone mainstem	CHA 1	4038045	665325	920 ft	Hwy. 146 before (east of) East Entrance station; follow fire road to parking area on the right before road crosses creek. Follow pink flagging to site.	North Chalone Peak	intermittent	Proposed	Gate key required; 4x4 may be needed in wet conditions
PINN	Chalone mainstem	CHA 2	4039344	664153	1000 ft	Hwy. 146 Road Bridge to visitor's center; site is downstream of bridge across from fire wayside exhibit and portable toilet	North Chalone Peak	dry summer to fall	Proposed	
PINN	North Fork Chalone	CHA 3	4041178	662881	1080 ft	Hwy. 146 Chalone Picnic Area; pass picnic area for access to North Wilderness trail; site is just upstream of West Fork	North Chalone Peak	dry summer to fall	Alternate	Note: Road along Chalone Creek has been removed in this area

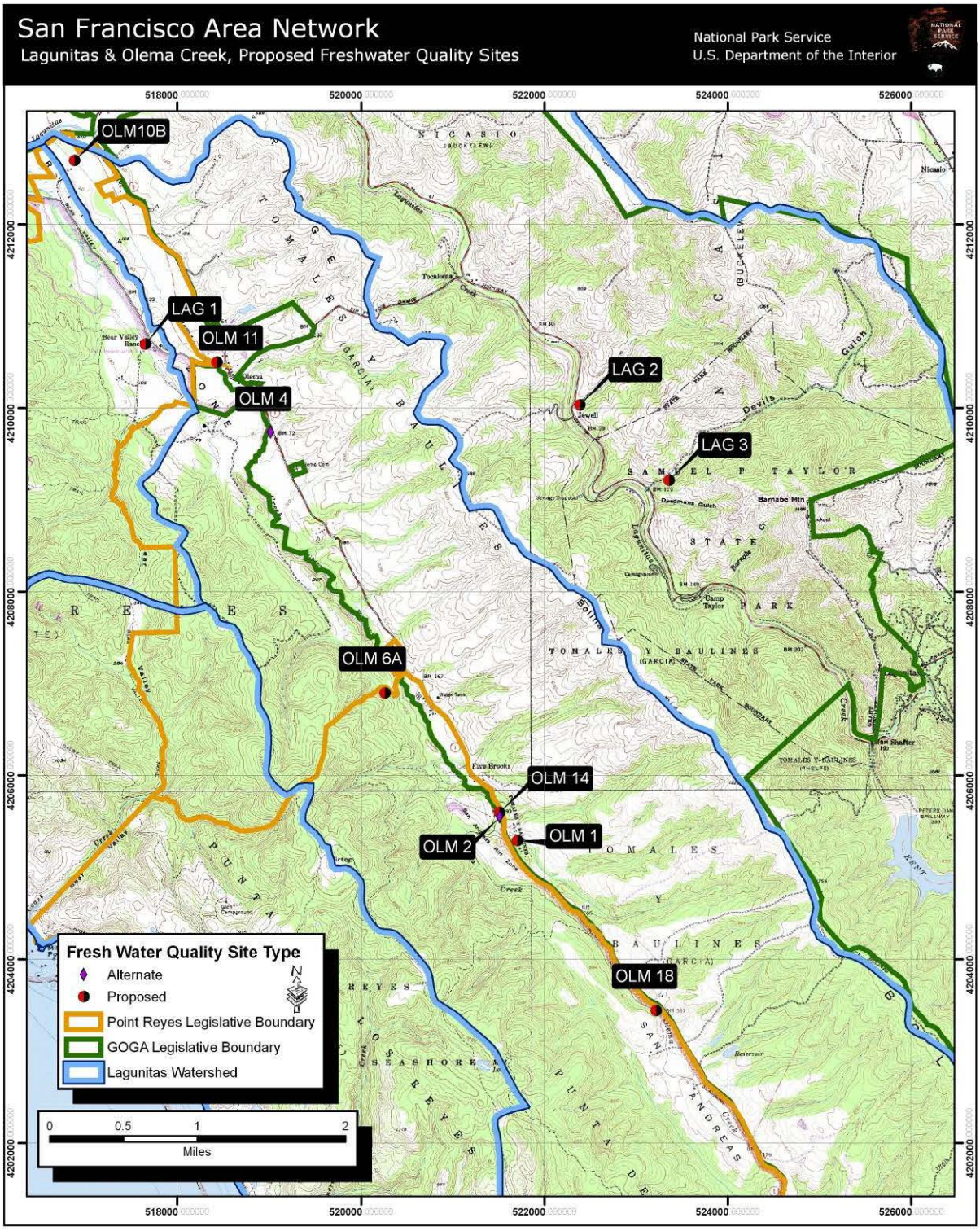
Site History and Site ID Selection

Site ID	Source of site location	Site ID the same?	Notes
OLM 18	PORE on-going database	yes	
OLM 14	PORE on-going database	yes	
OLM 11	PORE on-going database	yes	
OLM 10B	PORE on-going database	yes	
OLM 1	PORE on-going database	yes	
OLM 6A	PORE on-going database	yes	
OLM 4	PORE on-going database	yes	
OLM 2	PORE on-going database	no	This site is entered as OLM 2A in PORE WQ database (OLM 2 was downstream or culvert)
PNG 1	PORE on-going database	yes	near PGL 1 from GGNRA pre-1999 database
PNG 2	SFAN 2004 Macroinvert Sampling	yes	same as macroinvert site
PNG 3	SFAN 2004 Macroinvert Sampling	yes	same as macroinvert site
LAG 1	PORE on-going database	yes	
LAG 2	PORE on-going database	yes	
LAG 3	PORE on-going database	yes	
GG1	stables and Big Lagoon studies	no	GG north (draft protocol v. 2.01); check access since private property (Green Gulch Farm and Zen Center)
GG2	stables and Big Lagoon studies	no	GG Control (draft protocol v. 2.01); check access since private property (Green Gulch Farm and Zen Center)
GGD	GGNRA pre-1999 database, stables studies	no	GGD Culvert (draft protocol v. 2.01); similar to GGD 3 (RDW-4-1), but away from culvert affects
BAND 1	GGNRA pre-1999 database	yes	near "Banducci" site in 2004 USF (J.Lendvay) study; near Station 9 in 1994 USF (Leach, Podlech,Brown) study "Redwood Creek: Banducchi Bridge"
RDW 1	GGNRA pre-1999 database, USF studies	yes (pre-99 database)	close to Station 2 in USF Podlech, Brown, & Karentz study (1994) and Station 10 in USF Leach, Podlech, & Brown (1997)
RDW 2	GGNRA pre-1999 database	no	RDW3 (draft protocol v. 2.01)
RDW3	GGNRA pre-1999 database, stables and Big Lagoon studies, USF studies	no	RDW MuBe (draft protocol v. 2.01)RDW 22, Ped Bridge @ Muir Beach, Redwood Creek at Muir Beach Parking Lot, "Muir Beach" in J. Lendvay, 2004 (USF)
KC 1	GGNRA pre-1999 database	yes	
CDC 2	GGNRA pre-1999 database	yes	
FC 1	University of San Francisco (USF) studies	no	(USF - M. Podlech, 1994);Station 11 ("Fern Creek at the mouth, in Muir Woods"
FC 2	University of San Francisco (USF) studies	no	USF - Jack Lendvay, 2004; "Fern Creek" site name
BJC1	GGNRA pre-99 database; University of San Francisco (USF) studies;	yes, pre-99 database	RDW, pre-99 database and (draft protocol v. 2.01); USF - Jack Lendvay, 2004; "Bootjack Creek" site name and USF - Podlech, Brown, & Karentz, 1994; Station 3 ("Redwood Creek headwaters at Bootjack Camp")
GERB1	GGNRA pre-1999 database	no	ROD 6 (draft protocol v. 2.01)
RC1	GGNRA stables studies, SFAN 2004 monitoring; USF	no	RC 1-750 in stables study and (draft protocol v. 2.01); Station 3 in (Leach, Podlech, and Brown, 1997)
RC2	GGNRA pre-1999 database, stables studies	no	ROD 20, RC-1-2500 in stables study and (draft protocol v. 2.01), RC Control
TV1	GGNRA pre-1999 database, stables studies	no	TV 1-2615 stables study and (draft protocol v. 2.01) (site access restricted since near private residence?)

TV2	GGNRA pre-1999 database, stables studies, USF, SFAN 2004 Monitoring	no	also TV 1-2095 in stables study, pre-99 db and (draft protocol v. 2.01); Station 6 in USF (Leach, Podlech, and Brown, 1997)
TV3	GGNRA pre-1999 database, stables studies	no	TV1-1120 stables study and (draft protocol v. 2.01)also TV 8 in pre-1999 database, ; site ID same as SFAN 2004 monitoring
NYH 1	GGNRA pre-1999 database, SFAN 2004 monitoring	No, TV 9	changed name since it is not in the Tennessee Valley watershed
OAK 1	GGNRA pre-1999 database, SFAN 2004 monitoring	No, TV 3	changed name since it is not in the Tennessee Valley watershed
WU 1	SFAN 2004 monitoring	yes	
WU 2	SFAN 2004 monitoring	yes	
WU 3	SFAN 2004 monitoring	yes	
WU 4	new site, (SFAN 2003 recon)		
MGG 1	SFAN 2004 monitoring	yes	
FRA 1	SFAN 2004 monitoring	yes	
STR 1	SFAN 2004 monitoring	yes	
STR 2	SFAN 2004 monitoring	yes	
STR 3	SFAN 2004 monitoring	yes	
STR 4	SFAN 2004 monitoring	yes	
STR 5	SFAN 2004 monitoring	yes	
SC 1	PINN 1997-2002 monitoring, SFAN 2004 monitoring	yes	Same as SFAN 2004 monitoring
SC 2	new PINN site 2005 (assistance from SFAN)	Yes	Same as 2005 site
SC3	new PINN site 2005	Yes	Same as 2005 site
MC1	new PINN site 2005	Yes	Same as 2005 site
BG 2	PINN 1997-2002 monitoring, SFAN 2004 monitoring	Yes	Same as SFAN 2004 monitoring
CHA 1	PINN 1997-2002 monitoring, SFAN 2004 monitoring	Yes	Same as SFAN 2004 monitoring
CHA 2	PINN 1997-2002 monitoring, SFAN 2004 monitoring	Yes	Same as SFAN 2004 monitoring
CHA 3	PINN 1997-2002 monitoring	No	"North Fork - approximately 30-40 m upstream of confluence"

Appendix F. Maps of Watersheds and Sampling Locations


San Francisco Area Network
Proposed Fresh Water Quality Monitoring Sites
Golden Gate, Point Reyes, John Muir
National Park Service
U.S. Department of the Interior
Santa Rosa
Petaluma
Sonoma
Napa
Yountville
Vallejo
San Rafael--Novato
Concord
San Francisco--Oakland
METROPOLITAN OAKLAND INTL
SAN FRANCISCO INTL
Half Moon Bay
San Jose
Tomales Bay State Park
Point Reyes Nat'l Seashore
Samuel Taylor State Park
Golden Gate Nat'l Rec Area
Mount Tamalpais State Park
Wildcat Canyon Reg Park
Tilden Reg Park
Anthony Chabot Reg Park
Lagunitas & Olema Creek
Pine Gulch
Upper Redwood Creek
Lower Redwood Creek
Tennesse Creek
Rodeo Creek
Strentzel Creek
West Union Creek
N
Watersheds
Point Reyes Administrative Boundary
Golden Gate Legislative Boundary
John Muir Administrative Boundary
0 2.5 5 10 15 20
Miles


San Francisco Area Network
Lagunitas & Olema Creek, Proposed Freshwater Quality Sites
National Park Service
U.S. Department of the Interior
OLM10B
LAG 1
OLM 11
OLM 4
LAG 2
LAG 3
OLM 6A
OLM 14
OLM 1
OLM 2
OLM 18
Fresh Water Quality Site Type
Alternate
Proposed
Point Reyes Legislative Boundary
GOGA Legislative Boundary
Lagunitas Watershed
0
0.5
1
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Miles
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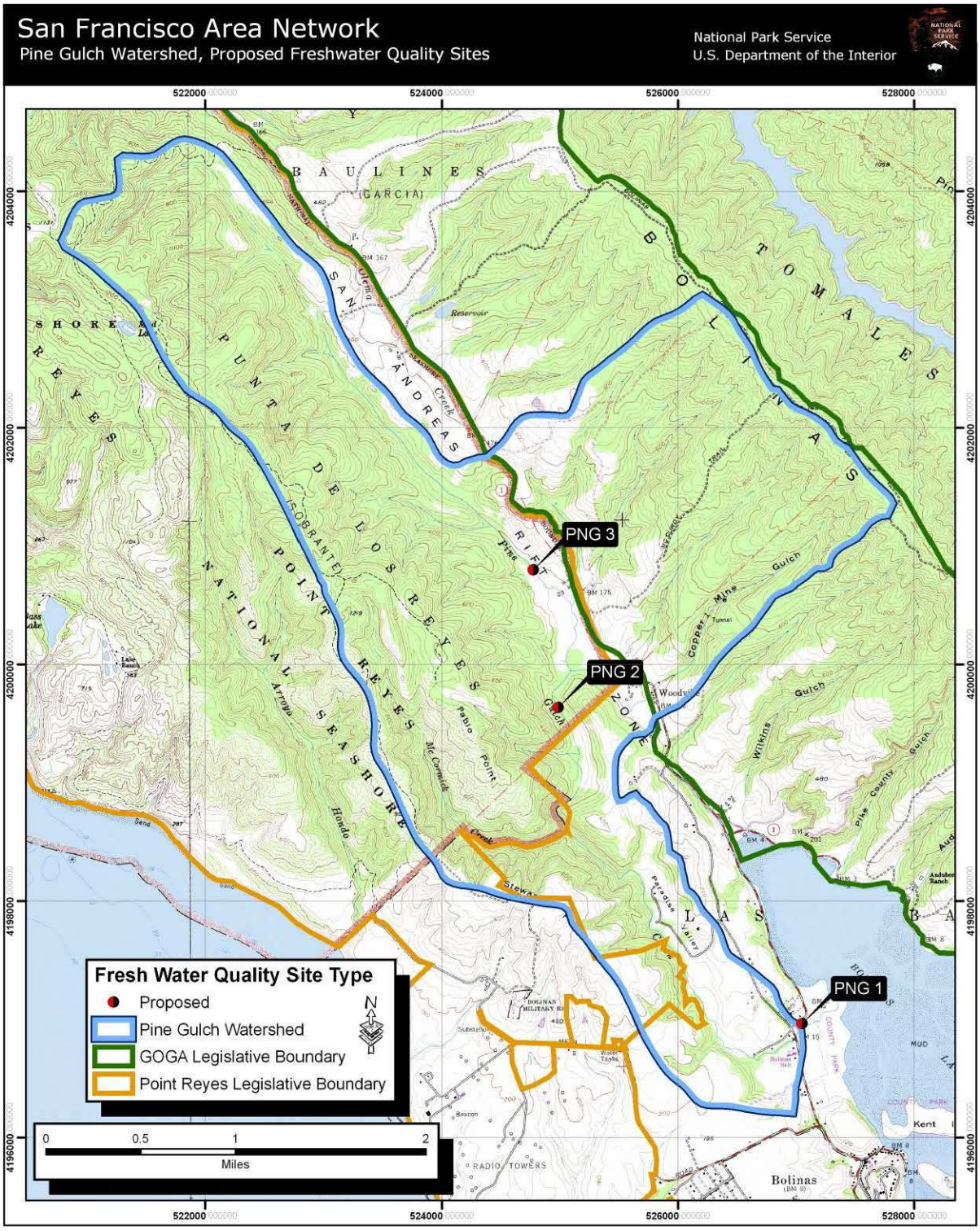
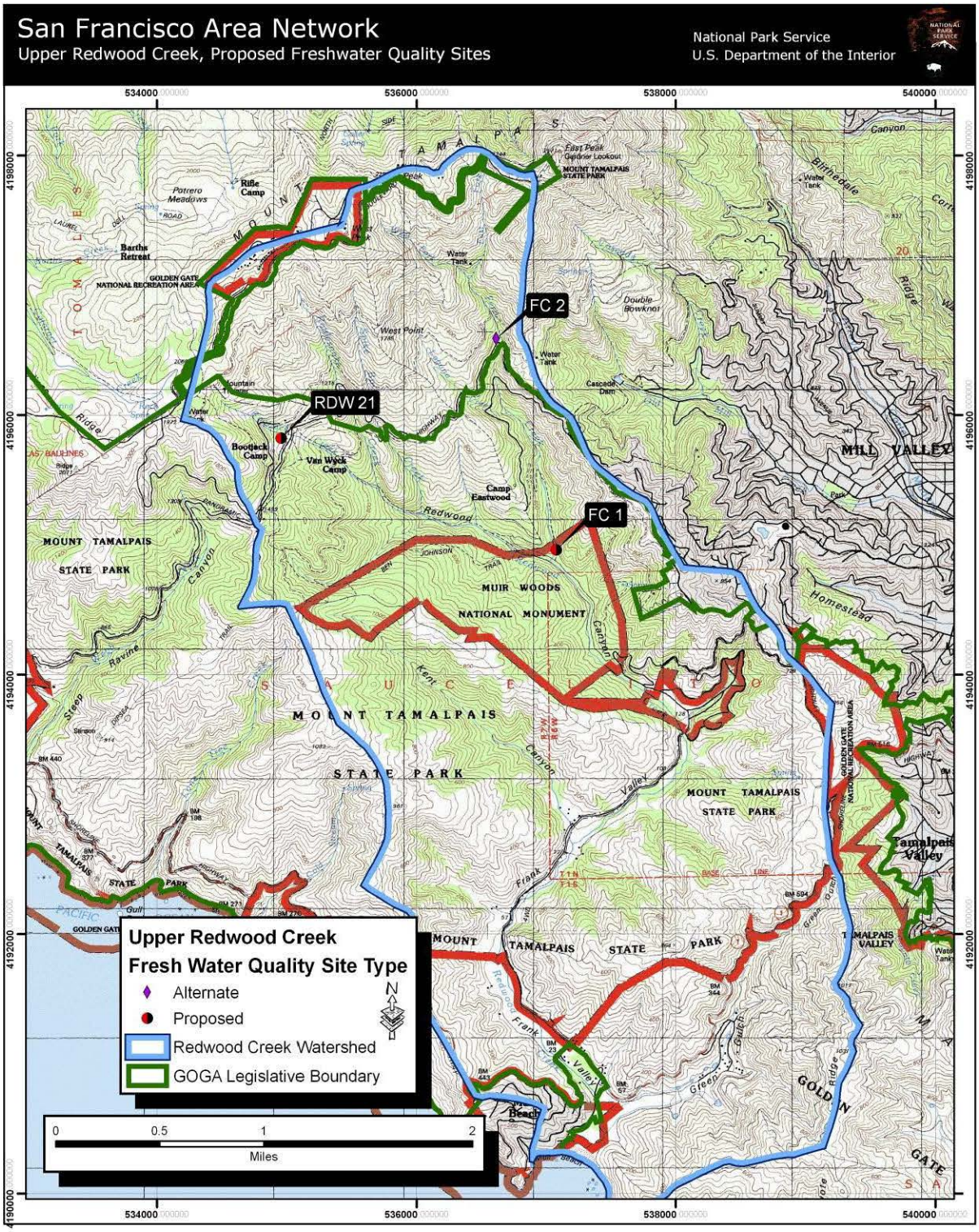
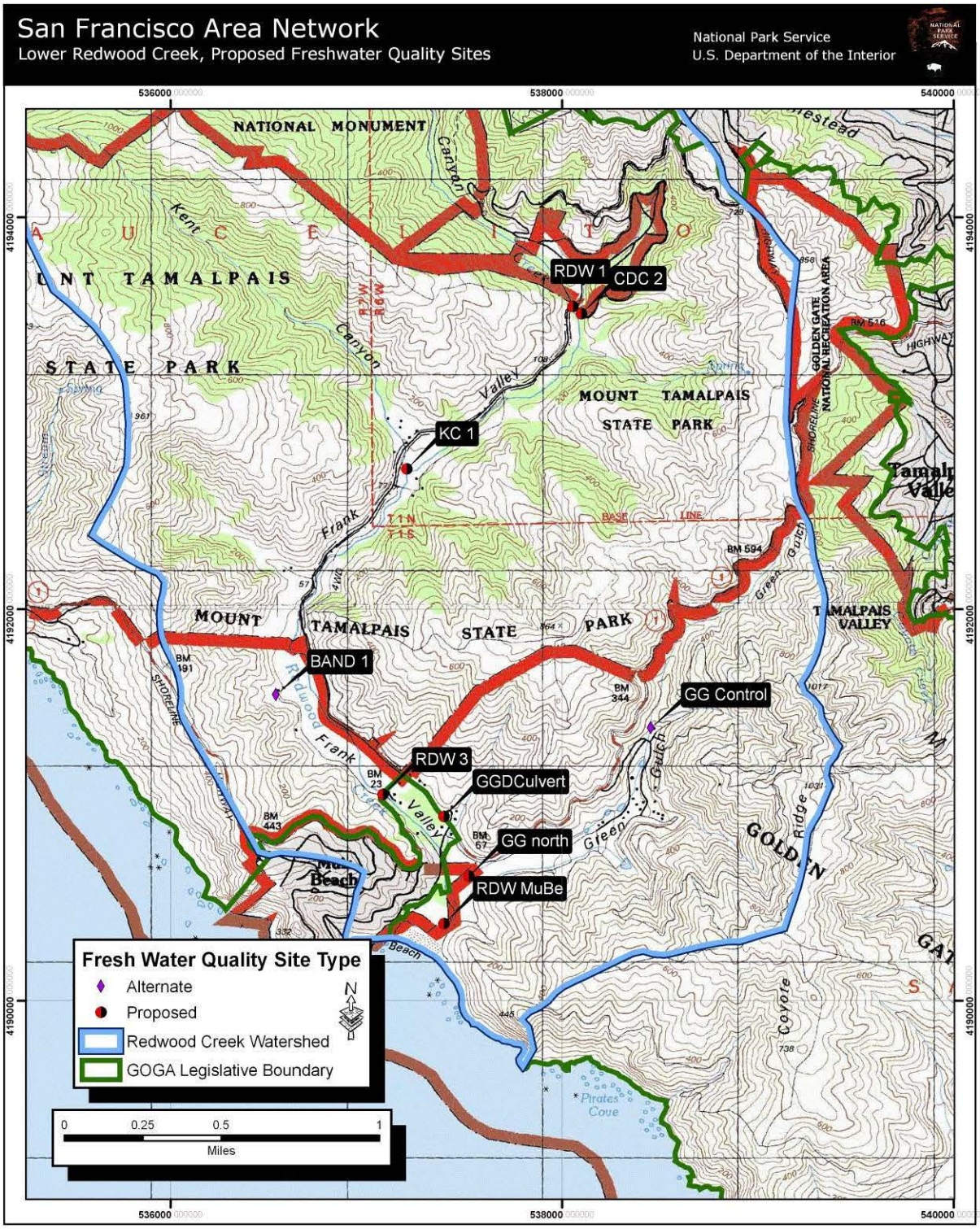
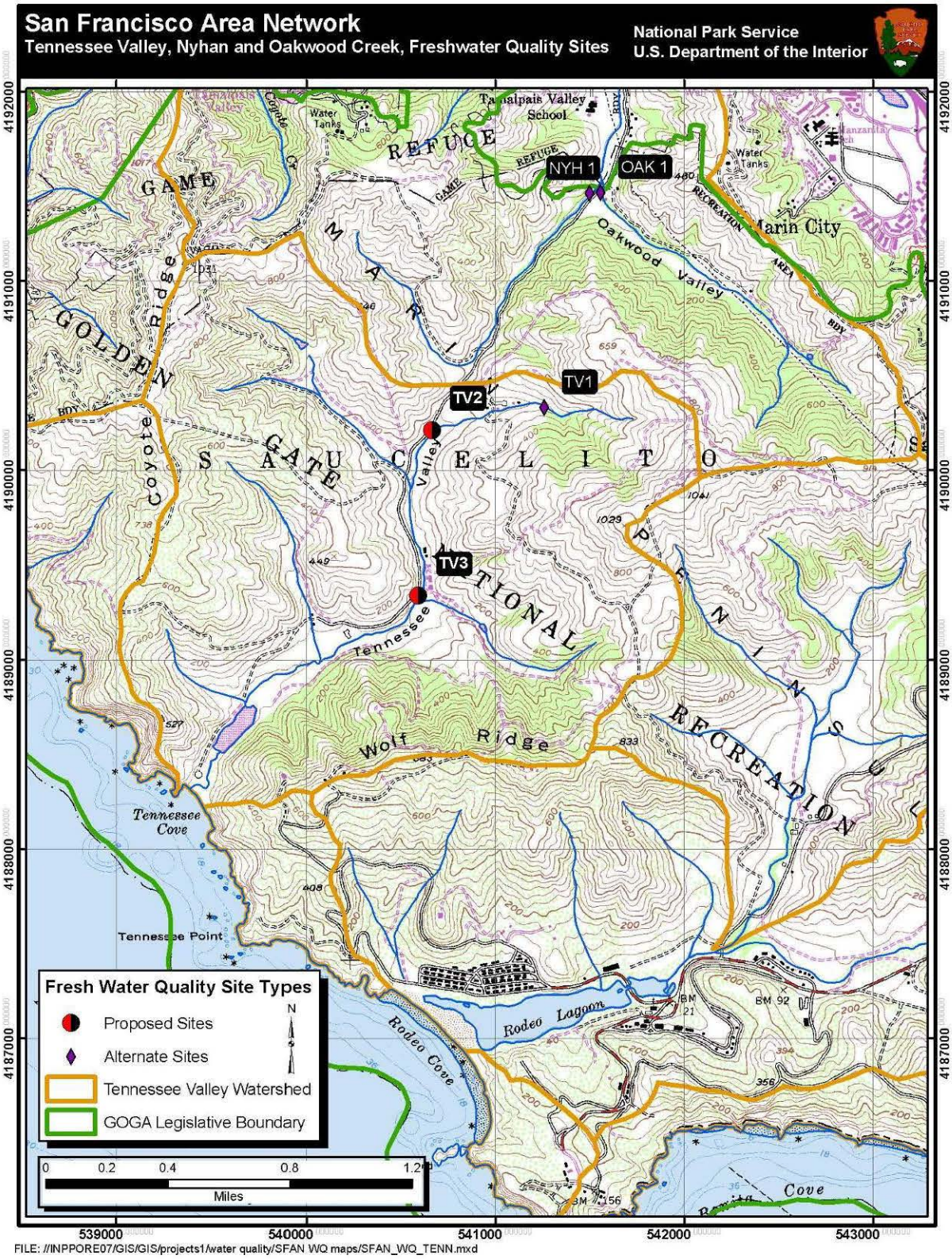
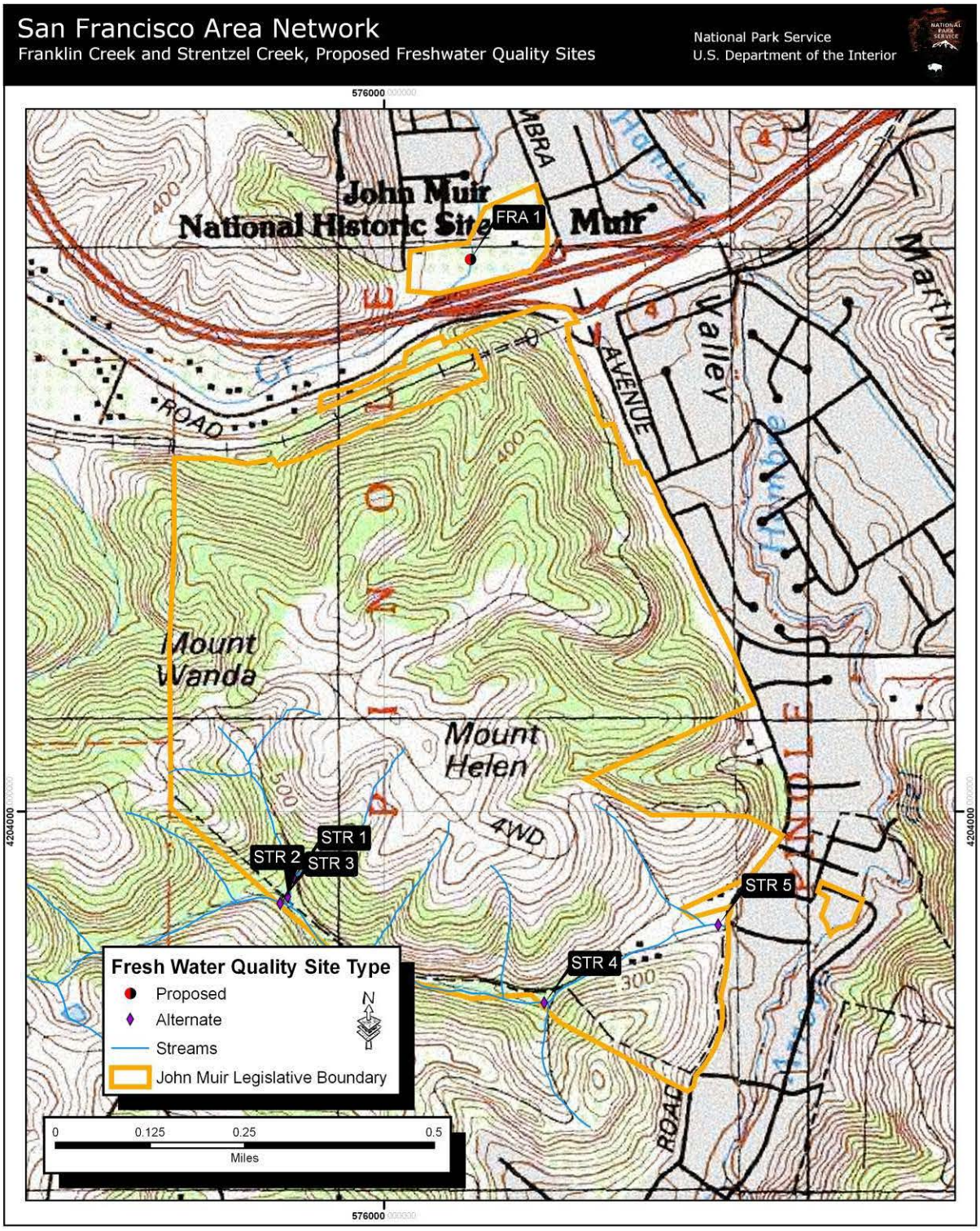

San Francisco Area Network
Pine Gulch Watershed, Proposed Freshwater Quality Sites
National Park Service
U.S. Department of the Interior
PNG 1
PNG 2
PNG 3
Fresh Water Quality Site Type
Proposed
Pine Gulch Watershed
GOGA Legislative Boundary
Point Reyes Legislative Boundary
N
0
0.5
1
2
Miles
522000
524000
526000
528000
4204000
4202000
4200000
4198000
4196000
BOLINAS RIDGE
TOMALES
PUNTA DE LOS REYES
SAN ANDREAS RIFT ZONE
POINT REYES NATIONAL SEASHORE
BOLINAS LAGOON
Bolinas
Kent

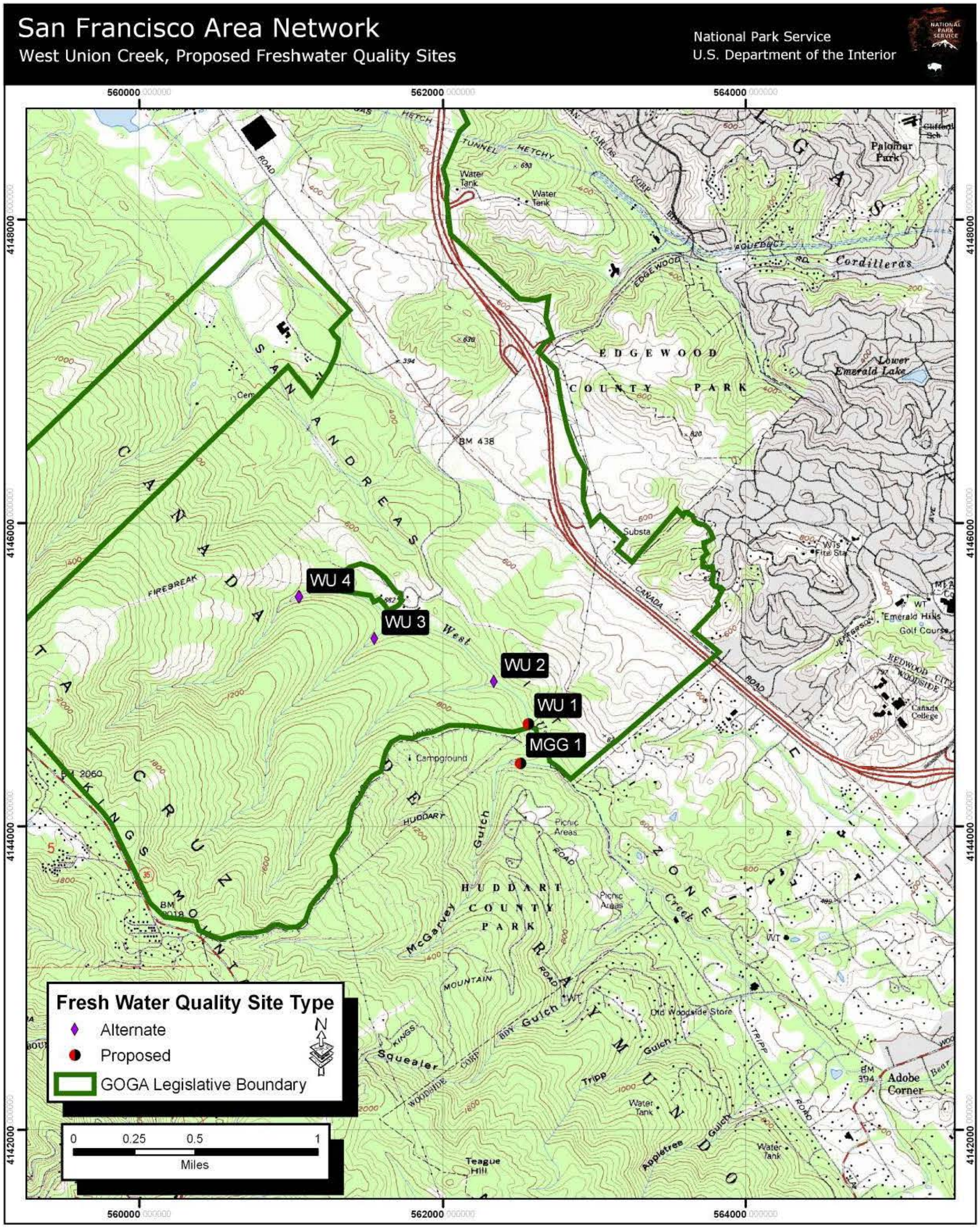

San Francisco Area Network
Upper Redwood Creek, Proposed Freshwater Quality Sites
National Park Service
U.S. Department of the Interior
FC 2
RDW 21
FC 1
MOUNT TAMALPAIS STATE PARK
MUIR WOODS NATIONAL MONUMENT
MILL VALLEY
Upper Redwood Creek
Fresh Water Quality Site Type
Alternate
Proposed
Redwood Creek Watershed
GOGA Legislative Boundary
N
0
0.5
1
2
Miles
534000
536000
538000
540000
4198000
4196000
4194000
4192000
4190000

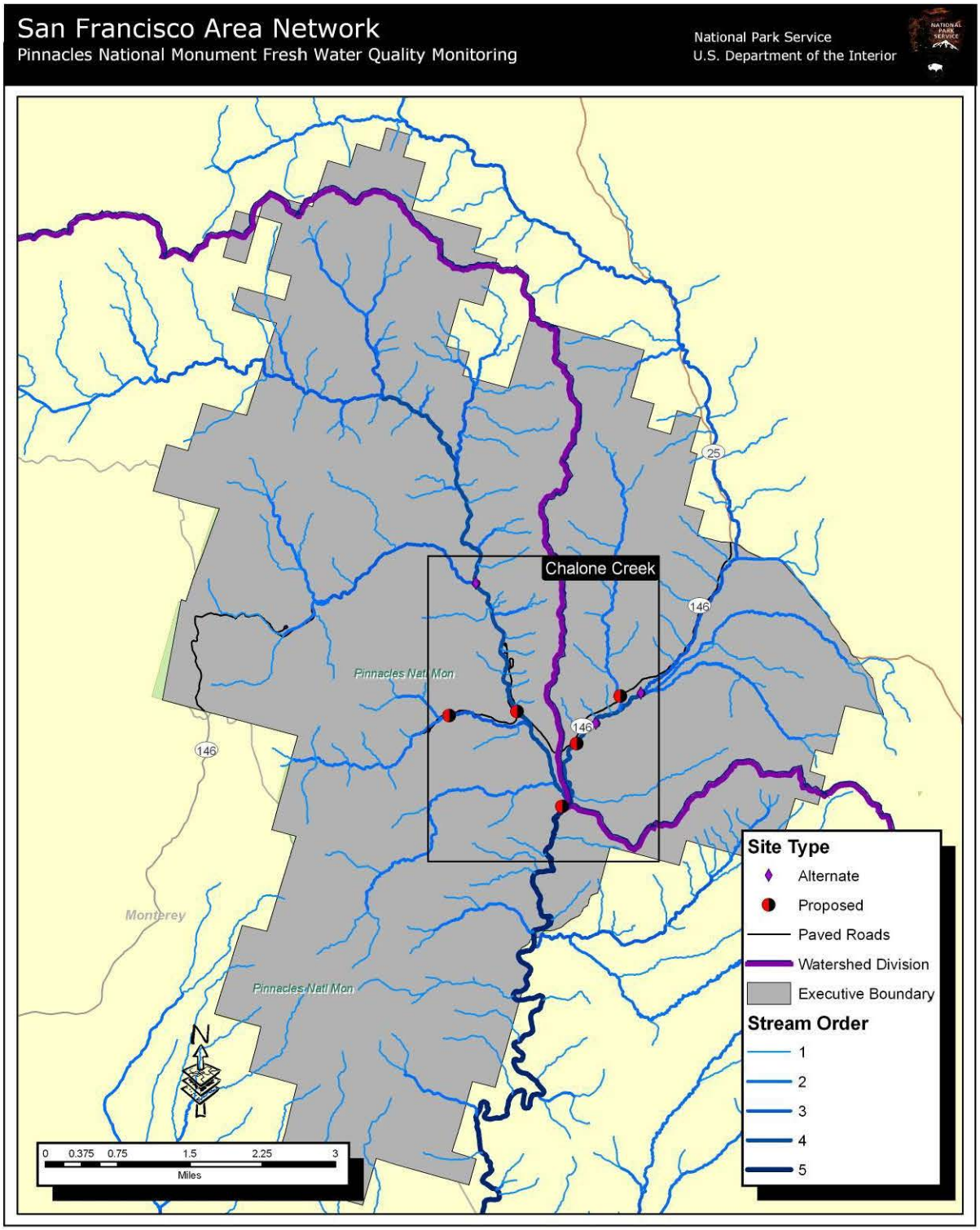

San Francisco Area Network
Lower Redwood Creek, Proposed Freshwater Quality Sites
National Park Service
U.S. Department of the Interior
NATIONAL MONUMENT
STATE PARK
MOUNT TAMALPAIS
STATE PARK
RDW 1
CDC 2
KC 1
BAND 1
RDW 3
GGDCulvert
GG north
RDW MuBe
GG Control
Fresh Water Quality Site Type
Alternate
Proposed
Redwood Creek Watershed
GOGA Legislative Boundary
N
0
0.25
0.5
1
Miles
536000
538000
540000
4194000
4192000
4190000

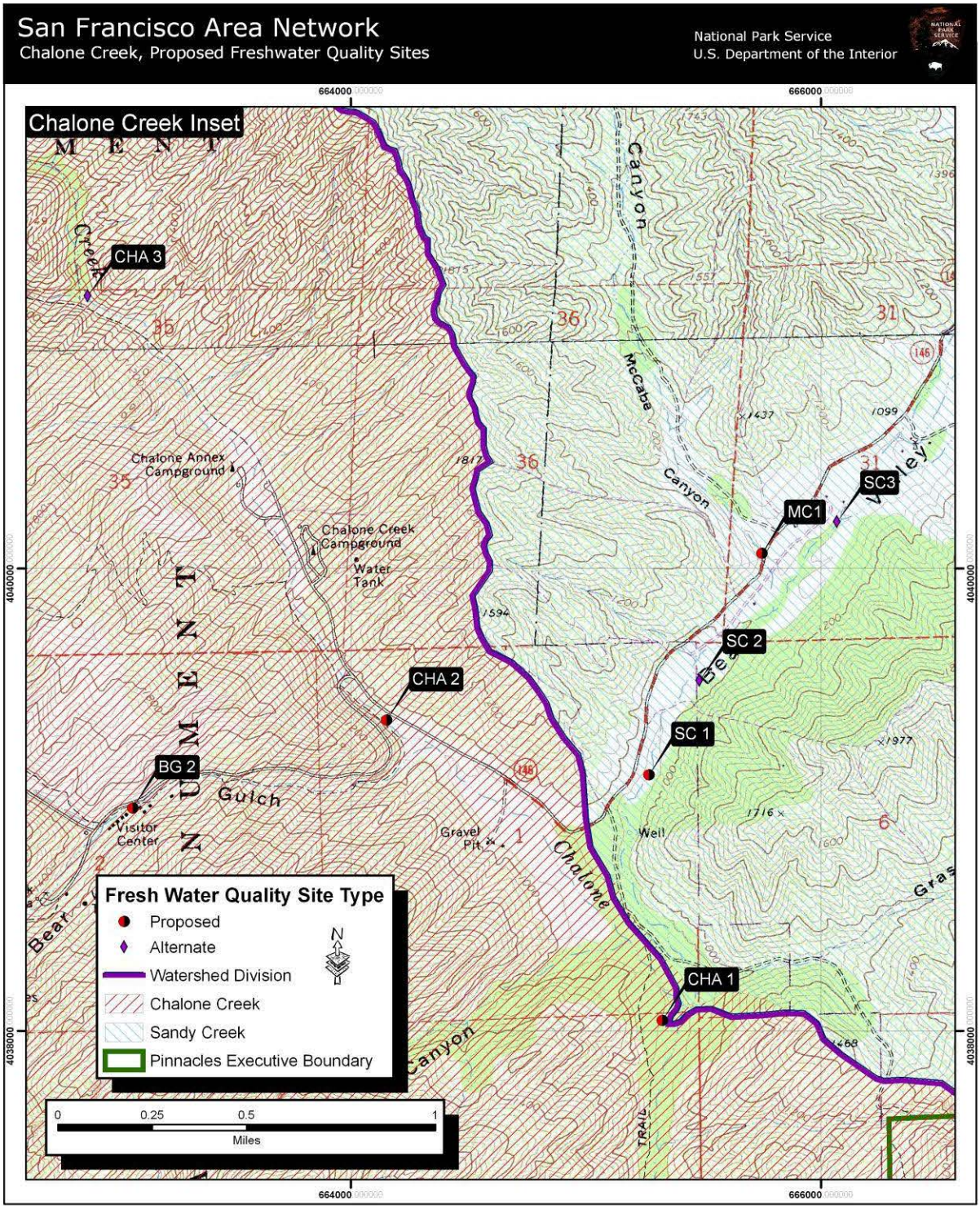

San Francisco Area Network
Tennessee Valley, Nyhan and Oakwood Creek, Freshwater Quality Sites
National Park Service
U.S. Department of the Interior
NYH 1
OAK 1
TV1
TV2
TV3
Fresh Water Quality Site Types
Proposed Sites
Alternate Sites
Tennessee Valley Watershed
GOGA Legislative Boundary
N
0 0.2 0.4 0.8 1.2
Miles
539000
540000
541000
542000
543000
4192000
4191000
4190000
4189000
4188000
4187000
FILE: //INPPORE07/GIS/GIS/projects1/water quality/SFAN WQ maps/SFAN_WQ_TENN.mxd


San Francisco Area Network
Rodeo Creek Watershed, Freshwater Quality Sites
National Park Service
U.S. Department of the Interior
GERB1
RC1
RC2
Fresh Water Quality Site Types
Proposed Sites
Alternate Sites
Watershed Boundary
GOGA Legislative Boundary
N
0 0.15 0.3 0.6 0.9 1.2
Miles
Sausalito
Marin City
Point Diablo Lighthouse
Fort Point Rock
Helmet Rock
Rodeo Lagoon
Rodeo Cove
Wolf Ridge
Tennessee Valley
Oakwood Valley
FORT BAKER MILITARY RESERVATION
GOLDEN GATE NATIONAL RECREATION AREA
MARIN PENINSULA
SAUCELITO
RICHARDSON BAY
GAME REFUGE
540000
541000
542000
543000
544000
545000
546000
4191000
4190000
4189000
4188000
4187000
4186000
4185000
FILE: //INPPORE07/GIS/GIS/projects1/water quality/SFAN WQ maps/SFAN_WQ_RODEO.mxd


San Francisco Area Network
Franklin Creek and Strentzel Creek, Proposed Freshwater Quality Sites
National Park Service
U.S. Department of the Interior
576000
4204000
John Muir
National Historic Site
FRA 1
Muir
Martin
Valley
AVENUE
ROAD
Mount
Wanda
Mount
Helen
4WD
STR 1
STR 2
STR 3
STR 4
STR 5
Fresh Water Quality Site Type
Proposed
Alternate
Streams
John Muir Legislative Boundary
N
0
0.125
0.25
0.5
Miles


San Francisco Area Network
West Union Creek, Proposed Freshwater Quality Sites
National Park Service
U.S. Department of the Interior
WU 4
WU 3
WU 2
WU 1
MGG 1
Fresh Water Quality Site Type
Alternate
Proposed
GOGA Legislative Boundary
0
0.25
0.5
1
Miles


San Francisco Area Network
Pinnacles National Monument Fresh Water Quality Monitoring
National Park Service
U.S. Department of the Interior
Chalone Creek
Pinnacles Nat Mon
Monterey
Pinnacles Natl Mon
25
146
146
146
N
0 0.375 0.75 1.5 2.25 3
Miles
Site Type
Alternate
Proposed
Paved Roads
Watershed Division
Executive Boundary
Stream Order
1
2
3
4
5


San Francisco Area Network
Chalone Creek, Proposed Freshwater Quality Sites
National Park Service
U.S. Department of the Interior
Chalone Creek Inset
CHA 3
CHA 2
CHA 1
BG 2
SC 1
SC 2
SC3
MC1
Chalone Annex Campground
Chalone Creek Campground
Water Tank
Visitor Center
Gravel Pit
Well
McCabe Canyon
Bear Gulch
Chalone Canyon
Fresh Water Quality Site Type
Proposed
Alternate
Watershed Division
Chalone Creek
Sandy Creek
Pinnacles Executive Boundary
N
0
0.25
0.5
1
Miles
664000
666000
4040000
4038000

Appendix G. Metadata Checklist and SFAN NPSTORET Characteristics Definitions Report

Metadata Checklist (Tucker, D. personal communication, 14 November 2004.)

Projects:
1) Project ID (8 characters or less)
2) Project Name (60 characters or less)
3) Start Date
4) Project Duration (15 characters or less) - typically this would be something like "Ongoing", "2 Years",
etc.
5) Project Purpose (4000 characters or less)

Stations:
1) Location ID (15 characters or less)
2) Name (60 characters or less)
3) Station Primary Type (Stream/River; Wetland, etc. from STORET Pick List)
4) Station Secondary Type (Only for certain Primary Types: e.g. Canal, CERCLA Superfund Site, Facility,
Mine/Mine Discharge, and Wetland)
5) Decimal degrees latitude/longitude
6) Lat/Lon Method (STORET Pick List)
7) Lat/Lon Datum (STORET Pick List)
8) County
9) State

Metadata:

For every characteristic measured, provide, as appropriate:

1) Official EPA STORET Characteristic Name (STORET Pick List)
2) Your Name for the Parameter/Characteristic
3) Sample Fraction (STORET Pick List)
4) Units
5) Value Type (Actual, Calculated, Estimated)
6) Field/Lab
7) Medium
8) Statistic Type (STORET Pick List)
9) Duration Basis (STORET Pick List)
10) Weight Basis (STORET Pick List)
11) Temperature Basis (STORET Pick List)
12) Particle Size Basis
13) Analytical Procedure - (e.g. Metals in Marine Waters by ICP/MS - EPA/ORD 200.1; Ammonia Nitrogen in Water, Hach 8038)

14) Gear Configuration (name or type of instrument and how it was configured)
15) Sample Collection Procedure/Description (for samples taken to a lab)
16) Sample Handling Procedure (e.g. Cool to 4°C, adjust pH <2 with H2SO4)
17) Lab Sample Preparation Procedure (e.g. filtration of water samples, 0.45 microns)
18) Lab Identification and Certification for Characteristic (what lab and was it certified for that characteristic)
19) Detection Limit
20) Lower Quantification Limit
21) Upper Quantification Limit
22) Description/Interpretation of the Limit
23) Lower Range Value (used for warning messages about possible out of range values during data entry)
24) Upper Range Value (used for warning messages about possible out of range values during data entry)
25) Free Text Characteristic/Parameter Description

Metadata Checklist (cont.)

