National Park Service
U.S. Department of the Interior

Natural Resource Program Center

San Francisco Bay Area Network (SFAN) Streamflow Monitoring Protocol

Volume 2: Standard Operating Procedures - Version 2.92

Natural Resource Report NPS/SFAN/NRR—2011/344



ON THE COVER
Olema Creek, Point Reyes National Seashore.
Photograph: NPS

San Francisco Bay Area Network (SFAN) Streamflow Monitoring Protocol

Volume 2: Standard Operating Procedures - Version 2.92

Natural Resource Report NPS/SFAN/NRR—2011/344

Darren Fong

National Park Service
Golden Gate National Recreation Area
Fort Cronkhite Bldg. 1061
Sausalito CA 94965

David Press
Marcus Koenen
Michael DeBlasi

National Park Service
Inventory and Monitoring Program
Fort Cronkhite Bldg. 1063
Sausalito CA 94965

April 2011

U.S. Department of the Interior
National Park Service
Natural Resource Program Center
Fort Collins, Colorado

The National Park Service, Natural Resource Program Center publishes a range of reports that address natural resource topics of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Report Series is used to disseminate high-priority, current natural resource management information with managerial application. The series targets a general, diverse audience, and may contain NPS policy considerations or address sensitive issues of management applicability.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. This report received formal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data, and whose background and expertise put them on par technically and scientifically with the authors of the information.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available from San Francisco Area Network Inventory and Monitoring website (http://science.nature.nps.gov/im/units/sfan/) and the Natural Resource Publications Management website (http://www.nature.nps.gov/publications/nrpm/).

Please cite this publication as:

Fong, D., D. Press, M. Koenen, and M. DeBlasi. 2011. San Francisco Bay Area Network (SFAN) streamflow monitoring protocol: volume 2: standard operating procedures - version 2.92. Natural Resource Report NPS/SFAN/NRR—2011/344. National Park Service, Fort Collins, Colorado.

NPS 963/107253, April 2011

Contents

Page

Standard Operating Procedure (SOP) 1. Procedures for Selection and Operation of Streamgages … SOP1.1

Standard Operating Procedure (SOP) 2. Data Management SOP2.1

Standard Operating Procedure (SOP) 3. Stream Gage Station Descriptions SOP3.1

Standard Operating Procedure (SOP) 4. Field Equipment for Flow Measurements and Station Maintenance SOP4.1

Standard Operating Procedure (SOP) 5. Training and Resources SOP5.1

Standard Operating Procedure (SOP) 6. Procedures for Tipping Bucket Rain Gage Stations SOP6.1

Standard Operating Procedure (SOP) 7. Data Analysis and Reporting SOP7.1

Standard Operating Procedure (SOP) 8. Revising the Protocol SOP8.1

Standard Operating Procedure (SOP) 9. Quality Assurance Plan (QAP) SOP9.1

Standard Operating Procedure (SOP) 10. Field Methods for Streamflow Measurements SOP10.1

Standard Operating Procedure (SOP) 11. Safety Procedures SOP11.1

Standard Operating Procedure (SOP) 12. Decontamination During and After Field Activities SOP12.1

Standard Operating Procedure (SOP) 1. Procedures for Selection and Operation of Streamgages

Version 3.06

Revision History Log

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.00		Darren Fong	Added and cleaned CR10x procedures	Prior version needed additional details	1.01
1.01	3/27/06	Travis Smith	Added WL 15& WL16	Updated and new equipment used	1.02
1.02	2/16/2007	Darren Fong and Marcus Koenen	Changed format, Added details on general operation, maintenance, and calibration	Prior version needed additional details	2.0
2.0	5/3/07	Paul Johnson	Proofreading throughout		3.01
3.01	5/9/07	David Press	Proofreading throughout		3.02
3.02	7/24/07	Darren Fong	General editing		3.03
3.03	8/6/08	Paul Johnson, Marcus Koenen	Proofreading throughout		3.04
3.04	1/30/2009	Darren Fong	Added/removed equipment		3.05
3.05	6/7/2010	Darren Fong, Kris Freeman, Marcus Koenen	General edits and proofreading, formatting, peer review comments.		3.06

Figures

Page

Figure SOP 1.1. Staff gage (left) and crest gage (right) PVC housing with graduated dipstick. ..... SOP 1.6

Figure SOP 1.2. Typical recording streamgage installation set-up (Easkoot Creek) using Campbell Scientific datalogger and shelter, stilling well and transducer, tipping rain bucket, crest gage, and staff gage. ..... SOP 1.9

Figure SOP 1.3. Debris underneath bridge on Olema Creek affecting winter stage-discharge relationship (Winter 2006–2007)..... SOP 1.22

Appendixes

Page

Appendix SOP 1 A. Construction and Installation of PVC Crest Gage ..... SOP 1.25
Appendix SOP 1B. Transducer and Datalogger Specifications..... SOP 1.29
Appendix SOP 1C. USGS Two-Peg Test (from Kennedy 1990) ..... SOP 1.35

Purpose

The purpose of this standard operating procedure (SOP) is to provide standardized guidance on routine visits to core NPS operated streamgages for the purposes of recording visual observations of stream stage, downloading electronic dataloggers, performing general maintenance activities, and performing calibration checks on pressure transducer equipment. This SOP is not intended to supplant manufacturer's equipment manuals as an operational guide.

Scope and Applicability

This SOP applies to In-Situ Level Troll 500 water level logger, Global Water WL15 and WL16 water level loggers, Campbell Scientific CR500 and 10x dataloggers, Instrumentation Northwest Inc. (Model PS9105), and Druck (Model PDCR 1830) pressure transducers and Onset and Davis Instruments II tipping rain buckets.

Reference Materials

General information on establishment of recording and non-recording streamgages is provided in Volume 1 of Rantz et al. (1982a). USGS released a technical memorandum governing accuracy in stage measurements (USGS 1992). However, because pressure transducers have been widely used only recently, standard procedures for their installation and use are not available in Rantz et al. (1982a). Other documents should be reviewed to learn more about stage measurement technologies and data recording devices. A good overview of the operational concepts behind submersible pressure transducers and their operation is provided Freeman et al. (2004). A good description of commercially available water stage recorders and standardized test results of major water stage measurement devices and data recorders is provided by a U.S. Bureau of Reclamation funded project (ITRC 1999). Finally, the field technician and program lead should be familiar with and have available manufacturers' instrumentation manuals for equipment listed in Section 2.0.

Selection of Streamgage Location

Selection of a streamgage location requires a field evaluation of conditions in order to place a streamgage that will collect accurate data while protecting the safety of personnel during site visits. Criteria useful for identifying a proper station have been detailed by Rantz et al. (1982b). In general, gaging sites should be downstream far enough from hydrologic features that might cause temporary non-uniformity in flow and upstream far enough from hydrologic features to avoid backwater effects (Rantz et al. 1982b). The ideal streamgage should have these characteristics:

1. The general course of the stream is straight for about 300 ft upstream and downstream from the gage site.
2. The total flow is confined to one channel at all stages, and no flow bypasses the site as subsurface flow.
3. The streambed is not subject to scour and fill, and is free of aquatic growth.
4. Banks are permanent, high enough to contain floods, and are free of brush.
5. Unchanging natural controls are present in the form of a bedrock outcrop or other stable riffle for low flow and a channel constriction for high flow, or a falls or cascade that is not submerged at all stages.

6. A pool is present upstream from the control at extremely low stages to ensure a recording of stage at extremely low flow, and to avoid high velocities during periods of high flow.
7. The gage site is far enough upstream from the confluence with another stream or from tidal effect to avoid any variable influence the other stream or the tide may have on the stage at the gage site.
8. A satisfactory reach for measuring discharge at all stages is available within reasonable proximity of the gage site. (It is not necessary that low and high flows be measured at the same stream cross section.)
9. The site is readily accessible for ease in installation and operation of the streamgage. (Rantz et al. 1982b)

Additional criteria for selecting locations of streamgages included co-location with other NPS vital sign monitoring sites and for coastal watersheds, stations that captured most of the watershed's water production. While all these factors were evaluated, there was no ideal station location that met all these requirements. None of the stations are located in bedrock reaches; section controls were generally gravel-dominated riffles. However, many of the stations are located in incised channels with inset floodplains where the total flow is confined by terrace banks. All of the stations are located at existing bridges or in close proximity such that there may be variable backwater effects. However, such sites are accessible under all flow conditions.

Streamgage Set-up

In lieu of directly measuring discharge, recording streamgages have automated devices that record a stream's water surface height, or stage, at set time intervals. The stage of a stream is the height of the water surface above an established datum. The water surface elevation is referenced to some fixed, arbitrary or recognized datum and is called the "gage height". Gage height and stage are synonymous and typically measured to an accuracy of 0.01 feet. To avoid confusion, data are selected so that reported numbers are always positive (Norris and Fisher 2006). Secondary measurement devices, crest and staff gages, are also installed for quality control purposes. Water stage data from automated stage devices require visual observations of stage from staff gages for calibration. Crest gages are used to assess the accuracy of peak water stage recorded by the automated stage devices. Discharge can be estimated by determining a relationship between corrected water level stage and individual discharge measurements using a stage-discharge relationship, or rating curve.

The purpose of this section is to describe the basic procedures for the establishment of a recording streamgage, the equipment used for this program, and general operation and maintenance guidelines for the selected equipment. The procedures described below do not cover installation and operation of tipping rain buckets, although several recording streamgages have tipping buckets associated with them. These installation procedures are provided in SOP 6 Procedures for Tipping Bucket Rain Gage Stations.

Selection of Streamgage Equipment

The materials chosen for the core streamgages were based on discussions with NPS Water Resources Division staff, hydrologic consultants, and review of costs for generally acceptable equipment. At this time, electronic dataloggers and pressure transducers have been identified as

the prime equipment used for collection of 15-minute stage data. These systems are in widespread use, relatively easy to install and maintain, and there are a variety of commercial options to choose from. Either integrated units (such as In-Situ or Global Water brands) or modular systems have been identified as being relatively cost-efficient. In addition, the stilling wells used to house these units are small and visually and ecologically unobtrusive. In the future, new technologies may arise that allow for cheaper and higher quality 15-minute stage data than our current installations. At that time, the network will rethink its plan for purchasing and installation of replacement equipment.

Construction and Installation of Crest and Staff Gage Equipment

Equipment used at streamgages will typically include an enamel staff gage (marked in hundredths of feet) and PVC crest gages (Figure SOP 1.1). The staff gages are essentially large rulers used to measure the water depth at a particular location. This information is used to calibrate water stage data from recording stations. Staff gages generally come in 3.4-foot segments and multiple segments can be added together to measure the expected range of water depths at the site. Crest gages record the height of peak flows using bits of cork that adhere to rods inside a pipe as peak flows recede. Both staff and crest gages are installed at all recording and non-recording streamgages. At recording stations, this equipment is important as part of standard quality assurance procedures.

Procedures for construction of PVC crest gages are provided by Randy Klein (Redwood National Park) but various manuals also provide simple instructions for construction of similar types, including Rantz et al. (1982a). Construction procedures of PVC crest gages used by our program are provided in Appendix SOP 1A. Enamel staff gages are available from commercial vendors that sell hydrologic equipment.

The installation of equipment is straightforward. The ideal location for both would be a protected location that would accurately record water stage changes and that would be minimally damaged and afford safe access to observers in times of peak flow. Based on previous experience, the upstream sides of bridges should be avoided for these reasons. Once the ideal location is selected, the crest gage and staff gage should be installed vertically. Depending on site conditions, the staff gages may be mounted on wood backing (typically 2 x 6 inch boards) and secured to fence posts. A carpenter's level should be used to make sure the installed gage is vertical.

Following installation, level surveys are done to establish the gage datum and to tie the staff gage to reference marks at the gaging site or nearby benchmarks. These procedures are described in Section *Level Surveys* below.

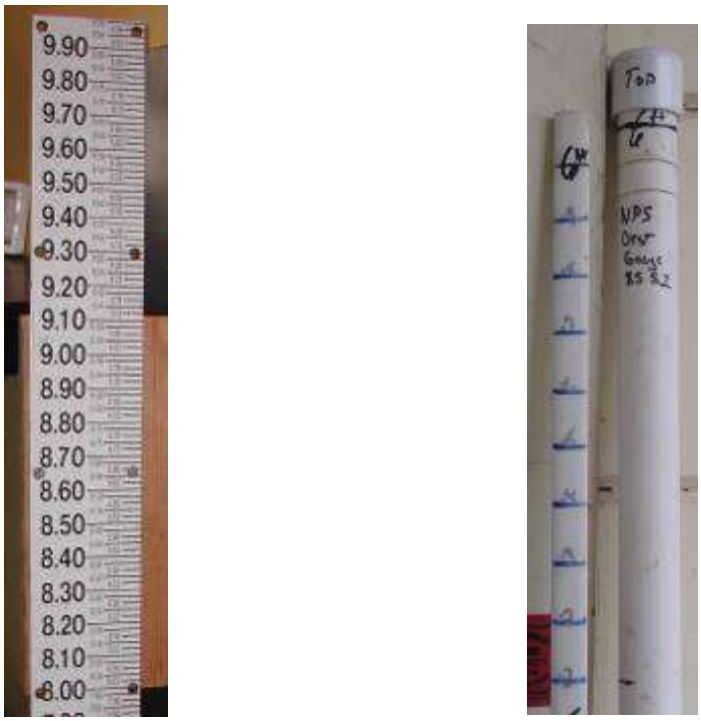


Figure SOP 1.1. Staff gage (left) and crest gage (right) PVC housing with graduated dipstick.

The transducers in this program are vented to the atmosphere and all brands work similarly. These transducers have diaphragms that measure the strain caused by varying water levels, and this response is linear. Vents remove the effects of changing atmospheric pressure and thus the transducer measures only the pressure exerted by the water column (Norris and Fisher 2006). Pre-installation calibration is required to establish the relationship between water stage and the electrical "strain." This information is used by the datalogger to convert and store measured data as water stage (ft).

Currently, GOGA and PORE have Campbell Scientific CR10x and CR500 dataloggers, Global Water WL15/16 integrated dataloggers and transducers, and an In-Situ Level Troll 500 integrated datalogger and transducer. PRES uses a SIGMA 950 75 kHz Ultrasonic meter for its streamgage. Campbell Scientific dataloggers have multiple channels that allow for the addition of various sensors (e.g., temperature, turbidity) as well as various storage, sampling, output, and transmission options. However, because of their capabilities, the Campbell Scientific dataloggers have been more difficult to set-up and operate than some of the integrated datalogger/transducer equipment (e.g., Global Water). The specifications of these dataloggers and transducers are provided in Appendix SOP 1B.

