



San Francisco Bay Area Network (SFAN) Streamflow Monitoring Protocol

Volume 1: Narrative and Appendixes - Version 2.92

Natural Resource Report NPS/SFAN/NRR—2011/343



ON THE COVER

Olema Creek, Point Reyes National Seashore.
Photograph: NPS

San Francisco Bay Area Network (SFAN) Streamflow Monitoring Protocol

Volume 1: Narrative and Appendixes - Version 2.92

Natural Resource Report NPS/SFAN/NRR—2011/343

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Standard Operating Procedures

Standard Operating Procedures (SOPs) are maintained by the network and are available in the succeeding volumes of this report.

SOP 1. Procedures for Selection and Operation of Streamgages

SOP 2. Data Management

SOP 3. Streamgage Station Descriptions

SOP 4. Field Equipment for Flow Measurements and Station Maintenance

SOP 5. Training and Resources

SOP 6. Procedures for Tipping Bucket Rain Gage Stations

SOP 7. Data Analysis and Reporting

SOP 8. Revising the Protocol

SOP9. Quality Assurance Plan (QAP)

SOP 10. Field Methods for Streamflow Measurements

SOP 11. Safety Procedures

SOP 12. Decontamination During and After Field Activities

Executive Summary

Knowing the condition of natural resources in national parks is fundamental to the National Park Service's ability to manage park resources “unimpaired for the enjoyment of future generations (National Park Service Organic Act 1916).” To uphold this goal, the Director of the NPS approved the Natural Resource Challenge to encourage national parks to focus on the preservation of the nation’s natural heritage through science, natural resource inventories, and expanded resource monitoring. Through the Challenge, 270 parks in the national park system were organized into 32 inventory and monitoring networks.

The San Francisco Bay Area Network (SFAN) units within this Streamflow monitoring protocol include Golden Gate National Recreation Area (GOGA), John Muir National Historic Site (JOMU), Pinnacles National Monument (PINN), Point Reyes National Seashore (PORE), and the Presidio of San Francisco (PRES). The network has identified vital signs, indicators of ecosystem health, which represent a broad suite of ecological phenomena operating across multiple temporal and spatial scales. Our intent is to monitor a balanced and integrated “package” of vital signs that meets the needs of current park management, but will also be able to accommodate unanticipated environmental conditions in the future. Streamflow represents a particularly high priority vital sign for SFAN because it is ecologically significant, supports a variety of endangered and threatened species, and is of high interest to the public.

This long-term monitoring protocol focuses on streamflow for the San Francisco Bay Area Network (SFAN) Inventory and Monitoring Program of the National Park Service. The emphasis on freshwater streams coincides with the prevalence of streams at all SFAN parks, the occurrence of significant natural resources dependent on streams there, and the existing and potential threats to streamflow from human influences. Some of the significant natural resources include state and federally endangered coho salmon (see also Reichmuth et al.2010), federally threatened California red-legged frog and steelhead trout.

This protocol narrative and standard operating procedures provide the basis for monitoring including the selection of sampling locations, detailed field methodology, methods for data analysis, reporting requirements, program budgets, and personnel qualifications. Specific SOPs describe in greater detail field procedures for establishing and operating streamgages, discharge measurement procedures, data management, quality assurance project plan, training and resources, and streamgage station descriptions. Many of the SOPs follow standardized protocols for streamflow monitoring that have been adopted by the United States Geological Survey. Many of their technical reports and memoranda are considered supplementary materials that are required for this monitoring plan.

The specific monitoring objectives are to:

1. Monitor the variability and long-term trends in streamflow using fixed, continuous, water stage recording stations by producing annual mean daily and monthly discharge estimates for core streamflow monitoring stations in GOGA, PRES, PINN, and PORE.

2. Monitor the frequency, magnitude and duration of peak flow events at fixed, surface water level monitoring stations by producing peak and daily summaries of stage height and discharge for core streamflow monitoring stations in GOGA, PORE and PINN.
3. Monitor the timing, frequency, magnitude and duration of unnatural or extreme low water/low flow events in stream reaches known to support threatened and endangered aquatic species in the dry season in GOGA, PORE, and PINN watersheds.

The SFAN Streamflow Monitoring Program includes six core streamgages: Redwood Creek (GOGA); Bear Creek (PINN); Olema Creek (PORE); Lobos Creek (Presidio of San Francisco); Lagunitas Creek at Samuel P Taylor State Park (GOGA/PORE); and Lagunitas Creek at Point Reyes Station (GOGA/PORE). I&M program monitoring efforts are focused at three of these core streamgages including Redwood Creek, Bear Creek and Olema Creek. The USGS operates and maintains the two core streamgages on Lagunitas Creek. Data from Lobos Creek is collected by the Presidio Trust but is managed by the I&M program.

Data are collected year-round at streamgages. The primary sampling parameters at core stations include water surface levels or stage height at the streamgages and individual measurements of stream discharge (cubic feet per second [cfs]). Discharge is computed at recording streamgages based upon stage-discharge relationships. Collected supplementary parameters include level data, water temperature, and rainfall.

Annual reports will provide standardized summary information including: daily values table for the water year, hydrograph of daily mean discharge and precipitation values, rating curves, station analysis, and photographs. Long-term monitoring reports will include similar information as the annual reports with the addition of flow-duration and flood frequency calculations. The long-term reports will also include recurrence interval analyses for rainfall events of standard durations (1-hour, 6-hour, and 24-hour). They will also include assessment of trends in streamflow distribution from the annual minimum (daily mean Q_0) to the annual maximum (daily mean $Q_{\max}$).

The annual I&M budget for the streamflow monitoring program is approximately \$15,000. This funding contributes to the network's water quality technician who collects and manages the data. Park contributions towards this effort includes staff support and direct PORE funding to support a 1/3 share of USGS operations of the Lagunitas Creek at Point Reyes Station gage. Quality control and reporting responsibilities are provided by the GOGA aquatic ecologist.

Acknowledgements

Sections of this protocol were written by Travis Smith (SCA Volunteer), Paul Johnson (Network Ecologist), Rob Carson (Network Water Quality Specialist) and Jennie Skancke (Water Quality Specialist). Significant contributions were made by Randy Klein, Hydrologist of Redwood National Park. Technical assistance was provided by Jeff Runde (Hydrologist, Northeast and National Capital Region). Gwen Gerber and Rick Inglis of the Water Resource Division provided technical reviews and helped answer many questions relating to streamflow monitoring and data analyses. We also wish to thank Brannon Ketcham, Penny Latham, Eric Starkey, James Kolva, and Stephen Blanchard for their comments to earlier drafts of this protocol.

1.0 Background and Objectives

1.1 Background

The primary mission of the National Park Service's (NPS) Inventory and Monitoring (I&M) Program is to provide park managers with scientifically based and statistically valid data to support resource management actions. The San Francisco Bay Area Network (SFAN) I&M Program has identified a suite of vital signs that serve as ecological indicators of ecosystem health for the national parks in the central California region (National Park Service 2005). These parks include Eugene O'Neill National Historic Site (EUON), John Muir National Historic Site (JOMU), Pinnacles National Monument (PINN), Point Reyes National Seashore (PORE), The Presidio (PRES), and Golden Gate National Recreation Area (GOGA) which administers Fort Point National Historic Site (FOPO) and Muir Woods National Monument (MUWO; Figure 1).

Streamflow characteristics offer some of the most appropriate and useful indicators for assessing river ecosystem integrity over time. The streamflow characteristics of a watershed reflect vegetation type, land characteristics and human use, the weather and climate conditions, and soil characteristics. Streamflow characteristics are extremely sensitive to human actions. Common human activities such as increasing impervious surface area in watersheds change the timing and magnitude of peak runoff events resulting in "flashy" systems (Dunne and Leopold 1978). Hydrologic variation in turn shapes the biotic diversity within river ecosystems by controlling critical habitat conditions within the river channel, the floodplain, and hyporheic zones. Stream hydrology data provide key "support" data for existing NPS vital sign protocols including water quality, stream threatened and endangered (T&E) species and fish assemblages, T&E amphibians and reptiles, wetlands, and riparian habitat (Adams et al. 2006). Information regarding streamflow frequency and recurrence intervals is essential to park management, informing park operations, restoration planning, and implementation. Further justification of this network's inclusion of streamflow as a monitoring Vital Sign is explained in Section 1.4.

The SFAN network identified freshwater dynamics and specifically streamflow as one of its top vital signs for monitoring. This streamflow monitoring protocol along with the Standard Operating Procedures (SOP) discusses the field methods, data management, field and office quality assurance procedures, data storage, data analysis and reporting, personnel requirements, and annual budgets for this SFAN program. The protocol and SOP meet many of the Quality Assurance Project Plan elements established by the EPA including: problem definition/background, project/task description, sampling objectives, sampling design, sampling methods, data management, analytical methods, documentation (reporting), project/task organization, staffing plan, and training requirements (EPA 2002).

1.2 Policies Related to Streamflow Monitoring

Federal law and NPS policies direct National Park managers to understand the status and trends in the condition of natural resources under their stewardship in order to fulfill the NPS conservation mission. NPS policies require that the primary management objectives in natural zones are the protection of natural resources and values for visitor enjoyment while ensuring their availability to future generations. Furthermore, the NPS is required to identify and promote the conservation of all federally listed threatened, endangered, or candidate species. Reliable inventory and monitoring data are essential to adequately protect natural resource values,

especially federally listed species. Within the San Francisco Bay Area network, examples of federally listed species dependent upon natural streamflow include coho salmon and California red-legged frog.

San Francisco Bay Area Network Inventory and Monitoring Program



Figure 1. National Park Service units within the SFAN Inventory and Monitoring Network.

A variety of federal Executive and Director's Orders have been issued to help protect wetlands (Director's Order 77-1, Executive Order 11990) and to avoid adverse impacts to floodplains (Executive Order 11988). The NPS Management Policies (NPS 2006) Section 4.6.6 articulates that implementation of these orders requires good streamflow data. Long-term streamflow monitoring data helps establish an understanding of the extent and inundation patterns of floodplains and the potential threats posed by management actions.

1.3 Existing and Significant Freshwater Resources

1.3.1 General Hydrologic Characteristics

The parks within this network have a broad array of freshwater resources that vary in terms of their hydrologic source (groundwater versus surface), duration of inundation (perennial versus seasonal), vegetative community, landscape position, degree of alteration, and flow characteristics (running water versus lentic or ponded water). Drier, interior Parks such as Pinnacles National Monument and John Muir National Historic Site have more limited natural wetlands and perennial streams when compared to a coastal park such as Point Reyes National Seashore. The range in mean annual precipitation across SFAN parks is 15–55 inches (Figure 2).

Runoff in Park streams in the San Francisco region is primarily due to rain generated by Pacific cold fronts typical of a Mediterranean climate. Over 90 percent of the annual runoff occurs between November and April and mainly during and immediately after storms (Wahrhaftig and Lehre 1974). The significant amount of runoff that occurs immediately after storms is attributed to three factors: 1) steep basins promoting rapid runoff, 2) shallow soils and bedrock of low permeability, and 3) much of the precipitation falling on saturated ground and running off (Wahrhaftig and Lehre 1974). Baseflows in unregulated streams in the region may be greatly influenced by summer fog. Recent research has demonstrated that fog drip constituted more than 30% of the annual precipitation in a northern California coastal redwood forest (Dawson 1998).

At PINN, the runoff regime is more similar to arid zones in that stream response is flashy, ephemeral, and sometimes a source for groundwater recharge. Other streams in the SFAN such as GOGA and PORE that are located along the coast have better sustained baseflows than PINN, although they lack the high summer-fall baseflows seen in wetter climates or in snow-melt dominated systems. In settings with Mediterranean climates, freshwater resources are a scarce and important commodity for both natural resources and agricultural and municipal purposes. Many of the larger NPS streams provide water for municipal and agricultural uses. One of the streams, Lobos Creek, is the sole source of potable water for the Presidio of San Francisco. Parks that have had past ranching activities, such as PORE, GOGA and PINN, often have onstream stock ponds. These impoundments alter natural hydrologic regimes.

Because of past and continued threats to stream resources from water appropriation as well as other facets of urbanization, many of the animals and plants that depend on freshwater resources are at risk of local or regional extinction—a characteristic that has resulted in the presence of large numbers of state and federally listed endangered and threatened animals in our Parks. Appendix A includes a complete list of state and federal special status animals and plants that are dependent on our freshwater resources.

Precipitation Patterns

National Park Service
U.S. Department of the Interior
SFAN Park Units

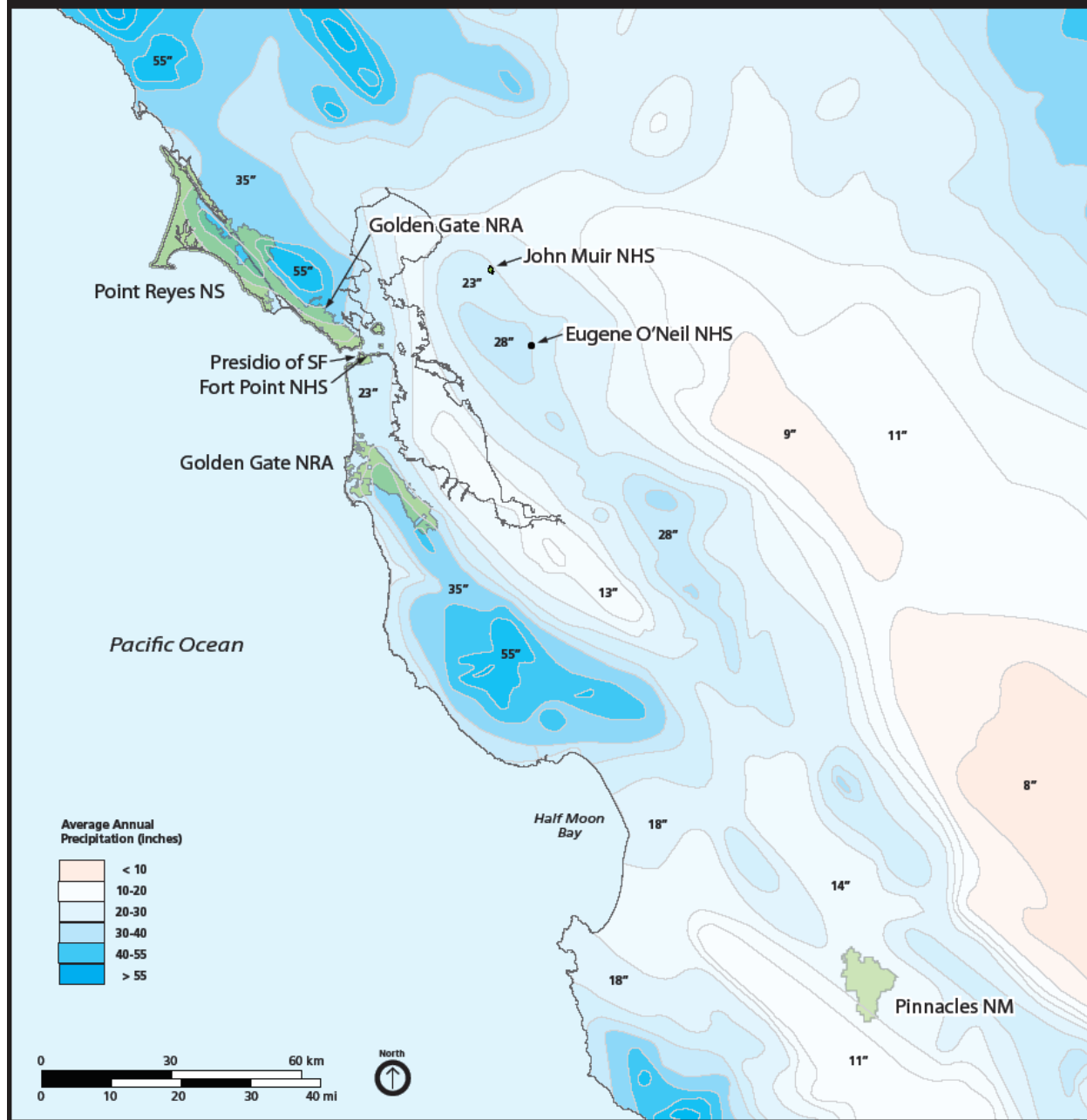


Figure 2. Precipitation patterns of average annual precipitation at the SFAN park units (NRCS 1961-1990).

1.3.2 SFAN General Watershed Descriptions and Significant Resources

Watersheds are delineated by the United States Geological Survey (USGS) using a nationwide system based on surface hydrologic features. All SFAN Parks except for PINN are located within the San Francisco Bay Subregion-1805 (Figure 3). PINN is located within the Central California Coastal Subregion-1806.

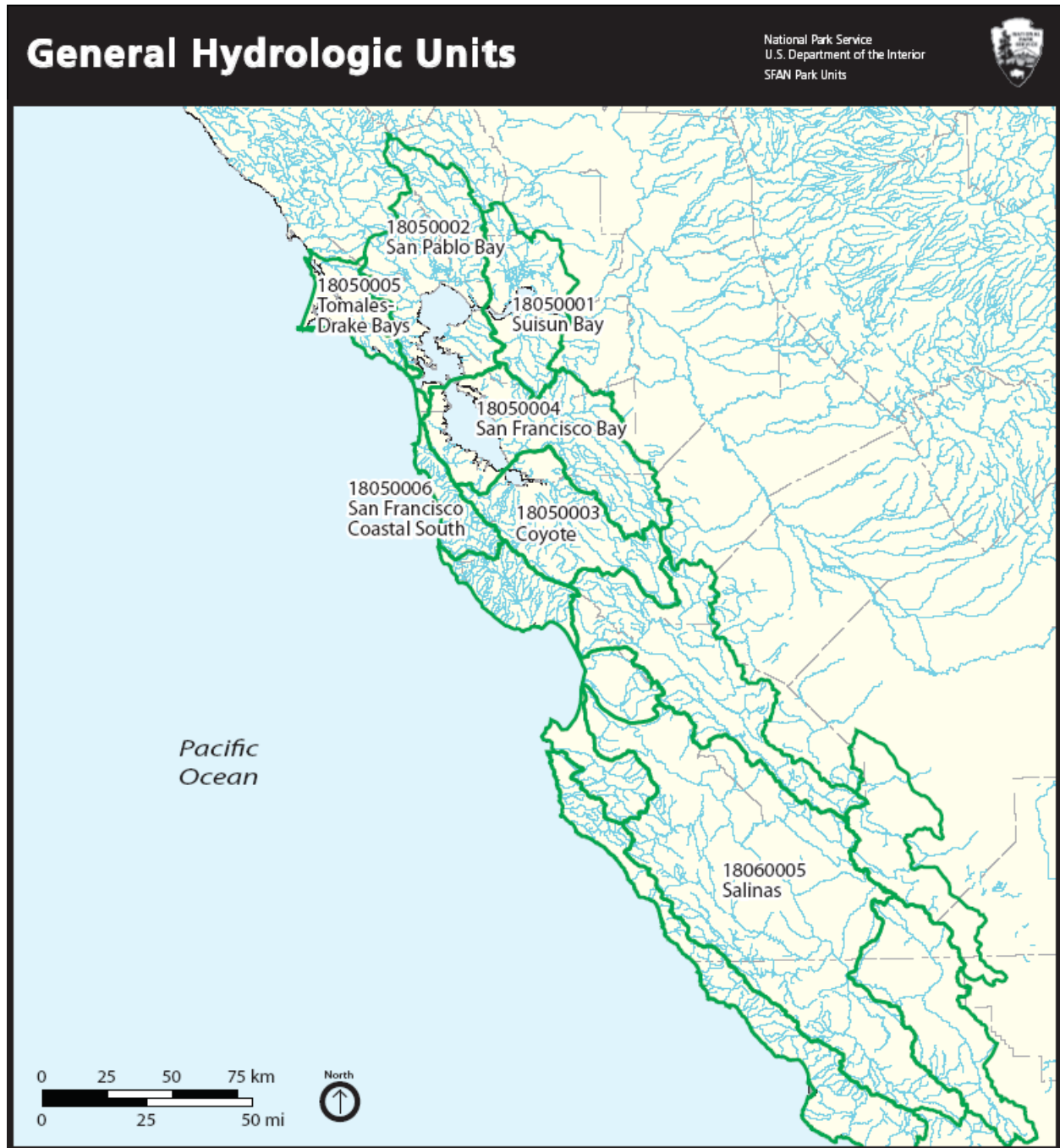


Figure 3. General hydrologic units for the San Francisco Bay Basin with sub-basins identified (modified after USGS, 2005).

1.3.2.1 Golden Gate National Recreation Area (GOGA): Five moderately sized drainages in GOGA are contained in Marin County. These drainages from north to south are: Lagunitas Creek, Olema Creek, Redwood Creek, Elk Creek (in Tennessee Valley) and Rodeo Creek. Many of these watersheds support federally listed aquatic animals including California red-legged frog (*Rana aurora draytonii*), California freshwater shrimp (*Syncaris pacifica*), tidewater goby (*Eucyclogorius newberryi*), coho salmon (*Oncorhynchus kisutch*), and steelhead trout (*Oncorhynchus mykiss*).