Results:
1) Station ID - one of the previously entered
2) Date
3) Time (optional)
4) Time Zone (required if Time given)
5) Activity/Sample ID
6) Replicate Number (optional)
7) Depth (optional)
8) Depth Units (required if Depth given)
9) Your Name for Parameter/Characteristic
10) Detection Condition (STORET Pick List)
11) Result Value/Text
12) Value Type (Actual, Calculated, Estimated)
13) Value Status (Final, Preliminary)
14) Lab Remarks (STORET Pick List)
15) Detection Limit (if not given in metadata and/or varies with results)
16) Lower Quantification Limit (if not given in metadata and/or varies with results)
17) Upper Quantification Limit (if not given in metadata and/or varies with results)
18) Description/Interpretation of the Limit (if not given in metadata and/or varies with results)

SFAN NPSTORET Characteristics Definitions Report
Printed 9/28/06 (contact SFAN for most current version)

NPSTORET Characteristics

San Francisco Bay Area Network ***Sorted by Sequence Number***

STORET Name: Temperature, air **Local** AirTemp_YSI85
Comp? ✔
Sequence 100 **Sample Value** Act **Unit of** deg C **Field/Lab:** Field
Medium Air **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**
Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit
QA/QC Lower Range 10 **QA/QC Upper Range** 38
Characteristic
Defined Procedures, Configuration, &&
Analytical: SFAN_SOP 5: Field Methods for Measurement of Core Parameters
Collection: WQ_PROBE: Field Methods for Measurement of Core Parameters
Gear Config: YSI 85: Multiparameter probe
Projects: SFAN_I&M: SFAN Long-Term Water Quality Monitoring Program
SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Groups: Field: Field Parameters (F)

STORET Name: Temperature, air **Local** AirTemp_Glass
Comp? ✔
Sequence 101 **Sample Value** **Unit of** deg C **Field/Lab:** Field
Medium Air **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**
Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit
QA/QC Lower Range **QA/QC Upper Range**
Characteristic

Defined Procedures, Configuration, &&

Projects: SFAN_I&M: SFAN Long-Term Water Quality Monitoring Program
Groups: Field: Field Parameters (F)

STORET Name: Temperature, air **Local** AirTemp_Oakton
Comp? ✔
Sequence 101.5 **Sample** **Value** **Unit of** deg C **Field/Lab:** Field
Medium Air **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**
Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit
QA/QC Lower Range **QA/QC Upper Range**
Characteristic Air temperature taken with the Oakton pHTestr 30
Defined Procedures, Configuration, &&

Projects:
Groups: Field: Field Parameters (F)

NPSTORET Characteristics

San Francisco Bay Area Network ***Sorted by Sequence Number***

STORET Name: Temperature, water **Local** H2OTemp_YSI85
Comp? ✔
Sequence 102 **Sample Value** Act **Unit of** deg C **Field/Lab:** Field
Medium Water **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**
Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit
QA/QC Lower Range 10 **QA/QC Upper Range** 17
Characteristic
Defined Procedures, Configuration, &&
Analytical: SFAN_SOP 5: Field Methods for Measurement of Core Parameters
Collection: WQ_PROBE: Field Methods for Measurement of Core Parameters
Gear Config: YSI 85: Multiparameter probe
Projects: SFAN_I&M: SFAN Long-Term Water Quality Monitoring Program
SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Groups: Field: Field Parameters (F)

STORET Name: Temperature, water **Local** H2OTemp_Oakton
Comp? ✔
Sequence 103 **Sample Value** **Unit of** deg C **Field/Lab:** Field
Medium Water **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**
Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit
QA/QC Lower Range **QA/QC Upper Range**
Characteristic
Defined Procedures, Configuration, &&

Projects: SFAN_I&M: SFAN Long-Term Water Quality Monitoring Program
Groups: Field: Field Parameters (F)

STORET Name: Temperature, water **Local** H2OTemp_Glass
Comp? ✔
Sequence 104 **Sample** **Value** **Unit of** deg C **Field/Lab:** Field
Medium Water **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**
Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit
QA/QC Lower Range **QA/QC Upper Range**
Characteristic
Defined Procedures, Configuration, &&

Projects: SFAN_I&M: SFAN Long-Term Water Quality Monitoring Program
Groups: Field: Field Parameters (F)

STORET Name: Specific conductance **Local** Cond_YSI85
Comp? ✔
Sequence 105 **Sample** **Value** Act **Unit of** uS/cm **Field/Lab:** Field
Medium Water **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**

NPSTORET Characteristics

San Francisco Bay Area Network *Sorted by Sequence Number*

Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit
QA/QC Lower Range WQ_PROBE: Field Methods for Measurement of Core Parameters **QA/QC Upper Range**
Characteristic YSI 85: Multiparameter probe
Defined Procedures, Configuration, && SFAN_I&M: SFAN Long-Term Water Quality Monitoring Program
SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Collection: Field: Field Parameters (F)

STORET Name: Specific conductance **Local** SC_YSI85 **Comp?** ✔
Sequence 106 **Sample** **Value** Cal **Unit of** uS/cm **Field/Lab:** Field
MediumWater **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:** 25 Deg C
Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit
QA/QC Lower Range **QA/QC Upper Range**
Characteristic
Defined Procedures, Configuration, &&
Analytical: SFAN_SOP 5: Field Methods for Measurement of Core Parameters
Collection: WQ_PROBE: Field Methods for Measurement of Core Parameters
Gear Config: YSI 85: Multiparameter probe
Projects: SFAN_I&M: SFAN Long-Term Water Quality Monitoring Program
SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Groups: Field: Field Parameters (F)

STORET Name: Salinity **Local** Salinity_YSI85 **Comp?** ✔
Sequence 107 **Sample** Dissolved **Value** **Unit of** ppth **Field/Lab:** Field
MediumWater **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**

Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit
QA/QC Lower Range **QA/QC Upper Range**
Characteristic Value determined by YSI85 using specific conductance and algorithms found in SMEWW. While technically unitless, values are close to those using mass of dissolved salts in given mass of water (parts per thousand).
Defined Procedures, Configuration, &&
Analytical: SFAN_SOP 5: Field Methods for Measurement of Core Parameters
Collection: WQ_PROBE: Field Methods for Measurement of Core Parameters
Gear Config: YSI 85: Multiparameter probe
Projects: SFAN_I&M: SFAN Long-Term Water Quality Monitoring Program
SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Groups: Field: Field Parameters (F)

NPSTORET Characteristics

San Francisco Bay Area Network ***Sorted by Sequence Number***

STORET Name: Dissolved oxygen saturation **Local** DO%_YSI85
Comp? ✔
Sequence 108 **Sample Value** Act **Unit of** % **Field/Lab:** Field
MediumWater **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**
Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit
QA/QC Lower Range **QA/QC Upper Range**
Characteristic
Defined Procedures, Configuration, &&
Analytical: SFAN_SOP 5: Field Methods for Measurement of Core Parameters
Collection: WQ_PROBE: Field Methods for Measurement of Core Parameters
Gear Config: YSI 85: Multiparameter probe
Projects: SFAN_I&M: SFAN Long-Term Water Quality Monitoring Program
SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Groups: Field: Field Parameters (F)

STORET Name: Dissolved oxygen (DO) **Local** DO_YSI85
Comp? ✔
Sequence 109 **Sample Value** Act **Unit of** mg/l **Field/Lab:** Field
MediumWater **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**
Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit
QA/QC Lower Range **QA/QC Upper Range**
Characteristic
Defined Procedures, Configuration, &&
Analytical: SFAN_SOP 5: Field Methods for Measurement of Core Parameters
Collection: WQ_PROBE: Field Methods for Measurement of Core Parameters

Gear Config: YSI 85: Multiparameter probe
Projects: SFAN_I&M: SFAN Long-Term Water Quality Monitoring Program
SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Groups: Field: Field Parameters (F)

STORET Name: pH **Local** pH_Oakton **Comp?** ✔
Sequence 110 **Sample Value** Act **Unit of** None **Field/Lab:** Field
Medium Water **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**
Detection Limit: 0.01 **Lower Quant** 0.0318 **Upper Quant** 15
Detection/Quantification Limit
QA/QC Lower Range 6.5 **QA/QC Upper Range** 8.5
Characteristic
Defined Procedures, Configuration, &&
Analytical: SFAN_SOP 5: Field Methods for Measurement of Core Parameters
Collection: WQ_PROBE: Field Methods for Measurement of Core Parameters
Gear Config: OAKTON_PH: Oakton pH Testr 30
Projects: SFAN_I&M: SFAN Long-Term Water Quality Monitoring Program
SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Groups: Field: Field Parameters (F)

NPSTORET Characteristics

San Francisco Bay Area Network *Sorted by Sequence Number*

STORET Name: pH **Local** pH_paper **Comp?** ✔
Sequence 111 **Sample** **Value** **Unit of** None **Field/Lab:** Field
Medium Water **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**
Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit
QA/QC Lower Range **QA/QC Upper Range**
Characteristic
Defined Procedures, Configuration, &&
Analytical: SFAN_SOP 5: Field Methods for Measurement of Core Parameters
Projects: SFAN_I&M: SFAN Long-Term Water Quality Monitoring Program
Groups: Field: Field Parameters (F)

STORET Name: Flow, severity (choice list) **Local** Flow_Severity **Comp?** ✔
Sequence 112 **Sample** **Value** Est **Unit of** None **Field/Lab:** Field
Medium Water **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**
Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit
QA/QC Lower Range 1 **QA/QC Upper Range** 6
Characteristic 1=No Flow; 2=Low Flow; 3=Normal Flow; 4=Flood Flow; 5=High Flow; 6=Dry. Subjective, non-sequencial values that will be relative measures for each stream. Used by SWQCB Surface Water Ambient Monitoring Program (SWAMP)
Defined Procedures, Configuration, &&

Collection: FLOW: Field Methods for Flow Measurements
Projects: OLM_TMDL: Olema Creek Pathogen TMDL Monitoring Program
SFAN_I&M: SFAN Long-Term Water Quality Monitoring Program
SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol

Groups: Field: Field Parameters (F)

STORET Name: Flow **Local** discharge **Comp?** ✔
Sequence 113 **Sample Value** Cal **Unit of** cfs **Field/Lab:** Field
Medium Water **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**
Detection Limit: 0.01 **Lower Quant** **Upper Quant**
Detection/Quantification Limit
QA/QC Lower Range **QA/QC Upper Range**
Characteristic
Defined Procedures, Configuration, &&
Analytical: SFAN_SOP 9: Field Methods for Flow Measurements
Collection: FLOW: Field Methods for Flow Measurements
Gear Config: FLO-MATE: Marsh-McBirney Flo-Mate
Projects: SFAN_I&M: SFAN Long-Term Water Quality Monitoring Program
SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Groups: Field: Field Parameters (F)

NPSTORET Characteristics

San Francisco Bay Area Network ***Sorted by Sequence Number***

STORET Name: Flow **Local** Estimated velocity **Comp?** ✓

Sequence 114 **Sample** **Value** Est **Unit of** ft/sec **Field/Lab:** Field

Medium Water **Statistic Type:** **Duration:**

Weight Basis: **Part. Size Basis:** **Temp. Basis:**

Detection Limit: **Lower Quant** **Upper Quant**

Detection/Quantification Limit

QA/QC Lower Range **QA/QC Upper Range**

Characteristic Estimation of stream flow velocity based on the "orange peel" method. Reported value is the average of a minimum of three replicates

Defined Procedures, Configuration, &&

Analytical: SFAN_SOP 9: Field Methods for Flow Measurements

Projects: OLM_TMDL: Olema Creek Pathogen TMDL Monitoring Program
PORE_BO: NOAA Fisheries Biological Opinion on Grazing
PORE_HSP: PORE Horseshoe Pond Restoration Project
PORE_WQ: PORE Water Quality Monitoring Program
SFAN_I&M: SFAN Long-Term Water Quality Monitoring Program
SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol

Groups: Field: Field Parameters (F)

STORET Name: Flow **Local** Estimated Flow **Comp?** ✓

Sequence 115 **Sample** **Value** **Unit of** cfs **Field/Lab:** Field

Medium Water **Statistic Type:** **Duration:**

Weight Basis: **Part. Size Basis:** **Temp. Basis:**

Detection Limit: **Lower Quant** **Upper Quant**

Detection/Quantification Limit

QA/QC Lower Range **QA/QC Upper Range**

Characteristic Estimated flow uses "orange peel" or "float" method to determine average velocity in the centroid of flow and several depths in the cross-section, along with stream width to determine an estimate of flow. Most likely to overestimate cfs due to avg. velocity being taken from the centroid of flow.

Defined Procedures, Configuration, &&

Analytical: SFAN_SOP 9: Field Methods for Flow Measurements

Projects: SFAN_I&M: SFAN Long-Term Water Quality Monitoring Program

Groups: Field: Field Parameters (F)

STORET Name: Gage height **Local** Gage Height **Comp?** ✔

Sequence 116 **Sample Value** Act **Unit of** ft **Field/Lab:** Field

Medium Water **Statistic Type:** **Duration:**

Weight Basis: **Part. Size Basis:** **Temp. Basis:**

Detection Limit: 0.2 **Lower Quant** **Upper Quant**

Detection/Quantification Limit

QA/QC Lower Range **QA/QC Upper Range**

Characteristic

Defined Procedures, Configuration, &&

Analytical: SFAN_SOP 9: Field Methods for Flow Measurements

Collection: FLOW: Field Methods for Flow Measurements

OLM_TMDL: Olema Creek Pathogen TMDL Monitoring Program
PORE_BO: NOAA Fisheries Biological Opinion on Grazing
PORE_HSP: PORE Horseshoe Pond Restoration Project
PORE_WQ: PORE Water Quality Monitoring Program
SFAN_I&M: SFAN Long-Term Water Quality Monitoring Program
SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Field: Field Parameters (F)

NPSTORET Characteristics

San Francisco Bay Area Network *Sorted by Sequence Number*

STORET Name: Stream width measure **Local** Stream Width
Comp? ✓
Sequence 117 **Sample Value** Act **Unit of** ft **Field/Lab:** Field
Medium Water **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**
Detection Limit: 0.1 **Lower Quant** 0.1 **Upper Quant**
Detection/Quantification Limit
QA/QC Lower Range **QA/QC Upper Range**
Characteristic
Defined Procedures, Configuration, &&
Analytical: SFAN_SOP 9: Field Methods for Flow Measurements
Collection: FLOW: Field Methods for Flow Measurements
Projects: OLM_TMDL: Olema Creek Pathogen TMDL Monitoring Program
PORE_BO: NOAA Fisheries Biological Opinion on Grazing
PORE_HSP: PORE Horseshoe Pond Restoration Project
PORE_WQ: PORE Water Quality Monitoring Program
SFAN_I&M: SFAN Long-Term Water Quality Monitoring Program
SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Groups: Field: Field Parameters (F)

STORET Name: Weather Comments (text) **Local** weather **Comp?** ✓
Sequence 118 **Sample Value** **Unit of** **Field/Lab:**
Medium **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**
Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit
QA/QC Lower Range **QA/QC Upper Range**
Characteristic

Defined Procedures, Configuration, &&

Projects: BEACH_WQ: Beach Recreational Water Quality Monitoring Program
OLM_TMDL: Olema Creek Pathogen TMDL Monitoring Program
PORE_BO: NOAA Fisheries Biological Opinion on Grazing
PORE_HSP: PORE Horseshoe Pond Restoration Project
PORE_WQ: PORE Water Quality Monitoring Program
SFAN_I&M: SFAN Long-Term Water Quality Monitoring Program
SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol

Groups: Field: Field Parameters (F)
GENERAL: General Observations

NPSTORET Characteristics

San Francisco Bay Area Network ***Sorted by Sequence Number***

STORET Name: Precipitation Time Since Event **Local** Last Precipitation
Comp? ✓
Sequence 119 **Sample Value** Est **Unit of** days **Field/Lab:** Field
MediumOther **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**
Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit
QA/QC Lower Range **QA/QC Upper Range**
Characteristic
Defined Procedures, Configuration, &&

Projects: BEACH_WQ: Beach Recreational Water Quality Monitoring Program
OLM_TMDL: Olema Creek Pathogen TMDL Monitoring Program
PORE_WQ: PORE Water Quality Monitoring Program
SFAN_I&M: SFAN Long-Term Water Quality Monitoring Program
SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Groups: Field: Field Parameters (F)
GENERAL: General Observations

STORET Name: Water appearance (text) **Local** Water Appearance
Comp? ✓
Sequence 120 **Sample Value** **Unit of** **Field/Lab:** Lab
MediumWater **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**
Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit
QA/QC Lower Range **QA/QC Upper Range**
Characteristic

Defined Procedures, Configuration, &&

Collection: WQ_SAMPLE: General Water Quality Procedures
Projects: BEACH_WQ: Beach Recreational Water Quality Monitoring Program
PORE_WQ: PORE Water Quality Monitoring Program
SFAN_I&M: SFAN Long-Term Water Quality Monitoring Program
SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Groups: Field: Field Parameters (F)
GENERAL: General Observations

STORET Name: General Observation (text) **Local** General Notes
Comp? ✔
Sequence 121 **Sample** **Value** **Unit of** **Field/Lab:** Field
Medium **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**
Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit
QA/QC Lower Range **QA/QC Upper Range**
Characteristic
Defined Procedures, Configuration, &&

BEACH_WQ: Beach Recreational Water Quality Monitoring Program
OLM_TMDL: Olema Creek Pathogen TMDL Monitoring Program
PORE_WQ: PORE Water Quality Monitoring Program
SFAN_I&M: SFAN Long-Term Water Quality Monitoring Program
SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Field: Field Parameters (F)
GENERAL: General Observations

NPSTORET Characteristics

San Francisco Bay Area Network *Sorted by Sequence Number*

STORET Name: Turbidity **Local** turbidity_Hach2100
Comp? ✔
Sequence 122 **Sample Value** Act **Unit of** NTU **Field/Lab:** Field
Medium Water **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**
Detection Limit: 0.01 **Lower Quant** 0.0318 **Upper Quant** 1000
Detection/Quantification Limit
QA/QC Lower Range **QA/QC Upper Range**
Characteristic
Defined Procedures, Configuration, &&
Analytical: 8195: Determination of Turbidity
Collection: DI_SAMPLE: Field and Laboratory Methods for Sediment
Projects: SFAN_I&M: SFAN Long-Term Water Quality Monitoring Program
SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Groups: Field: Field Parameters (F)
Sediment: Sediment Analysis (S)

STORET Name: Turbidity severity (choice list) **Local** turbidity severity
Comp? ✔
Sequence 123 **Sample Value** **Unit of** **Field/Lab:**
Medium **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**
Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit
QA/QC Lower Range **QA/QC Upper Range**
Characteristic
Defined Procedures, Configuration, &&

Projects: SFAN_I&M: SFAN Long-Term Water Quality Monitoring Program

SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol

Groups: Field: Field Parameters (F)
Sediment: Sediment Analysis (S)

STORET Name: Total Coliform **Local** total coliform
Comp? ✔
Sequence 124 **Sample Value** Est **Unit of** MPN/100ml **Field/Lab:** Lab
Medium Water **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**
Detection Limit: 2 **Lower Quant** 2 **Upper Quant** 1600
Detection/Quantification Limit Limits refer to Most Probable Number (MPN)/100mL of sample volume; Dilutions of 10x: 20-16,000; 100x: 200-160,000; 1000x: 2000-1,600,000
QA/QC Lower Range **QA/QC Upper Range**

SM 9221 B: Fecal and total coliform enumeration by Most Probable Number (multiple tube technique)
GRABSAMPLE: Field Methods for Sampling Fecal Indicator Bacteria

NPSTORET Characteristics

SFAN_I&M: SFAN Long-Term Water Quality Monitoring Program
SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
San Francisco Bay Area Network Bacteria: Bacteriologic Analysis (B) ***Sorted by Sequence Number***

STORET Name: Fecal Coliform **Local** fecal coliforms **Comp?** ✔
Sequence 125 **Sample Value** Est **Unit of** MPN/100ml **Field/Lab:** Lab
MediumWater **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**
Detection Limit: 2 **Lower Quant** 2 **Upper Quant** 1600
Detection/Quantification Limit detection limits and quantification limits can be changed if a sample is diluted; e.g., dilute 10x gives a lower detection limit of 20 and upper quantification limit of 16,000, etc.
QA/QC Lower Range **QA/QC Upper Range**
Characteristic
Defined Procedures, Configuration, &&
Analytical: SM 9221 B: Fecal and total coliform enumeration by Most Probable Number (multiple tube technique)
Collection: GRABSAMPLE: Field Methods for Sampling Fecal Indicator Bacteria
Projects: SFAN_I&M: SFAN Long-Term Water Quality Monitoring Program
SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Groups: Bacteria: Bacteriologic Analysis (B)

STORET Name: Escherichia coli **Local** E.coli **Comp?** ✔
Sequence 126 **Sample Value** **Unit of** MPN/100ml **Field/Lab:** Lab
MediumWater **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**
Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit
QA/QC Lower Range **QA/QC Upper Range**

Characteristic
Defined Procedures, Configuration, &&
Analytical: 9223-B: Enzyme Substrate Test, E. coli, Coliform Group
Collection: GRABSAMPLE: Field Methods for Sampling Fecal Indicator Bacteria
Projects: SFAN_I&M: SFAN Long-Term Water Quality Monitoring Program
SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Groups: Bacteria: Bacteriologic Analysis (B)

STORET Name: Enterococcus Group Bacteria **Local** Enterococcus
Comp? ✔
Sequence 127 **Sample** **Value** **Unit of** MPN/100ml **Field/Lab:** Lab
Medium Water **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**

NPSTORET Characteristics

San Francisco Bay Area Network *Sorted by Sequence Number*

Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit ENTEROLERT2000: Enterolert Quanti-Tray/2000; Multi Tube, Multi Well, for Enterococcii
QA/QC Lower Range GRABSAMPLE: Field Methods for Sampling Fecal Indicator Bacteria **QA/QC Upper Range**
Characteristic SFAN_I&M: SFAN Long-Term Water Quality Monitoring Program
Defined Procedures, Configuration, && SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Analytical: Bacteria: Bacteriologic Analysis (B)

STORET Name: Suspended Sediment Concentration (SSC)**Local** SSC **Comp?** ✔
Sequence 128 **Sample** Total **Value** **Unit of** mg/l **Field/Lab:** Lab
MediumWater **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**
Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit
QA/QC Lower Range **QA/QC Upper Range**
Characteristic
Defined Procedures, Configuration, &&
Analytical: 2540-D: Total Suspended Solids in Water
Collection: DI_SAMPLE: Field and Laboratory Methods for Sediment
Laboratory: SEQ: Sequoia Analytical Laboratory
Projects: SFAN_I&M: SFAN Long-Term Water Quality Monitoring Program
SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Groups: Sediment: Sediment Analysis (S)

STORET Name: Total Suspended Solids (TSS) **Local** TSS **Comp?** ✔
Sequence 129 **Sample** Suspended **Value** Est **Unit of** mg/l **Field/Lab:** Lab
MediumWater **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**

Detection Limit: 0.5 **Lower Quant** 1.59 **Upper Quant**
Detection/Quantification Limit
QA/QC Lower Range **QA/QC Upper Range**
Characteristic
Defined Procedures, Configuration, &&
Analytical: 2540-D: Total Suspended Solids in Water
Collection: DI_SAMPLE: Field and Laboratory Methods for Sediment
Projects: SFAN_I&M: SFAN Long-Term Water Quality Monitoring Program
SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Groups: Sediment: Sediment Analysis (S)

STORET Name: Nitrogen, ammonia (NH3) as NH3 **Local** Ammonia as NH3 **Comp?** ✔
Sequence 130 **Sample** Total **Value** **Unit of** mg/l **Field/Lab:** Lab
Medium Water **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**

NPSTORET Characteristics

San Francisco Bay Area Network *Sorted by Sequence Number*

Detection Limit: 0.1 **Lower Quant** 0.318 **Upper Quant**
Detection/Quantification Limit 350.3: Ammonia Nitrogen Using an ISE
QA/QC Lower Range SFAN_SOP 7: Field Methods for Sampling Nutrients **QA/QC Upper Range**
Characteristic SFAN_I&M: SFAN Long-Term Water Quality Monitoring Program
Defined Procedures, Configuration, && SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Analytical: Nutrient: Nutrient Analysis (N)

STORET Name: Nitrogen, ammonia as N **Local** Ammonia as N
Comp? ✔
Sequence 131 **Sample** Total **Value** **Unit of** mg/l **Field/Lab:** Lab
MediumWater **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**
Detection Limit: 0.1 **Lower Quant** 0.318 **Upper Quant**
Detection/Quantification Limit
QA/QC Lower Range **QA/QC Upper Range**
Characteristic
Defined Procedures, Configuration, &&
Analytical: 350.3: Ammonia Nitrogen Using an ISE
Collection: SFAN_SOP 7: Field Methods for Sampling Nutrients
Projects: SFAN_I&M: SFAN Long-Term Water Quality Monitoring Program
SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Groups: Nutrient: Nutrient Analysis (N)

STORET Name: Ammonia, unionized **Local** UIA **Comp?**
✔
Sequence 132 **Sample** **Value** Cal **Unit of** mg/l **Field/Lab:** Lab
MediumWater **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**
Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit

QA/QC Lower Range **QA/QC Upper Range**
Characteristic Calculated from Total Ammonia (TAN) x a conversion factor (given by pH and Temp).
Defined Procedures, Configuration, &&

Collection: SFAN_SOP 7: Field Methods for Sampling Nutrients
Projects: SFAN_I&M: SFAN Long-Term Water Quality Monitoring Program
SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Groups: Nutrient: Nutrient Analysis (N)

STORET Name: Nitrogen, Nitrate (NO3) as NO3 **Local** Nitrate as NO3
Comp? ✔
Sequence 133 **Sample** Total **Value** **Unit of** mg/l **Field/Lab:** Lab
Medium Water **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**

NPSTORET Characteristics

San Francisco Bay Area Network *Sorted by Sequence Number*

Detection Limit: 0.01 **Lower Quant** 0.0318 **Upper Quant**
Detection/Quantification Limit 300(B): Inorganic Anions by Ion Chromatography
QA/QC Lower Range SFAN_SOP 7: Field Methods for Sampling Nutrients **QA/QC Upper Range**
Characteristic SFAN_I&M: SFAN Long-Term Water Quality Monitoring Program
Defined Procedures, Configuration, && SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Analytical: Nutrient: Nutrient Analysis (N)

STORET Name: Nitrogen, Nitrate (NO3) as N **Local** Nitrate as N
Comp? ✓
Sequence 134 **Sample** Total **Value** **Unit of** mg/l **Field/Lab:** Lab
Medium Water **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**
Detection Limit: 0.01 **Lower Quant** 0.0318 **Upper Quant**
Detection/Quantification Limit
QA/QC Lower Range **QA/QC Upper Range**
Characteristic
Defined Procedures, Configuration, &&
Analytical: 300(B): Inorganic Anions by Ion Chromatography
Collection: SFAN_SOP 7: Field Methods for Sampling Nutrients
Projects: SFAN_I&M: SFAN Long-Term Water Quality Monitoring Program
SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Groups: Nutrient: Nutrient Analysis (N)

STORET Name: Nitrogen, Nitrite (NO2) as NO2 **Local** Nitrite as NO2
Comp? ✓
Sequence 135 **Sample** **Value** **Unit of** mg/l **Field/Lab:** Lab
Medium Water **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**
Detection Limit: 0.01 **Lower Quant** 0.0318 **Upper Quant**

Detection/Quantification Limit
QA/QC Lower Range **QA/QC Upper Range**
Characteristic
Defined Procedures, Configuration, &&
Analytical: 4500-NO2(B): Nitrite in Water by Colorimetry
Collection: SFAN_SOP 7: Field Methods for Sampling Nutrients
Projects: SFAN_I&M: SFAN Long-Term Water Quality Monitoring Program
SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Groups: Nutrient: Nutrient Analysis (N)

STORET Name: Nitrogen, Nitrite (NO2) as N **Local** Nitrite as N
Comp? ✔
Sequence 136 **Sample** Total **Value** **Unit of** mg/l **Field/Lab:** Lab
Medium Water **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**

NPSTORET Characteristics

San Francisco Bay Area Network *Sorted by Sequence Number*

Detection Limit: 0.01 **Lower Quant** 0.0318 **Upper Quant**
Detection/Quantification Limit 4500-NO2(B): Nitrite in Water by Colorimetry
QA/QC Lower Range SFAN_SOP 7: Field Methods for Sampling Nutrients **QA/QC Upper Range**
Characteristic SFAN_I&M: SFAN Long-Term Water Quality Monitoring Program
Defined Procedures, Configuration, && SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Analytical: Nutrient: Nutrient Analysis (N)

STORET Name: Nitrogen, Kjeldahl **Local** TKN **Comp?** ✔
Sequence 137 **Sample** **Value** **Unit of** mg/l **Field/Lab:** Lab
MediumWater **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**
Detection Limit: 0.5 **Lower Quant** 1.59 **Upper Quant**
Detection/Quantification Limit
QA/QC Lower Range **QA/QC Upper Range**
Characteristic
Defined Procedures, Configuration, &&
Analytical: 4500-NOR(B): Total Kjeldahl Nitrogen in Water
Collection: SFAN_SOP 7: Field Methods for Sampling Nutrients
Projects: SFAN_I&M: SFAN Long-Term Water Quality Monitoring Program
SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Groups: Nutrient: Nutrient Analysis (N)

STORET Name: Phosphorus, orthophosphate as P **Local** Orthophosphate as P
Comp? ✔
Sequence 138 **Sample** **Value** **Unit of** mg/l **Field/Lab:** Lab
MediumWater **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**
Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit

QA/QC Lower Range **QA/QC Upper Range**
Characteristic
Defined Procedures, Configuration, &&

Collection: SFAN_SOP 7: Field Methods for Sampling Nutrients
Projects: SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Groups: Nutrient: Nutrient Analysis (N)

STORET Name: Phosphorus, phosphate (PO4) as PO4 **Local** Phosphate as PO4 **Comp?** ✔
Sequence 139 **Sample** **Value** **Unit of** mg/l **Field/Lab:** Lab
Medium Water **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**

NPSTORET Characteristics

San Francisco Bay Area Network *Sorted by Sequence Number*

Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit
QA/QC Lower Range SFAN_SOP 7: Field Methods for Sampling Nutrients **QA/QC Upper Range**
Characteristic SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Defined Procedures, Configuration, && Nutrient: Nutrient Analysis (N)

STORET Name: Phosphorus **Local** Total Phosphorus **Comp?** ✔
Sequence 140 **Sample** **Value** **Unit of** mg/l **Field/Lab:** Lab
Medium Water **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**
Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit
QA/QC Lower Range **QA/QC Upper Range**
Characteristic
Defined Procedures, Configuration, &&
Analytical: 365.2: Phosphorus by Single Reagent Colorimetry
Collection: SFAN_SOP 7: Field Methods for Sampling Nutrients
Projects: SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Groups: Nutrient: Nutrient Analysis (N)

STORET Name: pH **Local** Lab pH **Comp?** ✔
Sequence 141 **Sample** **Value** **Unit of** None **Field/Lab:** Lab
Medium Water **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**
Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit
QA/QC Lower Range **QA/QC Upper Range**
Characteristic
Defined Procedures, Configuration, &&

Analytical: 150.1: pH
Collection: SFAN_SOP 7: Field Methods for Sampling Nutrients
Projects: SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Groups:

STORET Name: MBAS (detergents, surfactants) **Local** MBAS **Comp?** ✔
Sequence 142 **Sample** Total **Value** **Unit of** mg/l **Field/Lab:** Lab
Medium Water **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**

NPSTORET Characteristics

San Francisco Bay Area Network *Sorted by Sequence Number*

Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit 425.1: Methylene Blue Active Substances
QA/QC Lower Range SFAN_SOP 7: Field Methods for Sampling Nutrients **QA/QC Upper Range**
Characteristic SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Defined Procedures, Configuration, &&

STORET Name: Gage height **Local** Datalogger Gage Ht
Comp? ✔
Sequence 143 **Sample** **Value** **Unit of** ft **Field/Lab:** Field
Medium Water **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**
Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit
QA/QC Lower Range **QA/QC Upper Range**
Characteristic Recorded gage height from in-stream permanent pressure transducer.
Defined Procedures, Configuration, &&

Projects: SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Groups:

STORET Name: Flow **Local** Datalogger Discharge
Comp? ✔
Sequence 144 **Sample** **Value** **Unit of** cfs **Field/Lab:** Field
Medium Water **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**
Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit
QA/QC Lower Range **QA/QC Upper Range**
Characteristic Calculated discharge from datalogger gage height and stream's rating curve.

Defined Procedures, Configuration, &&

Analytical: FLOW FROM GAGE: Discharge from automatic gage and rating curve

Projects: SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol

Groups:

STORET Name: Copper **Local** Total Copper **Comp?**

Sequence 145 **Sample** Total **Value** **Unit of** ug/l **Field/Lab:** Lab

Medium Water **Statistic Type:** **Duration:**

Weight Basis: **Part. Size Basis:** **Temp. Basis:**

NPSTORET Characteristics

San Francisco Bay Area Network *Sorted by Sequence Number*

Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit 200.8(W): Metals in Waters by ICP/MS
QA/QC Lower Range SFAN_SOP 7: Field Methods for Sampling Nutrients **QA/QC Upper Range**
Characteristic SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Defined Procedures, Configuration, && Metals: Metals

STORET Name: Chlorophyll a, uncorrected for pheophytin **Local** Chlorophyll a
Comp? ✔
Sequence 146 **Sample** **Value** **Unit of** ug/l **Field/Lab:** Lab
Medium Water **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**
Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit
QA/QC Lower Range **QA/QC Upper Range**
Characteristic
Defined Procedures, Configuration, &&
Analytical: 10200-H: Chlorophyll a-b-c Determination
Collection: SFAN_SOP 7: Field Methods for Sampling Nutrients
Projects: SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Groups: Nutrient: Nutrient Analysis (N)

STORET Name: Alkalinity, Carbonate as CaCO3 **Local** Carbonate alkalinity
Comp? ✔
Sequence 147 **Sample** **Value** **Unit of** ug/l **Field/Lab:** Lab
Medium Water **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**
Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit
QA/QC Lower Range **QA/QC Upper Range**

Characteristic
Defined Procedures, Configuration, &&
Analytical: 310.1: Alkalinity by Titration
Collection: SFAN_SOP 7: Field Methods for Sampling Nutrients
Projects: SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Groups:

STORET Name: Alkalinity, Bicarbonate as CaCO3 **Local** Bicarbonate
Comp? ✔
Sequence 148 **Sample** **Value** **Unit of** mg/l **Field/Lab:** Lab
Medium Water **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**

NPSTORET Characteristics

San Francisco Bay Area Network *Sorted by Sequence Number*

Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit 310.1: Alkalinity by Titration
QA/QC Lower Range SFAN_SOP 7: Field Methods for Sampling Nutrients **QA/QC Upper Range**
Characteristic SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Defined Procedures, Configuration, &&

STORET Name: Alkalinity, Total (total hydroxide+carbonate+bicarbonate) **Local** Total Alkalinity **Comp?** ✔
Sequence 149 **Sample** **Value** **Unit of** mg/l **Field/Lab:** Lab
Medium Water **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**
Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit
QA/QC Lower Range **QA/QC Upper Range**
Characteristic
Defined Procedures, Configuration, &&
Analytical: 310.1: Alkalinity by Titration
Collection: SFAN_SOP 7: Field Methods for Sampling Nutrients
Projects: SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Groups:

STORET Name: Hardness, carbonate **Local** Hardness **Comp?** ✔
Sequence 150 **Sample** **Value** **Unit of** mg/l **Field/Lab:** Lab
Medium Water **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**
Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit
QA/QC Lower Range **QA/QC Upper Range**

Characteristic
Defined Procedures, Configuration, &&
Analytical: 2340: Hardness in Water by EDTA Titration
Collection: SFAN_SOP 7: Field Methods for Sampling Nutrients
Projects: SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Groups:

STORET Name: Solids, Dissolved **Local** TDS **Comp?**
✔
Sequence 151 **Sample** **Value** **Unit of** mg/l **Field/Lab:** Lab
Medium Water **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**

NPSTORET Characteristics

San Francisco Bay Area Network *Sorted by Sequence Number*

Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit 160.1: Filterable Residue - TDS
QA/QC Lower Range SFAN_SOP 7: Field Methods for Sampling Nutrients **QA/QC Upper Range**
Characteristic SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Defined Procedures, Configuration, &&

STORET Name: Chloride **Local** Chloride **Comp?** ✔
Sequence 152 **Sample** Total **Value** **Unit of** mg/l **Field/Lab:** Lab
MediumWater **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**
Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit
QA/QC Lower Range **QA/QC Upper Range**
Characteristic
Defined Procedures, Configuration, &&

Collection: SFAN_SOP 7: Field Methods for Sampling Nutrients
Projects: SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Groups:

STORET Name: Sulfur, sulfate (SO4) as SO4 **Local** Sulfate as SO4
Comp? ✔
Sequence 153 **Sample** Total **Value** **Unit of** mg/l **Field/Lab:** Lab
MediumWater **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**
Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit
QA/QC Lower Range **QA/QC Upper Range**
Characteristic

Defined Procedures, Configuration, &&

Analytical: 300(B): Inorganic Anions by Ion Chromatography
Collection: SFAN_SOP 7: Field Methods for Sampling Nutrients
Projects: SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Groups: Nutrient: Nutrient Analysis (N)

STORET Name: Fluorides **Local** Fluoride as F **Comp?**

Sequence 154 **Sample** Total **Value** **Unit of** mg/l **Field/Lab:** Lab
Medium Water **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**

NPSTORET Characteristics

San Francisco Bay Area Network *Sorted by Sequence Number*

Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit 300(B): Inorganic Anions by Ion Chromatography
QA/QC Lower Range SFAN_SOP 7: Field Methods for Sampling Nutrients **QA/QC Upper Range**
Characteristic SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Defined Procedures, Configuration, && Nutrient: Nutrient Analysis (N)

STORET Name: Calcium **Local** Calcium **Comp?** ✔
Sequence 155 **Sample** Total **Value** **Unit of** mg/l **Field/Lab:** Lab
MediumWater **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**
Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit
QA/QC Lower Range **QA/QC Upper Range**
Characteristic
Defined Procedures, Configuration, &&
Analytical: 200.7_M: ICP-AES For Trace Element Analysis
Collection: SFAN_SOP 7: Field Methods for Sampling Nutrients
Projects: SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Groups: Nutrient: Nutrient Analysis (N)

STORET Name: Magnesium **Local** Magnesium **Comp?** ✔
Sequence 156 **Sample** Total **Value** **Unit of** mg/l **Field/Lab:** Lab
MediumWater **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**
Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit
QA/QC Lower Range **QA/QC Upper Range**
Characteristic
Defined Procedures, Configuration, &&

Analytical: 200.7_M: ICP-AES For Trace Element Analysis
Collection: SFAN_SOP 7: Field Methods for Sampling Nutrients
Projects: SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Groups: Nutrient: Nutrient Analysis (N)

STORET Name: Potassium **Local** Potassium **Comp?** ✔
Sequence 157 **Sample** **Value** **Unit of** mg/l **Field/Lab:** Lab
Medium Water **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**

NPSTORET Characteristics

San Francisco Bay Area Network *Sorted by Sequence Number*

Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit 200.7_M: ICP-AES For Trace Element Analysis
QA/QC Lower Range SFAN_SOP 7: Field Methods for Sampling Nutrients **QA/QC Upper Range**
Characteristic SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Defined Procedures, Configuration, && Nutrient: Nutrient Analysis (N)

STORET Name: Sodium **Local** Sodium **Comp?** ✔
Sequence 158 **Sample** Total **Value** **Unit of** mg/l **Field/Lab:** Lab
Medium Water **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**
Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit
QA/QC Lower Range **QA/QC Upper Range**
Characteristic
Defined Procedures, Configuration, &&
Analytical: 200.7_M: ICP-AES For Trace Element Analysis
Collection: SFAN_SOP 7: Field Methods for Sampling Nutrients
Projects: SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Groups:

STORET Name: Iron **Local** Iron **Comp?** ✔
Sequence 159 **Sample** Total **Value** **Unit of** mg/l **Field/Lab:** Lab
Medium Water **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**
Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit
QA/QC Lower Range **QA/QC Upper Range**
Characteristic
Defined Procedures, Configuration, &&

Analytical: 200.7_M: ICP-AES For Trace Element Analysis
Collection: SFAN_SOP 7: Field Methods for Sampling Nutrients
Projects: SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Groups: Metals: Metals

STORET Name: Manganese **Local** Manganese **Comp?**
✔
Sequence 160 **Sample** Total **Value** **Unit of** mg/l **Field/Lab:** Lab
Medium Water **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**

NPSTORET Characteristics

San Francisco Bay Area Network ***Sorted by Sequence Number***

Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit 200.7_M: ICP-AES For Trace Element Analysis
QA/QC Lower Range SFAN_SOP 7: Field Methods for Sampling Nutrients **QA/QC Upper Range**
Characteristic SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Defined Procedures, Configuration, &&

STORET Name: Gold **Local** Gold**Comp?** ✔
Sequence 161 **Sample** Total **Value** **Unit of** ug/l **Field/Lab:** Lab
MediumWater **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**
Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit
QA/QC Lower Range **QA/QC Upper Range**
Characteristic
Defined Procedures, Configuration, &&
Analytical: 200.7(W): Metals in Water by ICP-AES
Collection: SFAN_SOP 7: Field Methods for Sampling Nutrients
Projects: SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Groups: Metals: Metals

STORET Name: Lead **Local** Lead**Comp?** ✔
Sequence 162 **Sample** Total **Value** **Unit of** ug/l **Field/Lab:** Lab
MediumWater **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**
Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit
QA/QC Lower Range **QA/QC Upper Range**
Characteristic
Defined Procedures, Configuration, &&

Analytical: 200.8(W): Metals in Waters by ICP/MS
Collection: SFAN_SOP 7: Field Methods for Sampling Nutrients
Projects: SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Groups: Metals: Metals

STORET Name: Zinc **Local** Zinc **Comp?** ✔
Sequence 163 **Sample** **Value** **Unit of** ug/l **Field/Lab:** Lab
Medium Water **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**

NPSTORET Characteristics

San Francisco Bay Area Network *Sorted by Sequence Number*

Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit 200.7(W): Metals in Water by ICP-AES
QA/QC Lower Range SFAN_SOP 7: Field Methods for Sampling Nutrients **QA/QC Upper Range**
Characteristic SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Defined Procedures, Configuration, && Metals: Metals

STORET Name: Antimony **Local** Antimony **Comp?** ✔
Sequence 164 **Sample** Total **Value** **Unit of** ug/l **Field/Lab:** Lab
Medium Water **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**
Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit
QA/QC Lower Range **QA/QC Upper Range**
Characteristic
Defined Procedures, Configuration, &&
Analytical: 200.8(W): Metals in Waters by ICP/MS
Collection: SFAN_SOP 7: Field Methods for Sampling Nutrients
Projects: SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Groups: Metals: Metals

STORET Name: Nickel **Local** Nickel **Comp?** ✔
Sequence 165 **Sample** Total **Value** **Unit of** ug/l **Field/Lab:** Lab
Medium Water **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**
Detection Limit: **Lower Quant** **Upper Quant**
Detection/Quantification Limit
QA/QC Lower Range **QA/QC Upper Range**
Characteristic
Defined Procedures, Configuration, &&

Analytical: 200.7(W): Metals in Water by ICP-AES
Collection: SFAN_SOP 7: Field Methods for Sampling Nutrients
Projects: SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol
Groups: Metals: Metals

STORET Name: Barium **Local** Barium **Comp?** ✔
Sequence 166 **Sample** Total **Value** **Unit of** ug/l **Field/Lab:** Lab
Medium Water **Statistic Type:** **Duration:**
Weight Basis: **Part. Size Basis:** **Temp. Basis:**

NPSTORET Characteristics

San Francisco Bay Area Network *Sorted by Sequence Number*

Detection Limit: **Lower Quant** **Upper Quant**

Detection/Quantification Limit 200.8(W): Metals in Waters by ICP/MS

QA/QC Lower Range SFAN_SOP 7: Field Methods for Sampling Nutrients **QA/QC Upper Range**

Characteristic SFAN_WQ: SFAN pilot monitoring for Freshwater Quality Protocol

Defined Procedures, Configuration, && Metals: Metals

Number of Complete Characteristics: 98
Number of Incomplete Characteristics: 0

Appendix H Standard Operating Procedures

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Appendix H Standard Operating Procedures

SOP #1 Protocol Revision and Review

1.1 Revision History Log

Prev. Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
	Jan. 2005	Mary Cooprider	Created SOP to document protocol revision procedures	Addressing comments by WRD	1.0
1.0	8-24-2006	Rob Carson	Added revision history table, and section containing protocol review comments, responses and approvals	Suggested by peer review	1.1

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.

1.2 Scope and Application

This Standard Operating Procedure explains how to make changes to the Freshwater Quality Protocol Narrative and accompanying SOPs, and explains procedures for tracking these changes. SFAN or park staffs editing the Protocol Narrative or any SOP need to follow this procedure to eliminate confusion in data collection and analysis methods. All SFAN aquatic resources staff should be familiar with this SOP in order to identify and use the most current methodologies. This SOP is adapted from the Bird Monitoring Protocol SOP #11 for Agate Fossil Beds National Monument, Nebraska and Tallgrass Prairie National Preserve, Kansas (Peitz et al., 2002). Their protocol can be accessed at http://science.nature.nps.gov/im/monitor/protocols/birds.htm

This SOP also contains a Table 1.1 listing the most current version of the protocol narrative and each of the SOP's. This will provide a single reference for ensuring that the most current documents are being used. Also included is a section containing comments from protocol review, responses to those comments and approvals.

Table 1.1 Current SFAN Freshwater Quality Protocol Documents.

Document Name	Current Version	Version Date	Author
San Francisco Bay Area Network Freshwater Quality Monitoring Protocol, Protocol Narrative	2.11	10/12/06	Cooprider, M. and Carson, R.
SOP#1: Protocol Revision and Review	1.1	8/25/06	Cooprider, M. and Carson, R.
SOP#2: Personnel Training and Safety	1.02	6/22/06	Cooprider, M. and Carson, R.
SOP#3: Equipment and Field Preparations	1.03	8/1/06	Cooprider, M. and Carson, R.
SOP#4: Quality Assurance Project Plan (QAPP)	2.04	10/13/06	Cooprider, M. and Carson, R.
SOP#5: Field Methods for Measurement of Core Parameters	1.03	8/1/06	Cooprider, M. and Carson, R.
SOP#6: Field and Laboratory Methods for Fecal Indicator Bacteria	1.1	8/11/06	Cooprider, M. and Carson, R.
SOP#7: Field Methods for Sampling Nutrients	1.02	3/16/06	Cooprider, M. and Carson, R.
SOP#8: Field and Laboratory Methods for Sediment	1.02	3/23/06	Cooprider, M. and Carson, R.
SOP#9: Field Methods for Measuring Stream Discharge	1.02	3/9/06	Cooprider, M. and Carson, R.
SOP#10: Data Analysis	1.03	9/28/06	Cooprider, M. and Carson, R.
SOP#11: Data Reporting	1.02	3/23/06	Cooprider, M. and Carson, R.
SOP#12: Site Selection and Documentation	1.01	3/9/06	Cooprider, M. and Carson, R.

1.3 Protocol Revision Procedures

1. The Freshwater Quality Monitoring Protocol Narrative and accompanying SOPs has made every effort to incorporate the most sound methodologies for collecting and analyzing water quality data. However, all protocols require editing as new and different sample collection, analysis, and data management information becomes available. Required edits should be made as soon as they are deemed necessary and appropriate reviews conducted.

2. All edits will be reviewed for grammatical and technical accuracy and overall clarity. Minor changes or additions to existing methods will be reviewed "in-house" by the SFAN aquatic professionals' team and other appropriate network staff. However, if a complete change in methods is anticipated, then an outside review is required. Regional (Pacific West Region) and National staff (Water Resources Division) of the National Park Service familiar with water quality monitoring and data analysis will be utilized as reviewers. Also, local and state experts in water quality monitoring and statistical methodologies outside of the Park Service will be utilized in the review process. A group of technical experts was utilized for the external peer review of the initial Freshwater Quality Protocol; these individuals would be called upon again to provide input related to any significant revisions in methodology.

3. Edits and protocol revisions will be documented in the Revision History Log that accompanies the Protocol Narrative and each SOP. Only changes in the Protocol Narrative or specific SOP that has been edited will be logged. "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).

4. 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.

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

6. When any significant changes in the sampling protocol occur such as changes in sample collection techniques or equipment, a change in analytical laboratory, or changes in staff, there should be an "overlap" of methods and personnel (Oakley et al., 2003). This requires using both the old and new techniques on a given sample as well as having both the outgoing and new staff sample concurrently. The National Park Service Water Resources Division (NPS-WRD) recommends an overlap of at least seven sampling events (Irwin, 2005).

1.4 Protocol Review

1.4.1 Reviewer Comments

Appendix A contains the PWR Protocol Review Checklist generated by the formal peer review process. Also included in this appendix are the consolidated comments and responses from formal peer review.

1.5 References

Irwin, R. 2005. Personal Communication. National Park Service, Water Resources Division, Fort Collins, Colorado.

Peitz, D.G., S. G. Fancy, L. P. Thomas, and B. Witcher. 2002. Bird monitoring protocol for Agate Fossil Beds National Monument, Nebraska and Tallgrass Prairie National Preserve, Kansas. Prairie Cluster prototype monitoring program. Version 1.00, September 6, 2002.

Oakley, K.L, L.P. Thomas, and S.G. Fancy. 2003. *Monitoring Protocol Guidelines*. Wildlife Society Bulletin 31(4): 1000-1003.

SOP #2 Personnel Training and Safety

2.1 Revision History Log

Prev. Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.0	8/05/05	M. Cooprider	Minor edits	Preparation for formal peer review	1.01
1.01	6/22/06	R. Carson	Revised JHA	Prev. version had GOGA Aquatic Ecol. JHA	1.02

Only changes in this specific SOP will be logged here. "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).

2.2 Acknowledgements

The USGS National Field Manual Chapter 9 (Safety) was used extensively (Lane and Fay 1997) during the writing of this protocol. In addition, the Job Hazard Analysis (JHA) from Golden Gate National Recreation Area (Fong et al., 2003) was followed for safety hazards specific to aquatic projects in the Coastal California Mediterranean climate. The Greater Yellowstone Network's Safety and Health SOP (O'Ney 2005) for their long-term water quality monitoring plan was also reviewed for ideas on format and content. The SFAN Water Quality Monitoring Program acknowledges the individuals involved in writing and researching these documents.

2.3 Scope and Application

Safety and training are included together in a single SOP because they are closely linked. Training for water quality sampling is much more than learning proper equipment use and sampling techniques. Safety and QA/QC are significant components of a long-term water quality monitoring plan. Many safety issues are associated with implementing a long-term water quality monitoring plan that includes extensive field work across multiple parks, with multiple staff in varying environmental conditions. Thorough planning is required to ensure that training and safety requirements are met and that the safety of field personnel is not compromised.

2.4 Training

2.4.1 Introduction

NPS staff collecting all water quality data and downloading continuous loggers and have either already been trained by other NPS staff or will be trained before plan implementation. Scientists

at PORE and GOGA have been conducting water quality related activities for several years and can provide training if necessary to network staff. Current network staff are trained in water quality procedures and can learn additional methods (e.g., use of Hydrolab mini-sondes for continuous measurement) from GOGA and PORE staff.

All technical staff involved in data collection will have education background in biological or physical sciences. The Network Water Quality Specialist (Program Lead) will have specialized experience in water quality or closely related aquatic resource. Where necessary (e.g., with staff turnover, adoption of new methods, etc.) local technical experts (universities/agencies) will be called upon for training assistance. Familiarity with GPS navigation will also be a qualification (or training will be provided). First Aid and CPR training are highly recommended. Boater certification will not be needed at this time. Field personnel (network hydrologic technician) will receive training in a variety of discharge (flow) measurement methods (e.g., low flow, high flow bridge-deployed).

Field personnel (Network Hydrologic Technician and other SFAN staff (biological technician/park Americorps crews)) will be evaluated on their field performance during field QA audits conducted by the SFAN Water Quality Specialist, other park aquatic professionals. Field performance audits are recommended every two years, or more often if necessary. If any deficiencies within a crew are noted during this QA audit, they will be documented and remedied prior to continued field sampling. This can be accomplished by additional training or by changing personnel, but verification of correction of any deficiencies must be documented in writing prior to the resumption of further sample collection activities.

2.4.2 Procedures

1. At least two network or park individuals will be trained in equipment use and sampling techniques, and QA/QC measures. 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 and it is recommended at other times as well.

2. Staff will be trained through review of written guidance plus a series of 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 (see SOP #4 – QA/QC SOP). The second sampling events or group of sites will give the trainees an opportunity to sample with guidance. The trainer (Network Physical Scientist) will periodically accompany the recently trained individuals to ensure that the protocol continues to be followed and to address any questions.

3. Ensure that all field personnel obtain First Aid and CPR training. This is also highly recommended for office personnel.

4. Supervisory staff should ensure that all field staff are well trained in the safety guidelines and policies outlined below.

2.5 Safety

2.5.1 Introduction

Safety is "the condition of averting or not causing injury, danger, or loss" (Lane and Fay, 1997). As a Federal employee, you are required to know and follow safety policies and requirements. The USGS National Field Manual (NFM) provides background information on safety policies from the Department of Interior (DOI), the Occupational Safety and Hazard Act (OSHA), the Environmental Protection Agency (EPA), and the Department of Transportation (DOT). The USGS National Field Manual extensively covers all of the topics below:

→Safety Policies, Regulations, and Requirements
→Field trip preparations and emergency contacts*
→Transportation*
→Surface water activities*
→Groundwater activities
→Chemicals*
→Contaminated Water*
→Environmental Conditions*
→Animals*
→Plants *
→Checklist of Safety Equipment*

The asterisk (*) denote topics that are covered here since they are most pertinent to the current SFAN water quality monitoring protocol. This SOP will also individually address potential safety hazards by focusing on an existing Job Hazard Analysis created for the aquatics program at GOGA. Consult the NFM at http://water.usgs.gov/owq/FieldManual/Chap9/content.html for complete recommended safety procedures. This document is included in the appendices and should be readily available as a reference in the field.

Plants
The USGS National Field Manual, Chapter 9 provides a thorough summary of field hazards. Some of the most common health hazards within SFAN include poison oak and stinging nettle. The safety briefing "Working in Poison Oak" (Brands-Maloney, 2001) provides an extensive review of poison oak identification, location, prevention, and treatment of contact dermatitis and is included in the appendix. Field personnel should review this BEFORE entering the field. Be familiar with the shape, color, and size of poison oak leaves twigs, vines, and, yes, shrubs. Stinging nettle is not a health threat but causes skin irritation which can be severe (though temporary) if in large amounts.

Animals and disease vectors
Although rare, large predators such as mountain lions inhabit some of the areas within the parks. Though some of these hazards are rare, it is important to be aware of all of them. Rattlesnakes may also occur but rarely near riparian areas where sampling will occur. Local information about ticks and Lyme disease is also included in the appendix. West Nile Virus, a more recent concern, is transmitted by mosquitoes. Though not a major threat, it is important to be aware of this virus. Only a few species of mosquitoes carry the virus and fewer are infected. Another issue to be aware of is Hantavirus which is spread through rodent feces and normally a concern indoors, or garages, or other areas where equipment may be stored. As with all hazards, consult the USGS National Field Manual for details.

Inclement Weather and Surface Water Activities
Sampling during storm events is of particular concern in Mediterranean climates. Most, if not all, of the streams in the SFAN are "flashy", meaning that water level rises 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. Do not attempt to wade in a stream for which values of depth multiplied by velocity are greater than or equal to 10 ft^2/s. During high flows use of a wading belt is recommended to avoid the waders filling with water. Any time chest waders are worn, a life jacket is required.

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. 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. A good summary of these hazards is provided in the Job Hazard Analysis (JHA) for Aquatic Projects (Fong et al, 2003) in the Appendix.