USGS provides an accuracy criterion that will be used for the selection of the proper water stage recorders for the streamgages. Rantz et al. (1982a) recommend an accuracy criterion of 0.01 ft for recording and non-recording streamgages. This recommendation was slightly modified by USGS in 1992. An acceptable balance between stage-measurement accuracy and other components of discharge-record accuracy can be achieved by using instruments capable of

sensing and recording stage with an accuracy of either 0.01 ft or 0.2 percent of the effective stage being measured, whichever is less restrictive (USGS 1992). Because of the small watershed areas within our network, the maximum range of recorded water depths would be between 10 and 15 feet. Using this criterion, water stage recorders that have accuracy of 0.02 and 0.03 ft or better would be adequate.

Currently, the pressure transducers at existing streamgages meet the recommended accuracy criterion. The In-Situ Level Troll 500 has a reported full scale accuracy of 0.1% over the range of expected temperature (http://www.in-situ.com/insitu/products/LevelTROLL/LevelTROLL500.html). Both Global Water transducers (Model WL16) and Druck (PDCR 1830) report full scale accuracies of 0.1% (http://www.globalw.com/products/, Campbell Scientific 2003). For Global Water transducers currently used by SFAN parks for recording streamgages, accuracy of water stage measurements is 0.015 ft (0-15 ft range). For Druck PDCR 1830, accuracy of water stage measurement is 0.012 ft (0-5 pounds per square inch [psig]) and 0.023 ft (0-10 psig), respectively. For Instrumentation Northwest (Model PS9105), accuracy of stage measurements is similar to the Druck PDCR 1830.

Certain brands of ultrasonic meters also meet the accuracy criterion. The Sigma 950 ultrasonic meter has a manufacturer's reported accuracy of +/-0.01 ft over its recommended range (0-15 ft) (Hach 2006). Information regarding the installation of ultrasonic meters is available from individual manufacturers and is not discussed further.

Construction and Installation of Dataloggers and Transducers

The procedures described below cover general pressure transducer and datalogger set-ups. Installation procedures will vary slightly depending on the type of water stage recorder used. The manufacturer's manuals should be consulted for guidance. These manuals are available to Park staff on the SFAN server (Network I&M:\Individual Vital Signs\Freshwater Dynamics\documents\Equipment Manual). Generally, the datalogger portion of the equipment should be located well outside the floodplain to prevent water damage as well as potential loss during extreme flood events. The dataloggers, depending upon brand, can be enclosed in a specialized weather-tight environmental shelter (e.g., Campbell Scientific) or placed in a home-made enclosure made from large diameter, schedule 40 PVC pipe (e.g., Global Water products). Light grey PVC pipe has UV protectors that help protect the pipe shelter from premature aging. The environmental shelters should contain color-indicating desiccant to keep moisture away from electronic components. In addition, vent tubes from the transducer cables should have desiccant tubes to prevent unwanted condensation from entering the cables. The cables connecting the datalogger to the transducer should be enclosed in a conduit (e.g., conduit or PVC pipe) to prevent damage by animals.

Many gaging sites have vertical stilling wells placed in protected areas along the bank which house the transducers. The bottom end of the stilling well is placed below the lowest expected water surface elevation. Often, fence-post pounders are used to drive metal well points below the stream bottom. The stilling wells can be constructed out of pipe (PVC or galvanized) and include slotted and blank portions of pipe. The diameter of the pipe can be variable depending upon the diameter of the transducers. Typically, our stilling wells are 1½ or 2 inches in diameter. The

bottom portion of the stilling well is typically slotted to allow free movement of water. To facilitate cleaning of sediment build-up over time, it is recommended that these stilling wells have a "clean-out" mechanism. This can consist of a "T-style" pipe fitting that fits between the well point and blank sections of pipe above it. A simple, removable drain plug can be placed in the pipe fitting.

Fine sediments can interfere with transducer operation. Two solutions are available for sites where fine sediments are known to be an issue. The nose cap of the transducers can be filled with silicone grease to stop mineral growth and prevent sediments from entering the nose cap, but still allow pressure to be transmitted to the diaphragm (ITRC 1999). Alternatively, the transducer can be fitted with a membrane barrier of plastic, latex, or similar materials to prevent fine sediments from interfering with operation of the transducer diaphragm. We have cut the fingers of nitrile or latex gloves and used them as sediment barriers. After removal of any sediment in the transducer, the membrane barrier can be placed over the transducer and filled with sediment-free water. Air bubbles are removed by submersing the unit in a bucket of sediment-free water, squeezing out any air bubbles between the membrane and transducer, and securing the membrane to the transducer with an elastic band.

The data cable and transducers should be suspended in the stilling well from a stable, fixed point called the hanging point (Freeman et al. 2004). Ideally, the transducers should be suspended by a separate steel cable to prevent stretching of the data cable. The cable supporting the transducer should be secured on the hanging point or outside the stilling well such that the transducer does not move. This can be done using hose clamps, cable ties, or wires. The data cable is marked at the hanging point using indelible ink so that possible slippage can be noted (Freeman et al. 2004). Prior to securing the data cable, the distance of the transducer and cable between the hanging point and diaphragm of the transducer should be measured and recorded.

A permanent mark or measuring reference point is engraved or filed onto the top of the stilling well housing. An elevation can be established for this measuring point using level surveys. This information is also critical for the base elevation of the transducer. The base elevation of the transducer would be the difference between the measuring point elevation and the distance to the diaphragm of the transducer. Periodic level surveys can determine whether there have been changes in the height of the stilling well. Additional reference marks near the stilling well should be established. The change in distance between reference marks and stilling well should aid in documenting horizontal movement of the stilling well.

Other ancillary features may be installed as well. For all of the Campbell Scientific streamgages, 20 watt solar panels have been used successfully to maintain charged batteries for data collection. For streamgage sites where rainfall data are needed, a tipping rain gage can be added and placed in accordance with SOP 6 Procedures for Tipping Bucket Rain Gage Stations. Typically, this includes placement in a clearing on a sturdy, level base. A typical installation setup with a solar panel, datalogger, tipping rain bucket, and stilling well is shown in Figure SOP 1.2.

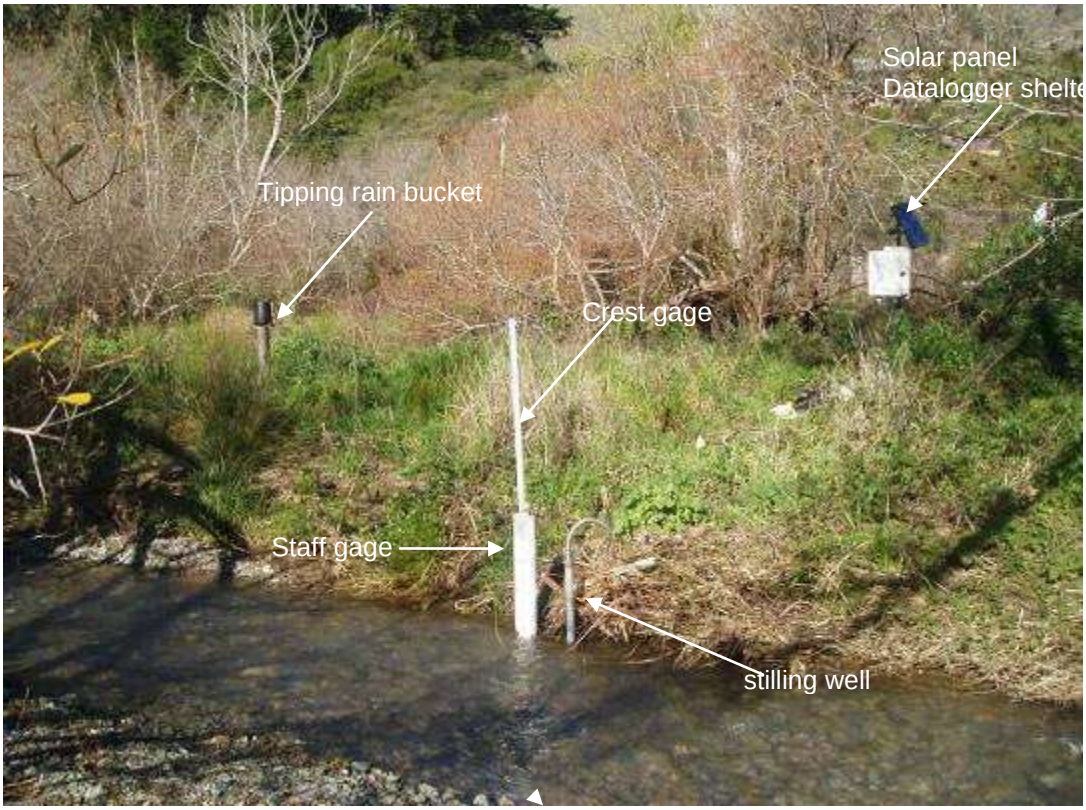


Figure SOP 1.2. Typical recording streamgage installation set-up (Easkoot Creek) using Campbell Scientific datalogger and shelter, stilling well and transducer, tipping rain bucket, crest gage, and staff gage.

Level Surveys

Level surveys are required to establish the elevations and horizontal distances of initial bench marks, reference marks, reference points and streamgages. The supporting structures of the gage such as bridges and other structures can settle or rise as a result of earth movement, frost action, static or dynamic loads, vibration, or battering by floodwaters and flood-borne ice or debris. Vertical movement of a structure makes the attached gages read too high or too low and, if the errors go undetected, can lead to increased uncertainties in streamflow records. Therefore, levels are run periodically to all bench marks, reference marks, reference points, and gages at each station to determine if any datum changes have occurred as a result of settlement or movement (Rantz et al. 1982b, Kennedy 1990).The datum of the streamgage is the elevation of the zero point of the base or reference gage. For most of our streamgages, the gage datum will be the bottom value of the staff gage. Any data corrections for electronic data will be tied to the gage datum of the original staff gage. Where possible, all measured elevations will be tied into a national datum (NAVD88). All streamgages in Marin County are within 1 mile of National Geodetic Survey benchmarks. Proposed streamgages at PINN are not near any benchmarks and alternative procedures other than standard level surveys may be needed to tie stations into a national datum. This data is important to ensure comparability of long-term datasets should the original streamgage be lost during catastrophic events. Level information (e.g., local benchmark

and reference mark information) will be documented in SOP 3 Stream Gage Station Descriptions and any datum corrections along with reasons will be included in annual Station Analyses. Levels are run at newly installed streamgages at the time of construction and at least every 3 years thereafter. Level surveys should be planned for low or no wind days and good light conditions. The equipment used by this program includes steel tape, rod, auto level, tripod, and appropriate safety equipment. Orange safety vests should be used for surveys near vehicular roads. There are a variety of rods available at the parks. An acceptable rod for use by this program would have an error of less than 0.005 ft and is checked with a steel tape prior to use.

Levels are run by use of field methods described in Kennedy (1990). Digital versions of this manual are available on the Internet and a copy has been placed in the reference documents folder of the SFAN computer network. Modifications to level procedures of Kennedy (1990) are described below. Most of the surveyed points at our streamgages can be observed from a single instrument set-up. Therefore side shots, or foresights from a single instrument setup, will be used. However, side shots will be run twice from different instrument setup heights as recommended by Kennedy (1990).

Field survey data are recorded in water-resistant field notebooks. Recorded data include event and level data page(s). Event information includes the survey date and time, weather conditions, survey team and roles, survey equipment, any equipment QA/QC checks, and a plan-view sketch. The plan-view sketch should indicate the location of the streamgage, reference marks, bench marks, direction of flow, stream banks, prominent structures, and access routes. These locations will also be georeferenced using GPS receivers for developing accurate plan-view maps of the streamgage. Both GPS data and site sketches should aid future surveyors or new field employees. Digital photographs will be taken to provide supplementary information on reference locations.

The level instruments are kept in proper adjustment by use of peg tests (Kennedy 1990). Peg tests will be conducted prior to level field work for the year. Peg test data are recorded on USGS field forms (Appendix SOP 1C). Documentation of all tests, adjustments, and service is maintained for each instrument in a level log binder for the network.

It is the responsibility of the crew leader to ensure that all field level notes are checked for readability and completeness in the field. After returning to the office, the results of the levels are transferred to the summary spreadsheet, *Level Notes*, will summarize level data specific to the streamgage (See SOP 2 Data Management for details). Any topographic data from the field surveys (e.g., control cross-section) are entered into the *Topographic Survey* spreadsheet for each station (See SOP 2 Data Management for details).

Programming of Dataloggers and Transducers

Various software packages are available to communicate with the dataloggers. Some are bundled with the purchase of the hardware, as is the case with Global Water and In-Situ equipment. Campbell Scientific dataloggers have separate software packages that are bundled with the equipment (e.g., PC200w and Shortcut) as well as some that are purchased separately (e.g. PC208W and NetLogger).

For the dataloggers in use, the following software programs should be used to setup the dataloggers for deployment: Global Logger (Global Water Model WL15), Global Logger II (Global Water Model WL16), Win-situ 5 (In-Situ Level Troll 500), and Campbell Scientific's Shortcut. The Campbell Scientific programs are created and compiled in the Shortcut program. Once the programs have been compiled, they then need to be uploaded to the datalogger using a separate communication program (PC200, PC208W). Subsequent modifications of the programs on Campbell Scientific dataloggers require the use of the EdLog function on PC208W. Because the Campbell Scientific programs have been difficult to use, we have received helpful technical assistance from NPS-Water Resources Division staff.

Regardless of the software package, all deployed dataloggers should have the same setup parameters. The clock time of the dataloggers should be set to Local Standard Time and should be set as accurately as possible to a reference clock (http:\\www.nist.gov). Many of the dataloggers (e.g., Campbell Scientific) use the setup computer as the basis for time. So, the setup computer clock should be accurate and on Local Standard Time and care should be taken not to adjust the clock time of the datalogger for daylight-savings time. The minimum data record fields should include date, time, battery status, and water stage (feet). Data collection should be programmed at 15-minute intervals with water stage stored as instantaneous data. For Campbell Scientific and In-Situ dataloggers, additional parameters may include rainfall (inches) or temperature (Celsius).

Generally, the transducers used for this program come with factory calibration settings. In rare situations, calibration actions are needed. Any programming activities involving the datalogger and transducer need to be recorded. The set-up information, including the dates of calibration, is recorded in the electronic transducer logbook. This logbook is a simple spreadsheet that includes information on the transducer (e.g., serial number) and a log of any calibration checks, new regression equations, and maintenance actions. Details of this logbook are provided in SOP 2 Data Management.