In San Mateo County, an unnamed intermittent streamflows through the GOGA lands at Milagra Ridge. San Pedro Creek, a perennial San Mateo County stream, is within the GOGA boundary and supports steelhead trout. Sanchez Creek, a heavily altered urban streamflows along the park boundary at Mori Point, and supports both native and introduced fish, as well as federally listed amphibians and reptiles. The creek and wetland complex at Mori Point support the only known population of federally endangered San Francisco garter snake (*Thamnophis sirtalis tetrataenia*) within the NPS. Drainages in Phleger Estates are tributaries to San Francisquito Creek, which flows to San Francisco Bay and provides habitat for California red-legged frogs and steelhead trout. Newly acquired Rancho Corral de Tierra near the town of Half Moon Bay has three perennial streams (Martini, San Vicente, and Denniston) that also support fish and amphibians.

1.3.2.2 Muir Woods National Monument (MUWO): The headwaters of Redwood Creek (Fern, Spike Buck, and Rattlesnake) drain the southern slopes of Mt. Tamalpais and flow through Mt. Tamalpais State Park lands before entering MUWO. The reach of Redwood Creek within MUWO is heavily shaded by riparian trees including coast redwoods (*Sequoia sempervirens*) (Figure 4). The creek provides year-round habitat for coho and steelhead trout as well as for amphibians such as California giant salamanders (*Dicamptodon ensatus*).



Figure 4. Redwood Creek in Muir Woods National Monument.

1.3.2.3 Fort Point (FTPO): Because of the small size of this National Historic site, there are few surface water features. Seeps from the bluffs at Fort Point flow into an artificial and historic ditch that runs along the access road (Marine Drive) to the fort. This non-descript wetland features is one of two remaining localities within the City of San Francisco for its namesake damselfly, the San Francisco fork-tailed damselfly (*Ischnura gemina*).



Figure 5. Public enjoyment at Lobos Creek, The Presidio, San Francisco (Jan. 18, 1998).

1.3.2.4 Presidio of San Francisco (PRES): Very few free-flowing streams still exist in San Francisco County. Lobos Creek is the largest creek that flows through the Presidio of San Francisco and empties into the Pacific Ocean (Figure 5). The contributing drainage area (3.24 sq. miles) extends into the surrounding, urbanized City of San Francisco which is underlain by porous dune sands (Schanz et al. 1995). The creek is largely managed by GOGA but a small portion flows through the water treatment facility at Baker Beach managed by the Presidio Trust. Here the water is diverted, treated, and used for potable water supply in the Presidio. With the exception of the much larger Lagunitas Creek, this spring-fed creek has the highest summer-fall baseflow within SFAN (approximately 3 cfs), based on flow measurements since the mid to late-1800s (Schanz et al. 1995).

1.3.2.5 Eugene O'Neill National Historic Site (EUON): Eugene O'Neill NHS is located within the approximately 150 sq. mile Walnut Creek watershed; Walnut Creek flows north into Suisun Bay. Tributaries to Walnut Creek include Lafayette Creek, Las Trampas Creek, Tice Creek, San Ramon Creek, and Pine Creek. No creeks flow through the park. An unnamed tributary to San

Ramon Creek flows behind the EUON property (about 1/8 mi north of the park boundary). Water from an adjacent stock pond occasionally overflows into a culvert that flows into this tributary. This former stock watering pond is located behind the EUON property on land owned by the East Bay Regional Park District (EBRPD); however, through an agreement with EBRPD, EUON manages the approximately two-acre pond. Damming of a small spring-fed canyon formed the pond. Through a separate agreement with the EBRPD, EUON also manages the springs and associated water tanks that are located on the adjacent Las Trampas Regional Wilderness. Though the springs are not used for drinking water by NPS, they were the water source for the O'Neill house. Major aquifers beneath the eastern sides of Las Trampas Ridge feed the springs. In addition to the springs and former stock pond, a small ephemeral unnamed stream (with an eroded canyon) flows behind the park headquarters. This stream flows into the tributary of San Ramon Creek just north of the park. During dry periods, all water in the park and the surrounding Las Trampas Regional Wilderness Area originates from spring flow.

1.3.2.6 John Muir National Historical Site (JOMU): John Muir NHS is located within the 16.5 mi² Alhambra Creek watershed in northwestern Contra Costa County that drains into the San Francisco Estuary at the Carquinez Straits. Two sub-watersheds are located within the park: Franklin Creek and Strentzel Creek. The 5 mi² Franklin Creek watershed supports an intermittent stream that flows alongside John Muir's orchard. This stream has been altered due to past activities and flows underneath a major state highway. However, a single steelhead trout was sighted in 2006 by network staff. Strenzel Creek is an ephemeral watershed that flows through park lands off Mt Wanda, and into Alhambra Creek just upstream of the John Muir gravesite. Flooding of adjacent properties by Strenzel Creek has prompted extensive hydrologic and geomorphic analysis of the watershed as well as a Regional Water Quality Control Board project to reduce sediment loading from the stream.

1.3.2.7 Point Reyes National Seashore (PORE): Point Reyes National Seashore managed lands, including the north district of GOGA contains the largest extent and types of freshwater wetland and aquatic sites within the SFAN network. These wetlands include dune swale wetlands along the coast, large creeks supporting salmon, and active ranch stock ponds supporting breeding California red-legged frog. There are three major creeks within the Seashore plus several small coastal watersheds that drain to Tomales Bay, Drakes Estero complex or straight to the Pacific Ocean. While most of the perennial watersheds support steelhead, three major watersheds in the park, including Lagunitas, Olema, and Pine Gulch Creeks are documented to support coho salmon. Lagunitas Creek, and one of its tributaries, Olema Creek are within the Tomales Bay Watershed. These watersheds are listed under Clean Water Act Section 303(d) as impaired by sediment, nutrients and pathogens. In 2006, the State Water Resources Control Board (SWRCB) adopted a load-based TMDL to control nonpoint source pathogen discharges and delivery within the Tomales Bay watershed. Drainages in the southern portion of the park, including Pine Gulch Creek, are part of the Bolinas Lagoon, a coastal estuary formed along the San Andreas fault. Along the Point Reyes Headlands, small drainages flow directly into Drakes Bay, the West Coast landing site of the English explorer, Sir Francis Drake in 1579.

The 88 mi² Lagunitas Creek watershed is the largest watershed within SFAN. Its headwaters flow from the north slopes of Mount Tamalpais, the highest peak in Marin County (and second highest in the San Francisco Bay Area). Within the Lagunitas Creek watershed, five reservoirs

are managed by Marin Municipal Water District (MMWD), including (from upstream to downstream) Lake Lagunitas, Bon Tempe Lake, Alpine Lake, Kent Lake, and Nicasio Reservoir. The dams forming Kent Lake and Nicasio Reservoir are identified as barriers under the National Marine Fisheries Service critical habitat designation for coho salmon and steelhead. These two dams effectively reduce available and accessible salmonid habitat by more than 50 % from pre-development conditions. The operations of the dams are to fill for public water supply. Once the reservoir system is full, all inflow from the upper watershed is passed through the dams and into the Creek. In association with unpermitted expansion of the Kent Reservoir following the drought of 1976–1977, the State Water Resources Control Board decision 95-17 mandated release flows throughout the year to support salmonids within the watershed. The flows for this regulatory requirement must be met at the USGS gage 11460400 Lagunitas Creek at Samuel P Taylor.

1.3.2.8 Pinnacles National Monument (PINN): Chalone Creek is the major drainage of PINN. Most of the Park's 25 square miles drains into this tributary which eventually empties into the Salinas River and Monterey Bay. Much of the flow is subsurface during summer (Figure 6). The terrain in the Gabilan Range is rugged and deeply dissected. The tributaries of Bear Creek and Chalone Creek originate just outside the PINN boundary. Chalone Creek and Sandy Creek are unimpeded throughout their course in the PINN, but their uppermost branches on private lands are impounded in small stock ponds.

Bear Creek is impounded behind a dam built during the CCC-era. That reservoir is not being used for domestic purposes, although it is now depended upon by wildlife, including the California red-legged frog. Flowing water is generally found from November through early May. Water exists in the reservoir year-round and in small sheltered plunge pools along the streambed.

The freshwater habitat within PINN is primarily restricted to stream corridors, with a few artificial ponds. A small population of federally threatened California red-legged frog occurs with PINN and unlike populations in wetter habitats of PORE and GOGA, breeding and rearing activities occur commonly in the streams. Because of the potential threats to this aquatic resource, the U.S. Fish and Wildlife has designated both private and NPS lands within this area as critical habitat (Critical Habitat Unit San Benito-3; USFWS 2006). Western pond turtles (*Clemmys marmorata*), a species of special concern, are also present.

Nine springs are known and marked within PINN and additional small seeps may appear seasonally in wetter years. Springs generally occur along fault lines, as is true for Willow Spring, along rock fractures, or along lithologic contacts. Springs are no longer used as domestic water supplies for facilities due to their inadequate water production.



Figure 6. Chalone Creek, Pinnacles NM, under summer baseflow conditions, and prior to growth of vegetation in channel.

1.4 Rationale for Selecting This Resource to Monitor

The SFAN network is focusing its monitoring of freshwater dynamics on streamflow. A number of related indicators including water quality and coho salmon monitoring are dependent and responsive to streamflow conditions. Monitoring of the hydrologic dynamics of seasonal wetlands, freshwater aquatic sites, or tidally influenced systems are beyond the scope of this protocol but this decision may be revisited if funding and personnel limitations change. The emphasis on freshwater streams coincides with the prevalence of streams at all SFAN parks, the occurrence of significant natural resources dependent on streams there, and the existing and potential threats to streamflow from human influences.

The channel, floodplain, terraces, and other features in the stream corridor are formed primarily through the erosion, transport, and deposition of sediment by streamflow (Federal Interagency Stream Restoration Working Group 1998). Stream channels and their floodplains are constantly adjusting to the water and sediment supplied by the watershed. Alterations in channel and floodplain morphology result in a chain of events including changes in stream hydraulics, stream function and capacity (habitat, sediment transport, and storage), and alteration of biological features. This chain of events may also result in feedback loops that reinforce a trend in channel or floodplain morphology.

Therefore, monitoring of streamflow characteristics offers some of the most appropriate and useful metrics for assessing watershed and river ecosystem integrity over time. The hydrologic

output of a watershed is a function of the land characteristics and use, the weather and climate conditions, urbanization and soil characteristics. Hydrologic variation (the variation of stream discharge annually, seasonally and between storm and non-storm periods) plays a key part in structuring the biotic diversity within river ecosystems by controlling critical habitat conditions within the river channel, the floodplain, and hyporheic zones (Poff and Ward 1989; Arthington and Pusey 1994; Townsend and Hildrew 1994; Richter et al. 1996).

Hydrologic variation is recognized as a major influence on instream habitat because it drives fluvial processes that maintain a dynamic mosaic of channel and floodplain habitat structures (Leopold et al. 1964), creating patchy and shifting distributions of environmental factors that sustain diverse biotic assemblages (Sparks et al. 1990; Schlosser 1991; NRC 1992; DeAngelis and White 1994; Sparks 1995). Advocates for using the natural variability of ecosystems as a guide for ecosystem management express the perspective that “managing an ecosystem within its range of natural variability is an appropriate path to maintaining diverse, resilient, productive, and healthy systems” (Swanson et al. 1993; Morgan et al. 1994). Thus, if conservation of native biodiversity and protection of ecosystem integrity are objectives of river management, then river management targets must accommodate the natural flow model.

Landscape alterations (e.g, urbanization, vegetation type conversion), water diversion and impoundment, and stream channelization can profoundly alter the hydrology of watersheds. Urbanization and channelization tend to increase the ‘flashiness’ of stormflows, promoting higher peak flows and more rapid stormflow recession (Savini and Kammerer 1961; Dinicola 1990; Burgess et al. 1998). In our parks, roads and trails are prevalent in watersheds. These transportation networks generally increase the number of small channels and intercept slow-moving groundwater thereby facilitating higher peak flows (Forman and Alexander 1998). Increased frequency or duration of high flow levels may displace velocity-sensitive organisms, such as some periphyton, phytoplankton, macrophytes, macroinvertebrates, young fish, and deposited eggs (Moog 1993; Allan 1995). These hydrologic changes also affect the delivery of nutrients, toxins and sediments. In coastal watersheds, increased freshwater discharge affects the salinity patterns and circulation in tidal and intertidal areas.

Streamflow data helps assess the health of aquatic species. SFAN parks include watersheds that support federally threatened and endangered aquatic species, including coho salmon and steelhead. The success of these species depends largely on streamflow characteristics. Low streamflow in PINN may result in sections of red-legged frog breeding habitat drying before successful metamorphosis of tadpoles. Conversely, extremely high winter flows in PINN may transport non-native fish from upstream reservoirs into breeding habitats resulting in predation on California red-legged frog tadpoles or may wash them away.

1.5 Significance to Management/Management Triggers

Monitored watersheds within the SFAN streams support significant fisheries resources dependent on natural streamflow runoff processes. Streamflow data provide important information for park resource management including habitat protection, floodplain management, watershed management, water allocation, design of hydraulic structures for creek restoration projects, and instream flow protection, to name a few. Many Park streams are being used for municipal and agricultural water supply including Lobos Creek (PRES), tributaries to Bolinas

Lagoon (GOGA), Redwood Creek (GOGA), Pine Gulch Creek (PORE/GOGA), and Lagunitas Creek (PORE/GOGA). The lack of knowledge regarding streamflow conditions can result in major problems. Past water withdrawals on a tributary to Bolinas Lagoon by a water district resulted in dry stream conditions that killed threatened steelhead trout below their diversion. Since then, the water district has adopted a management plan that includes streamflow monitoring and management triggers for different flow conditions (Stetson Engineers Inc. 2003). A reliable record of the frequency, magnitude and duration of extreme low flow events would help the parks to identify adverse conditions affecting aquatic life that may be linked to water appropriation activities. This data need is reflected as a key monitoring objective (Section 1.8).

Several network streams have identified management triggers and resultant actions. The most specific triggers and actions have been defined for streams in the network such as Lagunitas and Lobos Creeks where water appropriation activities occur (Table 1). On Redwood Creek, an adaptive management plan developed by the local community services district in response to a water rights permit from the state (MBCSD 2005, SWRCB 2001) resulted in a creek physical condition being identified as a required trigger for management actions to reduce water withdrawals. Streamflow data on Lagunitas Creek could be useful as a legal trigger should upstream water appropriation result in instream flows that are less than the park's appropriative right at the recent Giacomini wetland restoration site.

For most streams in the network, particularly those with limited baseline data or the absence of water appropriation activities, park managers have not identified measurable management triggers and actions. In cases such as this, placeholders will be used until replaced by specific language by park managers or applicable documents (e.g., resource stewardship plans or water right orders) in the future. Currently, the listed management objective as "no significant change" can be considered as an interim trigger/threshold (Table 1). In some instances, management triggers provided by Park managers are not definable without further data. At Pine Gulch Creek, PORE park managers have indicated a management goal to maintain spring and summer flow adequate to support salmonid outmigration and rearing habitat (Table 1). However, additional fisheries data (outside of this monitoring program) would be needed to define the instream flow need to protect fish habitat (e.g., 2 cfs) and the period of applicability (e.g., dry years?).

Knowledge of streamflow is essential to managing and protecting threatened and endangered park aquatic resources. In 1995, in response to unpermitted expansion of the Kent Reservoir, the State Water Resources Control Board, under Decision 95-17 mandated instream flow requirements measured at the USGS Lagunitas Creek at Samuel P Taylor State Park streamgage (SWRCB 1995). Required summer flows maintain habitat for rearing juvenile salmonids as well as endangered California freshwater shrimp, while winter releases are intended to provide winter baseflow adequate to allow salmonids to enter the stream through the spawning season. On Redwood Creek in GOGA, the NPS has used streamflow monitoring to determine reaches of stream that go dry due to water supply pumping. Based on the monitoring information, the NPS was able to negotiate adjustments to operations to protect intermittent summer habitat for juvenile coho salmon and steelhead. GOGA is currently working with the community services district to investigate withdrawal activities that would minimize impacts to instream flows. Continued annual monitoring is necessary to ensure protection of these resources.

Knowledge of streamflow also helps the Parks provide for public enjoyment. Although our freshwater streams are too small for boating enthusiasts, one of our urban streams is heavily used by children and their families in their self-exploration and discovery adventures (Figure 5). Past water diversion rates from Lobos Creek, for example, resulted in a dry stream channel as it crosses a heavily visited beach. As a result, a streamgage was installed by the Presidio Trust on Lobos Creek in 2001. The intent of this streamgage was to provide on-demand streamflow data to the water treatment plant operators so that they can adjust water withdrawal operations to maintain a minimum flow in the creek (0.77 cfs) and allow the creek to remain connected to the Pacific Ocean.

Streamflow data are also critical for providing design criteria for creek restoration projects. Many of the Park streams in urban settings have been severely altered requiring enhancement actions to allow more natural functioning. For example, the channel along Franklin Creek (JOMU) has been substantially altered and interest has been expressed by park staff to allow for more natural functioning of the channel while protecting the culturally significant orchard.

Streamflow data are also critical for evaluation of water quality objectives, particularly those identified as impaired. Many of these same watersheds are listed as water quality limited by sediment, nutrients, and pathogens under Clean Water Act Section 303(d). Streamflow data can help determine loading of 303(d)-listed contaminants into Park waterbodies. Data would assist Park managers and regulatory agencies understand contaminant dynamics and help manage for protection and enhancement of water quality and aquatic habitat.

Knowledge of streamflow characteristics is important for individual parks, the SFAN network, and regional organizations. Streamflow data such as bankfull discharge and bankfull channel characteristics form the foundation for many creek restoration plans for parks. In areas where reliable streamflow records are not available, regional regression equations can be used to provide an alternate means of estimating discharge events at desired frequency intervals. In addition, streamflow data are critical for helping parks comply with Executive Orders (Floodplain Protection) and NPS guidance documents (DO 77-1). Streamflow characteristics often shape aquatic communities and its importance as a dataset is reflected in the many linkages to other SFAN Vital Signs (See Sec. 1.9). Finally, individual parks have been contacted by county public works and flood control districts for streamflow data to aid in their planning and assessments.

Knowledge of local streamflow responses to global climate change may be critical to understanding biological change. Recent interpretation of long-term meteorological and hydrologic datasets have shown runoff trends in the U.S. are consistent with previously documented precipitation trends with increases in low to moderate streamflow during the summer and fall (Lins and Slack 2005). Other studies have tried to bridge the gap between the documentation of hydrologic and associated biological changes. For instance, Cayan et al. (2001) found that changes in the timing of streamflow patterns were associated with changes in the first blooming of certain plants. Individual parks within the SFAN have either completed or are in the process of updating general management plans (GMP). For many of the parks, the GMPs are providing guidance on how to assess, respond to, and interpret the impacts of global climate

change on park resources (GOGA 2008). Good streamflow and linked biological data would help provide Park resource personnel with information that can help guide resource decisions.

Table 1. Streams, management triggers, and potential management.

Park	Stream	Potential Management Objective/Trigger	Management Action
PORE/GOGA	Lagunitas Cr. at Samuel P Taylor	Range of minimum instream flows depending upon season and water year type (SWRCB 1995)	Compliance reporting required of water district by SWRCB.
PORE/GOGA	Lagunitas Creek at Point Reyes Station	2 cfs	Ensure at least 2 cfs to meet Senior appropriative water right for Giacomini.
PORE	Olema Cr.	No significant change	TBD
PORE	Pine Gulch	Assure spring and summer flow adequate to support salmonid outmigration and rearing habitat	Work with riparian/appropriative water users on Pine Gulch to modify pumping schedule
JOMU	Franklin Cr.	No significant change	TBD
GOGA	Easkoot Cr.	No significant change	TBD
GOGA	Redwood Cr.	SWRCB Permit 21085 (SWRCB 2001): streamflows that cause disconnection of pools	Pool disconnections resulting in enforced water conservation measures (MBCSD 2005). Long-term cooperation in modifying pumping regime and increasing water storage.
PRES	Lobos Cr.	Maintain flow 0.77 cfs	TBD
PINN	Chalone Cr.	No significant change	TBD
PINN	Sandy Cr.	No significant change	TBD
PINN	Bear Cr.	No significant change	TBD

1.6 History of Streamflow Monitoring in the Region

1.6.1 Past and Ongoing Monitoring in the Network

The streamflow monitoring efforts described below illustrate NPS streamflow monitoring programs conducted prior to initiation of the network's monitoring program. Streamflow monitoring efforts conducted by other interests (e.g., USGS) are described in the succeeding section.