Contaminated Water
Waterborne pathogens include typhoid, tetanus, hepatitis, polio, and rabies. Excess quantities of E. coli can cause gastrointestinal problems but are usually less severe than the previously mentioned pathogens. Never drink water straight from a creek. Water being sampled may be contaminated with pathogens or harmful chemicals. Use extra precautions when working with water that is known to be contaminated. Some precautions include not eating or drinking while sampling and not putting objects such as pencils in your mouth. In particular, keep hands away from nose, ears and mouth (this also helps reduce spreading of poison oak). Wash hands thoroughly before eating. If no soap and water are available, use of an antibacterial hand cleanser is highly recommended.

Chemicals
Some potentially hazardous chemicals are required for cleaning of water quality instruments. Chemicals become hazardous when they are used improperly or care is not taken. Know the location of Materials Safety Data Sheets (MSDS) and consult these BEFORE using any chemical. Also, know the storage requirements and proper location for the chemical.

Transportation
Safety considerations for vehicles used to reach sampling sites are covered in the attached JHA. Most of us drive a vehicle regularly and may not always think about the hazards associated with it. It is very important to inspect the vehicle before leaving. Ensure that safety equipment is in the vehicle. During driving to and from sampling areas it is particularly important to consider issues such as nighttime driving and fatigue, storms, road flooding, driving in (initially) unfamiliar areas and remote areas where large animals may be crossing the road. Additional details regarding transportation safety procedures and policies are listed in the USGS National Field Manual.

Environmental Hazards and General Emergency Information
Individual parks have occupant emergency plans which cover safety procedures for medical emergencies, earthquakes, floods, fires, bomb threats. Be familiar with the procedures and emergency contact numbers of your duty station park as well as other parks you may visit during field sampling activities. Overall, be aware of your environment, use common sense, do not exceed your limits (for example, operation of equipment; lifting heavy objects and equipment; physical tolerance to exertion, heat, and cold), and trust your instincts (Lane and Fay, 1997).

2.5.2 Procedures for Safety Preparation

Adapted from the California Water Resources Control Board Surface Water Ambient Monitoring Program (SWAMP) Appendix H of the Quality Assurance Management Plan (Puckett, 2002).

Basic planning is required before each field sampling event. A large component of the planning effort involves gathering safety information and documenting all aspects of field sampling trip plans. A trip plan should be completed. One copy should be left at the office and additional copies should be given to field personnel involved in the trip. The trip plan should contain the following information:

- Destination information (parks, streams/sites)
- Field trip participants including guests and observers along with emergency contact information for each
- Estimated departure and return times and dates
- Lodging information and contact phone numbers when traveling overnight
- Vehicle information (make and model of vehicle to be used)
- Phone numbers for mobile phones or park radio frequencies
- Contact number of staff at destination park (if applicable)
- Dispatch phone numbers for each park

The trip plan is a valuable tool in the overall trip planning process. In addition, the plan provides valuable information for other staff not participating in the trip (who may assist you should an emergency occur). Other safety preparations include:

- Check the weather and be aware of changing weather conditions and potential for storms, floods and landslides.

- ♦Carry basic safety equipment (first aid kit, flashlight, boots, rain gear, and antibacterial hand cleanser)
- ♦Carry the USGS NFM Ch.A9, basic first aid protocols, emergency phone numbers and Material Safety Data Sheets (if applicable)
- ♦Collect and update emergency contact information prior to the field season
- ♦Consult the safety checklist in this SOP as well as the equipment checklist in SOP #3 before each sampling event
- ♦Note and discuss potential hazards at each site with field staff

Requirements for All Field Personnel:

1. At least two network or park individuals will be trained and introduced to all potential safety hazards. This will help ensure continuity should one person leave a position or otherwise not be available for a particular sampling event.
2. It will be mandatory that two field staff be present for sampling during the winter (high flows) and it is highly recommended at other times as well.
3. Staff will review the attached Job Hazard Analysis (JHA) adapted from the GOGA JHA for Aquatic surveys and projects. The USGS National Field Manual will be available for, and reviewed by, all staff.
4. A tetanus shot is required for field personnel.
5. As indicated in the training section, all field personnel should be certified in CPR and First Aid.

2.5.3 Forms

Complete for each park:

2.5.3.1 Emergency Contact Form (from USGS National Field Manual, Ch. A 9)

Personal contacts

Name: Phone: (home) (work) _____

Name: Phone: (home) (work) _____

SFAN contacts

Golden Gate National Recreation Area _____

John Muir National Historic Site _____

Pinnacles National Monument _____

Point Reyes National Seashore _____

Local emergency contacts (or call 911)

Hospital Phone: _____

Address: _____

Other medical facility (24-hour care) Phone: _____

Address: _____

Police_____

Fire_____

Utility_____

Health Information Centers

Center for Disease Control_____

Information Hotline: _____

Fax: Disease Directory: _____

Other_____

_____

2.5.3.2 Medical Information form for Office Personnel (USGS National Field Manual, Ch. A9)

Medical Information for Office Personnel

Employee name: _____ Home phone: _____

Treatment preference: medical _____ other (specify) _____

Doctor: _____ Phone: _____

Other emergency contact: _____ Phone: _____

Allergies and other medical conditions	Medications being taken	Medications to avoid

Relevant medical history:

Allergies and other medical conditions:

Special instructions:

Figure 9-2. Example of medical information form to be completed and taken on field trips.

2.5.4 Checklists for Standard Safety Equipment

Checklists are helpful for ensuring that personnel have the appropriate safety equipment available during field trips. Each study team needs to consider the specific needs for their work and should customize these checklists as necessary.

2.5.4.1 Safety Equipment Checklists

Check	Item
√	**Climatic and UV protection, etc.**
	Boots
	Fluids (for example, water and sports drinks)
	Hat, wide-brimmed
	Insect repellent (unscented)
	Rain gear
	Sunglasses
	Sunscreen
	Antibacterial soap or hand lotion
	Temperature-modifying clothing

2.5.4.2 Items for Vehicles

Check	Item
√	**Flotation and reflective protection**
	Orange flotation vests and jackets
	Safety harness
√	**Chemical protection and storage**
	Chemical spill kit
	Eye wash kit (replace old or expired wash solution)
	Material Safety Data Sheets (MSDS)
	Chemical reagents (stored in appropriate area)
	Flammable solvents (stored in appropriate dedicated area)
	Pressurized gases (stored in appropriate area)
√	**Communications and instructions**
	Field folder (including maps, emergency phone numbers for medical facilities, office contacts, family contacts)
	Cellular phone/communication equipment (check that the service is operational for the area to be traveled)
√	**First aid and protective equipment**
	Complete change of clothes (stored in dry area)
	Fire extinguisher (safely secured)
	First aid kit and manual (check for missing or old, expired items and replace if necessary)
	Orange reflective vest
√	**Miscellaneous equipment**
	Bungee cords (to secure loose articles)
	District flood plan (most current version)
	Flagging
	Flares
	Flashlight (including fresh batteries)
	Flexible hose (to vent exhaust away from vehicle)
	Safety cones
	Tool kit
	U.S. Geological Survey TWRI Book 9 Chapter A9.

2.6 References

Brands-Maloney, C. 2001. Working in Poison Oak. Point Reyes National Seashore Safety Briefing. U.S. Department of Interior, National Park Service.

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SOP #2 Appendix A Job Hazard Analysis for Aquatic Surveys and Projects

Note: not all hazards apply to water quality monitoring

Job Hazard Analysis
I&M/PORE – Water Quality

U.S. Department of Interior National Park Service	WORK PROJECT/ACTIVITY **Water Quality Sampling and Projects**	LOCATION **San Francisco Bay Area Network (SFAN) Point Reyes NS (PORE)**	UNIT **Nat'l Resource Mngt and Science**
JOB HAZARD ANALYSIS (JHA) Adapted from Aquatic surveys and projects JHA developed by Darren Fong (GOGA) and Baker Holden III and David Anderson (REDW)	DEVELOPED BY **Rob Carson (SFAN – PORE)**	JOB TITLE **Water Quality Specialist**	DATE PREPARED **Revised 14 July 2006**

APPROVED BY: DATE:

Required and/or Recommended Personal Protective Equipment:

Sturdy work boots	Life Preserver
Warm clothing / hat	Felt sole waders (chest, hip, neoprene)
Sun hat	Felt sole wading boots
Sun glasses	Cotton gloves / wool gloves
Sunscreen	
Personal water bottles	Latex gloves
First Aid Kit	Survivor kit
Park radio	Polarized sunglasses
Technu (poison oak cleanser)	Maps
Forceps / vial	
Safety glasses	

TASKS/PROCEDURES	HAZARDS	ABATEMENT ACTIONS Engineering Controls*Substitution*Administrative Controls* Personal Protection Equipment
All Tasks and Procedures	**Unfamiliarity**	**All people (permanent, seasonal, VIPs) involved in any project should receive a general orientation and tailgate safety session specific to the task prior to beginning of work.**

1. Driving to and from remote field sites.	1a. Narrow, single-lane roads with bumpy or "washboard" surfaces;	WEAR SEATBELTS AT ALL TIMES WHEN VEHICLE IS MOVING 1a. Maintain a safe speed (this if often below the legal speed limit) for the road conditions; stay clear to the right, especially on curves, *drive with headlights on at all times*; when turning around on mountain roads always "face the danger" (versus backing toward the cliff edge, e.g.); the passenger should get out and spot for driver when backing up;
	1b. Driving with limited visibility;	1b. Maintain windshield cleaner fluid level and clean both sides of windows regularly (remember back window); *slow down*; if blinded by sun or dust, proceed slowly or pullover and wait for hazard to pass; keep to the right hand side of the road and drive with your *lights on*;
	1c. Sharp rocks on edge or in middle of road;	1c. Get out and move sharp rocks out of the way, reduce speed substantially in places with large amounts of rock fall; make sure tires are properly inflated and check tread and walls regularly for damage; make sure tire jack fits the vehicle and all parts are in the vehicle;
	1d. Large animals crossing or standing in roads (including park bypass);	1d. Slow down where animals might be present to allow for reaction time; do not swerve abruptly to avoid hitting an animal, if necessary it's better to ride out the impact;
	1f. Fatigue at night and after a long shift in the field;	1f. Be aware of signs of fatigue- pull over and rest! Take a short catnap or eat a snack or have a partner drive; do not take chances by continuing to drive; communicate with your field partner;
	1g. Storm conditions – wind, lightning, muddy/ slippery roads;	1g. Keep informed on the current weather- check www.weather.com or www.wrh.noaa.gov; if winds exceed 15 mph, or the excessive wind category on Beaufort scale (tree tops swaying, twigs and leaves falling, etc.), do not travel into the field; avoid going to the field if lightning is present and avoid using radios; drive slowly when roads are muddy and slippery or snow covered, check with geologists if you are uncertain of back road conditions; avoid wet clay roads as much as possible, these roads can fail after storms, especially in spring, *maintain a slow speed when driving on these roads!;* if you damage waterbars make sure you repair them immediately;
	1h. Fallen trees on road;	1h. For small trees, try and remove tree or cut with a handsaw and remove portion of tree; for large trees, notify support crew to remove tree;
	1i. Others driving on the road;	1i. Do not assume you are the only one on the road behind locked gates (day or night), people from other agencies use these roads; be alert to the idea that others may be coming in from the field in the early a.m. - *drive slow and keep right*!; if you encounter an unusual situation, contact your partner to inform and notify the supervisor or park ranger- avoid confrontational situations with

2. Communication	2a. Unable to reach a radio repeater in a remote location.	2a. Make sure radio is charged- try to raise someone on the radio to inform them of your predicament; if you are unable to reach a repeater from your location climb up slope toward a ridge top or knoll and try again; try at regular intervals, just meandering around may help in getting a signal; use cell phone in vehicle (if available), as this may be more reliable for communication in remote locations.
3. Hiking	3a. Steep, rugged, and slippery terrain	3a. Assess terrain conditions to find safe route and modify sampling plans to avoid unsafe areas; Proper footwear is VERY important- wear boots with Vibram or other slip-resistant soles with tops well above the ankle, broken in before the field season, plus 2-3 pairs of cotton or wool socks, NO TENNIS SHOES; if wearing wading boots be cognizant that they are slippery on grass and mud, carry supplies in backpack, make sure pack is comfortable and secure, waist belt recommended; take care when walking on hardwood leaf litter and on wet ground; maintain an erect posture when contouring steep slopes; avoid walking below another person due to the potential for rocks to dislodge from above; use caution when crossing large and/or wet logs.
	3b. Undergrowth	3b. Wear safety glasses (or other glasses) when hiking in brushy areas to protect eyes from protruding objects.

4. Encountering noxious plants, animals, disease, and people	4a. Poison oak	4a. Make sure you can identify poison oak in all its growth forms, foliage, bare twigs, and berries (the plant is toxic in winter when foliage is absent!); apply barrier cream to prevent exposure; wear long sleeves or Tyvex suit (or comparable); avoid sitting with arms resting on knees; use Technu (or something similar) lotion to prevent exposure; wash with Technu soap immediately after returning from the field; bring an extra set of clothes and shoes to change into after coming out of field; wash field clothes separately from other laundry.
	4b. Bees/Wasps/Hornets	4b. Determine if any field crew are allergic to bee stings. Notify other crew members and the supervisor if you know you are allergic to bee stings. Ensure that individual carries prescribed medication to prevent anaphylactic shock; Carry a bee sting kit or Benadryl or other antihistamine; Be aware of the ground where you step- some hornets build nests in the ground at the base of trees or shrubs, or in rotten logs- watch for bees buzzing in and out of holes or around ground level; if possible, flag a nest so future surveyors won't run into it;
	4c. Ticks	4c. Know how to identify and distinguish the "deer tick" that carries Lyme disease, from the "wood tick" that does not; if bitten by a tick, remove it (grasp tick with tweezers at head and pull straight out), and follow instructions for preserving it and turn it in to the county health department so they can determine if it was carrying Lyme; fill out a CA-1 (accident report) in the event that symptoms of Lyme disease appear eventually; 4d. Inspect items left lying on the ground, e.g., clothing, for scorpions prior to putting them on; 4e. Avoid rattlesnakes by inspecting the ground near logs before stepping over them; avoid placing hands on rock ledges or other natural hoists without visually inspecting them first; in the unlikely event you're bitten by a rattlesnake, stay calm, sit still, and call and wait for help; 4g. Avoid mountain lions; if you encounter a lion that doesn't run from you- leave the area; if attacked- fight back! 4h. Stay away from dead rodents and rodent feces, especially in closed buildings. 4i. Report uncomfortable encounters with strangers in the park to a supervisor as soon as possible; report apparent illegal activity to a park ranger, do not get

5. Exposure to environmental variables	5a. Treatment of general injuries	5a. All NPS field staff and contractors will be required to have current First Aid certification.
	5b. Hypothermia	5b. Always anticipate bad weather and dress accordingly, or carry warm clothes with you. Always travel in pairs as a minimum. Keep clothing as dry as possible. Eat high energy nutritional supplements between meals. Cover the head and neck to prevent heat loss. Keep active to maintain the body's metabolism. Drink plenty of liquids to prevent dehydration, although an individual does not "feel" thirsty. Drink warm liquids not cold. Understand the effects of cold and wind: most hypothermia cases develop between 30°F and 50°F.
	5c. Hyperthermia	5c. Hyperthermia may occur during high temperatures, monitor for dehydration, heat exhaustion, heat cramps, and heat stroke; symptoms include nausea, headache, and flushed, red skin; drink plenty of water (even when you are not thirsty); as heat increases, take frequent breaks in cool locations; wear a light shirt.
	5d. Giardia	5d. Giardia is caused by drinking contaminated water- carry plenty of water on outings. Consider all streams contaminated.
	5e. Sunburn	5e. Much of the work takes place in full sunlight (estuary seining, snorkeling, etc.) so prevent sunburn, use 15+ or greater SFP sunscreen and lip balm; and wear a hat, sunglasses, and shirt.
6. General work in or near streams	6a. Working near unstable, steep, deep channels, swift flows.	6a. Reconnoiter to familiarize yourself with stream and reach adjacent to project. Know the current and projected flow conditions from weather forecasts and stream gauge info. Familiarize yourself with work area prior to fieldwork. Review maps and aerial photos to determine access points, reference points, and potential evacuation points. Develop evacuation plans for remote stream sites and make sure you sign out (including location) on the checkout board prior to leaving for the field.
	6b. Giardia	6b. Refer to 5d.
	6c. Sunburn	6c. Refer to 5e.
	6d. Undergrowth	6d. Refer to 3b.

7. Aquatic surveys, Water Quality/Flow Sampling, Culvert Surveys, Spawning/Carcass Counts, Habitat Monitoring, Frog Surveys, Fish Distribution Study, Habitat Improvement Design and Layout, and Project Monitoring	7a. Wading/walking in and across streams	7a. Wear proper waders, felt-soled, chest or hip boots for conditions. When using waders, wear wading belt or similar. Purchase and use waders with felt soles or retrofitted with anti-slip devices. In cold weather, wear neoprene waders or wear warm, preferably polyester garments with standard waders. Use walking stick to improve stability in current. Walk slowly and carefully. Work in teams of two or more and within sight of one another. Cross-stream at shallow riffles, and avoid deep, swift areas. Consult weather forecast each morning or call local observer to determine stream and flow conditions. Avoid wet logs and slippery rocks. Sign out/in at board in front office each day. All people must be CPR and First Aid Certified. Carry a means of communication (e.g., cell phone or radio).
	7b. Wading/walking in and across aquatic sites	7b. Refer to 7a. When wading in aquatic sites with deep, fine sediments, test fine sediment depths with wading rod before entering. Do not enter when fine sediment depths extend above knee.
	7c. Crossing Debris Jams	**7c. Determine the safest route along the creek; either climbing around on either side of the banks, or by going under and/or on top of the jam. When crossing you should be in sight of your coworkers in case anything should occur. Free both hands to assist with climbing jams. If crossing under and/or on top of the jam, be cognizant of its structural integrity. Walk or crawl on the larger key pieces/logs in the jam as smaller woody pieces are more prone to shift, break, or completely give way. Usually, the larger pieces are the most stable and structurally sound. The same is true for any handholds you may use when climbing the jam. If unsure, do not put all your weight on a piece at once, be slow and maintain your handholds if possible. Avoid slick wet logs without bark and if cold, be aware of ice that may be on their surfaces. DO NOT JUMP onto log pieces.**
	7b. Hypothermia 7c. Giardia 7d. Sunburn	7b. Refer to 5b. 7c. Refer to 5d. 7d. Refer to 5e.

8. Boats (non-motorized)	9a. Drowning	9a. Wear proper boating protective/floatation gear (life vests, water-repellent clothing) at all times. Use boats ONLY if trained and knowledgeable in boat use. Work in pairs or teams. Consult flow gauge to determine stream safety level.
	9b. Capsizing	9b. Watch out for large organic debris (sweepers) in the channel. Scout unfamiliar obstacles before paddling through. Balance the weight in the boat. Be cognizant that a boat can be easily tipped by shifting your weight.
	9c. Hypothermia	9c. See 5a.

JHA Instructions

The JHA shall identify the location of the work project or activity, the name of employee(s) involved in the process, the date(s) of acknowledgment, and the name of the appropriate supervisor approving the JHA. The supervisor acknowledges that employees have read and understand the contents, have received the required training, and are qualified to perform the work project or activity.

Identify all tasks and procedures associated with the work project or activity that have potential to cause injury or illness to personnel and damage to property or material. Include emergency evacuation procedures (EEP).

Identify all known or suspect hazards associated with each respective task/procedure listed. For example:

- **a. Research past accidents/incidents.**
- **b. Research the Health and Safety Code, or other appropriate literature.**
- **c. Discuss the work project/activity with participants.**
- **d. Observe the work project/activity.**
- **e. A combination of the above.**

Identify appropriate actions to reduce or eliminate the hazards identified. Abatement measures listed below are in the order of the preferred abatement method:

- **a. Engineering Controls (the most desirable method of abatement). For example, ergonomically designed tools, equipment, and Furniture.**

Emergency Evacuation Instructions

Work supervisors and crewmembers are responsible for developing and discussing field emergency evacuation procedures (EEP) and alternatives in the event a person(s) becomes seriously ill or injured at the worksite.

Be prepared to provide the following information:

- **a. Nature of the accident or injury (avoid using victim's name).**
- **b. Type of assistance needed, if any (ground, air, or water evacuation).**
- **c. Location of accident or injury, best access route into the worksite (road name/number), Identifiable ground/air landmarks.**
- **d. Radio frequencies.**
- **e. Contact person.**
- **f. Local hazards to ground vehicles or aviation.**
- **g. Weather conditions (wind speed & direction, visibility, temperature).**
- **h. Topography.**
- **i. Number of individuals to be transported.**
- **j. Estimated weight of individuals for air/water evacuation.**

The items listed above serve only as guidelines for the development of emergency evacuation procedures.

JHA and Emergency Evacuation Procedures Acknowledgment

We, the undersigned work leader and crewmembers, acknowledge participation in the development of this JHA (as applicable) and accompanying emergency evacuation procedures. We have thoroughly discussed and understand the provisions of each of these documents:

SIGNATURE DATE SIGNATURE DATE

b. Substitution. For example, switching to high flash point, non-toxic solvents. **c. Administrative Controls. For example, limiting exposure by reducing the work schedule; establishing appropriate procedures and practices.** **d. PPE (least desirable method of abatement). For example, using hearing protection when working with or close to portable machines (chain saws, rock drills, and portable water pumps).** **e. A combination of the above.** **Copy of the JHA as justification for purchase orders when procuring PPE.**		

SOP #2 Appendix B. Working in Poison Oak – Safety Briefing

(hardcopy only)

SOP #3 Equipment and Field Preparations

3.1 Revision History Log

Prev. Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.0	8/5/05	M. Cooprider	Minor edits	Preparation for formal peer review	1.01
1.01	3/8/06	R. Carson	Minor edits, updates to text and tables	Addressing peer reviewer comments	1.02
1.02	8/1/06	R. Carson	Minor edits, updates to reference documents, inclusion of USGS continuous monitoring equipment guidelines	Availability of USGS reports and WRD guidance	1.03

Only changes in this SOP will be logged. "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).

3.2 Acknowledgements

Several other Standard Operating Procedures and technical guidance were consulting while writing this SOP. The overarching guidance is from the USGS National Field Manual. In addition, *Procedures for Collection of Required Field Parameters, Version 1.0, Standard Operating Procedure #5* (O'Ney, 2005), the *Crissy Field Restoration Monitoring Program Quality Assurance Project Pla*n (Ward, 2004), the *Quality Assurance Management Plan for the State of California's Surface Water Ambient Monitoring Program ("SWAMP"*) (Puckett, 2002), and the Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Station Operation, Record Computation, and Data Reporting.(Wagner et. al., 2006)were also consulted for guidance on specific parameters, instruments, or methods. Finally, equipment log sheets and the equipment technical support guide were compiled by Amelia Ryan. Much appreciation is extended to the individuals involved in the production of these documents.

3.3 Scope and Application

3.3.1 Introduction

Field measurements should represent the natural condition of the surface water at the time of sampling. Equipment calibration and maintenance will help ensure that field measurements reflect the actual site conditions as closely as possible. Keeping routine records of equipment calibrations, maintenance, and repair is an integral part of QA/QC efforts in the water quality

monitoring program. In addition knowledge of expected stream conditions is necessary in order to determine whether field measurements are accurate or equipment is out of calibration.

This SOP will follow guidelines provided by equipment manufactures (e.g., Oakton, YSI, Inc., Marsh-McBirney) for equipment operation and maintenance as well as calibration guidelines outlined in the USGS National Field Manual. This includes calibration methods and frequency, equipment cleaning, changing pH electrodes, D.O. membranes, etc. Procedures for dealing with deficient equipment are also discussed and include preventative maintenance procedures and schedules to minimize downtime of sampling and measurement equipment. Information on spare parts, batteries and contingency plans for equipment back-up is also provided.

To minimize or avoid downtime of measurement instruments, all field sampling and laboratory equipment will be maintained in good working order. Also, spare equipment or common spare parts (e.g., batteries, D.O. membranes, and pH electrodes) will be available so that repairs or replacement can be made as quickly as possible and measurements will not be lost. All field equipment having manufacturer-recommended schedules of maintenance will receive preventive maintenance according to that schedule (see Table 3.1). Other equipment used only occasionally will be inspected at least monthly. After use in the field, all equipment will be re-checked for needed maintenance.

An instrument or device used in obtaining an environmental measurement must be calibrated by the measurement of a standard. Every instrument or device has a specialized procedure for calibration and a special type of standard used to verify calibration. See instrument manuals for further details. A log book will be kept to record dates of calibration and any equipment errors or failures, battery changes, changes of calibration solutions, and repair notes. The log book will also contain calibration methods, this schedule of inspections and calibrations, and a list of needed supplies and equipment.

3.4 Equipment Calibration, Inspection, and Maintenance

Overview of Calibration Tasks:

- Field instruments calibration and maintenance should be logged in the equipment binder. Include: the date of calibration, any change of calibration solutions, changed batteries, D.O. membranes, pH electrodes, date and description of repairs conducted by the manufacturer.
- The log book should be reviewed before leaving for the field.
- Each instrument (meters and sensors) should be calibrated if appropriate, then error-checked against calibration acceptance criteria before leaving for the field.
- Measurement technique should be practiced if the instrument is new to the operator.
- Backup instruments should be readily available and in good working condition.

Table 0.1 Calibration schedule (modified from O'Ney, 2005).

Parameter	Calibration Frequency	Acceptance Criteria	Corrective Actions
Temperature Liquid-in-glass thermometer:	Calibration-check every 3 to 6 months, using a 2-point calibration-check, and annually, using a 3-point calibration-check 10% of the readings taken each day must be duplicated, or a minimum of 1 reading if fewer than 10 samples are read.	±1.0 ºC	Re-test with a different thermometer; repeat measurement
Temperature Thermistor thermometer:	Every 3 to 4 months, check calibration, annually, using a 5-point calibration check	Same as above	Re-test with a different thermometer; repeat measurement
Specific Conductance	Prior to field mobilization, at the field site, and calibration check at day's end; 10% of the readings taken each day must be duplicated or a minimum of 1 reading if fewer than 10 samples are read.	±5%	Re-test; check low battery indicator; use a different meter; use different standards; repeat measurement
Dissolved oxygen	Prior to field mobilization, at the field site, and calibration check at day's end	±10%	Re-enter altitude; re-test; check low battery indicator; check membrane for wrinkles, tears or air bubbles; replace membrane; use a different meter; repeat measurement
Eureka Manta ® multiprobe datalogger	Beginning and end of each deployment	See manual	Follow manual suggestions for calibrating or calibration-checks of each parameter probe.
pH meter	Prior to field mobilization (three point calibration using buffer solutions (pH 4,7, and 10)) At the field site, and calibration check at day's end (one point calibration) 10% of all reading taken each day must be duplicated or a minimum of 1 reading if fewer than 10 samples are read.	±0.2 pH unit; ±0.2 pH unit RPD ±0.1 pH unit	Re-test; check low battery indicator; use different standards; repeat measurement

Notes on Table 3.1
-All instruments should be visually inspected before use
-Check batteries before use
-Rinse all equipment after use
-Insure that pH electrodes and D.O. membrane remain moist.

3.4.1 Multiparameter instrument (dissolved oxygen and conductivity)

Network staff should consult the manufacturers' instruction manual for detailed calibration procedures for multiprobe instruments (Appendix A). All calibration and maintenance activities must be recorded in a Calibration Logbook (see Appendix D). The minimum calibration schedule and calibration acceptance criteria are in Table 3.1 above. General guidelines for conductivity and dissolved oxygen are provided below.

- D.O. (and conductivity) should be calibrated before each site;
- Clean sensors thoroughly with deionized water (DIW) before and after making a measurement (this is sufficient cleaning in most cases)
- Rinse and clean (use tiny brush) YSI 85 with tap water.
- Remove oils or other chemical residues (salts) with detergent (soak in solution of water and detergent)
- If these residues persist, then, a chemical (acid) recommended by YSI may be used
- Always calibrate from low to high specific conductance
- Calibrate at the field site – bring conductivity standards to water sample temperature
- Record the sources of calibration standards; standards should be traceable to a source such as NIST (National Institute of Standards and Technology or EPA certified vendors.
- Never re-use standards or use expired standards
- For short-term storage (days to a couple weeks): ensure that sponge in probe chamber remains saturated; have extra (unused) sponges available
- For longer term storage (2 weeks or more): remove all sensors from the multiprobe and store per manufacturers instructions; store clean and dry
- Ensure that conductivity standards are clearly labeled with the expiration date. Never used an expired solution to calibrate
- All instruments must meet the calibration error limits stated in Table 3.1
- Record all calibration and maintenance activities in the log book
- The Winkler titration method is used as a back-up if the oxygen sensor fails in the field. It can also be used to calibrate D.O. in the laboratory. It is a good idea to practice this method in the laboratory before the possibility of needing to use it in the field. See SOP#5 for details about the technique.

On an annual basis, place all the probes in the same bucket or appropriate deep lab sink, leave them a few minutes to equilibrate, and then compare the readings. Usually, they will not give identical readings but should agree within acceptance criteria. If they do not, note the differences, perform troubleshooting on the sensors that do not read correctly after recalibration and again check against the appropriate standard(s) using error check procedures

Consult the YSI manual for details on how to calibrate conductivity and dissolved oxygen and how to clean the conductivity cell and dissolved oxygen sensor. If chemicals are necessary for D.O. probe/conductivity cell cleaning, review the chemicals' MSDS for required handling and disposal. Also consult the MSDSs for conductivity standards.

3.4.2 Thermometer/Thermistor

(From USGS National Field Manual Ch. 6.1)

Accurate determination of other field measurements depends on accurate temperature measurements. This is particularly important for thermistors incorporated in specific electrical conductance and dissolved-oxygen instruments, such as the hand-held YSI 85. These thermistors are used for automatic temperature compensation of the measurements being made.

Thermistors included in other field-measurement instruments must be calibration-checked routinely.

The thermistor in the YSI 85 multiprobe should be checked for accuracy against a NIST-traceable rated, liquid-filled thermometer by Network staff upon receipt from the manufacturer and at a minimum quarterly thereafter (see procedure below). The thermistors should be checked against a broad range of temperatures (e.g. from an ice water bath to beyond the range water body temperatures are expected to be encountered in the field; e.g. 45°C). Conduct an annual 5-point calibration check.

If a temperature probe is found to not meet the temperature calibration requirements set forth in the Table 3.1, the entire multiprobe should be returned to the manufacturer for replacement. Once calibrated by the manufacturer, thermistor thermometers are one of the more accurate and stable sensors requiring the least maintenance. Multiparameter instruments are generally equipped with a thin-walled, titanium-sleeved thermistor that offers fast response and resists corrosion. The device is of high precision (e.g. 2252 ohms @ 25° C w/precision of ± 1%) and uses an imbedded algorithm to convert resistance to temperature. When handled according to manufactures specifications, and checked on a regular basis, the sensor should provide a long period of useful operation. Radtke et al. (1998) detail the proper calibration and documentation for thermometers and thermistor thermometers.

All temperature measurements should be made and reported in units of degrees Celsius (°C). Each Network lab should be equipped with a NIST-Traceable rated liquid-filled or digital calibration thermometer (preferred) or a liquid-in-glass thermometer graduated at 0.1 °C with a minimum range of –5 to + 45 °C. Prior to conducting fieldwork, temperature sensors used should be tested against thermometers rated by the National Institute of Standards and Technology (NIST) as traceable for lab testing of temperature equipment. A second NIST-Traceable rated liquid-filled or digital thermometer may also be appropriate for field use and may best serve to field check the thermistor-based measurements of the multiprobes and measure ambient air temperatures when at the monitoring station.

CALIBRATION EQUIPMENT

- Calibration thermometer, liquid-in-glass sensor, rated as Traceable by NIST
    - Temperature range at least –5 to +45°C
    - 0.1°C graduated
- Thermometer, liquid-in-glass sensor
    - Temperature range –5 to +45°C
    - Minimum 0.5°C graduated
    - Calibrated accuracy within 1 percent of full scale or 0.5°C, whichever is less
    - Calibration-checked and certified against calibration (NIST) thermometer
- Thermistor thermometer
    - Calibration checked accuracy within 0.1°C to 0.2°C
    - Digital readout to at least 0.1°C
    - Calibration-checked and SFAN certified against calibration (NIST) thermometer
- Soap solution (1 L), nonphosphate laboratory detergent
- Deionized water (1 L), maximum conductivity of 1 mS/cm

- Paper tissues, disposable, soft, and lint free (e.g., ChemWipes)
- Log book, for recording all calibrations, maintenance, and repairs

CALIBRATION PROCEDURE

The standard thermometer against which all other thermometers are calibration checked must be NIST-traceable rated. It must be accurate to 0.1°C. Confirm the traceability of the a NIST thermometer before checking field thermometers. NIST-traceable rated thermometers are not for field use.

Thermometers being calibration checked must meet NIST specifications to a minimum of three temperatures at approximately 0°, 25°, and 40°C. Thermistors must be calibration checked at 5 points within this range. If environmental water or air temperatures will fall below 0°C or rise above 40°C, add additional calibration points to bracket the temperatures to be measured. Field checking thermometer calibration by comparing readings with another field thermometer does not substitute for required laboratory calibration check procedures. When measuring water temperature in the laboratory:

1. Submerge the bulb and liquid column of the total-immersion thermometer.
2. Keep the NIST-traceable rated thermometer and the thermistor sensor submerged in the container throughout calibration.
3. Read the NIST-traceable rated thermometer and record the thermistor readings throughout warming and cooling periods.
4. Check the meter batteries periodically for proper voltage.
5. Record the calibration data in the instrument log book for each thermistor thermometer, noting if a sensor has been replaced.
6. Tag acceptable thermometers as "SFAN certified" with calibration check date and certifier's initials.

The following procedure will be used to check the calibration at 0°C:

1. Freeze several ice cube trays filled with deionized water.
2. Fill a 1,000-mL plastic beaker or Dewar flask three-fourths full of crushed, deionized ice. Add chilled, deionized water to the beaker. Place the beaker of ice/water mixture in a larger, insulated container or Dewar flask. Place the NIST-traceable thermometer into the ice/water mixture and make sure that the temperature is uniform at 0°C by stirring and checking at several locations.
3. Pre-cool the test thermometer sensor to 0°C by immersing it in a separate ice/water bath.
4. Add the test thermometer sensor(s) to the ice/water mixture. Position the sensor(s) so that they are properly immersed and so that the scales can be read. Periodically stir the ice/water mixture and allow at least 2 minutes for the thermometer readings to stabilize.
5. When the readings stabilize, compare the temperature of one test thermometer at a time with that of the NIST-traceable thermometer. Without removing the temperature sensor(s) from the test bath, read the test thermometer(s) to the nearest graduation (0.1 to 0.5°C) and the NIST-traceable thermometer to the nearest 0.1°C.
    - Take three readings for each thermometer within a 5-minute span.
    - Calculate the mean of the three temperature readings for each thermometer and compare its mean value with the NIST thermometer.

- If the test liquid-filled thermometer is found to be within ±1 percent of full scale or ±0.5°C of the NIST-traceable thermometer, whichever is less, set it aside for calibration checks at higher temperatures.
- If the test thermistor is found to be within ±0.2°C of the NIST thermometer, set it aside for calibration checks at higher temperatures.

6. For "room temperature" calibration (about 25°C), place a Dewar flask or container filled with about 1 gallon of water in a box filled with packing insulation. (A partially filled insulated ice chest can be used for multiparameter instruments.) Place the calibration container in an area of the room where the temperature is fairly constant (areas away from drafts, vents, windows, and harsh lights).
7. Properly immerse the NIST-traceable rated and test thermometer sensor(s) in the water. Cover the container and allow the water bath and thermometers to equilibrate. Stir the water and check every couple of hours for temperature uniformity using the NIST thermometer—it may be necessary to let the bath equilibrate overnight.
8. Compare one test thermometer at a time with the NIST- thermometer. Calibrate as described in step 5 above.

- For greater than 25°C temperature calibration, place a beaker (1,000 mL or more) of warm water (about 40°C) on a magnetic stirrer plate and repeat procedure as described in step 5 above.
- Tag acceptable thermometers as "Certified" with calibration check date and certifier's initials.
- Record procedure in calibration logbook.

Corrections can be applied to measurements made with a thermistor instrument system if necessary, using a calibration curve or table plotted in the log book. Thermometers found to be out of calibration by more than 0.2°C must be recalibrated per manufacturer's instructions or returned to the manufacturer for proper calibration and (or) repairs.

Thermometers can easily become damaged or out of calibration. Take care to:

- Keep thermometers clean (follow manufacturer's recommendations).
- Carry thermometers in protective cases; thermometers and cases must be free of sand and debris.
- Store liquid-filled thermometers in a bulb-down position and in a cool place away from direct sunlight.
- As an additional precaution on field trips, carry extra calibrated thermometers as spares, and a supply of batteries for instrument systems.
- Never carry a mercury-filled thermometer in the field.

3.4.3 pH Meter

(Adapted from the Surface Water Ambient Monitoring Program Quality Assurance Management Plan (Puckett, 2002) and USGS National Field Manual Ch. 6.4)

Because a large variety of pH meters and electrodes are available on the market, it is very important to be thoroughly familiar with the instruction manual provided by the manufacturer.

Electrodes must be clean and properly operating to produce accurate results. The liquid junction also must be free flowing, and the electrolyte solution in the electrode must be at the proper level. Because of the variety of electrodes available, follow the cleaning and storing instructions provided by the manufacturer. In this case, SFAN will be using the Oakton pH Testr 30. It is a waterproof meter requiring four A76 batteries. See the appendix for manufacturer recommended calibration and maintenance.

When single function pH meters are used, pH is calibrated for each day of use, and at each sampling site. Additional calibrations may be necessary if questions arise regarding a particularly measurement. The pH meter should be calibrated with a buffer of pH 7.0 and either 4.0 for naturally acidic waters or pH 10.0 for alkaline waters. The pH of SFAN waters is generally between 6.5 and 8.5. The pH buffers contain high concentrations of phosphate. Care must be taken during calibration to avoid leaving traces of buffer on equipment or at the work place that could contaminate water samples. Buffer solutions prepared in the field offices from reagent powder or concentrate are labeled with date of preparation and replaced after one month (Puckett, 2002).

- Ensure that the pH electrode remains moist at all times.
- Rinse and clean (use tiny brush) pH meter with tap water
- Never wipe the pH electrode membrane with anything or store it dry (check manufacturer's instructions)
- Record any operation difficulties, batteries changed, or pH electrodes changed in the equipment log book
- Check MSDS for pH buffer solutions
- Always cap the buffer solutions to prevent evaporation and contamination from atmospheric carbon dioxide
- Take care not to dilute a buffer (e.g., with water dripping from a sensor) or contaminate with another buffer
- Never pour used buffer into a stock solution bottle or allow anything else to enter the stock bottle
- Discard buffers on their expiration date; copy the expiration data onto any container into which the buffer is
  transferred
- Calibrate before heading to the field.
- Calibrate as close to the temperature of the water body as possible*

* This is important for older pH tester technology. The Oakton pH Testr 30 that is being used by SFAN water quality personnel is equipped with a microprocessor that performs autocalibration operations that automatically compensate for buffer temperatures by deriving the Nernst slope

Buffer solutions in the calibration kit that are taken from the stock bottle should be replaces by new solution from the stock bottle at least weekly. Be sure to note in the equipment maintenance log that the calibration solutions were changed.

The table in the Appendix B demonstrates how pH calibration standards differ based on temperature. A bucket can be used to place the calibration standards (capped) in while they equilibrate with the sample water temperature (approximately 15 minutes).

3.4.4 Post-Calibration Checks

From Procedures for Collection of Required Parameters, SOP#5 by O'Ney (2005)

Post-calibration checks must be performed after each use of the instrument and before any instrument maintenance. The sooner this procedure is performed, the more representative the results will be for assessing performance during the preceding field measurements. Calibration and post-calibration should be no more than 24 hours apart. Take the same care used in performing the initial calibration by rinsing the sensors and waiting for functions to stabilize. After making measurements at the last station, fill the sampling cup with ambient water (not deionized or tap water). Repeat the initial calibration procedures performed before the sampling trip. Record post-calibration values in a Calibration Logbook (generally on the same page with the initial calibration for that sampling trip).

Do not adjust the instrument (using calibration controls) during the post-calibration check. The purpose of the post-calibration is to determine if the instrument has held calibration during the day of sampling. Compare the post-calibration values to the expected values for the standards, so the field measurements for the day can be reported with confidence. The difference between the post-calibration value and expected standard value can be used to indicate both calibration precision and instrument performance.

Post-Calibration Check Error Limits

Calibrations made prior to field mobililzation, or at the site, and post-calibration should take place no more than 24-hours apart. If post-calibration values (Table 3.2) fall outside the error limits for DO, pH, and specific conductance, data collected does not meet quality assurance (QA) and should not be reported. If post calibration measurements do not consistently fall within the error limits after in-house trouble shooting, the instrument should be returned to the manufacturer for maintenance.

Table 0.2. Post-Calibration Check Error Limits for water-quality equipment.

PARAMETER	Error Limits Acceptance Criteria	USGS Error-Check Acceptance Criteria (multiparameter monitoring equip.) (Wagner, et al. 2006)
Temperature	± 1 °C, annual calibration check	± 0.2 °C
Specific Conductance	± 5%	The larger of ± 5uS/cm or ± 3%
pH	± 0.5 standard units	± 0.2 standard units
Dissolved Oxygen	± 0.5 mg/L, ± 6% saturation	± 0.3 mg/L, ± 3% saturation

The more stringent acceptance criteria from the USGS in the third column above, and is presented as a goal for NPS networks. The less stringent criteria presented in the second column is minimum recommendations by WRD and may be adjusted in the future. See WRD online

guidance for the latest recommendations. SFAN will strive to achieve the USGS recommended values, but will at least attain WRD suggested values, and note when USGS values were not attained.

3.4.5 Continuous Water-Quality Monitoring Equipment

(e.g. Eureka Manta® multiprobe datalogger)

The USGS publication "Guidelines and standard procedures for continuous water-quality monitors" by Wagner et al (2006) should be used as a guide for the operation, calibration, data processing and reporting of continuous water-quality monitoring equipment.
Procedures for the operation, calibration, data correction and reporting
Procedures for calibration and cleaning of the Eureka Manta® multiprobe are outlined in Appendix C. Calibration steps are divided in four parts: pre-field calibration, post field calibration, cleaning, and downloading. The manual can be found at:
http://www.eurekaenvironmental.commanta/documents/Manta.pdf

For instruments used in continuous monitoring mode, post-calibrations should follow the USGS protocols separating corrections due to biofouling from instrument drift. The USGS post-calibration error check acceptance criteria for multiparameter instruments can be seen in the third column of Table 3.2 (above).

Some of the QA/QC measures for conductivity and dissolved oxygen, temperature, and pH are embedded in the sections above. The following are QA/QC measures are from the Crissy Field Restoration Monitoring Program Quality Assurance Project Plan (Ward, 2004):

- Never accept any calibration for which you have received a warning message. Determine and correct the cause of the problem and re-calibrate.
- Don't use expired standards and use fresh solutions for calibration. Probes may be rinsed with expired solutions, but **NOT** calibrated.
- Replace the D.O. membrane before each deployment, allowing the probe to sit at least 6 hours after replacement before pre-field calibration error checking and deployment. Note that new technology present in digital luminescent DO sensors do not use a Clark cell membrane and largely make these steps unnecessary.

3.4.6 Equipment and Supplies: Maintenance and Storage

The following is a guide for maintaining calibration standards and other solutions and supplies (Table 3.3). Although some samples have an extended shelf life, they should be replaced when they exceed the manufacturers' expiration date.

Table 0.3 Storage time for calibration standards.

Item	Shelf Life
Conductivity standards	1.5 years
pH buffer solution in small bottle	1 month in small container
pH buffer solution in stock container	Expiration data stamped on bottle
pH buffer powder	Indefinite
D.O. electrolyte crystals or solution	indefinite

The following information applies to all water quality equipment and instruments.

Long Term Storage
Field instruments are often stored for indefinite periods. For example, back-up instruments are used during repair of the primary instrument. The instrument cannot be kept in a perpetual state of readiness without regular maintenance.
Whenever equipment is to be stored for extended periods of time:

- Thoroughly clean the sensors.
- Remove installed batteries (AA batteries, C batteries, polarizing batteries).
- Fill the storage cap about 1/3 full of tap water (if the multiprobe may be exposed to freezing temperatures a solution of ½ tap water and ½ methanol should be used).
- Store away from direct sunlight. ----The instrument can be reliably reactivated for field use with minimum of effort the day before field use.

(From the State Water Resources Control Board Surface Water Ambient Monitoring Program (SWAMP) Part of Appendix E Quality Assurance Management Plan)

3.5 Field Preparations

The network Water Quality Specialist (Hydrologist/Physical Scientist) will determine which lab will be used for the sampling event based on executed purchase orders or Blanket Purchase Authority (BPA). Analytical laboratories often have different constraints on the number of samples they can process and the days and times that they can accept samples. The laboratory should be notified of the sampling event as soon as possible. Information to be provided includes the number of sites and times/days that samples will be collected, what parameters will be analyzed, and any courier services needed. This gives ample time for the laboratory to provide sample bottles and other supplies (coolers, blue ice, labels, and COC forms). Chain of Custody (COC) forms should be completed and faxed to the chosen laboratory at least one day prior to sampling or as required by the laboratory. Call the lab in advance (1-2 weeks or more) to schedule a sample pick-up or drop-off and notify the lab of the # of samples and analyses required. In addition, call the lab the morning of the sampling to verify.

A number of steps should be taken at the office to insure that all of the equipment is in the vehicle. Be sure to use the following checklist for equipment inventory (Table 3.4).

Table 0.4 Field Equipment Checklist.

Check	Item
√	Equipment for Collecting Required Field Parameters
	Calculator (for calculating centroid of flow)
	Bacteria bottles: Sterile 100 mL bottles (provided by lab)
	Nutrient bottles: Sterile sample bottles, (provided by lab)
	Sediment bottles: 500mL or 1-liter sample bottles (CLEAN!)
	Sharpie, pen, pencil
	Clipboard
	Field collection data sheets (on Rite in Rain paper if necessary)
	Labels from laboratory
	Labels for sediment bottles (and nutrient bottles if necessary)
	Chain of Custody
	Disposable rubber gloves
	Paper towels or rag for drying bottles before labeling
	YSI 85 or (YSI 30 and YSI 55) multiparameter probes
	Extra AA batteries (6) for YSI meter
	pH meter*
	Extra pH meter or pH tape at the very least
	pH meter batteries (four A76 watch batteries)
	1-3 Large coolers
	1 small cooler
	Blue ice
	Flow meter and extra D batteries
	Top-setting wading rod
	50m measuring tape
	Chaining pins (or similar)
	Waders/rubber boots
	Radio or cell phone (depending on location)
	Keys and/or combinations for gate locks, dataloggers
	Water jugs with tap water for rinsing boots
	Water jug with distilled water for rinsing pH electrodes and YSI probe
	All maintenance log books and calibration standards for all field equipment
	Digital camera with optional waterproof case
	GPS unit
	Hand sanitizer and/or antibacterial soap
	All maintenance parts and calibration standards for field equipment
	NIST calibrated Centigrade thermometer for air temp
	NIST calibrated Centigrade thermometer for back-up
	Winkler titration kit for D.O. back-up
	Stopwatch and headset for discharge measurements (for pygmy or price AA- flow meters)
	Personal flotation device
	Traffic safety vest, cones, signs, warning lights
	First aid kit
	Highway emergency kit
	Tool kit
	Tape (electrical, fiber, other)
	Fire extinguisher
	Flashlight with extra batteries
	Weather report
	Field trip itinerary
	Work gloves
	Drinking water
	Copy of safety SOP
	Maps
	Deionized water

3.6 QA/QC Procedures for Equipment

Table 0.5 QA Protocols.

Measurement Parameter	QA Protocol
*Total Kjeldahl Nitrogen	Duplicates 10% of samples, lab matrix spike
*Nitrate as N	Duplicates 10% of samples, lab matrix spike, Field Blank, Trip Blank
*Nitrite as N	Duplicates 10% of samples, lab matrix spike, Field Blank, Trip Blank
*Nitrate + Nitrite	Duplicates 10% of samples, lab matrix spike, Field Blank, Trip Blank
*Ammonia	Duplicates 10% of samples, lab matrix spike, Field Blank, Trip Blank
*Fecal coliforms	Lab and field duplicates, Field Blank, Trip Blank
*Total coliforms	Lab and field duplicates , Field Blank, Trip Blank
*Total Suspended Solids	Lab and field duplicates, Field Blank, Trip Blank
Turbidity	Equipment blanks; duplicates 10% of samples

*Also refer to laboratory QA manuals for lab parameters

The primary QA/QC measure conducted in the lab before commencing field work are the "equipment blanks". These tests are used to ensure that equipment used during sampling does not contaminate samples. Equipment blanks are run when new equipment , equipment that has been cleaned after use at a contaminated site, or equipment that is not dedicated for surfact water sampling, is used. Consult the Quality Assurance Project Plan (SOP #4) for additional details.

Check precision in the field every tenth sample by repeating an in situ measurement three separate times or by repeating the measurements on three separate aliquots from the same composited sample volume (e.g. from a churn splitter). Note that these should all be recorded as the same sample and only one value included in the data analysis.
Document ability to make accurate measurements by measuring known reference solutions (e.g. zero DO solution).

3.7 References

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Ward, K. 2004. Water Quality Standard Operating Procedures. *In* Draft Crissy Field Restoration Monitoring Program Quality Assurance Project Plan, Appendix 1. Golden Gate National Recreation Area, U.S. Department of Interior, National Park Service. San Francisco, CA.

YSI Incorporated. 1998. YSI Model 85® Handheld Oxygen, Conductivity, Salinity and Temperature System Operations Manual. Revision D. Yellow Springs, Ohio, USA.