Global Water

Global Water transducers and dataloggers use a two point calibration, generally the shallowest and deepest water stages that would be encountered by the equipment. Generally, the shallowest depth would be water height of zero (air calibration). The manufacturer's calibration procedures must be followed prior to deployment. Values obtained through calibration that are uploaded to the datalogger should be recorded in the electronic transducer logbook described above. Calibration details are provided below in the section ***Routine Inspection and Maintenance for Transducers***.

Campbell Scientific

The latest version of Campbell Scientific's Shortcut program (currently Ver. 2.5.2) should be used for programming the datalogger. Actual wet calibration of the transducer is not needed. Information regarding the relationship between transducer output, in millivolts, and pressure, in feet of water, is provided by the transducer manufacturer. This information is provided on the specification and certification sheets supplied by the manufacturer for each transducer. After setting up the appropriate measurement and recording parameters in the Shortcut program, instructions are provided for wiring the transducer and other equipment to the datalogger. Most importantly, the Shortcut program provides an uploadable program for the datalogger (*.dld file).

Calibration details are provided below in the section ***Routine Inspection and Maintenance for Transducers***.

In-Situ, Inc.: The Level Troll 500 is factory calibrated. Any departures from their acceptable air readings (+/- 0.005 PSI for our 5 PSI logger) can trigger a field recalibration. Simple instructions are provided in the field manual (In-Situ Inc. 2008). They involve setting current air pressure reading of sensor to zero. Calibration details are provided below in the section ***Routine Inspection and Maintenance for Transducers***.

Site Documentation Procedures (Photographic Documentation)

Photographs of newly installed gage houses, station controls, reference marks, damaged structures, etc., are made by field personnel for the purpose of documenting gage house construction, changes in control conditions, or to supplement various forms of written descriptions. All field crews should carry a digital camera for every field visit. Photos should be taken at the highest quality level possible (Norris and Fisher 2006).

Photopoints are established that include vantage points that capture areas upstream and downstream of the streamgage, including major reference points (e.g., a house) that can aid in a historical comparison of photographs. These photopoints are documented by text descriptors (e.g., 10 ft southwest of west bridge abutment) in the field notes and GPS coordinates. These photopoints should be re-occupied for future pictures. To aid in quick re-occupation of photopoints, a sketch map should be made of reference photopoints showing key features. One set of photos from each photopoint should be printed and used to re-locate the same field of view as prior visits. A copy of the sketch map and photos should be brought into the field as well as a copy should be placed in the datalogger shelter. Information about the photopoints are captured on discharge datasheets and transferred to the Microsoft Access discharge database.

Routine Site Visit Procedures

All core streamgages are visited on a monthly basis to download the datalogger, to take a manual streamflow measurement, to record water stage information from non-recording streamgages, and to document channel conditions and minor maintenance activities. Any streamflow measurements should be performed before downloading of dataloggers. All field visits and activities should be recorded on field datasheets (see SOP 10 for detailed instructions on completing datasheet). The datasheet attempts to integrate all recorded data for a field visit including any event data, water quality parameters, discharge measurements, download information, and site visit comments. Almost all fields are filled out for each site visit, except for water quality or discharge measurement fields, if the site visit does not include these measurements. This same data form is used regardless of the datalogger type. The reader is referred to the field definition descriptions for the procedures for filling out the data form (See SOP 10). Field procedures that require more explanation are provided below.

Recording Crest and Staff Gage Readings

Staff gages are typically read during all visits to streamgages. Crest gages are generally just read during visits in the high flow season. Field data will be recorded on stream discharge measurement form (See SOP 10 and Appendix SOP 10B). Recorded information includes time of measurement (local standard time), stage height (to nearest 0.01 ft), and height of the cork line

on the crest gage's dipstick. Water stage height readings taken under poor light conditions may require the use of a flashlight. During storm events, water levels may be surging on the staff gage. Rantz et al. (1982a) recommend that the mean height (intermediate between the peak and trough) be recorded. For our purposes, we recommend that the peak and trough heights be recorded as ranges to provide an indication of water stage conditions at the time of measurement. For crest gages, the height of the cork line is read as if it was the water line on the staff gage. For instance, if the bottom of the crest gage dipstick touches the '5.00' line on the staff gage and the height of the cork line on the dipstck is '1.00' feet, the recorded crest gage height will be '6.00' feet. Field staff should also indicate the approximate age of the cork line in the comments field.

Recording General Site Conditions

The field crew is the 'eyes and ears' of the program and it is important that they record any conditions that may affect the stage-discharge relationship on paper and with photographs. At minimum, for every site visit, a digital photo is taken of the control. The photo should include major reference points (e.g., a house) that can aid in a historical comparison of photographs. Information about capturing photos is provided in the prior section on Site Documentation.

The field crew visually inspects all equipment and their status is recorded in the *Observation/Comments* field. Any problems and resulting remedial actions are included in this field. Typical problems that have been identified with visual inspections include inoperable tipping rain buckets due to plugging with bird droppings, large downed trees in the channel near the streamgage, and vegetation growing over and shading solar panels.

In certain situations, maintenance may be required. However, the impacts of any maintenance actions on the stage-discharge relationship need to be documented both before and after actions. Detailed procedures are provided below in Stream Gage Maintenance Procedures section of this SOP.

Downloading Dataloggers

At this time, a Windows-PC laptop is required to download all dataloggers in the field. Since there are multiple dataloggers, the field laptop should have all the applicable datalogger programs as well as electronic versions of the manuals loaded on the laptops. The field laptop case should also include all applicable data cables as well as any spare batteries (e.g., 9 volt). Table 30 in SOP 4 provides information on the equipment needed to download dataloggers (including specific data cables).

Campbell Scientific and PC208W Overview

The following procedures describe the communication steps between the field laptop and the Campbell Scientific dataloggers and some routine maintenance items that are needed to keep the dataloggers in working condition. Our monitoring program is currently using Campbell Scientific's PC208W program for communication although upgraded software programs are available that perform similar functions.

A Campbell Scientific, Inc. software program, PC208W, provides computer/datalogger communication for data collection and real-time data display. In addition, it provides tools for setting the datalogger clock, transferring datalogger programs, and testing communication links.

The number of days of data that the datalogger will hold depends on the sampling frequency and the number of columns of data that are being saved. The current setup with a 15-minute data interval allows up to two months worth of data to be stored before it is overwritten. The datalogger has a ring memory configuration and overwrites the oldest data. A manual is available, although the software [**Help**] function from the menu bar and the laminated program instruction card are more understandable and helpful.

Communication with Datalogger and Initial Setup

1. Connect Campbell Scientific cable (Model SC929) from laptop to datalogger (Note: standard 9-pin serial cable does not work!)
2. Start the PC208w program on the laptop
3. Station Setup (if station name has not yet been entered):
    a. Select [**Setup**] from menu bar.
    b. Select [**Add device**] button.
    c. Choose type of device (in this case CR10X), highlight "COM1" to connect device to, click [**OK**].
    d. Select [**Data collection**] tab and make sure the settings include 'append to end of file,' 'ascii, comma separated'.
    e. Enter name for site, click [**Save edits**].
    f. Close Setup window.
4. To connect to a datalogger (once the station name has been setup):
    a. Select [**Connect**] from the menu bar.
    b. Select your station name from the list of stations. If the station name is not there, use Station Setup procedures listed above.
    c. Click [**Connect**], connection has succeeded when the laptop and datalogger date and time appear, also refer to elapsed time. Record date:time data. If date and times differ significantly and you're positive the laptop clock is accurate (and at local standard time), click [**Set Datalogger CLK]**. Record synchronization action in field book and new datalogger date:time.

Data Download and Recording Procedures

1. Click the check box [ ] "prompt for data file name."
2. Click [**Collect**], [**Browse**], enter file name. Use the standardized file name format (e.g., EK061205.dat where the first two letter correspond to the streamgage initials; '06' are the last two digits of the current calendar year, '12' is the current numeric month, and '05' is the current day. Record the filename on the datasheet in the appropriate field.
   Note: "Collect" means since the last time the datalogger was downloaded by the same laptop . "Collect all" means the entire memory of the datalogger.

Recording Real-time Datalogger Data and Checking Recorded and Observed Stage

1. To record the real-time parameters from the dataloggers including battery status and stage, select [**Numeric display**] tab at bottom of window.

2. Record parameter values on the field datasheet. Record the reported stage 3 different times.
3. Compare the observed stage with the stage recorded by the datalogger. If the values differ by 0.1 ft or less, normalize the recorded stage to the observed stage by entering the data correction value in the box labeled [**Offset**] by placing the cursor over the box and right-clicking. Record the data correction value and the new recorded stage (which should now match the observed stage). If the values differ by more than 0.1 ft, the transducers should be examined for damage or debris and recalibrated (See procedures in Section 9.0 of this SOP).
4. Click [Disconnect], click [Close session].

Upload or Retrieve a Datalogger Program

1. Select [**Connect**] from the menu bar.
2. To upload a new program, select [**Associate DLD program**] to choose the program to upload, select [**Send**] button to copy the *.dld file from the laptop to the datalogger, overwriting the previous program in the datalogger. The"Loc" names in the *.csi file of the associated *.dld file will label values in the "numeric values" window.
3. To retrieve a program from the datalogger to the laptop, select [**Retrieve**]. Retrieve copies the *.dld file from the datalogger to the laptop, at which point you will asked to assign the retrieved file a name.

Checking Desiccant

The datalogger, power supply, and transducer vents need to be kept in a dry and low-humidity environment to minimize condensation that can damage the equipment. Indicator desiccant in good condition is typically blue and turns pink when full of moisture. Desiccant inside the enclosure should be replaced with fresh desiccant when the colorized indicator turns pink. The typical replacement frequency is three to four times per year.

Checking Battery

The main battery powers the datalogger and sensors; the solar panel recharges the battery. When recharged by a solar panel, this type of lead-acid battery should last three to four years before needing to be replaced. Toward the end of the battery life, the storage of charge is reduced. The datalogger will not function with battery voltages below 10.6 volts. There is a smaller, lithium internal battery (Model CR2430) within the datalogger module that maintains the program and data when the main battery is disconnected. This lithium battery has an expected life of 4 years and should be replaced when voltage drops below 2.4 V (Campbell Scientific 1997). If the battery is used without a solar panel, then a lead-acid battery should be replaced if the voltage is below 11.8 volts.

Replacing Batteries

Use an existing battery charger to make sure that a fully charged battery is available for replacement. Older dataloggers (like the CR10) will lose all data and their program instructions if battery power is lost, even for a second. So, be careful when changing batteries (even with the newer dataloggers, in case the small internal battery has lost its charge). There are two side-by-

side ports for the battery clip to go into; put new battery-wire clip into slot next to old battery-wire clip and don't detach old battery until the numeric display value shows that battery voltage has increased. After the old battery has been detached and the new battery fully installed, check the numeric-value window again to insure that the datalogger has not lost power during the battery change process. If the battery is making poor contact try these trouble-shooting techniques: (1) sometimes you need to slide the clip on and off a few times to clean the contacts; (2) other times, the batteries have shifted in the battery pack and need to be adjusted to make sure each terminal is making contact.

Global Water Dataloggers

The following describes general communication procedures between the field laptop and the Global Logger dataloggers and some routine maintenance items that are needed to keep the dataloggers in working condition. Unlike the Campbell Scientific communication program, communication procedures between the datalogger and computer are straightforward and adequately described in the manufacturer's user manual (GWI 2002, 2005). The reader is referred to the user manuals that are located on the SFAN server (Network I&M:\Individual Vital Signs\Freshwater Dynamics\documents\Equipment Manual).

Similar setup parameters to the Campbell Scientific datalogger are programmed into the Global Water dataloggers. These include sample collection intervals of 15-minutes, ring memory configuration collection to allow over-write of old data with new, and water height units in English, engineering scale.

Different Global Water dataloggers require different communications software, although the all function similarly. Because the SFAN currently has two models (WL-15 and WL-16), the field laptop used for communicating with both should have Global Logger (WL-15) and Global Logger II (WL-16). Global Water uses the same data cable to connect the computer with both models.

Both WL-15 and WL-16 run on 9-volt batteries. They should be replaced when voltage drops below 7.5 V (Wl-15) or 15 V (WL-16).

Data Download and Recording Procedures

To save data, select [**Get History**] button. Global Water data is saved in a default comma-delimited format. Use the standardized file name format (e.g., EK061205.csv where the first two letter correspond to the streamgage initials; '06' are the last two digits of the current calendar year, '12' is the current numeric month, and '05' is the current day. Record the filename on the datasheet in the appropriate field.

Recording Real-time Datalogger Data

1. To record the real-time parameters from the datalogger including battery status and stage, select [**Get Sample**] button
2. Record parameter values on the field datasheet. Record the reported stage 3 different times.
3. Compare the observed with the recorded stage. The dataloggers do not allow the user to enter a data correction value to correct for any instrument measurement drift. So, for data

differences greater than 0.1 feet the transducers should be examined for damage or debris and recalibrated (See procedures in Section 9.0 of this SOP).

4. Compare the datalogger date:time to the laptop value. If the data:time is incorrect, select the [**Sync Time**] button and the datalogger will be synched with the laptop. Record the corrected date:time on the datasheet.
5. Click [Disconnect]; click [Close session].

In Situ Level Troll 500

The following describes general communication procedures between the field laptop and the In-Situ Level Troll 500 datalogger using the Win-Situ communications program and some routine maintenance items that are needed to keep the datalogger in working condition. Unlike the Campbell Scientific communication program, communication procedures between the datalogger and computer are straightforward and adequately described in the manufacturer's user manual. The reader is referred to the user manuals that are located on the SFAN server (Network I&M:\Individual Vital Signs\Freshwater Dynamics\documents\Equipment Manual).

Data Download and Recording Procedures

To save data, select the 'Logging' icon in the tab bar (the row of icons below the header menu bar). The log file should already be select, chose the [**Download**] button at the menu bar at the bottom of the screen. Select 'Download All.' Record the default file name on the data form. View log file to check the recorded values.