1.6.1.1 Point Reyes National Seashore and Golden Gate National Recreation Area: Streamflow monitoring has been conducted by PORE and GOGA since 1997. The original streamflow monitoring program was intended to provide supplemental information to assess hydrologic influences on salmon. Thus, streams originally selected for monitoring were those that had significant salmonid resources. Stations were established on Pine Gulch Creek (PORE), Olema Creek (PORE), and Redwood Creek (GOGA). In 1999, a streamflow monitoring program was established on Easkoot Creek (GOGA) as part of an effort to determine critical low flow conditions for salmonids.

On Lagunitas Creek, two USGS maintained streamgages are operated within the Legislative boundaries of GOGA. Each of these gage stations are served by the USGS on the National Water Information System Real-Time Network. Provisional data for each station is available and updated hourly. Gage 11460600 (Lagunitas Creek at Point Reyes Station) has a record beginning in October 1974, while gage 11460400 (Lagunitas Creek at Samuel P Taylor) has been operating since December 1982.

1.6.1.2 Presidio: One of our earliest accounts of measured streamflow comes from Lobos Creek. Flow measurements in the mid- to late 1800s indicate that streamflows were approximately 3.4 cfs (Schanz et al. 1995). More recently, continuously recorded streamflow data was collected starting in Water Year 1999. Contractors for NPS installed a streamgage in October 1998 which ran for two years before being replaced by a system that had fewer maintenance requirements. A streamgage was installed by the Presidio Trust on Lobos Creek in 2001 to ensure that water treatment plant operators are able to maintain a minimum flow in the creek (0.77 cfs) and allow the creek to be connected to the Pacific Ocean.

1.6.1.3 John Muir National Historic Site: In 2003, a streamflow monitoring station was established on Franklin Creek in order to better understand hydrologic conditions along this creek (Coopridier 2004). The data were intended to help support future management decisions associated with potential creek restoration and to provide data to support two other vital sign indicators (salmonids and freshwater quality). From 1964 to 1982, USGS had a streamgage on Arroyo del Hambre (also known as Alhambra Creek), located about 2 miles downstream from Franklin Creek.

1.6.1.4 Pinnacles National Monument: The streamflow data available for this park relate to their water infrastructure. Historic data are available regarding water surface elevations within the Bear Gulch reservoir and various well logs (Chad Moore, former PINN physical scientist, pers. comm. 2006). Data collected by W.B. Reed in 1965 (Oak Tree Spring) and 1979 (Oak Tree Spring, Willow Spring, and Moses Spring) characterize the major spring resources within the park. Limited historical streamflow data are available for larger streams in the Park. From 1997-2002, event-based and routine streamflow sampling occurred at more than 15 sites (C. Moore pers. comm., 2006). Routine streamflow measurements were taken on Chalone Creek and Bear every two weeks when water was present (C. Moore, pers. comm., 2006). Currently, streamflow data are collected incidentally with water quality parameters at fixed stations with the network's water quality monitoring program.

1.6.2 Other Regional Monitoring Programs

The US Geological Survey (USGS), among other endeavors, conducts hydrologic monitoring on many streams and rivers across the country, including a number of streamgages in the vicinity of SFAN parks. Moreover, NPS streamgages can, to a large extent, 'fill in the gaps' of hydrologic monitoring within the USGS streamgage network. Because of the high quality of data, nearby USGS streamgages may be used to provide hydrologic data when none are available for the Park, or to assist in establishing a regional relationship to allow for fixing data gaps at Park stations. All of the USGS stations listed here have streamgages. Two of the USGS stations on Lagunitas Creek are located within the boundaries of SFAN parks and one of the two is partly funded by

NPS monies. These stations are summarized in Table 2. The station locations are illustrated in Figures 7 and 8. Additionally, there are also streamflow monitoring programs that have been established by other organizations along streams draining NPS lands. In GOGA, the Stinson Beach County Water District established streamflow monitoring stations in 2004 along streams where surface diversions are occurring (Stetson Engineers Inc. pers. comm., 2005). These watersheds include Stinson Gulch and Easkoot Creek.

Table 2. Historic and current non-NPS streamgages adjacent or within San Francisco Area Network streams.

Station Name	Agency	Site_no	Latitude (decimal)	Longitude (decimal)	Elev. (ft)	Datum	HUC	Contrib. Drainage Area (sq. mi)	Begin_date	End_date
Lagunitas Cr at Samuel P Taylor Sp	USGS	11460400	38.026867	122.736377	102.89	NGVD29	18050005	34.3	12/21/1982	Present
Lagunitas Cr nr Point Reyes Station	USGS	11460600	38.080200	122.784435	13.31	NGVD29	18050005	81.7	10/1/1974	Present
Alamo Cr at Dublin	USGS	11174500	37.701319	121.919125			18050004	38.7	10/1/1914	9/30/1920
Alamo Cr nr Pleasanton	USGS	11174600	37.686042	121.916069			18050004	40.8	8/30/1979	9/30/1983
Arroyo Del Hambre at Martinez	USGS	11182400	38.003333	122.128889	48.33	NGVD29	18050001	15.1	10/1/1964	9/30/1982
Corte Madera Cr at Ross	USGS	11460000	37.962424	122.556644	7.97	NGVD29	18050002	18.1	4/1/1951	9/30/1993
Arroyo Corte Madera D Pres at Mill Valley	USGS	11460100	37.897148	122.536087	1.85	NGVD29	18050002	4.69	10/1/1965	9/30/1986
Morses Cr at Bolinas	USGS	11460160	37.919092	122.670261	3.85	NGVD29	18050005	0.7	6/1/1967	9/30/1969
Pine Cr at Bolinas	USGS	11460170	37.918537	122.693040	6.19	NGVD29	18050005	7.83	6/1/1967	9/30/1970
Arroyo Nicasio nr Point Reyes Station	USGS	11460500	38.072144	122.759434			18050005	36.6	10/1/1953	9/30/1960
Walker Cr nr Marshall	USGS	11460750	38.175753	122.818325			18050005	31.1	10/1/1983	Present
Walker Cr Nr Tomales	USGS	11460800	38.209641	122.860827	56.74	NGVD29	18050005	40.1	7/1/1959	9/30/1984
Unnamed Trib 1.0000 To Upper Abbotts Lagoon, Point Reyes NS	USGS		38.127145	122.936386	20	NGVD29	18050005		2/6/1999	2/22/2001
Webb Creek ¹	SBCWD									
Black Rock Creek ¹	SBCWD									
Fitzhenry Creek ¹	SBCWD									
Stinson Gulch ¹	SBCWD									
Redwood Creek ²	MBCSD		37.873279	122.583494			18050005	6.66	11/1/2009	Present

Key: USGS (U.S. Geological Survey), SBCWD (Stinson Beach County Water District)

¹Streamgages by the SBCWD are intended for monitoring low-flow and not winter-spring high-flow conditions.²Muir Beach Community services District's (MBCSD) continuously recording streamgage for monitoring stage.

USGS Stream Gaging Stations

National Park Service
U.S. Department of the Interior
SFAN Park Units



Figure 7. Locations of existing USGS stations near NPS units in the San Francisco Bay Area Network.

USGS Stream Gaging Stations

National Park Service
U.S. Department of the Interior
Pinnacles National Monument

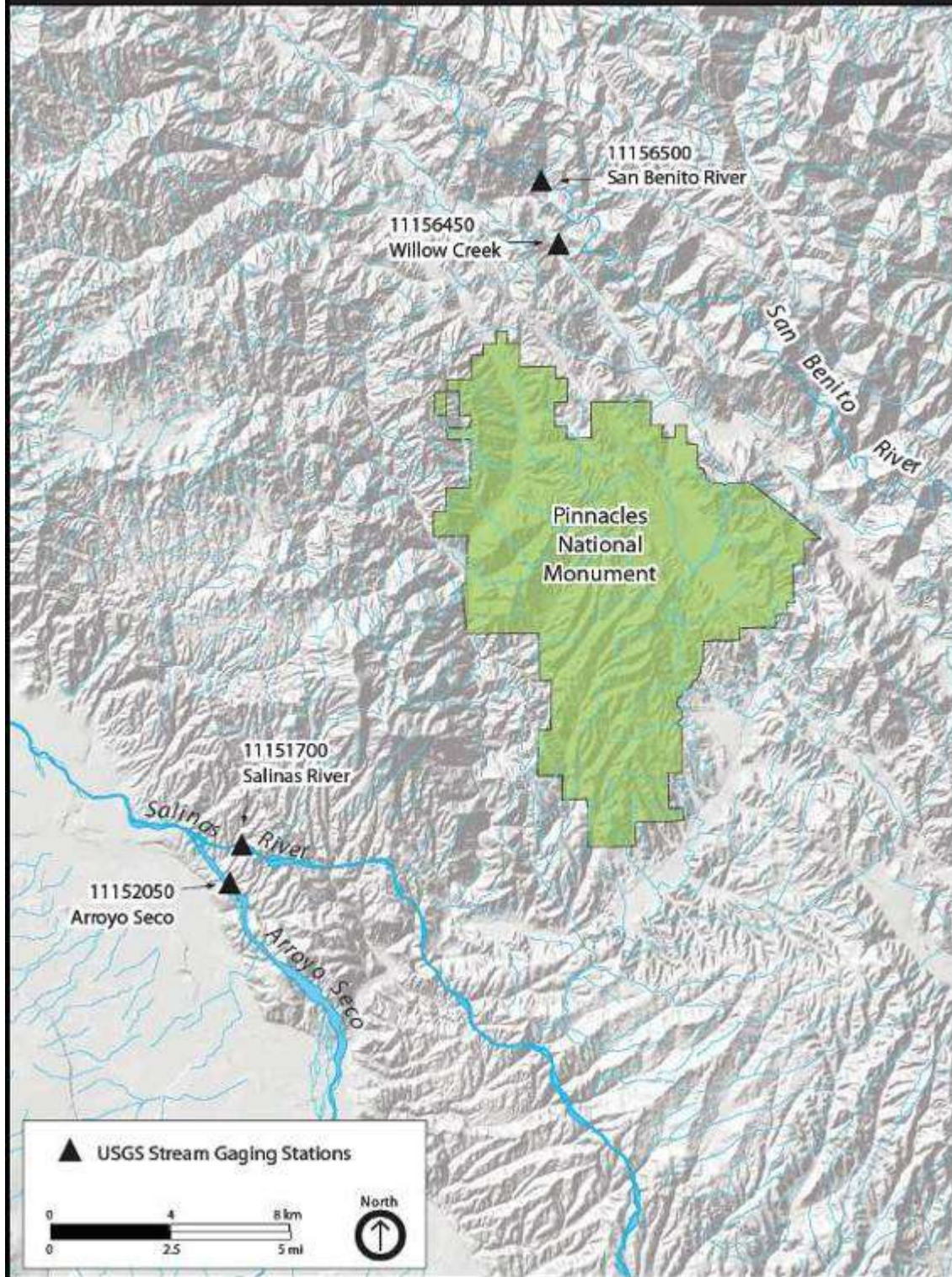


Figure 8. Locations of existing USGS stations near Pinnacles NM.

1.7 Monitoring Questions

Accurate hydrological data are useful for a variety of conservation management questions. The monitoring effort in this program is designed to help answer the following keystone questions.

1. What is the variability in streamflow?
2. What is the flood frequency distribution at various park streams?
3. What is the flow duration distribution at various park streams?

The following questions, categorized as future research, may be answered in part by this monitoring protocol but additional information will need to be gathered:

- Do summer base flows in Redwood, Pine Gulch and Olema Creek support rearing salmonid habitat?
- Is spring and summer base flows affected by water diversion in the Redwood, Pine Gulch and Olema Creek watersheds?
- What is winter baseflow and how does it affect overwintering salmonid habitat?
- How do water quality parameters respond to changes in flow conditions?
- If observed changes in streamflow are outside the natural range of variation, what are the potential causative factors (e.g., increase in drainage density)?
- How has development in or near parks (e.g. roads and trails) changed streamflow dynamics?
- How do parkland streams respond to local weather patterns?
- How is climate change affecting streamflow patterns in SFAN parks?
- Are existing hydrologic conditions conducive to aquatic ecosystem sustainability?
- How has vegetative community change influenced streamflow dynamics both in terms of watershed runoff characteristics and potential summer-fall baseflow in introduced species dominated riparian areas?

Depending on the scale, answers too many of these questions may come from outside of the network, particularly for issues that are regional or global in nature. For instance, assessment of climate effects on streamflow dynamics may be best answered through collaborative efforts with local universities or outside agencies (e.g., USGS, Western Regional Climate Center). A growing effort in the United States is occurring to link plant and animal life cycle events and how they are influenced by seasonal and interannual variations in climate. A USA National Phenology Network (USA-NPN) is currently being designed and organized to engage federal agencies, environmental networks and field stations, educational institutions, and mass participation by citizen scientists. The USA-NPN is currently focused on engaging the public in monitoring the occurrence of key flowering plants (e.g., Project Budburst). There may be contributions that this monitoring program can undertake to help understand the local effects of climate change on SFAN streams. Finally, a basic hydrologic dataset such as the one we are proposing may serve to inspire and support future research questions that rely on basic streamflow data.

1.7.1 Conceptual Framework

Many of the monitoring questions are general and the conceptual framework is intended to help explain the rationale behind the questions and to describe the measurement parameters. To help determine how to answer the monitoring questions, we used a literature review to decide on

appropriate measurement parameters. There has been much evaluation regarding the types of hydrologic data proven useful for ecological assessments. The five recognized and ecologically important components of the flow regime include:

- Magnitude of flow for any given time interval or state (e.g., maxima and minima);
- Frequency of flow above a given magnitude;
- Duration of a specific flow;
- Timing or predictability of a given magnitude of flow; and
- Flashiness or rate of change in flows (Clausen and Biggs 2000; Poff et al. 1997; Richter et al. 1996, 1997).

1.7.2 Discussions of Specific Monitoring Questions

17.2.1 Monitoring Question 1. What is the variability in streamflow?

NPS Management Policies (NPS 2006) emphasizes “that natural resources will be managed to preserve fundamental physical and biological processes.” As previously noted in Section 1.5 the full range of natural intra- and inter-annual variation of hydrologic regimes, and associated characteristics of magnitude, timing, duration, frequency, and rate of change, are critical in sustaining the full native biodiversity and integrity of aquatic ecosystems (Richter et al. 1997). It is important to identify the range of variability to determine whether management measures are needed to protect native aquatic ecosystem biodiversity and integrity. Unfortunately, almost all of the SFAN watersheds (due to their past and current human uses) have had landscape level alterations that have likely affected hydrology. These include roads and trails, urban development, historic logging, grazing, and altered fire regimes. Therefore, it would be difficult to establish a streamflow monitoring program for our network that would look at the natural variability in annual streamflow. In addition, there is no historic gaging data prior to the occurrence of these landscape level alterations. What we can do is to describe the current variability in streamflow statistics that are of biological interest to the parks and use that data to better understand the linkages between hydrology and biological condition.

We selected various hydrologic summary statistics to describe characteristics of streamflow and surface water level; generally, those that would be of biological and geomorphic interest are selected (e.g., 7-day-annual minimum flow, annual instantaneous peak flow) (Table 3). Many of the selected metrics have been identified by The Nature Conservancy as useful for detecting anthropogenic effects on streamflow and aquatic life (Richter et al. 1996, 1998). Currently, physical scientists from USGS Western Ecological Research Center and Western Geographic Science Center are working with the SFAN and Klamath I&M networks to identify linkages and trends in climate, streamflow, vegetation, salmon, and ocean conditions. The output from this multi-year study will help refine the hydrologic statistics that are predictive of salmon abundance in our streams.

Dry season streamflows are often a factor limiting the production of listed salmonids. For one SFAN streamgage site, the variability in dry season streamflow would be determined. The dry season hydrograph of Olema Creek is relatively unimpaired due to the absence of water withdrawals. Information from other SFAN streamgage sites in Marin County (Lagunitas, Pine Gulch, Easkoot, and Redwood Creeks) can be compared with Olema Creek to determine the nature of dry season impacts from water withdrawals actions. Information regarding the natural diurnal fluctuations in stage height at Olema Creek during the summer of a drought year was used to identify water level fluctuations associated with well pumping in Redwood Creek.

It is critically important to have a sufficiently long dataset so that cyclic climatic conditions associated with El Nino / Southern Oscillation (ENSO) can be included. The years with ENSO are associated with wetter than normal conditions from October through March with SFAN parks. Prior to 1976, the frequency of such occurrences was once every 3–7 years (WRCC 1998). Since 1976, the interval has decreased to 2.2 years (WRCC 1998). Suggested data collection periods for determining natural variability include 20–30 years or more (Richter et al. 1997; Huh et al. 2005)

17.2.2 Monitoring Question 2. What is the flood frequency distribution at various park streams?

Flood frequency distribution has been identified as a key hydrologic data need. The frequency of floods for gaged sites is determined by analyzing the annual time series of maximum flow values (typically the largest for the year). These calculations are useful in a variety of ways including describing variability in streamflow, developing parameters for restoration design, interpreting observed biological changes, and assessing susceptibility of Park infrastructure near streams to flooding. For sites lacking sufficient gaging records, indirect estimation of flood frequency characteristics can be done, often based on regional regression relationships for undeveloped watersheds. Details of both direct and indirect methods of data analyses are provided in SOP 7 Data Analysis and Reporting.

17.2.3 Monitoring Question 3. What is the flow duration distribution at various park streams?

Flow duration is expressed as a percentage of time a given streamflow was equaled or exceeded over a given period. Discharge is often normalized per drainage area unit (e.g., cubic feet per second per square mile) (Dunne and Leopold 1978). It is a summary of historic flow information that provides hydrologists with a basic understanding of a stream. Data are often useful for stream restoration planning. For example, the relative amount of time that flows past a site are likely to equal or exceed a specified value is extremely useful for the design of structures in a stream. If fishery biologists want a log structure to be inundated at least 40% of the time, design engineer and hydrologists can use the flow duration data to appropriately locate the designed log structure in a channel. Also, the shape and slope of the flow duration curves can provide information about whether a drainage basin is dominated by stable groundwater flow or a flashy rain-driven system.

1.8 Monitoring Objectives

The overall purpose of long-term monitoring of freshwater flow dynamics is to establish a long-term, well-documented and systematic discharge record for selected streams for use in basic hydrologic/geomorphic characterization, evaluation of potential hydrologic impacts, and calculation of hydrologic/hydraulic parameters for use in design and planning. With the exception of PINN, the focus will be on perennial reaches of freshwater (non-tidally influenced) streams.

The specific monitoring objectives are to:

1. Monitor the variability and long-term trends in streamflow using fixed, continuous, water stage recording stations by producing annual mean daily and monthly discharge estimates for core streamgages in GOGA, PRES, PINN, and PORE.
2. Monitor the frequency, magnitude and duration of peak flow events at core streamgages in GOGA, PORE and PINN and produce peak and daily summaries of stage height and discharge .

3. Monitor the timing, frequency, magnitude and duration of unnatural or extreme low water/low flow events in stream reaches known to support threatened and endangered aquatic species in the dry season in GOGA, PORE, and PINN watersheds.

Not all streamgages are expected to meet all specific monitoring objectives individually; however, the network's overall monitoring program has been designed to meet the objectives collectively. The assessment of trends is only possible through the long-term commitment to a standardized monitoring program. The monitoring objectives will be fully met under flow regimes that can be measured with a high level of confidence (e.g., those that are above one cubic feet per second and less than twice the highest measured discharge). For conditions outside this range, the quality of discharge data would be poor.

These monitoring objectives assist with answering the monitoring questions. The objectives can also be expressed as summary statistics such as annual instantaneous peak streamflow (Table 3). These summary statistics have been identified either by Richter et al. (1996) as biologically relevant hydrologic attributes sensitive to hydrologic alterations or by Lins and Slack (1999, 2005) as useful for documenting hydrologic responses to climatic changes. These summary statistics are listed in Table 3 and descriptions of how they would be analyzed to determine trends over time are provided in SOP 7 (Data Analysis and Reporting).

Table 3. Hydrologic summary statistics.

Hydrologic Parameter	Regime Characteristic
Annual instantaneous peak streamflow	Magnitude
Mean daily, annual maximum (100th percentile)	Magnitude
Mean daily, 90th percentile	Magnitude
Mean daily, 70th percentile	Magnitude
Mean daily, 50th percentile	Magnitude
Mean daily, 30th percentile	Magnitude
Mean daily, 10th percentile	Magnitude
Mean daily, annual minimum (0th percentile)	Magnitude
Mean daily, each calendar month	Magnitude
Annual 7-day minimum streamflow	Magnitude/Duration
Annual 30-day minimum streamflow	Magnitude/Duration
Annual 90-day minimum streamflow	Magnitude/Duration
Annual 7-day maximum streamflow	Magnitude/Duration
Annual 30-day maximum streamflow	Magnitude/Duration
Annual 90-day maximum streamflow	Magnitude/Duration
Julian date of mean daily, annual maximum	Timing
Julian date of mean daily, annual minimum	Timing
Number of high pulses within Water Year (>75 th percentile)	Magnitude/Frequency
Julian date of first high pulse	Timing
Julian date of last high pulse	Timing

1.9 SFAN Vital Sign Integration and Linkages

This vital sign monitors natural processes and provides important information for other vital signs (e.g., freshwater fish) and is influenced by other vital signs (e.g., weather). There are linkages with other vital signs including: Freshwater Quality, Salmonid, Amphibians and Reptiles, and Wetland Habitat (Adams et al. 2006). Annual monitoring reports for these vital signs will often include summary streamflow information that will be developed, verified and reported through this program.