SOP #3 Appendix A. YSI Multiparameter Probe Manual

(hard copy only)

SOP #3 Appendix B. Oakton pH Meter Manual

(hard copy only)

SOP #3 Appendix C. Eureka Environmental Engineering – Manta multiprobe User's Manual

(hard copy only)

USGS Continuous WQ Monitor Field Form

USGS Calibration Log Sheet

Eureka Manta Calibration Instructions

From Wagner et al. 2006

February 2006

Station No._____

USGS
science for a changing world

U.S. GEOLOGICAL SURVEY
CONTINUOUS WATER-QUALITY MONITOR FIELD FORM

Station No. _____ Station Name _____

Monitor Inspected By _____ Date _____ Watch Time _____ Time Datum _____

Gage Ht _____ (Rising, Falling, Steady, Peak) Channel Conditions _____

Monitor Make/Model _____ Monitor Serial No. _____

Field Meter Make/Model _____ Field Meter Serial No. _____

Weather Cold Cool Warm Hot Rain Mist Sleet Snow Humid Dry Cloudy Pt Cloudy Overcast Clear Windy Gusty Breeze Calm

Comments:

MONITOR FOULING CHECKS

Parameter	Before Cleaning Time _____ Recorded/ Live Value	Before Cleaning Time _____ Field Meter	After Cleaning Time _____ Recorded/ Live Value	After Cleaning Time _____ Field Meter
Temp (°C)				
pH (units)				
DO (mg/L)				
SC (µS/cm)				
Turbidity (FNU FNMU FBU) Method code _____				
Other _____				

CALIBRATION DRIFT CHECKS

TEMPERATURE Calibration Criteria: ± 1 percent or ± 0.5 °C for liquid-filled thermometers; ± 0.2 °C for thermisters	Calibration Check Time _____	Recalibration Time _____

Comments:

SPECIFIC CONDUCTANCE Calibration Criteria: the greater of 5 µS/cm or 3% of measured value				Calibration Check Time _____			Recalibration Time _____		
STD VALUE	STD LOT NO.	STD TYPE KCl; NaCl	EXP. DATE	STD TEMP	SC READING	Error %	STD TEMP	SC READING	Error %
Cell range =	Reading in air = (should be zero)								

Comments:

Station No. _____

DISSOLVED OXYGEN Calibration Criteria: ± 0.3 mg/L			Calibration Check Time _____				Recalibration Time _____						
TEMP °C	BARO PRES mm Hg	DO TABLE READING mg/L	SALINITY CORR. FACTOR	DO READING	ERROR %	Reading in zero DO sol'n	TEMP °C	BARO PRES mm Hg	DO TABLE READING mg/L	SALINITY CORR. FACTOR	DO READING	ERROR %	Reading in zero DO sol'n
SALINITY:		SALINITY CORRECTION APPLIED? Y N		DO CHARGE:			DO GAIN:			Date Barometer Calibrated:			
COMMENTS:													

pH Calibration Criteria: ± 0.2 pH units				Calibration Check Time _____			Recalibration Time _____				
pH BUFFER	THEO-RETICAL pH FROM TABLE	BUFFER LOT NO.	BUFFER EXP DATE	TEMP	pH READ-ING	ERROR %	TEMP	pH READ-ING	ERROR %	SLOPE	MILLI-VOLTS
pH 7											
pH ___											
pH ___											
Comments:											

TURBIDITY Calibration Criteria: ± 0.5 Turbidity Units or ± 5%			Calibration Check Time _____			Recalibration Time _____		
	Lot no. or Date Prepared	CONC _____	TEMP °C	READING	ERROR %	TEMP °C	READING	ERROR %
Stock Turbidity Standard								
Zero Standard (DIW)								
Standard 1								
Standard 2								
Standard 3								
Turbidity Sensor Limit :		Comments:						

FINAL READINGS			Time _____		
Parameter	Recorded/ Live Value	Field Meter	Parameter	Recorded/ Live Value	Field Meter
Temp (°C)			Turbidity (FNU FNMU FBU) METHOD CODE _____		
pH (units)					
DO (mg/L)			Other _____		
SC (µS/cm)					

Monitor form ver. 3.0

1–2

Station No. _____

MAINTENANCE RECORD FOR CONTINUOUS MONITOR

Correction factors applied to field meter readings? YES NO

Battery changed? YES NO Voltage _____volts

Sensors cleaned? YES NO Type of fouling _____

Calibration check: WT SC pH DO TURB Recalibrated: WT SC pH DO TURB

Sensor changed? SC YES NO Sensor ID _____

pH YES NO Sensor ID _____

DO YES NO Sensor ID _____

Turbidity YES NO Sensor ID _____

Sonde Changed? YES NO New Sonde No. _____ Old Sonde No. _____

DO Membrane changed? YES NO Date Changed: _____ Membrane allowed to relax _____ hrs

Comments _____

Reference (Field) Meter(s)	Make/Model	Serial No.	Corr. Factor Applied?
Multi-Meter			None Yes No
Temperature			None Yes No
Conductivity			None Yes No
pH			None Yes No
Dissolved Oxygen			None Yes No
Turbidity (1)			None Yes No
Turbidity (2)			None Yes No
Other			None Yes No

COMMENTS/OBSERVATIONS:

Turbidity method codes are available at: http://water.usgs.gov/owq/FieldManual/Chapter6/6.7_contents.html

Modified from Wagner et al (2006)

Standard protocol for the operation and maintenance of a continuous water-quality monitor

1. Conduct site inspection
    - Record monitor readings, time and monitor conditions
    - With an independent field meter, observe and record readings and time near the continuous sensor(s)
2. Remove sonde from the monitoring location
3. Clean Sensors
4. Return sonde to the monitoring location
    - Record monitor readings and time
    - Using an independent field meter, observe and record readings near the sensor(s)
5. Remove sonde, rinse thoroughly, and check calibration
    - Record calibration-check values
    - Recalibrate if necessary (i.e. values are outside the calibration criteria)
6. Return sonde to monitoring location
    - Record monitor readings and time
    - Using an independent field meter, observe and record readings near the sensor

From Eureka Environmental Engineering Manta Water Quality Multiprobe Startup Guide

Eureka Manta instructions for cleaning, calibration and deployment

Cleaning: (see table on page 12 and 13 of Manta startup guide for specific instructions by probe type)
In general, wash housing and probe sensors with warm soapy water and a soft brush, use a soft lint-free cloth to wipe membranes dry.

General Calibration Procedures

1) Clean and perform routine maintenance if necessary.
2) Rinse sensors thoroughly (more than once may be required) with DI (deionized) water between calibrations. Shake the transmitter vigorously to remove traces of old calibration solutions – repeat if necessary.
3) Select a calibration standard whose value is near to your representative field sample. For example, if your pH is generally alkaline, choose pH 7 and pH 10.
4) Rinse the sensors twice with a small quantity of your calibration standard. Discard and do not reuse calibration standard.
5) Secure your Manta with the sensors pointing up, and fill the calibration cup as required to perform the calibration.
6) For best results, use fresh calibration solutions, and discard once they have been used.

Temperature

This sensor is factory calibrated and does not require calibration

Clark Cell Dissolved Oxygen (% Saturation Method)

If you have replaced the membrane, it is best to wait 24 hours before calibration.

1) Fill your calibration cup up to the level of the DO membrane with a tap water, DI water, your conductivity standard, or a pH standard. Contrary to other manufacturers, Eureka allows you to use high salinity standards during an air calibration.

2) With a paper towel, make certain the membrane is dry and free of water droplets.
3) Place the black rubber cal cup cover upside down over the calibration cup.
4) Wait approximately two minutes for the air to become fully saturated and the temperature to equilibrate. Make sure your circulator is turned off. Follow the calibration procedures on your Amphibian or on the desktop software.
5) DO % saturation also calibrates DO mg/L.
6) If you used pH buffer or Conductivity standard, add more to your cal cup and proceed to that calibration.

pH Calibration

pH is a two or three point calibration. Choose your calibration buffers to bracket the likely pH of your sample waters.

1) Rinse with a pH buffer, and then fill the calibration cup with enough buffer to cover both the pH glass bulb and reference.
2) Follow the instructions on your Amphibian or PC to perform the calibration.
3) Discard the buffer, rinse with second buffer. Add second buffer to cover pH glass and reference. Calibrate with second buffer.
4) Repeat steps 2 & 3 if you are performing a three point calibration.

Note – the order of pH buffers is not important, and using pH 7 buffer is not required.

Conductivity Calibration

This procedure calibrates specific conductance and salinity.

1) Fill the calibration cup to cover the conductivity sensor. Tap gently on the cup to make sure there aren't bubbles trapped in the conductivity sensor.
2) Follow the instructions on the Amphibian or Manta PC software to calibrate the sensors.

Depth Calibration

Depth is a one point calibration, which should be done in air to set the zero point.

1) Make sure there is no water in contact with the depth sensor. Shake it a bit if necessary.
2) Follow the instructions on the Amphibian or Manta PC software to calibrate the sensors.

The Manta Internal Battery Pack

The Manta with Internal Battery Pack includes 8 C-cell batteries inside a Manta 3 inch housing. Since every Manta has onboard memory, the batteries supply the power need for turning a Manta into a datalogger. There are basically four parts to Manta logging:

- Turning it on or off
- Changing the batteries
- Downloading data
- Changing the logging interval

Turning the Manta Logger ON or OFF

Loosen the stainless steel thumb screw on the top of the Manta. Rotate the on-off switch, and insert the thumb screw in the hole on the left of the picture.

You will notice that the lights will begin flashing on the Manta. It is waking up, looking at the time, and determining when to log a reading.

The Manta ships with a default interval of two minute warm-up and 30 minute interval. Therefore, if you turn it on at 17 minutes past the hour, it will wake up, and determine that it needs to go to sleep until 28 after the hour. It will then wakeup at 28 past, warm-up for two minutes, and log a reading. It will then enter sleep mode for 28 minutes.

Changing the Batteries

Turn the large knob on top of the Manta counter-clockwise until the entire top has worked its way off.

Top Cap

Remove the batteries. They will slide out. Replace batteries as indicated by the + / - indication stickers. It is recommended to use the same brand of batteries. Make sure each column is pointed in the right direction!

Downloading Data

1) Clean all contaminants from the Manta before downloading data – this helps protect the seals and connectors.
2) Remove the data-port knob on top by turning counter-clockwise until the lid is removed.
3) Plug the download cable into the download jack on the Manta and to your USB port on the computer
4) Launch the Manta Manager Software. Data will begin transfer automatically.
5) When complete, you can unplug the Manta.

Calibration

Calibrating is just the same as with any Manta. However, you will want to remove the batteries first – otherwise they will fall out! Use the Download cable and connect it to your PC's USB port. Launch the Manta Manager Software.

Changing the Logging Interval

See the Manta Manager software for a description of changing the logging interval or file-name.

attached with some moisture present (e.g., put wet sponge in calibrator cup or
place a small amount of DI water in cup).

SOP #3 Appendix D. Equipment Log Sheets

Water Resources Instrument Log

Date	Instrument	Operator	Instrument Spot Check (✓)		Calibration (note what parameter calibrated if more than one possible)	Comments
			In Range	Out Of Range (Calibrate)		

pHTestr Instrument Log (indicate pH Testr2 or Testr3 and ID #)

Name	Date	Buffer Changed (specify which buffer/s 4,7,or10)	Batteries Changed (specify which Testr)	Electrode Soaked in Buffer (✓)	Electrode Changed (specify which Testr)

YSI 85 Instrument Log

Name	Date	Membrane Change (✓)	Battery Change (✓)	DO Calibration	Conductivity cell cleaning	Conductivity cell spot check reading	Conductivity calibration

SOP #3 Appendix E. Technical Support Information

Instrument	Supplier	Technical Support
Turbidimeter	**HACH**	Steps to help: 1. Call the Hach Service line : (800) 227-4224 2. Choose the technical support and service menu option. When you speak to the service department on the phone, they will try to determine if you need to send the instrument in for servicing. If so, make sure to get a JOB NUMBER from them. Without this you will not be able to send the product in for service. They will also give you the name and contact info of a service technician who can help you.
YSI 30,55,85	**YSI**	EquipCo (Authorized Repair Center) 1 (800) 550-5875 2100 Meridian Park Blvd Concord, CA 94520 Or YSI 800-897-4151 937-767-7241 Fax:937-767-1058 E-mail: environmental@ysi.com
Flo-mate 2000 flowmeter	**Marsh-McBirney**	Service Department: Tel: 1 (800) 368-2723 Fax: (301) 874-2172 Email: service@marsh-mcbirney.com
pH, TDS Testrs	**OAKTON**	OAKTON Instruments P.O. Box 5136, Vernon Hills, IL 60061, USA Tel: toll free 1-888-4OAKTON (1-888-462-5866) Fax: (1) 847-247-2984 E-mail:info@4oakton.com http://www.4oakton.com (Call before 3 pm) New Electrode Sensors: Item # WD-35624-38 $58.25
pH Solution	**OSH** (Orchard Supply and Hardware), **Bens**, etc.	N/A
Eureka Manta	**Eureka Environmental Engineering**	Eureka Environmental Engineering 2113 Wells Branch Parkway, Suite 4400 Austin, TX 78728 Tel: 512-302-4333 Fax: 512-251-6842 E-mail: support@eurekaenvironmental.com

SOP #4 Quality Assurance Project Plan (QAPP)

4.1 Revision History Log

Prev. Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.0	February 16, 2005	Mary Cooprider	Table 4.10, few minor edits	Clarification of QA/QC measures	1.01
1.01	May 12, 2005	Mary Cooprider	Update tables and schedule	Preparation for technical peer review	2.0
2.0	August 3, 2005	Mary Cooprider	Minor edits and updates	Preparation for formal peer review	2.01
2.01	March, 2006	Rob Carson	Minor edits, updates to text and tables	Addressing peer reviewer comments	2.02
2.02	September, 2006	Rob Carson	Minor edits, inclusion of updated field forms	Availability of new USGS and WRD guidance; and changes to field forms	2.03
2.03	October 2006	Rob Carson	Minor Edits to MQO table and discussion of bias and % difference (PD)	Availability of updated WRD advise based on EDSC guidance	2.04

4.2 Acknowledgements

The preparation of this Quality Assurance Project Plan (QAPP) was funded by the National Park Service Water Resources Division. This QAPP is adapted from the Quality Assurance Management Plan (QAMP) for the San Francisco Bay Regional Water Quality Control Boards' Surface Water Ambient Monitoring Program (SWAMP) (Puckett, 2002). The content of the SWAMP QAMP is used frequently here. This QAPP follows the formatting and guidelines set forth by the California Department of Water Resources' *Guidelines for Preparing Quality Assurance Project Plans* (California Department of Water Resources, 1998). In addition, Golden Gate National Recreation Area's Crissy Field Restoration Program QAPP (Ward, 2004) was closely followed. Quality assurance guidelines and procedures for continuous water-quality monitoring equipment were taken from the most recent USGS techniques and methods paper (Wager,et al, 2006). In order to insure the highest level of data comparability within NPS park units, this QAPP mirrors the Crissy Field QAPP where applicable.

4.3 List of Acronyms for SOP #4

CMS	Client Matrix Spike
COC	Chain of Custody
CWA	Clean Water Act
DFG	Department of Fish and Game
DHS	Department of Health Services
DQO	Data Quality Objective
DWR	Department of Water Resources
ELAP	Environmental Laboratory Accreditation Program
EMAP	Environmental Monitoring and Assessment Program (EPA's)
LCS	Laboratory Control Spike
MDL	Method Detection Limit
PQL	Practical Quantitation Limit
QAMP	Quality Assurance Management Plan
QAPP	Quality Assurance Project
QA/QC	Quality Assurance/Quality Control
RDL	Reporting Detection Limit
RPD	Relative Percent Difference
RSD	Relative Standard Deviation
RWQCB	Regional Water Quality Control Board
SFEI	San Francisco Estuary Institute
SOP	Standard Operating Procedure
SWAMP	Surface Water Ambient Monitoring Program
SWRCB	State Water Resources Control Board
TMDL	Total Maximum Daily Load
UC	University of California
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey

4.4 Project Management

4.4.1 Distribution List

Table 0.1 QAPP Distribution List.

Name	Agency/Affiliation
Rob Carson, Water Quality Specialist	San Francisco Area Network
Brannon Ketcham, Hydrologist	Point Reyes National Seashore
Tamara Williams, Hydrologist	Golden Gate National Recreation Area
Darren Fong, Aquatic Ecologist	Golden Gate National Recreation Area
Marcus Koenen, I&M Coordinator	San Francisco Area Network
Denise Louie, Chief Natural Resources	Pinnacles National Monument

4.4.2 Project/Task Organization

This plan is intended to be a long-term monitoring plan. However, tasks and budget will be organized in five year increments. The plan will be managed and largely implemented by network (SFAN) personnel with assistance from park staff and technical expertise from the NPS Water Resources Division (WRD) and local experts where necessary (Table 4.2). Decisions regarding the I&M Water Quality Program development and long-term monitoring plan have been and will continue to be informally made by consensus of the SFAN Aquatic Professionals group. The I&M Water Quality Program will remain adaptive to changing park and network needs. This group consists of key network staff including the water quality specialist, network coordinator, park hydrologists and an aquatic ecologist. Broader-based, long-term decisions are approved by the NPS-WRD. These include approval of WRD-funded staff workplans and approval of the overall monitoring plan.

Table 0.2 Project Tasks and Responsibilities.

Name	Title/Responsibility
Rob Carson, Water Quality Specialist (SFAN)	Technical Lead, oversee collection of monitoring data and data management, coordinate report writing and protocol staff revision
Marie Denn, Aquatic Ecologist (PWR) Darren Fong, Aquatic Ecologist (GOGA) Brannon Ketcham, Hydrologist PORE) Tamara Williams, Hydrologist GOGA)	Aquatic Professionals Team, technical
Marcus Koenen, SFAN I&M Coordinator	Coordinate with water quality specialist reporting requirements, assist with peer review process
Dave Press, SFAN Data Management Lead	Assist with water quality data collection and validation; database uploading to WRD

4.4.3 Problem Definition/Background

"National Park managers are directed by federal law and NPS policies and guidance to know the status and trends in the condition of natural resources under their stewardship to fulfill the NPS mission of conserving parks unimpaired" (Welch, 2003). The mission of the National Park Service is:

> "*...to promote and regulate the use of the Federal areas known as national parks, monuments, and reservations hereinafter specified by such means and measures as conform to the fundamental purposes of the said parks, monuments, and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations* (National Park Service Organic Act 1916)."

"Recognizing the need to understand the condition of natural resources within the park system, a servicewide inventory and monitoring (I&M) program was established (NPS-75 1995; http://science.nature.nps.gov/im/monitor/nps75.pdf). The I&M program was given the responsibility to determine the nature and status of natural resources under NPS stewardship and to monitor changes in the condition of these resources over time. Information from inventory and monitoring efforts can then be incorporated into NPS planning, management, and decision making" (Welch, 2003).

In addition to the overarching NPS goal of resource stewardship, other policies and guidance are aimed specifically at maintaining or improving water quality. California's Porter-Cologne Water Quality Control Act and the federal Clean Water Act (CWA) direct water quality programs to implement protection and restoration of the integrity of State waters. Section 303d of the Clean Water Act lists all impaired waters. These are waters with compromised quality and/or limited use due to an excess of one or more pollutants. Related to this, the overarching Government Performance and Results Act (GPRA) goal for water quality is that "…99.3% of streams and rivers managed by NPS will meet State and Federal water quality standards". Impaired water bodies in SFAN are listed in Table 4.3. Primary SFAN water quality issues include agricultural operations (dairy and beef cattle ranching, vegetable farming, viticulture, mariculture), recreational use (beaches, stable operations, dog walks), erosion and sedimentation, and water supply (flooding, overwithdrawal).

Table 0.3 Impaired water bodies in the SFAN.

Water body	Park Unit	Pollutant
Coyote Creek	GOGA	Diazinon
Lagunitas Creek	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	GOGA	Diazinon, Sediment
San Pedro Creek	GOGA	High Coliform
Tomales Bay	PORE, GOGA	Pathogens, Sediment, Nutrients, Mercury

The primary objectives of this monitoring program are to 1) Maintain waters that vary within their natural chemical and biological ranges and meet applicable federal and state water quality criteria, 2) Improve the water quality of impaired waters, and 3) Maintain high water quality where it exists.

Based on these objectives, monitoring data from this program will be used to answer the following 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?

4.4.4 Project/Task Description

4.4.4.1 Quality Assurance

The SFAN Water Quality Monitoring Program has been developed and will be implemented with the objective of collecting high quality monitoring data that could be of the most use to the National Park Service, U.S. Geological Survey, and California and San Francisco Bay Area monitoring programs. A technical panel of aquatic resource specialists will be consulted regarding QA/QC measures and plan implementation.

4.4.4.2 Data Management, Data Evaluation, and Reporting

Data management, evaluation, and reporting will be high priorities of SFAN. The NPSTORET database will be the central depository of all data collected by SFAN. The SFAN version of NPSTORET will be sent annually to the WRD. NPSTORET Templates are designed to capture all critical field information for uploading data and required meta-data into STORET. These templates should be used whenever feasible to do so as that should streamline the data management process significantly. The discussion of this data management system and links to

example NPSTORET templates may be found at www.nature.nps.gov/water/infoanddata. Alternatively, and electronic data deliverable file (EDD) may be generated but it should capture all the ancillary information and meta-data that the NPSTORET templates would.

It is the goal of the SFAN data management program to ultimately provide standardized data management, evaluation, and reporting. It is also a goal of SFAN to be as "paperless" as possible, and to develop a database that will allow internet web access to all parties interested in the data and technical reports produced through SFAN studies. SFAN will include the use of existing data to the extent that it can be verified and placed or linked into centralized locations, but such "outside data" shall not be a part of the official SFAN database at this time. A summary of the NPSTORET data base is included in the protocol narrative of the overall water quality monitoring plan.

Table 0.4 Project Task Extended Timetable.

Deliverables	**FY06**	**FY07**	**FY08**	**FY09**	**FY10**
Develop QAPP	X				
Meet with local technical experts to review monitoring protocol	X				
Finalize protocol and have peer reviewed	X				
Conduct equipment inventory and calibration, purchase any needed equipment	X	X			
Collect monitoring data		X	X	X	X
Produce annual summary report		X	X	X	X
Share results with parks and scientific community at annual "Water Quality Forum"		X	X	X	X
Produce comprehensive data analysis and synthesis (trends) report					X

Table 0.5 Overall 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 for five consecutive weeks in winter and summer

4.4.5 Data Quality Objectives (DQOs) and Criteria for Measurement Data

DQO's are qualitative and quantitative statements of the quality of data needed to support specific decisions or actions. Data acceptability criteria are included in DQOs. The purpose of DQOs is to document 1) the intended use of the data in order or importance, 2) decision to be made when data are obtained, and 3) decision makers who will use the data (California Department of Water Resources, 1998). Decision makers for SFAN will generally be the same for each parameter. Recommendations will be developed by network staff and park aquatic professionals. These recommendations in the form of annual reports or summaries will be made to managers such as Resource Management Chief's and Park Superintendents. Other decision makers may include local agencies and landowners. All data including core parameters, bacteria, nutrients, and sediment have the same intended uses since they all help identify pollution sources and areas of concern with respect to aquatic health and other beneficial uses.

Table 0.6 Data utilization and Related Management Decisions.

Parameter	Intended use of data	Relevant Management Decision
Core parameters	Determine the natural variation and range in water quality parameters. Analyze data from control sites or reference streams; analyze annual, seasonal, and daily data for each station and each group of stations in a stream or watershed	If results are unexpected (i.e., out of normal range), choose different reference, or "control" sites or pursue geological and other studies that would help explain the variability
Core parameters	Determine the long-term trends in water quality parameters. Analyze data from all sites. Analyze annual and seasonal data for each station and for each group of stations in a stream or watershed.	If data trends point to problems (e.g., consistent decline in D.O., or consistent increase or decline in pH or temperature) check data with surrounding areas, compare with local and regional climate data, compare data with other indicators (e.g., air quality)
Core parameters, nutrients, bacteria, sediment	Determine if water bodies are meeting water quality criteria. Determine the level of compliance with beneficial uses. Focus on sites known to be impaired; analyze data for each site for each group of stations (collectively) in a stream.	Determine what level of compliance is acceptable (e.g., 100% of stations meeting the criteria 90% of the time); adapt monitoring strategy if necessary to focus on stations that do not meet criteria
Core parameters, nutrients, bacteria, sediment	Determine the sources of water quality degradation within park watersheds. Compare data from individual sites from one sampling event to another; also compare data from multiple sites within a stream. Provide data to local agencies (where appropriate and not for regulatory purposes) and landowners	Make decision on how to present data and work internally with other park divisions where applicable, with local landowners, and with agencies to alleviate problems; work with local groups on implementation strategies related to the BMPs
Core parameters, nutrients, bacteria, sediment	Determine if management actions are improving water quality. Compare data from individual sites from one sampling event to another; also compare data from multiple sites within a stream. Provide data to local agencies (where appropriate)	Continue management action if effective and use to encourage additional use of BMP; improve or change BMP,

Goals For Achieving Data Quality Objectives (DQO's)

Data quality objectives will be achieved in a number of ways including:

- Developing standard operating procedures (SOP) with standardized field and laboratory methods,
- Forming and convening a SFAN External Scientific Planning and Review Committee which will serve to bring together scientists that are "external" to the NPS as well as internal to provide on-going peer review of all SFAN water quality monitoring activities, with QA oversight being one of the primary focuses; and
- Documenting the comparability of laboratory and field methods that are consistent with the DQO's.

The intent is to provide 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 major goal that this SFAN QAPP (SOP 4) can accomplish, is to have representative, comparable, accurate and precise data that can be shared statewide and nationwide, to the extent possible. Refer to Table 4.7 below to see a summary of SFAN data quality assurances.

The following SOPs were completed as part of the DQO process:

SOP 1: Revising the Protocol
SOP 2: Personnel Training and Safety
SOP 3: Equipment and Field Preparations
SOP 4: Quality Assurance Project Plan (QAPP)
SOP 5: Field Methods for Measurement of Core Parameters
SOP 6: Field Methods for Sampling Nutrients
SOP 7: Field and Laboratory Methods for Sampling Bacteria
SOP 8: Field and Laboratory Methods for Sediment
SOP 9: Field Methods for Measuring Flow
SOP 10: Data Analysis
SOP 11: Data Reporting
SOP 12: Site Selection and Documentation

These SOPS are in Appendix H of the Freshwater Quality Protocol Narrative ("protocol narrative"). The generally accepted goal at least for the first several years of the "start-up" of the SFAN Water Quality Monitoring Program is to ***"standardize where possible; document otherwise"***. The need for flexibility to accommodate park-specific sample collection needs was acknowledged, along with the need to standardize methods to the extent possible. Data quality will be attained by maximizing and documenting the accuracy and precision of the methods used. Any changes in procedures due to equipment changes or to improved precision and accuracy will be documented. Wherever possible, there should be overlap in sampling methods as well as overlap of staff when turnover occurs. Data quality objectives include

representativeness, comparability, completeness, and precision. These are discussed further below (*from* Puckett, 2002):

Representativeness

The representativeness of the data is mainly dependent on the sampling locations and the sampling procedures adequately representing the true condition of the named target population at the sample site(s). Requirements for selecting sample sites are discussed in more detail in the protocol narrative. Selection of appropriate sample sites and the use of only approved/documented analytical methods will ensure that the measurement data does represent the conditions at the investigation site, to the extent possible. Assuring representiveness of the data for the site and times sampled 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 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 eventually 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.

Comparability

The comparability of data produced by SFAN is predetermined by the commitment of its staff and contracted laboratories to use standardized methods, where possible, including USGS field methods and U.S. Environmental Protection Agency (EPA) approved analytical methods, or documented modifications that provide equal or better results. These methods have specified units in which the results are to be reported. For internal data comparability,

the SOP's of the SFAN Freshwater Quality Monitoring Protocol carefully describe the methods to be followed during water quality sampling. If followed carefully, these should provide the methodological and temporal consistency that will ensure internal data comparability. This includes such discussions as training, overlap of sampling methods when equipment, personnel or methods change, and documentation of bias between old and new methods. The comparability of SFAN data to the data collected by outside entities from the state to consultants and volunteers will depend on the documentation of methodologies and QA/QC practices of these groups. The project manager will meet with outside project leaders to determine and document methodologies of outside projects. 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 specifications for precision, bias and sensitivity.

Because the state was involved in discussions through guidance and review of this protocol, data collected as part of SFAN water quality monitoring activities should be directly comparable to the state-collected data. Regular consultation with outside monitoring groups will establish and/or maintain a high level of comparability wherever possible. All contracted labs will use standardized methods and will be NELAP or CA ELAP-certified.

Table 0.7 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). • Systematic verification of data in the database, as well as periodic review of stated procedures and included documentation (SOP's). • 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. • 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. • All methods used for laboratory samples will follow Standard Methods using APHA/AWWA/WEF methods or comparable EPA methods. • Laboratory QC measures will include matrix spikes, method blanks, calibration standards, lab and field-duplicated samples.

Data Comparability Issue	SFAN Data Quality Assurance
Sensitivity	• For lab parameters: Calculation of both Method Detection Limit (MDL) and Minimum Level of Quantitation (ML). • 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). • For Lab Measurements: Duplicate analysis of 10% of samples. Report the Relative Percent Difference (RPD).
Bias	• Maintain consistent personnel and methodology where possible. • 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. • Analyze such overlapping samples to determine the contribution of bias (if any) to any variance in the data. • Control bias by: Use and analysis of "blank" samples (Field, Trip or Lab Blanks) to determine contamination by methodology. • 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 4.10.
"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.

Completeness

The completeness of data is basically a relationship of how much of the data is available for use compared to the total potential data before any conclusion is reached. Ideally, 100% of the data should be available. However, the possibility of data becoming unavailable due to laboratory error, insufficient sample volume, or samples broken in shipping must be expected. Also, unexpected situations may arise where field conditions do not allow for 100% data completeness.

- Therefore, 90% data completeness is required for data usage in most cases.

Precision and Accuracy

The precision and accuracy of data are determined by particular actions of the analytical laboratory and field staff. The precision of data is a measure of the reproducibility of the measurement when an analysis is repeated. It is reported in Relative Percent Difference (RPD) or Relative Standard Deviation (RSD). The accuracy of an analysis is a measure of how much of the constituent actually present is determined. It is measured, where applicable, by adding a known amount of the constituent to a portion of the sample and determining how much of this spike is then measured. It is reported as Percent Difference. The acceptable percent deviations and the acceptable percent recoveries are dependent on

many factors including: analytical method used, laboratory used, media of sample, and constituent being measured.

It is the responsibility of the program manager (water quality specialist) to control the precision and accuracy of the field data, while verifying that the data are representative. For samples that undergo laboratory analysis, the analytical data's precision, accuracy, and comparability are mainly the responsibility of the laboratory. The program manager also has prime responsibility for determining that the 90% data completeness criteria are met or for justifying acceptance of a lesser percentage.

Laboratories performing the analysis of samples for this project have developed precision and accuracy limits for acceptability of data. For parameters and matrices which have EPA established criteria, the limits are either equal to, or more stringent than, the established limit. In no case will measurement quality objectives for precision and bias be less stringent than marine EMAP recommendations.

4.4.6 Special Training/Certification

Field

Proper training of field personnel represents a critical aspect of quality control. Details of staff training are presented in SOP 2. Safety issues related to water quality work are presented in SOP 2; all field staff will be well-versed in this SOP. . The USGS offers a comprehensive two-week training course in field methods entitled "Field Water-Quality Methods for Ground Water and Surface Water" for hydrologic field technicians. This training is available for NPS staff when slots are available. The WRD may be a resource for locating and scheduling such training for staff.

NPS staff downloading continuous loggers and collecting all other water quality data have either already been trained by other NPS staff or will be trained before plan implementation. Scientists at PORE and GOGA have been conducting water quality related activities for several years and can provide training if necessary to network staff. However, the water quality specialist is expected to be independent and knowledgeable in chemistry and water sampling techniques.

All technical staff involved in data collection will have educational background in biological or physical sciences. The network water quality specialist will have specialized experience in water quality or closely related aquatic resource. Where necessary (e.g., with staff turnover, adoption of new methods, etc.) local technical experts (universities/agencies) will be called upon for training assistance. Familiarity with GPS navigation will also be a qualification (or training will be provided). First Aid and CPR training are highly recommended. Boater certification will not be needed at this time. Field personnel will receive training in a variety of discharge (flow) measurement methods (e.g., low flow, high flow bridge-deployed).

Field personnel will be evaluated on their field performance during field QA audits conducted by the SFAN water quality specialist and other park aquatic professionals. Field performance audits

are recommended every two years, or more often if necessary. If any deficiencies within a crew are noted during this QA audit, they will be documented and remedied prior to continued field sampling. This can be accomplished by additional training or by changing personnel, but verification of correction of any deficiencies must be documented in writing prior to the resumption of further sample collection activities.

Laboratory

Meetings, whether by phone or in person, will be held with the laboratory (-ies) at regular intervals to review QA/QC procedures and make recommendations for future revisions to the SFAN QAPP. The more frequent the interactions with laboratory staff the better the understanding of any key issues or correction of problems will be. Issues such as timing of sample transport and analysis and lab capability and capacity for samples are important to QA/QC data completeness objectives.

4.4.7 Documentation and Records

- All field data gathered will be recorded on standardized field data entry forms that include metadata to be entered into the NPSTORET database.
- Data will be scanned upon receipt from laboratory and during and immediately after field measurements (this is also true of data from data loggers such as turbidity sensor, pressure transducer, or multiparameter mini-sonde data).
- Data will be more thoroughly 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.
- Field data will not be entered into the database until laboratory results have arrived.
- Field and laboratory data sheets will be copied and stored in a "data to be entered" folder.
- Original copies of datasheets and laboratory chain of custody forms will be stored in the SFAN Water Quality Monitoring Program Office in the Marin Headlands (GOGA).
- SFAN data managers will work with the SFAN hydrologic technician to ensure that data is well-understood and entered into the proper fields in NPSTORET.
- 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. Each datasheet will be initialed and dated by the person entering the data.
- A different individual than the one that entered the data will verify the datasheet information against the database.
- Data will also be validated; during this process questionable data are identified, reviewed, and corrected if necessary.
- After data entry, verification, and validation, copies will be retained by the person entering the data for one year. After that time or another appropriate time, data will be archived.

Sample datasheets are included in the Appendix A of this document. Chain of custody forms vary depending upon the laboratory. Reporting of results including summary charts and reports are explained in more detail in the Water Quality Protocol Narrative.

4.5 Data Generation and Acquisition

4.5.1 Sampling Process Design (Experimental Design)

Table 0.8 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	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	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	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	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	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)

Stream	Park	Parameters	Frequency	Personnel	Protocols
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)
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	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; 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 for Olema, Pine Gulch, Redwood, Tennessee Valley, Rodeo, Franklin, and Chalone Creeks

4.5.2 Sampling Methods

All measurements and sampling associated with monitoring activities will be conducted according to the SOPs outlined in the protocol narrative. If there is a change in the protocol such as a change in sampling method, equipment, or staff, then there will be overlap of methods and personnel where possible (see SOP 1: Methods for Protocol Revision).

4.5.3 Sample Handling and Custody Requirements

Proper sample handling procedures for water, sediment, and biological samples are provided in Table 4.8. This table provides a summary of recommended sample containers, sample volumes, initial preservation, and maximum storage times for water samples. In the field, all samples will be packed in frozen ice packs during shipment, so that they will be kept at approximately 4˚C. Samples will be shipped in insulated containers. All caps and lids will be checked for tightness prior to shipping. All samples will be handled, prepared, transported and stored in a manner so as to minimize bulk loss, analyte loss, contamination or biological degradation. Sample

containers will be clearly labeled with an indelible marker. Where appropriate, samples may be frozen to prevent biological degradation. Water samples will be kept in glass or plastic bottles and kept cool at a temperature of 4˚C until analyzed.

Table 0.9 Summary of Sample Handling Requirements.

Analyte	Sample Container	Minimum Sample Volume/Typical Sample Volume	Holding Time	Preservation
Total Kjeldahl Nitrogen (TKN)	Plastic bottle	600 mL	Recommend: 7 days; Maximum: 28 days	Cool to 4°C
Nitrate and Nitrite	Plastic bottle	125 mL/150 mL	48 hours	Cool to 4°C
Ammonia	Plastic bottle	125 mL/500 mL	48 hours 28 days with preservative	Sulfuric acid preservative, Cool to 4°C
Fecal & Total Coliform	125 ml sterile plastic (high density polyethylene or polypropylene) container	100 ml volume sufficient for both fecal and total coliform analyses	6 hours at 4°C, dark for regulatory data use; lab must be notified well in advance. Possibly 24hr hold time at 4C dark, if non-regulatory data use.	Sodium thiosulfate is pre-added to the containers in the laboratory (chlorine elimination). Cool to 4°C; dark.
Suspended Sediment Concentration (SSC) or Total Suspended Solids (TSS)	500 ml clean plastic bottle	500 ml (one bottle)	7 days	Cool to 4°C
Turbidity	glass vial	15 mL	NA	NA

4.5.3.1 Laboratory Custody Log

Laboratories chosen will be National Environmental Laboratory Accreditation Program (NELAP) certified (or CA ELAP-certified) and this is discussed further in the protocol narrative. Therefore, they are expected to follow standard procedures. Laboratories will maintain custody logs sufficient to track each sample submitted and to analyze or preserve each sample within specified holding times.

4.5.3.2 Field Log

The following items will be recorded on data sheets for each sampling station:

- Time of sample collection;
- Sample ID numbers,
- The results of any field measurements (temperature, D.O., pH, conductivity, turbidity) and the time that measurements were made;
- Qualitative descriptions of relevant water conditions (e.g. color, flow level, clarity) or weather (e.g. wind, rain) at the time of sample collection;

- A description of any unusual occurrences associated with the sampling event, particularly those that may affect sample or data quality.

Field personnel will have custody of samples during field sampling. Chain of custody forms will accompany all samples during transport/shipment to the contract laboratories. Field personnel will enter sampling time and other relevant data on the chain of custody forms. All water quality samples will be transported to the analytical laboratory directly by the field crew or by overnight courier. See Appendix A for field data sheets. Chain of custody forms vary depending on the laboratory.

4.5.4 Analytical Methods Requirements

Detection limits may be affected by instrument sensitivity or by bias due to contamination or matrix interferences. Common laboratory practice is to adjust detection limits upward in cases where high instrument precision (i.e., low variability) results in calculated detection limits that are lower than the absolute sensitivity of the analytical instrument. In these cases, best professional judgment is used to adjust detection limits upward to reduce false positives and values below the detection limit are not reported. In all cases, results cannot be reported for values less than the Method Detection Limit (MDL). Most MDLs are considerably lower than water quality objectives and provide the foundation for having a high level of certainty in the data (Puckett, 2002).

Data below or beyond an MDL will not be presented numerically. Data falling between the MDL and minimum level of quantitation (ML) are considered detected but not quantifiable and can be given a result of Present, below quantification level. The ML is equal to the MDL multiplied by 3.18 (or some number between 2 and 10 that may be determined by the analytical laboratory). (Irwin, 2006). See the section “Preparing the Raw Data Set for Analysis” in SOP #10 (data analysis)

The SFAN Water Quality Monitoring Program will follow recommendations in the recent Helsel (2005) book for recommended use of detection and quantification limits:

We will not report into a database any value higher than the MDL but lower than the ML. Instead, the detection condition field is set to "Present, below Quantification Limit". With that detection condition, STORET automatically enters "*Present <QL" in the result field. (A major advantage of this approach is that no "estimates" are treated as quantitative when in fact they are not quantitative.) In (eventual) statistical analyses, values between the MDL and ML are best interpreted using either an interval-censored method (parametric), or a rank-based method (nonparametric) where all in-between values are represented as the same tied rank. The older recommendation of censoring to half the MDL is clearly no longer recommended. Helsel (2005) also gives recommendations for how not to report into data bases (for example, never report single values below the MDL or even the ML, and do not report nondetects as half the detection limit. One should also not report nondetects as a negative (“-“) sign followed by the actual MDL value, because someone invariably decides it really is a negative number

In Summary:

- Values below the Method Detection Limit (MDL) are to be reported as a (<) sign followed by the actual MDL value, and flagged with an ND = not detected.
- Values between the MDL and the ML (or quantification limit) should be reported as "*Present, below Quantification Limit".
- Values above the ML (or quantification limit) are deemed as acceptable values without reservation, and are shown as the actual measured value, and assigned a QA code of A (acceptable without reservation).

In general, laboratories should strive to meet target reporting limit recommendations for undetected analytes. In those cases where high concentrations of some analytes require analysis of a diluted sample and the dilution results in non-detects for other analytes, analysis of the sample at several different dilutions may be required to meet program detection limits as fully as practical. Table 4.9 lists analytical methods and measurement quality objectives (MQOs) for all water quality parameters except flow. In addition to the MDL, these include precision, and systematic error/bias/percent recovery. Details of QA/QC for flow measurements will be outlined in a separate protocol.

Table 0.10 Measurement Quality Objectives.

Parameter	**Instrument or Method**	**Precision (RPD of duplicates)**	[1] **Measurement Systematic Error (% recovery)**	[2]**Alternative Measurement Sensitivity (AMS)**	**Method Detection Limit**	[3] **Minimum Level of Quantitation (ML)**
pH	Oakton pH testr 30	± 0.1 units	95-105% (5% PD)	***	0.01 pH	0.0318 pH
Dissolved oxygen	YSI 85	± 0.3 mg/L	95-105% (5% PD)	***	0.01mg/L	0.0318 mg/L
Salinity	YSI 85	± 2% or ±0.1 ppt	5% PD%	***	0.1 ppt	0.318 ppt
Temperature	YSI 85	± 0.2 ^{0}C	95-105% (5% PD)	***	0.1^{0}C	0.318 ^{0}C
Specific Conductance or Conductivity	YSI 85	± 5 uS/cm or ± 3% of the measured value, whichever is greater	95-105% (5% PD)	2.5 µS/cm	0.1 µS/cm	0.318 µS/cm
Total Kjeldahl Nitrogen	SM 4500 EPA 300	±30%	90-110% (5% PD)	0.5 mg/L (Puckett, 2002)	0.1 mg/L	3.18 x MDL
Nitrate as N	SM 4500 EPA 300	±30%	90-110% (10% PD)	0.01 mg/L	0.1 mg/L	3.18 x MDL
Nitrite as N	SM 4500 EPA 300	±30%	90-110% (10% PD)	0.01 mg/L	0.05 mg/L	3.18 x MDL
Ammonia-Nitrogen	SM 4500F	±30%	90-110% (10% PD)	0.1 mg/L	0.1 mg/L	3.18 x MDL
Fecal	SM 9221B	±60%	See Note[6]	To be	2	3.18 x MDL

Parameter	Instrument or Method	Precision (RPD of duplicates)	[1] Measurement Systematic Error (% recovery)	[2]Alternative Measurement Sensitivity (AMS)	Method Detection Limit	[3] Minimum Level of Quantitation (ML)
coliforms[4]				calculated	MPN/100 mL	
Total coliforms[4]	SM 9221	±60%	See Note[6]	To be calculated	2 MPN/100 mL	3.18 x MDL
Total Suspended Solids	SM 2540D	30%	90-110% (10% PD)	0.5 mg/L	0.5 mg/L	3.18 x MDL
Turbidity	Hach 2100 turbidity meter	±2 NTU or ±5 % of the measured value, whichever is greater (USGS) ± 2% (Hach)	90-110% (10% PD)	0.5 NTU (Puckett, 2002)	0.01 NTU	3.18 x MDL

[1] Often referred to as accuracy

[2] Formerly referred to as the Reporting Detection Limit; AMS is the measurement precision uncertainty based on a sample size of seven environmental samples (not blank) and 99% confidence (Irwin, 2004). This should be calculated at the beginning of the field season, during the winter (high flow) and at the end of the field season.

[3] Formerly referred to as Practical Quantitation Limit (PQL) and the Limit of Quantification (LOQ) in the SWAMP QAMP (Puckett, 2002). The ML is generally the MDL multiplied by 5 (or some number between 1-10 that may be determined by the analytical laboratory). See: http://www.epa.gov/waterscience/methods/det/rad/rad.pdf

[4] The bacteria detection limit is 2-1600 (20-16,000, etc. if dilutions are needed). This detection limit is consistent with the California Regional Water Quality Control Board's Surface Water Ambient Monitoring Program (Puckett, 2002).

[5] MDLs for nutrients are those recommended by the San Francisco Bay Regional Water Quality Control Board (Peter Krottje, personal communication, June 2005).

[6] Measurement Systematic Error for bacterial parameters requires the addition of a known concentration of bacteria to a sample to measure percent recovery. This spike will be acheived using IDEXX QA/QC kits and will be repeated with each new lot # of trays or reagent. With this data we hope to establish a % recovery objective that is comparable with the EPA advice of 84-116%.

Citations for MQOs:

- Precision obtained from USGS (Wagner et al., 2000) and YSI 85, Oakton, and Hach manuals
- Measurement Systematic error, % recovery numbers obtained from the laboratory and WRD guidance.
- MDLs obtained from SWAMP QAMP (Puckett, 2002), Crissy Field Restoration QAPP Ward, 2004), and the YSI 85 Manual
- Use EPA's EMAP http://www.epa.gov/emap/nca/html/docs/c2k_qapp.pdf
- MLs (formerly PQLs) are calculated as 3.18 x MDL

4.5.5 Quality Control Requirements

4.5.5.1 Laboratory Quality Control Requirements

There is a broad range in the quality of waters within SFAN. For more pristine waters (those in wilderness areas), it is critical that laboratories be able to provide low-level detection of pollutants. Some of the approaches required will include laboratory matrix spikes, laboratory method blanks, calibration standards, laboratory- and field-duplicated samples, and others as appropriate. The definition and use of each of these types of quality control samples are explained further below (Puckett, 2002).

Laboratories providing analytical support for chemical or biological analyses will have the appropriate facilities to store, prepare, and process samples and appropriate instrumentation and staff to provide data of the required quality within the time period dictated by the project (Puckett, 2002).

Laboratories will be able to provide information documenting their ability to conduct the analyses with the required level of data quality. Such information might include results from interlaboratory calibration studies, control charts and summary data of internal QA/QC checks, and results from certified reference material analyses and/or spikes (Puckett, 2002). Laboratories should provide a laboratory QA plan, SOPs, Analytical Methods Manual, Instrument Performance Information, and Control Charts.

Measurement Quality Objectives (MQOs)

Some MQOs and quality control checks are defined below (*from* Puckett, 2002):

Completeness

Data completeness is the amount of data collected compared against the expected amount. SFAN will strive for at least 90% data completeness.

Precision criteria

Precision is the reproducibility of an analytical method. Each laboratory is expected to maintain control charts for use by analysts in monitoring the overall precision of the CRM (Certified Reference Materials) or LCM. Upper and lower control chart limits (e.g., warning limits and control limits) will be continually updated; control limits based on 99% confidence intervals around the mean are recommended. The relative standard deviation (RSD) will be calculated for each analyte of interest in the CRM based on the last 7 CRM analyses.

Laboratory Replicates for Precision

A minimum of one field sample per set of SFAN water samples submitted to the laboratory will be processed and analyzed in duplicate to determine precision. The relative percent difference among duplicate samples (RPD expressed as percent) will be less than the targets in the Precision column in Table 4.10. We will use RPDs to be consistent with 2006 Environmental Data Standards Council (EDSC) standardized calculations for precision (http://www.envdatastandards.net/content/article/detail/646).

In cases where three of more samples are used to estimate precision, for example long term precison over time, the relative percent difference (RSD) will be calculated as the CV x 100%.

A laboratory control spike (LCS) and duplicate (LCSd) will be analyzed to determine percent recovery of each specific method. In addition, the State of California ELAP requires that 1 in 20 samples have a CMS, or client matrix spike. Therefore, in addition to the laboratory spikes, the client's samples are also spiked. However, CMS' are not conducted for bacteria samples (Mark Valentini, personal communication, December 2004).

Laboratory Method Blank

Laboratory method blanks (also called extraction blanks, procedural blanks, or preparation blanks) are used to assess laboratory contamination during all stages of sample preparation and analysis.

Surrogates

Surrogates are compounds chosen to simulate the analytes of interest in organic analyses. Surrogates are used to estimate analyte losses during the extraction and clean-up process and must be added to each sample, including QA/QC samples, prior to extraction.

Bias Calculations for CRMs and Spikes

In 2006, the Environmental Data Standards Council (EDSC, an interagency group including EPA, States and Tribes) standardized the basic calculation and terminology definitions for bias using percent differences (PDs, rather than % recovery, see document at: http://www.envdatastandards.net/content/article/detail/646). We will do the same to be consistent with this recent guidance, which uses the correct (NIST/ISO compliant) terminology (bias rather than accuracy). The equation the EDSC give for Percent Different calculations is: PD = [Y - X) / X] * 100, where X is the known (usually "correct" or "expected") or spiked amount, and Y is the measured concentration. To be consistent with SWAMP and other agencies, we may also calculate % recoveries as another way to look at bias. Additional Detail on Spikes:

Matrix Spike and Matrix Spike Duplicate

A laboratory fortified sample matrix (commonly called a matrix spike, or MS) and a laboratory fortified sample matrix duplicate (commonly called a matrix spike duplicate, or MSD) will be used both to evaluate the effect of the sample matrix on the recovery of the compound(s) of interest and to provide an estimate of analytical precision. Recovery is the accuracy of an analytical test measured against a known analyte addition to a sample.

Travel Blanks

The purpose of the travel blank is to determine if there is any cross-contamination of volatile constituents between sample containers. Travel blanks are not required for other analytes, but are encouraged to be utilized for other analytes as possible and appropriate.

Field Duplicates
Duplicate samples will be collected for all parameters at an annual rate of 5% of total samples to be collected within a given year's monitoring plan. The duplicate sample will be collected in the same manner and as close in time as possible to the original sample. This effort is to attempt to examine field homogeneity as well as sample handling, within the limits and constraints of the situation. The precision for determining precision of field duplicates is described in SOP #10-Data Analysis.

Field Blanks
A field blank is designed to assess potential sample contamination levels that could occur during field sampling and sample processing. Field Blanks (DI water) are taken to the field, transferred to the appropriate container, preserved (if appropriate), and otherwise treated the same as the corresponding sample type during the course of a sampling event. Field blanks are to be collected at a 5% rate for the following nutrient and bacteria samples. Field blanks for other analytes should be conducted upon initiation of sampling, and if field blank performance is acceptable, further collection and analysis of field blanks for these other media and analytes need only be performed on an as-needed basis, or during field performance audits.

Copies of laboratory QA/QC work will be included with analytical results and kept on file

Table 0.11 QA protocols.

Measurement Parameter	QA Protocol
*Total Kjeldahl Nitrogen	Duplicates 10% of samples, lab matrix spike
*Nitrate as N	Duplicates 10% of samples, lab matrix spike, Field Blank, Trip Blank
*Nitrite as N	Duplicates 10% of samples, lab matrix spike, Field Blank, Trip Blank
*Nitrate + Nitrite	Duplicates 10% of samples, lab matrix spike, Field Blank, Trip Blank
*Ammonia	Duplicates 10% of samples, lab matrix spike, Field Blank, Trip Blank
*Fecal coliforms	Lab and field duplicates, Field Blank, Trip Blank
*Total coliforms	Lab and field duplicates, Field Blank, Trip Blank
*Total Suspended Solids	Lab and field duplicates, Field Blank, Trip Blank
	Equipment blanks
Turbidity	

*Also refer to laboratory QA manuals for lab parameters

4.5.6 Instrument/Equipment Testing, Inspection, and Maintenance Requirements

To minimize or avoid downtime of measurement instruments, all field sampling and laboratory equipment will be maintained in good working order. Also, spare equipment or common spare parts (e.g., batteries, D.O. membranes, and pH electrodes) will be available so that repairs or replacement can be made as quickly as possible and measurements will not be lost. All field equipment having manufacturer-recommended schedules of maintenance will receive preventive maintenance according to that schedule (see Table 4.11). Other equipment used only occasionally will be inspected at least monthly. After use in the field, all equipment will be re-checked for needed maintenance.

4.5.7 Instrument Calibration and Frequency

An instrument or device used in obtaining an environmental measurement must be calibrated by the measurement of a standard. Every instrument or device has a specialized procedure for calibration and a special type of standard used to verify calibration. See instrument manuals for further details. A log book will be kept to record dates of calibration and any equipment errors or failures, battery changes, changes of calibration solutions, and repair notes. The log book will also contain calibration methods, this schedule of inspections and calibrations, and a list of needed supplies and equipment. When a change in equipment occurs, overlapping measurements will be made using both the old and new equipment in order to document precision in reproducibility.

Table 0.12 Routine Instrument Inspections and Calibrations.

Parameter	**Calibration Frequency**	**Acceptance Criteria**	**Corrective Actions**
Temperature Liquid-in-glass thermometer:	Every 3 to 6 months, using a 2-point calibration check, and annually, using a 3-point calibration check 10% of the readings taken each day must be duplicated, or a minimum of 1 reading if fewer than 10 samples are read.	±1.0 ºC	Re-test with a different thermometer; repeat measurement
Temperature Thermistor thermometer:	Every 3 to 4 months, check calibration, annually, using a 5-point calibration	Same as above	Re-test with a different thermometer; repeat measurement
Specific Conductance	Prior to field mobilization, at the field site, and calibration check at day's end; 10% of the readings taken each day must be duplicated or a minimum of 1 reading if fewer than 10 samples are read.	±5%	Re-test; check low battery indicator; use a different meter; use different standards; repeat measurement

Parameter	Calibration Frequency	Acceptance Criteria	Corrective Actions
Dissolved oxygen	Prior to field mobilization, at the field site, and calibration check at day's end	±10%	Re-enter altitude; re-test; check low battery indicator; check membrane for wrinkles, tears or air bubbles; replace membrane; use a different meter; repeat measurement
Eureka Manta Multiprobe datalogger	Beginning and end of each deployment	See manual	
pH meter	Prior to field mobilization (three point calibration using buffer solutions (pH 4,7, and 10))	±0.2 pH unit;	Re-test; check low battery indicator; use different standards; repeat measurement
	At the field site, and calibration check at day's end (one point calibration)	±0.2 pH unit	
	10% of all reading taken each day must be duplicated or a minimum of 1 reading if fewer than 10 samples are read.	RPD ±0.1 pH unit	
Flow meter (velocity meter)	Prior to field mobilization, before each sampling run; some flow meters required and annual calibration by the manufacturer		

-All instrument should be visually inspected before use
-Check batteries before use
-Rinse all equipment after use
-Insure that pH electrodes and D.O. membrane remain moist

4.5.8 Inspection/Acceptance Requirements For Supplies And Consumables

Not Applicable.

4.5.9. Data Acquisition Requirements (Non-direct Measurements)

Water quality monitoring data from sources other than this WRD-funded monitoring plan will not be entered directly into the SFAN version of NPSTORET. However, other monitoring entities will be encouraged to collect appropriate metadata so that their data can be used by other entities and most likely by this program. Other groups will be encouraged to upload their data to the National version of STORET. SFAN can then use this data if it can be used to help answer monitoring questions for existing sites or will help fill in data gaps that this program cannot cover. In addition, other data collected by SFAN monitoring programs (e.g., weather and stream hydrology data) will be utilized in conjunction with the water quality data.

4.5.10 Data Management

A general overview has been provided in sections A6 (Project /Task Description) and A9 (Documents and Records). Data management is covered in detail in the SFAN Freshwater Quality Protocol Narrative including database structure and metadata requirements. SFAN personnel will work closely with WRD regarding use of, and modifications to the NPSTORET database.