Recording Real-time Datalogger Data

1. To see the real-time parameters from the datalogger including battery status and stage, navigate to the 'Home' screen by selecting the 'Home' icon in the tab bar (the row of icons below the header menu bar). Select the [**Read/Play**] button at menu bar at the bottom of the screen to refresh values.
2. Record parameter values (battery, date:time, PSI, temperature, stage) on the field datasheet. Record the reported stage 3 different times.
3. Compare the observed with the recorded stage. If the values differ by 0.1 ft or less, normalize the recorded stage to the observed stage by editing the existing log file or by creating a new log file. To do this, navigate to the 'Device Setup' screen. Keep the same parameter values. Select 'Level-Surface Elevation' and select 'Set New Reference.' Enter the existing stage. Record the data correction value and the new recorded stage (which should now match the observed stage). If the values differ by more than 0.1 ft, the transducers should be examined for damage or debris and recalibrated (See procedures in Section 9.0 of this SOP).
4. Compare the datalogger date:time to the laptop value. If the data:time is incorrect, select the [**Clock Sync**] button and the datalogger will be synched with the laptop. Record the corrected date:time on the datasheet.
5. Click [**Disconnect**] button at menu bar on the bottom right side of the screen.

The In-Situ Level Troll 500 has a factory replaceable lithium battery. No user replacement of batteries is needed.

Routine Equipment Inspection and Maintenance for Crest and Staff Gages

Maintenance procedures are simple. After reading crest-gages, the cork on the inside of the gage is washed down using a water bottle. Any granulated cork left on the dipstick is wiped off. In the summer, periphyton growth can coat the surface of staff gages. A non-abrasive scouring pad (no steel wool) can be used to remove growth both above and below the existing water stage. Periodic topographic surveys are conducted every 2-3 years to determine whether the gages may have shifted vertically and gages are reset to match levels when differences greater than 0.02 ft are measured (Rantz et al. 1982a). For replacement of cork, bottle corks ground with a cheese grater work fine. Fresh cork should be replaced into the crest gages periodically when cork becomes dirty and does not float or adhere well.

Routine Inspection and Maintenance for Transducers

General: Evaluation of the transducers should be performed if there is major disagreement between staff gage reading and datalogger output. Environmental changes to the transducer (e.g., fine sediments at diaphragm) may be a cause for this disagreement rather than failure of the instrument. Our biggest problems in the past with transducers have been the absence of maintenance and the buildup of silt against the diaphragms of the transducers. Suggested preventative treatment options (e.g., membrane barrier on transducer) and flushing stilling well to remove fines are described previously in this SOP. Other potential problems that could cause erratic data include: open and short circuits, water leakage into transducer housing, grounding problems, datalogger failures, and power surges (Freeman et al. 2004). Procedures to diagnose symptoms and provide quick fixes are provided by Freeman et al. (2004).

The procedures below describe the calibration checks used to see if the sensor readings correspond to actual water depths. All calibration checks, including the test results, should be recorded in the electronic transducer logbook (See SOP 2 Data Management). Help in Campbell Scientific programs are found using the help command in both Shortcut and PC208w software packages as well as the accompanying manuals.

Transducer Evaluation

1. Record time and water stage from staff gage.
2. Connect to datalogger and record current water stage from datalogger.
3. Check data cable at the top of the stilling well to see if there might have been slippage. If so, record the amount of slippage.
4. Pull the sensors from the stilling wells.
   Note whether there is heavy sediment buildup above the transducer in the stilling well.
   Use creek water to flush sediments out of stilling well.
5. Perform calibration check.
   a. Mark transducer cable at equal increments with steel measuring tape over the operational range of the transducer.

b. Place transducer at two points and obtain at least two measurements. The calibration checks require a container that holds water to the maximum depth of calibration. We use a long PVC pipe that is sealed at one end.

c. Average measurements and compare actual water depths with the reported water stage from datalogger. If the difference between the actual and reported water depths is less than 0.01 ft, it passes the calibration check.

6. If calibration check fails, perform cleaning and additional tests.
   a. Water condensation in the transducer's vent tube may interfere with readings. Apply slight pressure to the end of the vent tube and see if any change is observed in reported water stage. If plugged with moisture, try changing desiccant attached to vent tube and in the datalogger shelter.
   b. Inspect the transducer diaphragm by removing the protective nose cone (Druck and Instrumentation Northwest transducers).
   c. If mineral deposits are present on the diaphragm, soak the transducer in a dilute cleaning solution such as CLR (ITRC 1999)
   d. Clean any fine sediment from Druck and Instrumentation Northwest diaphragm by removing the nose cone and swirling the transducer in clean water. Do not use items such as cotton swabs to clean the diaphragm. If there is heavy sediment buildup in the stilling well, consider using a membrane barrier to prevent sediments from pressing against the diaphragm.
   e. For Global Water models, clean sensor screen using clean water and toothbrush to remove algae, mud, or sludge (Global Water 2005).
   f. Repeat procedures 5a-c. If actual and reported water depths are in close agreement, place transducers back in stilling well. Record maintenance action, water depth at staff gage, and reported water stage from datalogger. If the actual and reported water stages are not in agreement, a new relationship between transducer output (millivolt) and water stage may be needed.

Transducer Calibration Procedures

Global Water Datalogger Series: The procedures for calibrating the WL-15 and WL-16 are similar. General instructions are provided below. Staff unfamiliar with the software program should refer to electronic versions of the datalogger manuals that are on the SFAN streamflow network.

1. Connect Global Water datalogger cable between laptop and datalogger.
2. Open the software program for the datalogger (Global Logger for WL15 and Global Logger II for WL16)
   a. Download existing data
   b. Click the [Setup] menu button for either program. WL16 requires additional selection of the steps. For WL16, select [**Action**] [**Program Settings**] from the menu bar.
   c. Ensure that the **Unit** field is feet

d. Enter the two water depths that the transducer would be calibrated at. The deepest depth would be entered in the **High EU** field. This deepest water depth should be as close to the maximum range of the transducer as practical. The lowest depth would be entered in the **Low EU** field. Typically, this would be zero depth.
e. Enter the maximum and minimum depth range of the unit in the **Disp High** and **Disp Low** fields, respectively. The current SFAN units have a designed range from 0 to 15 ft.
f. Record the settings.
g. Click the [Calibrate] button
h. Enter the deepest calibration depth in feet and place the transducer at this depth and click [Next] button
i. A new window appears that shows the raw value corresponding to the desired calibration depth. Wait until the value stabilizes and click [Next] button
j. Repeat procedures h–i for zero depth. In this situation, the transducer should be removed from water.
k. For WL16, the program settings need to be saved. Record the file name of the new calibration settings.

Campbell Scientific Dataloggers:

1. Connect Campbell Scientific datalogger cable between laptop and datalogger
2. Create dummy program to determine new y-intercept and slope for transducer
    a. Download existing data.
    b. Create a copy of the existing *.dld program for your streamgage in Windows
    c. Open PC208w, click [**Program**] button, and open the copy of *.dld program. This will invoke the program EDLOG which will allow editing and documenting datalogger programs for the Campbell series. To start edits, you'll need to create a *.csi program by clicking [**File**][**Document**]
    d. You'll need to reset the y-intercept (offset) and slope (multiplier). To do this, find the instruction line for the transducer. This is usually P6 (full-bridge). Set the value for the multiplier to "1" and the offset to "0".
    e. After edits are complete, go to the menu bar to [**Save**] this program and recompile it [**Compile**].
    f. [**Associate**] and [**Upload**] the new program to the datalogger.
3. Obtain data for new linear relationship.
    a. Record actual water depth (feet) and reported values (millivolt) for 5 depths. Obtain at least two measurements at each depth.
    b. Use Microsoft Excel or other spreadsheet program to determine linear relationship between the independent variable or transducer output (millivolts) and the dependent variable, waterdepth (feet). Enter the independent variable data into the first column of the spreadsheet. Enter the dependent variable data in the second column. Insert a Scatter graph onto the spreadsheet and use the mouse to right-click on the datapoints. Select [**Add Trendline**] and select a linear regression

option and display the equation on the graph showing the slope and y-intercept of the linear equation. Record this new linear equation in the transducer log.

c. If the relationship is linear (R^2 close to 1), follow the procedures for editing the dummy *.dld program while still in the EDLOG program above, but replace the multiplier (slope) and offset (y-intercept) with the new data. After replacing these values, this new program needs to saved and uploaded to the datalogger using the instructions in lines 2e-f above.

d. If relationship is not linear, follow procedures in Freeman et al. (2004) to see if other factors may be influencing performance of transducer. If all else fails, contact manufacturer.

4. Once successful calibration checks have been completed, place transducer back into stilling well. Record action, date:time, water depth at staff gage, and reported water stage from datalogger.

In-Situ Dataloggers: If the air reading (PSI) is greater than +/-0.0005 PSI, select the 'Sensors' icon in the tab bar. With the device in the air, select **[Calibrate].** Once successful calibration checks have been completed, place transducer back into stilling well. Record action, date:time, water depth at staff gage, and reported water stage from datalogger.

Streamgage Maintenance Procedures (Including Debris Removal)

Winter storm events can cause major channel changes due to erosion activities and from the transport and deposition of sediments and debris at the streamgage or at nearby sites downstream. These changes may affect the relationship between water stage and discharge under high flow by altering channel control, low flow conditions by altering the section control, or both. For example, this deposit of small woody debris downstream of the Olema Creek streamgage (Figure SOP 1.3) likely has altered the stage-discharge relationship under high flow conditions—at least until the materials get blown out by the next storm. In some cases, this buildup of debris may also pose potential problems for structures by causing scour and undermining of bridge footings. During the fall, the buildup of leaves at the channel control just downstream of the streamgage may raise water levels and give a false sense of an increase in streamflows.

There are no easy solutions. Detection of problems that may require maintenance involves frequent visits to the streamgages and the ability to spot existing or potential problems. One option is to meet with local residents and provide them with the ability to detect such problems as well as a means to document how channel changes may have affected stream stage. Documentation of channel changes should include written descriptions of effects (including gage height at zero flow), photographic evidence, and date:time of observations. All this information may be needed later to assist with shift adjustments to the rating curve for the streamgage. Most importantly, Rantz et al. (1982b) noted that the best way to understand how changes in the channel affect the stage-discharge relationship is from actual discharge measurements particularly at the peak stage of the effect.

If materials are lodged in a manner that would result in damage to monitoring equipment or downstream structures, the field technician and program lead should discuss possible removal activities. However, maintenance activities should not be done without consideration of

permitting and compliance issues; NEPA staff for individual parks should be contacted for advice. Many of the streamgages are located in streams that support federally listed fish and wildlife species, many of whom depend on instream woody debris for habitat. Instream maintenance activities may need to be covered under Section 7 of the Endangered Species Act.

Should maintenance activities be initiated, actual and reported water stage measurements should be recorded both prior to and after maintenance activities. A description of maintenance actions needs to be recorded in the field notebook. Also, a discharge measurement should be obtained.



Figure SOP 1.3. Debris underneath bridge on Olema Creek affecting winter stage-discharge relationship (Winter 2006–2007).

Equipment Repairs, Replacements and Upgrades

Transducers and dataloggers will be used until failure. At Redwood NP, some existing Campbell Scientific datalogger and Druck pressure transducers have been in operation for over 8 years without problems (Randy Klein, pers. comm. 2006) and several of PORE and GOGA stations are approaching this age as well. Our typical problems with the Campbell Scientific dataloggers have been related to dead internal batteries. Occasionally, the rechargeable 12V gel cell batteries need replacement because of their inability to hold a charge. In addition, the internal clock battery (Model CR2430, lithium) needs replacement every couple of years. However, routine data checks after monthly downloads combined with annual field cleaning and calibration will be used to determine whether equipment needs replacement or repair. Because of changing technology, the program lead should constantly re-evaluate whether higher quality data at a cheaper cost can be provided by new technology.

Literature Cited

Campbell Scientific. 1997. CR10x measurement and control module operator's manual. Logan, Utah. Campbell Scientific, Logan, Utah. Manuals and other information available from (http://www.campbellsci.com). Accessed 24 March 2010.

Campbell Scientific. 2003. CS420-L and CS425-L Druck's Models PDCR 1830 and 1230. Campbell Scientific, Logan, Utah. Manuals and other information available from (http://www.campbellsci.com). Accessed 24 March 2010.

Freeman, L. A., M. C. Carpenter, D. O. Rosenberry, J. P. Rousseau, R. Unger, and J. S. McLean. 2004. Use of submersible pressure transducers in water-resources investigations. Chapter A3 *in* Techniques of water-resources investigations. Book 8. U.S. Geological Survey, Washington. D.C. Online. (http://www.ecy.wa.gov/programs/eap/models/usgs_twri.html). Accessed 30 March 2010.

[GWI] Global Water Instrumentation, Inc. 2002. WL15 water level logger user's guide. [Manual, covers WL16s and WL16u data loggers]. Gold River, California. Manuals available online (http://www.globalw.com/). Accessed 24 March 2010.

[GWI] Global Water Instrumentation, Inc. 2005. WL16 data logger. [Manual, covers WL16s and WL16u data loggers]. Gold River, California. Manuals available online (http://www.globalw.com/). Accessed 24 March 2010.

Hach Company. 2006. Hach Sigma 950 series permanent/portable open channel flow meters. [Datasheet]. Manuals available online (http://www.hach.com/). Accessed 24 March 2010.

In-Situ Inc. 2008. Level TROLL Operator's manual. Fort Collins, Colorado.

[ITRC] Irrigation Training and Research Center. 1999. Water level sensor and datalogger testing and demonstration. 1999 February. California Polytechnic State University, San Luis Obispo. (www.itc.org/reports/sensors/waterlevelsensor.htm). Accessed 24 March 2010.

Kennedy, E. J. 1990. Levels at streamflow gaging stations. Chapter A19 *in* Techniques of water-resources investigations of the United States Geological Survey. Book 3. U.S. Geological Survey, Washington, D.C. Online. (http://www.ecy.wa.gov/programs/eap/models/usgs_twri.html). Accessed 30 March 2010.

Norris, M. and G. Fisher 2006. National Capital Region Network: surface water dynamics protocol. National Park Service, National Capital Region. Online: http://science.nature.nps.gov/im/monitor/protocols/NCRN_Streamflow_Data-Protocol&SOPs_Ver_1.pdf. Accessed 10 June 2010.

Rantz, S. E., et al. 1982a. Measurement of stage and discharge. Volume 1 *in* Measurement and computation of streamflow. U.S. Geological Survey Water-Supply Paper 2175. U.S. Government Printing Office, Washington, D.C.

Rantz, S. E., et al. 1982b. Computation of discharge. Volume 2 *in* Measurement and computation of streamflow. U.S. Geological Survey Water-Supply Paper 2175. U.S. Government Printing Office, Washington, D.C.