Streamflow data are critical for the interpretation of water quality data. Pollutant loading typically is associated with “first-flush” rainfall events. The importance of streamflow data to the water quality vital sign is indicated by the co-location of water quality monitoring stations near existing streamgages. The results of the I&M streamflow monitoring program can be immediately integrated into other priority network indicators, and are also immediately available for park managers to respond to extreme (high and low) stream discharge conditions.

Within the Tomales Bay watershed, rainfall-runoff conditions are important factors affecting pollutant loading and water quality impacts to Clean Water Act 303(d)-listed Tomales Bay and its tributaries, including Lagunitas and Olema Creek. Water quality monitoring parameters include the collection of streamflow at each sampling location. Maintenance of a streamgage may augment the water quality data analysis, allowing park managers to adapt concentration results from water quality samples to loading amounts from each watershed.

Operation of these streamgages offers opportunities for supplemental and complementary work. As an example, streamflow and water quality concentration data collected at watershed streamgages were used by the Regional Water Quality Control Board in the development of the Tomales Bay Pathogen TMDL. From October 2004 to May 2006, through a USGS Water Resources Division grant, the USGS added sediment monitoring at the two core stations in order to assist with planning for the upcoming sediment TMDL.

Streamflow information will be vital for data analyses of biological vital signs. For example, streamflow data will aid the interpretation of California red-legged frog reproductive success (Amphibian Vital Sign Monitoring) at PINN. For coho and steelhead trout (Salmonid Vital Sign Monitoring), streamflow data will be used to understand the relationship of these anadromous species to timing, duration, and extreme streamflow events during all life stages.

Other potential linkages may be developed with the SFAN streamflow monitoring network. Although it was not ranked as a network priority, at PINN, there is a strong linkage with groundwater dynamics, particularly because of the influence of groundwater dynamics on streamflow (Adams et al. 2006). There is interest in groundwater dynamics monitoring at PINN because of extensive groundwater withdrawal activities by adjacent neighbors. These actions may impact riparian communities and freshwater dynamics. The establishment of surface water streamflow monitoring stations will assist management at PINN and other areas with groundwater withdrawals, and will help identify long-term trends in streamflow characteristics (e.g., duration of zero flow). Linked with groundwater withdrawal data, these may point to the need for management actions.

Several academic institutions (e.g., Univ. of California, Berkeley), local flood control districts, regional water quality board, and hydrologic consulting firms have contacted Park units for streamflow data. Their data needs are similar to ours— streamflow data provide the foundation for interpreting collected aquatic resource information and developing management recommendations. To aid in data sharing and to prevent mis-interpretations, we have tried to document our datasets as much as possible

and build redundant metadata into datasets and protocol. As an example, our Microsoft Excel 15-minute discharge records include not just the records themselves, but streamgage information (e.g., type of equipment, drainage area)—in case the monitoring protocol document becomes separated from the data records (See SOP 2 Data Management).

2.0 Sampling Design

To design a monitoring program, the project team evaluated sampling site selection methods, prioritized the most important streams to monitor within SFAN parks, identified appropriate streamgaging sites, and recognized program constraints such as stream access and available budgets. Because of the details involved, we have addressed the selection of gaging sites in SOP 1 (Procedures for Selection and Operation of Streamgages).

2.1 Monitoring Site Selection

There are three options for designing monitoring programs (EPA 2002). These options include:

1. Census (monitoring every water body)
2. Statistical surveys (probability-based)
3. Judgmental or targeted (specific water bodies and locations are targeted based on what is known).

2.1.1 Census

Given limited budgets, monitoring every water body is impractical.

2.1.2 Statistical Survey

This probability-based design uses monitoring stations that are selected in a statistically random manner. Randomization in the site selection process is the way to assure that sites are selected without bias. The random selection of stations ensures that every potential station has the same probability of being selected, so inferences can be made about the population from the sample. This approach is utilized by the EPA Environmental Monitoring and Assessment Program. The drawbacks of a probability-based design include the selection of monitoring sites that may not meet management information needs and the potential selection of remote stations that pose access and maintenance issues.

2.1.3 Judgmental Sampling

This approach selects monitoring locations based on best professional judgment that the sites are representative of the subpopulation of surface waters. The method assumes that the stations selected represent all waters in a particular subpopulation. Monitoring stations from an existing sampling network are periodically reviewed to determine the initial reason and validity for continued site location. The judgmental design allows for selection criteria to be restricted to accessible sites, sites suitable for accurate measurements, and re-occupation of historic gaging sites that were selected because of management needs. The Washington State streamflow monitoring program uses the *judgmental design* (Butkus 2005), a sample survey approach recommended by the EPA (1997). Deficiencies in the judgmental design involve limited inference due to biases associated with selecting sites (e.g., installation of streamgages on undersized bridges).

2.2 Target Population

SFAN has adopted a judgmental design where the full suite of potential streams for monitoring were prioritized based on a set of criteria. The stream prioritization criteria were created during

the development of the SFAN water quality monitoring protocol (Coopridier and Carson 2006). These criteria include:

1. Natural resource based needs (e.g., endangered species habitat, instream flow requirements);
2. Presence and proximity to facilities that may threaten or be threatened by streamflows;
3. Ease of access and safe sampling conditions, particularly during high flow events;
4. Linkage to other NPS vital signs monitoring program;
5. Amount of stream under NPS management; and
6. Presence of any long-term streamflow monitoring by other regional monitoring programs.

The suite of streams includes perennial and intermittent streams within the SFAN (Table 4 and Appendix B). Streams rated the 'Highest' included streams that provide breeding and rearing habitat for one or more federally listed fish and wildlife species, are threatened by water appropriation activities, require monitoring or assessment data for restoration activities, have non-native aquatic species that could be dispersed by high flows, or have infrastructure that are affected by streamflow conditions. Streams rated 'Highest' also have a major portion of their length under NPS management and are associated with other vital sign monitoring efforts. From this list, we removed ephemeral drainages and those located in steep or difficult to access terrain. We then considered those streams that have long-term datasets, unique hydrographic setting, and where individual Park units can offer financial or personnel assistance (outside the network I&M program).

Table 4. Evaluation of streamgages in the San Francisco Bay Area Network

Station Name (Park)	Station type	Period of Record	Natural Resource Data Value	Pre-existing Station	Ease of Access	Recording Datalogger	Crest Gage
USGS Lagunitas at Point Reyes Station (GOGA/PORE)*	Core	1974–Present	High	Yes: USGS Operation	Good, bridge	USGS	Yes
USGS Lagunitas at Samuel P Taylor (GOGA/PORE)*	Core	1982–Present	High	Yes: USGS Operation	Good, bridge	USGS	Yes
Olema Cr (PORE)	Core	1998–Present	High	Yes	Good, bridge	In-Situ	Yes
Redwood Cr (GOGA)	Core	1997–Present	High	Yes	Good, bridge	In-Situ	Yes
Lobos Creek (PRES/GOGA)	Core	2001–Present	High	Yes: PRES Operation	Good, culvert	Proprietary	Proposed
Bear Creek (PINN)	Core	2008–Present	High	No	Good, bridge	Global Water	Proposed
Pine Gulch (PORE)	Secondary	1998–Present	High	Yes	Good, bridge	Global Water	Yes
Franklin Cr (JOMU)	Secondary	2003–2008	High	Yes	Good, culvert	Global Water	Yes
Easkoot Cr (GOGA)	Secondary	1999–Present	High	Yes	Good, bridge	Campbell	Yes
Sandy Creek (PINN)	Secondary	Proposed	High	No	Good, culvert	Global Water	Proposed
Chalone Creek (PINN)	Secondary	Under consideration	High	No	Good, culvert	Not proposed	Proposed

*Operated by USGS. All other stations operated by NPS.

Long-term datasets are considered important for trend detection and hence we favored continuation of existing sites rather than establishment of new ones. Easkoot and Franklin Creeks have existing NPS streamgages but only a portion of these creeks are under NPS management. However, both streams scored high for resource data value and have other vital signs monitoring activities at the sites. Lobos Creek is currently being monitored by the Presidio Trust without cost to the I&M program. However, their data are not being summarized by the Presidio Trust and only mean daily discharge data are being stored. Streamflow data from Lobos Creek exist from the late 1800's—the longest such hydrologic dataset within our network. As a unique spring-fed stream, it has discharge characteristics different from all other streams in the network and one of the highest summer baseflows for its size.

Some of the “Highest” rated streams were not selected at this time for a variety of reasons. Both Bear Valley and Cheda Creeks in PORE may merit future consideration for monitoring. Both creeks are within the Tomales Bay Watershed and represent streamflow characteristics for smaller, coastal watersheds. At GOGA, three streams (Gerbode, Rodeo, and Tennessee Creeks) are not considered for monitoring despite their high scores. These streams drain small, coastal watersheds and have summer–fall baseflows that are not accurately measured using standard

meters. Discharge measurements would require measurement by flumes and it would not be practical given the installation cost and personnel expense.

2.3 Program Constraints

The sampling design for this monitoring protocol has been tempered by pragmatic considerations. The US Geological Survey is the Nation's premier authority on streamflow monitoring and assessment. If costs were of no concern, the network would provide funding to USGS for the operation of all streamgages to provide the needed information. However, at \$22,000 or more per USGS managed station per year, the cost is prohibitive. Given limited funding (approximately \$15,000 annually, see section 6 below), we chose six core stations from the list of highly rated stations (Table 4) for monitoring and reporting a full suite of hydrologic parameters to address previously stated monitoring objectives. Data would be collected and managed at four stations: Olema Creek (PORE), Redwood Creek (GOGA), Lobos Creek (PRES), and Bear Creek (PINN). Two core stations (Lagunitas Creek) are currently being operated by USGS (and partly funded by the sponsoring park) and already report the desired suite of hydrologic parameters. These core stations represented the highest priority streams for each Park expressed by their representatives at a November 4–6, 2008 protocol review meeting with NPS-WRD. Secondary stations were selected from the high priority streams (Table 5) which were of interest to individual Parks, but for which only minimal data would be obtained with no annual reporting by SFAN.

2.3.1 Core Stations

The six core stations include: Redwood Creek (GOGA), Olema Creek (PORE), Lobos Creek (PRES), Bear Creek (PINN), and two USGS-operated stations on Lagunitas Creek, including Station 11460600 – Lagunitas Creek at Point Reyes Station (PORE/GOGA) and 11460400 – Lagunitas Creek at Samuel P. Taylor State Park (PORE/GOGA).

Olema Creek streamflow data was deemed critical by PORE due to its value for interpreting water quality and salmonid data. Of the GOGA streams, Redwood Creek streamflow was most important due to its linkages to water quality and salmonid monitoring data, as well as its value for Park issues such as water rights and creek restoration planning. For PINN, logistical and data quality considerations were important. Bear Creek was the easiest to access, being located adjacent to the Park administrative area. Its stable channel represented the best site for gaging and flow measurements. Lobos Creek, managed jointly by PRES and GOGA, was identified as a core station due to the value of the data for determining instream flows for aquatic life below the diversion as well as its uniqueness as a spring-fed system and distinction as the largest remaining free-flowing stream in San Francisco.

At present, the USGS operates two stations on Lagunitas Creek with nearly a thirty year record. The MMWD is mandated to maintain the streamgage at Lagunitas Creek at Samuel P. Taylor State Park to ensure flows are met as defined under State Water Resource Control Board Decision 95-17. The USGS Lagunitas Creek at Point Reyes Station maintains the longest record in the area, and is operated with 1/3 share paid by Point Reyes National Seashore, 1/3 by MMWD, and 1/3 by North Marin Water District (NMWD).

Table 5. Locations of core and secondary streamgages in the San Francisco Bay Area Network.

Station Name (Park)	Station type	Longitude (deg-min-sec)	Latitude (deg-min-sec)
USGS Lagunitas at Point Reyes Station (GOGA/PORE)*	Core	122°47'00"W	38°04'49"N
USGS Lagunitas at Samuel P Taylor (GOGA/PORE)*	Core	122°44'07"W	38°01'37"N
Olema Cr (PORE)	Core	122°47'23"W	38°2' 30"N
Redwood Cr (GOGA)	Core	122°34'42.607"W	37°51'58.028"N
Lobos Creek (PRES/GOGA)	Core	122°29'1.9"W	37°47'16.8"N
Bear Creek (PINN)	Core	121°10'46.69"W	36°28'55.75"N
Pine Gulch (PORE)	Secondary	122°41'30.6744"W	37°55'11.114"N
Franklin Cr (JOMU)	Secondary	122°7'56"W	37°59'32"N
Easkoot Cr (GOGA)	Secondary	122°38'29"W	37°53'53.9"N
Sandy Creek (PINN)	Secondary	121°08'47.83"W	36°29'32.34"N
Chalone Creek (PINN)	Secondary	121°10'10.26"W	36°29'13.31"N

*Operated by USGS. All other stations operated by NPS.

2.3.2 Secondary Stations

Secondary stations include: Easkoot Creek (GOGA), Pine Gulch Creek (PORE), Franklin Creek (JOMU), Chalone Creek (PINN), and Sandy Creek (PINN). These gaged streams are of interest to their respective parks and annual reporting may be conducted by those respective parks.

Additional information on these streamgages including detailed station descriptions and maps are provided in SOP 3 Streamgage Station Descriptions.

2.4 Representativeness (and Level of Inference)

This term refers to the degree “to which data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition” (ANSI/ASQC 1995). The streams chosen by this monitoring program will not accurately reflect the streamflow dynamics of the true population of SFAN network streams. Our program deliberately avoids sampling of non-perennial waters (except for PINN streams) that constitute the majority of stream types within the network. The network’s streamflow monitoring program will provide long-term gage data that can be applied to ungaged reaches of the same or similar streams in the region. Details regarding the characteristics of the drainage areas above the gaged sites (both proposed and existing) can be found in SOP 3 Streamgage Station Descriptions. Local hydrologic consulting firms and researchers at local universities have frequently contacted the Parks in this network for streamgage data for this purpose.

2.5 Selection of Sampling Parameters and Frequency

The parameters collected at core and secondary sampling sites are summarized in Table 6.

Table 6. Sampling parameters, sampling frequency and derived output of core (*) and secondary (**) streamgages. The key for the measured data is available at the end of this table. (

Station (Park)	Applicable Monitoring Objectives (Resp. Party)	Measured Data (Frequency)							Derived Output				Equipment
		Indiv. Discharge measurements	Crest gage height	Observed stage	Recorded stage	Photo data	Water temp	Rainfall	Topographic Data	Mean daily discharge	Peak events	Low flow events	
Lagunitas at Point Reyes Station (GOGA/PORE)*	1,2,3 (USGS)	D	D	D	D	D	D	D	D	D	D	D	- Water stage recorder - Staff and crest gages
Lagunitas at Samuel P Taylor (GOGA/PORE)*	1,2,3 (USGS)	D	D	D	D	D	D	D	D	D	D	D	- Water stage recorder - Staff and crest gages
Olema Cr (PORE)*	1,2,3 (SFAN)	√ MS	√ MS	√ MS	√ F	√ MS	√ F	D	√ A	√	√	√	- Staff and crest gages, - Discharge measurement equipment (Swoffer, Gurley, Marsh-McBirney) - Equipment suspension (rod or cable) - CR10x datalogger, Druck PDCR 1830 transducer, thermistor, solar panel - Digital camera - Survey Equip (Rod, level, tape)

Table 6. Sampling parameters, sampling frequency and derived output of core (*) and secondary (**) streamgages. The key for the measured data is available at the end of this table. (continued).

Station (Park)	Applicable Monitoring Objectives (Resp. Party)	Measured Data (Frequency)							Derived Output				Equipment
		Indiv. Discharge measurements	Crest gage height	Observed stage	Recorded stage	Photo data	Water temp	Rainfall	Topographic Data	Mean daily discharge	Peak events	Low flow events	
Redwood Cr (GOGA)*	1,2,3 (SFAN)	✓ MS	✓ MS	✓ MS	✓ F	✓ MS	✓ F	✓ C	✓ A	✓	✓	✓	• Staff and crest gages, • Discharge measurement equipment (Swoffer, Gurley, Marsh-McBirney, Parshall flume) • Equipment suspension (rod or cable) • In-Situ Level Troll 500, Onset RG-2 tipping bucket • Digital camera • Survey Equip (Rod, level, tape)
Lobos Creek (PRES/GOGA)*	1 (SFAN)	✓ I	✓	✓	D	✓	D	D	✓	✓			• Staff gage, • Discharge measurement equipment (H-Flume, SIGMA 950 75 kHz Ultrasonic Flow Meter) • Equipment suspension (rod) • Wireless transmitter, desktop computer used as datalogger,
Bear Creek (PINN)*	1,2,3 (SFAN)	✓ MS	✓ MS	✓ MS	✓ F	✓ MS		D	✓ A	✓	✓	✓	• Staff and crest gage, • Discharge measurement equipment (Marsh-McBirney, volumetric) • Digital camera • Global Water WL15/16

Table 6. Sampling parameters, sampling frequency and derived output of core (*) and secondary (**) streamgages. The key for the measured data is available at the end of this table. (continued).

Station (Park)	Applicable Monitoring Objectives (Resp. Party)	Measured Data (Frequency)							Derived Output				Equipment
		Indiv. Discharge measurements	Crest gage height	Observed stage	Recorded stage	Photo data	Water temp	Rainfall	Topographic Data	Mean daily discharge	Peak events	Low flow events	
Pine Gulch (PORE)**	1,2,3 (Park responsible)	I	I	I	√	I	√	√	I	P	P	P	- datalogger and transducer - Survey Equip (Rod, level, tape) - Staff and crest gages, - Discharge measurement equipment (Swoffer, Gurley, Marsh-McBirney, Parshall flume) - Equipment suspension (rod or cable) - Global Water WL15 datalogger. Onset RG-2 tipping bucket - Digital camera - Survey Equip (Rod, level, tape)
Franklin Cr (JOMU)**	1,2,3 (Park responsible)	I	I	I	√	I			I	P	P	P	- Staff and crest gages, - Discharge measurement equipment (Swoffer, Gurley, Marsh-McBirney, Parshall flume) - Equipment suspension (rod or cable) - Global Water WL15/16 datalogger and transducer - Digital camera - Survey Equip (Rod, level,

Table 6. Sampling parameters, sampling frequency and derived output of core (*) and secondary (**) streamgages. The key for the measured data is available at the end of this table. (continued).

Station (Park)	Applicable Monitoring Objectives (Resp. Party)	Measured Data (Frequency)							Derived Output				Equipment
		Indiv. Discharge measurements	Crest gage height	Observed stage	Recorded stage	Photo data	Water temp	Rainfall	Topographic Data	Mean daily discharge	Peak events	Low flow events	
Easkoot Creek (GOGA)**	1,2,3 (Park responsible)	I	I	I	√	I			I	P	P	P	tape) • Staff and crest gages, • Discharge measurement equipment (Swoffer, Gurley, Marsh-McBirney, Parshall flume) • Equipment suspension (rod or cable) • CR10x datalogger, Druck PDCR 1830 transducer, solar panel • Digital camera • Survey Equip (Rod, level, tape)
Sandy Creek (PINN)**	1,2,3 (Park responsible)	I	I	I	√	I		D	I	P	P	P	• Staff and crest gages, • Discharge measurement equipment (Marsh-McBirney, volumetric) • Equipment suspension (rod or cable) • Global Water WL15/16 datalogger and transducer • Digital camera • Survey Equip (Rod, level, tape)
Chalone Creek (PINN)*	1,2,3			I		I		D				P	• Staff and crest gages,

Table 6. Sampling parameters, sampling frequency and derived output of core (*) and secondary (**) streamgages. The key for the measured data is available at the end of this table. (continued).

Station (Park)	Applicable Monitoring Objectives (Resp. Party)	Measured Data (Frequency)							Derived Output			Equipment
		Indiv. Discharge measurements	Crest gage height	Observed stage	Recorded stage	Photo data	Water temp	Rainfall	Topographic Data	Mean daily discharge	Peak events	
	(Park responsible)											- Digital camera - Survey Equip (Rod, level, tape)

Key: I = Infrequent, D = Data available elsewhere, P = Individual parks responsible for output if desired, √ = Collected by SFAN, M = monthly, MS = monthly plus storm events, F = data collected at 15-minute interval and downloaded monthly, C = continuous data downloaded monthly, A = annual or as conditions warrant.