4.6 Assessment and Oversight

4.6.1 Assessments and Response Actions

Field staff will sometimes be required to work independently, though ideally there will be two individuals in the field. Having two individuals not only is a safety measure, but can also serve as a quality control measure. In most cases, the primary individual conducting monitoring will be the SFAN Water Quality Specialist who has the dual role of Project Leader and Quality Assurance Manager. Additional field assistants may be park or SFAN staff or volunteers as available. If problems in field sampling arise, the water quality specialist will determine whether sampling should be re-scheduled or sampling equipment/methods modified. Records will be kept of all quality control issues and corrective actions.

If site conditions or method improvements/modifications require protocol revision, the Project Leader will discuss these changes with field crew and document protocol revision (see SOP 1: Revising the Protocol). If major changes are warranted, the SFAN Aquatic Professionals group will meet to discuss recommended changes. Final revisions to the QAPP will be approved by the SFAN Aquatic Professionals Group and WRD. If necessary, a group of local technical experts (the same group, if possible, as the external peer review team) will meet to discuss methods issues.

4.6.2 Reports to Management

Annual summary reports will be provided to WRD and to individual parks by October 30 of each year. Additionally, comprehensive reports will be created every three to five years for more detailed analysis including trends. These reports will include data from 2-4 years since watersheds are monitored on a two-year rotating basis. These comprehensive reports will be provided to WRD and to the individual parks with data analysis customized for the individual parks. The comprehensive reports will include a Quality Assurance Report explaining the results of data completeness and other QA/QC issues.

4.7 Data Validation and Usability

4.7.1 Data Review, Verification, and Validation Requirements

The EPA has recently provided a comprehensive guidance document (EPA 2001), entitled *Guidance on Environmental Data Verification and Data Validation (EPA QA/G-8).* The purpose of this guidance is to explain how to implement data verification and data validation, and to provide practical advice and references. Although data verification and data validation are commonly-used terms, they are defined and applied differently in various organizations and quality systems. The Surface Water Ambient Monitoring Program (SWAMP) follows EPA's informal guidance on this topic, as provided in EPA 2001, and incorporates the following definitions (*from* Puckett, 2002):

Data Verification is confirmation that what has been entered into the database is what is actually on the datasheets. Data verification is the process of evaluating the completeness, correctness, and conformance/compliance of a specific data set against the method, procedural, or contractual requirements (Puckett, 2002).

Data Validation is an "analyte-and sample-specific process that extends the evaluation of data beyond method, procedural, or contractual compliance (i.e., data verification) to determine the analytical quality of a specific data set" (Puckett, 2002). In other words, 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 will also occur. 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 or nonsense 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.

4.7.2 Validation and Verification Methods

All data reported for the SFAN Water Quality Monitoring Program will be subject to checks for errors in transcription, calculation, and computer input. Field data are initially validated by data graphing and recognition of outliers needing verification. These checks are described in the protocol narrative and in section A9.

All laboratory data forms must be accurate and complete. Any changes to the data forms will be noted, initialed and dated on the form. Any actions taken as a result of the data review will also be noted on the data sheet (Puckett, 2002).

4.7.3 Reconciliation with Data Quality Objectives

Any data that do not meet DQO will not be used. If data quality issues arise, a determination will be made on whether the error was caused by equipment failure or operator error. If additional staff training, equipment repair, or minor revisions to the protocol or SOPs do not correct the problem, then the DQOs will be re-evaluated for feasibility of attainment. If they are determined to be unattainable, then they will be modified or the use of the parameter(s) in question will be evaluated. In some cases, a parameter may be eliminated if no reasonable/acceptable DQOs can be attained (Ward, 2004).

4.8 References

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Ward, K. 2004. Crissy field restoration area monitoring program quality assurance project plan (draft). Golden Gate National Recreation Area.

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SOP #4 Appendix A. Field Data Sheet – Stream Site

SFAN Water Quality Monitoring Program
Field Data Sheet – Stream Site

Station ID: _____ Date:_____
Site Location: Time:_____PST_
_____

Field Crew _____

Parameter	*Measurement	Units	**Value Type	Instrument	Notes***
Air Temperature		ºC	Actual		
H_20 Temperature		ºC	Actual	YSI 85	
Conductivity		µS/cm mS/cm	Actual	YSI 85	
Specific Conductance		µS/cm mS/cm	Actual	YSI 85	
Salinity		ppt	Actual	YSI 85	
Dissolved Oxygen		%	Actual	YSI 85	
Dissolved Oxygen		mg/L	Actual	YSI 85	
pH		S.U.	Actual	Oakton	
Flow		cfs	Calculated		
Turbidity		NTU	Actual	Hach 2100	

* Take 7 measurements at the beginning of each quarter (Oct., Jan., April, July) to obtain standard deviation for calculating PQL
** Actual, Calculated, Estimated (Cross out and enter in notes if different from default)
***Note duplicated field measurement values (QA); any equipment issues or observations.

Field Conditions:
_____
_____

Time since last significant rainfall:_____

Notes
_____
_____
_____
Flow measurement taken? _____ Flow Severity: □**1**none □**2** low □**3** normal □**4** flood □**5** high □**6** dry
Lab Samples taken? (which?)_____
Photographs taken? _____

Stabilization Criteria:
Temp: Thermistor = ±0.2ºC
Thermometer = ±0.5ºC
Specific Conductivity:
When ≤ 100µS/cm = ±5%
When > 100µS/cm = ±3%
pH: = ±0.1 SU
DO: Amperometric method = ±0.3 mg/L

Entered into NPSTORET □
Validated □

SFAN Water Quality Monitoring Program
Field Data Sheet For Flow Measurements

Date _____Time _____PST

Station ID _____

Field Crew _____

Site Location

Flow Instrument:_____

_____

Flow Measurements:

Gage Height _____ ft Stream Width _____ ft

Bed Level _____ ft

Begin Time_____PST/ Begin Gage Height_____ft End Time_____PST / End Gage Ht_____ft

Station (ft)	Depth (ft)	Velocity (ft/s)	Average V	Cumulative Q
REW:				
LEW:				

V – velocity Q – discharge

Notes from USGS Flow Measurement Methods:

- For shallow depths, use 6/10 method
- For deep depths (> 1.5 ft) use the 2/10 and 8/10 method
  - To get 2/10 depth multiply 6/10 depth by 2
  - To get 8/10 depth divide 6/10 depth by 2
- Space the verticals so that no sub-section has more than 10% (ideally 5%) of the discharge
- There should be 20-30 sub-sections
- Keep the first sub-section as small as possible (depth will often be zero and assume no flow)

- Streambed should be free of large rocks, obstructions
- Parts of the stream cross-sections with greater depth and velocity should have closer verticals
- Face the bank while taking measurement (stand beside not behind wading rod)
- Position yourself at least 18' from the wading rode
- Measure velocity for at least 40 seconds
- Check the meter during measurement
- Have an idea what the discharge will be before measurement
- Read gauge height after measurement
- Reach should be straight and uniform; measure downstream of riff

SOP #5 Field Methods for Measurements of Core Parameters

5.1 Revision History Log

Prev. Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.0	08/05/05	Mary Cooprider	Minor edits	Preparation for formal peer review	1.01
1.01	3/7/06	Rob Carson	Minor edits and updates of text and tables	Addressing peer reviewer comments	1.02
1.02	8/1/06	Rob Carson	Updated continuous monitoring guidelines with Wagner, et al 2006.	Release of USGS report, and purchase of new equipment.	1.03

Only changes in this specific SOP will be logged here. "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).

5.2 Acknowledgements

Several SOPs and guidance documents were utilized to develop this SOP. Much of the content of this SOP originated in one or more of the following documents:

- Penoyer, P. 2003. Vital Signs Long-Term Monitoring Projects: Part C, Draft Guidance on WRD Required Parameter Measurements, General Monitoring Methods and some design considerations in Preparation of a Detailed Study Plan (Work in Progress); National Park Service – Water Resources Division http://science.nature.nps.gov/im/monitor/protocols/wqPartC.doc .
- Puckett, M. 2002. Quality Assurance Management Plan for the State of California's Surface Water Ambient Monitoring Program ("SWAMP"). California Department of Fish and Game, Monterey, CA. Prepared for the State Water Resources Control Board, Sacramento, CA. 145 pages plus Appendices.
- Wilde, F.D. and Radtke, D.B., eds., chapter sections variously dated, Field Measurements: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A6, available online at http://pubs.water.usgs.gov/twri9A. National field manual for the collection of water-quality data (USGS Techniques of Water-Resources Investigations Book 9, Chapter A1-A9)

- Shelton, L. 1994. Field Guide for Collecting and Processing Stream-Water Samples for the National Water Quality Assessment Program. Open-File Report 94-455. U.S. Geological Survey, Sacramento, CA.

Standard operating procedures from other parks were also followed including SOP#5 – "Procedures for Collection of Required Field Parameters" from the Greater Yellowstone Network (O'Ney, 2005) and water quality SOPS from the Crissy Field Restoration Area Monitoring Plan (Presidio of San Francisco) (Ward, 2004).

5.3 Scope and Application

5.3.1 Core/Required Parameters

The Freshwater Workgroup Subcommittee of the National Park Service – Water Resources Division provided recommendations for required water quality monitoring parameters (National Park Service, 2002). These include:

1) Temperature
2) Specific conductance
3) pH
4) Dissolved oxygen

These parameters are considered the "core" parameters for the SFAN Freshwater Quality Monitoring Protocol. These parameters are interrelated and describe the basic water chemistry. They are the first indicators of water quality and typically the simplest to measure. If one or more of these parameters is out of the normal range for a particular stream or does not fall within water quality criteria limits, then concern is raised. The degree of concern is related to the extent that the parameter exceeds criteria or typical ranges and the duration of the exceedence. A one-time exceedence could indicate an episodic pollutant event or an error in measurement. The objective of this SOP is to reduce the possibility of the latter being an option.

Thorough knowledge of these core parameters is also needed in order to better understand or explain levels of other parameters such as nutrients and bacteria. An overview of past monitoring for these core parameters is provided in the *SFAN Preliminary Water Quality Status Report* (Cooprider, 2004). This includes background information on factors affecting the core parameters as well as their typical ranges in SFAN streams. Water quality criteria for these parameters are discussed in the protocol narrative. These criteria will be referenced during data analysis procedures (SOP #10). The core parameters are discussed in greater detail in "Vital Signs Long-Term Monitoring Projects: Part C, Draft Guidance on WRD Required Parameter Measurements, General Monitoring Methods and some design considerations in Preparation of a Detailed Study Plan" (Work in Progress) August 6, 2003 Draft Update (Penoyer, 2003).

The Water Resources Division (WRD) has also noted the importance of flow/discharge measurements, biomonitoring, and alkalinity measurements. The first parameter, flow/discharge, is a critical component of the SFAN Freshwater Quality Monitoring Protocol. The second important parameter, biomonitoring, was included in the list of SFAN Vital Signs

but not chosen as a priority indicator. However, recent aquatic bioassessment data exists for many of the SFAN streams. Results of on-going data analyses should provide insight for future possible aquatic bioassessment through the long-term monitoring program. Existing aquatic macroinvertebrate data will provide a baseline for future monitoring efforts. WRD also listed alkalinity as an important indicator. However, it is not an issue in the Bay Area streams since they are well-buffered. Lendvay and Benning (2004) provide a good example of this buffering in Redwood Creek (GOGA).

5.4 Measurement Procedures

Details of measurement procedures will focus on the use of a waterproof electronic pH meter and a multiparameter probe to measure temperature, specific conductance, and dissolved oxygen. Calibration procedures for these instruments are discussed in SOP#3. COMPLETE THESE CALIBRATION TASKS BEFORE PROCEEDING. Flow measurements will be discussed in SOP #9.

Because there can be significant diel variation in some of the core parameters (temperature, pH and dissolved oxygen in particular), the sites will be visited in the same order during each sampling trip in order to ensure that visits will fall into the same two-hour window (wherever possible) to minimize the effect of diel variation on single site variability over the long-term monitoring project. An effort will be made to collect data on the natural diel range of these parameters at particular sites through the use of datalogger probes or through synoptic data collection across sites or across the diel (24-hour) period. This would allow cross-calibration of values between those collected at some sites in the morning, and others that are regularly visited in the afternoon.

The following steps provide an overview of field collection techniques for the core parameters:

Details to be covered include:
- ♦ Equilibration of instruments with ambient water
- ♦ Location of sensor/probe within sample site
- ♦ Measurement techniques for flowing water (riffles or glides/runs) vs. standing water (pools)
- ♦ Location of sensor/probe in water column (obtaining a vertical profile)
- ♦ Tips for measuring each parameter
- ♦ Monthly/weekly and continuous monitoring

5.4.1 Monthly/Weekly Monitoring

Steps in Collection of Field Measurements:
1. Test and calibrate field equipment (SOP #3); clean with deionized or distilled water before each measurement
2. Obtain a flow measurement at the cross-section where samples are to be collected (SOP #9)
3. Locate the centroid of flow if sampling in a riffle or run/glide
4. Collect water samples for nutrients, bacteria, and sediment (SOPs #6-8)
5. Allow sensors to equilibrate with ambient water while samples are collected (2 minutes)
6. Complete general information on field data sheet

7. Collect a vertical profile of field measurements
8. Monitor field measurement readings (take mean of readings over 1 minutes, ending with dissolved oxygen)
9. Report the mean value
10. Clean the sensor with deionized or distilled water after taking the measurement

5.4.1.1 Sampling in Riffles/Runs (Centroid of Flow Method)

Standard Operating Procedure #9 for flow/discharge measurements should be followed first. Collect field measurements at the centroid of flow. The centroid is the midpoint of that portion of the stream width that contains 50% of the total flow. This is calculated in the field by adding a "cumulative discharge" column to the flow field sheet. The San Francisco Bay Regional Water Quality Control Board's SWAMP project uses the centroid of flow method (Puckett, 2002). If the stream is well-mixed with relatively uniform discharge, then the centroid of flow method can be used (Wilde et al., 1999).

If taking measurements in the centroid of flow has the potential to compromise safety, then either wade only to a safe distance or take measurements from the bank. Do not attempt to wade in a stream for which values of depth multiplied by velocity are greater than or equal to 10 ft^2/s. For example, a stream only 2 ft deep but with velocities of 5 ft/s or more can be dangerous to wade.

5.4.1.2 Sampling in Pools

Many of the monitoring questions require sampling in both flowing and still habitats within the stream. For still habitats (pools) the location and number of measurements points depends upon the specific monitoring questions listed in Appendix D of the Protocol Narrative. The USGS National Field Manual indicates that for still waters "measurements made at discrete depths through the vertical water column must not be averaged or reported as a median value." Pools in SFAN streams and tributaries indicated in the protocol narrative can be up to 3 feet deep during the dry season (May-October) and much deeper during the wet season (November-April). General guidelines for taking field measurements in pools:

The USGS recommends that if a pool is shallow (< 1 ft), take measurements at a middle depth. If the pool is from 1-4 ft deep collect measurements just below the surface, just above the stream bottom (taking care not to bury the probe in sediments) and at a location between the two (Wilde and Radke, variously dated). This can be done for the core parameters buts not for laboratory analytes because it would be cost prohibitive.

5.4.1.3 Equilibration & Stabilization of Sensors

- If water samples are to be collected, then leave the multiparameter probe in the water to equilibrate while samples are collected. Before recording a field measurement, the sensors must equilibrate to the water temperature at the sampling site. Allow a minimum of two minutes for the YSI 85 (multi-parameter probe) to equilibrate to the ambient water temperature. Equilibrate in the D.O, mode (Puckett, 2002). Equilibration has been achieved when the variability among instrument readings has stabilized according to the criteria in 5.1.

- The natural variability of surface water typically falls within the ranges listed in the table. Therefore, if the instrument is calibrated properly (see SOP #3) then these stabilization criteria should be met.

- Sensors have equilibrated adequately when instrument readings have stabilized, that is, when the variability among measurements does not exceed an established criterion. For surface waters, allow at least 60 seconds (or follow manufacturer's guidelines) for sensors to equilibrate, and then take instrument readings until the stabilization criteria in Table 5.1 are met. Record the median of the final three or more readings as the value to be reported for that measurement point.

- For sites at which variability exceeds the criteria of Table 5.1; allow the instrument a longer equilibration time and record more measurements. To determine the value to be reported for that measurement point, use either the median of the final five or more measurements recorded, or apply knowledge of the site and professional judgment to select the most representative of the final readings. Be sure to note how the measurement was selected in the field notes (Wilde et al., 1999).

- Allow at least 1 minute for sensors to equilibrate with the water. Obtain readings until the stabilization criteria are met. Record the median of the final three or more readings (Wilde et al., 1999).

- If the variability in measurements exceeds the criteria listed in the table, allow a longer equilibration time for the instruments. To select a final reading for the site, use the median of the final five or more measurements recorded or use knowledge of the site and professional judgement to select the most representative final readings (Wilde et al., 1999).

- In order to be efficient, water samples can be collected while the sensors are equilibrating. Leave the multi-parameter probe in the water to equilibrate while samples are collected. Field measurements are generally taken in the same location as water samples are collected (Wilde et al., 1999). Ch. 6

Table 0.1 Measurement Stabilization Criteria (core parameters) (from USGS National Field Manual) and WRD recommended instrument stabilization criteria for recording field measurements. Note the units to be used and recommended calibration frequencies.

Standard Direct Field Measurement	**Stabilization Criteria For Measurements (variability/repeatability should be within the value shown)**
[1]Temperature:	
Thermistor Thermometer	± 0.2°C
Liquid-in-glass Thermometer	± 0.5°C
[2]Conductivity (Specific Cond.)	
When ≤ 100 µS/cm	± 5 percent
When > 100 µS/cm	± 3 percent
[3]pH:	
Meter displays to 0.01	± 0.1 unit
[3]Dissolved oxygen:	
Amperometric method	± 0.3 mg/L

** Resolution/Sensitivity is a data quality indicator related to detection limits but typically handled differently for field probes than for laboratory parameters. For more information, see Part B (http://science.nature.nps.gov/im/monitor/protocols/wqPartB.doc) (Irwin, 2004).
***In the case of field probes, accuracy is typically a "best case" maximum deviation from known correct values (typically based on comparisons with known NIST certified reference materials or standards). True accuracy is a combination of high precision and low bias (see Part B for more details).
[1] Recommended frequency of sensor calibration checks is quarterly
[2] Recommended frequency of sensor calibration is daily
[3] Recommended frequency of sensor calibration is at beginning and end of sampling at each station (twice a day minimum)

5.4.1.4 Field Observations

Note the field conditions and general observations on the data sheet in Appendix A. Note the general field conditions including time of day, rain/no rain, rising/falling limb of hydrograph, watercolor, runoff conditions, etc. Also note the land use or any situations out of the ordinary. This data may be useful particularly if unusual parameter readings are observed.

Site information to record includes:

♦ Site ID, date, time, field personnel

Field observations to record include:

♦ Weather: Time since last rain, current heavy rain, dry, cold, etc.
♦ Water color and other characteristics: Unusual amount of suspended solids, debris, foam
♦ Biological activity: Note excessive macrophyte (plants), phytoplankton (microscopic floating aquatic plants) or periphyton (microscopic plants and animals firmly attached to aquatic substrate) growth and the presence of birds, fish, and spawning fish
♦ Water odors-sewage, hydrogen sulfide
♦ In-stream activities-bridge construction, mowing near the stream, livestock watering upstream,

etc.

♦ Beneficial uses – swimming, wading, irrigation pumps, etc.

5.4.1.5 Field Measurements

1. Stand downstream of sensors to reduce/eliminate affects of streambed disturbance and/or potential cross-contamination from other sites. Cross-contamination can also be avoided by rinsing field boots as well as the sensors.
2. Go to the centroid of flow as determined above. Obtain measurements directly from the water body by immersing the multiprobe instrument. Allow to equilibrate for at least two minutes before measurements are recorded.
3. Measure at multiple depths within the vertical containing the centroid of flow or within the pool as outlined in Table 5.2.
4. Monitor field measurement readings (take mean of readings over 1 minute, ending with dissolved oxygen). The value recorded will be the mean of values observed within 1 minute after the sensor has equilibrated.
5. Measure at multiple depths in the vertical. The value recorded at the vertical represents the mean of values observed within approximately 60 seconds after sensor(s) have equilibrated with stream water. Record DO last.
6. The final field-measurement value is the mean of the *in situ* value for the vertical. The mean of pH is calculated as below (see tips for pH measurement)

Depth-integrating and width-integrating sampling methods can be used to collect and composite samples that can then be sub-sampled (e.g. using a churn splitter) for some field measurements. The same field measurements can also be performed on discrete samples collected with thief, bailer, or grab samplers. These samples can yield good data for conductivity, pH, turbidity, and alkalinity as long as correct procedures are followed and the water is not anoxic. Do not measure temperature or DO on subsamples.

Table 0.2 Recommended Depths for Conducting Field Data Measurements (from Puckett, 2002).

Depth	Notes
Water Depth Less than 5 feet (<1.5m)	If the water depth is less than 5 feet (1.5m), multi-probe measurements are taken at approximately 0.2m (8 in).
Water Depth Greater than 5 feet (>1.5m)	If the water depth at the sampling point exceeds 5 feet (1.5m) in depth, a vertical profile of dissolved oxygen, temperature, pH and specific conductance are made using the multiparameter probe equipment. *NOTE: for most SFAN streams, if the depth is > 5 ft, then the discharge is too great to safely and accurately obtain a vertical profile.
Vertical Depth Profiles and Depth-Integrated Sample Collection	If vertical profile measurements are being conducted, multi-probe measurements are made starting at a depth of 0.2 m (8 in), and are then conducted at 1.0 m (3.28 ft) depth intervals.

5.4.1.6 Parameter Specific Details and Tips for Measurement

Temperature (°C):

- As a back-up procedure, temperature can be measured with a hand-held, centigrade thermometer.
- In wadeable streams, stand so that a shadow is cast upon the site for temperature measurement.
- Hold the thermometer by its top and immerse it in the water. Position the thermometer so that the scale can be read.
- Ensure that the temperature sensor is completely submerged in the water. Temperature readings made with digital instruments are accurate to within ± 0.1° C.
- Air temperature
- Read air temperature with a dry, calibrated thermometer.
- Place the thermometer about 5 ft above the ground in a shaded area protected from strong winds but open to air circulation. Avoid areas of possible radiant heat effects, such as metal walls, rock exposures, or sides of vehicles.
- Allow 3 to 5 minutes for the thermometer to equilibrate, and then record the temperature and time of day.
- Measure the air temperature as close as possible to the time when the water temperature is measured.
- Report routine air temperature measurements to the nearest 0.5°C.

pH (S.U.):

- "Is the value real or is the instrument out of calibration?" Avoid having to guess at an answer by having pH standards in the field to help verify values that fall outside the expected range. For example, the expected pH is around 7.0 and the reading is 9.5. A known standard can be put in the instrument storage cup to determine if the instrument is reading correctly or out of calibration.
- If the pH meter value does not stabilize in several minutes, out gassing of carbon dioxide or hydrogen sulfide, or the settling of charged clay particles may be occurring (Rawson, 1982).
- If out gassing is suspected as the cause of meter drift, collect a fresh sample, immerse the pH probe and read pH at one minute.
- If suspended clay particles are the suspected cause of meter drift, allow the sample to settle for 10 minutes, and then read the pH in the upper layer of sample without agitating the sample.
- In low-ionic strength water (<50µS/cm) the pH measurements may not stabilize and a mean or median value must be taken from a range covering several tenths of pH units (Penoyer, 2003).
- To average pH measurements, the pH values must first be converted to the antilog, and average value computed, then converted back to the log value.

To compute a mean pH for the stream:

- Convert each pH value to hydrogen-ion activity, using the equation, Activity = 10-(pH).
- Calculate the mean of the activity values by adding the values and dividing the sum by the total number of values.

- Convert the calculated mean activity back to pH units, using the equation, pH = (-) (log10)(mean H+ activity).

Specific Conductance (uS/cm) and Conductivity (uS/cm)

- As with pH measurements, having specific conductance standards in the field can help verify values that fall outside the expected range. For example, the expected specific conductance is around 200 and the reading is 1500. A known standard can be put in the instrument storage cup to determine if the instrument is reading correctly or out of calibration.
- Be sure to note the units as conductivity may range from uS/cm to mS/cm.
- A common physical problem in using a specific conductance probe (or meter) is entrapment of air in the conductivity probe chambers. The presence of air in the probe is indicated by unstable specific conductance values fluctuating up to $\pm$ 100 micro-siemens/cm (uS/cm). This can be minimized by slowly, carefully placing the probe into the water; and when the probe is completely submerged, quickly move it through the water to release any air bubbles.
- For specific conductance, the degrees C is flashing; for conductivity it is not flashing. Specific conductance is the conductance measured at 25°C. Since conductivity varies with temperature, it should always be reported as specific conductance.
- Always rinse the conductivity cell with clean water after each use (YSI Inc., 1998)
- Record the "raw" measurement (all digits). When reporting to STORET, round to the nearest two or three significant figures (if the value exceeds 100). If the value exceeds 1000, record to four significant figures.

Dissolved Oxygen (mg/L and % saturation):

- Check the sample location sheet for site elevation; calibrate the YSI 85 meter (oxygen probe) for elevation. Keeping the probe in its calibration (storage) chamber, press "mode" until one of the oxygen parameters appears on the screen. Then, press the down and up arrows simultaneously. The screen should have a single large number, then "alt x 100" in the right-hand corner. For an elevation of 400 ft select 4, then press "Enter". Wait for the resading to stabilize, then press "Enter" again to accept the calibration value. See the YSI 85 manual for detailed instructions (YSI, Inc. 1998).
- The DO measurement typically takes the longest to stabilize (Penoyer, 2003). This may take 5-15 minutes in some cases depending upon the water body and the instrument. Record this parameter *after* temperature, conductivity, and pH.
- Since dissolved oxygen takes the longest to stabilize, if the electronic DO meter is not functioning properly, DO can be measured by Winkler titration (Eckblad, 1978). The Winkler titration procedure is described in Appendix B.
- The sensor must be moved back and forth if placed in still water since the sensor consumes oxygen. YSI (1998) recommends that the sensor be moved through the sample at a rate of 1 ft/s to provide sufficient stirring. If the stream velocity at the sampling point exceeds 1 ft/s, the probe membrane can be pointed upstream into the flow and manual stirring can be avoided (Rawson, 1982).
- The probe should never be allowed to penetrate the sediments, especially when DO is low. If the probe does accidentally hit anoxic sediments it should be allowed to re-

equilibrate at least a minute before readings are resumed.

Oxygen meters use a polarographic electrode to measure the dissolved oxygen concentration in water. The instrument senses the partial pressure of oxygen at the surface of the membrane, rather than the actual concentration of oxygen (weight/volume). The relationship between partial pressure and concentration is dependent upon atmospheric pressure and temperature when a reading is made in the air (i.e., during the air calibration procedure), whereas, the equilibrium solubility of oxygen in water is influenced by temperature, salinity, and pressure (of the gaseous phase) (Puckett, 2002). Corrections for these factors must be made either by the instrument, by the user during calibration or after readings are taken. The Winkler titration directly measures oxygen equivalents and reports dissolved oxygen concentration (weight/volume) in a form that requires no corrections.

5.4.2 Continuous Monitoring

This section described methods for using an in-situ datalogger, or continuous multi-parameter probe to gather core parameter values from SFAN freshwater streams. Comprehensive guidelines and standard operating procedures for continuous water-quality monitors can be found in the USGS Techniques and Methods paper #1-D3 (Wagner, et al. 2006), available online at: http://pubs.usgs.gov/tm/2006/tm1D3/pdf/TM1D3.pdf. The procedures in this report should be followed for station operation, equipment calibration, and maintenance of continuous meters wherever possible. Included below is a brief outline of the use of one such instrument.

The specific procedure below is for the Eureka Environmental Manta® multiprobe. The Manta® can record data for temperature, conductivity, dissolved oxygen, and pH as well as two additional parameters (with additional sensors) continuously over the length of deployment. The entire user's manual can be found on-line at:
http://www.eurekaenvironmental.commanta/documents/Manta.pdf

SFAN will employ a continuous probe such as this one which will be moved from watershed to watershed on a rotating basis for Olema, Pine Gulch, Redwood, Tennessee Valley, Rodeo, Franklin, and Chalone Creek in order to collect diel and seasonal variation of physical and chemical parameters at key sites. The continuous probe will be rotated through watersheds, including extended deployment at a single stream site, or rotated to different sites in the same priority stream. Deployments in each priority stream will last a minimum of two weeks, and rotations will continue through the watersheds in the current panel year-round so that each priority stream has a minimum of two weeks of continuous data during each season. This will allow for a characterization of diel and seasonal variation of core parameters at particular sites in priority streams.

The continuous datalogger will most likely be placed near the streambank in order to be properly secured. The standard procedure is to deploy the data logger 1ft below the surface. However, the location of the logger will be dependent on the monitoring questions and the depth of the stream. Since the logger probes must remain fully submerged throughout the year, the location of the logger is often limited to the deepest part of a pool in smaller streams or to a part of a

perennial stream with a sufficient water depth to cover the probes. Regular maintenance and calibration requirements dictate how long the logger stays in place.

The continuous datalogger should be left in place for 2 weeks. Leaving it in place for longer than 3 weeks is not recommended since biofouling is likely to occur (Hydrolab Corporation, 1998). After two weeks field personnel should perform the following standard protocol, using the USGS Continuous WQ Monitor Field Form in Appendix C of SOP #3: Equipment and Field Preparations.

Standard protocol for the operation and maintenance of a continuous water-quality monitor (Modified from Wagner et al (2006)**)**

7. Conduct site inspection
    - Record monitor readings, time and monitor conditions
    - With an independent field meter, observe and record readings and time near the continuous sensor(s)
8. Remove sonde from the monitoring location
9. Clean Sensors
10. Return sonde to the monitoring location
    - Record monitor readings and time
    - Using an independent field meter, observe and record readings near the sensor(s)
11. Remove sonde, rinse thoroughly, and check calibration
    - Record calibration-check values
    - Recalibrate if necessary (i.e. values are outside the calibration criteria)
12. Return sonde to monitoring location
    - Record monitor readings and time
    - Using an independent field meter, observe and record readings near the sensor

Datalogger cleaning, calibration, and downloading should be conducted according to the manufacturer's recommendations (Eureka Environmental 2006). Details of these steps are included in SOP #3.

Notes on Continuously Recorded Temperature (from the USGS National Field Manual)

The USGS defines three temperatures of concern when monitoring continuous stream temperature: true stream temperature (TST), temperature near sensor (TNS), and temperature recorded (TRC) (Stevens et al., 1975). Ideally, all three of these temperatures would be the same; however this is not always the case. The true stream temperature is defined as an instantaneous measurement obtained in a shaded location in the main flow of the stream outside of the influence of tributaries or groundwater influx with a full immersion thermometer calibrated against an ASTM standard thermometer. It can also be calculated as the weighted average of a cross-section temperature profile. For reasons of safety and convenience, sensors for stream temperature recorders are often placed closer to shore than would represent true stream temperature (Essig, 1998). The actual temperature of the water surrounding the sensor reflects its position in the channel cross-section, and is known as the temperature near sensor (TNS). Whether it is the same as the TST may vary depending on flow and time of day (Essig,

1998). The temperature recorded (TRC) is the measurement read and recorded. If the thermometer or sensor has been calibrated, then TRC can be adjusted to TNS.

5.5 Data Management

The SFAN Freshwater Quality Protocol Narrative as well as the overall Data Management Plan should be consulted for a thorough review of data management procedures. A summary of data management tasks is below.

- Record and verify observed or measured data values. This includes completing paper forms and entering data into NPSTORET and/or other electronic databases.
- Schedule and perform regular data transfer and backup.
- Conduct regular data verification and correction
- Ensure that field forms, field notebooks and other hardcopy records are secure, organized and readily available for viewing, reproduction or transfer upon request and/or at the end of each field season.

5.6 Quality Assurance/Quality Control

The QAPP describes methods used to ensure that the data collected is as representative of the natural environment as possible. Quality assurance procedures are required in all data collection efforts for the long-term monitoring plan. The following should be conducted to ensure the quality of data collected (adapted from O'Ney, 2005):

- Field measurements should be made only with calibrated instruments
- The instruments should be tested, calibrated and error checked against acceptance criteria before leaving for the field
- At a minimum, DO and pH shall be calibrated again in the field at the monitoring station immediately before taking measurements
- Practice your measurement technique if the instrument or measurement is new to you.
- Each field instrument must have a permanent log book for recording calibrations, error check results and repairs. Review the log book before leaving for the field (see also SOP#3).
- All manually recorded field measurement data should be collected on field forms
- Automatically recorded data should be obtained electronically and the equipment used should be documented on field forms
- Complete records are maintained for each uniquely identified sampling station and all supporting metadata should be recorded appropriately (field forms or electronically)
- Have backup instruments readily available and in good working condition.
- Quality-assurance protocols are mandatory for every data collection effort, and include practicing good field procedures and implementing quality-control checks.
- Make field measurements in a manner that minimizes artifacts that can bias the result.
- Check field-measurement precision and accuracy (variability and bias).
- Check measurement sensitivity

The SFAN Quality Assurance Project Plan (SOP #4) contains all of the details related to QA/QC requirements for field measurements. A summary of this is provided in Table 5. 3 below. Many of the QA/QC procedures are covered in SOP#3- Equipment Preparations: Calibration, Handling, and Storage. However, there are several QA/QC measures for the field. One of these involves calculating measurement sensitivity and is described below.

Table 0.3 Data Quality Objectives for Field Measurements.

Parameter	**Instrument or Method**	**Alternative Measurement Sensitivity (AMS)**	**Method Detection Limit**	**Report as: (for STORET)**
pH	Oakton pH testr 30	***	0.01 pH	0.1 units
Dissolved oxygen	YSI 85	***	0.01mg/L	0.1 mg/L
Salinity	YSI 85	***	0.1 ppt	
Temperature	YSI 85	***	0.1	0.2^0 C with a thermistor and 0.5^0 C with a liquid in glass thermometer
Specific Conductance	YSI 85	2.5 uS/cm	0.1 uS/cm	rounded number

"Measurement Sensitivity" is a term typically used for laboratory parameters that may often yield results near zero. This is not an issue with field measurements that are always above a "limit of quantitation" (the minimum level of quantitation or ML. The ML is a lower limit below which there is no way to accurately determine (i.e., be 100% sure) how much of a compound such as nitrate is present. However, with field measurements the lower limits are not a concern. For example, specific conductance in a natural stream cannot be zero; there are always ions present and this results in some level of electrical conductivity.

Measurement Sensitivity is used for laboratory parameters while the term "Alternative Measurement Sensitivity" (AMS) is used for field parameters. The AMS is more specifically defined as "the measurement precision uncertainty based on a sample size of seven environmental samples (not blank) and 99% confidence" (Irwin, 2004).

The AMS is calculated as follows:

- Follow the above procedures for equipment equilibration and stabilization
- Follow steps 1-6 for Field Measurements
- Take seven distinct measurements for each parameter at regular intervals
- Take the standard deviation of the seven samples (this can be calculated in Excel) and multiply by 3.708, the *t* value for a 99% confidence interval and a sample size of 7 (6 degrees of freedom). This number is taken from a standard table of *t* distribution critical values.

→ Calculate the AMS for each parameter at the beginning of the field season, during the winter (high flow) and at the end of the field season. Once a consistent range is developed, this can be conducted annually.

5.7 References

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SOP #5 Appendix A. Field Data Sheet for Core Parameters

SFAN Water Quality Monitoring Program

Field Data Sheet – Stream Site

Station ID: _____ Date:_____
Site Location: Time:_____PST_
_____

Field Crew _____

Parameter	*Measurement	Units	**Value Type	Instrument	Notes***
Air Temperature		ºC	Actual		
H_20 Temperature		ºC	Actual	YSI 85	
Conductivity		µS/cm mS/cm	Actual	YSI 85	
Specific Conductance		µS/cm mS/cm	Actual	YSI 85	
Salinity		ppt	Actual	YSI 85	
Dissolved Oxygen		%	Actual	YSI 85	
Dissolved Oxygen		mg/L	Actual	YSI 85	
pH		S.U.	Actual	Oakton	
Flow		cfs	Calculated		
Turbidity		NTU	Actual	Hach 2100	

* Take 7 measurements at the beginning of each quarter (Oct., Jan., April, July) to obtain standard deviation for calculating PQL
** Actual, Calculated, Estimated (Cross out and enter in notes if different from default)
***Note duplicated field measurement values (QA); any equipment issues or observations.

Field Conditions:
_____
_____

Time since last significant rainfall:_____

Notes
_____
_____
_____
Flow measurement taken? _____ Flow Severity: □**1**none □**2** low □**3** normal □**4** flood □**5** high □**6** dry
Lab Samples taken? (which?)_____
Photographs taken? _____

Stabilization Criteria:
Temp: Thermistor = ±0.2ºC
Thermometer = ±0.5ºC
Specific Conductivity:
When ≤ 100µS/cm = ±5%
When > 100µS/cm = ±3%

pH: = ±0.1 SU
DO: Amperometric method = ±0.3 mg/L

Entered into NPSTORET□
Validated □

SOP #5 Appendix B. Winkler Titration Method for Dissolved Oxygen Measurement

Winkler Titration Method

From Eckblad, J.W. 1978. Laboratory Manual of Aquatic Biology. Wm. C. Brown Company Publishers, Dubuque, Iowa. 231 pp.

If the electronic DO probe is inoperable, DO should be measured by Winkler titration (Texas Natural Resource Conservation Commission, 1997). A Winkler titration kit includes:

- Two 300-mL biochemical oxygen demand (BOD) bottles with stoppers (may substitute a 300-mL Erlenmeyer flask for titration).
- One sewage sampler.
- Manganous sulfate powder pillows.
- Alkaline-iodide-azide reagent powder pillows.
- Sulfamic acid powder pillows.
- 10-mL pipettes; 200- or 250-mL graduated cylinder.
- 0.025*N* phenylarsineoxide (PAO) (replace annually or as needed in field kit).
- Stable starch reagent indicator solution. (Starch solution is stable for 1 month under field conditions. It should be renewed from stock, which is stable for up to 1 year in refrigerator.)
- Scissors or knife for opening powder pillows.

The following steps summarize Winkler titration procedures:

1. Collect a sample for titration by placing a 300-mL BOD bottle in a sewage sampler and lowering the top of the sewage sampler to a depth of 1 ft.
2. The sewage sampler will fill in 30 to 45 seconds.
3. The sampler is filled with water when it ceases bubbling.
4. The sewage sampler should not be withdrawn until it has filled completely.
5. The sampler should be carried upright until the BOD bottle is removed.
6. Carefully remove the BOD bottle from the sewage sampler.
7. The bottle should be filled to the top of the lip.
8. Gently pour the upper 3 to 4 mL of water out of the flared mouth of the bottle.
9. Add the contents of one manganous sulfate powder pillow to the full bottle.
10. Add the contents of one alkaline-iodide-azide reagent powder pillow to the full bottle.
11. Incline the bottle slightly and recap with a glass stopper in a quick, twisting thrust.
12. Do not allow air bubbles to be trapped in the bottle. Sometimes this can be accomplished by just touching the top of the liquid with the stopper tip and then dropping it into position.
13. Invert the bottle at least 25 times to mix completely and then set the bottle aside out of direct sunlight.
14. A brown flocculent indicates the presence of DO. Allow the flocculent to settle halfway down the bottle (approximately 5 minutes).
15. Invert the bottle another 25 times and let the flocculent settle once again. The flocculent will settle very slowly in sea water, which requires a minimum of 2 minutes reaction

time. Results will not be affected if the flocculent refuses to settle or if some of the reagent powder does not dissolve.

16. When the flocculent has settled after the second inversion so that the upper one-third of the bottle is clear, or after waiting 2 minutes, add the contents of one sulfamic acid powder pillow.
17. Recap and gently invert the bottle another 25 times until all the flocculent has disappeared. The solution should be clear and straw-colored in appearance. The intensity of the yellow color is related directly to the original concentration of DO in the sample. A clear, pale solution indicates a very low DO concentration. A dark, clear, yellow solution indicates a high DO concentration.

Samples prepared with the addition of sulfamic acid can be stored for 4 hours before completion of the Winkler titration. Samples can be stored for a maximum of 6 hours in the dark if the bottle is stored at the temperature of collection or water-sealed by putting water around the lip and kept at 10 to 20 °C (American Public Health Association, 1995).

As soon as the precipitate has completely dissolved as a result of acidification, the sample is ready to titrate.

18. Use a clean, graduated cylinder to transfer 200 mL of the solution to a 300-mL BOD bottle or Erlenmeyer flask.
19. Place the flask on a magnetic stirrer, if this equipment is available. Otherwise, use a pipette and bulb, swirling the sample by hand.
20. Stir the sample at a moderate rate without aerating the sample. Titrate with 0.025*N* PAO until the solution is pale straw-yellow in color.
21. Add 1 to 2 mL of stable starch reagent and note the blue color, which indicates the presence of iodine. A few drops should give the blue indicator color (not gray). If more than 1 or 2 mL are needed to produce the color, the sample titration results should be rejected and the starch solution replaced.
22. Continue the titration just until the blue color disappears. Do titration against a white background. This step requires either continuous stirring or vigorous swirling to ensure that the titration endpoint is accurate. Disregard the reappearance of the blue color after a few minutes.

The total volume (in milliliters) of PAO used in the titration is equal to the DO concentration, expressed in milligrams per liter. The DO concentration from the titration should be recorded to the nearest 0.1 mg/L. For a 200-mL sample, the volume of titrant added is directly proportional to the DO concentration in milligrams per liter. To compute DO for a sample greater or less than 200 mL, use the following formula:

$$\text{DO (mg/L)} = \frac{200}{\text{sample volume x titrant added (in mL)}}.$$

Corrections to Dissolved Oxygen Measurements Made With Dissolved Oxygen Meters

Some DO meters report measurements that are not compensated for salinity. Field DO measured with meters that are not salinity compensated and that are measured in waters with specific conductance exceeding 1,800 µS/cm, must be corrected. This correction is made by multiplying

the field DO concentrations by a correction factor, which is computed from the following formula:

$$F = 1 - \frac{[0.003439 + 0.361]}{(22.1 + T)^2} \times \frac{C}{1{,}000},$$

where
F = adjustment factor;
T = water temperature in degrees Celsius; and
C = specific conductance in microsiemens per centimeter,

Corrected DO = field DO x F.

The sample collector should record the corrected DO concentration.

SOP #6 Field and Laboratory Methods for Monitoring Fecal Indicator Bacteria

6.1 Revision History Log

Prev. Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.00	8/5/05	M. Cooprider	Minor edits	Preparation for formal peer review	1.01
1.01	3/23/06	R. Carson	Minor edits	Addressing peer review comments	1.02
1.02	8/11/06	R. Carson	Major changes reflecting inclusion of monitoring for *E. coli* using Quanti-Tray	Improves constraints of holding time, cost, and EPA recommendation for indicator bacteria	1.1

Only changes in this SOP will be logged. "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).

6.2 Acknowledgements

Other protocols and guidelines for followed during the development of this SOP. Many thanks are extended to the authors of these documents:

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6.3 List of Acronyms Used

APHA	American Public Health Association
AWWA	American Water Works Association
EPA	Environmental Protection Agency
FDA	Food and Drug Administration
FIB	Fecal Indicator Bacteria
GOGA	Golden Gate National Recreation Area
I&M	Inventory and Monitoring
JOMU	John Muir National Historic Site
MPN	Most Probable Number
NAWQA	National Ambient Water Quality Assessment
PINN	Pinnacles National Monument
PORE	Point Reyes National Seashore
RWQCB	Regional Water Quality Control Board
SFAN	San Francisco Bay Area Network
SOP	Standard Operating Procedure
SWAMP	Surface Water Ambient Monitoring Program
TMDL	Total Maximum Daily Load
USGS	United States Geological Survey
WEF	Water Environment Federation

6.4 Scope and Application

6.4.1 Fecal Indicator Bacteria and Their Relation to Water Quality

Wastes from warm-blooded animals harbor numerous intestinal bacteria that can be pathogenic to humans and other animals. These wastes can enter surface waters via surface runoff, groundwater flow, direct access of animals to a creek, leaky septic systems, and leaky sewer pipes. Fecal indicator bacteria (FIB) are used as indicators of the possible presence of pathogenic bacteria that may occur in wastes. Indicator species, as opposed to the pathogenic bacteria themselves, are enumerated because they are easier and safer to work with in the laboratory.

The most commonly used fecal indicator organisms or groups include total coliforms, fecal coliforms, fecal streptococcus, *E. coli*, and Enterococcus. The number of fecal coliforms is often highly correlated with other indicator species or groups including *E. coli* and *Enterococcus* though they cannot definitively be used interchangeably (Noble et al., 2000). Unlike total coliforms, *E. coli* and fecal coliforms are more frequently found in mammalian or avian intestines. Therefore, they are more pertinent as indicators of fecal material and associated pathogens in water. Total coliforms, including species in the genera *Klebsiella*, *Enterobacter*, and *Escherichia*, are indicators of all members of the *Enterobacteriaceae* family. However, some members of this family do not pose threats to human health so it is not particularly useful to know their occurrence (Turco, 1995). Another coliform, *Enterobacter aerogenes* is also frequently isolated from soils regardless of the presence of animal wastes. Total coliforms are ubiquitous in nature (Baxter-Potter and Gilliland, 1988). Numbers of total coliforms and other FIB in "natural" surface waters are listed in Table 6.1.

Table 0.1 Ranges of fecal indicator bacteria typically found in uncontaminated surface water and contaminated surface water (from Table 7.1-1 in the USGS National Field Manual).

Bacterial Group	Uncontaminated surface water	Fecal-contaminated surface water
	colonies/100mL	
Total coliform	<1 to 80,000	1,200- > 4,000,000
Fecal coliform	<1 to 5,000	200 to > 2,000,000
Escherichia coli	<1 to 576	126 to > 2,000,000
Fecal streptococococcus	<1 to 1,000	400 to > 1,000,000
Enterococcus	<1 to 100	100 to > 1,000,000
Clostridium perfringens	<1 to 100	100 to > 10,000

Fecal coliforms indicate the presence of feces that may contain pathogens in the genera *Salmonella*, *Mycobacterium*, *Leptospira*, *Clostridium*, and *Bacillus*, foot-and-mouth disease virus, entroviruses, and helminthes (parasitic worms) (Reddy et al, 1981). *E.coli* is rarely pathogenic. However, some pathogenic strains of *E. coli* can cause gastroenteritis, diarrhea, colitis, or dysentery. Strain O157:H7 can be fatal to infants, older adults, and individuals with compromised immune systems.

6.4.2 Water Quality Standards for Fecal Indicator Bacteria

Water quality standards for FIB have been established to protect human health. The San Francisco Bay Regional Water Quality Control Board (Regional Board) sets numeric and narrative objectives for water quality (Regional Water Quality Control Board, 1995). Table 6.2 shows water quality objectives for the primary beneficial uses of SFAN water bodies.

Table 0.2 General numeric objectives for select beneficial uses in surface waters in the San Francisco Bay Area.

Beneficial Use	Fecal Coliform (MPN/100mL)	Total Coliform (MPN/100mL)
Contact recreation	Log mean < 200 90^{th} percentile < 400	Median < 240 No sample > 10,000
Non-contact recreation	Mean < 2000 90^{th} percentile < 4000	
Shellfish harvesting	Median < 14 90^{th} percentile < 43	Median < 70 90^{th} percentile < 230

For the purposes of FIB monitoring, waters can be divided into three broad categories of beneficial uses including recreational, shellfish-growing waters, and ambient waters. Recreational waters are used for "contact recreation" such as swimming or kayaking. Ambient waters are used for "non-contact recreation" such as hiking and picnicking.

E.coli and *Enterococci* are the preferred indicators for contact recreational monitoring since they have greater survival in marine waters. Therefore, they are better indicators of swimming-related gastroenteritis in marine and freshwaters than total coliforms, fecal coliforms, and fecal streptococci. While, the I&M program will not be monitoring recreational waters which primarily include marine waters within PORE and GOGA, we will follow the EPA recommendations for indicator bacteria species.

6.4.3 Fecal Indicator Bacteria Levels in SFAN Waters

The UC Berkeley report *A Review of Water Quality Monitoring Programs in the National Parks in Central Coastal California* (Stafford and Horne, 2004) contains additional background information related to fecal indicator bacteria. Ranges in fecal indicator bacteria concentrations in SFAN parks are listed in Table 6.2. Additional information about FIB levels and sources in SFAN waters is included in the SFAN Preliminary Water Quality Status Report (Cooprider, 2004).

Table 0.3 Range in Fecal Indicator Bacteria* in SFAN parks (MPN/100mL) based on land use.

Park	Overall Land Use (overall range)	Wilderness (mean range)	Grazed (mean range)	Dairy (mean range)
GOGA	2 to 300,000			
JOMU	17 to 900			
PINN	3 to 440 (*E.coli*)			
PORE†		17 to 540	1,000 to 46,000	2,400 to 710,000

* Fecal coliforms unless otherwise indicated

† The overall range in fecal coliforns at PORE was < 200 to > 1 million

Several water bodies within SFAN have elevated levels of FIB. A few of these water bodies are on the Clean Water Act Section 303d list due to impairment by fecal coliforms. Sources of fecal bacteria within SFAN include agriculture (dairy and beef cattle ranching and vegetable farming), residential areas (septic systems), and recreational land uses (equestrian operations and dog walking). Other streams are impaired due to their urban location and proximity to sewer pipes.

6.4.4 Tomales Bay Pathogen Total Maximum Daily Load (TMDL) Project

The San Francisco Bay RWQCB has identified Tomales Bay (PORE/GOGA) and its tributaries (Lagunitas Creek and Walker Creek) as impaired by fecal coliform. Health concerns have arisen due to contamination of shellfish with pathogenic bacteria. SFAN staff has collaborated with the RWQCB regarding monitoring of indicator bacteria in Olema Creek a tributary to Lagunitas Creek. The RWQCB recently completed a final Total Maximum Daily Load (TMDL) project report for pathogens in Tomales Bay (RWQCB, 2004). Implementation of monitoring for the Tomales Bay Pathogen TMDL program includes monthly monitoring plus five consecutive weeks of monitoring during the winter and summer in order to obtain a geometric mean of the most probable number (MPN) of fecal coliform bacteria present.

The TMDL Implementation Plan is focused on attaining the water quality standard for shellfish harvesting areas of 14 MPN/100 mL for fecal coliforms. The Food and Drug Administration (FDA) regulates shellfish harvesting areas based on fecal coliforms. Therefore, although other FIB can be used to determine the presence of pathogenic bacteria, PORE is required to monitor fecal coliforms as part of the TMDL implementation strategy. In order to maintain consistency with other RWQCB Tomales Bay TMDL sites, samples from PORE/GOGA will be analyzed for fecal coliforms at the same laboratory used by the RWQCB, whenever possible.

6.4.5 FIB Sampling and Analysis Methods Overview

The definition of the coliform group has traditionally been based on the detection method used (lactose fermentation or defined enzyme substrate tests). A common technique for determining lactose fermentation involves inoculating multiple test tubes with the water sample. For defined enzyme substrate tests, the water sample is combined with a reagent that reacts to detect the enzyme β-glucuronidase produced by *E. coli*, the mixture is distributed in a series of individual wells in a tray. Results of the examination of replicate tubes (or wells) and dilutions are reported in terms of the Most Probable Number (MPN) of organisms present. This number is based on certain probability formulas and is an estimate bacteria density in the sample (APHA, AWWA,

WEF, 1998). Results are reported in units of MPN/100mL. Most Probable Number tests for total and fecal coliforms and *E. coli* usually result in greater recovery of microorganisms than other techniques such as membrane filtration (Myers, 2003).

The U.S. EPA recommends testing for *E. coli* and enterococci indicators in place of total and fecal coliform indicators because recent epidemiological studies indicate that *E. coli* and enterococci show a direct correlation with swimming-associated gastrointestinal illness rates, while fecal coliforms do not (USEPA, 2003). While SFAN must continue to analyze Tomales Bay TMDL samples for fecal coliforms to comply with RWQCB projects, samples from other SFAN streams will begin to be analyzed for total coliform and *E. coli* using enzyme substrate methods cited below. Overlap in methods will occur to the degree that is feasible in order to ensure long-term comparability of methods and results. One way is to process the Tomales Bay TMDL samples at the regional lab for fecal coliform as well as at the in-house lab for *E. coli.* Such overlap would provide more than 70 annual samples that could be analyzed to provide information on the comparability of the two methods.