Appendix SOP 1 A. Construction and Installation of PVC Crest Gage

PLASTIC CREST STAGE GAGE FOR AUTOMATIC RECORDING OF HIGH WATER

Randy Klein

It is often important to know the maximum elevation of a water surface for some time period of interest. Direct observation, although it is the most reliable method, is usually not feasible because of time and/or access constraints. This write-up describes an inexpensive, reliable method of obtaining high water records using a variation of the type of crest stage gage commonly used by the USGS and other water data collection agencies.

The crest stage gage (CSG) is designed to provide a record of the highest water level attained in wells, streams, lakes, tidal zones, etc. This is accomplished by floating powdered cork on the water surface in a confined chamber, causing the cork to be retained at the maximum water elevation over the time period between site visits. The gage can be fabricated from common hardware store materials using primarily hand tools. It consists of a lath stip placed in a vertical standpipe which has hydraulic communication with the body of water to be measured (except when used in small diameter cased wells, where the well casing becomes the CSG chamber) (Figure 1).

FABRICATION

The most difficult part is to fabricate the lath for placing inside the pipe. The best material for this is 3/4" PVC pipe which has been ripped lengthwise on a table saw into quarter sections. This is ideal because it is relatively chemically and biologically inert, has low displacement volume, and has a concave side which helps preserve the high water mark as the lath is being pulled out of the pipe. Also, unless you can get your hands on some "lab" grade ground cork, which is expensive, you'll have to grind up wine corks on a hand grater (the three sided kind works well). The middle size range of your grindings works best (i.e., gives the clearest line on the lath), so you can sieve it and use what is retained between a set of 1 mm and 2 mm sieves. If you don't want to do this, then at least pull out and discard the biggest chunks.

If desired, the outside of the CSG can be used as a staff gage to read stages directly at the time of each site visit. The outside of the standpipe can be graduated by either drawing marks by hand or by attaching pre-graduated tape. An inexpensive material for this is a section of old fiberglass surveying tape, which can be glued onto the standpipe with contact cement. A more expensive, but preferable material is leveling rod replacement tape. This is normally used for leveling rods which have had the numbers and graduations worn off. It comes adhesive backed and is available from surveying equipment stores or mail order outlets.

In most cases, the standpipe and lath lengths should be cut oversized and then cut to length in the field to fit the specifics of the site. The rest of the fabrication happens in the field during installation. Remember: none of the PVC connections should be glued together so that the whole thing can be disassembled for cleaning.

INSTALLATION PROCEDURE

Select a location where the bank is high, steep and stable (if possible). A tall, steep bank will give you the greatest vertical range for measuring high water levels. Drive in a metal fencepost into the creek bed next to the bank. Make sure the top of the post is a few inches below where the top of the gage is to go (the top of the gage goes at an elevation where it can be easily serviced but above the expected high water level). The goal is to utilize as much of the available range (vertical) as possible. Obviously, the top of the gage needs to be higher than the highest expected water level.

Cut the PVC pipe to length: it should extend from just above the creek bed to about a foot higher than the highest expected water level (Figure 2). Slip on the lower end cap so it is very snug and place a permanent mark on the pipe at the top of the cap so that it can be replaced to the same spot if it is removed for cleaning. Cut about four slits in the lower 6" of the pipe (cut them about 1/3 of the way through, no more). Attach the pipe to the fencepost with two hoseclamps (tighten the hoseclamps well so that the pipe cannot slip or be easily forced up or down). Place a permanent mark on the pipe at the height of the top of the fencepost as a check to insure the pipe remains at the same elevation through time. Slip the lath into the pipe so it rests on the bottom cap, then mark where the top of the pipe is on the lath. Cut the lath off at the mark and set back into the pipe. Pour a pinch of ground cork into the pipe and wash it down with a little water. Cut a small slit for a vent in the pipe just below where the top cap will sit. Put on the top cap, and the gage is ready to go.

In most studies, you'll want to reference the crest stages to some datum (mean sea level, an arbitrary datum, etc.). If your comparing stages at two locations, you'll want them referenced to the same datum, even if its arbitrary. This will have to be accomplished by some sort of leveling procedure. In a lake or tidal zone, the water level itself may prove suitable for leveling if you're confident there's no slope between locations when the leveling is done. Otherwise, a surveying instrument will be required. I usually level to the top of the fencepost and measure the stages relative to that. For example, if the elevation of the top of the fencepost is known, the elevation of the bottom of the lath can be calculated by measuring the height from the bottom of the lath up to the top of the fencepost. With that, the height of the cork line on the lath is added to the elevation of the bottom of the lath to get high water elevation.

The fencepost is fairly free from vandalism, and so can be used to re-establish the elevation of a lost or damaged gage.

SERVICING

Soon after a high water event, visit the site and check the height of the highest water since your last visit. Before doing anything, check the marks on the outside of the standpipe to make sure they're at the correct elevations. Carefully pull out the lath so you don't shake off the cork, although it will probably still be wet and will adhere well. There may be several cork lines, but the highest one should be the most distinct (the others are from lower peaks which followed the highest one). Measure and record the height of the cork line above the bottom of the lath as well as the current stage, date, time of day, and any other observations which may be relevant (e.g., flood or ebb flow, turbidity, weather, etc.). Alternatively, the lath can be marked with graduations related to your datum.

If the bottom of the lath is muddy, the standpipe may need to be cleaned of sediment by removing the bottom cap and flushing with water. Check the marks on the standpipe (near the bottom cap and the top of the fencepost) to make sure all the heights are correct after servicing. Wipe the cork from the lath back into the pipe, maybe add a little more cork, wash it down, and replace the lath and top cap. You're ready for the next peak (crest) stage.

TROUBLESHOOTING

The most likely problems you might encounter with the gage itself are from a plugged standpipe (sediment accumulation) or vandalism. Even if there are no obvious signs of vandalism, you should **always** check the datum marks on the outside of the standpipe to be sure. Undetected datum changes will make the data erroneous, and it might not be obvious in the data. Another source of error in stream applications is from scour or fill at the gage site and/or a change in hydraulic control affecting the gage site. Always check these things out on every field visit.

Figure 1. Anatomy of a crest stage gage (CSG).

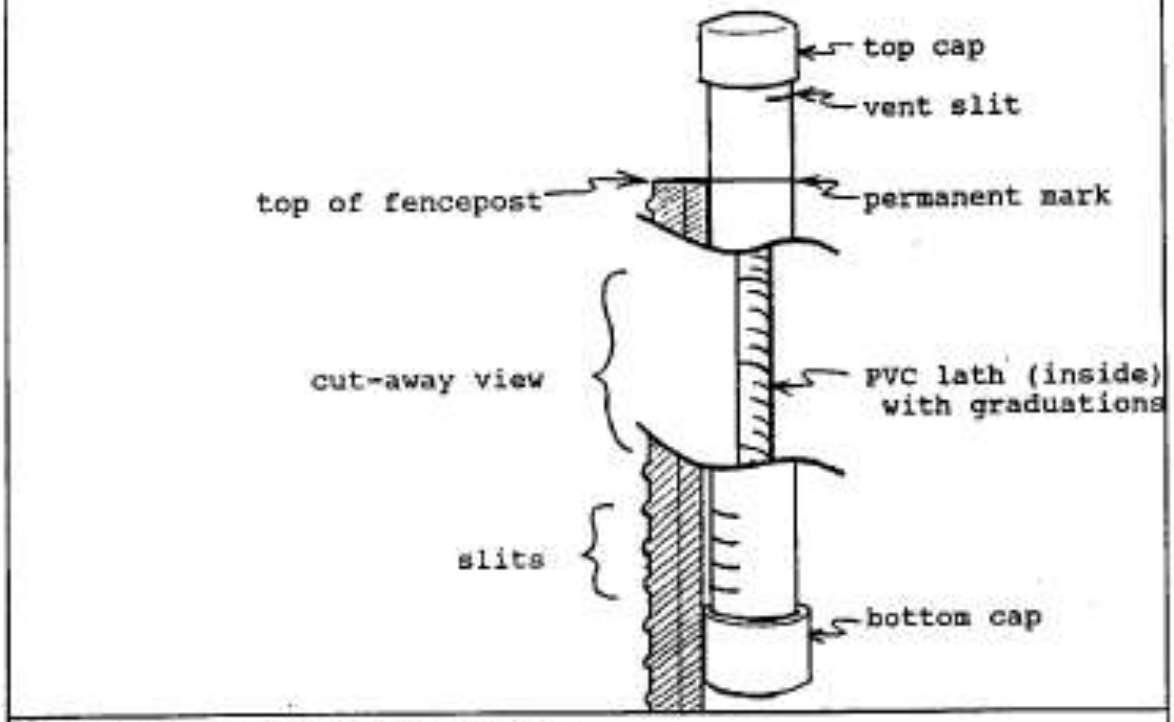
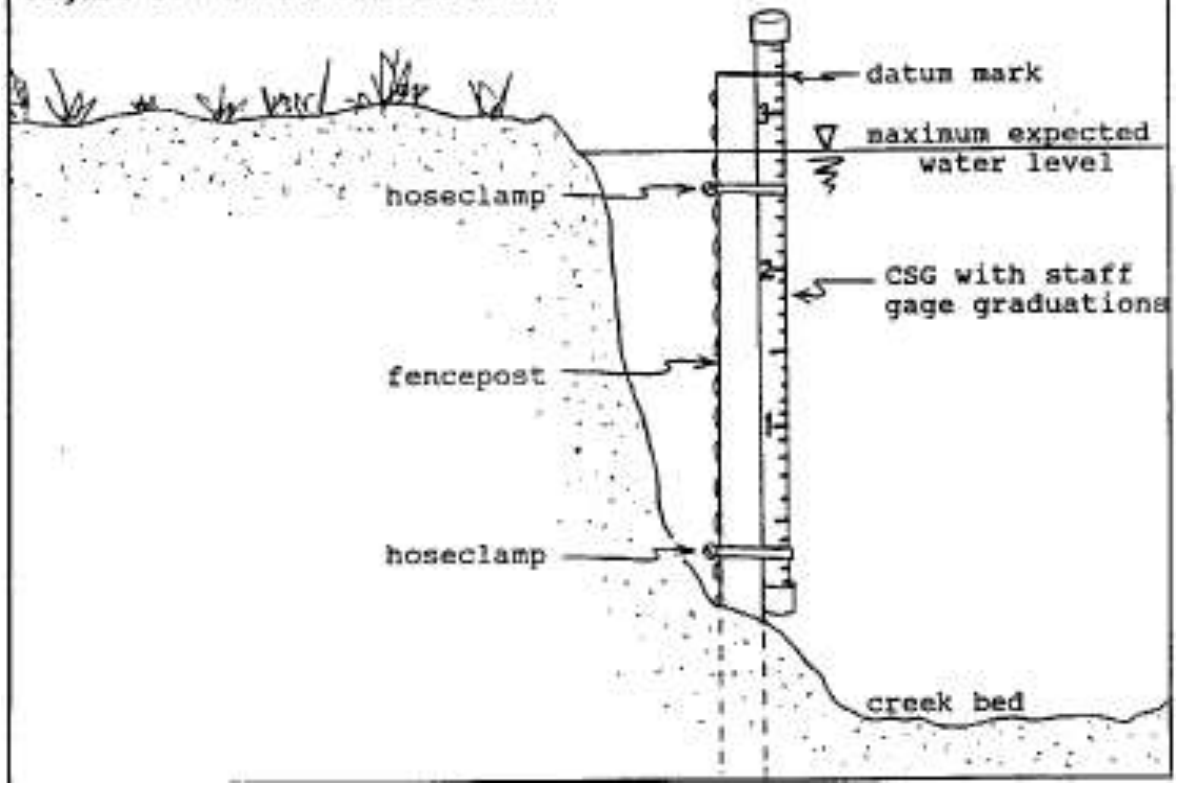


Figure 2. Field installation.



Appendix SOP 1B. Transducer and Datalogger Specifications

CR10X Specifications

Electrical specifications are valid over a -25° to +50°C range unless otherwise specified; non-condensing environment required. To maintain electrical specifications, Campbell Scientific recommends recalibrating dataloggers every two years.

PROGRAM EXECUTION RATE

Program is synchronized with real-time up to 64 Hz. One channel can be measured at this rate with uninterrupted data transfer. Burst measurements up to 750 Hz are possible over short intervals.

ANALOG INPUTS

NUMBER OF CHANNELS: 6 differential or 12 single-ended, individually configured. Channel expansion provided by AM16/32 or AM416 Relay Multiplexers and AM25T Thermocouple Multiplexers.

ACCURACY: ±0.1% of FSR (-25° to 50°C);
±0.05% of FSR (0° to 40°C);
e.g., ±0.1% FSR = ±5.0 mV for ±2500 mV range

RANGE AND RESOLUTION:

Full Scale Input Range (mV)	Resolution (µV) Differential	Single-Ended
±2500	333	666
±250	33.3	66.6
±25	3.33	6.66
±7.5	1.00	2.00
±2.5	0.33	0.66

INPUT SAMPLE RATES: Includes the measurement time and conversion to engineering units. The fast and slow measurements integrate the signal for 0.25 and 2.72 ms, respectively. Differential measurements incorporate two integrations with reversed input polarities to reduce thermal offset and common mode errors.

Fast single-ended voltage:	2.6 ms
Fast differential voltage:	4.2 ms
Slow single-ended voltage:	5.1 ms
Slow differential voltage:	9.2 ms
Differential with 60 Hz rejection:	25.9 ms
Fast differential thermocouple:	8.6 ms

INPUT NOISE VOLTAGE (for ±2.5 mV range):
Fast differential: 0.82 µV rms
Slow differential: 0.25 µV rms
Differential with 60 Hz rejection: 0.18 µV rms

COMMON MODE RANGE: ±2.5 V

DC COMMON MODE REJECTION: >140 dB

NORMAL MODE REJECTION: 70 dB (60 Hz with slow differential measurement)

INPUT CURRENT: ±9 nA maximum

INPUT RESISTANCE: 20 Gohms typical

ANALOG OUTPUTS

DESCRIPTION: 3 switched, active only during measurement, one at a time.

RANGE: ±2.5 V

RESOLUTION: 0.67 mV

ACCURACY: ±5 mV; ±2.5 mV (0° to 40°C)

CURRENT SOURCING: 25 mA

CURRENT SINKING: 25 mA

FREQUENCY SWEEP FUNCTION: The switched outputs provide a programmable swept frequency, 0 to 2.5 V square wave for exciting vibrating wire transducers.