2.5.1 Core Stations

The monitoring objectives dictate how the sampling parameters will be measured at each station including the frequency of collection. The intent is to collect data that would describe peak and extreme low flow events as well as long-term daily means. The primary sampling parameters at core stations include water surface levels or stage height at the streamgages and individual measurements of stream discharge (cubic feet per second [cfs]). Computed data would be stream discharge at recording streamgages based upon stage-discharge relationships. Collected supplementary parameters include level data, water temperature, and rainfall.

Stage height will be recorded in four ways: staff gage, crest gage, observed high water marks, and recording datalogger. All streamgages will include staff and crest gages. Observers will read staff and crest gages to describe existing and peak water surface elevations, respectively. Reliable high water marks based on features defined by Benson and Dalrymple (1967) will be recorded by observers in the streamgage reach. At sites where continuous water surface level and discharge data are desired, electronic dataloggers and transducers will be installed and maintained. Electronic dataloggers and pressure transducers will collect stage height at 15-minute intervals consistent with other streamflow monitoring programs. Use of consistent equipment enables program staff to consult a variety of technical experts (including NPS WRD staff) when technical problems inevitably occur. Pressure transducers have been identified as a relatively easy and inexpensive way for collecting water surface level data given the conditions of our streams. At stations where continuous streamflow data are desired, field personnel will collect individual discharge measurements to construct stage-discharge relationships.

Data will be collected year-round. However, sampling activities to collect discharge measurements and stage height will focus on winter storm events and flows, which are strong determinants of stream habitat conditions. Consequently, sampling frequency during the winter is event-driven rather than on a regular interval. Because of the absence of storms, sampling during the dry season (June–September) can be conducted on a regular interval. Dry season station visits and discharge measurements will occur at least once a month to update and/or validate the discharge rating curve (see SOPs, below).

A variety of supplementary parameters will be collected to aid in interpreting the stage and discharge record. For sites distant from weather stations, rainfall data will be collected by this program using tipping buckets. Rainfall data provides a quality assurance check of the derived stream discharge record. Level data provide information to determine whether there are temporal changes to the elevation and location of gaging equipment and key locations along the creek. Information regarding bed elevation at the cross-section of streamgages is needed during and following large storm events to determine if the stage-discharge rating curve has shifted. Digital photographs will be used to document changes to the stream and equipment that may affect the stage-discharge relationship. Water temperature is collected, not as a parameter that would aid in this protocol's monitoring objectives, but as a parameter for the SFAN Salmonid and the Water Quality Monitoring Protocols. Water temperature thermistors are often bundled with datalogger and transducers systems for streamgages.

The I&M program will not alter operations of the two USGS core stations. For these two stations, all data collection, quality assurance and reporting will be continued through the USGS programs. These programs are peer-reviewed, robust, and scientifically credible.

2.5.2 Secondary Stations

Sampling activities at secondary stations identified in Table 5 will be at a reduced frequency. The data will be provided to the individual parks and any post-collection processing will be their responsibility. Dataloggers will be maintained to collect stage data at 15 minute intervals as in core stations. Individual site visits to download data and collect discharge data will occur every 1–2 months. There will be no attempt to collect peak discharge measurements during the winter and spring. Any data collected during these visits would be provided to individual parks (e.g., staff and crest gage readings).

2.6 Sampling Units

Height and discharge measurements will be recorded and reported in English units. Water surface height from crest and staff gages will be recorded to the nearest 0.01 ft. Stream width and depth for discharge measurements will be recorded to 0.1 and 0.01 ft, respectively. Velocity measurements will be recorded to 0.01 ft per second. Secondary data such as topographic information will be collected and reported in English units to the nearest 0.01 ft. Temperature and rainfall will be collected and reported to the nearest 0.1° C and 0.01 inch, respectively. The recording interval for streamgage dataloggers will be 15 minutes.

2.7 Accuracy and Detection Limits

Accuracy is defined as the overall agreement of a measurement to a known value; it includes a combination of random error (precision) and systematic error (bias). For many parameters, true bias will be difficult to estimate (e.g., true discharge). The accuracy of surface water discharge records depends on the cumulative accuracy of discharge measurement, rating definition, and the completeness and accuracy of the gage-height record (USGS 1992). Estimated accuracies of discharge records for individual days commonly are about 5 to 10 percent (USGS 1992). Precision estimates for individual discharge measurements seldom are better than 2 percent (Sauer and Meyer 1992). The quality control and assurance procedures associated with these issues are described in greater detail in SOP 9 Quality Assurance Project Plan.

2.7.1 Minimum Detectable Differences

A minimum detectable difference represents the statement of how big of a change or difference monitoring needs to be able to detect (Irwin 2008). Desired minimum detectable differences for individual discharge measurements have been identified by USGS and nominal precision of surface water measurements for data analyses is described by Sauer (2002). Manufacturers of field equipment provide product specifications about their equipment's ability to register a change in measurement. However, manufacturer's reported limits may not reflect minimum detectable differences in field situations. Further information on minimum detectable differences is described in greater detail in SOP 9 Quality Assurance Project Plan.

2.8 Co-location of Sample Sites

Monk et al. (2007) argue that understanding the influence of flow variability on stream ecology is hampered by the absence of high-quality, long-term paired datasets of both hydrological and ecological datasets. To address this issue, we made a conscious effort to evaluate and select potential streamgage locations at sites where they will provide linkages to other vital sign datasets (e.g., Amphibian and Salmonid). In addition, co-location of sample sites helps reduce operational costs. The field personnel used for conducting streamflow monitoring activities is

also responsible for water quality sampling. Co-locating streamflow with water quality sampling stations greatly reduces travel costs.

3.0 Field Methods

The collection of stage and streamflow data at core streamgages is a primary component of field activities associated with this monitoring protocol. At each core streamgage, field staff will be responsible for making monthly visits to download data, record existing conditions, and troubleshoot inoperable dataloggers. All staff must be familiar with the streamgage equipment at the sites prior to heading to the field. Information on the type of equipment used at each station is provided in SOP 3 and specific instructions for using that equipment provided in SOP 1. As an overview, a workflow diagram of a typical site visit is included in Figure 9. In addition, streamflow measurements would also be made by field staff during these monthly visits. As an overview, a workflow diagram of a typical discharge measurement is provided in Figure 10. For most of the year, streamflow measurements would be conducted using wading equipment (e.g., pygmy meter and wading rod). During the wet season, additional streamflow measurements would be conducted to encompass the range of peak streamflows that could occur at the site. Under some high flow conditions, safety issues will require discharge measurements from bridge structures. Level surveys would be scheduled as needed to determine the stability of streamgage equipment relative to a datum and to determine corroborate whether any shifts may have occurred to stage-discharge relationship.

It is important for all personnel involved with this monitoring protocol to be informed of the surface water data collection policies and procedures established by the USGS. They are the nation's lead agency on collection of stream data and their procedures are the benchmark standard. Our program's field procedures for establishing and maintaining streamgages and obtaining individual streamflow measurements are provided in the SOPs annotated below.

3.1 Standard Operating Procedures

The field procedures for installation, operation and troubleshooting of these stations are provided in a series of Standard Operating Procedures (SOPs). These procedures are described in SOPs rather than in the main protocol narrative because many of the SOPs are “living” documents that may be updated frequently. The intent of these SOPs is to provide detailed field guidance that may be updated periodically as new innovative procedures that collect high-quality data become standard. Much of the content of the following SOPs is derived from USGS technical reports involving collection of streamflow data.

3.1.1 Procedures for Selection and Operation of Streamgages (SOP 1)

This SOP describes the selection of recording streamgages, measurement of stage using staff plates, crest gage, and electronic transducers. It details field downloading procedures. Maintenance and equipment calibration information is provided.

3.1.2 Data Management (SOP 2)

This SOP describes all details of routine data management for the SFAN streamflow monitoring program. The SOP describes how the SFAN streamflow monitoring protocol meets data management objectives through data entry specifications, database design, quality assurance and control measures, metadata development, data maintenance, data storage and archiving, and data distribution.

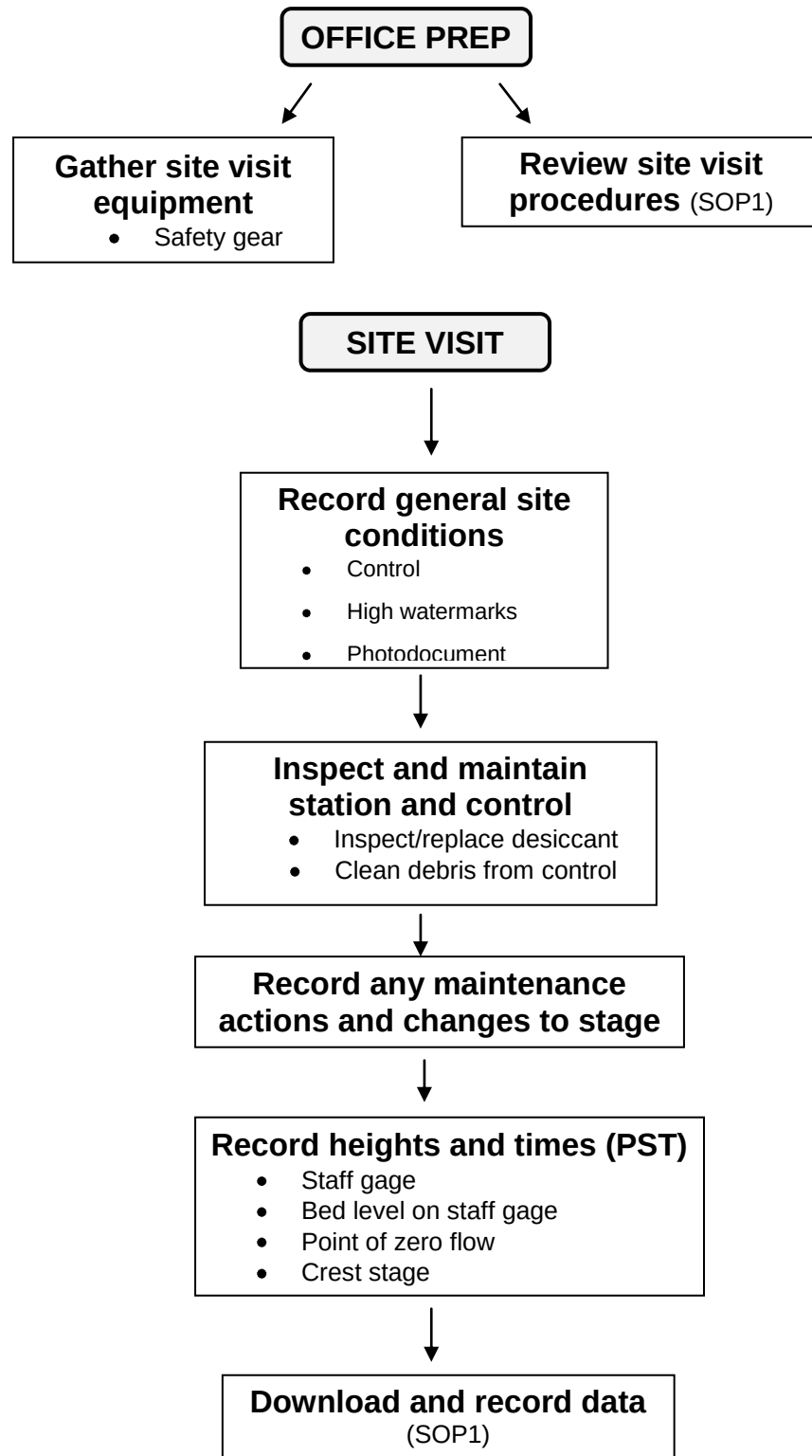


Figure 9. A generalized workflow chart of streamgage site visit procedures, SFAN streamflow monitoring program.

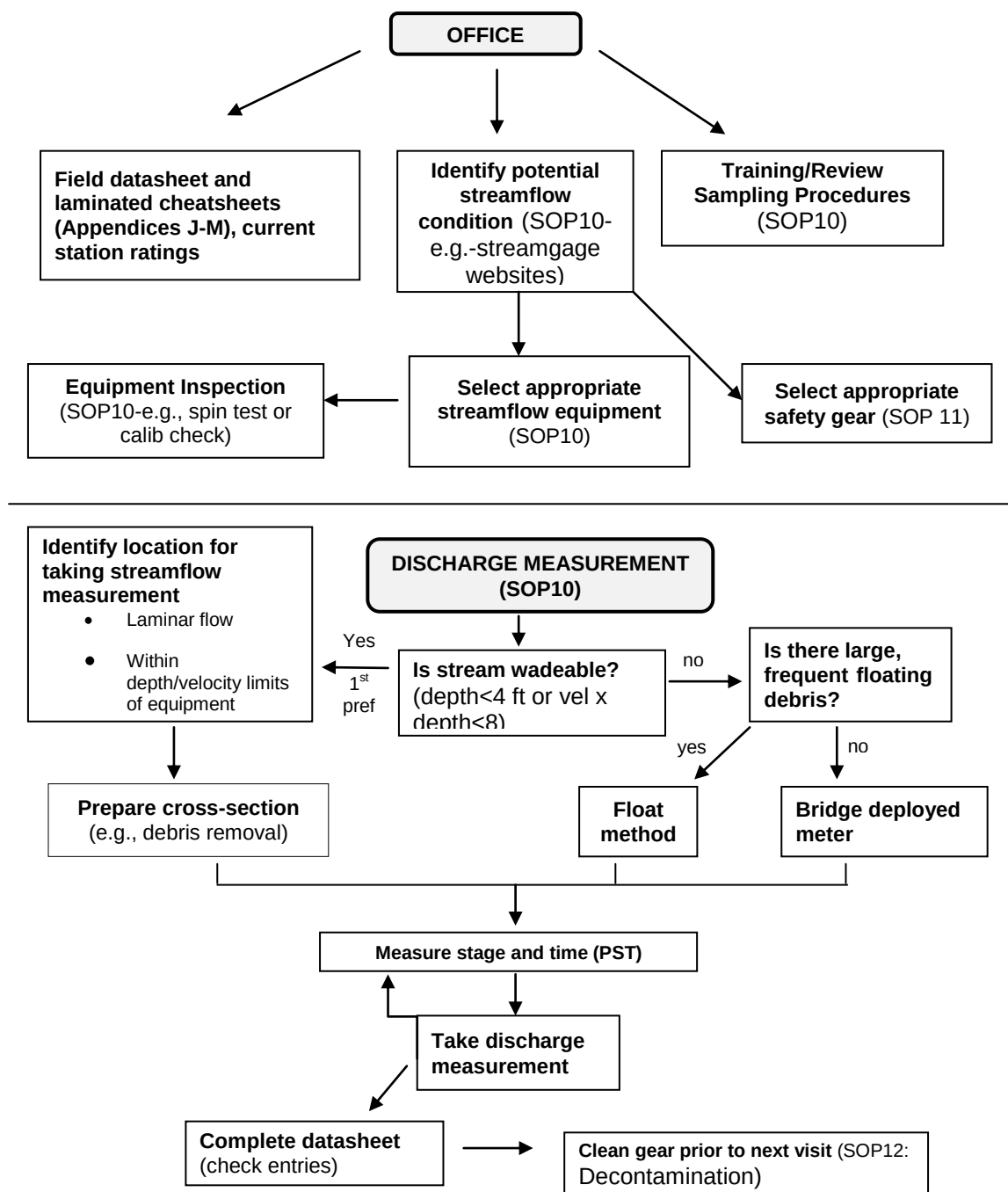


Figure 10. A generalized workflow chart of discharge measurement procedures, SFAN streamflow monitoring program.

3.1.3 Streamgage Station Descriptions (SOP 3)

This SOP provides a description of each established streamgage including supplementary watershed data that will aid the interpretation of the discharge record developed by this program. Much of the contents of the *Station Descriptions* include the fields required for *Station*

Descriptions by the USGS. Typical information includes location descriptions, access information, and photographs of the streamgage for each sampling site.

3.1.4 Field Equipment for Flow Measurements and Station Maintenance (SOP 4).

This SOP summarizes routine equipment as well as task-specific equipment (e.g., topographic surveys) needed during field visits.

3.1.5 Training and Resources (SOP 5).

This SOP lists information resources and training material for new staff associated with key components of this monitoring program including topographic surveys, stream discharge measurements, data management, and streamgage operations.

3.1.6 Procedures for Tipping Bucket Rain Gage Stations (SOP 6)

This SOP provides information on the installation and maintenance of tipping bucket rain gages associated with our streamgages.

3.1.7 Data Analysis and Reporting (SOP 7)

This SOP provides detailed information on data processing including the calculation of individual discharge measurements using various measurement techniques, formatting of recording streamgage records, creation of stage-discharge relationships, and simple tabular summaries of data for reports.

3.1.8 Revising the Protocol (SOP 8)

Each SOP includes a record of revisions. This SOP provides guidelines and a detailed administrative record for tracking revisions. Peer review comments will also be addressed and tracked through this SOP.

3.1.9 Quality Assurance Project Plan (SOP 9)

This SOP provides guidance for field and office procedures to ensure high data standards are met associated with streamflow monitoring. The template for this QAPP follows procedures established for USGS quality-assurance plans.

3.1.10 Field Methods for Streamflow Measurements (SOP 10)

This SOP was taken and modified from the Water Quality Monitoring Protocol (Coopridge and Carson 2006). The SOP provides information for streamflow measurements. It includes information on the various field parameters collected during streamflow measurements, procedures for collecting measurements under low and high flow conditions (e.g., wading or bridge).

3.1.11 Safety Procedures (SOP 11)

This SOP was developed to address field and office safety considerations unique to this protocol.

3.1.12 Decontamination (SOP 12)

This SOP was developed to guide decontamination procedures during and after field activities to minimize spread of contaminants such as the chytrid fungi.

3.1.13 Miscellaneous SOPs

Aside from these program-specific SOPs, all field personnel involved with this monitoring protocol should also be familiar with the following Network SOPs:

SOP Personnel Training and Safety (See also Freshwater Quality SOP 2)
SOP Vehicle Accident Report Form

These SOPs are archived on the network drive: X:\Shared\Standard Operating Procedures.

3.2 Data Forms

Field data for this protocol will be stored on standardized datasheets (see SOPs 1 and 10). The datasheets are based on the USGS 'Discharge Measurement Notes' Form 9-275-F. They were modified to include field data from water quality sampling activities as well as download information from dataloggers. All discharge datasheets will be stored chronologically in binders by station. All field books and binders are located at the SFAN I&M Office, Building 1063, Fort Cronkhite, Sausalito CA 94965. Instructions on filling out field notebooks and discharge datasheets are provided in SOPs 1 and 10).

3.3 Instrument/Equipment Inspection, Maintenance, Calibration and Frequency

It is important to ensure continual quality performance of all equipment and instruments. All mechanical and electronic equipment requires routine inspection to determine if it is working properly. The SOPs that involve field measurements also include sections for inspection and maintenance of standard field equipment. Details of equipment calibration are provided in SOPs 1 and 10. Details identifying the magnitude of measurement errors and acceptable limits are provided in SOP 9.

3.4 Permit Requirements

Parks do not currently require NPS permits for network research. If parks change this policy, permit requests will be submitted to the parks via the Research Permit and Reporting System (RPRS) available online: <https://science1.nature.nps.gov/research/ac/ResearchIndex>. For streamgage installations that are located within the right-of-ways or owned property of state, county, or private entities, site specific permission will likely be required. In such instances, any written agreements or permits should be kept.

Many of the streamgages, including Redwood Creek and Olema Creek are located on state or county bridge facilities. In order to install and maintain these stations, the SFAN staff is responsible for applying for and maintaining encroachment permits for each of the stations on public facilities. If stations are established on private bridge structures, the NPS should establish an MOU for access and operations at that location.

4.0 Data Handling, Analysis and Reporting

4.1 Data Management

A standardized, systematic approach to data management is an essential part of any monitoring program. The objectives of data management are to ensure that data are stored and transferred accurately, secured from loss or damage, and made available to decision makers in a timely and understandable manner (Peterson et al. 1995). In order for this program to meet these objectives, a detailed management plan is needed to ensure data quality, interpretability, security, longevity and availability. The data management plan is provided in SOP 2 Data Management.

The SFAN staff has developed a relational Microsoft (MS) Access XP database for the program's field streamflow measurements (see SOP 2). The data are organized around sampling events at the streamflow stations, which are described and geographically defined in a locations table. Besides actual event, streamflow, and stream condition data, the database is used to maintain records of data history, field personnel, photo points, and streamflow meter metadata. Streamflow measurements taken in the field are recorded on the "Discharge and Water Quality Measurement Form" (see SOP 2). Individual discharge measurements will be entered into the database by the field technician who collected the measurements as soon as possible from the field. This should reduce transcription errors associated with having different personnel enter field collected data. The database then computes the discharge (Q) and standard error associated with the measurement and these values are recorded on the measurement form. All streamflow measurements are validated at a later date by an alternate individual. The measurement form is initialed when the data has been entered and validated.