Bacteria are often associated with sediment particles. Therefore, USGS recommends that depth-integrated sampling be conducted for bacteria sampling in the same way that it is conducted for sediment. However, the San Francisco Bay RWQCB does not use depth-integrated sampling for bacteria or nutrient TMDL monitoring (Peter Krottje, personal communication). The RWQCB's Surface Water Ambient Monitoring Program (SWAMP) also does not collect depth-integrated samples for bacteria. Regardless, in many cases with SFAN streams, there is not sufficient depth, except during storm events, to obtain a meaningful depth-integrated sample. And, during storm events, SFAN stream conditions often preclude safe wading, and therefore, collection of depth-integrated samples. In order to maintain consistency at each of the sites and throughout the sampling season, it is best to obtain a "grab" or "hand-dipped' sample.

This field SOP will focus on field sample collection including sterile technique to avoid contaminating a sample and location of sample in the water column. Details of sample bottle labeling, storage, and transport to laboratories (including chain of custody forms) will also be discussed. Analysis will be conducted either by an analytical laboratory or by in-house analysis using IDEXX Quanti-Tray®/2000. Fecal coliform samples will be analyzed at an EPA approved laboratory using the SM 9221E Multiple Tube Technique (Most Probable Number) in "Standard Methods for the Examination of Water and Wastewater" (APHA-AWWA-WEF, 1998). Recommendations for analysis methods and laboratory selection, including choosing a NELAP-certified lab, are discussed in the SFAN Freshwater Quality Protocol Narrative. Samples that will be analyzed for *E. coli* using Quanti-Tray®/2000 will be processed and handled by the SFAN Water Quality Specialist, or properly-trained staff. The principle, procedure, interpretation, reporting and quality-control for enzyme substrate testing using SM 9223 Enzyme Substrate Coliform Test are included in "Standard Methods for the Examination of Water and Wastewater" (APHA-AWWA-WEF, 1998).

For training in the laboratory methods for IDEXX products, short videos are available online at: http://www.idexx.com/water/video/index.jsp

Additional references are available in Appendix A, including instructions for Quanti-Tray®/2000, an MPN table, the users manuals for the tray sealer.

6.5 Techniques

6.5.1 Tips for collection of bacteria samples:

- Collect water samples first before disturbing the sediment
- Note potential sources of contamination at each site
- Wear appropriate disposable, powderless gloves
- Use correct sample-handling procedures to avoid sample contamination
- Establish a routine for sample collection; use a consistent sampling technique
- Obtain training for and practice field techniques under supervision before collecting water samples.
- Collect a sufficient number of appropriate types of quality-control samples
- Prevent nose, mouth, eye, and direct skin contact with water

6.5.2 Aseptic Technique (from O'Ney, 2004)

Disposable latex or rubber gloves should be used to collect bacteria samples. Some individuals have severe allergic reactions to latex. Field staff must avoid touching the opening of the sample collection container or its cap, or having the sample touch hands or arms. For each sample:

- Wash and scrub hands thoroughly to the mid-forearm, using antibacterial hand soap (or a hand sanitizer at 50 ppm chlorine equivalency, if available).
- Open the sample container taking care to avoid touching the inside surfaces or otherwise causing contamination
- Remove a glove by holding it from the wrist side opening inner surface. Avoid any contact with the outer surface of the glove.
- Do not touch anything with the exterior of the glove except the sample.
- If you have concern that the glove may be contaminated, discard that glove and use another sterile glove.
- With the gloved hand, collect the sample.
- After sample has been collected, close the sample container, remove and discard the glove and place sample in a cooler.

6.5.3 Sample Bottles

Use only sterile 100 mL bacteriologic sample bottles (supplied by the laboratory or purchased). It is important to have extra bottles as they occasionally can be swept away in current or contaminated. Some laboratories provide bottles with relatively "waterproof" labels already attached. Other labels are more susceptible to wear and generally consist of regular paper. If this is the case, it is best to place a scotch tape over the label. It is sometimes easier and more efficient to label the bottle before sampling; this avoids having to dry off the bottle or write on a wet label. Pre-labeling (in the office or field vehicle) can also save time in the field especially important when it is raining.

Laboratory-supplied bottles may contain a tablet or powdered form of sodium thiosulfate which is used to neutralize chlorine. This is required for drinking water samples. This tablet is not needed for SFAN surface water samples and does not affect the bacteria. However, in the event that chlorine may be present and to be consistent, the tablet or powder should remain in the bottle.

6.5.4 Collecting the Samples

(Adapted from Wilde et al, 1999)

Prepare for sampling

1. Upon arrival at the field site, set out safety equipment such as traffic cones and signs.
2. Park vehicle in a location and direction to prevent sample contamination
3. Take extra bottles in case of contamination or loss
4. Take enough bottles to obtain QA/QC samples (see QAPP)
5. Label bottles but leave "time" field blank until actual sample collection

Determine the sampling location

1. Visually inspect the stream from bank to bank and longitudinally, observing velocity, width, and depth distribution, and apparent distribution of sediment and aquatic biota along the cross section. Note and document the location of stagnant water, eddies, backwater, reverse flows, areas of faster than normal flow, and piers or other features along the cross section.
2. Check the site list to determine whether the sample is to be collected in a pool or flowing area (or both). If sampling from a flowing area, identify the area of the stream that appears to be completely mixed (the centroid of flow). This may be determined ahead of time from reliable discharge measurements (see Initial Site Establishment – SOP#11 and Flow Measurement – SOP#9). Do not disturb the sediment before collecting a water sample.
3. For pools, if shallow (< 1 ft) take measurements at a middle depth. If the pool is from 1-4 ft deep collect a sample at a depth that meets monitoring objectives (Wilde et al, 1999).
4. For flowing water, sub-surface samples are taken at 0.1 m (4 inches) below the water surface if water level is < 5 ft (1.5 m). Samples are collected at the surface when water depth is < 0.1 m (Puckett, 2002). Sampling from the shoreline of any water body (meaning standing on shore and sampling from there) is the least acceptable method, but in some cases is necessary (Puckett, 2002).
5. Collect the bacteria sample at the same location as you will be collecting the core parameters.

Water samples should be collected from a location in the stream where the stream visually appears to be completely mixed. Ideally this would be at the centroid of the flow (*Centroid* is defined as the midpoint of that portion of the stream width, which contains 50% of the total flow), but depth and flow etc. do not always allow centroid collection (Puckett, 2002).

Collect the sample

Note: Collect water samples first to avoid disturbing the sediment and re-suspending sediment or bacteria

The USGS uses the "Hand-dip" method (Myers, 2003) if stream depth or velocity is not sufficient to use depth-integrated sampling. The procedure minimizes the collection of surface films and avoids contact with the streambed. The method is as follows:

1. Open a sterile, narrow-mouth borosilicate or plastic bottle; grasp the bottle near the base, with hand and arm on the downstream side of the bottle.
2. Without rinsing, plunge the bottle opening downward below the water surface. Allow the bottle to fill with the opening pointed slightly upward into the current.
3. Remove the bottle with the opening pointed upward toward the water surface and tightly cap it, allowing about 2.5 to 5 cm of headspace. Laboratory supplied bottles typically have an "EPA fill line" that allows for this amount of headspace.
4. Inspect each sample, looking for overfilling and (or) the presence of large amounts of particulates that might have been captured due to excessive streambed disturbance during sample collection. If you note either or both of these conditions, discard the sample, making sure there are no residual particulates left in the container, and resample.
5. Place the sample bottle in an ice-chest immediately. [NOTE: Use blue ice (often provided by labs), not wet ice to avoid possible contamination by contact with the melt water.] Ensure that the bottle label is completed with the date, time, site ID, and initials of field personnel.
6. Check the temperature of the ice-chest and refrigerator (if used); it must be between 1-4 °C. Samples should be stored in the dark.
7. Ensure that the samples are transported to the laboratory for analysis within the 6 hour EPA hold time.

6.5.5 Preparing the Samples and Laboratory Analysis

1. Ensure that the sample is processed within the 6-hour EPA hold time, and that the sample has been stored at <4°C
2. Mix sample well by inverting bottle numerous times
3. If processing sample at a requested dilution, extract appropriate sample volume and add to sterile sample bottle, and fill to 100mL with distilled water.
4. Add contents of Colilert® reagent pack to sample bottle, recap and mix well.
5. Open sterile Quanti-Tray® at the top, and pour in sample and reagent mix.
6. Carefully insert filled tray into sealer gasket, then carefully feed the gasket and tray into the sealer
7. Take sealed tray from the return tray of the sealer, remove gasket
8. Place sealed tray into35°C incubator for 24 hours.
9. Remove tray from incubator and observe tray for:
    a. Total number of large and small wells that are yellow (more yellow than the IDEXX comparator tray.

b. Total number of large and small wells that fluoresce blue (more fluorescent than the IDEXX comparator tray.

10. Using the numbers obtained in step 9, use the MPN table to determine the most-probable-number of total coliform bacteria (yellow) and *E. coli* (blue) from each sample.

For complete instructions, and to view training videos, visit the IDEXX website at: http://www.idexx.com/water/video/index.jsp

Additional references are available in Appendix A, including instructions for Quanti-Tray®/2000, an MPN table, the users manuals for the tray sealer.

6.6 Field Preparations and Laboratory Coordination

When starting work with a new laboratory, the Water Quality Specialist should develop a good working relationship with a laboratory manager and also a chemist/microbiologist at the laboratory. Discuss analytical methods, detection limits, holding times, and laboratory constraints such as limited incubator size. Obtain official chain of custody forms from the lab as well as any needed bottles, cooler, and ice packs if the laboratory provides these. Discuss sample drop-off and pick-up possibilities. Also discuss the labs' capacity for the number of samples you will have. General tasks list include:

- Notify the lab at the beginning of the season, or as early as possible, of your sampling schedule
- Call the lab the day before or the morning of sampling to verify sample collection
- If at all possible, schedule sampling early in the week rather than later.
- Fill out the chain of custody form ahead of time except for the sample time; include the dilution in the comments field*

* It is critical to know the expected concentrations of coliforms since dilutions may be required in order to quantify bacteria (i.e., in order to avoid "censored data" that is greater than (>) or less than (<) a detection limit). Refer to the site list for dilution information.

The chain of custody form is a means of tracking samples from receipt in the laboratory through analysis, to final disposal of the sample. It should be filled out in ink. The chain-of-custody forms travel with the samples during the transfer, and are filed in the laboratory project files. Upon arrival at the laboratory, the "sample custodian" at the lab inspects the sample containers to ensure that the sample seals are intact and the sample containers have not been damaged. If any seals have been broken and/or any sample containers damaged, the sample custodian records the condition of the seals and containers on the chain-of-custody form. The sample custodian takes custody of the samples by signing, dating, and noting the time in the on the chain-of-custody form.

Once at the laboratory, if samples need to be subdivided and submitted to another laboratory sub-contractor, this information should be noted on the original Chain-of-Custody Form, and a new Chain-of-Custody Form with the other lab should be initiated (Puckett, 2002).

6.6.1 Equipment Checklist

Scotch tape
Hand sanitizer
Bottle labels
Disposable gloves
Sterile sample bottles
Data sheets printed on waterproof paper
Ice chest
Thermometer for ice chest
Chain-of-custody form
Sharpie (permanent pen)
Water jug for washing hands
Soap

Also, consult SOP#2 for safety equipment as well as SOP#3 for equipment calibration.

6.7 Quality Assurance/Quality Control (Check with QAPP)

"Depending on the data quality requirements of the study and site conditions, quality control samples (field blanks and field replicates) generally constitute from 5 to 20 percent or more of the total number of samples collected in a year or during a given period of time (Myers, 2003). A field duplicate and a field blank are required as follows:

Field Blank – 1 in every 10 to 20 samples; pass deionized water into a sterile sampling container; have container analyzed for FIB

Field Replicate – collect and analyze 1 field replicate for every 10-20 samples. A split sequential replicate is recommended. Two samples are collected and each sample is analyzed in duplicate (Myers, 2003).

One important element of QA/QC is the development of measurement quality objectives (MQO's) for systematic error/bias as percent recovery. Using the QA/QC kits that are available through IDEXX, we will test for percent recovery for each lot number of trays or reagent used in our analysis. Eventually, with enough data collected during the first years of sampling, SFAN will develop numeric MQO's for bacterial parameters.

6.8 References

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SOP #6 Appendix A

Quanti-Tray®/2000 Insert Instructions and MPN Table
(hard copy only)

IDEXX Quanti-Tray® Sealer Model 2x User Manual
(hard copy only)

Preventative Maintenance Instructions for Quanti-Tray® Sealer Model 2X
(hard copy only)

SOP #7 Field Methods for Sampling Nutrients

7.1 Revision History Log

Prev. Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.0	8/5/05	M. Cooprider	Minor edits	Preparation for formal peer review	1.01
1.01	3/16/06	R. Carson	Minor Edits	Addressing peer-review comments	1.02

Only changes in this SOP will be logged. "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).

7.2 Acknowledgements

SFAN staff borrowed from several other protocols and guidelines. Many thanks are extended to the authors of these documents, most notably:

Puckett, M. 2002. Quality Assurance Management Plan for the State of California's Surface Water Ambient Monitoring Program ("SWAMP"). California Department of Fish and Game, Monterey, CA. Prepared for the State Water Resources Control Board, Sacramento, CA. 145 pages plus Appendices.

O'Ney, S. 2004. Procedures for Collection of Regulatory Parameters, Version 1.0, Standard Operating Procedure #6. *In* Regulatory Water Quality Monitoring Protocol, Version 1.0, Appendix E-SOPs, National Park Service, Great Yellowstone Network. Bozeman, MT. 37 pp. plus appendices.

Wilde, F.D., Radtke, D.B., Gibs, Jacob, and Iwatsubo, R.T., eds., September 1999, Collection of water samples: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A4, accessed 2005 at http://pubs.water.usgs.gov/twri9A4/

7.3 Scope and Application

7.3.1 Nutrients and Their Relation to Water Quality

Nitrogen and phosphorus are the primary plant nutrients and are ubiquitous in the environment. Aquatic systems are either nitrogen limiting or phosphorus limiting in reference to algal growth. Algae use nitrogen and phosphorus at a ratio of about 7:1 by mass. A significantly narrower ratio means that there is a greater supply of phosphorus than nitrogen and that nitrogen is limiting growth. In this case, nitrogen is referred to as the "limiting nutrient". In most Bay Area freshwater streams, nitrogen is the limiting nutrient (California Regional Water Quality Control Board, 2003).

If a system is nitrogen limiting, then inputs of nitrogen can cause excessive growth (eutrophication) or toxicity to aquatic organisms. Eutrophication occurs at lower levels than toxicity (California Regional Water Quality Control Board, 2003). Nitrate and un-ionized ammonia can cause nutrient toxicity. Excess nutrients can also harm aquatic life through depletion of oxygen. Excess algal growth leads to greater respiration by live algae and decomposition of dead plant and algal material. Oxygen producing photosynthesis only occurs during the day while respiration, an oxygen depleting process, occurs 24 hours a day. Therefore, dissolved oxygen is lowest just before dawn.

Nitrogen occurs naturally in several forms in the environment. Organic nitrogen (N) is anything that is organically bound including protein and peptide nucleic acids, urea, and synthetic organic materials. Organic nitrogen varies from 100ug/L in lakes to more than 20mg/L in raw sewage. Organic nitrogen and ammonia together are referred to as Total Kjeldahl Nitrogen (TKN) named after the Kjeldahl method. Total Ammonia Nitrogen or TAN is chemically represented as NH_4^+ and is present naturally in surface waters and wastewaters. Un-ionized ammonia or UIA is chemically represented as NH_3 and is toxic to aquatic organisms at low levels. This is of particular concern in SFAN streams supporting threatened and endangered species including coho salmon and steeelhead trout, California red-legged frog, and the California freshwater shrimp. Total oxidized or inorganic N is nitrate and nitrite. Nitrate generally occurs in trace quantities in surface water (APHA/AWWA/WEF 1998). Anthropogenic forms of nitrogen include fertilizers and wastes from warm-blooded animals that contain ammonia and organic nitrogen (among other forms of nitrogen). These wastes can enter surface waters via surface runoff, groundwater flow, direct access of animals to a creek, leaky septic systems, and leaky sewer lines.

Phosphates also exist in different forms including: orthophosphate, metaphosphate (or polyphosphate) and organically bound phosphate. Orthophosphates are produced by natural processes and are found in wastewater. Polyphosphate forms are used for treating boiler waters and are found in detergents. Poly forms of phosphate can change to the ortho form in water. Organic phosphates are a natural part of the environment but may also result from the breakdown of organophosphate pesticides. The common mineral source of phosphorus is insoluble rock phosphate [Apatite - $Ca_5(PO_4)^3(F_3OH)$] (Swaddle, 1997 *In* Thompson and Chambers, 2000).

7.3.2 Nutrient Levels in SFAN Waters

The UC Berkeley report *A Review of Water Quality Monitoring Programs in the National Parks in Central Coastal California* (Stafford and Horne, 2004) contains additional background information related nutrients. Additional information about nutrient levels and sources in SFAN waters is included in the SFAN Preliminary Water Quality Status Report (Cooprider, 2004). Water quality standards for nutrients are listed in Section 1.0 of the Freshwater Quality Protocol Narrative.

The San Francisco Bay RWQCB has identified Tomales Bay and its tributaries, Lagunitas Creek and Walker Creek, as impaired by nutrients. Once the nutrient monitoring implementation plan is complete, SFAN staff will be collaborating with the RWQCB regarding monitoring of key nutrients, primarily nitrogen parameters, in Lagunitas Creek and its tributaries, including Olema Creek. A *Conceptual Approach for Developing Nutrient TMDLs for San Francisco Bay Area Water Bodies* was prepared by the San Francisco Bay RWQCB (RWQCB, 2003).

7.3.3 Nutrient Sampling and Analysis Methods Overview

The San Francisco Bay RWQCB does not use depth-integrated sampling for nutrient TMDL monitoring (Peter Krottje, personal communication). Also, the RWQCB's Surface Water Ambient Monitoring Program (SWAMP) does not collect depth-integrated samples for nutrients. Regardless, in many cases with 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, it is best to obtain a "grab" or "hand-dipped' sample.

Monthly monitoring will be conducted for nitrate, and ammonia, and Total Kjeldahl nitrogen. Collection of samples at each site will take place within the same two-hour window each month, where possible, to minimize the effect of diel variation in nitrogen compounds that could complicate the detection of trends.

Table 0.1 Summary of methods for laboratory parameters (modified from Puckett, 2002).

Parameter	Sample Volume (mL)	*Method Detection Limit (MDL)	Preservation & Storage	Holding Time	Method
Total Kjeldahl Nitrogen	600 mL	0. 10 mg/L	Unfiltered; Cool to < 4° C; dark	7 days (28 days max)	SM 4500
Ammonia	500 mL	0.10 mg/L	Unfiltered; H_2SO_4, preservative, Cool to < 4° C	48 hours; or 28 days with preservative	EPA 350.3
Nitrate	150 mL	0.10 mg/L	Unfiltered; Cool to < 4° C; dark	48 hours	EPA 300 / (EPA353)**
Nitrite	150 mL	0.05 mg/L	Unfiltered; Cool to < 4° C; dark	48 hours	EPA 300 / (EPA353)**

* There are often several approved methods and they vary depending on the lab and the type of instruments that they have. Also, methods change and improve over time. The important consideration is that the labs use a method that has the desired MDL. MDLs are those recommended by the San Francisco Bay Regional Water Quality Control Board (Peter Krottje, personal communication, 1 July 2005).

7.4 Techniques

7.4.1 Tips for collection of nutrient samples:

- Collect water samples first before disturbing the sediment
- Note potential sources of contamination at each site
- Wear appropriate disposable, powderless gloves
- Use correct sample-handling procedures to avoid sample contamination
- Establish a routine for sample collection; use a consistent sampling technique
- Obtain training for and practice field techniques under supervision before collecting water samples.
- Collect a sufficient number of appropriate types of quality-control samples
- Prevent nose, mouth, eye, and direct skin contact with water

7.4.2 Aseptic Technique (from O'Ney, 2004)

Disposable latex or rubber gloves should be used to collection of nutrient samples. Some individuals have severe allergic reactions to latex. Field staff must avoid touching the opening of the sample collection container or its cap, or having the sample touch hands or arms. For each sample:

- If collecting samples for regulatory purposes, wash and scrub hands thoroughly to the mid-forearm, using antibacterial hand soap (or a hand sanitizer at 50 ppm chlorine equivalency, if available).
- Open the sample container taking care to avoid touching the inside surfaces or otherwise causing contamination
- Remove a glove by holding it from the wrist side opening inner surface. Avoid any contact with the outer surface of the glove.
- Do not touch anything with the exterior of the glove except the sample.

- If you have concern that the glove may be contaminated, discard that glove and use another sterile glove.
- With the gloved hand, collect the sample.
- After sample has been collected, close the sample container, remove and discard the glove and place the sample in a 4ºC cooler.

7.4.3 Sample Bottles

Use 150 to 600 mL plastic nutrient sample bottles (supplied by the laboratory). It is important to have extra bottles as they occasionally can be swept away in current or contaminated. Some laboratories provide bottles with relatively "waterproof" labels already attached. Other labels are more susceptible to wear and general consist of regular paper. If this is the case, it is best to place a scotch tape over the label. It is sometimes easier and more efficient to label the bottle before sampling; this avoids having to dry off the bottle or write on a wet label. Pre-labeling (in the office or field vehicle) can also save time in the field (important during rain events).

Laboratory-supplied bottles contain a small amount of sulfuric acid preservative for samples to be analyzed for ammonia. These bottles should be clearly marked with "H_2SO_4". Since this is a strong acid, avoid contact with skin. Use a clean "transfer" bottle to collect the sample, and then transfer it to the bottle containing preservative. Bottles for analysis of other nitrogen parameters will not contain preservative.

7.4.4 Collecting the Samples

(Adapted from USGS-NFM #5)

Prepare for sampling

6. Upon arrival at the field site, set out safety equipment such as traffic cones and signs.
7. Take extra bottles in case of contamination or loss
8. Take enough bottles to obtain QA/QC samples (see QAPP)
9. Label bottles but leave "time" field blank until actual sample collection

Determine the sampling location

6. Visually inspect the stream from bank to bank and longitudinally, observing velocity, width, and depth distribution, and apparent distribution of sediment and aquatic biota along the cross section. Note and document the location of stagnant water, eddies, backwater, reverse flows, areas of faster than normal flow, and piers or other features along the cross section.
7. Check the site list to determine whether the sample is to be collected in a pool or flowing area (or both). If sampling from a flowing area, identify the area of the stream that appears to be completely mixed (the centroid of flow). This may be determined ahead of time from reliable discharge measurements (see Initial Site Establishment – SOP#11 and Flow Measurement – SOP#9). Do not disturb the sediment before collecting a water sample.
8. For pools, if shallow (< 1 ft) take measurements at a middle depth. If the pool is from 1-4 ft deep collect a sample at a depth that meets monitoring objectives (Wilde et al, 1999)

9. For flowing water, sub-surface samples are taken at 0.1 m (4 inches) below the water surface if water level is < 5 ft (1.5 m). Samples are collected at the surface when water depth is < 0.1 m (Puckett, 2002). Sampling from the shoreline of any water body (meaning standing on shore and sampling from there) is the least acceptable method, but in some cases is necessary (Puckett, 2002).
10. Collect the nutrient sample at the same location as you will be collecting the bacteria sampling and measuring core parameters.

Water samples are collected from a location in the stream where the stream visually appears to be completely mixed. Ideally this would be at the centroid of the flow (*Centroid* is defined as the midpoint of that portion of the stream width, which contains 50% of the total flow), but depth and flow etc. do not always allow centroid collection (Puckett, 2002).

Collect the sample

Note: Collect water samples first to avoid disturbing the sediment and re-suspending sediment or bacteria

The USGS uses the "Hand-dip" method (Myers, 2003) if stream depth or velocity is not sufficient to use depth-integrated sampling. The procedure minimizes the collection of surface films and avoids contact with the streambed. The method is as follows:

1. Open plastic bottle; grasp the bottle near the base, with hand and arm on the downstream side of the bottle.
2. Without rinsing, plunge the bottle opening downward below the water surface. Allow the bottle to fill with the opening pointed slightly upward into the current.
3. Inspect each sample, looking for overfilling and (or) the presence of large amounts of particulates that might have been captured due to excessive streambed disturbance during sample collection. If you note either or both of these conditions, discard the sample, making sure there are no residual particulates left in the container, and resample.
4. Place the sample bottle in an ice-chest immediately. [NOTE: Use blue ice (often provided by labs), not wet ice to avoid possible contamination by contact with the melt water.] Ensure that the bottle label is completed with the date, time, site ID, and initials of field personnel.
5. Check the temperature of the ice-chest and refrigerator (if used); it must be between 1-4 °C. Samples should be stored in the dark.
6. Ensure that the samples are transported to the laboratory within designated EPA hold time (see Table 7.1 in this SOP).

7.5 Field Preparation and Laboratory Coordination

When starting work with a new laboratory, the Water Quality Specialist should develop a good working relationship with a laboratory manager and also a chemist/microbiologist. Discuss analytical methods, detection limits, holding times. Obtain official chain of custody forms from the lab as well as any needed bottles, cooler, and ice packs if the laboratory provides these.

Discuss sample drop-off and pick-up possibilities. Also discuss the labs' capacity for the number of samples you will have. General tasks list include:

- Notify the lab at the beginning of the season, or as early as possible, of your sampling schedule
- Call the lab the day before or the morning of sampling to verify sample collection
- If at all possible, schedule sampling early in the week rather than later.
- Fill out the chain of custody form ahead of time except for the sample time

The chain of custody form is a means of tracking samples from receipt in the laboratory through analysis, to final disposal of the sample. It should be filled out in ink. The chain-of-custody Forms travel with the samples during the transfer, and are filed in the laboratory project files. Upon arrival at the laboratory, the "sample custodian" at the lab inspects the sample containers to ensure that the sample seals are intact and the sample containers have not been damaged. If any seals have been broken and/or any sample containers damaged, the sample custodian records the condition of the seals and containers on the chain-of-custody Form. The sample custodian takes custody of the samples by signing, dating, and noting the time in the on the chain-of-custody form.

Once at the laboratory, if samples need to be subdivided and submitted to another laboratory sub-contractor, this information should be noted on the original chain-of-custody form, and a new chain-of-custody form with the other lab should be initiated (Puckett, 2002).

Equipment Checklist
Scotch tape
Hand sanitizer
Bottle labels
Disposable gloves
Sample bottles
Data sheets printed on waterproof paper
Ice chest
Thermometer for ice chest
Chain-of-custody form
Sharpie (permanent pen)
Water jug for washing hands
Soap

Also, consult SOP#2 for safety equipment.

7.6 Quality Assurance/Quality Control

Duplicate samples should account for 10% of the total number of nutrient samples collected. It is also recommended that a field blank and trip blank be conducted (1 for every 20 samples). The lab will conduct a "matrix spike." Also consult the laboratory and request information on their quality control as well. Data Acceptability Criteria for Analysis of Water Quality Samples

and QA/QC requirements are discussed further in the QAPP.

7.7 Data Reporting

A data analysis overview is provided in the protocol narrative. Details of data analysis are discussed in SOP #10.

Regardless of the form of the nitrogen measured, it should be reported in units of milligrams of nitrogen per liter (mg-N/L), so that there is the same amount of nitrogen in 2mg-N/L of nitrate as in 2mg-N/L of ammonia. Labs don't always report nitrogen this way; sometimes it is reported as the nitrate-nitrate. If it were reported in mg/L of ammonia and mg/L of nitrate, it would be difficult to compare them, since one molecule of nitrate is much heavier than one molecule of ammonia.

To convert from mg/L of ammonia to mg-N/L of ammonia, use the ratio of the molecular weight of nitrogen to the molecular weight of ammonia (14:18). To convert from mg/L of nitrate to mg-N/L of nitrate, use the ratio of the molecular weight of nitrogen to the molecular weight of nitrate (14:62).

Conversion factors:
N-molecular weight = 14
Oxygen molecular weight = 16
N/NO3 = 14/14 +48 = 14/62 = 0.2258 (approximate conversion factor)

So if you have 45 mg/L of NO3 that equals 10 mg/L of NO3-N
45 mg/L NO3 * 14N/62 NO3 = 10 mg/L of nitrate-N

NH3:
N = 14
H = 1

N/NH3 = 14/14 +3 = 14/17 = 0.8235 (conversion factor)

7.7.1 Calculating Unionized Ammonia

Ammonia results are often reported as total ammonia (TAN). The unionized ammonia (UIA), which is the toxic fraction, can be calculated as follows:

TAN x conversion factor from Table 1 = UIA (mg/L)

Using the stream and pH and temperature at the time of sample collection, determine the conversion factor from Table 1.

Table 0.2 Fraction of unionized ammonia in aqueous solution at different pH values and temperatures. Calculated from data in Emmerson et al. (1975).

	Temperature													
pH	42.0 (°F)	46.4	50.0	53.6	57.2	60.8	64.4	68.0	71.6	75.2	78.8	82.4	86.0	89.6
	6 (°C)	8	10	12	14	16	18	20	22	24	26	28	30	32
7.0	.0013	.0016	.0018	.0022	.0025	.0029	.0034	.0039	.0046	.0052	.0060	.0069	.0080	.0093
7.2	.0021	.0025	.0029	.0034	.0040	.0046	.0054	.0062	.0072	.0083	.0096	.0110	.0126	.0150
7.4	.0034	.0040	.0046	.0054	.0063	.0073	.0085	.0098	.0114	.0131	.0150	.0173	.0198	.0236
7.6	.0053	.0063	.0073	.0086	.0100	.0116	.0134	.0155	.0179	.0206	.0236	.0271	.0310	.0369
7.8	.0084	.0099	.0116	.0135	.0157	.0182	.0211	.0244	.0281	.0322	.0370	.0423	.0482	.0572
8.0	.0133	.0156	.0182	.0212	.0247	.0286	.0330	.0381	.0438	.0502	.0574	.0654	.0743	.0877
8.2	.0210	.0245	.0286	.0332	.0385	.0445	.0514	.0590	.0676	.0772	.0880	.0998	.1129	.1322
8.4	.0328	.0383	.0445	.0517	.0597	.0688	.0790	.0904	.1031	.1171	.1326	.1495	.1678	.1948
8.6	.0510	.0593	.0688	.0795	.0914	.1048	.1197	.1361	.1541	.1737	.1950	.2178	.2422	.2768
8.8	.0785	.0909	.1048	.1204	.1376	.1566	.1773	.1998	.2241	.2500	.2774	.3062	.3362	.3776
9.0	.1190	.1368	.1565	.1782	.2018	.2273	.2546	.2836	.3140	.3456	.3783	.4116	.4453	.4902
9.2	.1763	.2008	.2273	.2558	.2861	.3180	.3512	.3855	.4204	.4557	.4909	.5258	.5599	.6038
9.4	.2533	.2847	.3180	.3526	.3884	.4249	.4618	.4985	.5348	.5702	.6045	.6373	.6685	.7072
9.6	.3496	.3868	.4249	.4633	.5016	.5394	.5762	.6117	.6456	.6777	.7078	.7358	.7617	.7929
9.8	.4600	.5000	.5394	.5778	.6147	.6499	.6831	.7140	.7428	.7692	.7933	.8153	.8351	.8585
10.0	.5745	.6131	.6498	.6844	.7166	.7463	.7735	.7983	.8207	.8408	.8588	.8749	.8892	.9058
10.2	.6815	.7152	.7463	.7746	.8003	.8234	.8441	.8625	.8788	.8933	.9060	.9173	.9271	.9389

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SOP #8 Field and Laboratory Methods for Sediment

8.1 Revision History Log

Prev. Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.0	8/8/05	M. Cooprider	Minor edits, incorporated comments from technical reviewer	Preparation for formal peer review	1.01
1.01	3/23/06	R. Carson	Minor Edits	Addressing formal peer review comments	1.02

Only changes in this SOP will be logged. "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).

8.2 List of Acronyms Used for SOP #8

APHA	**American Public Health Association**
DI	depth-integrated
DIW	deionized water
EWI	equal width increment
FISP	Federal Interagency Sedimentation Project
FTU	formazin turbidity unit
GOGA	Golden Gate National Recreation Area
I&M	Inventory and Monitoring
JOMU	John Muir National Historic Site
JTU	Jackson candle turbidity unit
LEW	left edge of water
NPS	National Park Service
NTU	nephelometric turbidity unit
PINN	Pinnacles National Monument
PORE	Point Reyes National Seashore
REW	right edge of water
RWQCB	Regional Water Quality Control Board
SFAN	San Francisco Bay Area Network
SOP	standard operating procedure
SSC	suspended sediment concentration
TMDL	total maximum daily load

TSS	total suspended solids
TTS	turbidity threshold sampling
USDA	United States Department of Agriculture
USGS	United States Geological Survey
USEPA	United States Environmental Protection Agency

8.3 Scope and Application

The purpose of this standard operating procedure (SOP) is to provide detailed guidance on methods of sediment sampling in the water column and analysis of sediment samples for turbidity, total suspended solids, and suspended sediment concentration. This SOP also provides guidance on operation of a turbidity threshold sampling station. Sampling locations and frequencies for 10 watersheds in four National Park Service (NPS) units of the San Francisco Bay Area network (SFAN) are discussed.

8.3.1 Introduction

Sources of sediment in streams include erosion from stream banks, runoff from various source areas within a watershed, and re-suspension from the streambed during storm events. Some suspended solids can also originate from algal and bacterial growth. Sediments are deposited in areas where stream flow is slow. For example, gravel bars form along streambanks where flow is slower since a slower flow cannot transport as much sediment as high flows. Erosion and sedimentation are natural processes. However, agriculture and land development can accelerate these processes and result in an imbalance in the amount of sediment in a stream system.

The amount of sediment in water is quantified as milligrams per liter (mg/L) of total suspended solids (TSS). The method for determining TSS utilizes a sub-sample (100mL) of the overall sample. The method for determining suspended sediment concentration (SSC) is very similar to the TSS method except that the entire sample is used. Turbidity, another measurement of suspended sediment, is the capacity of suspended solids including clay, silt, finely divided organic and inorganic matter, soluble colored compounds, plankton, and microscopic organisms in water to scatter light (American Public Health Association et al., 1998). Turbidity is often measured in Nephelometric Turbidity Units (NTU). Other equivalent units that are used include Formazin Turbidity Units (FTU) and Jackson Candle Turbidity Units (JTU). High turbidity water can be described as cloudy or milky.

8.3.2 Sediment Impaired Waters within SFAN

In 2000, the San Francisco Bay Regional Water Quality Control Board ("Regional Board") identified both Lagunitas Creek and Tomales Bay as impaired by sediment. These watersheds are located in western Marin County within Golden Gate National Recreation Area (GOGA) and Point Reyes National Seashore (PORE). San Francisquito Creek is also listed as sediment impaired. West Union Creek, a tributary of San Francisquito Creek in San Mateo County, flows through Phleger Estate in GOGA. The Regional Board has established a timeline for

development of Total Maximum Daily Loads (TMDLs) associated with these impairment listings (Table 8.1).

Other watersheds within SFAN are negatively impacted by sediment but are not specifically listed but the Regional Board. One example is Strentzel Creek, partly located within John Muir National Historic Site (JOMU). Strentzel Creek is within the Alhambra Creek watershed in Contra-Costa County. Redwood Creek (GOGA) and other watersheds within SFAN also have sediment-related issues.

Table 0.1 San Francisco Bay Regional Water Quality Control Board TMDL Project Timeline as of 6-29-05.

Water body	Park Unit	Pollutant	Project Report Completion	Regional Board Adoption Date
San Francisquito Creek	GOGA	Sediment	Dec. 2005	Dec. 2006
Lagunitas Creek	PORE, GOGA	Sediment	Dec. 2006	Feb. 2008
Tomales Bay	GOGA, PORE	Sediment	Dec. 2007	Dec. 2008

These streams are listed because of habitat degradation due to deposition of fine sediments and due to their significance in providing critical habitat for threatened and endangered anadromous fish in the Bay Area. Populations of steelhead, salmon, and other native aquatic species have declined in the past fifty years in Bay Area streams. Other problems associated with excess sediment are related to water supply and include high turbidity and filling in of reservoirs (San Francisco Bay Regional Water Quality Control Board, 2003).

An approach for developing sediment TMDLs in San Francisco Bay Area streams was developed by the Regional Board in 2003. The first step in developing sediment TMDLs is to determine what factors impact fish populations (e.g., lack of flow, too much sediment, and fish migration barriers). These analyses also help establish priorities for watershed assessment, management, and restoration. Where sediment is verified to be a limiting factor, a sediment budget study will be conducted in order to quantify sediment inputs and outputs in a stream. A sediment budget study seeks to identify all sources of sediment and quantitatively estimate the amount of sediment transport to streams (San Francisco Bay Regional Water Quality Control Board, 2003).

SFAN staff is coordinating with the Regional Board. At this time it is uncertain what requirements there will be for sediment monitoring in the Olema, Lagunitas, and West Union Creek watersheds in association with the Sediment TMDL. Point Reyes National Seashore has monitored TSS in Olema Creek since 2000. Monitoring for TSS in GOGA began as early as 1964 in some watersheds. SFAN also recently began water quality monitoring in West Union Creek, a tributary to San Francisquito Creek. In addition, in order to facilitate the development of a sediment TMDL for Tomales Bay and Lagunitas Creek, a Turbidity Threshold Sampling (TTS) unit was installed in Olema Creek, a tributary to Lagunitas Creek, in December 2002. This unit includes an automatic pump that collects water samples at a set of turbidity "thresholds" during a storm event. Samples are then analyzed for SSC. The turbidity, SSC, and

water level data associated with the TTS station provide insights into the sediment transport dynamics within the creek.

8.3.3 Water Quality Criteria Recommendations for Sediment

Visible turbidity is considered to be greater than 5 NTU (Strausberg, 1983). Turbidities of 25 NTU or greater have caused reductions in juvenile salmonid growth (Sigler et al., 1984). The National Park Service Water Resources Division uses a "screening criteria" of 50 NTU to determine water quality exceedences in its Baseline Water Quality Inventory and Analysis Reports (National Park Service, 2003). More damage to fish and macroinvertebrates is probable if high turbidities remain in a stream system (Newcombe and MacDonald, 1991).

The UC Cooperative Extension Fact Sheet on Fishery Habitat provides a summary of the effects of varying turbidity and TSS concentrations on salmonids (Larsen, 1999; Lloyd, 1987). Juvenile and adult salmon experience moderate stress when exposed to more than six days of TSS greater than 10 mg/l or one day of exposure to TSS > 50 mg/L (Newcomb and Jensen, 1996). High TSS (> 300 mg/L; ~ >40 NTU) inhibits fish feeding, can clog fish gills and can cover gravel spawning-beds (Creek Connections, 2004; Horne, 2003). Table 8.2 summarizes recommended water quality criteria. Ecoregion II refers to the "Western Forested" Region that includes GOGA, MUWO, and PORE. Ecoregion III is the "Xeric West" that includes PINN and JOMU.

Table 0.2 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		
ϕTurbidity	25 NTU		1.30 NTU	2.34 NTU

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

In streams, the most desirable algae species are the diatoms, the golden brown algae. The golden brown color of coastal California streams is due to a thin coating of diatoms on the rocks and cobble. These diatoms can move slowly and form a nutritious biofilm on the rocks that is a major food supply for valuable insect larvae such as mayflies, caddis flies and snails. Clear water with low TSS is vital since not only must sunlight reach the steam bed but sediment-laden water will scour the rocks killing the diatom biofilm (Stafford and Horne, 2004). Certain species of macroinvertebrates are also sensitive to changes in sediment. Maintaining streams with TSS levels low enough to support fish, algae and other aquatic life is a significant concern for SFAN.

8.3.4 Sediment Levels in SFAN Waters

Total suspended solids and turbidity have been measured in GOGA since 1964. At Pinnacles National Monument (PINN), TSS has been measured from 1997 to 2001, not including 1999. At PORE, TSS has been monitored since 1997. A summary of TSS and turbidity data is included in Tables 8.3 and 8.4.

Table 0.3 Total Suspended Solids in mg/L.

	PORE	**GOGA**	**PINN**
Maximum	1281	8000	240
Median	0.8	23	< 5 mg/L (detection limit)
Mean	10.2	98	154
# of observations	465	614	10

Table 0.4 Turbidity in Nephelometric Turbidity Units (NTU).

	GOGA
Maximum	255, 270
Median	22.8
Mean	35.7

Note: Data is not currently available for PORE.
PINN did not collect turbidity data. Data included in this table is from 1964 to 2002 from the GOGA database (up to 1999) and subsequent stables studies (2000-2001).

8.3.5 Sediment Monitoring Rationale & Objectives

8.3.5.1 Sediment Concentration and Turbidity Comparisons

Investigations regarding the comparability of TSS and SSC analytical results conclude that SSC and TSS collected from natural waters "are not comparable and should not be used interchangeably" (Gray et. al., 2000). The methods for analyzing TSS and SSC are essentially the same except that SSC measurements are derived from the entire natural water sample while TSS samples are derived from a subsample (usually 100 ml of a 1 liter sample) of the natural water sample. Subsampling by either pipette or pouring from an open mouth bottle tends to produce a sand-deficient sample (Glysson et al., 2000). Therefore, TSS is typically slightly less than SSC (Glysson and Gray, 2002). Originally, TSS was developed as a proxy for SSC in wastewater samples. This comparability breaks down when conducted on natural water samples.

Turbidity is a measure of interference in the water column produced by both mineral and organic particles. Monitoring efforts in the northern coast of California show that at certain times, the organic component of the flow can account for 60 – 80% of the turbidity measured at a site (Madej et al., 2002). TSS and SSC do not include this organic component.

There is a range of literature available showing that TSS and turbidity information can be correlated resulting in well-established relationships (Packman et al., 2000; Lewis et al., 2002). The same cannot be done with SSC and TSS (Glysson and Gray, 2002). While better correlation

is found in samples with low sand content, there is a wide variability in these conditions between stations. While direct correlations between these parameters are problematic, the NPS proposes collection of TSS or SSC in addition to turbidity. Results of paired analysis (turbidity and either TSS or SSC) will be used to report results for each of the monitored stations.

8.3.5.2 Sediment Monitoring Questions

1. Is turbidity chronically high (how long does turbidity remain in a stream after the peak of a storm event)? *Justification: Chronic turbidity is more of a concern for fish then sediment spikes that are typical in winter storms in coastal California; fish find refuge during storms. This can also help determine whether management practices to reduce erosion are effective. In addition, data can be plotted with lines indicating various turbidity thresholds; see Section 1.3 of this SOP*.

2. Are the magnitudes of the winter spikes changing? *Justification: This helps assess the condition of the land and determine whether the sediment load is increasing or decreasing over time. This can also help determine whether management practices to reduce erosion are effective.*

3. What and where are the sources of sediment within the watersheds? *Justification: If problems are identified through questions #1 and #2, the sediment sources will need to be identified. Much sediment reduction work is conducted via geomorphology or other surveys and may not necessarily require water quality sampling for sediment. It is critical that park and network staff work together to identify sediment sources and discuss possible site locations for sediment monitoring if it is deemed necessary*..

4. Is there a significant relationship between turbidity and SSC during a storm event or at other times of the year? Justification: Once a relationship is established, turbidity can be used as the primary indicator of sediment water quality. Turbidity is a more simple and cost effective means of monitoring sediment.

Monitoring questions #2 and #4 require a turbidity threshold sampling station and therefore would only apply to Olema Creek. Monitoring question #3 may be beyond the scope of the I&M program but is included here since it is important for the parks. Monitoring as part of the freshwater quality protocol will focus on question #1. However, additional information related to questions #2, 3, and 4 is provided in this SOP as reference. Table 8.4 provides information about monitoring location and frequency for each of the sediment monitoring questions.

Table 0.5 Sediment monitoring questions, location, sampling frequency and analysis.

Monitoring Question	Watershed	Location	Frequency	Analysis
Chronic turbidity	All; in-situ sensor priority: Lagunitas, Olema, Redwood, Pine Gulch, West Union	All water quality monitoring sites, in-situ turbidity sensors at stream gauges if applicable	After storms and continuously (rotate the in-situ turbidity sensor to cover all watersheds)	Turbidity by turbidimeter and in-situ sensor; TSS
Magnitude of sediment spikes	All	At long-term water quality monitoring stations or fish index reaches	2-3 storm events each annually (must catch peak of storm event)	Turbidity, TSS, particle size
Sediment sources	As needed	Upstream and downstream of suspected sources	Storm events; coarse level erosion inventory	Turbidity, TSS
Turbidity vs. SSC	Olema	Bear Valley Rd. bridge, TTS station	As many winter storm events as possible	Turbidity by in-situ sensor, SSC

Watersheds to be monitored for chronic turbidity (question #1) include Lagunitas Creek, Olema Creek, Redwood Creek, Pine Gulch, West Union Creek, Strentzel Creek, Rodeo Creek, Tennessee Valley, Chalone Creek, and Franklin Creek. Water samples should be collected as soon as possible after a storm peak. Collect at least 1-2 samples near the peak, then daily until the water clears (Randy Klein, personal communication, 5 July 2005). Just 4-5 samples during the recessional limb of a hydrograph can be useful since this is when chronic turbidity occurs (Randy Klein, personal communication, 5 July 2005).

8.4 Field Techniques

8.4.1 Introduction

Sampling during storm events presents unique challenges in the San Francisco Bay Area. Winter weather is unpredictable with significant variation in rainfall quantity and distribution among and within the parks. Watersheds are small and stream stage and velocity can increase rapidly in a very short period. The I&M Freshwater Dynamics protocol will include measuring stream stage and velocity in order to create a hydrograph. The hydrograph is a very useful tool to predict stream flow. In planning sediment sampling events, it is important to be aware of impending weather conditions and to be familiar with each stream's hydrograph.

8.4.2 Preparations and Field Rinsing of Equipment

(Adapted from Radtke and Wilde, 2002)

Most equipment used for sample collection and processing is field rinsed with the water to be sampled just before the water samples are collected. The purposes of field rinsing are to condition, or equilibrate, the equipment to the sample environment and to help ensure that all cleaning solution residues have been removed before sampling begins.

To field rinse a surface-water sampler and sample bottle:

1. Put on appropriate disposable, powderless gloves.
2. Partially fill and rinse the sampler and bottle with the water to be sampled (rinse water). Avoid getting sand in the rinse water. If there is not a sufficient amount of sample water, use deionized water (DIW).
3. Shake vigorously to rinse. Discard the rinse water by swirling the solution out of the bottle or sampler. Swirl and then drain the rinse water from the sampler through the nozzle. Shake off adhering water droplets.

Equipment Checklist
Gloves
Bottles appropriate for DH 48 sampler
DH 48 wading sampler
Velocity meter
Tape measure/tag line
Chaining pins

Personal flotation device and other safety equipment
Watch
Data sheets/*Rite in the Rain*™ notebook

8.4.3 Isokinetic, Depth-Integrated Sampling

Because suspended sediment concentration varies from the water surface to the stream bed and laterally across a stream, depth integrated sampling will be utilized. This will help ensure that the entire water column of the stream is adequately represented. For depth-integrated sampling within SFAN, the equal-width-increment (EWI) method will be used. Consult the USGS National Field Manual for specific information regarding this method.

There are several different kinds of samplers used for depth-integrated sampling; SFAN uses the sampler model DH-48. For isokinetic sampling with a bottle sampler, the mean velocity of the vertical that is sampled must exceed 1.5 ft/s (Webb et al., 1999). In the sampling operation the intake nozzle is oriented into the current and held in a horizontal position while the sampler is lowered at a uniform rate from the water surface to the stream bottom and instantly reversed. The sampler continues to take its sample throughout the time of submergence. For detailed specifications, sampler assembly, and instructions for use of the DH-48 sampler see the Federal Interagency Sedimentation Project information on the DH-48 sampler ((FISP, 1958). This information can be found at http://fisp.wes.army.mil/Instructions%20US%20DH-48%20001010.PDF or in Appendix A of this SOP.

Before field work, clean appropriate parts of the sampler and store in plastic for transport to the field site. All sampling equipment should be checked prior to heading out into the field. A clean sampling container and nozzle should be used for every sample. Refer to the pre-field check list for the D-48 isokinetic sampler in Table 8.5.

Table 0.6 Pre-field check list for D-48 hand-held samplers (adapted from the Federal Interagency Sedimentation Project (FISP, 1958) and Webb and Radtke, 1998, Selection of Equipment for Collection of Water Samples.

√	Items	Comment
	Sampler body	Inspect sampler body for damage and missing parts.
	Air exhaust port	Both ends should be clear and unobstructed to ensure inflow efficiency.
	Nozzle	The yellow nozzle should be straight with no visible signs of damage, check for damage to the threads on the nozzle; also inspect the bore for straightness and any signs of burrs or deformity. If damage or burrs are found in the bore or at either opening, it should be discarded and replaced with a new nozzle.
	Bottle gasket	If the gasket is hard to the touch torn, or will not fit flush in the gasket seat of the sampler, it should be discarded and replaced. If the gasket is in good condition, it should remain in place once it is pressed into the seat.
	Sampling container	Inspect the bottle for cracks and ensure that it is clean.
	Wading rod and extensions	Check for damage to screw threads.
	Mechanical Operation	Test the overall working condition of the sampler.
	Laboratory results from analysis of sampler blank	Make sure the sampler has been quality assured with an annual equipment blank and certified for water-quality use.
	Separate sets of sampler components and back-up components	If at all feasible, for a given field trip when collecting multiple water samples, prepare and use separate sets of sampler bottles, caps, and nozzles for each sampling site. Have backup equipment available on-site.
	Field-cleaning supplies and blank water	If separate sets of sampler components are not available, then clean equipment between sampling sites and be prepared to process the number of field blanks needed to document that equipment was adequately cleaned.

Preparation for sampling:

- Set up a tape measure or tag line across the stream, record the left edge of water (LEW), facing downstream, and the right edge of water (REW) and width (see data sheets in Appendix B).
- Obtain a discharge measurement noting the range in velocities across the channel. Consider whether the distribution of sediment will change during sample collection.
- Velocity must at least 1.5 ft/s but should not exceed 9.0 ft/s in order to collect an isokinetic sample with the DH-48 (Webb et al., 1999).
- When choosing a cross sectional width to sample, avoid side channel eddies. The depth-integrated sampler cannot be used where there is upstream eddy flow.
- Maximum safe wading depths depend on the size of the field technician, the stream velocity, and the streambed material. In general, do not attempt to wade in a stream for which values of depth multiplied by velocity are greater than or equal to 10 ft^2/s. Caution should also be used if the stream depth is greater than 3 ft.
- Always wear a personal flotation device and be familiar with other safety procedures listed in SOP#2-Personnel Training and Safety.
- A rope deployed depth-integrated sampler such as the DH-59 can be utilized from a bridge during high flows where the wading sampler cannot be used. The DH-59 is recommended for high road bridges such as Bear Valley Rd.

over Olema Creek, Hwy. 1 over Redwood Creek, and Hwy. 146 over Chalone Creek).

- Alternatively, for depths too deep to wade, the DH-48 has wading rod extensions in 3-ft lengths that can be added for use from a boat or low bridge (e.g., pedestrian trail bridges over Franklin Creek, Rodeo Creek, and Bear Gulch). With all extensions, the maximum sampling depth is 9 ft.
- A plastic 500mL sample bottle should be used for depth-integrated sampling. Ensure that the sampling bottle is not cracked.

Depth-integrated sampling technique: (*adapted from Webb et al., 1999*)

1) Divide the channel into 10-15 vertical panels ("increments"), no more than 20 depending on the width of the channel and the range in velocities. For a cross-sectional width of < 5 ft, use as many increments as practical, but equally spaced a minimum of 3 in. apart. For a width of > 5 ft use a minimum of 10 equal width increments.
2) Starting at the LEW, take a sample from the midpoint of each vertical into the same bottle.
3) Lower the sampler until slight contact is made with the streambed.
4) Do not pause upon contacting the streambed. Raise the sampler immediately at a constant transit rate to complete the vertical traverse. The descending transit rate does not have to equal the ascending transit rate, but each rate must be unidirectional and constant, until the sampler bottle is full.
5) Take care not to disturb the stream bed or disrupt flow (be aware of your location the stream)
6) Fill the bottle 75-90% full (approximately 375 to 420 mL). If the bottle becomes entirely full full, the sample should be discarded since it may not be representative (Federal Interagency Sedimentation Project)
10) Note the stage height. If it is changing rapidly, move fast across the stream as you fill the bottle.
11) Dry the bottle and label each bottle with site location ID, date, time and initials of field crew. It is helpful to partially fill out the label before heading into the field.
12) Place the bottle in a cooler with blue ice and keep chilled at 4°C in the dark. Samples should be analyzed for SSC as soon as possible (within 24hrs), and should not be stored more than seven days. Turbidity measurements should be taken as soon as possible within 24 hrs. (American Public Health Association et al, 1998).