RESISTANCE MEASUREMENTS

MEASUREMENT TYPES: The CR10X provides ratiometric bridge measurements of 4- and 6-wire full bridge, and 2-, 3-, and 4-wire half bridges. Precise dual polarity excitation using any of the switched outputs eliminates dc errors. Conductivity measurements use a dual polarity 0.75 ms excitation to minimize polarization errors.

ACCURACY: ±0.02% of FSR plus bridge resistor error.

PERIOD AVERAGING MEASUREMENTS

The average period for a single cycle is determined by measuring the duration of a specified number of cycles. Any of the 12 single-ended analog input channels can be used. Signal attenuation and ac coupling are typically required.

INPUT FREQUENCY RANGE:

Signal peak-to-peak[1] Min.	Max.	Min. Pulse w.	Max Freq.[2]
500 mV	5.0 V	2.5 µs	200 kHz
10 mV	2.0 V	10 µs	50 kHz
5 mV	2.0 V	62 µs	8 kHz
2 mV	2.0 V	100 µs	5 kHz

[1]Signals centered around datalogger ground
[2]Assuming 50% duty cycle

RESOLUTION: 35 ns divided by the number of cycles measured

ACCURACY: ±0.01% of reading (number of cycles ≥100)
±0.03% of reading (number of cycles <100)

TIME REQUIRED FOR MEASUREMENT: Signal period times the number of cycles measured plus 1.5 cycles + 2 ms

PULSE COUNTERS

NUMBER OF PULSE COUNTER CHANNELS: 2 eight-bit or 1 sixteen-bit; software selectable as switch closure, high frequency pulse, and low level ac.

MAXIMUM COUNT RATE: 16 kHz, eight-bit counter; 400 kHz, sixteen-bit counter. Channels are scanned at 8 or 64 Hz (software selectable).

SWITCH CLOSURE MODE
Minimum Switch Closed Time: 5 ms
Minimum Switch Open Time: 6 ms
Maximum Bounce Time: 1 ms open without being counted

HIGH FREQUENCY PULSE MODE
Minimum Pulse Width: 1.2 µs
Maximum Input Frequency: 400 kHz
Voltage Thresholds: Count upon transition from below 1.5 V to above 3.5 V at low frequencies. Larger input transitions are required at high frequencies because of input filter with 1.2 µs time constant. Signals up to 400 kHz will be counted if centered around +2.5 V with deviations ≥ ±2.5 V for ≥ 1.2 µs.
Maximum Input Voltage: ±20 V

LOW LEVEL AC MODE
(Typical of magnetic pulse flow transducers or other low voltage, sine wave outputs.)

Input Hysteresis: 14 mV

Maximum ac Input Voltage: ±20 V

Minimum ac Input Voltage:

(Sine wave mV RMS)	Range (Hz)
20	1.0 to 1000
200	0.5 to 10,000
1000	0.3 to 16,000

DIGITAL I/O PORTS

8 ports, software selectable as binary inputs or control outputs. 3 ports can be configured to count switch closures up to 40 Hz.

OUTPUT VOLTAGES (no load): high 5.0 V ±0.1 V; low < 0.1 V

OUTPUT RESISTANCE: 500 ohms

INPUT STATE: high 3.0 to 5.5 V; low -0.5 to 0.8 V

INPUT RESISTANCE: 100 kohms

SDI-12 INTERFACE STANDARD

Digital I/O Ports C1-C8 support SDI-12 asynchronous communication; up to ten SDI-12 sensors can be connected to each port. Meets SDI-12 Standard version 1.2 for datalogger and sensor modes.

CR10XTCR THERMOCOUPLE REFERENCE

POLYNOMIAL LINEARIZATION ERROR: Typically <±0.5°C (-35° to +50°C), <±0.1°C (-24° to +45°C).

INTERCHANGEABILITY ERROR: Typically <±0.2°C (0° to +60°C) increasing to ±0.4°C (at -35°C).

CE COMPLIANCE (as of 09/01)

STANDARD(S) TO WHICH CONFORMITY IS DECLARED:
EN55022: 1995 and EN61326: 1998

EMI and ESD PROTECTION

IMMUNITY: Meets or exceeds following standards:
ESD: per IEC 1000-4-2; ±8 kV air, ±4 kV contact discharge
RF: per IEC 1000-4-3; 3 V/m, 80-1000 MHz
EFT: per IEC 1000-4-4; 1 kV power, 500 V I/O
Surge: per IEC 1000-4-5; 1 kV power and I/O
Conducted: per IEC 1000-4-6; 3 V 150 kHz-80 MHz

Emissions and immunity performance criteria available on request.

CPU AND INTERFACE

PROCESSOR: Hitachi 6303

PROGRAM STORAGE: Up to 16 kbytes for active program; additional 16 kbytes for alternate programs. Operating system stored in 128 kbytes Flash memory.

DATA STORAGE: 128 kbytes SRAM standard (approximately 60,000 data values). Additional 2 Mbytes Flash available as an option.

OPTIONAL KEYBOARD DISPLAY: 8-digit LCD (0.5" digits)

PERIPHERAL INTERFACE: 9 pin D-type connector for keyboard display, storage module, modem, printer, card storage module, and RS-232 adapter.

BAUD RATES: Selectable at 300, 1200, 9600 and 76,800 bps for synchronous devices. ASCII communication protocol is one start bit, one stop bit, eight data bits (no parity).

CLOCK ACCURACY: ±1 minute per month

SYSTEM POWER REQUIREMENTS

VOLTAGE: 9.6 to 16 Vdc

TYPICAL CURRENT DRAIN: 1.3 mA quiescent, 13 mA during processing, and 46 mA during analog measurement.

BATTERIES: Any 12 V battery can be connected as a primary power source. Several power supply options are available from Campbell Scientific. The Model CR2430 lithium battery for clock and SRAM backup has a capacity of 270 mAhr.

PHYSICAL SPECIFICATIONS

SIZE: 7.8" x 3.5" x 1.5" - Measurement & Control Module; 9" x 3.5" x 2.9" - with CR10WP Wiring Panel. Additional clearance required for serial cable and sensor leads.

WEIGHT: 2 lbs

WARRANTY

Three years against defects in materials and workmanship.

We recommend that you confirm system configuration and critical specifications with Campbell Scientific before purchase.

CAMPBELL SCIENTIFIC, INC.
815 W. 1800 N. - Logan, Utah 84321-1784 - (435) 753-2342 - FAX (435) 750-9540
Offices also located in: Australia • Brazil • Canada • England • France • South Africa • Spain

Copyright © 1998, 2004
Campbell Scientific, Inc.
Printed March 2004

Global Water WL15 Water Level Data Logger (www.globalwater.com)

Submersible Pressure Transducer

Sensor Element: Silicone Diaphragm, Wet/Wet Transducer
Pressure Range: 0-3', 0-15', 0-30', 0-60', 0-120', 0-250'
Linearity and Hysteresis: ±0.1% FS
Overpressure: Not to exceed 2 x full scale range
Accuracy: ±0.1% of full scale at constant temperature, ±0.2% over 35°F to 70°F range
Compensation: Uses dynamic temperature compensation 30-70 F. Automatic barometric pressure compensation

Housing

Material: 304L Stainless Steel, SS microscreen (hundreds of holes to prevent fouling), electronics are fully encapsulated in marine grade epoxy, guaranteed not to leak
Size: Up to 7" long x 13/16" diameter (small enough for a 1" well)

WL15X Cable

Conductors: 4 each 22 AWG
Jacket Material: Marine Grade Polyurethane
Vent Tube Material: HD Polyethylene
Shield: Aluminum Mylar
Outer Diameter: 3/16"
Temperature Range: -22° to +185°F
Weight: 0.7 oz/ft *Length:* Standard 25' (up to 500')

WL15X Water Level Data Logger

Memory: Non-volatile flash memory
Battery: 9V Lithium
Battery Life: Up to 3 years (depending on recording intervals)
Backup Battery: 3V Lithium
Resolution: 12 bit
Moisture Protection: Acrylic coat (prevents damage to electronics from condensation)
Storage Capacity: 24,400 time and date stamped data points, 270,000 bytes
Recording Rate: Linear fixed intervals from 1-256 seconds, 1-256 minues, 1-256 hours, or 1-256 days; Logarithmic test (for pump and slug tests)
Data Overwrite: Select memory wrap or unwrap (unwrap will stop logging data once memory is full)
Clock: Synchronizes to the time and date of user's computer
Clock Accuracy: 0.0015%
Clock Format: Month/Day/Year Hour/Minute/Second
Enclosure: 1 7/8" diameter x 12" length (fits inside a 2" well), stainless steel UV protected PVC vented for barometric pressure compensation
Temperature: -40° to +170°F
Humidity: 0-95% non-condensing
Weight: 1.6 lbs (with battery and 25' cable)
Communication: RS232 (cable provided)
Communication: 38,400 kbs
Data Transfer Rate: 2MB/4 minutes
File Type: Comma Separated Value (.CSV)

Global Water Software

Compatible with Microsoft's Windows 95, 98, ME, 2000, NT, and XP
Windows and Excel are trademarks of the Microsoft Corporation
Tabular Display/Printout

Data in standard spreadsheet format
RS232 cable included (connects logger's data port to PC)

Global Water WL16 Water Level Data Loggers (www.globalwater.com)

Memory: Non-volatile flash memory
Power: Two 9VDC Alkaline Batteries
Battery Life: Up to 1 year (depending on recording intervals)
Resolution: 12 bit
Moisture Protection: Silicon coating (prevents damage to electronics from condensation)
Temperature: -40° to +185°F
Humidity: 0-95% non-condensing
Storage Capacity: 81,759 time and date stamped data points including battery voltage
Sample Modes: High Speed (10 samples per second), Fixed Interval (Programmable from 1 sec to >1 year), Logarithmic, Exception
Data Overwrite: Select memory wrap or unwrap (unwrap will stop logging data once memory is full)
Clock: Synchronizes to the time and date of user's computer
Clock Accuracy: 0.0025% or 1 minute in 1 month
Clock Format: Month/Day/Year Hour/Minute/Second
Enclosure: 1 7/8" diameter x 11.5" length (fits inside a 2" well), stainless steel UV protected PVC vented for barometric pressure compensation
Weight: 1.6 lbs (with battery and 25' cable)
Communication Port:
WL16S: RS-232 4-pin circular connector
WL16U: USB Type B
Selectable Baud Rates:
9600,19200,28800,38400,57600,115200

Global Water Level Logger Software

Compatible with Microsoft's Windows 98, ME, 2000, NT, and XP
Windows and Excel are trademarks of the Microsoft Corporation
Tabular Display/Printout
Data in standard spreadsheet format (.CSV)
Programmable alarm start and stop times
Field calibration software and help files included

Water Level Logger Vented Cable

Conductors: 4 each 22 AWG
Material: Marine grade polyurethane jacket, polyethylene vent tube, full foil shield
Shield: Aluminum Mylar
Outside Diameter: 3/16"
Temperature Range: -22° to +185°F
Length: Standard 25' (up to 500' from factory)

Submersible Pressure Transducer

Sensor Element: Silicone Diaphragm, Wet/Wet Transducer
Pressure Range: 0-3', 15', 30', 60', 120', 250', 500'
Linearity and Hysteresis: ±0.1% FS
Overpressure: Not to exceed 2 x full scale range
Accuracy: ±0.1% of full scale at constant temperature, ±0.2% over 35°F to 70°F range
Compensation: Uses dynamic temperature compensation 30-70 F. Automatic barometric pressure compensation

Housing: Up to 7" long x 13/16" diameter (small enough for a 1" well)
Material: 304L Stainless Steel, SS microscreen (hundreds of holes to prevent fouling), electronics are fully encapsulated in marine grade epoxy, guaranteed not to leak

PDA software: CE and Mobile compatible.

Instrumentation Northwest, Inc PS9105 transducer (INW 1998)

Linearity/repeatibility/hysteresis*: max. +/-0.25% FSO, typ. +/-0.1% FSO
Zero offset: max. +/-3mV
Sensitivity: max. typ. 15-16 mV/V (ratiometric)
Common mode voltage: typ. Vi/2
Thermal hysteresis: the output will typically return to within +/-0.25% FSO of its initial reading subsequent to one full cycle over the compensated temperature range.
Transducer voltage: typ. 2.5 V
Temperature Error (0-50° C)**: max +/-2% FWO
Compensated temperature range: 0-50° C
Operating temperature range: -5° C to +70° C
Length: 9.125”
O.D. 0.840”
Body material: 316 stainless steel
Wire seal material: Vito/Buna-N
Diaphragm: 316 stainless steel
Cable O.D.: max 0.28”
Cable jacket: polyurethane
Conductor type: 9-conductor, vented
Vent tube: nylon
Break strength: typ. 138 lbs.