Edits to the records in the database are extremely important to keep track of. The streamflow database employs a data history table that links to the survey data in which the user may date and justify any edits made. Because data edits may alter final discharge calculations, the data history table provides an important means for users to track and explain differences in data summaries and data outputs from the database over time.

The data management plan describes the computer programs used to store and process data for analyses and summary reports. Raw data files from recording streamgages will be archived in their native text formats (tab or comma delimited). Microsoft ExcelTM spreadsheets will be used to store formatted instantaneous data and processed data for each automated streamgage and water year (1 Oct. – 30 Sept.). The streamflow database, as described above, will be used to store field discharge measurements, calculate discharge estimates, and estimate potential error of individual measurements (Sauer and Meyer 1992). A new commercial rating curve program (Aquatic Informatics Inc. 2009) has been purchased based on recommendations by WRD to develop stage-discharge rating relationships. Microsoft Excel was used to process and store stage-discharge data prior to Water Year 2008. A standardized filing tree has been established for storage of electronic data. The data management plan (SOP 2) also includes a description of all data variables. Finally, the data management plan details procedures for data entry, verification and validation to ensure that high data quality is maintained.

4.2 Quality Assurance Procedures

The ultimate success of a monitoring program depends on the quality of the data collected and used in decision-making. Quality assurance is the application of procedures that reduce bias and improve precision, accuracy, comparability, completeness, and sensitivity. The quality assurance procedure begins with study design, and is in place throughout data collection, analysis, integration, and storage (NPS 1992). Quality control is the application of specific procedures in sampling and analysis to ensure that precision and accuracy of results are built into the monitoring effort. Precision is the degree to which repeated measurements of a quantity vary from one measurement to another when no true change has occurred. Accuracy is the degree to which measurements differ from a true value (Peterson et al. 1995). Three factors influence the precision and accuracy of the measurements: (1) the precision and accuracy of the measuring tools and instruments, (2) the abilities of the individuals using the tools, and (3) the care and attention with which the measurements are made under the variable conditions of day-to-day operations (see also below). Common problems encountered in long-term monitoring programs have been with data quality, consistency and comparability, and availability and accessibility (Shampine 1993). A quality assurance/quality control effort can effectively address these problems.

The NPS (1992) defines six procedures that are routinely applied:

- Use of consistent collection and analytical methods over time unless scientific and/or technological advances allow for improvements, so long as later data are still comparable with earlier data
- Use of equivalent monitoring equipment among different sites
- Use of consistent formats in field and laboratory data reporting and structure of files
- Use of procedures that maximize the capacity to integrate data sets with a minimum of manual data re-entry (GIS technologies)
- Maximum use of automated data handling techniques that ensure quick access to recently acquired data and ease of access to all data
- Use of existing and proven data collection protocols

The justification for change in any specific steps employed in gathering data are driven principally by changes in precision and accuracy objectives (NPS 1992) and by scientific and technological advances (R. Klein, pers. comm. 2006). New methods are not to be employed merely for convenience or on the suspicion that they may improve data precision and accuracy. Instead, new methods are to be adopted when it has been determined that there is a need and/or opportunity for data with better precision and accuracy. At that point, change should be brought about by smooth transition between the “old” and “new” procedures in a manner that provides for continuity and comparability (NPS1992).

A primary criterion in ensuring high data quality is consistent use of proven procedures, a process best ensured by hiring and retaining qualified and committed personnel (NPS1992). Seasoned, committed personnel can detect situations that appear to deviate from the norm through familiarity with the indicators they are observing and an understanding of analytical

procedures. Moreover, their observations or suspicions are often the keys in detecting the need for better procedures, or perhaps even in taking a new conceptual approach in data acquisition or research.

Specific to this monitoring protocol, our monitoring objectives (see above) rely on field data that are processed to provide relevant information such as mean daily discharge. As might be expected, we would like to ensure that the network and other users of the data have confidence in the accuracy of the data and when there are periodic lapses in good data quality, that the monitoring program is able to document the departures and identify causation. Therefore, the purpose of our specified quality assurance activities is *to reduce measurement errors to agreed-upon limits and to produce results of acceptable and known quality*.

Quality assurance is not only an important consideration in the collection of data but also in the transfer of data into the streamflow database. Review and verification of data entries in the streamflow database is required. Upon completion of the initial data entry, the field technician should check all of his/her entered records in the database. In addition, data are reviewed and error-checked by someone other than who entered the data prior to finalizing data for each water year. Furthermore, the project manager should verify discharge measurement data entries by field technicians. For new field technicians, 100 percent of discharge data entries will be verified for the first month. Thereafter, the project manager will verify a random selection of 10% of the data entered. If greater than a 5% error rate is detected, then 100% of the discharge data records will be reviewed.

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 procedures that check the data as they are entered is built into the streamflow database and will be modified, as needed, to improve error checking abilities. These automatic validations are programming elements that “censor” the data based on known ranges. Examples of common errors are missed decimal places or numerical data placed in the wrong field (e.g., for date and times out of normal limits).

To aid in this process, we have used USGS’s 1995 “A Workbook for Preparing Surface Water Quality Assurance Plans for Districts of the U.S. Geological Survey, Water Resources Division” as a template for describing procedures that ensure high quality in the collection, processing, analysis, computer storage, and publication of surface-water data. Details of these procedures are provided in SOP 9 (Quality Assurance Plan).

4.3 Data Analyses

Routine data analyses will be conducted for each Water Year (WY) and streamgage. All of the desired data (e.g., mean daily discharge, flood recurrence interval) require substantial data processing. The computation of streamflow records involves the adjustment of recorded data, determination of stage-discharge relationships, and documentation of analyses for all streamgages. A generalized workflow chart for acquiring 15-minute data leading to the computation of instantaneous discharge for annual summaries is provided in Figure 10. A more prescriptive workflow or checklist of actions (including QA/QC procedures) for getting data ready for and completing annual summaries is provided in Table SOP 7.1 (SFAN Water Year Discharge Computation Checklist). The basis of these data analyses is provided in Rantz et al.

(1982), Kennedy (1983), Meyer (1996), and USGS (2006). The specific procedures, particularly associated with the equipment and computer software in use by this monitoring program, are provided in SOP 7 Data Analysis and Reporting.

4.4 Routine Data Summaries and Reporting

There are four types of reporting that will be provided by this monitoring program:

- Annual summary reports
- Long-term monitoring reports
- Updated station descriptions
- Electronic databases

The proposed type and contents of annual reporting come from USGS's streamflow monitoring program (Rantz et al. 1982; USGS 2006). Data will be reported in English units and using USGS's guidelines for standard significant figures for surface water data (Rantz et al. 1982, Sauer 2002). Electronic versions of all final reports will be made available through postings on the SFAN website (<http://science.nature.nps.gov/im/units/sfan/index.cfm>). Hard-copies will be made for each individual park participating in this monitoring program. Electronic data will be provided upon request. Formats of all reports will follow the Natural Resource Publications Management template (<http://www.nature.nps.gov/publications/nrpm/finalreport.cfm>).

4.4.1 Annual Summary Report

On an annual basis, a summary report for all recording streamgages will be prepared for the past Water Year. The annual summary report is responsive to Monitoring questions 2 and 3. The components of the annual summary report will include standardized summary information and format similar to USGS reporting (USGS 2006):

- Daily values table for the water year including short header with gage station information
- Hydrograph of daily mean discharge and precipitation values
- Rating curves
- Station analysis
- Photographs

However, the standard USGS reporting assumes reader familiarity with field sampling methods. In order to make our reporting more compatible with the I&M reporting format, the summary report will also include a brief description of individual streamgages (abbreviated station description (see Figure SOP 2.20) and a summary of field methods. Much of this information is expected to be similar each year and is included to ensure that annual summary reports are stand-alone data summaries. The report provides information on personnel involved with the monitoring program and their roles and responsibilities. It also provides a description of major hydrologic events that may have affected all streamgages in the region during the Water Year. Some of this information, particularly descriptions of major rainfall and flooding events, are detailed by the National Weather Service and are included in the appendices for completeness. The main section of the report will also describe program-specific QA/QC measures that were

conducted during the Water Year. These may include major repairs to field equipment and individual meter ratings.

The discharge daily values table will include the following key data (example provided in Table 7):

- Annual and monthly yield (acre-feet): The monthly yield will be calculated and reported by converting the total monthly discharge (cfs) to unit volume (acre-ft) using appropriate time and volume conversion factors. Annual yield for the water year will be the summation of all months.
- Mean daily discharge (cfs): Guidelines provided by Rantz et al. (1982) will be used to determine significant figures. For mean daily discharges less than 1 cfs, values will be reported to the nearest hundredth, to the nearest tenth from 1.0 to 10 cfs, to the nearest unit from 10 to 999 cfs, and to three significant figures above 1,000 cfs. Mean daily discharge is computed and reported as the average of all the instantaneous, 15-minute discharges for the day (Rantz et al. 1982).
- Total, mean, max, min monthly discharge (cfs): These values are summaries of daily discharge. Total monthly discharge is the sum of daily values (Rantz et al. 1982). Mean monthly discharge will be calculated as a grand mean (mean of each mean daily discharge). Max and minimum monthly discharges represent maximum and minimum daily values for the month.
- Minimum, peak, and mean annual discharge (cfs): Mean annual discharge will be calculated as a grand mean (mean of each mean monthly discharge). Instantaneous peak and minimum annual discharge will be calculated from all instantaneous, 15-minute discharges for the year. The date and 24-hour local Standard Time of these extreme events will be reported as well.

For streamgages with tipping rain buckets, an additional daily precipitation table will be prepared in a similar format to the discharge daily values table (see Table 8). It will include the following:

- Daily rainfall (inches): Rainfall will be reported to the nearest hundredth of an inch. Rainfall is recorded at 15-minute intervals. Daily rainfall is computed as the total of all 15-minute rainfall amounts for the day.
- Total, mean, max, min, and max-15 minute monthly rainfall (inches): Total monthly rainfall is the sum of daily rainfall for the month. Mean monthly rainfall will be calculated as the mean of each daily rainfall amount. Maximum and minimum monthly rainfall represents the maximum and minimum daily rainfall amounts for the month. The maximum rainfall in a 15-minute period is also summarized on a monthly basis.

For details of the annual reports see SOP 7 (Data Analysis and Reporting).

Table 7. Mean daily discharge (example)

UNITED STATES DEPARTMENT OF THE INTERIOR - NATIONAL PARK SERVICE - WATER RESOURCES DIVISION
 STATION NUMBER 375353122381901 EASKOOT CREEK AT STINSON BEACH, CA
 LATITUDE 375353 LONGITUDE 1223819 DRAINAGE AREA 1.7 sq. mi. DATUM 16.08 ft. msl
 PROVISIONAL DATA SUBJECT TO REVISION
 DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1999 TO SEPTEMBER 2000
 DAILY MEAN VALUES

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	0.01	0.05	0.98	0.02	0.97	7.4	0.57	0.16	0.15	0.15	0.08	0.24
2	0.01	0.04	0.73	0.02	1.0	5.0	0.54	0.15	0.08	0.13	0.08	0.23
3	0.01	0.04	0.61	0.01	1.1	3.4	0.51	0.15	0.09	0.15	0.09	0.21
4	0.01	0.05	0.41	0.01	0.86	3.8	0.5	0.11	0.10	0.17	0.08	0.16
5	0.01	0.05	0.30	0.01	1.1	6.8	0.55	0.09	0.07	0.24	0.08	0.13
6	0.01	0.06	0.23	0.01	1.3	4.9	0.59	0.1	0.13	0.27	0.09	0.17
7	0.01	0.45	0.18	0.01	1.1	3.6	0.59	1.3	0.32	0.27	0.09	0.17
8	0.01	0.28	0.19	0.01	1.0	3.5	0.55	4.2	0.44	0.33	0.11	0.14
9	0.01	0.10	0.54	0.01	0.87	3.4	0.55	2.0	0.24	0.37	0.09	0.12
10	0.01	0.08	0.25	0.01	4.4	3.0	0.54	1.4	0.19	0.38	0.09	0.09
11	0.01	0.06	0.25	1.6	10	2.6	0.49	1.0	0.14	0.41	0.07	0.10
12	0.01	0.05	0.25	0.94	19	2.2	0.59	0.85	0.10	0.33	0.07	0.15
13	0.01	0.05	0.20	0.51	65	2.0	0.7	0.8	0.11	0.31	0.07	0.22
14	0.01	0.06	0.14	0.30	37	1.7	0.87	1.8	0.06	0.40	0.05	0.08
15	0.01	0.05	0.11	0.30	9.7	1.5	0.71	4.1	0.07	0.33	0.03	0.07
16	0.01	0.24	0.18	1.9	4.9	1.3	2.8	3.3	0.12	0.29	0.04	0.12
17	0.01	0.12	0.10	1.1	3.0	1.2	11	2.3	0.18	0.25	0.07	0.17
18	0.01	0.10	0.10	1.7	2.3	1.0	4.1	1.8	0.15	0.19	0.08	0.15
19	0.01	0.60	0.10	2.6	1.9	0.97	2.4	1.4	0.18	0.16	0.08	0.19
20	0.01	0.25	0.10	4.5	2.0	0.95	1.6	1.2	0.19	0.18	0.12	0.21
21	0.01	0.22	0.09	3.5	2.3	0.89	1.2	0.93	0.18	0.12	0.17	0.25
22	0.01	0.16	0.07	3.2	4.6	0.79	0.86	0.83	0.18	0.08	0.19	0.25
23	0.01	0.13	0.05	19	9.7	0.77	0.65	0.70	0.25	0.07	0.16	0.11
24	0.01	0.10	0.05	42	5.5	0.78	0.55	0.64	0.12	0.06	0.14	0.10
25	0.01	0.10	0.05	9.6	3.6	0.69	0.44	0.45	0.14	0.07	0.16	0.12
26	0.01	0.09	0.04	3.9	6.2	0.64	0.37	0.36	0.18	0.05	0.18	0.11
27	0.85	0.07	0.03	2.1	14	0.62	0.3	0.30	0.17	0.06	0.22	0.09
28	0.57	0.05	0.03	1.4	7.9	0.61	0.22	0.29	0.16	0.11	0.15	0.11
29	0.10	0.29	0.03	0.99	9.4	0.59	0.18	0.26	0.20	0.14	0.17	0.18
30	0.07	1.5	0.02	1.0	---	0.57	0.16	0.21	0.17	0.14	0.19	0.21
31	0.05	---	0.02	0.98	---	0.56	---	0.16	---	0.10	0.22	---
TOTAL	1.9	5.49	6.43	103.24	231.7	67.73	35.68	33.34	4.86	6.31	3.51	4.65
MEAN	0.06	0.18	0.21	3.33	7.99	2.18	1.19	1.08	0.16	0.20	0.11	0.16
MAX	0.85	1.5	0.98	42	65	7.4	11	4.2	0.44	0.41	0.22	0.25
MIN	0.01	0.04	0.02	0.01	0.86	0.56	0.16	0.09	0.06	0.05	0.03	0.07
AC-FT	3.8	11	13	205	460	134	71	66	9.6	13	7.0	9.2

SUMMARY STATISTICS**HIGHEST DAILY MEAN****LOWEST DAILY MEAN****ANNUAL SEVEN-DAY MINIMUM****INSTANTANEOUS PEAK FLOW****INSTANTANEOUS PEAK STAGE****INSTANTANEOUS LOW FLOW****WATER YEAR 2000**

65 Feb 13 2000

0.01 Oct 17 2000

0.01 Oct 01 2000

108 Feb 13 2000 1930 hr

2.40 Feb 13 2000 1930 hr

0.01

Table 8. Daily rainfall (example).

UNITED STATES DEPARTMENT OF THE INTERIOR - NATIONAL PARK SERVICE												
GOLDEN GATE NATIONAL RECREATION AREA												
Easkoot Creek Below Entrance Road				Water Year 2006				Daily Rainfall (inches)				
PROVISIONAL DATA SUBJECT TO REVISION												
Day	Oct 05	Nov 05	Dec 05	Jan 06	Feb 06	Mar 06	Apr 06	May 06	Jun 06	Jul 06	Aug 06	Sep 06
1	0	0.01	1.87	0.21	2.16	0.26	0.18	0.00	0.00	0.00	0.00	0.00
2	0	0.02	0.02	0.67	0.56	0.16	0.57	0.00	0.00	0.00	0.01	0.00
3	0	0.1	0	0.16	0.02	0.61	0.35	0.00	0.00	0.00	0.00	0.00
4	0	0.05	0	0	0.42	0.1	0.81	0.00	0.00	0.00	0.00	0.00
5	0	0.01	0	0	0	0.76	0.09	0.00	0.00	0.00	0.00	0.00
6	0	0.24	0.01	0.08	0	0.67	0.00	0.00	0.00	0.00	0.00	0.00
7	0	0.17	0.02	1.10	0	0.22	0.33	0.00	0.00	0.00	0.00	0.00
8	0	0.23	0.01	0	0	0	0.00	0.00	0.00	0.00	0.00	0.02
9	0	0	0	0.01	0	0.25	0.07	0.00	0.00	0.00	0.00	0.00
10	0.01	0.01	0	0.02	0	0.24	0.11	0.00	0.00	0.00	0.01	0.01
11	0	0.15	0	0.59	0	0.12	1.89	0.00	0.00	0.00	0.00	0.01
12	0	0.01	0	0.01	0	0.27	0.85	0.00	0.00	0.00	0.00	0.00
13	0	0.01	0	0.19	0.02	0.30	0.00	0.00	0.00	0.00	0.00	0.00
14	0.14	0	0.01	0.34	0.01	0.90	0.00	0.00	0.01	0.00	0.00	0.00
15	0.03	0	0	0.00	0.00	0.02	0.90	0.00	0.00	0.00	0.00	0.00
16	0	0	0	0.00	0.00	0.78	0.02	0.00	0.00	0.00	0.00	0.00
17	0	0	0.61	0.55	0.33	0.01	0.01	0.00	0.00	0.00	0.00	0.00
18	0.01	0	2.01	0.26	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	0	0	0.06	0.00	0.02	0.00	0.00	0.24	0.00	0.00	0.00	0.00
20	0	0	0.89	0.02	0.00	0.48	0.00	0.00	0.00	0.00	0.00	0.00
21	0	0	0.73	0.78	0.00	0.03	0.00	0.09	0.00	0.00	0.00	0.00
22	0.01	0	1.45	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
23	0	0.01	0.03	0.02	0.10	0.00	0.02	0.01	0.00	0.00	0.00	0.00
24	0.02	0.01	0.03	0	0.00	0.92	0.01	0.02	0.00	0.00	0.00	0.00
25	0.02	0.87	0.83	0.14	0.10	0.32	0.00	0.00	0.00	0.00	0.00	0.00
26	0.29	0	0.14	0.06	0.44	0.01	0.00	0.00	0.00	0.00	0.00	0.00
27	0	0	0.65	0.48	1.01	0.26	0.00	0.00	0.00	0.00	0.00	0.00
28	0.32	0.94	0.54	0.9	0.11	0.19	0.00	0.00	0.00	0.02	0.00	0.00
29	0	1.51	0.03	0.02		0.70	0.01	0.00	0.00	0.09	0.00	0.00
30	0.01	0.17	1.34	0.98		0.02	0.01	0.00	0.00	0.00	0.00	0.00
31	0		1.66	0.02		0.47		0.00		0.00	0.00	
TOTAL	0.86	4.52	12.94	7.61	5.44	9.08	6.23	0.36	0.01	0.11	0.02	0.04
MEAN	0.03	0.15	0.42	0.25	0.19	0.29	0.21	0.01	0.00	0.00	0.00	0.00
MAX DAILY	0.32	1.51	2.01	1.10	2.16	0.92	1.89	0.24	0.01	0.09	0.01	0.02
MIN DAILY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MAX 15-min	0.08	0.12	0.19	0.19	0.11	0.23	0.16	0.02	0.01	0.01	0.01	0.01
WATER YR TOTAL	47.22											

NOTES: Rain gage was only recording 75% of actual rainfall before calibration on 6/01/06 at 1240 (Pacific Standard Time). After calibration rain gage recording 98% of actual rainfall. Data uncorrected.

4.4.2 Long-term Monitoring Report

The value of hydrologic data comes from interpretation of the long-term record. Two of the monitoring questions require collection of a sufficiently long enough dataset:

- What is the variability in streamflow and are there any discernable trends for streamflow and surface water level?
- Are observed changes in streamflow within a natural range of variation?

Our current hydrologic dataset would be insufficient to determine whether observed values fall within the range of expected values. Huh et al. (2005) noted that at least 20 years of record on either side of a one standard deviation shift may be necessary to adequately characterize high-flow variability while 30 years of record may be required to characterize low-flow variability.

By WY2008, many of the streamgages established by GOGA and PORE will have been in operation for about 10 years. The first long-term monitoring report will be prepared by 2018, so that a 20-year dataset would have been available for analysis. Thereafter, a long-term monitoring report will be prepared every 10 years.