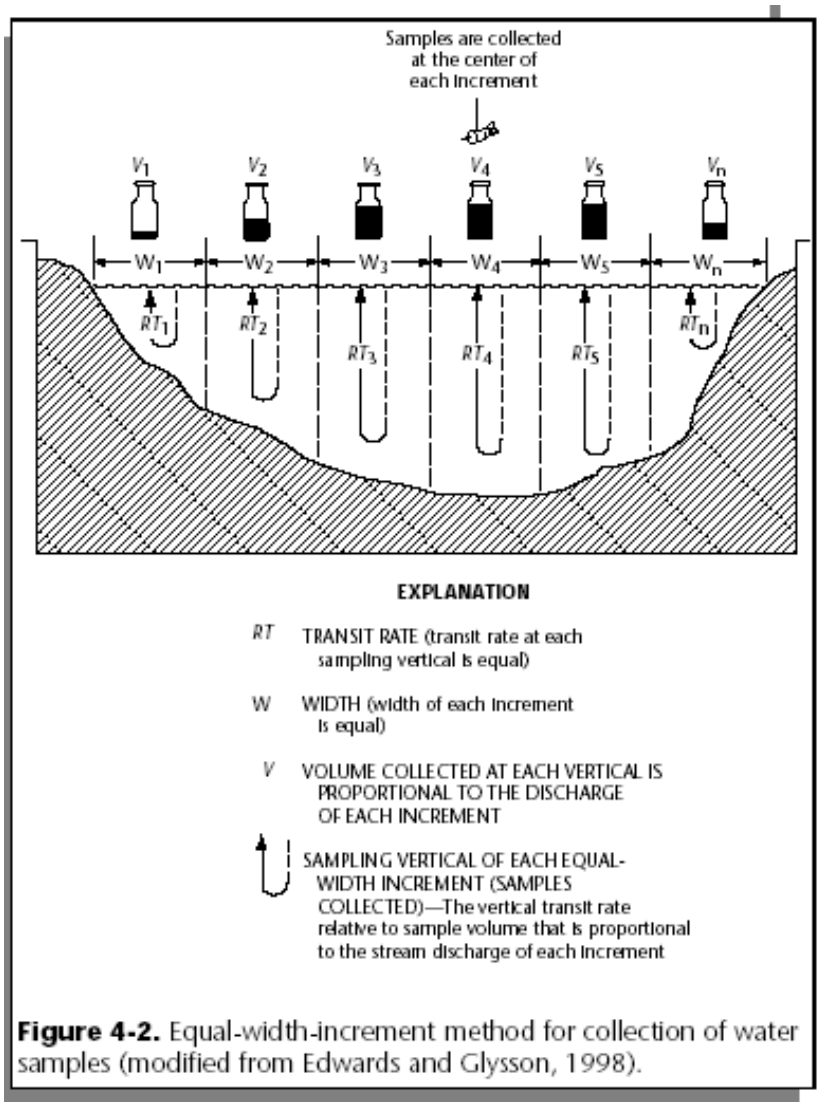

Figure 4-2. Equal-width-increment method for collection of water samples (modified from Edwards and Glysson, 1998).

Figure 0.1 From USGS National Field Manual (Webb and Radke, 1998).

8.4.4 Non-isokinetic Sampling

For isokinetic sampling with a bottle sampler, the mean velocity of the vertical that is sampled must exceed 1.5 ft/s. If this minimum velocity is not met, collect grab samples using an open mouth sampler at the centroid of flow approximately 12 inches below the water surface, if possible. The hand-held bottle sampler is the simplest type of open-mouth sampler. A bottle is dipped to collect a sample where depth and velocity are less than the minimum requirements for depth-integrating samplers.

8.4.5 Turbidity Threshold Sampling

Due to the status of Lagunitas Creek and Tomales Bay as sediment-impaired waters, Olema Creek, a tributary to Lagunitas Creek, was chosen as a location to conduct turbidity threshold sampling (TTS). As part of this pilot project, Point Reyes National Seashore contracted with Graham Matthews & Associates to perform the installation of the TTS unit and to provide training for operation of the TTS unit. In December 2002, the TTS unit was installed at the Olema Creek stream gauge at the Bear Valley Road Bridge near the park headquarters. Over the past few years, the consultant has made numerous system modifications and park staff has been learning the operation and maintenance of the system. The system was fully functional in May 2003. Subsequent storms have damaged this sampling station and the functionality of the TTS unit. Repairs will be made, and the unit will be brought back online as time and funding permit.

8.4.5.1 Introduction

Turbidity threshold sampling involves methodology and instrumentation developed by the U.S. Department of Agriculture (USDA), Forest Service, Redwood Sciences Laboratory (Lewis, 1996; Lewis and Eads, 1996; Eads and Lewis, 2002; Lewis, J., R. Eads, and N. Cambell-Lund, 2002). The TTS procedure involves collecting water samples that are distributed over a range of rising and falling sediment concentrations in a stream. The data resulting from TTS can be used to determine suspended sediment loads by establishing a relationship between sediment concentration and turbidity. A general description of turbidity threshold sampling was written by Rand Eads (2001) and is included below. The document with photos of TTS station components can be found at http://www.fs.fed.us/psw/topics/water/tts/tts_inst.shtml .

The Importance of Automated Data Collection:

The ability to collect useful information about suspended sediment transport and water discharge is dependent on the timing and frequency of data collection during storms. All river systems, particularly smaller watersheds that respond very quickly to rainfall, benefit from automated data collection. In rain dominated regions most suspended sediment is transported during a small number of events. Although it is possible to rely solely on manual measurements, important storm flows are usually infrequent and difficult to predict. When they do occur, trained personnel may not be available to collect the required information. Infrequent, systematic manual sampling will not provide adequate information to make credible suspended sediment load estimates under these conditions. As of yet, there is no reliable method to directly measure suspended sediment concentration in the field. Usually water discharge is not a good predictor of sediment concentration for rivers and streams that transport the bulk of their sediment load as fines because the delivery of sediment to the channel from hillslopes, roads, and landslides is highly variable. For rivers that transport mostly sand, water discharge and concentration may be more closely coupled if transport depends mainly on stream power to mobilize in-channel sources that are not easily flushed from the system. However, in streams transporting fine sediment, a sampling scheme that employs a parameter such as turbidity, which can be well correlated with suspended sediment concentration, can be expected to improve sampling efficiency and load estimation. Turbidity threshold sampling collects physical samples that are distributed over a range of rising and falling turbidities (Lewis and Eads: 1996, 1998 and 2000). The resulting set of samples can be used to accurately determine suspended sediment loads by establishing a relationship

between sediment concentration and turbidity for any sampled period and applying it to the continuous turbidity data.

How Turbidity Threshold Sampling Works:

Turbidity is an optical measure of the number, size, shape, and color of particles in suspension. A number of manufacturers offer turbidity probes that can be deployed on a continuous basis in streams. The optical properties of sediment, mainly size and shape, have a large influence on the magnitude of the turbidity signal. For instance, sand particles return a much lower turbidity signal for a given concentration than silt and clay particles of the same concentration. TTS utilizes turbidity thresholds, points at which physical samples are collected, distributed across the entire range of expected rising and falling turbidities. Contamination of turbidity probe's optics by debris, algae, or macroinvertebrates can lead to a noisy, or progressively increasing, turbidity signal. Sensors with reliable optical wipers, such as the DTS-12, manufactured by FTS, can reduce optical fouling and are recommended to improve data quality. Careful design of the turbidity probe's housing and mounting hardware can reduce fouling from large organic debris.

Turbidity thresholds are selected by taking into consideration the maximum expected turbidity value for a stream, the range of the turbidity probe, and the number of desired physical samples based on the magnitude of the storm. In our experience, using a square-root scale to distribute the thresholds provides an adequate pairing of turbidity-concentrations to produce acceptable regressions. For the smallest storms, three or four samples should be adequate, while large events may produce 5 to 15 samples. Different sets of thresholds are used when turbidity is rising and falling, with more thresholds required during the much more prolonged falling period. The user can fine-tune the distribution of thresholds to maximize efficiency. A set of rules, in addition to the predefined turbidity thresholds, aids in reducing sampling during short duration turbidity spikes, ensures that a "startup" sample is collected at the beginning of a storm, and defines reversals in turbidity. The rules permit continued sampling when turbidity levels exceed the turbidity probe's range, and they allow collection of non-threshold, manually triggered samples to be paired with depth-integrated samples or to augment sample numbers if desired.

Closely spaced turbidity measurements produce interesting trends in sediment transport such as spikes superimposed on the storm turbidigraph that often indicate landslides or streambank failures upstream. In the case of nested watersheds, the timing and magnitude of these sediment pulses may provide additional information about cumulative effects, or dilution, downstream. Authenticity of these turbidity spikes is confirmed when physical samples taken during the spikes have higher concentrations than surrounding samples.

Instrumentation:

Data Logger and Sampling Logic

A programmable data logger is required to make the required sampling decisions. For remote locations, it is important that the data logger has low power requirements in order to preserve the battery's capacity. The TTS program only requires input information about stage and turbidity to decide what actions to take. Wake-up intervals are either set at 10-minutes for small, flashy watersheds, or at 15-minute intervals for larger basins. At the beginning of each wake-up interval, the OBS-3 turbidity probe, under control of the program logic, collects 60 measurements in 30 seconds (mention of product names is not an endorsement by the USDA Forest Service). Next, the raw turbidity values are sorted and the median value is determined. We have found that these two operations effectively reduce outlier values. In the case of the DTS-12, the sampling frequency and period, and reported statistics, are controlled by the sensor's onboard processor. The program next collects 150 stage readings in three seconds from a pressure transducer and computes the mean stage. The mean stage is then compared against the minimum operating stage to determine if the turbidity probe and sampler intake are adequately submerged (stage is above "baseflow") to allow sampling. If the program logic determines that a sample is required, based on the rules discussed above, it activates an automatic water sampler to collect one sample. Other instruments, such as tipping bucket rain gages and water temperature probes, may be connected to the data logger to provide additional information. Finally, all pertinent records are written to data logger memory. The TTS logic, discussed above, has been developed for Campbell data loggers. The TTS program is executed from the Campbell CR10X data logger platform

Turbidity Probe

The OBS-3 turbidity probe, manufactured by D&A Instrument Company, is a backscatter nephelometer that emits infrared radiation (IR) into the water column. The distance the IR penetrates the water depends on the probe's optical configuration and the amount and type of sediment in suspension. The penetration, or volume sampled, decreases with increasing concentration of material. The scattered IR returned to the sensor's detector is a function of particle size and shape and the number of particles in suspension. Comparisons made with different turbidimeters should be viewed with some skepticism due to inconsistencies in light sources, calibrations, and the sampled volume. Periodic calibration of the turbidity sensor in formazin standards is required to compensate for instrument drift and scratched optical surfaces. Sensors with a small viewing area (1 cm or less) reduce the chance that large debris will be viewed by the optics and allow for shallow deployment. Small viewing areas often do not provide adequate sampling volume and may produce noisy data. Large viewing areas (7 to 25 cm) have the opposite characteristics. A viewing area of 4 to 7 cm is a good choice.

The turbidity probe housing reduces contamination from organics by shedding debris. The housing, if properly designed, can reduce hydrodynamic noise caused by turbulence and the entrainment of air or re-suspension of sediment close to the sensor. The housing also protects the sensor from direct impacts by large submerged organic debris.

Note: The DTS-12 turbidity sensor is now more commonly used, is the recommended sensor, and is self-cleaning (Randy Klein, personal communication, 7 July 1005).

Sampling Boom

The boom positions the turbidity probe and sampler intake at the appropriate position and depth in the stream. Since the boom is articulated, large floating organic debris can, on impact, lift the vertical arm of the boom to the surface and pass underneath. Increasing water velocity and depth pushes the vertical boom arm downstream, raising the turbidity sensor higher in the water column. A counterweight prevents the boom from rising to the water surface. The highest probability of contamination by organics, and resulting loss of data, occurs during flood stages when organic material is recruited from flood plains. A bank-, cable-, or bridge-mounted retrievable boom is desirable for all but the smallest streams to allow debris removal during high flows. The depth of the turbidity probe can be adjusted as needed to position the probe above the zone of bedload transport and below the water surface. Changing the depth of the turbidity probe can change the ratio of coarse and fine particles sampled by both the turbidity probe and sampler intake.

-By Rand Eads,Redwood Sciences Laboratory, 2001.

TTS is a high level of monitoring and is very intensive in terms of maintenance/troubleshooting and the number of samples that are collected. For example, 200 samples could be collected during a few storm events. A significant amount of time is also required to correct turbidity data. For other streams besides Olema, a lower level of monitoring can be just as effective. For a turbidity threshold sampling station, instead of fixing on one turbidity threshold as a standard, it is useful to determine the number of hours that turbidity exceeded various thresholds such as 25, 50, 100, 200, 500, and 2000 NTU ((Randy Klein, personal communication, 7 July 2005).

Without a TTS unit it is difficult to capture the peak of a storm event. A useful alternative is to take samples during the recessional limb of a storm since this is where chronic turbidity occurs. Even four to five samples can provide enough points to create a recessional turbidity curve. Four to five samples from four storm events can provide enough points to have an overlay that fits well over the curve produced from 200+ samples collected by the Isco automatic sampler. Overlaying these curves on each other also allows you to see the point at which watershed size and geology affects on the curve disappear. Focus on taking 1-2 samples immediately after the storm peak then one every day until the water clears. Favor more samples closer to the peak (Randy Klein, personal communication, 7 July 2005).

8.4.5.2 TTS Program

The Turbidity Threshold Sampling Program for the CR10X datalogger contains all of the program information including turbidity threshold codes, sample codes, subroutines, pressure transducer and turbidity sensor wiring and connections and other electronic aspects of the program (Lewis et al., 2002). The program "wakes-up" and records measurements every 10 minutes at the Olema TTS station. The OBS-3 sensor measures turbidity at 0.5 second intervals for 30 seconds for a total of 60 readings. The median turbidity of these readings is then saved.

The median turbidity and average stage values are used to trigger a pumping sampling if the sampling criteria are satisfied (Lewis et al., 2002).

Detailed instructions on programming the data logger, initializing a new station, connecting to an existing station, and retrieving data from a TTS station are included in the TTS Field Manual in Appendix C.

8.4.5.3 Summary of Field Tasks and Data Analysis for TTS

1. Check the station weekly and during every storm event (see Table 8.6)
2. Troubleshoot station instrumentation as needed
3. Calibrate turbidity
4. Calibrate sediment concentration using depth integrated (DI) sampling during a storm event
5. Conduct laboratory and data analysis including:
    - Conduct laboratory analysis for SSC
    - Develop a standard procedure for data management
    - Develop turbidity - sediment rating curve (TTS rating curve)
    - Plot DI sample turbidity against ISCO sampler turbidity
    - Plot DI sample SSC against ISCO sample SSC

Table 0.7 TTS Weekly Field Visits (complete these tasks in the order listed).

Task	**Notes**
Observer Record	In the yellow "Rite in the Rain" ® station notebook record the following: ▪ Date, time, observer initials, battery IDs ▪ Presence of sediment, debris, or obstructions affecting turbidity probe. Wait until after data collection to correct problems ▪ View Left, Right, and Inside State
Check the ISCO Sampler	▪ Note the "next sample" value displayed by ISCO ▪ If > 2 minutes until a wakeup, inspect samples ▪ If volumes are too low* or high, see "Troubleshooting" in the TTS field manual (Appendix C)
Interrogate the data logger	▪ Launch the PC208Q software and connect to data logger. ▪ View and record the current values in the numeric window. ▪ Staff plate reading must be verified within 5 minutes of data record on display in numeric window
Optional: collect a DI or AUX sample	▪ Set appropriate sample flag ▪ Collect the sample at the next wakeup ▪ Update your record of staff plate readings and current values shown in the numeric window
Retrieve Data	▪ Choose between a "snapshot" data check and a Data Dump ▪ If dumping, set Dump Flag. (Confirm staff plate reading). ▪ Collect data, then disconnect from data logger and exit PC208 W program.
Service turbidity probe	▪ Remove debris and sediment from housing, mounting apparatus, etc. ▪ Inspect/remove debris from inside housing. ▪ During non-storms, clean optics if necessary

Service flume or weir or rated section (section with hydrologic rating curve)	▪ Clear branches and debris ▪ Shovel sediment deposits downstrream through flume. ▪ Flush stilling well intakes if needed. ▪ Record changes in staff plate readings.
ISCO Sampler	Only if data is dumped, change ISCO bottles and reset distributor arm
System batteries	Replace low Gel cell battery only after confirming 9V > 9.0 volts
Dessicants	Check/replace dessicants
Additional Tasks	▪ See maintenance schedule ▪ Troubleshoot suspect equipment
Plot the data	▪ Run R_FieldPlot to graph the data
Complete the electronic field form	Run the Corel Database program to create an electronic field form incorporating your comments from the station notebook.

*ISCO sample bottles are 1000mL, the minimum sample volume for SSC analysis is 350 mL.

8.4.5.4. Calibrating the TTS Station

The USGS protocol for wading vs. bridge sampling is when the velocity x depth is $\geq$ 10, then use a rope deployed sampler (DH 59) for DI sampling from a bridge. Otherwise, use common sense to determine when to use the DH 48 wading sampler. Calibration should be conducted during a storm event in order to capture a large range of turbidities. Ideally, the DI sample would be taken during the largest storm event in order to have the most turbidity thresholds (all thresholds that would occur for that particular stream). The TTS station needs to be calibrated several times at different stages in the hydrograph. Depth-integrated sampling needs to be done for each new turbidity threshold so that a rating curve can be developed. DI samples represent the cross-sectional average sediment concentration and are used as "truth" to correct the TTS station ISCO pumped samples that are not flow-weighted but are point samples. The DI sample field data sheet is in Appendix B.

Sediment Calibration

1) Set up a tape measure across the stream, record LEW and REW, and width.
2) Measure the range in velocities across the channel.
3) See Section 2.3 for details on collecting a depth-integrated sample.
4) Divide the channel into 10-15 panels (no more than 20) depending on with of channel and range in velocities.
5) Download datalogger ("collect all" on PC208W program).
6) Follow page 10 of the TTS Field Manual "Collecting a DI Sample".
7) Collect the DI sample at approximately the same time as the ISCO sampler. You want to be halfway through your DI sampling when the ISCO pumps. The Olema Creek gauge at the Bear Valley Road bridge takes 35 seconds to start the rinse. It finishes pumping after 2 minutes and 20 seconds.
8) Collect several samples during the storm as long as it is safe to do so.
9) Conduct laboratory analysis for SSC on the DI samples and the ISCO samples following Section 3.1 in this SOP.

Turbidity calibration

Calibrate turbidity once a month. The turbidity probe should be approximately five inches below the water surface or at 50% of the depth. Collect a grab sample immediately downstream of the turbidity probe. Insert the sample bottle facing down and then turn horizontally so that the mouth of the bottle is facing upstream. Compare the field turbidity meter (e.g., Hach 2100P) reading with the turbidity probe reading. Consult the OBS-3 instruction manual for specific information about the turbidity probe (D&A Instrument Company, 2001). See Section 3.2.1 of this SOP and the Hach manual for detailed instructions on the Hach 2100P turbidimeter (Hach, 2001).

8.5 Sample Preservation, Storage, and Analysis

8.5.1 Suspended Sediment Concentration (SSC) and Total Suspended Solids (TSS)

Samples should be analyzed for suspended sediment concentration or total suspended solids as soon as possible (within 24hrs) and should not be stored more than seven days. The laboratory method for analyzing SSC is included in Appendix D. The TSS method follows the American Public Health Association (APHA) method (APHA et al., 1998). Laboratory analysis for SSC will be conducted at a certified laboratory. Analysis for TSS will be conducted either at a certified lab or at the GOGA wet lab. The SFAN water quality specialist and other trained staff will conduct the analyses. However, due to staff time constraints with the 7 day holding time and the need to sample during storm events, it may be necessary to have an outside laboratory analyze the samples.

8.5.2 Turbidity

Turbidity is time sensitive, so measurements should be obtained in the field. Biodegradation, settling, or sorption of particulates in a sample or precipitation of humic acids and minerals can affect the turbidity.

8.5.2.1 Turbidimetric Determination Using a Cuvette-Based Turbidimeter

It is highly recommend that program staff read the USGS National Field Manual Chapter section on Turbidity (Anderson, 2004). The following information about equipment calibration and maintenance is taken from both the National Field Manual and the Hach 2100P turbidimeter equipment manual (Hach, 200l).

Equipment and supplies:
Turbidimeter
Turbidity stock solutions and standards
    Formazin stock suspension (StablCal ®)
    Manufacturer provided secondary turbidity standards (Gelex ®)
Sample cells (10 mL cuvettes), clear colorless glass
Sample bottle (preferably one that does not adsorb suspended sediment; use an amber glass bottle if the sample is to be stored temporarily.

Silicon oil, optical grade
Paper tissues, extra lint free
Disposable gloves
Deionized water for rinsing
Non-phosporus detergent for cleaning sample cells
#2 single-hole stopper and syringe for degassing samples

Maintenance & Calibration of the Turbidimeter (see also Anderson, 2004 and Hach Instrument Manual, 2001)

- Protect instruments from extreme temperatures.
- Shield the instrument from direct sunlight.
- Check and replace batteries regularly.
- Follow the Hach manual for specific calibration procedures and preparation of formazin standards.
- Formazin standards are affected by temperature. To avoid the affects of temperature changes on the calibration, perform the Formazin and the secondary standard calibration at room temperature in the lab. Use three calibration standards that bracket the anticipated range of turbidity.
- Conduct instrument checks against the secondary standards in the field.
- Use the Gelex® standards for instrument verification only, not for calibration
- Periodically check two turbidimeters against each other.
- Discard turbidity standards that have expired and never pour used standard solution back into a stock container.
- Keep sample cells clean inside and out.
- Wash sample cells with non-phosphate detergent between each use and rinse with deionized water so that all detergent is removed.
- Let cells air dry in a dust-free environment.

Collecting Samples for Turbidity Measurement

- Turbidity measurements can be taken from either a grab-sample at the centroid of flow, from a pumped sample (ISCO sampler), or from a depth-integrated (discharge-weighted) sample.
- Turbidity measurements should be made in the field whenever possible. If it is necessary to store samples, the holding time should not exceed 24hrs (ASTM International, 2003a). Samples should be stored at $\leq$ 4°C to prevent biodegradation of solids.

Obtaining Turbidity Measurements:

- Shake the sample bottle vigorously to disperse all of the solids.
- Pour the sample into a sample cell to the line marked on the neck. Do not touch the cell walls with fingers.
- Remove air bubbles by degassing via vacuum produced using the stopper and syringe apparatus (see USGS National Field Manual, Anderson, 2004).
- Remove condensation from the cell with a clean, soft lint-free cloth or tissue.

- Apply a thin coat of silicon oil on the outside of the cell about every third time the cell is wiped free of moisture. The oil will mask minor imperfections and scratches; too much oil will attract dirt and could foul the cell compartment.
- Be sure that the sample is correctly oriented. Insert the sample cell so that the arrow on the cell faces the notch on the turbidimeter sample cell chamber.
- Press the "read" button to obtain a turbidity reading.
- Turbidity readings can be affected by unmatched cell orientation, condensation, gas bubbles, fingerprints, scratches, or dirt on the surfaces of the sample cell or turbidity probe.
- Avoid trying to run extremely high color or organic matter samples or else dilute. Otherwise the sample may be over range.
- Use in low light.
- Use on a level surface to help avoid stray light entering the measurement chamber.

Reporting Turbidity
- Turbidimeter specifications to include in the NPSTORET database are provided in Table 8.8.
- Guidelines for reporting turbidity measurements are included in the Table 8.9.

Table 0.8 Hach 2100P Turbidimeter Specifications.

Resolution	Measurement Range	% Difference from NTU Standards
0.01 NTU	<10 to 1,000 NTU	-5%, 20, to 950 NTU

Table 0.9 From USGS National Field Manual, Section 6.7 (Anderson, 2004).

Table 6.7–6. Guidelines for reporting turbidity units

[For ASTM and USGS measurements, refer to table 6.7–3 for reporting units based on instrument design. **Abbreviations:** USGS, U.S. Geological Survey; ASTM, ASTM International; EPA 180.1, U.S. Environmental Protection Agency method 180.1 (1993); GLI, Great Lakes Instruments; ISO 7027, International Organization for Standardization method 7027 (1999); NTU, nephelometric turbidity units; FNMU, Formazin Nephelometric Multibeam Units; FNU, Formazin Nephelometric Units; N/A, not applicable; <, less than; ≥, equal to or greater than]

Turbidity Reading	USGS	ASTM	EPA 180.1 (NTU)	GLI Method 2 (FNMU)	ISO 7027 (FNU)
0–<1	0.05	0.05	0.05	0.05	0.01
1–<10	.1	.1	.1	.1	.1
10–<40	1	1	1	1	1
40–<100	1	1	5	5	N/A
100–<400	10	10	10	10	N/A
400–<1,000	10	10	50	50	N/A
≥1,000	50	50	100	100	N/A

8.5.2.2 In-Situ Turbidity Sensor

An OBS turbidity sensor is currently included with the turbidity threshold sampling station on Olema Creek. Additional sensors will be purchased as funding allows. These sensors would bed

rotated from watershed to watershed annually and would be used in conjunction with sampling for suspended sediment concentration. See the OBS instruction manual from D&A Instrument Company for wiring, configuration, calibration and other specific features and tasks (D&A Instrument Company, 2001).

8.6 Quality Assurance/Quality Control

Field and laboratory duplicates are required. Analyze at least 10% of the sediment samples in duplicate. Duplicate determinations should agree within 5% of their average weight (American Public Health Association et al., 1998). Field and lab blanks are also required. See the SFAN Quality Assurance Project Plan, SOP#4, for more details.

8.7 References

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SOP #8 Appendix A Sampling with the US DH-48 Depth-Integrating Suspended-Sediment Sampler

http://fisp.wes.army.mil/Instructions%20US%20DH-48%20001010.PDF

SOP #8 Appendix B Depth Integrated Sampling Form Stream Flow Measurement Field Form

Depth Integrated (DI) Sampling for Sediment Calibration of Turbidity Threshold Sampling Station

Date: _____

Site ID: _____

Personnel: _____

Stream section/location: _____

Flow (velocity): _____

LEW: _____ft REW: _____ft

Stream Width: _____ ft

BT (being time): _____ ET (end time): _____

BSH (beginning stage height): _____ ESH (ending stage height): _____

Bottles: _____

# of verticals (# of times in the water):_____

Panel size: _____

Type of sample (DI or AUX): _____

Equipment: DH 48 or other_____

Pass: _____

Weather: _____

ISCO bottle #: _____

ISCO sample time: _____

Notes:

SFAN Water Quality Monitoring Program
Field Data Sheet For Flow Measurements

Date _____Time _____PST

Station ID _____

Field Crew _____

Flow Instrument:_____

Site Location

_____

Flow Measurements:

Gage Height _____ ft Stream Width _____ ft

Bed Level _____ ft

Begin Time_____PST/ Begin Gage Height_____ft End Time_____PST / End Gage Ht_____ft

Station (ft)	Depth (ft)	Velocity (ft/s)	Average V	Cumulative Q
REW:				
LEW:				

V – velocity Q – discharge

Notes from USGS Flow Measurement Methods:

- For shallow depths, use 6/10 method

- For deep depths (> 1.5 ft) use the 2/10 and 8/10 method
  - To get 2/10 depth multiply 6/10 depth by 2
  - To get 8/10 depth divide 6/10 depth by 2
- Space the verticals so that no sub-section has more than 10% (ideally 5%) of the discharge
- There should be 20-30 sub-sections
- Keep the first sub-section as small as possible (depth will often be zero and assume no flow)

- Streambed should be free of large rocks, obstructions
- Parts of the stream cross-sections with greater depth and velocity should have closer verticals
- Face the bank while taking measurement (stand beside not behind wading rod)
- Position yourself at least 18' from the wading rode
- Measure velocity for at least 40 seconds
- Check the meter during measurement
- Have an idea what the discharge will be before measurement
- Read gauge height after measurement
- Reach should be straight and uniform; measure downstream of riffle

SOP #8 Appendix C Turbidity Threshold Sampling Field Manual

SOP #8 Appendix D Laboratory Procedures For Determining Suspended Sediment Concentration

SOP #8 Appendix E Turbidimeter Instrument Log

SOP #9 Field Measurements for Flow Measurements

9.1 Revision History Log

Prev. Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.0	8/3/05	Mary Cooprider	Minor changes	Finalizing for formal peer review	1.01
1.01	3/9/06	Rob Carson	Minor updates to text and tables	Addressing peer reviewer comments	1.02

Only changes in this SOP will be logged. "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).

9.2 Acknowledgements

Significant portions of this SOP were taken directly from the Greater Yellowstone Network's (GRYN) SOP #5 – *Procedures for Collection of Required Field Parameters* (O'Ney, 2005). We appreciate the time and effort devoted to this and other SOPs written by Susan O'Ney.

9.3 Introduction

The San Francisco Bay Area Network (SFAN) Water Quality Status Report provides an overview of flow monitoring locations and history within the SFAN parks (Cooprider, 2004). Stream gauges are located in watersheds within Golden Gate National Recreation Area (GOGA), John Muir National Historic Site (JOMU), and Point Reyes National Seashore (PORE). These stream gauges are equipped with a pressure transducer water level monitor and automatically record stage height at 10-15 minute intervals. These stream gauges have been managed by the individual parks. However, SFAN staff is currently considering methods of consolidating the maintenance and operation of these stations into the SFAN Freshwater Dynamics program. Staff implementing the Freshwater Dynamics program will focus on creating hydrographs (rating curves), operating the stream gauges, and managing the data. Stream flow measurements will be taken at cross sections near these gauges in order to obtain a stream flow rating curve that provides a relationship between stream stage and stream discharge. Once a rating curve is established for a stream gauge then water level can be used to predict stream flow. In addition to automated stream gauges, there are also several staff gauges located throughout the parks. Some of the SFAN long-term water quality monitoring stations are co-located with stream gauges and/or staff gauges.

Flow measurements collected in conjunction with water sample collection and stream chemistry measurements are critical to the SFAN Water Quality Monitoring Program. First, flow

measurements are necessary to determine where to collect field measurements and samples. Flow measurements also provide useful information about seasonal variability in water quality parameters and pollutant load estimates. Therefore, quantitative stream flow will be assessed at all water quality monitoring sites where practical. Where time or stream conditions do not permit flow measurements then a qualitative estimate will be provided. Other methods and instructions on when to use a particular method will be discussed further in the SOP.

9.4 Calibration

9.4.1 Calibration of Current Velocity Meters (Flow meters) (from O'Ney, 2005)

All technicians should review "Measurement of Stream Discharge by Wading" by Michael Nolan and Ronald R. Shields, USGS Water Resources Investigations Report 00-4036, available on CD. Also, refer to USG Technical Memorandum, found at http://water.usgs.gov/admin/memo/SW/sw99.06.html for the care of vertical axis current meters.

Field teams may be using one of three types of current velocity meters, a photooptical impeller type meter (e.g., Swoffer Model 2100) a vertical axis meter (e.g., Price type AA), or an electromagnetic type meter (e.g., Marsh McBirney Model 201D). General guidelines regarding performance checks and inspection of current meters are presented below. Consult the operating manual for the specific meter and modify this information as necessary.

9.4.2 General Performance Checks

(From Peck et al., 2001)

9.4.2.1 Photoelectric Impeller Meters (e.g., Swoffer Model 2100)

- Check that the calibration adjustment cover screws are tightly fitted on the display case.
- Periodically check the condition of the connector fitting between the display unit and the sensor.
- Connect the sensor to the display unit and check the calibration value stored in memory. If this value is less than the correct value for the display unit-sensor rotor combination, replace the batteries.
- Periodically perform a spin test of the rotor assembly, following the instructions in the meter's operating manual. A displayed count value of 300 or greater is indicative of satisfactory performance at low current velocities.
- If a buzzing sound occurs when the rotor assembly is spun by hand, or if the shaft shows visible wear, replace the rotor assembly.
- Periodically examine the thrust-bearing nut on the rotor assembly. If a "cup" begins to form on the bottom surface of the nut, it should be replaced.

9.4.2.2 Vertical-axis Meters (from Smoot and Novak, 1968)

- Inspect the bucket and wheel hub assembly, yoke, cups, tailpiece, and the pivot point each day before use.
- Inspect the bearings and check the contact chamber for proper adjustment.

- Periodically conduct a spin test of the meter. The minimum spin time is 1.5 minutes, while the recommended time is between 3 and 4 minutes.

9.4.2.3 Electromagnetic Meters

- Check the meter calibration daily as part of morning routine. Calibration value should be 2.00 + 0.05.
- Once per week, check the zero value using a bucket of quiescent water. Place the probe in the bucket and allow to sit for 30 minutes with no disturbance. The velocity value obtained should be 0.0 + 0.1. Adjust the meter zero if the value is outside this range.
- An annual calibration by the manufacturer or by the USGS Hydrologic Instrumentation Facility (Stennis Space Center, Mississippi) is recommended.

9.5 Measurements Techniques

Stream discharge will be measured quantitatively by using the USGS method for measurement of stream discharge (Rantz et al., 1992). The flow velocity (ft/s) will be taken using the Marsh-McBirney Flo-Mate, Swoffer 2000 flow meter, or pygmy meter. A top-setting wading rod (measured in tenths of feet) and a tape measure with gradations every tenth of a foot are also required equipment. A cross-section of the stream is chosen and the stream is divided into panels or sections. The width, depth, and velocity of each section are then recorded. Discharge is the sum of measurements in each panel and is recorded in cubic feet per second (ft^3/s or cfs).

Field personnel are encouraged to review the USGS tutorial CD *Measurement of Stream Discharge by Wading* (Nolan and Shields, 2000). It provides details on the process and theory of stream flow measurements and proper methods and equipment. It is also important to have a hydrologist or someone well-versed in discharge measurement techniques to assist with training of field personnel. Consult the SFAN Freshwater Dynamics Monitoring Protocol (in development) for more background and details on flow monitoring. Coordinate with the Freshwater Dynamics program personnel when possible.

Stream discharge measurements can be obtained from the following:

- USGS gauging station
- National Park Service stream gauge with established rating curve
- Mechanical flow meter (e.g., Pygmy current meter, AA, Swoffer 2000)
- Electric flow meters (e.g., Marsh-McBirney Flo-Mate)
- Orange peel or trained eye estimate
- Qualitative descriptions

9.5.1 Quantitative Methods (from O'Ney, 2005; Adapted from Texas Commission on Environmental Quality, 2003)

9.5.1.1 Introduction

Flow/discharge measurements representative of field conditions are needed to determine where to collect field measurements and samples. When flow is measured first, take care not to deploy

a multiprobe instrument or to collect water samples in the area disturbed during flow measurement. The method (or instrument) used to measure flow must be reported.

When flow cannot be measured:
The following are two exceptions to the requirement for obtaining flow measurements:

- **No flow and pools.** If there is no flow at a stream site, and accessible, isolated pools remain in the stream bed, collect and report the required field data and laboratory samples from the pools and report instantaneous flow. Under these conditions, report flow (ft^3/s) as zero.
- **Dry**. If the stream bed holds no water, no sampling is required. Report that the stream was "dry" in the observations.

9.5.1.2 Measuring Flow

Several methods exist for measuring discharge but most methods share several similar steps. They include:

1. Selection and calibration of a current meter or other means of determining velocity
2. Proper site selection
3. Dividing the channel cross-section into equal increments (usually 20 or more)
4. Making the current measurements (by meter or other means) at several points in the vertical while allowing enough time for the device to stabilize (40 seconds for most current meters)
5. Determining the mean velocity at each vertical
6. Tabulating the data in field notes
7. Making field computations using the tabulated data

Equipment used to measure discharge or flow (e.g. current meters) should be tested/calibrated prior to mobilization to the field. Consult the manufacturers' manual for specific calibration methods and appropriate applications for selected current meter and other devices used in the flow/discharge determinations.

9.5.1.2.1 Recording flow data: Record the following information on a flow measurement form (see Appendix A) for a blank form):

- Station location and station ID
- Date
- Time the measurement is initiated and ended
- Name of person(s) measuring flow
- Total stream width and width of each measurement section
- The midpoint, section depth, and flow velocity for each cross section
- Staff gage reading

Do not round values when recording flow data. For example, if the velocity is 1.99 do not round to 2.0. If each value is rounded on the worksheet, it could introduce an error in the final value. Only the final value is rounded.

9.5.1.2.2 Establishing a cross section profile: Stretch the measuring tape across the stream at right angles to the direction of flow. When using an electronic flow meter, the tape does not have

to be exactly perpendicular to the bank (direction of flow). When using a propeller or pygmy type meter, however, make corrections for deviation from perpendicular. Measure and record the stream width between the points where the tape is stretched (waters edge to waters edge).

If necessary, the measuring cross section can be modified on smaller, low-flow streams. This can be done by building dikes to cut off dead water and shallow flows, remove rocks, weeds, and debris in the reach of stream 1 to 2 meters upstream from the measurement cross section. After modifying a streambed, allow the flow to stabilize before starting the flow measurement.

9.5.1.2.3 Determining the number of flow cross sections: Determine the spacing and location of flow measurement cross sections. Some judgment is required, depending on the shape of the stream bed. Measurements must represent the velocity within the cross section. Fewer measurements are needed if the stream banks are straight, the depth nearly constant, the bottom is free of large obstructions, and the flow is homogeneous over a large section. Flow measurement sections should be of equal width, unless an obstacle or other obstruction prevents an accurate velocity measurement at that point. No single cross section should have greater than 10 percent of the total flow. The rule of thumb is as follows:

- If the stream width is less than 5 feet, cross sections widths are 0.5 feet.
- If the stream width is greater than 5 feet but less than 10 feet, the minimum number of cross sections is 10.
- If the stream width is greater than 10 feet, the preferred number of cross sections is 20 to 30.

9.5.1.2.4 Determining the midpoint of the cross section: To find the midpoint of a cross section, divide the cross section width in half, as described below.

- The total stream width is 26 feet with 20 cross sections, and the width of each cross section is equal to 1.3 feet (26/20 = 1.3).
- Divide 1.3 feet in half to get the midpoint of the cross section, 0.65 feet. In this example the measuring tape at waters edge is set at 0.0 feet.
- Add 0.65 to 0.0 to get the midpoint of the first section, 0.65 feet.
- Find each subsequent midpoint by adding the section width (1.3 feet) to the previous midpoint.
- Use the measuring tape to place the top-setting wading rod at 0.65 feet (from the bank) for the first measurement.
- Using a top setting wading rod, measure the depth at the midpoint of the first cross section and record to the nearest 0.01 feet. Total depth at each cross section is measured with the *depth gauge rod*. The depth is entered into Column C of the flow measurement form. Each single mark represents 0.10 feet, each double mark represents 0.50 feet, and each triple mark represents feet. See Figure 9.1, Top-Setting Wading Rod.

9.5.1.2.5 Adjusting the sensor depth at a cross section: Adjust the position of the sensor to the correct depth at each midpoint. The purpose of the top setting wading rod is to allow the user to

easily set the sensor at 20, 60, and 80 percent of the total depth. See Figure 9.1, Top-Setting Wading Rod.

- If the depth is 1.5 feet or less, only one measurement is required at each cross section. To set the sensor at 60 percent of the depth, line up the foot scale on the *sliding rod* with the *tenth scale*, located on top of the depth gauge rod. If, for example, the total depth is 1.1 feet, then line up the **1** on the foot scale with the **1** on the tenth scale (Marsh McBirney 1990).
- If the depth is greater than 1.5 feet, two measurements are taken at 20 and 80 percent of the total depth.
  - **20 percent of the depth**. Multiply the total depth by 2. If the total depth is 3.1 feet, the rod would be set at 6.2 feet (3.1 x 2). Line up the **6** on the sliding rod with the **2** on the tenth scale.
  - **80 percent of the depth**. To set the sensor at 80 percent of the depth, divide the total depth by two. For example, the total depth is 3.1 feet and the rod would be set at 1.05 feet (3.1/2). Line up the **1** on the sliding rod between the **0** and **1** on the tenth scale. Use the average of the two velocity measurements in the flow calculation. See Columns D and E on the flow measurement form. When the depth is greater than 2.5 feet, never set the wading rod at the actual depth. In this case, it would not be set at 3.1 feet.

Note: The point where the rod is set for 20 and 80 percent of the depth will not equal values derived by calculating 20 and 80 percent of the total depth.

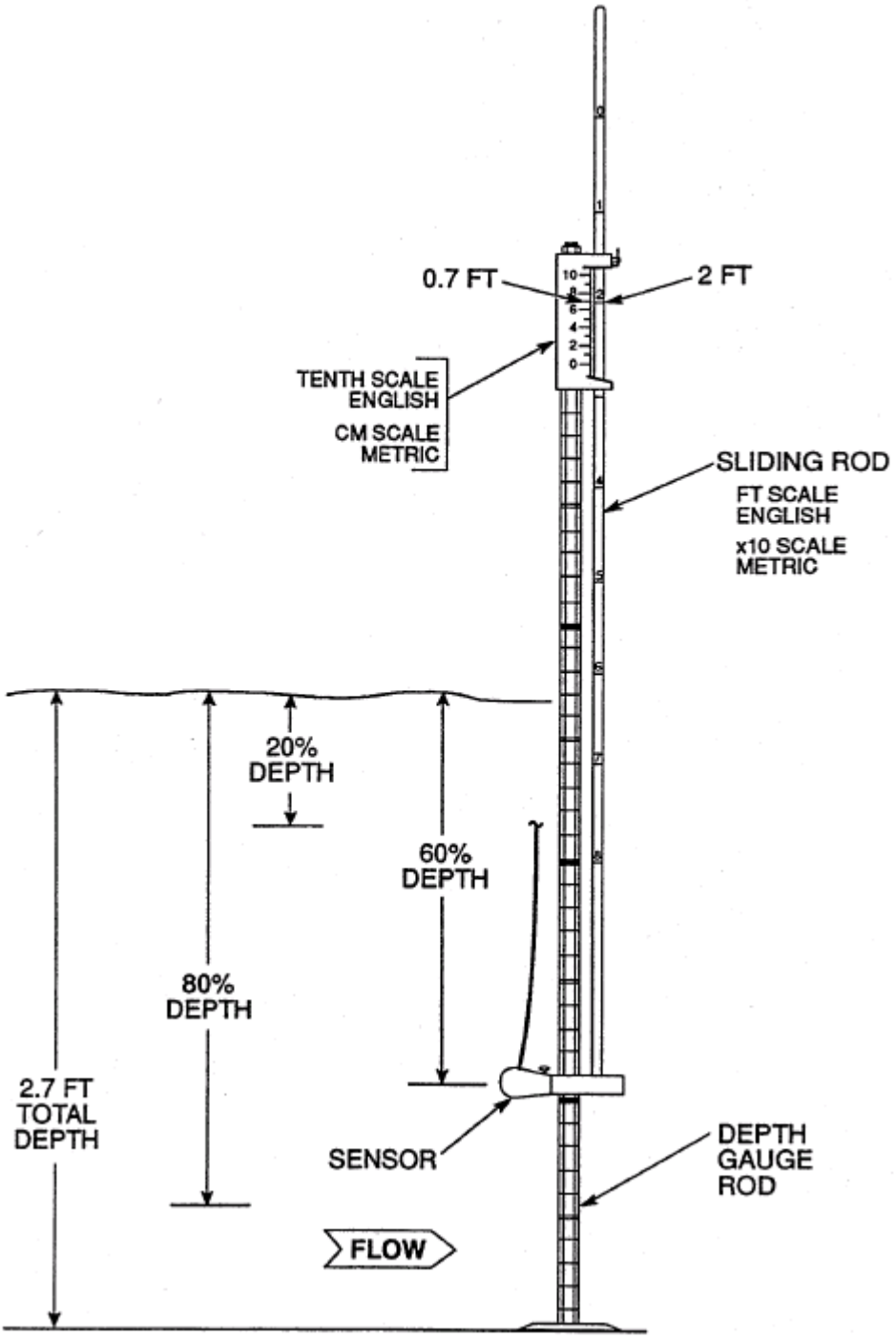

Figure 0.1 Top setting wading rod.

9.5.1.2.6 Measuring velocity: Follow these steps to measure velocity:

1. Position the meter at the correct depth and place at the midpoint of the flow measurement section. Measure and record the velocity and depth. While measuring velocity with an electronic flow meter, keep the wading rod vertical and the flow sensor kept perpendicular to the tape, rather than perpendicular to the flow. When using a propeller or pygmy-type meter, however, the instrument should be perpendicular to the flow.
2. Permit the meter to adjust to the current for a few seconds. Measure the velocity for a minimum of 40 seconds (preferably 2 minutes with the Price and pygmy meters).
3. When measuring the flow by wading, stand in the position that least affects the velocity of the water passing the current meter. The person wading stands a minimum of 1.5 feet downstream and off to the side of the flow sensor.
4. In cases where the flow is low and falling over an obstruction, it may be possible to measure the flow by timing how long it takes to fill a bucket of known volume.
5. Avoid measuring flow in areas with back eddies. The first choice would be to select a site with no back-eddy development. However, this cannot be avoided in certain situations. Measure the negative flows in the areas with back eddies. These negative values will be included in the final flow calculation.

9.5.1.3 Calculating Flow

Follow these steps when calculating flow: Calculate flow at each cross section by multiplying the width (W) x depth (D) x velocity (V) to determine flow in cubic feet per second (cfs or ft3/sec). See Figure 9.2, Stream Flow (Discharge) Measurement.

Q = Total Flow (or discharge), W = Width, D = Depth, V = Velocity.
Q = (W1 x D1 x V1) + (W2 x D2 x V2) + ... (Wn x Dn x Vn)

- When flow is calculated for each cross section add them together for the total stream flow (refer to Figure 9.2).

- For each individual cross section flow, **do not** round values. For example, if the calculated flow for a cross section is 1.23956, do not round. If each value is rounded on the worksheet, it could introduce an error in the final value.

- ***Do not*** treat cross sections with negative flow values as zero. Negative values obtained from areas with back eddies should be subtracted during the summation of the flow for a site.

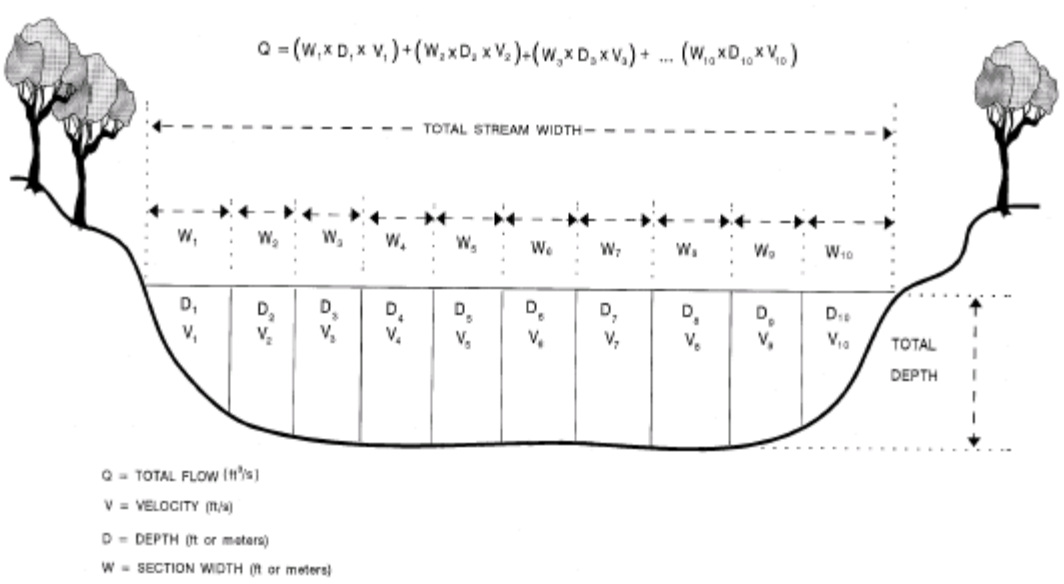

Figure 0.2 Flow calculations.

9.5.1.4 Reporting Final Flow Values

Report instantaneous flow as follows:

- Report values **less than 10 but greater than 0.1 cfs** to the nearest tenth (for example, 9.35 to 9.4).
- Report values **greater than 10 cfs** to the nearest whole number (for example, 20.62 to 21).
- Report actual values **less than 0.1 cfs but greater than or equal to 0.01 cfs**. These values should not be rounded (for example, 0.07 would be reported as 0.07).
- Report **flow values < 0.01 cfs** as < 0.01. See Table 3-11, Final Format for Reporting Field Data.

When reporting final flow values, it is also useful to include the number of days since the last significant precipitation. Significant precipitation is defined as any amount that visibly influences water quality. Water quality in small to medium streams and in the headwaters of many reservoirs is influenced by runoff during and immediately after rainfall events. This influence is site specific and poorly studied. To understand and regulate the adverse effects of runoff, the SFAN would like to associate recent rains with ambient water quality, using a parameter defined as days since last significant precipitation.

Using best professional judgment, record the number of days, rounded to the nearest whole number, since a rainfall event that may have influenced water quality. Here are some guidelines:

- If it is raining when the sample is collected, or has rained within the last 24-hours, report a value of <1.
- If it has been a long time since a significant rain, record this as greater than that particular value, for example >7 days.

If confidence about the recent history of precipitation is low, don't report a value.

9.5.2 Alternative Methods

A qualitative flow measurement cannot always be obtained using the USGS established method. Equipment limitations and safety considerations may preclude taking flow measurements. Since flow measurements can be very important in determining pollutant loads or explaining measured parameters it is often useful to obtain an estimate. This usually occurs during storm events when stream flow is too high to safely obtain a traditional flow measurement. However, storm flows are often needed in order to understand pollutant loads. One method that can be used to estimate flow is the "orange peel" method. Citizen (volunteer) monitoring groups often employ this method as a safe, cost effective technique.

1. Establish a longitudinal stream length to measure and stretch the measuring tape across that length (from Point A to Point B). The length will depend on the velocity of the stream but 1-3 meters usually works well.
2. Using a stopwatch, record how long it takes the orange peel to float from Point A to Point B.
3. Throw the orange peel into the center of the stream. If available, have another person start and stop the stopwatch at your command.
4. It is recommended that you do this three times and take the mean of your three estimates. Alternatively, have other field crew members conduct the estimates.
5. As you become more familiar with each stream and obtain more and more flow measurements, you may find over time that you can estimate flow simply through visual observation. This can provide more information than a strictly qualitative estimate such as flow severity. Always indicate on the data sheet and in the database that your flow/discharge value was estimated.

9.5.3 Qualitative Methods

Flow severity, a qualitative estimation of flow is commonly used in water quality monitoring and is included as a field in NPSTORET. It is also used by the San Francisco Bay Regional Water Quality Control Board's Surface Water Ambient Monitoring Program (SWAMP). The SWAMP program monitors several sites within the SFAN parks.

Flow severity should be recorded for each visit to a freshwater streams. It should be recorded regardless of whether or not it was possible to measure flow. There are no numerical flow guidelines associated with flow severity. This is an observational measurement that is highly dependent on the stream and knowledge of monitoring personnel. It is a simple but useful piece of information when assessing water quality data. For example, a bacteria value of 10,000 with a flow severity of 1 would represent something entirely different than the same value with a flow severity of 5. See Table 9.1 for detailed descriptions of flow severity values. The six flow severity values are; No Flow (1), Low Flow(2), Normal(3), Flood(4), High(5), Dry(6). The following table includes descriptions of severity values.

Table 0.1 Flow Severity Values.

Value	Notes
1	**No Flow -** When a flow severity of one (1 = no flow) is recorded for a sampling visit, then a flow value of zero ft^3/s should also be recorded for that sampling visit. **A flow severity of one (1) (no flow) describes situations where the stream has water visible in isolated pools.** There should be no obvious shallow subsurface flow in sand or gravel beds between isolated pools. Low flow does not only apply to streams with pools. It also applies to long reaches of bayous and streams that have no detectable flow but may have water from bank to bank.
2	**Low Flow** - When stream flow is considered low a flow severity value of two (2) is recorded for the visit and the corresponding flow measurement is also recorded for that visit. In streams too shallow for a flow measurement but in which water movement is detected, record a value of < 0.10 cfs. Note: Use a stick or other light object to verified the direction of water movement, i.e., movement is downstream and not the affect of wind. What is low for one stream could be high for another.
3	**Normal Flow -** When stream flow is considered normal, a flow severity value of three (3) is recorded for the visit and the corresponding flow measurement is also be recorded for that visit. Normal is highly dependent on the stream. Like low flow, what is normal for one could be high or low for another stream.
4 and 5	**Flood and High Flow** - Flow severity values for high and flood flows have long been established by USEPA and are not sequential. Flood flow is reported as a flow severity of four (4) and high flows are reported as a flow severity of five (5). High flows would be characterized by flows that leave the normal stream channel but stay within the stream banks. Flood flows are those which leave the confines of the normal stream channel and move out on to the flood plain.
6	**Dry** - When the stream is dry a flow severity value of six (6 = dry) is recorded for the sampling visit. In this case the flow is not reported. This will indicate that the stream is completely dry with no visible pools.