*best fit straight line method
**output normalized to excitation current

Druck PDCR 1830 transducer (Campbell Scientific 2000)

Overpressure: 8x for 1 to 2.5 psig range, 6x for 5 psig range, 4x for 10 psig and above ranges
Excitation voltage: 10 V at 5 mA maximum
Output Voltage: 25 mV for 1 psig range, 50mV for 2.5 and 5 psig ranges, 100 mV for ranges 10 psig and above. Output is ratiometric to supply
Combined non-linearity, hysteresis, and repeatability: +/-0.1% of full scale, best fit straight line
Operating temperature range: -20° C to +60° C
Compensated temperature range: -2 to + 30° C
Long-term stability: typ. =/- 0.1mV/annum

In-Situ Inc. Level Troll 500

Operating temperature range	-20 to 80°C
Dimensions	18.3 mm (0.72 in) OD, 21.6cm (8.5 in) long
Weight (includes hanger)	0.197 kg (0.43 lb)
Output options	Modbus (RS-485/232), SDI-12, 4-20mA
Housing material	Titanium
Nose cone material	Black Delrin®
Power	
Internal battery	3.6V Lithium
Typical life*	5 yrs or 2-million readings
External power	8-36VDC
Logging	

Memory / data points**	1 MB / 100,000+
Logging Rate	User selectable from 0.5 sec -- 49 days
Modbus	0.5 sec
SDI-12	0.5 sec
Measurement Types	Linear, Fast Linear, Event
	**data point = time and date plus one parameter logged
Level Sensor	Silicon strain gauge
Type	Vented or non-vented
Material	Titanium
Accuracy, FS***	+/-0.05% (15C)
FS = Full Scale	+/-0.1% (-5 to 50C)
	+/-0.25% (-20 to -5C & 50 to 80C)
	*** Accuracy with 4-20mA output option: +/-0.25% typical
Resolution	0.005% FS or better
Range	Vented: ▪ 3.5 m, 11.5 ft (34.4 kPa, 5 psi) ▪ 11 m, 35 ft (103.4 kPa, 15 psi) ▪ 21 m, 69 ft (206.8 kPa, 30 psi) ▪ 70 m, 231 ft (689.5 kPa, 100 psi) ▪ 211 m, 692 ft (2068 kPa, 300 psi) ▪ 351 m, 1153 ft (3446 kPa, 500 psi) Non-vented: ▪ 10.9 m, 35.8 ft (206.8 kPa, 30 psi) ▪ 60.1 m, 197.3 ft (689.5 kPa, 100 psi) ▪ 200.7 m, 658.7 ft (2068 kPa, 300 psi) ▪ 341.3 m, 1120 ft (3446 kPa, 500 psi) Note: subtract barometric pressure to obtain usable range
Temperature Sensor	
Material	Silicon
Accuracy	+/-0.1°C
Resolution	0.01°C or better
Range	-20° to 80C° (-4° to 176°F). Temperature compensated: -5° to 50°C (23° to 122° F)
RuggedCable® with Twist-Lock Connectors	
Connector	Twist-Lock connector OR stripped & tinned wire
Number of conductors	6
Internal Conductor Material	Polypropylene
Diameter 6.7mm (0.265 in)	Break strength 127 kg (280 lbs)
Bend Radius	2X diameter of cable = 13.72mm / 0.54 in
Cable Types:	Vented or Non-Vented Polyurethane Vented or Non-Vented Halogen-Free Polyurethane - LSZH rated Vented FEP (Generic Teflon®)

Appendix SOP 1C. USGS Two-Peg Test (from Kennedy 1990)

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION

PEG TEST OF ENGINEER'S LEVEL

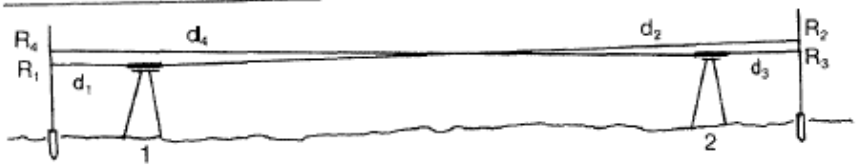
Date _____ Tested by _____

Level type and ID _____

c found _____ Fixed scale ☐

Last test date _____ c left _____ Peg test ☐

TEST AS FOUND



$$* c = 100 \times \frac{(R_1+R_3) - (R_2+R_4 - {}^{**}CR)}{(d_2+d_4) - (d_1+d_3)}$$

$$c = 100 \times \frac{(\quad + \quad) - (\quad + \quad - \quad)}{(\quad + \quad) - (\quad + \quad)}$$

$$c = 100 \times \frac{\quad - \quad}{\quad - \quad} = \quad \text{As found}$$

	R	d
1		
2		
3		
4		

ADJUSTMENT (level remains set up at 2 and sighted at R_4)

Adjust cross hair to $R_4 - \frac{cd_4}{100} =$ _____ = _____

Cross hair setting = _____

REPEAT OF TEST AFTER ADJUSTMENT

$$c = 100 \times \frac{(\quad + \quad) - (\quad + \quad - \quad)}{(\quad + \quad) - (\quad + \quad)}$$

$$c = 100 \times \frac{\quad - \quad}{\quad - \quad}$$

c = _____ As left

	R	d
1		
2		
3		
4		

* c is the collimation factor, the inclination of the line of sight in ft/100 ft, minus when up from the instrument, and plus when down.

**CR is twice the curvature and refraction correction for a sight of $\frac{d_2 + d_4}{2}$ ft. Its value, which increases the rod reading is tabulated at right.

$(d_2 + d_4)/2$	**CR
0 - 110	0
110 - 190	.001
190 - 245	.002
245 - 290	.003
290 - 350	.004

San Francisco Bay Area Network (SFAN) Streamflow Monitoring Protocol: SOPs

Standard Operating Procedure (SOP) 2. Data Management

Version 2.16

Revision History Log

Prev. Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
	12/28/2006	Darren Fong	Used SFAN landbird data management as template		1.0
1.0	3/7/07	D. Press and Marcus Koenen	Added gaps		2.1
2.1	5/3/07	Paul Johnson	Proofreading throughout		2.11
2.11	5/11/07	David Press	Proofreading throughout		2.12
2.12	8/6/08	Paul Johnson	Proofreading throughout		2.13
2.13	2/17/2009	Darren Fong	Updates throughout	New software and procedures from reviewers	2.14
2.14	10/26/09	David Press			2.15
2.15	06/5/2010	Darren Fong, Kris Freeman, Marcus Koenen	General edits, formatting, peer review comments	Response to reviewer comments	2.16

Figures

Page

Figure SOP 2.1. Table relationships in the SFAN Stream Discharge Database. ..... SOP 2.7

Figure SOP 2.2. Database switchboard: Main screen of the user interface, viewed at startup. ..... SOP 2.8

Figure SOP 2.3. Gateway to the data entry screens, for browsing and selecting from data that have already been entered. ..... SOP 2.10

Figure SOP 2.4. Primary field data entry form, displaying the ‘gage height’ and ‘observers’ subforms. ..... SOP 2.11

Figure SOP 2.5. Subform for entering field streamflow measurements associated with sampling events. ..... SOP 2.12

Figure SOP 2.6. Subform for viewing flow-calculated values associated with sampling events. ..... SOP 2.13

Figure SOP 2.7. Subform for entering flume measurement data. ..... SOP 2.14

Figure SOP 2.8. Subform for entering volumetric streamflow measurement data. ..... SOP 2.14

Figure SOP 2.9. Subform for entering digital photo data associated with sampling events. ..... SOP 2.15

Figure SOP 2.10. Subform for entering data verification or editing events associated with sampling events. ..... SOP 2.16

Figure SOP 2.11. Form for entering and editing project location information. ..... SOP 2.17

Figure SOP 2.12. Form for selecting criteria and generating summary flow queries. ..... SOP 2.18

Figure SOP 2.13. Form to view and edit contact information. ..... SOP 2.19

Figure SOP 2.14. Form for entering flow meter descriptions and metadata, including rating equations and maintenance logs. ..... SOP 2.20

Figure SOP 2.15. Form for entering or editing photo point locations and descriptions. ..... SOP 2.21

Figure SOP 2.16. File directory structure for the SFAN Stream Discharge Database. ..... SOP 2.23

Figure SOP 2.17. File directory structure for the digital photos for network. ..... SOP 2.24

Figure SOP 2.18. Form for viewing and entering release information with a subform for known bug descriptions. ..... SOP 2.25

Figure SOP 2.19. Example of directory structure of streamflow files stored on the Marin Headlands server at the Golden Gate National Recreation Area. ..... SOP 2.27

Figure SOP 2.20. Example of an abbreviated site description or metadata worksheet and the relevant fields for Recording Streamgage Spreadsheet. ..... SOP 2.29

Figure SOP 2.21. Example of FieldDescriptor worksheet and relevant fields for Recording Streamgage Spreadsheet. ..... SOP 2.30

Figure SOP 2.22. Example of a site visit and data correction worksheet and relevant fields for Recording Streamgage Spreadsheet. ..... SOP 2.31

Figure SOP 2.23. Example of a data worksheet and relevant fields for Recording Streamgage Spreadsheet. ..... SOP 2.32

Figure SOP 2.24. Example of DailySum worksheet and relevant fields for Recording Streamgage Spreadsheet. ..... SOP 2.33

Figure SOP 2.25. Example of Stage-Discharge Rating Worksheet and relevant data fields. ..... SOP 2.35

Figure SOP 2.26. Example of topographic data spreadsheet and fields for Pine Gulch Creek. ..... SOP 2.42

Tables

Page

Table SOP 2.1. Stream codes used for file names. ..... SOP 2.26

Table SOP 2.2. Field names and types for pre-Water Year 2009 stage discharge worksheet. ..... SOP 2.36

Table SOP 2.3. Field names and types for Water Year 2008 to present stage-discharge file. ..... SOP 2.38

Table SOP 2.4. Field names and types exported for Rainfall Worksheet. ..... SOP 2.39

Table SOP 2.5. Field names and types for Notes Worksheet. ..... SOP 2.39

Table SOP 2.6. Field names and types for Topographic Survey spreadsheet. ..... SOP 2.41

Table SOP 2.7. Field names and types for Level Notes spreadsheet. ..... SOP 2.43

Appendixes

Page

Appendix SOP 2 A. Data Dictionary: Raw Recording Streamgage Data Files ..... SOP 2.47

Purpose

Two critical long-term goals of the SFAN I&M Program are to:

- Integrate natural resource inventory and monitoring information into National Park Service planning, management, and decision making.
- Share National Park Service accomplishments and information with other natural resource organizations and form partnerships for attaining common goals and objectives.

In order for the streamflow monitoring program to meet I&M Program goals, a detailed management plan is needed to ensure data quality, interpretability, security, longevity, and availability. The streamflow monitoring protocol is a data-intensive monitoring program. As an example, a single recording streamgage collecting water surface elevation, battery voltage, and rainfall data every 15 minutes may result in a raw dataset that has more than 120,000 records for each Water Year. In addition, this raw data must be processed to derive estimates of streamflow using stage-discharge relations. With such large datasets, a detailed data management plan is especially critical.

The elements in this SOP meet much of the Quality Assurance Project Plan (QAPP) guidance established by the EPA (EPA 2002). Many of the 24 elements such as data management and sampling methods are items that have already been incorporated as part of the overall monitoring plan and supporting SOPs (e.g., problem definition/background, project/task description, sampling objectives, sampling design, sampling methods, data management, analytical methods, documentation (reporting), project/task organization, staffing plan, training requirements Those typical sections of a QAPP that are not addressed in the protocol and other SOP are discussed below.

Scope and Applicability

The procedures below cover routine data management activities for the SFAN streamflow monitoring program. This Standard Operating Procedure 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. Data management procedures are explained for all the components of the protocol, including field stream discharge measurements, datalogger downloads, raw data processing, stage-discharge rating equation development, rainfall measurements, and stream topography measurements.

Description of Streamflow Monitoring Data Files

SFAN Stream Discharge Database

The SFAN staff has developed a relational Microsoft (MS) Access XP database for the program's field streamflow measurements (see SOP 1) compliant with the Natural Resource Database Template (NRDT) Version 3.1, an application developed by the National Park Service's (NPS) Natural Resource Inventory and Monitoring Program (I&M). The data are organized around sampling events at 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. Table relationships are displayed in Figure 12. A complete data dictionary is built into the database. The user interface for the database is modeled after the NRDT Front-end Application Builder (FAB) Version 1.0, an MS Access user-interface template designed by the NPS Natural Resource GIS Program. The SFAN Stream Discharge Database strays from the NRDT FAB in that it includes the tables with the forms in a single database format, whereas the NRDT FAB is designed for a front-end / back-end database model. All database elements of the NRDT FAB used to link to and manage back-end tables have therefore been removed from the SFAN Stream Discharge Database.

The primary streamflow measurement events table, tbl_Events, is linked to tbl_Event_Details in a one-to-one relationship via an EventID Globally Unique Identifier (GUID) (Figure 12). Whereas, tbl_Events is a standardized table that simply stores event location, date, and time values, tbl_Event_Details stores data values specific to the streamflow sampling events, such as weather details and stream conditions. Tbl_Events is linked to seven tables by one-to-many relationships (Figure 12). Tbl_Gage_Height can store several stream gage heights recorded during a single streamflow measurement event. When digital photos are taken during measurement events, details of the photos, file names, and locations on the Marin Headlands server are stored in tbl_Photos. Actual stream depth and flow measurements taken along a cross section of the stream are entered into tbl_Flow_Data. Tbl_Flume_Data and tbl_Volumetric are used to enter streamflow data that are alternatively collected by flume or volumetric methods. Tbl_DataHistory records any data verification, validation, or editing procedures associated with the streamflow event and related data. Finally, xref_Event_Contacts is a cross-reference table linked to tlu_Contacts which documents the field personnel present during data collection and their role in the sampling event.

Each of the streamflow measurement devices used in the monitoring program is identified with a unique name. The name of the device used in the field during sampling events is entered into the database with the remainder of the event data. A relationship between tbl_Events and tlu_Meters links the event data with metadata pertaining to the streamflow meter used in the field (Figure SOP 2.1). Associated with tlu_Meters are tbl_MaintLog and tbl_RatingEq, which respectively store maintenance records for the streamflow meters and associated rating equations (Figure SOP 2.1).

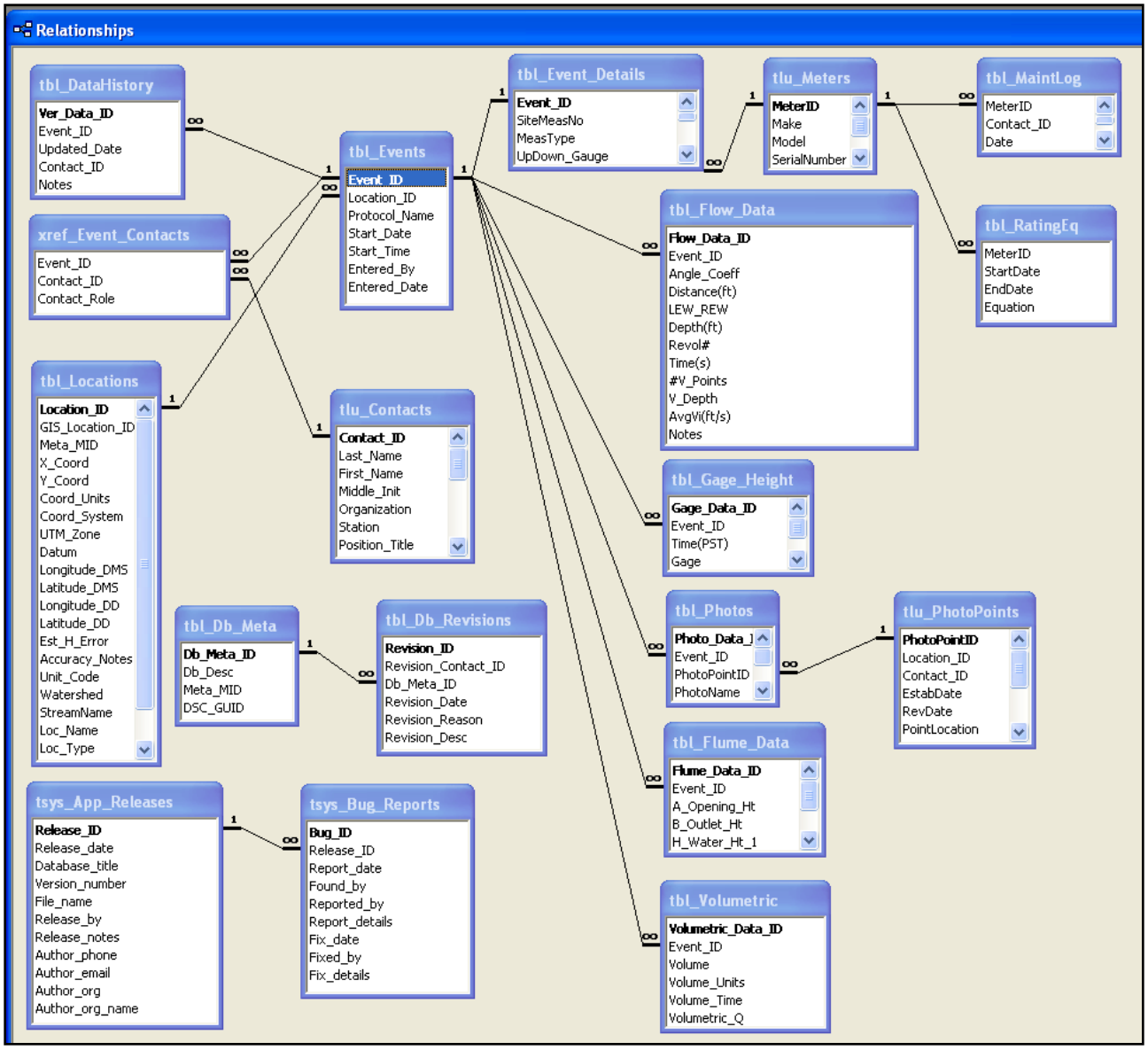


Figure SOP 2.1. Table relationships in the SFAN Stream Discharge Database.