The long-term monitoring reports will include similar information as the annual reports with the addition of flow-duration and flood frequency calculations. It would also include summary and trend analysis of the 20 annual hydrologic parameters identified by the Nature Conservancy as important indicators of hydrologic alteration that are listed in Table 3. Trend analysis will be conducted using the non-parametric Mann-Kendall test for each parameter and, and significant trends will be identified when p-values are less than $\alpha = 0.05$. The long-term reports will also include recurrence interval analyses for rainfall events of standard durations (1-hour, 6-hour, and 24-hour). They will also include assessment of trends in streamflow distribution from the annual minimum (daily mean Q_0) to the annual maximum (daily mean $Q_{\max}$). Trend analysis will provide a more complete picture of how the streamflow regime is changing at network streams. These issues tie directly into the monitoring objectives and questions listed in this protocol. Details of the data analysis for the long-term monitoring report are provided in SOP 7 Data Analysis and Reporting.

4.4.3 Station Descriptions and Updates

Station descriptions are standardized metadata about the recording streamgages. A station description describes the location and the characteristics of the streamgages. Our station descriptions are provided in SOP 3 Streamgage Station Descriptions. They include important information such as the watershed setting, location of streamgage, station equipment, and period of record. Station descriptions are reviewed annually and are updated as needed and become a history of the station. As a station description is updated the superseded description is archived in the station files, thus the station description becomes a living document detailing the history of the station. Station descriptions are written to include specific types of information in a consistent format. Examples of the standard format are provided in most USGS streamflow publications (Kennedy 1983, Meyer 1996). Information provided in the station description addresses the following:

- Location
- Directions to station

- Establishment of station
- Elevation
- Drainage area
- Description of the gage
- History of the station
- Reference and benchmarks
- Watershed conditions (NPS added)
- Geology (NPS added)
- Channel description
- Control
- Discharge measurement descriptions
- Point of zero flow
- Winter flow
- Regulations and diversions
- Period of record
- Landowners
- USGS quadrangle (7.5 minute)
- Relevant figures and photographs

Two of the fields (Watershed conditions and Geology) are non-standard USGS information and are included to provide a better understanding of the influences on streamflow dynamics that will be reported on.

Abbreviated versions of the station descriptions will be included for each annual report. This information is also included in the *Recording Gaging Station* spreadsheets (Metadata worksheet, Figure SOP 2.20)

4.4.4 Electronic Databases

Individual parks that have supported streamgages receive frequent requests for processed electronic streamflow data for analyses by universities and consultants. We anticipate that these requests will continue. With the exception of Lobos Creek (PRES), all of the streamgages are in natural channels and their data require significant post-collection processing. The formats of our electronic databases for this protocol have been standardized to allow ease of data interpretation by outside individuals not familiar with our monitoring program. Data interpretation aids include streamgage metadata embedded into *Recording Streamgage Spreadsheets* as well as complete descriptions of data fields in SOP 2. Databases that can be provided to the public include the following:

- *Stream Discharge Measurement Database* (individual discharge measurements for the SFAN monitoring program in a single database)
- *Recording Streamgage Spreadsheet* (separate Microsoft Excel spreadsheet for each streamgage and Water Year that includes all 15-minute data)
- *Stage-Discharge Rating Spreadsheet* (separate Microsoft Excel spreadsheet for each streamgage and Water Year that includes stage-discharge data and rating curves)

4.4.5 Outreach

In addition to annual reports, project staff will update the IM website annually. The website archives annual reports and links to available data. In addition, the project lead updates an executive briefing about the program to summarize recent findings and trends. The executive briefing follows a standard format such as those posted to the current website:

<http://science.nature.nps.gov/im/units/sfan/ResourceBriefings.cfm>

In addition, the NPS I&M Program maintains an on-line natural resource bibliographic database known as NRInfo Reference Application. NRInfo Reference Application records will be created for all of the streamflow monitoring documents, including the protocol, annual reports, and any resulting publications. PDF versions of the documents will also be posted for download in NRInfo. The public version of NRInfo is in development by the NPS I&M program.

Additional outreach may be conducted by presenting results at regional scientific meetings or by hosting presentations in the parks.

4.5 Metadata Procedures

A full description of the metadata procedures for this monitoring protocol is provided in SOP 2 Data Management.

4.6 Data Archival Procedures

Data archiving focuses on long-term storage and access through GOGA's network server at the Marin Headlands with additional offsite storage being achieved through cooperation with the National I&M Data Manager, located in Fort Collins, CO. The IT Branch at Golden Gate NRA, Ft. Mason Bldg. 201, maintains backup copies of the data with an additional digital copy forwarded to Ft. Collins. Full details of data archival procedures are also provided in SOP 2 Data Management.

4.7 Protocol Reviews

Periodic formal reviews will be conducted every 5 years in order to ensure that the protocol is meeting its stated objectives. This protocol review should include an "in-person" visit to discuss technical difficulties and new technologies, observe field procedures, as well as review the appropriateness of streamgage location and equipment. This outside technical review will be conducted by hydrologists running accepted long-term streamflow monitoring programs at other NPS units (e.g., REDW hydrologist) or through technical assistance requests through the NPS Water Resources Division.

The periodic reviews should include the following:

- Periodic formal reviews of field operations, results, and efficacy of quality assurance procedures
- Review of protocol design and product to determine whether changes are needed
- Written assessment of existing monitoring program and recommendations to the SFAN I&M program

Recommendations must be addressed and subsequent changes to the protocol will be documented in the Revision History Log. For example, a protocol review conducted in 2008–2009 by WRD personnel resulted in changes in this protocol.

5.0 Personnel Requirements and Training

5.1 Core Duties

The core duties for implementing this program include the following field measurements and maintenance operations at streamgages:

- Making minor repairs at streamgages
- Conducting measurements of streamflow
- Downloading dataloggers
- Maintaining field equipment in good condition for field work
- Assisting with quality assurance procedures for equipment and data
- Processing, tabulating and annually summarizing data
- Producing annual and long-term monitoring reports
- Responding to data requests

5.2 Staffing Plan

During the development of this monitoring plan, we evaluated its implementation using various staffing models. These models included USGS, a university-based stream monitoring program, long-term contract with hydrologic consulting firms, support from interns, hydrologic specialists, base-funded staff from individual parks, and the SFAN I&M staff.

The USGS model provided an implementation option that is the nationally recognized standard for streamflow data collection and management. Annual streamflow station operation costs for the USGS in FY2009 are \$21,600, while installation costs for a new USGS station are equivalent. The costs for establishing and maintaining four new stations would be cost-prohibitive.

The university-based model was attractive because of the proximity of a nationally recognized hydrology program at U.C. Berkeley, and initial communications with Dr. Matt Kondolf were established. It would have provided practical field experience opportunities for students in the hydrology field while also providing a hydrologic dataset that may be useful for evaluating research questions of interest to the Park and scientific community. These benefits were outweighed by the financial costs, necessity of cementing a long-term agreement, and continuity/data quality issues associated with the expected turnover in student personnel.

Initial discussions were also held with a local consulting hydrologist. The benefits of using a consulting firm included a potentially reduced work-load on existing SFAN and Park-base funded personnel, high operational flexibility (relative to the government), and generally good quality data from established hydrologic firms with low personnel turnover. However, costs for operating hydrologic monitoring stations spread thinly over a wide geographic area were prohibitive. Ballpark estimates of operating four or five stations including field work and preparation of reports was about \$14,000 (Dave Shaw, Balance Hydrologics, pers. comm. 2005).

This estimate did not include equipment costs or any operation of streamgages at PINN due to travel distance.

Within the last few years, we were able to evaluate the costs and benefits of operating a weather and streamflow monitoring program using interns from the Student Conservation Association and national Americorps program. The use of interns provided great educational and career growth opportunities for hired individuals at a relatively low financial cost, but use of short-term interns resulted in data quality challenges and high time costs for park staff overseeing the program.

The use of a full-time hydrologic field technician supervised by the Park hydrologist has been done successfully by Redwood National Park's long-term monitoring program. It offers high data quality in the long-term if that position has low turnover; however, it offers less flexibility should program needs change. A full-time hydrologic technician may be unnecessary for our program's size.

The proposed staffing plan involves both base-funded specialists from individual park units in oversight and review capacities and SFAN I&M staff for data management and field assistance (Table 9). Salaries of base-funded staff will not be reimbursed by the SFAN I&M program. The field crew will consist mainly of the SFAN water quality specialist. This staffing plan provides the opportunity for collecting high quality data at a slightly lower cost than a consulting firm. This option, however, places a higher work-load burden on both SFAN and park base-funded personnel. The details of each functional position are described in greater detail below.

Table 9. Summary of positions and key responsibilities to implement monitoring program.

Position	Key Duties	Approx. no. pay periods per year
Network Water Quality Specialist (PORE; GS-6/7)*	Lead Field Person (Year-round position) For GOGA and PORE sites: • Correctly and accurately making discharge measurements of various types. • Installing, servicing, and repairing streamgage instruments. • Entering data retrieved from streamgage instruments into the SFAN database and spreadsheets • Update station descriptions. • Helping construct gaging facilities. • File and organize paper and digital records in accordance to data management SOP. • Assist with annual summaries	2
Network Water Quality Technician (PORE; GS-5)*	Field and Office Assistant For GOGA and PORE sites: • Correctly and accurately making discharge measurements of various types. • Entering data retrieved from streamgage instruments into the SFAN database and spreadsheets • File and organize paper and digital records in accordance to data management SOP.	<1
Network Ecologist (PINN; GS-9)	Same as for Network Water Quality Specialist (for PINN stations)	
Aquatic Ecologist (GOGA; GS-12)	Technical Program Lead • Oversee data-collection activities • Assure the accuracy of the streamgage records. • Maintaining expertise in all phases of data-collection, compilation, and computation. • Provide training. • Produce annual summaries and long-term trend reports, • Assist in field data collection as needed	2
Network Data Manager (PORE; GS-9 or 11)	• Respond to data summary requests. • Maintain MS Access discharge database • Oversee maintenance and management of digital files and paper records	<1
NPS-WRD Hydrologist(s)	• Provide programmatic review in technical assistance	TBD
SFAN Aquatic Professionals Working Group	• Programmatic review of SFAN streamflow program • Review of draft documents (annual and long-term reports)	
Volunteer-in-Parks	• Field assistance	TBD

*Additional field assistance may be provided by other staff including (but not limited to) SFAN Salmonid Monitoring Staff.

5.2.1 Network Water Quality Specialist (Field Lead)

Because the freshwater quality sampling stations are located near existing and proposed streamgages, it is possible for the Network Water Quality Specialist to fulfill most streamflow field duties concurrent with water quality activities with little extra time. The Network Water Quality Specialist is the lead field position for this monitoring program. The position will also help with data management and reporting procedures.

5.2.2 Network Water Quality Technician

Currently, funding is available to support a field and office technician to assist the Network Water Quality Specialist. A small portion of this position's time will be used to help support the field and data management needs of this monitoring program.

5.2.3 Network Ecologist (PINN)

Given the distance of PINN from the other parks, the field duties at PINN will be covered by the Network Ecologist stationed there. In addition, this position will work with the Network Water Quality Specialist, Data Manager, and the Aquatic Ecologist to prepare annual and long-term monitoring reports.

5.2.4 Network Data Manager

While much of the data management is handled by the Water Quality Specialist and Aquatic Ecologist (Technical Program Lead), the SFAN data manager will assist with general data management. These duties will include the following:

- Keeping monitoring program personnel informed of procedural and technical data requirements from above (e.g., NPS or DOI data standards)
- Participating periodically in field activities to clearly understand data issues and needs
- Providing technical assistance in maintenance and modifications for monitoring program databases
- Ensuring appropriate rules are followed for network data storage and archiving
- Providing secondary quality assurance oversight

5.2.5 Aquatic Ecologist (Technical Program Lead)

A technical program lead will be responsible for general oversight of the network streamflow monitoring program. Ideally, this role will be served by a Hydrologist (GS-1315-9/11/12) with a strong technical background in surface water hydrology. Currently, these duties are filled by the GOGA Aquatic Ecologist:

- Managing and directing the project streamflow monitoring activities
- Participating in annual work plan review and development with network staff including budget, tasks, deliverables, and deliverable timelines (with occasional severe penalties for program leads for failure to meet timelines)
- Ensuring that all personnel participating in streamflow monitoring activities have proper technical and safety training.

- Completing annual data summaries and analyses with assistance from hydrologic technician
- Maintaining professional and technical expertise in all surface-water data collection, data management, and reporting techniques associated with this monitoring program
- Updating and reviewing program monitoring protocol as needed

5.2.6 NPS-WRD Hydrologist (Technical Assistance)

Because this program is staffed by individuals who are not professional hydrologists, periodic assistance will be needed as technical issues arise and to ensure proper data quality. Some typical assistance will include periodic review of annual reports, annual datasets, and infrequent long-term monitoring reports. In addition, every five years, a protocol review will be required from NPS-WRD.

5.2.7 Volunteer-in-Parks

There are opportunities for use of volunteers to assist with field data collection. Winter streamflow sampling requires a minimum of two people for safety and logistical reasons. Volunteers, particularly interns, can and will be vital to ensuring high quality field data collection during the winter. The network water quality specialist will be responsible for training and coordinating use of volunteers.

One of the future research questions- “How is climate change affecting streamflow patterns in SFAN parks?” may best be answered through assistance by a large citizen science/volunteer program. Local citizens living adjacent to Park lands are keenly aware of conditions around them. A citizen monitoring effort could be developed to track long-term changes in the connectivity of tributary streams to mainstem creeks supporting salmonids over time.

5.2.8 SFAN Aquatic Professional Working Group and Steering Committee

This plan is intended to be a long-term monitoring plan and as such, future changes in the direction and operation of this plan will undoubtedly be required. Major programmatic changes often based on outside technical reviews will be discussed and decisions reached through consensus in the SFAN Aquatic Professionals group. Internal reviews of annual and long-term monitoring reports will be conducted by this group. This group consists of key network staff including the water quality specialist, network coordinator, park hydrologists and park and regional aquatic ecologists. Recommended programmatic changes by the SFAN Aquatic Professionals group will require approval by the SFAN Technical Steering Committee.

5.3 Qualifications and Training

Field staff (including technician, volunteers, and program lead) must be in sufficient physical condition to be able to reach sampling sites across rough terrain, even during inclement weather. NPS personnel involved with this protocol should have completed Basic First Aid training.

Because of the technical nature of this monitoring program, it is important that key positions (such as Lead Field and Technical Program Leads) have appropriate hydrologic background whether it is from prior work experience or through specialized training courses or through academic coursework (upper level undergraduate to graduate level) in surface water hydrology.

The rating plan and KSAs (knowledge, skills, and abilities) for future hiring's should reflect the need for this level of expertise.

While this protocol provides an overview of the monitoring procedures, it cannot substitute for good technical judgment. Professional or educational experience in surface water hydrology is obligatory. Professional experience can be gained by taking hydrology coursework. Two nearby universities (U.C. Davis and U.C. Berkeley) offer both undergraduate and graduate courses in hydrology, fluid mechanics, surface water hydrology, and geomorphology. Professional training is also offered by USGS to federal employees. A listing of these resources is available via the Internet. Specific training information is provided in SOP 5 Training and Resources.

6.0 Operational Requirements

6.1 Budget

The monitoring protocol has been trimmed to what is essential for obtaining quality data. Total annual costs are \$31,400. Of this, \$17,200 are provided by the parks and \$15,200 are provided by the network (Table 10). Periodic costs (once every 5 years or so) will vary to cover equipment replacement, software, periodic review and trend reports (Table 10).

6.1.1 Annual Implementation Costs

Personnel costs will include the contributions made by the Network Water Quality Specialist, Water Quality Technician, and the Network Ecologist (PINN). The Network Data Manager provides data management support to all vital signs monitoring efforts and is not included in the project budget (Table 10). Funds are provided through the SFAN I&M program. The budget presented below includes salary to cover overtime costs and night/weekend differential pay. Some sampling will likely occur during non-regular work week hours in order to collect samples during peak storm flows.

Based on previous years, annual supply costs are estimated at \$800. This covers equipment costs including desiccant, batteries, flagging, etc. If additional funds are required for equipment maintenance including routine equipment calibrations, requests can be made to the network's equipment fund.

Because many sampling locations of the water quality program and this program have been co-located, additional travel including vehicle costs are not expected. However, a small budget of \$400 is recommended in case extra travel costs are incurred.

PORE contributes 1/3 share of operational expenses for USGS to operate the Lagunitas Creek at Point Reyes Station gage. In FY2009, this contribution totals \$7,200.

6.1.2 Periodic Costs

Periodic technical reviews could involve up to one pay period of a GS-11/12 hydrologist from other NPS streamflow monitoring programs or the NPS Water Resources Division. Periodic technical training costs should also be budgeted. Equipment costs are minimal because Parks have already purchased equipment using their own funds. Some additional materials and supplies will be required to establish streamgages at PINN (Table 11) and cover equipment replacement. Equipment costs include supplies for stilling wells, staff plates, and crest gages. Other equipment costs may include the purchase of a bridge board, Model A-55 sounding reel, and 50-lb weights for winter high flow measurements for PINN. The first year of storm monitoring will determine whether this purchase will be required. An optional, but desirable field measurement device is a hand-held discharge computer that stores individual measurements and calculates individual discharge measurements in the field. Although the replacement frequency of our electronic equipment is unknown, it is likely that dataloggers and transducers may need replacement every 10 years at approximately \$2000 each. For six recording stations supported by this network, this averages to \$6,000 every five years. Finally, NPS Water Resources Division has suggested that the Park purchase commercially available software to assist with development of rating curves (Aquatic Informatics Aquarius Rating Curve Software). This one-time expense was \$4500. The

SFAN may consider a synoptic Water Resources Division Program Grant as potential strategy to upgrade stations and operational equipment.

Table 10. Estimated annual budget (as of February 2010).

Item	Description	Park Contribution	SFAN Contribution	Total
Personnel	Water Quality Specialist – I&M (GS-6/7) 2 pp*		\$5,000	\$5,000
	Network Ecologist – PINN (GS-9) 2 pp		\$7,000	\$5,000
	Aquatic Ecologist – GOGA (GS – 12) 2 pp*	\$8,000		\$8,000
	Water Quality Tech – I&M*		\$2,000	\$2,000
	PORE share of Lagunitas Creek at Point Reyes Station gage 11460600	\$7,200		\$7,200
	Other Network and park staff to support winter high flow measurements	\$2,000		\$2,000
Supplies	Supplies and Equipment		\$800	\$800
Travel	Site visits		\$400	\$400
Subtotal/Total		\$17,200	\$15,200	\$32,400

*I&M recommends that 1/3 of project costs should be allocated to data management. Approximately 40% of time for these positions go to data management, data analyses and reporting.

Table 11. Periodic equipment and personnel costs for the program.

Item	Description	Budget
Materials	Sounding reel (Mod A-55)	\$1,300*
	Bridge Board	\$300*
	50-lb weight	\$300*
	Discharge computer (e.g., AquacalcPro™)	\$2,500*
	Staff plates, PVC, etc.	\$200*
	Data Logger (replace every 10 years)	\$2,000
	Aquarius Rating Curve Software	\$4,500
Personnel	Technical review (one pay-period GS-11/12, including benefits)	\$4,000
Travel and Lodging	Technical review site visit	\$1,500

*Indicates supplies that may be needed for PINN startup. (Total approximate startup \$4,600.)

6.2 Implementation Schedule

As mentioned in the Monitoring Objectives (Section 1.9), the intent of the program is to provide a long-term, systematic, and well-documented discharge record. It is anticipated that this would

involve operating this monitoring program for the indefinite future. Trend analyses for hydrologic data require at least 20 or more years to detect a significant change from natural variation (Huh et al. 2005).

On an annual basis, field sampling and data entry associated with this protocol will occur year-round (Table 12). Reporting is initiated at the end of the water year (after Sept. 30). Streams at PINN are dry throughout much of the summer and fall reducing the number of site visits required. Site visits may be more frequent during the winter rainy period to capture high flows.

Table 12. Annual work schedule for Water Quality Specialist.

Activity	Winter (Dec–Feb)	Spring (Mar–May)	Summer (Jun–Aug)	Fall (Sept–Nov)
Site visits (data collection; station maintenance) ¹	Monthly; during high flows	Monthly; during high flows	Monthly	Monthly
Data entry	Year-round	Year-round	Year-round	Year-round
Prepare equipment for water year. ¹			Gather and check equipment to prepare for rainy season.	
Calibrate transducers and tipping buckets ¹			Annually or more frequently if problems arise.	
Annual reports for water year (ends Sept.) ^{1, 2, 3}				Due 1 Dec.

¹Network Ecologist assists for sites at Pinnacles National Monument (see Table 9).

²Aquatic Ecologist assists with these tasks by providing review (see Table 9).

³Data Manager assists with these tasks (see Table 9).