9.6 Data Analysis & Reporting

The National Park Service Water Resources Division uses a database that is a modification of EPA's STORET database. This database, NPSTORET, has five digit parameter codes. Table 9.2 outlines the different types of flow parameters, and their associated codes included in NPSTORET.

Flow values should be reported in (ft^3/s). The flow measurement method should be reported along with the flow severity value or estimate. The flow severity value should be reported as a descriptive characteristic with the numerical value in parentheses (e.g. Normal Flow (3) or Flood Flow (4)). Reporting of the quantitative value for flow is recommended, but not required.

Table 0.2 NPSTORET Flow Monitoring Codes and Definitions.

Flow	Notes
Flow (00061)	Measurements reported in cubic feet per second. Report instantaneous flow as follows: •Report values less than 10 but greater than 0.1 cfs to the nearest tenth (for example, 9.35 to 9.4). •Report values greater than 10 cfs to the nearest whole number (for example, 20.62 to 21). •Report actual values less than 0.1 cfs but greater than or equal to 0.01 cfs. These values should not be rounded (for example, 0.07 would be reported as 0.07). •Report flow values < 0.01 cfs as < 0.01.
Flow method (89835)	**Refer to codes in NPSTORET**
Flow, severity (01351)	When there is no flow (pools) report a flow severity of 1, and the instantaneous flow (00061) as 0.0 cfs. If the stream is dry, record only the flow severity value of 6. (No Flow (1), Low Flow(2), Normal(3), Flood(4), High(5), Dry(6))

9.7 References

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SOP #9 Appendix A Field Form for Recording Flow Measurements

SFAN Water Quality Monitoring Program
Field Data Sheet For Flow Measurements

Station ID _____ Date _____Time _____PST
Site Location
_____
Field Crew _____
Flow Instrument:_____

Flow Measurements:

Gage Height _____ ft Stream Width _____ ft
Bed Level _____ ft

Begin Time_____PST/ Begin Gage Height_____ft End Time_____PST / End Gage Ht_____ft

Station (ft)	Depth (ft)	Velocity (ft/s)	Average V	Cumulative Q
REW:				
LEW:				

V – velocity Q – discharge

Notes from USGS Flow Measurement Methods:

- For shallow depths, use 6/10 method
- For deep depths (> 1.5 ft) use the 2/10 and 8/10 method

To get 2/10 depth multiply 6/10 depth by 2

To get 8/10 depth divide 6/10 depth by 2

- Space the verticals so that no sub-section has more than 10% (ideally 5%) of the discharge
- There should be 20-30 sub-sections

• Keep the first sub-section as small as possible (depth will often be zero and assume no flow)
• Streambed should be free of large rocks, obstructions • Parts of the stream cross-sections with greater depth and velocity should have closer verticals • Face the bank while taking measurement (stand beside not behind wading rod) • Position yourself at least 18' from the wading rode • Measure velocity for at least 40 seconds • Check the meter during measurement • Have an idea what the discharge will be before measurement • Read gauge height after measurement • Reach should be straight and uniform; measure downstream of riffle

Example flow calculation worksheet

Stream:	Bear Gulch		Location:	Chalone Creek, PINN	
Site:	BG 2				
Date:	2/26/2004		Crew:	MC, MK	
Time:	13:41			Comments:	
Stage Height:					
Distance (ft)	Depth (ft)	Velocity (ft/s)	Width (ft)	Area (ft^2)	Flow (cfs)
2.4	0.18	0.00	1.75	0.32	0.000
3.5	0.40	0.20	1.05	0.42	0.084
4.5	0.45	1.15	1	0.45	0.518
5.5	0.60	1.50	1	0.60	0.900
6.5	0.62	1.10	1	0.62	0.682
7.5	0.65	1.50	1	0.65	0.975
8.5	0.55	1.45	1	0.55	0.798
9.5	0.75	1.54	1	0.75	1.155
10.5	0.72	1.72	1	0.72	1.238
11.5	0.75	1.62	1	0.75	1.215
12.5	0.78	1.35	1	0.78	1.053
13.5	0.70	1.31	1	0.70	0.917
14.5	0.55	1.42	1	0.55	0.781
15.5	0.65	1.18	1	0.65	0.767
16.5	0.60	0.00	1	0.60	0.000
17.5	0.50	0.00	1	0.50	0.000
18.5	0.30	0.00	1	0.30	0.000
19.5	0.32	0.00	1	0.32	0.000
20.5	0.20	0.00	0.95	0.19	0.000
21.4	0.00	0.00	-10.25	0.00	0.000
			-10.7	0.00	0.000
			0	0.00	0.000
			0	0.00	0.000
			0	0.00	0.000
			0	0.00	0.000
			0	0.00	0.000
			0	0.00	0.000
			0	0.00	0.000
			0	0.00	0.000
			0	0.00	0.000
			0		
				Total flow (cfs):	11.08
				Stage height (ft):	

SOP 10 Data Analysis

10.1 Revision History Log

Prev. Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.0	8/5/05	M. Cooprider	Additional guidance on data analysis and presentation	Preparation for formal peer review	1.01
1.01	3/23/06	R. Carson	Minor Edits on treatment of censored data and controlling sensitivity; precision and bias	Addressing formal peer review comments	1.02
1.02	9/28/06	R. Carson	Inserted Sample Size and MDD tables	Quantify statistical objectives	1.03

Only changes in this SOP will be logged. "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).

10.2 Introduction and Acknowledgements

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). Water quality data is usually highly variable, both temporally and spatially. Data characteristics often utilized for water quality data include: a measure of the center of the data, a measure of spread or variability, a measure of the symmetry of data distribution, and possibly estimates of extremes (Helsel and Hirsch, 1992). This SOP provides guidance on how to prepare and analyze data given these characteristics. Sections of this SOP were obtained from the Greater Yellowstone Network SOP#9 - Data Analysis Procedures in the *Regulatory Water Quality Monitoring Protocol* (O'Ney, 2004). David Lewis (University of California Cooperative Extension) also provided valuable insight. Finally, the internet accessible text, *Statistical Methods in Water Resources* (Helsel and Hirsch, 1992) was frequently consulted. While the basics of water quality data analysis are covered here, this statistics text should be followed for greater details.

10.3 Preparing the Raw Data Set for Analysis

10.3.1 Sample Sizes and Minimum Detectable Differences and Quantifying Data Quality

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. 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).

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 10.1, below.

Table 0.1 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 18-20 FIB samples	72-96 (108-144 FIB samples)	PORE	FY07-FY08 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) that we will be able to distinguish given the sample sizes in the current protocol (Table 10.2). 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 0.2 Minimum Detectable Differences for 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%

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.

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, 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, broad inferences can be made to the watershed as a whole. 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.

Ensuring the quality of the data collected is crucial prior to performing data analyses. Detailed information about the data quality procedures for this protocol are available in SOP#4 the Quality Assurance Project Plan. Below is a brief summary of the field methods that will allow SFAN to quantify the effect of errors and changes in method, equipment and personnel that are an inevitable part of long-term monitoring (Table 10.3)

Table 0.3 SFAN Data Quality Assurances.

Data Quality Issue	SFAN Data Quality Assurances
Sensitivity	• For lab parameters: Calculation of both Method Detection Limit (MDL) and Minimum Level of Quantitation (ML). • 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). • For Lab Measurements: Duplicate analysis of 10% of samples. Report the Relative Percent Difference (RPD).
Bias	• Maintain consistent personnel and methodology where possible. • 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. • Analyze such overlapping samples to determine the contribution of bias (if any) to any variance in the data. • Control bias by: Use and analysis of "blank" samples (Field, Trip or Lab Blanks) to determine contamination by methodology.
"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.

10.3.2 Censored Data and Outliers

Water quality data is often "censored" or reported as less than the detection limit. In some cases, there are also instances of data values greater than or equal to the upper detection limit. This occurs most frequently with fecal coliform data since the proper dilution, based on the expected range, is sometimes difficult to predict particularly during storm events. Censored data is considered outside the range of quantitation (i.e., it cannot be quantified and a number cannot be assigned to it) and generally should not be statistically analyzed. However, censored data are presented as less than or greater than the ML in order to compare it to water quality criteria (Irwin, 2004). Therefore, although these data should not be included in statistical analysis, they are still useful for water quality assessment.

More advanced methods for dealing with censored data are outlined in Ch. 13 in Helsel and Hirsch (1992). This chapter describes how observed data may be combined with censored data in order to calculate estimates of summary statistics. Also refer to the recent publication *Nondetects and Data Analysis: Statistics for Censored Environmental Data* (Helsel, 2004).

The SFAN Quality Assurance Project Plan (SOP#4) describes the details of data quality objectives and measurement quality objectives in relation to data reporting. A summary of how data should be reported is as follows:

- Values below the Method Detection Limit (MDL) are to be reported as a (<) sign followed by the actual MDL value, and flagged with a ND = not detected.
- Values between the MDL and the ML (or quantification limit) should be reported with the detection condition of " *Present <QL" or Present, below quantification limit. This condition will trigger the database to enter *Present, <QL into the result field. These values are considered semi-quantitative.
- Values above the ML (or quantification limit) are deemed as acceptable values without reservation, and are shown as the actual measured value, and assigned a QA code of A (acceptable without reservation).

Do not immediately remove outliers from a data set because they appear unusual. It is important to first verify that no human errors have been made such as copying a number wrong or putting a decimal point in the wrong place. Rather than eliminating possibly important data in order to use standard statistical analyses (e.g., tests requiring normally distributed data), methods that are resistant to outliers should be utilized. (Helsel and Hirsch, 1992). Some of the summary statistics that are resistant to outliers are discussed in Section 3.0 of this SOP.

10.3.3 Replicates and Data Transformations

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

The goal of data transformations is to "make data more symmetric, to make data more linear, and to make data more constant in variance" (Helsel and Hirsch, 2002). Some examples include logarithmic transformations and adjusting data for flow. Use logarithmic transformations with fecal indicator bacteria (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. Log transformations are also commonly used with discharge measurements and sometimes with nutrient data. Basically, use log transformations on data when there is a broad range of data. It is helpful to display both the transformed data and non-transformed data to understand how transformations affect the data. This is particularly useful when presenting to a general audience (Dave Lewis, personal communication, 29 July 2005).

Flow adjusted or flow-weighted data is simply the concentration (C) of the analyte divided by the discharge (Q). Transformations (either logarithmic or flow-adjusted) can make the data more "normal" (symmetric) and increase the possibility of using parametric statistics which are slightly more powerful at determining statistical differences. Transforming the data does not change the median and interquartile range (IQR). However, transforming does change the mean and standard deviation (Helsel and Hirsch, 1992). This is why both the mean and standard deviation as well as the median and IQR are reported for water quality data or any other data that is typically non-parametric.

10.4 Data Analysis

Before data analysis:

- Review data promptly to detect potential outliers or errors
- Conduct log transformations on bacteria data and calculate flow-weighted data
- Use the mean of replicate samples for statistical analysis
- Don't conduct statistical analyses on censored data but use all data for overall comparisons against water quality criteria.
- Export data from the NPSTORET to Microsoft Excel to conduct analysis. Further analysis can be conducted with other statistical software. However, NPSTORET does have several statistical and graphical functions that could be used as they become available.

Use graphs before data analysis to learn more about the data set. A plot of raw data values (for one site) against time is an important preliminary tool to assist in visualizing the data distribution and to provide a check for temporal patterns and extreme values (outliers).

10.4.1 Summary Statistics and Tabular Data Presentation

The following descriptive statistics should be performed:

Mean
Standard Error
Median
Std. deviation
Variance
Kurtosis (peakedness)
Skewness (lack of symmetry about the mean)
Range/Interquartile Range (IQR)
Minimum
Maximum
Sum
Count
Confidence intervals for mean and median (95 or 99% confidence level)

- Use all data (including censored data) for comparison against water quality criteria.
- Analyze reference or control sites separately to determine a baseline for specific streams.
- To limit seasonal variability, conduct statistical tests on each of the different seasons.
- Summarize data for each site and for each parameter seasonally and annually
- Summarize data from all stations within each watershed seasonally and annually.
- Compare data from stations upstream and downstream of a suspected pollution source or tributary.
- Use flow (discharge) weighted data and group data by season to account for seasonal variation.
- Discrete and continuous data should be analyzed separately. However, data from the same days may be compared for quality control and to obtain a relationship between the datalogger readings and instantaneous monthly/weekly data.

- Determine the inherent variability of a sampling technique by calculating the standard deviation of replicates (see as Section 3.1.2 below)
- Present data in tabular form for each station and watershed as follows:

SFAN I&M Water Year 2006 Water Quality Data - Station ID

Date	pH	TEMP	DO	COND	Total NH3	NH3-tox	NO3	Total N	FC	TURB
_ Nov 06										
_ Dec. 06										
_ Jan 06										
_Feb 06										
_March 06										
_April 06										
_May 06										
_June 06										
_July 06										
_Aug 06										
_Sept 06										
_Oct 06										
Statistics										
Mean										
Std. Error										
Median										
Std. Dev.										
Variance										
Kurtosis										
Skewness										
Range										
Min										
Max										
Sum										
Count										
Confidence Level										

- Next, summarize all data and compare to water quality criteria using the following example (from Rugg, 2000).

Table I
All 99-2000 (98-9) Data

	Dissolved Oxygen mg/l	Total Ammonia mg/l	Un-ionized Ammonia mg/l	Conductivity • mhos/cm
Average *	**9.29** (10.09)	**0.420** (1.004)	**0.0068** (0.014)	**577** (412)
Range	**6.2-10.3** (2.0-15.9)	**0-25.2** (0-17.4)	**0-1.071** (0- 0.377)	**8-2342** (75-1690)
Criteria**	5.0-7.0	-	0.025	750
Exceedances	**53** (14)	-	**39** (77)	**125** (73)
Percent Exceedance	**6.36** (2)	-	**4.68** (12)	**15** (12)

* 833 measurements
** SF Bay RWQCB Basin Plan

10.4.1.1 Statistics for fecal coliform data

In addition to the above summary statistics, a geometric mean should be calculated for fecal coliform and *E. coli* data.

For the Olema Creek data (Pathogen TMDL sampling), calculate the 30-day geometric mean of samples from five consecutive weeks to determine whether standards are being exceeded. Water quality standards are listed in SOP#6 and in the Protocol Narrative. To calculate the estimated geometric mean (*In* O'Ney, 2005; adapted from WY-DEQ 1999):

1. convert each CFU count/100ml to its log
2. add the logs
3. divide the total of the logs by the number of samples to get the mean
4. take the antilog of (3); that number is the geometric mean (in CFU/100mL)

Example: test results are 760, 3100, 300, 632 and 805
Arithmetic mean = 760 + 3100 + 300 + 632 + 805 = 5597 / 5 = 1119.4
Arithmetic median = 760
Geometric mean = 816.58

$\log_{10} 760 = 2.88$
$\log_{10} 3100 = 3.49$
$\log_{10} 300 = 2.48$
$\log_{10} 632 = 2.80$
$\log_{10} 805 = 2.91$

sum of the logs = 14.56
mean of the logs = 14.56/5= 2.912
antilog 2.912 = 816.58

An alternative method is to multiply the CFU counts/100ml together and take the nth root, where n = number of samples (5 in this example). Using the test results above:

760 x 3100 x 300 x 632 x 805 = 3.6 x 1014
(3.6 x 1014)1/5 or (3.6 x 1014).2 = 815.19

Results from field blanks should also be reviewed to establish that a sample is not being contaminated by conditions associated with the collection or custody of a sample or by cross-contamination during sampling or shipping. Another way to determine whether field methods are adequate is to calculate precision from duplicates. Fecal coliform duplicate precision is calculated for the Number of Colonies /100 ml value (not the log transformation) and is typically set at ±50%. See section 3.2 in this document for guidance on calculating precision.

10.4.1.2 Calculating Precision

The following is an explanation for calculating precision of field duplicates. Other QA/QC measures, including calculating precision of lab duplicates, are discussed in SOP #4.

(*In* O'Ney, 2004; Adapted from WY-DEQ, 2000)

Precision is defined as how closely repeated measurements agree with each other. Precision indicates the degree of agreement between sequential independent samples at a site, collected by applying the same collection method. If the sample is representative and the sampling methods are consistent, two or more measurements made consecutively with a field instrument usually agree very closely (less than 10 per cent difference). Estimates of precision are also known as sampling error. Precision should be calculated as soon as results from duplicate analyses are available, no later than 7 days after receipt from laboratory.

The precision measurement is calculated using the relative percent difference (RPD) between duplicate sample results per analyte (parameter). For duplicate samples, the smaller test result is subtracted from the larger test result. The resulting difference is divided by the average of the two results, and the result is multiplied by 100 to express the number as a percent. The formula is: [(S1 - S2) / ((S1 + S2)/2)] x 100 = RPD, where S1 is the larger test result value.

For precision results, not only should RPDs be reported, but also raw numbers. This will allow for calculation of uncertainty statistics later, should this be needed.

10.4.2 Graphical Data Presentation

Important graphical features or comparisons to utilize include:

- Location (line) showing detection limit on graph
- Distance from suspected source or distance from source
- Display pH, D.O., and temperature on one chart to show relationships
- Parameter against time (shows seasonal changes) for each station
- Parameter against time for all stations in a watershed
- Site comparisons for each parameter
- Display all data for one station on one page
- For continuous data, graph daily, monthly, and seasonally
- Relationships of conductivity to fecal coliforms
- Relationship of flow to all other variables

Chapter 2 (Graphical Data Analysis) and Chapter 16 (Presentation Graphics) of *Statistical Methods in Water Resources* (Helsel and Hirsch, 1992) should be followed for graphical data analysis. Tables can be used in association with graphs but presentation of data should not rely solely on tables. Graphics should generally include:

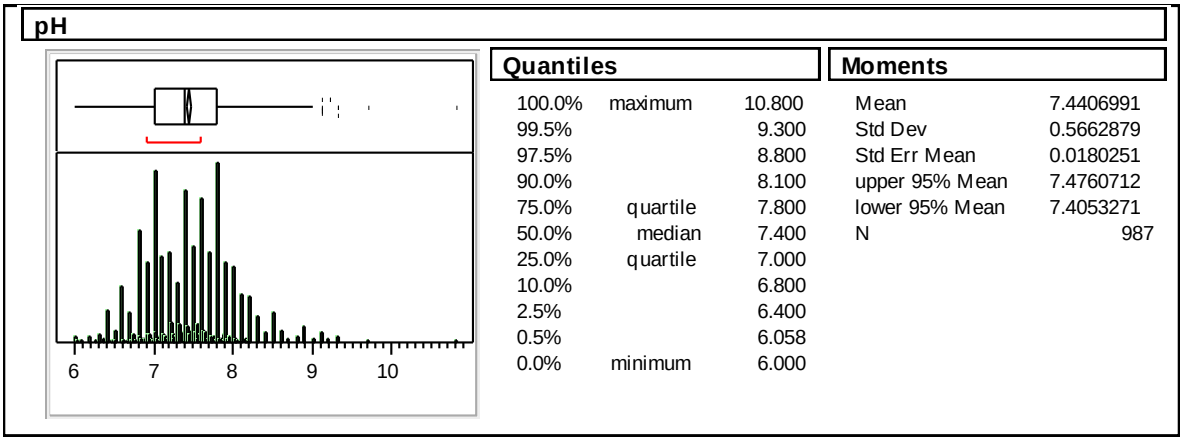
1) **histograms** (e.g., streamflow vs. number of occurrences): useful for depicting large differences in shape or symmetry. They are better for data that have natural categories or groupings; they are not as good with continuous data since it is difficult to depict this type of data accurately in a discrete group. It would work well for the number of sites exceeding different levels of water quality criteria (e.g., non-contact recreation and contact recreation).

2) **simple box plots** (box and whiskers plot) Whiskers are drawn to the points of maximum and minimum data, a box depicting the 25^{th} and 75^{th} percentile is drawn, and a horizontal line through the box depicts the median. These can be used for reviewing one set of data or for comparing multiple data sets. "They are valuable guides in determining whether central values, spread, and symmetry differ among groups of data." They can be used to determine whether tests based on the assumption of normality can be used (Helsel and Hirsch, 1992).

3) **scatterplots** – relationship between two variables (e.g., flow vs. fecal coliforms); a "smoothe" may be used to help determine the relationship of x to y. The preferred procedure for this is LOWESS (LOcally WEighted Scatterplot Smoothing) (Helsel and Hirsch, 1992).

Summary tables, histograms, and box and whisker plots can be used to show median and interquartile ranges (non-parametric), mean and standard deviation (parametric), and 95% confidence intervals for means and medians. Example histograms and box plots are illustrated in Figures 10.1 and 10.2, respectively (from Stafford and Horne, 2004).

Figure 0.1 Example data summary chart.

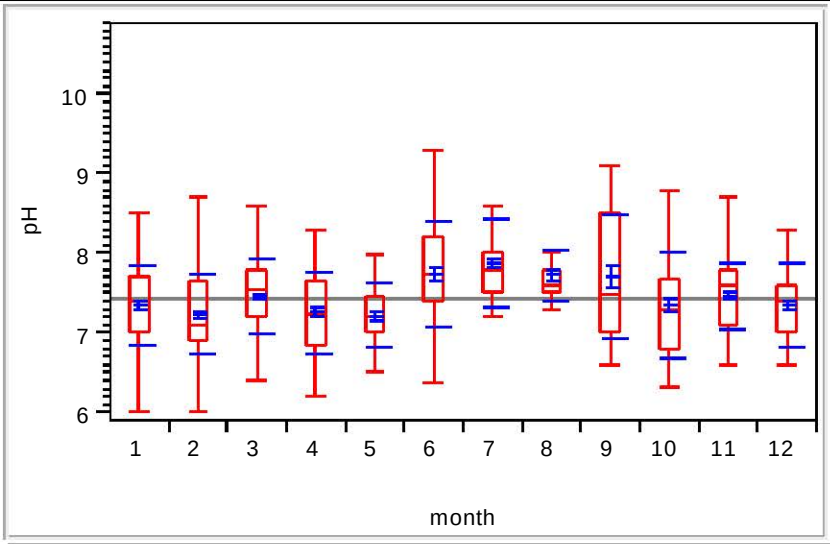


The heights of the bars in the histogram represent the number of times an observation was recorded. The outlier box-plot above the histogram shows the interquartile range within the box. The line across the middle of the box identifies the median sample value. The diamond represents the mean and 95% confidence interval. The lines extending from each end of the box, or the whiskers, encompass the quartiles +/- 1.5x (interquartile range). Points beyond the whiskers indicate extreme values that are possible outliers. The bracket along the edge of the box identifies the shortest half, or the densest 50% of the observations. To the right of the histogram, the quantiles and moments are displayed. The total number of observations is listed as N.

from Stafford and Horne, 2004

Figure 0.2 Example box and whiskers plot, quantiles, and mean and standard deviation summaries by month.

Oneway Analysis of pH By month



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
1	6	6.8	7	7.4	7.7	8	9.1
2	6	6.74	6.9	7.1	7.65	7.9	8.7
3	6	6.8	7.2	7.53	7.8	8	8.6
4	6.2	6.6	6.8525	7.225	7.64	8	8.3
5	6.25	6.776	7	7.2	7.45	7.824	8.2
6	6.03	6.793	7.4	7.725	8.2	8.5	9.3
7	6.65	7.4	7.5	7.8	8.015	8.888	9.7
8	7.3	7.5	7.5	7.6	7.8	8.38	8.5
9	6.6	6.9	7	7.495	8.5	8.87	9.1
10	6.31	6.6	6.8	7.3	7.685	8.22	9.2
11	6.6	6.9	7.1	7.6	7.8	7.9	8.7
12	6.06	6.824	7	7.39	7.6	7.8	10.8

Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
1	117	7.34658	0.504041	0.04660	7.2543	7.4389
2	133	7.22684	0.494876	0.04291	7.1420	7.3117
3	165	7.45412	0.473718	0.03688	7.3813	7.5269
4	80	7.25337	0.514993	0.05758	7.1388	7.3680
5	53	7.21811	0.409939	0.05631	7.1051	7.3311
6	88	7.73273	0.677939	0.07227	7.5891	7.8764
7	85	7.87094	0.559012	0.06063	7.7504	7.9915
8	21	7.72381	0.320788	0.07000	7.5778	7.8698
9	30	7.70433	0.785821	0.14347	7.4109	7.9978
10	53	7.34094	0.665173	0.09137	7.1576	7.5243
11	69	7.46609	0.415367	0.05000	7.3663	7.5659
12	93	7.34860	0.531717	0.05514	7.2391	7.4581

from Stafford and Horne, 2004

In the example in Figure 10.2, data from all stations is grouped together for each month. "Level" is referring to month. One drawback of using maximum and minimum values is that as the data set grows, the most extreme values just keep extending and don't necessarily reflect common conditions. They are useful for immediate management decisions, since they often indicate something is wrong, but are not as useful for an overall sense of the water quality conditions.

10.4.3 Long-term trend analysis

Long-term trend analysis is generally conducted on five to ten years of data more. However, data for most SFAN watersheds will be collected on two-year intervals. Trend analysis can be conducted on 4, 6, and 8 years of data and so on. The basic question in trend detection is "What is the affect of time on the given parameters?" If time is shown to have an affect, then we to ask "Are changes sudden or gradual?" and "What is the extent of the change?" Trend analysis should account for flow in order to be meaningful. Trend analysis should also account for seasonal differences. 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).

10.4.3.1 Basic trend analysis: Graphing and other useful tools

For trend analysis, at a minimum, produce histograms displaying data from multiple years. Combine all data from all stations and display the maximums, means, range and number of water quality criteria exceedences (if applicable). Use the following graphs from Rugg (2000) as a guide.

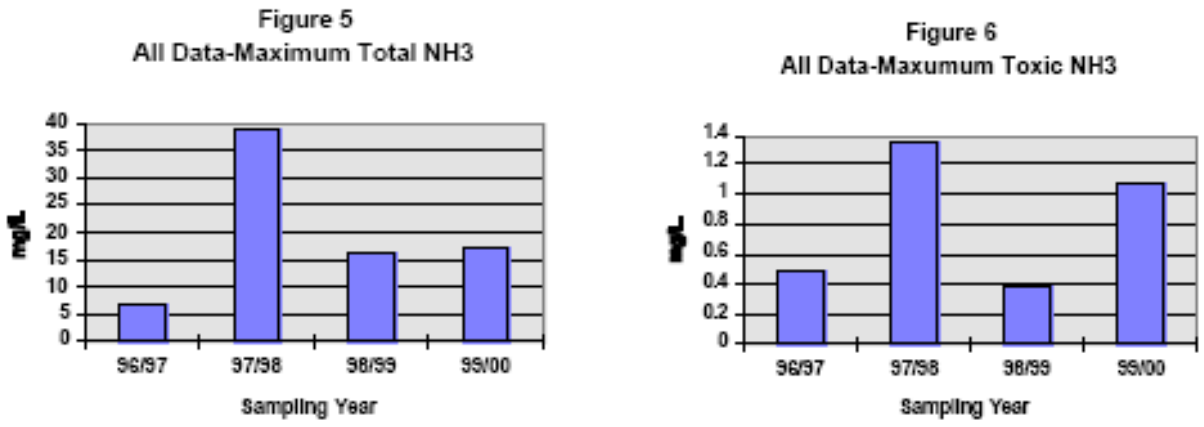


Figure 0.3 Histograms displaying data from multiple years, such as these from Rugg 2000.

When graphing data for more than one year, seasonal patterns may be readily apparent. Each seasonal effect (strata) should be partitioned and graphed alone so that trends which develop over the long-term become visually clear. Examples of partitioned graphic representations are:

- the concentration of a particular variable (y-axis) during low-flow periods (x-axis),
- suspended sediments during winter storm events (refer to stream hydrograph),
- nutrient values during the spring and summer (high productivity)
- dissolved oxygen during peak temperature periods (summer)

Tips:

- 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.
- The above approach can also be used for analysis of large (past) data sets with varying sampling frequencies

Maps displaying water quality trends are also a useful tool. Water quality stations can be identified by an increasing or decreasing trend or no trend. Another possibility is to utilize (or create) a water quality index to present SFAN data to a wide audience. One good example of a WQI was developed by the Washington Department of Ecology (Hallock, 2002).

10.4.3.2 Trend Detection (modified from Hirsch et al., 1991)

Other routine trend analyses can be done according to Helsel's Internet Published Text Book (Helsel and Hirsch 1992). Consult Ch. 12 of the Helsel and Hirsch (1992) text for techniques for trend analysis. This includes accounting for the affect of flow, other seasonal affects, and addresses both parametric and nonparametric statistics. Stafford and Horne (2004), suggest the use of monotonic trends to look for gradual changes in water quality. The protocol narrative also discusses various data analysis scenarios based on the distribution of the data (parametric, non-parametric, or mixed) and whether the data is flow-weighted. The Helsel and Hirsch (1992) text covers this in greater detail.

Tables 10.4 through 10.7 summarize recommendations for monotonic and step trend detection, depending on the type of data under analysis. Monotonic trends are to be used for gradual changes, and step trends are to be used before and after a change at a specific point in time. The monotonic trend hypothesis is more commonly used for general monitoring unless there is a reason to test for a step trend. The step trend hypothesis may be used after implementation of best management practice if there is expected to be a detectable change. The parameters classified as "mixed" in the first two tables have both parametric and nonparametric components that are typically executed in separate steps.

Regression on season uses a periodic function of time of year, as does Tobit regression on season. Tobit regression is a type of linear regression that considers both censored and non-censored values of the response variable, and uses maximum-likelihood estimation for determining slope and intercept of the modeled trend line (Hoppe, 2003).

Deseasonalizing is done by subtracting seasonal medians from each of the values to be regressed. The Seasonal Kendall test is the Mann-Kendall test for trend done for each season, with the

Seasonal Kendall test statistic being the sum of the several Mann-Kendall test statistics. The seasonal Kendall trend test accounts for seasonal variations in concentrations by comparing ranks of data from the same recurring time intervals; for example, in a four-season year, springtime values are compared only to other springtime values, summer values to summer values, and so forth.

LOWESS is locally weighted scatterplot smoothing. The LOWESS curve represents a nonlinear, smoothed relation between two variables (instantaneous discharge and each water quality parameter). The method uses a series of weighted least squares regressions; observations are weighted by both distance from the fitted line and the magnitude of residuals from the previous regression. LOWESS is more desirable than simple regression because it makes no assumptions of data linearity or normality (Hoppe, 2003). Flow may be replaced by a transformation of flow in any of these analyses.

The Seasonal Rank Sum test is the Rank Sum test (also known as the Mann-Whitney "U" test (Kirchner, 2003), done for each season, with the Seasonal Rank Sum test statistic being the sum of the several test statistics.

Table 0.4 Options for testing monotonic trends in uncensored water quality data

	Not Flow Adjusted	Flow Adjusted
Fully parametric	Regressions of concentration on time and season	Regression of concentration on time, season, and flow
Mixed	Regression of deseasonalized concentration on time	Seasonal Kendall on residuals from regression of concentration on flow
Nonparametric	Seasonal Kendall	Seasonal Kendall on residuals from LOWESS of concentration on flow

Table 0.5 Options for testing step trends in uncensored water quality data.

	Not Flow Adjusted	Flow Adjusted
Fully parametric	Analysis of covariance of concentration on season and group (before and after)	Analysis of covariance concentration on season, flow and group
Mixed	Two-sample t test on deseasonalized concentration	Seasonal Rank Sum on residuals from regression of concentration on flow
Nonparametric	Seasonal Rank Sum	Seasonal Rank Sum on residuals from LOWESS of concentration on flow

Table 0.6 Options for testing for monotonic trends in censored water quality data.

	Not Flow Adjusted	Flow Adjusted
Fully parametric	TOBIT regression of concentration on time and season	TOBIT regression of concentration on time, season and flow
Nonparametric	Seasonal Kendall	no test available

Table 0.7 Options for testing for step trends in censored water quality data.

	Not Flow Adjusted	Flow Adjusted
Fully parametric	TOBIT analysis of covariance of concentration on season and group	TOBIT analysis of variance of concentration on season, flow and group
Nonparametric	Seasonal Rank Sum	no test available

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SOP #11 Data Reporting

11.1 Revision History Log

Prev. Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.0	8/5/05	M. Cooprider	Minor edits	Preparation for formal peer review	1.01
1.01	3/23/06	R. Carson	Minor edits	Addressing formal peer review comments	1.02

Only changes in this SOP will be logged. "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).

11.2 Introduction

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.

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 11.1.

Table 0.1 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. - Archive old data and document monitoring activities -Describe current condition of the resources -Document changes in the monitoring protocol -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. - Determine patterns and trends -Discover correlations among resources being monitored -Analyze data to determine the level of change that can be detected using the existing sampling scheme -Provide context, interpret data for the park within a multi-park, regional, or national context -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 -Review of protocol design and product to determine if changes are needed -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

Communcaction Product	Lead	Audience	Schedule	Summary
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.
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.

In addition to data reports, a quality assurance should also be produced every few years to explain the results of data completeness and other QA/QC issues. See the Quality Assurance Project Plan (SOP #4) for more details.

11.3 Report Format

Reports should be standardized with other I&M reports but will generally be written in 12 point Times New Roman text. Tables, figures, and photographs are encouraged to present data and site conditions. The following is the suggested outline by Peitz and Rowell (2004):

TITLE PAGE

- Title
- Author(s)
- Institutions
- Prepared for
- Date

TABLE OF CONTENT PAGE (optional)

EXECUTIVE SUMMARY PAGE (abstract)

1.0 INTRODUCTION

1.1 Background
1.2 Justification for Study
1.3 Objectives

2.0 METHODS

2.1 Study area(s)
2.2 Field method(s)
2.3 Analytical method(s)

3.0 RESULTS

4.0 DISCUSSION

5.0 MANAGEMENT IMPLICATIONS

6.0 ACKNOWLEDGEMENTS

7.0 LITERATURE CITED

11.4 Review Procedure

11.4.1 Internal Review

One or more editorial reviews should be sought before submitting the report for review by staff in the park(s) where monitoring occurred and before external review. Internal review by person(s) skilled in technical writing for clarity and directness should fulfill this review requirement. Internal reviews will be conducted by the SFAN Aquatics Group or other SFAN staff or individuals known to be skilled in writing and editing.

If reports are written to update findings only and they do not deviate significantly from previously reviewed and distributed reports than the review process may stop here. However, review by park staff and subsequent external reviews must be sought for new reports or those that deviate significantly from previously reviewed and distributed reports. Also, if management activities within a park are not clearly understood than park review should be sought for a report to clarify results and management implications.

11.4.2 Park Review

Park staff, generally the Resource Managers are in a unique position since they can supply details about management activities that may influence findings presented in a report. Also, they will most likely be directly involved in applying management recommendations to their respective parks. Therefore, review by park staff is vital to the interpretation of findings and the assessment of proposed management implications. Review by park staff should be conducted before a report is submitted for external review.

11.4.3 External Review

External review by two or more experts in water quality monitoring should be sought for the first report in a series of annual reports. In addition, analytical methods employed on data presented in the report need to be reviewed by one or more statisticians. If a report updates a previously

reviewed and distributed report than external review is not required. However, external reviews must be sought for new reports or those that deviate significantly from previously reviewed and distributed reports. In order to conserve reviewer time, external reviews must follow the internal and park review process.

11.5 Distribution Procedure

11.5.1 Identifying Stakeholders

The primary stakeholders in our Water Quality Monitoring efforts are park staff. Additional stakeholders include the SFAN I&M program and the San Francisco Bay Regional Water Quality Control Board. Other potential stakeholders include any of the national water quality monitoring programs, universities and the general public.

11.5.2 Distributing the Report

Reports will be provided to the respective parks where water quality monitoring was conducted. Additionally, a copy will be kept on file with the SFAN office of the National Park Service, Sausalito, California and made available to all interested parties upon request.

All data collected by the SFAN is public property and is subject to requests under the Freedom of Information Act (FOIA). The data management plan for Channel Island National Park (Dye 1998) describes appropriate procedures to respond to FOIA requests, including the protection of sensitive data such as endangered species locations. In the future, reports containing non-sensitive data will be disseminated through a website. Through the website, those requesting data will be asked to provide information to document by whom and for what purpose the report is being used. By documenting requests, users can be informed when updated reports are available. Users requesting paper copies will be documented also.

11.6 References

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SOP #12 Site Selection and Documentation

12.1 Revision History Log

Prev. Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.0	3/9/06	Rob Carson	Minor Edits to text	Addressing peer reviewer comments	1.01

Only changes in this SOP will be logged. "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).

12.2 Acknowledgements

O'Ney SE. 2005. Initial Site Establishment, Version 1.0, Standard Operating Procedure #1. *In* Regulatory Water Quality Monitoring Protocol, Version 1.0, Appendix E – SOPs, National Park Service, Greater Yellowstone Network. Bozeman, MT. 37 pp. plus appendices

12.3 Field Preparation and Site Selection

12.3.1 Permission and Access

Some sites are located on private lands or local or state government lands. In these cases it is necessary to obtain some form of permission. This may range from a phone call notifying the landowner of a sampling event to obtaining a permit. For example, California State Parks require a permit. Be sure to consider not only the site location but also the access route. Although a site may be on National Park lands, a road, trail, or parking outside Park lands may be required to access the site.

Other agreements include a Memorandum of Understanding (MOU) with other agencies that are conducting monitoring on parklands. This can be useful in setting guidelines, study boundaries, and coordinating efforts. A MOU with the San Francisco Bay Regional Water Quality Control should be established in order to coordinate I&M monitoring efforts with the Surface Water Ambient Monitoring Program (SWAMP) efforts.

On both National Park and private lands site access may require a key or combination to a lock. Contact a park representative or landowner when necessary.

12.3.2 Site Selection

Sampling locations have been described in tables and maps in the Appendix D through F of the Protocol Narrative. The purpose of the site location descriptions is to provide the individual with enough information to drive or walk to a site. The tables also indicate the time of data and type of habitat (flowing or standing water) to be sampled. However, the exact place to collect samples is not specified. To establish sites follow the tips in the following section.

12.3.2.1 Tips for Site selection

(Adapted from O'Ney, 2005)

- Avoid culverts since streams may be impacted by roads and trails; in most cases establish a site at least 20 m upstream of a culvert. This reduces the affect of the road. For large roads and/or water that is "backed-up" against the culvert or bridge; move site further upstream.
- Verify each site using GPS where possible and attention to maps and access directions
- Safety and access (i.e., not only how to get to the stream, but how to reach the sample site). The most common hindrances to site access are steep banks and dense stands of poison oak, blackberry and stinging nettle.
- Consider appropriate locations for measuring flow. Straight channel reaches where flow is uniform are ideal.
- Consider the monitoring objectives and questions, types of data needed, equipment needs, and sampling methods (see the site location tables; also see the table of monitoring questions and related sampling location (habitat), and time of day).
- Obtain all available historical information on the site location.
- Sites immediately upstream or downstream of tributaries or point sources should also be avoided to minimize problems caused by backwater effects or poorly mixed flows. Typically, a distance of 5 stream widths below the influence of a tributary is adequate distance to ensure mixing. Complete vertical and lateral mixing within the cross section is generally desirable.
- Samples collected directly downstream from a bridge should be avoided, as they can be contaminated from the bridge structure or runoff from the road surface.
- Access to any sampling site is directly related to monitoring program cost. Bridges are frequently chosen for establishment of water quality monitoring stations due to access during most flows and they permit sampling at any point across the stream width. Samples should be collected upstream of the bridge.
- Monitoring of turbulent streams or during peak flows can be a safety concern for monitoring personnel. Monitoring locations should be chosen that allow sampling at peak flow with minimal risk to sampling personnel.

12.3.2.2 Randomization in Site Selection

Stream selection and site locations within a stream have been selected judgmentally for a variety of reasons described further in the Protocol Narrative. It is important to have some level of randomness incorporated into the water quality sampling regime. Within a flowing water or standing water area, the exact sampling spot can be chosen randomly. In flowing water, it is important to collect samples and parameter measurements in the centroid of flow whenever possible. Therefore, in order to maintain a level of randomness, within the desired sampling strata (run, riffle or pool) a random-number generator can be used to specify the distance to move parallel (positive-upstream or negative-downstream direction) to the stream flow direction while remaining in some desired sampling strata, and within the centroid of the stream. For

standing water, it is helpful to sketch the pool first. Then, using a random number table, choose two numbers to represent the width and length of the sampling spot from the edge of the pool. Where these intersect is the sampling location.

To be consistent with the USGS centroid or cross-section flow protocol for data comparability, then only randomize lengthwise (direction of flow of the stream) when flow is present and once there, collect the sample using the USGS centroid/cross section protocol.

Another randomization method is to use a stopwatch in the following way: The investigator starts the digital stopwatch so that single digits (at far right, ignore other numbers farther to the left) are racing fast. Let it run a while then have someone else call "start" then record the last digit (for example, say it the last digit to the right is "4", then if one is sampling riffles only, go 0.4 of the total length of the riffle upstream from the start and sample in the centroid, and if the cross section can't be made there due to logistics, make it in the closest spot upstream feasible. This method can be used to determine the distance up or downstream within the centroid one should sample.

12.4 Site Documentation

12.4.1 Establishing a Preliminary Profile of Field Measurements

(from O'Ney, 2005)

After a tentative selection of a sampling site is completed, the next step is to develop a preliminary profile of required field measurements (discharge, temperature, dissolved oxygen, conductivity, pH) at various locations along the cross section. The field measurement profile is used to indicate reach homogeneity. To obtain data representative of the section, the variability of discharge and field measurements across the stream must be known (NPS, 2003).

To establish a profile of field measurements:

1. Establish a cross sectional profile of stream discharge (see SOP #9 – Field Methods for Flow Measurements).
2. Check the cross-sectional profile data of the stream site to determine the variability of discharge per unit width of the stream.
3. Determine the increment (vertical) at which discharge in that increment is equal (approximately) on both sides of that point. This is the centroid of flow, and the point at which measurements for core parameters should be obtained.
4. Make individual measurements of required field parameters (temperature, dissolved oxygen, pH and conductivity) at a number of equally spaced verticals along the cross section and at multiple depths within each vertical.
5. Check the cross-sectional profile data to determine the variability of core field parameters per unit width of the stream.
6. Field-measurement profiles of stream variability are needed for low- and high-flow conditions and should be verified at least every 2 years.

Record the information collected in 1-5 above. Include in Field Folders for each station.

12.4.2 Obtaining Station Coordinates

(Adapted from WY-DEQ, 1999)
If the cross sectional profile of stream discharge and field measurements indicates that the section is not homogeneous, then repeat the procedure at additional locations until a suitable site has been identified.

After determining the station location, use GPS equipment to obtain station coordinates. GPS location data are collected by GRYN field technicians for each monitoring station. Readings are taken near the water's edge. Technicians record the GPS field file, GPS start time and stop time, GPS latitude/longitude coordinates, and after the files are processed, fill in the corrected latitude/longitude coordinates on the Field Data sheet. After the GPS field files are differentially corrected, the location data are entered onto NPSTORET station files, Field Data sheets and field log books. All GPS data files will be sent electronically to the GRYN Bozeman office to be archived.

Field technicians are referred to the GRYN Data Manager for details on using GPS equipment and software. On-line training is available. The GRYN should provide initial and refresher training as necessary
.

12.4.3 Photographic Documentation

Develop a standardized naming system for the photographs such as site ID and direction. Photographic documentation has many purposes and one of them is to track site changes over time. For this purpose, we want to document periphyton, riparian cover, location and extent of gravel bars

(Adapted from WY-DEQ, 1999):

Each sampling site must be documented with a series of photographs to establish site conditions. These photographs will be used to accurately relocate monitoring sites and to document field conditions. Individual photographs are taken looking upstream and downstream from the base of the sampling reach.

Photographs should be identified with:

- The photograph number, frame and/or roll;
- Date and time, even if the photographs are automatically date stamped by the camera;
- The subject;
- The location in narrative format and lat/long coordinates;
- The photographer;
- Witnesses, if any;
- The location from which the photograph was taken; and
- A short narrative related to the photographs

New photographs should be taken at the beginning of each field season (i.e., summer/fall before the next water year), and whenever site conditions change significantly.

12.4.4 Establishing NPS-STORET project files

(from O'Ney, 2005)

Field personnel are responsible for establishing and maintaining electronic and paper project and site files. NPS policy requires specific information on surface water sampling sites. Technicians are referred to http://science.nature.nps.gov/im/monitor/protocols/wqPartE.doc for detailed discussions of NPS data and metadata requirements, and to Data Management Procedures (SOP#8) of this protocol for detailed instructions.

Project files should be established prior to site reconnaissance visits, using the NPSTORET database template. Project, station, and metadata information are only entered once (unless a new project is started, new stations are added, or procedures change). All monitoring results collected at stations are assigned to projects. For Project ID, enter SFAN followed by WQ to indicate that it is a water quality project and then a sequence number (e.g. the first project in the Network would be SFANWQ01). Most of the information entered about the Project on the Main and Additional Info tabs should be readily available in network planning documents. You can paste in relevant information directly from a monitoring plan or other document. Additionally, the entire document can be stored as an Adobe Acrobat PDF file in the database (Documents screen) to permanently associate important reference material directly with the data. Other references (entered in the Metadata template) can be associated with the project on the Citations tab.

Refer to Data Management Procedures in the protocol narrative for the minimum information required for establishing electronic project files in NPS-STORET, and details for entry.

12.4.5 Entering Station Information in NPSTORET

Prepare a description of the location, and compile other required information (including digital photograph) for establishing NPS-STORET files. Upon returning to the office, enter all information into the SFAN water quality database. Some example station IDs are included in Table 12.1.

Table 0.1. Station IDs for water quality sampling locations

Water body	Location Description	Station ID
Chalone Creek	South wilderness,	PINN_I&M_CHA1
Gerbode Creek	Above Rodeo Creek confluence	GOGA_I&M_ROD6
Olema Creek	At Bear Valley Rd. bridge, upstream	PORE_I&M_OLM11
Franklin Creek	Franklin Creek at JOMU bridge	JOMU_I&M_FRA1

The NPSTORET site naming convention for Station ID's is:

Park Code_Project Grouping_Station name/abbreviation/code

STORET allows station Ids with up to 15 characters. For old station ideas, most systems allow you to carry along secondary station names so those names can be preserved.
Works well for sorting stations

12.4.6 Entering Additional Information Into NPSTORET

In addition to the information required for site establishment, information must be entered related to the parameters collected at each site. See the SFAN Quality Assurance Project Plan (SOP #4) and Protocol Narrative for additional information.

12.4.7 Creating Field Folders

Selected information that is needed for reference while at a sampling station is kept in a field folder. The field folder contains information needed by trained personnel to locate and safely collect and process water quality samples, and is taken along on each sampling trip. Assemble a field folder for each sampling station to contain the following:

- Station description:
    - Location of gaging station (if one is present) and USGS contact information.
    - Location of sample-collection sites. Actual sampling locations may differ slightly depending on flow conditions.
    - Hydrologic and geologic maps, if available.
    - Name of landowner, tenant, or other responsible party.
    - Current copy of research and collection permit (if site located within NPS boundaries)
    - Site access instructions (for example, call owner or site operator before arrival at site, obtain key to unlock security gate).
    - Photographs to document site conditions.

- Maps to site (state and local)

- Profiles of cross section of stream channel at sampling locations
    - Stream bottom geometry
    - Physical and chemical measurements

- Safety information (SOP#3):
    - Nearest emergency facilities.
    - Phone numbers (home) of project manager or supervisor.
    - Traffic condition and traffic plan showing where to park, placement of flags and cones.
    - Location of power lines.
    - Environmental hazards, such as weather and animals.

- Sampling schedule
    - Laboratory analyses to be requested and associated codes
    - When to collect samples
    - Bottle types needed for each analytical schedule

- Sampling instructions:
    - Discharge curves and velocity cross sections
    - Discharge rating curves and/or tables

    - Preservation, storage, and handling requirements
    - Quality control sample requirements

- Shipping instructions (if applicable)
    - Amount of ice to use and holding time requirements
    - Mailing labels to and from laboratory
    - Location of nearest post office or shipping agent

- Field forms and examples of completed forms for both required and regulatory field parameters:
    - Analytical service request forms
    - Permission forms and data collection forms

- Laboratory Chain of Custody Forms including proper dilutions for fecal indicator bacteria samples.

- Equipment check lists
- Other local information including park contacts, local advisories (fire, flood, landslide, rock fall, problem exotics), etc.

12.5 Equipment Installation

12.5.1 Installation of a Staff Gauge

(Adapted from USGS, 1999)

For recurring discharge measurements at a monitoring location, it is usually best to install a staff gage (non-recording) in the absence of any nearby automated (recording) gaging station. A staff gage is a scale (usually enameled steel) placed in a stream to show the elevation of the water surface. It is calibrated by referencing the numbered height on the gage to the surveyed elevation of the water surface and its associated flow at the time of installation. A rating curve or stage-discharge relationship is then developed from numerous stage measurements and discharge computations made at the site during variations in flow by plotting stage versus discharge (typically gage height in feet versus discharge in cubic feet per second) on log-log paper. The more points, the more precise the rating curve is likely to be.

Vertical staff gages are used as reference gages for setting a recording device. The vertical staff gage can be used in a stilling well or in a stream. Standard staff gages should be purchased, and installed on a 4x4 post (or affixed to a permanent structure such as a bridge) adjacent to the sampling station. The staff gage should be located in an area that will provide some degree of protection from debris flows, etc. The staff gages installed at specific water monitoring locations will be read at the time water samples are taken to determine the stage or elevation of the water surface at that location. Anchored in the stream bed, the gage will consist of a vertical scale that is permanently marked in increments of 0.01 feet and the stage reads directly from these markings to the nearest 0.01 feet. Stream stage is defined as the elevation of the water surface above an arbitrary zero datum at that specific point in the stream. Thus, the zero discharge point does not necessarily correspond to a stage of zero.

12.5.2 Installation of an Automatic Stage Recorder and Establishing a Rating Curve

Measuring continuous discharge requires the installation of a pressure transducer and electronic data logger in conjunction with the staff gage. A Keller pressure transducer and Campbell Scientific data logger are recommended, however, there are numerous other pressure transducers and data loggers that would also be adequate (O'Ney, 2005). SFAN currently uses Druck and Global Water pressure transducers. Follow the operating instructions provided by the manufacture.

The best way to install the pressure transducer/data logger in surface water is to use a 2" pipe to protect the sensor and the data logger. You can use PVC schedule 40, or ABS sewer drain pipe. The best protective pipe is PVC schedule 40 electrical conduit. This light grey pipe has UV protectors and pre-formed "sweeps" or bends which enable the pipe to conform to the contours of the river bank. The sensor will slide down through 45 or 90 degree sweeps. The pipe may be buried in the river bank, secured with rocks, or fastened to the bank with large staples made by bending pieces of concrete reinforcing steel in half and driving them into the bank. The pipe should have several large (1/2" diameter) holes drilled near the sensor location in order to eliminate velocity effects on the sensor. Also, a smaller 1/4" hole should be drilled near the top of the pipe to allow air movement when the water goes up and down. A standard slip cap or a locking well cap can be used to protect the top of the data logger. You can also adapt the pipe for a screw-on cap.

Depending on site conditions, it may be more appropriate to install the sensor and data logger in a stilling well. Various kinds of automatic stage recorders can be set up in stilling wells. A stilling well is a chamber that is hydraulically connected to the stream through intake pipes. The stilling well eliminates turbulence that may occur in the stream and the elimination of waves and surges results in more accurate readings. Manufacturers' instructions are followed for the specific installation and operation.

The next step is to establish a rating curve by making a series of independent flow measurements and simultaneous staff gage measurements for that station at different water levels using the velocity-area method (see Field Methods for Measurement of Core Parameters, SOP#5). The rating curve converts stage height to discharge. Discharge measurements using the velocity-area method should be made over a range of stage heights. Discharge rating curves are usually determined empirically by means of periodic measurements of discharge and stage using a current meter (minimum of 10 per year is recommended initially). However the rating curve may shift over time and periodic measurements are necessary after the first year to either confirm the permanence of the rating or to follow changes/shifts in the rating. It is important that the rating curve include measurements made at flow extremes (e.g. flood conditions) and under ice conditions to be most accurate. Volume 2 of USGS WSP 2175 (Rantz et. al., 1982) discusses stage-discharge relations ranging from simple to complex and the various parameter variables (slope, velocity index) that should be considered when computing discharge rating curves under more complex situations.

It is recommended that for at least the first year of sampling, discharge measurements be taken for each sampling event, to help establish a reliable stage/discharge relationship.

12.6 References

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National Park Service
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Natural Resource Program Center
1201 Oakridge Drive. Suite 150
Fort Collins, Colorado 80525

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