7.0 Glossary

Datum – elevation selected as a reference point for subsequent measurements. Datum may be a recognized datum (e.g., mean sea level, North American Vertical Datum of 1988) or an arbitrary one. With respect to the gage, the datum is a fixed, non-moving reference point used for the life of the gage. For our purposes, the gage datum is typically the bottom of our staff gage ('0' mark).

Discharge – amount of water passing a plane in a stream over a certain amount of time. It can be measured directly or indirectly calculated based on a stage-discharge relationship.

Gage height – see stage.

Pressure transducer – automated device used to measure water stage (height).

Rating curve – a relationship between stage and measured discharge.

Stage – height of the water surface above an established datum plane. Stage is typically measured with a staff gage (a fixed ruler). Synonymous with gage height and typically measured to an accuracy of 0.01 feet or 0.001 meters.

Streamgage – permanently established station where discharge is measured.

Ultrasonic sensors – devices which measure water depths by transmitting and receiving sound waves to and from a target and converting the elapsed time into distance.

Water Year – the water year coincides with the fiscal year and runs 1 Oct. through 30 Sept.

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Appendix A. Special-status Plants and Animals Associated with Freshwater Habitats Found in San Francisco Bay Area Network Parks

Scientific Name	Common Name	Legal Status				Habitat Requirement and/or Association	Micro Habitat	Occurrence Known in Park Units								Species Distribution/Range
		Federal	CNPS	State	PORE			GOGA	MUWO	PRES	FOPO	JOMU	EUON	PINN		
Plants																
<i>Alopecurus aequalis</i> var. <i>sonomensis</i>	Sonoma alopecurus	FE	1B		Freshwater marshes and swamps, riparian scrub.	Wet areas, marshes, and riparian banks with other wetland species. 5–360m. Known from a few occurrences in sonoma and marin counties.	X								Central Coast	
<i>Limnanthes douglasii</i> ssp. <i>sulphurea</i>	Point Reyes meadowfoam		1B	SE	Fresh. Marsh, vernal pools, coastal prairie, meadows and seeps, cismontane woodland.	Only known from San Mateo and Marin Counties. Vernal wet depressions in open rolling, coastal prairies and meadows; typically in dark clay soil. 10–120m.	X								North Coast (Marin Co.), Central Coast (San Mateo Co.)	
<i>Navarretia squarrosa</i>	Skunkbush	FSL C			Sandy alluvium, roadsides, dryer winter pools, open wet gravelly flats, slopes.	Dunes, sandy soils									North Coast Ranges, n Sierra Nevada Foothills (Sacramento, Amador cos.) San Francisco Bay Area, South Coast Ranges	
<i>Potentilla hickmanii</i>	Hickman's potentilla = Hickman's cinquefoil	FE	1B	SE	Coastal bluff scrub, closed-cone coniferous forest, meadows and seeps, marshes and swamps.	Freshwater marshes, seeps, and small streams in open or forested areas along the coast. 5–125m.		X							n&c Central Coast. Greene's popcorn flower is extirpated in San Francisco.	
<i>Sidalcea calycosa</i> ssp. <i>Rhizomata</i>	Point Reyes checkerbloom	FSL C	1B		Marshes and swamps.	Freshwater marshes near the coast. 5–75(245)m.	X								c&s North Coast (Mendocino, Sonoma cos.), n Central Coast (Marin Co.)	

Appendix A. Special-status Plants and Animals Associated with Freshwater Habitats Found in San Francisco Bay Area Network Parks
(continued)

Legal Status						Occurrence Known in Park Units									
Scientific Name	Common Name	Federal	CNPS	State	Habitat Requirement and/or Association	Micro Habitat	PORE	GOGA	MUWO	PRES	FOPO	JOMU	EUON	PINN	Species Distribution/Range
Invertebrates															
<i>Anodonta californiensis</i>	California floater (mussel)	FSC	n/a		Freshwater lakes and slow moving streams and rivers.	Generally in shallow water		X							
<i>Caecidotea tomalensis</i>	Tomales asellid	FSC	n/a		Inhabits localized freshwater ponds or streams with still or near-still water in several bay area counties.		X	X							
<i>Hydrochara rickseckeri</i>	Ricksecker's water scavenger beetle	FSC	n/a		Various water bodies.	Aquatic; known from the San Francisco Bay area.	?	?				?	?		Marin, San Mateo, Sonoma, and Solano County (occurrences)
<i>Hydroporus leechi</i>	Leech's skyline diving beetle	FSC	n/a		Aquatic.	Known to inhabit permanent ponds in northern San Mateo County.	?	?				?	?		Known to inhabit permanent ponds in the North end of San Mateo County. (occurrences).
<i>Optioservus canus</i>	Pinnacles riffle beetle	n/a	n/a	n/a	Stream									X	California endemic present in Chalone Creek; CNDDDB rank G1S1 (extremely endangered, CA endemic)
<i>Syncaris pacifica</i>	Californian fresh water shrimp	FE	n/a	SE	Streams of 12–36 inches in depth with exposed live roots of trees along undercut banks > 6" with over hanging woody debris			X							Tributary streams in the lower Russian River drainage westward to the pacific Ocean.
Fish															
<i>Eucyclogobius newberryi</i>	Tidewater goby	FE	n/a		Brackish water habitats along the CA coast from Agua Hedionda Lagoon, San Diego Co. to the mouth of the Smith River.	Found in shallow lagoons and lower stream reaches, they need fairly still but not stagnant water and high oxygen levels.		X							Eastern Pacific: Del Norte County in northern California to Del Mar in southern California.

Appendix A. Special-status Plants and Animals Associated with Freshwater Habitats Found in San Francisco Bay Area Network Parks
(continued)

Scientific Name	Common Name	Legal Status			Habitat Requirement and/or Association	Micro Habitat	Occurrence Known in Park Units								Species Distribution/Range
		Federal	CNPS	State			PORE	GOGA	MUWO	PRES	FOPO	JOMU	EUON	PINN	
<i>Lampetra ayresi</i>	River lamprey	FSC	n/a		Lower Sacramento River, San Joaquin River and Russian River. May occur in coastal streams north of San Francisco Bay.	Adults need clean, gravelly riffles, ammocoetes need sandy backwaters or stream edges, good water quality and temps <25 c									Eastern Pacific: Tee Harbor, Alaska to Sacramento-San Joaquin drainage in California, USA. Freshwater resident population in Morrison Creek, Vancouver Island, British Columbia
<i>Lampetra tridentata</i>	Pacific lamprey	FSC	n/a		Freshwater streams.	Pacific lamprey spend most of their life in freshwater streams before entering the ocean as adults to feed.		X							Range in California, Oregon, Washington, and Idaho with the most precipitous documented declines in the upper Columbia, Snake, and North Umpqua River basins.
<i>Oncorhynchus kisutch</i>	Coho salmon-- Central California coast	FE,S E, CH	n/a	SE	Coastal streams draining to ocean (including those to S.F. Bay) with spawning habitat, juvenile rearing habitat, and migratory corridor		X	X	X						Point Hope, Alaska south to Chamalu Bay, Baja California, Mexico.
<i>Oncorhynchus mykiss</i>	Steelhead — Central California Coast	FT, CH	n/a		Coastal streams draining to ocean (including those to s.f. bay) with spawning habitat, juvenile rearing habitat, and migratory corridor		X	X	X			X			California streams from the Russian River to Aptos Creek, and the drainages of San Francisco and San Pablo Bays eastward to the Napa River (inclusive).
<i>Oncorhynchus tshawytscha</i>	Chinook salmon — California coastal	FT	n/a		Large coastal streams and rivers with spawning habitat, juvenile rearing habitat, and migratory corridors.		X								Arctic and Pacific: drainages from Point Hope, Alaska to Ventura River, California; occasionally strays south to San Diego.

Appendix A. Special-status Plants and Animals Associated with Freshwater Habitats Found in San Francisco Bay Area Network Parks
(continued)

Legal Status							Occurrence Known in Park Units								Species Distribution/Range
Scientific Name	Common Name	Federal	CNPS	State	Habitat Requirement and/or Association	Micro Habitat	PORE	GOGA	MUWO	PRES	FOPO	JOMU	EUON	PINN	
Reptiles/Amphibians															
<i>Clemmys marmorata</i>	western pond turtle	FSC	n/a		Slow moving waterways, lakes and ponds.	Aquatic turtle: requires ponds, slow-moving waterways, such as creeks and irrigation ditches where water ponds. Prefers habitats with basking sites, aquatic vegetation, and suitable upland habitats for egg-laying.	X	X	X				X	X	Occurs on suitable aquatic habitats throughout California west of the Sierra Nevada and in parts of Oregon and Washington.
<i>Rana draytonii</i>	California red-legged frog	FT, CH	n/a		Ponds and other permanent slow-moving waterbodies: lakes, reservoirs, slow streams, marshes, and bogs.	Adults require a dense, shrubby or emergent riparian vegetation closely associated with deep (> 0.7 meters) still or slow-moving water.	X	X		H			X		California red-legged frogs are still locally abundant within portions of the San Francisco Bay area (including Marin County) and the central coast. Within the remaining distribution of the species, only isolated populations have been documented in the Sierra Nevada, northern Coast, and northern Transverse ranges.
<i>Rana boylei</i>	Foothill yellow-legged frog	FSC	n/a		Partly shaded, shallow streams and riffles with a rocky substrate in a variety of habitats.	Egg clusters attached to downstream side of submerged rocks. Need at least some cobble-sized substrate for egg-laying. Need at least 15 weeks to attain metamorphosis.	H		H						West of crest of Cascade mountains, Ore., south in coastal mountains. Of California to San Gabriel River, Los Angeles County. Sierra Nevada foothills to about 6000'; Baja California.
<i>Thamnophis sirtalis tetrataenia</i>	San Francisco garter snake	FE	n/a	SE	Freshwater habitats are primary foraging sites. Adjacent uplands for basking and hibernaculae.	Prefer densely vegetated ponds with adjacent plants for basking. Preferred prey is the red-legged frog. Estivates in burrow holes.		X							Historically San Francisco peninsula currently known from South San Francisco near airport and Mori Point near Pacifica. Known occurrence at Mori Point.

Appendix A. Special-status Plants and Animals Associated with Freshwater Habitats Found in San Francisco Bay Area Network Parks
(continued)

		Legal Status			Occurrence Known in Park Units										
Scientific Name	Common Name	Federal	CNPS	State	Habitat Requirement and/or Association	Micro Habitat	PORE	GOGA	MUWO	PRES	FOPO	JOMU	EUON	PINN	Species Distribution/Range
Birds ²															
<i>Agelaius tricolor</i>	Tricolored blackbird	FSC	n/a		(Nesting colony) highly colonial species, most numerous in Central Valley and vicinity. Largely endemic to California.	Requires open water, protected nesting substrate, and foraging area with insect prey within a few km of the colony.	X								Gregarious; found year-round in large flocks in open country and dairy farms; nests in large colonies in marshes.
<i>Botaurus lentiginosus</i>	American bittern	FSC	n/a		Freshwater and slightly brackish marshes. Also in coastal saltmarshes.	Dense reed beds.									Breeds from southeastern Alaska, Manitoba, and Newfoundland south to California, New Mexico, Arkansas, and Carolinas.
<i>Empidonax trailii brewsteri</i>	Little willow flycatcher		n/a	SE	Breeds in shrubby vegetation in meadow and riparian woodlands, typically where there are mature, dense stands of willows, cottonwoods, or alders.		X	X							Breeds in wet meadows and montane riparian habitas from 2,000–8,000 feet in elevation.
<i>Geothlypis trichas sinuosa</i>	Saltmarsh common yellowthroat	FSC	n/a		Resident of the San Francisco Bay region, in fresh and salt water marshes.	Requires thick, continuous cover down to water surface for foraging; tall grasses, tule patches, willows for nesting.									Canada to s. Mexico. Winters southern U.S. to West Indies, Panama.
<i>Laterallus jamaicensis coturniculus</i>	Black rail		n/a	ST	Mainly inhabits salt-marshes bordering larger bays.	Occurs in tidal salt marsh heavily grown to pickleweed; also in fresh-water and brackish marshes, all at low elevation.	X	X							NE and central U.S. and central California south locally to West Indies, Chile
<i>Pelecanus occidentalis californicus</i>	California Brown pelican	FE	n/a	SE	Forage over near shore marine areas including open coast, San Francisco Bay, and rodeo lagoon. Utilize islands, rocks, cliffs, and some protected beach areas for roosting.		X		X						Coasts: southern U.S. to northern Brazil and Chile. Northern extent of breeding is Channel Island, southern California.

Appendix A. Special-status Plants and Animals Associated with Freshwater Habitats Found in San Francisco Bay Area Network Parks
(continued)

							Occurrence Known in Park Units									
Scientific Name	Common Name	Legal Status			Habitat Requirement and/or Association	Micro Habitat	PORE	GOGA	MUWO	PRES	FOPO	JOMU	EUON	PINN	Species Distribution/Range	
		Federal	CNPS	State												
<i>Circus cyaneus</i>	Northern harrier			SC	(Nesting) coastal salt and fresh-water marsh. Nest and forage in grasslands, from salt grass in desert sink to mtn cienagas.	Nests on ground in shrubby vegetation, usually at marsh edge; nest built of a large mound of sticks in wet areas.									All California	
<i>Dendroica petechia brewsteri</i>	Yellow warbler		n/a	SC	(Nesting) riparian plant associations. Prefers willows, cottonwoods, aspens, sycamores, and alders for nesting and foraging.	Also nests in montane shrubbery in open conifer forests.									Neotropical migrant. Breeds in riparian habitat and wet meadows in California.	
Mammals²																
<i>Aplodontia rufa phaea</i>	Point Reyes Mountain Beaver	FSC	n/a		Coastal area of Point Reyes in areas of springs or seepages.	North facing slopes of hills and gullies in areas overgrown with sword ferns and thimbleberries.	X								110 square miles in the Point Reyes area of Marin County	

Key: FE = federally endangered; FT = federally threatened; FC = federal candidate; FSC = federal species of concern; FSLC = federal species of local concern; CH = designated critical habitat; SE = state endangered; ST = state threatened; SC = state species of concern; SR = state rare; 1B = California Native Plant Society (CNPS) ranking system for plants of varying degrees of concern (1B = rare throughout their range and the majority are California endemics); H = historic occurrence; ? = potential occurrence; X = presently occurring.

Appendix B. Ranking Criteria for Identifying SFAN Streams Where Streamflow Data Would Be Useful

Note: Streams italicized in blue are ranked highest overall.

Creek	Park Unit	Resource Data Value ¹	Vital Signs Link? ²	Managed by NPS? ³	Current hydrologic monitoring?
White Gulch	PORE			Yes	
<i>Bear Valley Creek</i>	<i>PORE</i>	<i>High (1,2,5)</i>	<i>SF, WQ</i>	<i>Yes</i>	
Haggerty Gulch	PORE			Partial	
<i>Olema Creek</i>	<i>PORE</i>	<i>High (1,2,4,5,6,7)</i>	<i>WQ,SF</i>	<i>Yes</i>	<i>NPS</i>
Cheda Creek	GOGA	High (1,3,5)	SF	Yes	
Devil's Gulch	GOGA	Low (1)	WQ	Yes	
<i>Lagunitas Creek</i>	<i>PORE GOGA</i>	<i>High (1,2,3,4, 5,6,7)</i>	<i>WQ,SF</i>	<i>Mostly</i>	<i>USGS</i>
Santa Maria Creek	PORE	Med (1,2)		Yes	
Coast Creek	PORE	Med (1,2)		Yes	
Alamere Creek	PORE	Med (1,2)		Yes	
Arroyo Hondo	PORE	Low (2)		Yes	
Glenbrook Creek	PORE	Med (1,2)		Yes	
Muddy Hollow	PORE	Med (1,2)		Yes	
Laguna Creek	PORE	Med (1,2)		Yes	
McClure's Creek	PORE	Low (2)		Yes	
Kehoe Creek	PORE	Low (2)		Yes	PORE monthly discharge measurement
Abbott's Creek	PORE	Low (2)		Yes	PORE quarterly discharge measurement
Home Ranch Creek	PORE	Med (1,2)		Yes	PORE monthly discharge measurement
Creamery Creek	PORE	Low (2)		Yes	
A Ranch	PORE	Low (2)		Yes	

Appendix B. Ranking Criteria for Identifying SFAN Streams Where Streamflow Data Would Be Useful (continued).

Creek	Park Unit	Resource Data Value ¹	Vital Signs Link? ²	Managed by NPS? ³	Current hydrologic monitoring?
B Ranch Creek	PORE	Low (2)		Yes	
C Ranch Creek	PORE	Low (2)		Yes	
<i>Pine Gulch</i>	<i>PORE</i>	<i>High (1,4,5,6,7)</i>	<i>WQ,SF</i>	<i>Yes</i>	<i>NPS</i>
McKinnan Gulch	GOGA	Med (2,5)		Yes	
Morses Gulch	GOGA	Low (1)		Yes	
Stinson Gulch	GOGA	Med (1,4)		Yes	Stinson Beach County Water District (SBCWD 2003)
Laurel Creek	GOGA	Hi (1,4,7)		Partial	Stinson Beach County Water District (SBCWD 2003)
Black Rock Creek	GOGA	Med (1,4)		Partial	Stinson Beach County Water District (SBCWD 2003)
Fitzhenry Creek	GOGA	High(1,4,7)		Partial	Stinson Beach County Water District (SBCWD 2003)
Easkoot Creek	GOGA	High (1,4,7)	SF	Partial	NPS
Cold Stream	GOGA	Low (7)		Partial	
<i>Redwood Creek</i>	<i>GOGA</i>	<i>High (1,4,5,6,7)</i>	<i>WQ,SF</i>	<i>Yes</i>	<i>NPS</i>
Green Gulch	GOGA	Low (4)	WQ	Partial	
Kent Creek	GOGA	Low (1)	SF, WQ	Partial	
Fern Creek	GOGA	Med (1,7)	SF, WQ	Partial	
<i>Tennessee Valley</i>	<i>GOGA</i>	<i>High (2,5,6,7)</i>	<i>WQ</i>	<i>Yes</i>	
<i>Rodeo Creek</i>	<i>GOGA</i>	<i>High (1,5,6,7)</i>	<i>WQ</i>	<i>Yes</i>	
<i>Gerbode Creek</i>	<i>GOGA</i>	<i>High (1,5,6,7)</i>	<i>WQ</i>	<i>Yes</i>	
Nyhan Creek	GOGA	Low (7)	WQ	Partial	

Appendix B. Ranking Criteria for Identifying SFAN Streams Where Streamflow Data Would Be Useful (continued).

Creek	Park Unit	Resource Data Value ¹	Vital Signs Link? ²	Managed by NPS? ³	Current hydrologic monitoring?
Oakwood Valley	GOGA	Low (7)	WQ	Yes	NPS
Coyote Creek	GOGA	Low (7)		Minimal	
Franklin Creek	JOMU	High (1,5,6,7)	WQ,SF	Minimal	
Strentzel Creek	JOMU	Low (7)	WQ	Partial	
Lobos Creek	PRES	High(4,5,7)		Yes†	Presidio Trust, infrequent historic monitoring since late 1800s
El Polin Spring	PRES	Med (5,7)		Yes†	
Dragonfly Creek	PRES	Med (5,7)		Yes†	
Tennessee Hollow	PRES	Med (5,7)		Yes†	Presidio Trust
Milagra Creek	GOGA	Low (7)		Minimal	
Calera Creek	GOGA	Low (7)		Minimal	
Sanchez Creek	GOGA	Med (2,7)		Minimal	
West Union Creek	GOGA	Med (1,7)	WQ	Partial	
<i>Chalone Creek</i>	<i>PINN</i>	<i>High (2,6,7)</i>	<i>WQ,SF</i>	<i>Partial</i>	
<i>Sandy Creek</i>	<i>PINN</i>	<i>High (2,6,7)</i>	<i>WQ</i>	<i>Minimal</i>	
<i>Bear</i>	<i>PINN</i>	<i>High (2, 4,6,7)</i>	<i>WQ</i>	<i>Yes</i>	

¹Overall stream ratings (High–Low) were based on the presence of 7 High Value/Risk attributes.

Overall rankings: High = 3 or more attributes; Medium = 2; Low = 1. Habitat Value/Risk: 1 = federally listed fish breeding and rearing habitat; 2 = federally listed amphibian breeding and rearing habitat; 3 = federally listed invertebrate breeding and rearing habitat; 4 = water withdrawal/instream flow needs; 5 = restoration assessment or planning data; 6 = dispersal of non-native aquatic species; 7 = Park or neighbor infrastructure near creek and streamgage.

²The creek is a site of other SFAN network monitoring activities: WQ = water quality; SF= salmonid.

³Yes = watershed located entirely or mostly within park boundaries and managed by NPS; Yes† = watershed located primarily within park boundaries and Presidio Trust; Partial = watershed partially located within parklands and/or managed by multiple agencies (e.g., Lagunitas Creek Watershed is managed by NPS, California State Parks, and the Marin Municipal Water District); Minimal = watershed primarily located outside parklands.

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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