Digital photos taken in the field will often be taken from fixed, defined photo points, which are cataloged in tlu_PhotoPoints. When applicable the PhotoPointID is entered in tbl_Photos so that the photos can be linked to the associated photo point metadata in tlu_PhotoPoints (Figure SOP 2.1).

All data stored in the database are geo-spatially referenced by the link between tbl_Events and tbl_Locations. Users must enter a Location_ID value for each streamflow data collection event. Master Location_ID records are maintained in tbl_Locations, with corresponding geographic coordinates in both UTM and latitude/longitude.

Use of the database is facilitated by a complete user interface adopted from the NRDT Front-End Application Builder Version 1.0. The user interface is designed to aid with data entry, data extraction, and database documentation. Command buttons and code driven text boxes are used to navigate to forms, add data records, locate and edit data records, and query the data. Where possible, default values are set and combo boxes with fixed values are used to reduce data entry errors. For example, all fields that identify project personnel are set as combo boxes which link to the look-up table tlu_Contacts. The user interface includes the following key features:

frm_Switchboard
A start-up or welcome form which allows the user to navigate to data entry forms, set user default values, and view database release history (Figure SOP 2.2). The start-up form is displayed automatically when the database is opened.

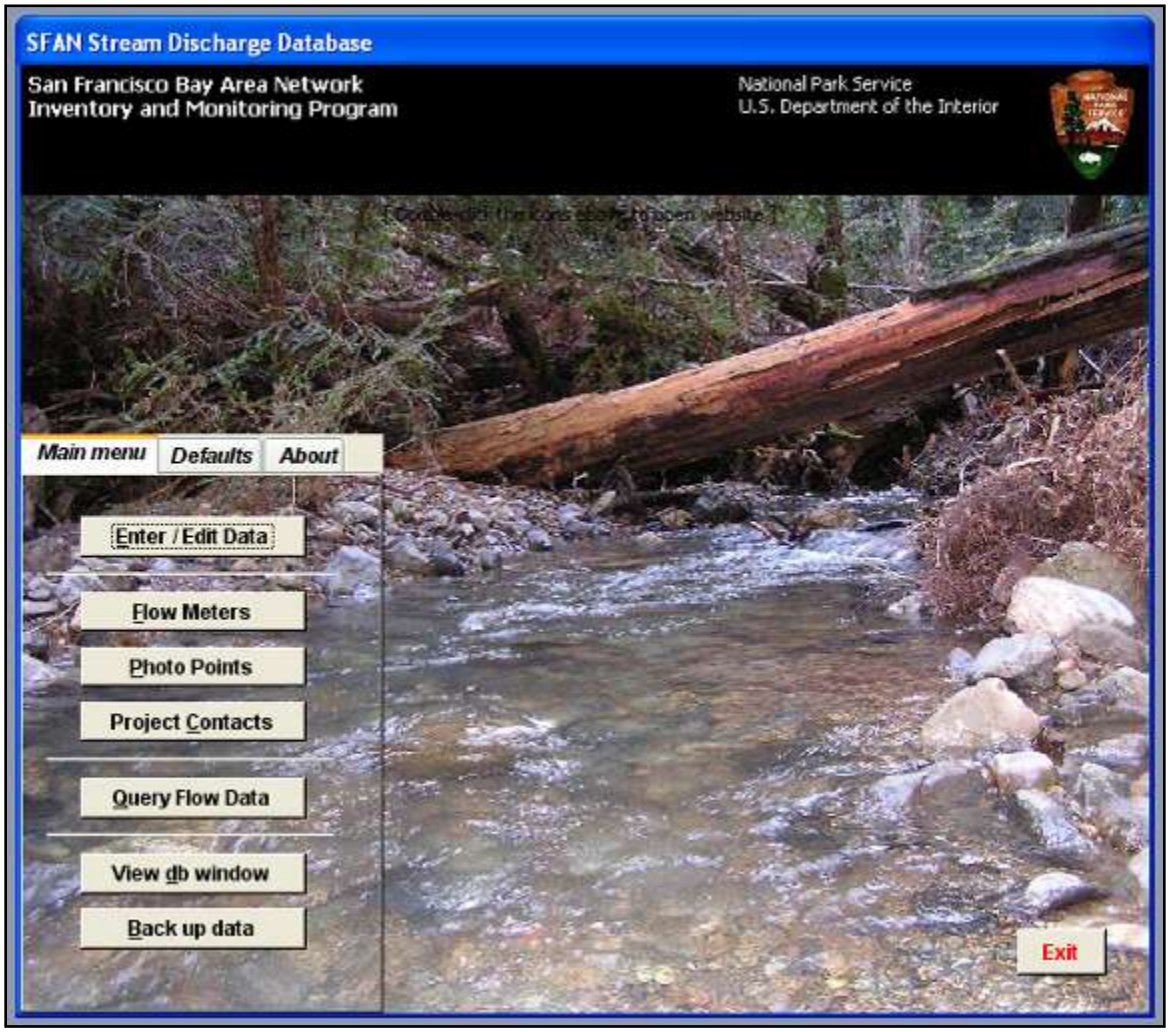
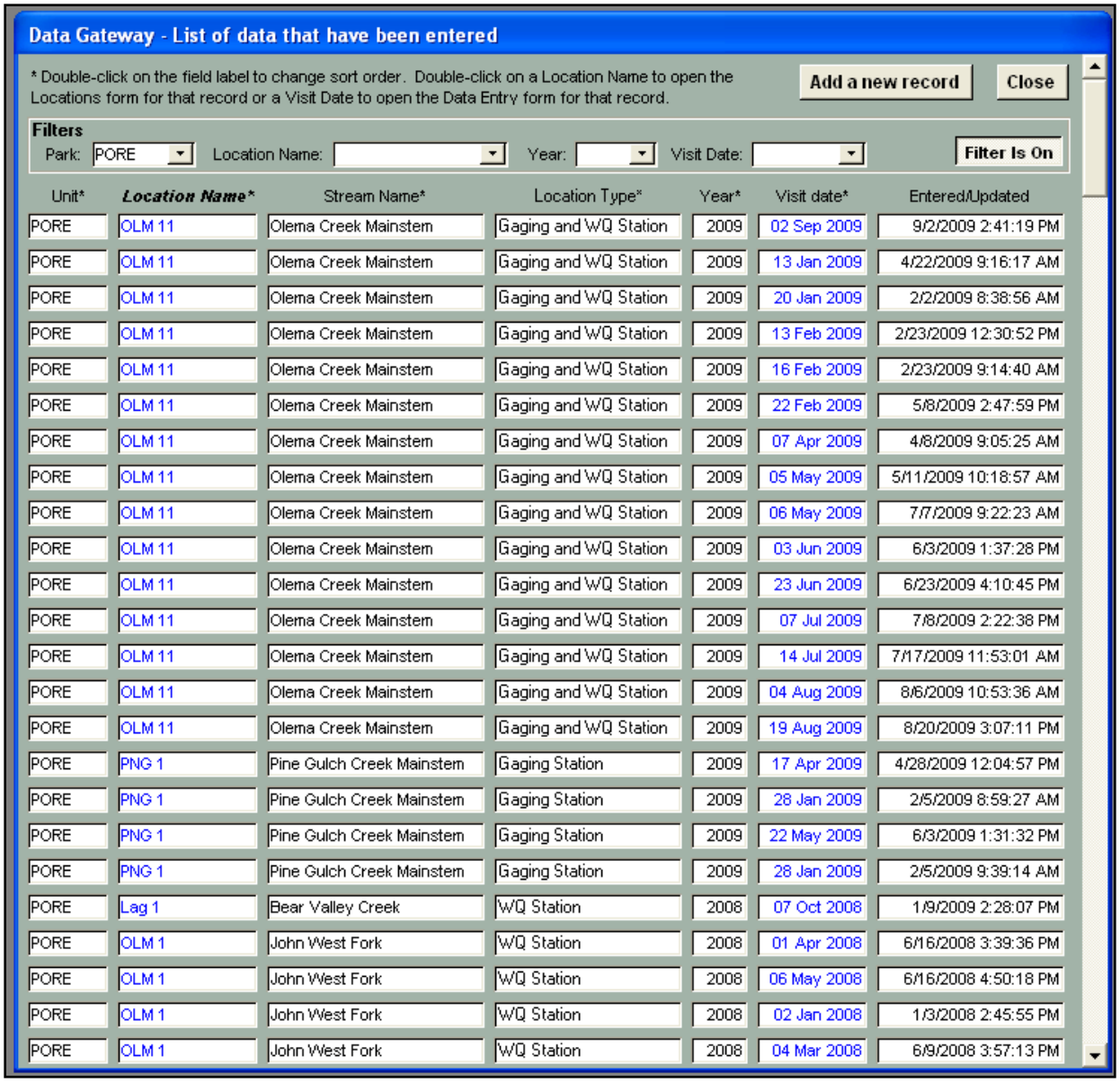


Figure SOP 2.2. Database switchboard: Main screen of the user interface, viewed at startup.

frm_Set_Defaults
Prior to entering or editing streamflow data, user default settings must be set or verified. Frm_Set_Defaults allows the user to specify their name, park, datum, and UTM zone. The values are then used as defaults in the data entry gateway and data entry form. Frm_Set_Defaults can be accessed by clicking the "Enter / Edit Data" button on the "Main Menu" tab of frm_Switchboard or by clicking the "Change" button on the "Defaults" tab of frm_Switchboard. The control source for frm_Set_Defaults is the hidden systems table tsys_App_Defaults.

frm_Data_Gateway
A form that serves as a gateway to the streamflow event data entry form (Figure SOP 2.3). The form allows the user to continue forward to add a new record in frm_Data_Entry or to browse and select from data that has already been entered. Listings for already entered data records are automatically filtered when the form opens based on the user default settings. The form opens after navigating to enter data from frm_Switchboard and entering the user default settings in frm_Set_Defaults. The control source is the query qfrm_Data_Gateway.



Unit*	Location Name*	Stream Name*	Location Type*	Year*	Visit date*	Entered/Updated
PORE	OLM 11	Olema Creek Mainstem	Gaging and WQ Station	2009	02 Sep 2009	9/2/2009 2:41:19 PM
PORE	OLM 11	Olema Creek Mainstem	Gaging and WQ Station	2009	13 Jan 2009	4/22/2009 9:16:17 AM
PORE	OLM 11	Olema Creek Mainstem	Gaging and WQ Station	2009	20 Jan 2009	2/2/2009 8:38:56 AM
PORE	OLM 11	Olema Creek Mainstem	Gaging and WQ Station	2009	13 Feb 2009	2/23/2009 12:30:52 PM
PORE	OLM 11	Olema Creek Mainstem	Gaging and WQ Station	2009	16 Feb 2009	2/23/2009 9:14:40 AM
PORE	OLM 11	Olema Creek Mainstem	Gaging and WQ Station	2009	22 Feb 2009	5/8/2009 2:47:59 PM
PORE	OLM 11	Olema Creek Mainstem	Gaging and WQ Station	2009	07 Apr 2009	4/8/2009 9:05:25 AM
PORE	OLM 11	Olema Creek Mainstem	Gaging and WQ Station	2009	05 May 2009	5/11/2009 10:18:57 AM
PORE	OLM 11	Olema Creek Mainstem	Gaging and WQ Station	2009	06 May 2009	7/7/2009 9:22:23 AM
PORE	OLM 11	Olema Creek Mainstem	Gaging and WQ Station	2009	03 Jun 2009	6/3/2009 1:37:28 PM
PORE	OLM 11	Olema Creek Mainstem	Gaging and WQ Station	2009	23 Jun 2009	6/23/2009 4:10:45 PM
PORE	OLM 11	Olema Creek Mainstem	Gaging and WQ Station	2009	07 Jul 2009	7/8/2009 2:22:38 PM
PORE	OLM 11	Olema Creek Mainstem	Gaging and WQ Station	2009	14 Jul 2009	7/17/2009 11:53:01 AM
PORE	OLM 11	Olema Creek Mainstem	Gaging and WQ Station	2009	04 Aug 2009	8/6/2009 10:53:36 AM
PORE	OLM 11	Olema Creek Mainstem	Gaging and WQ Station	2009	19 Aug 2009	8/20/2009 3:07:11 PM
PORE	PNG 1	Pine Gulch Creek Mainstem	Gaging Station	2009	17 Apr 2009	4/28/2009 12:04:57 PM
PORE	PNG 1	Pine Gulch Creek Mainstem	Gaging Station	2009	28 Jan 2009	2/5/2009 8:59:27 AM
PORE	PNG 1	Pine Gulch Creek Mainstem	Gaging Station	2009	22 May 2009	6/3/2009 1:31:32 PM
PORE	PNG 1	Pine Gulch Creek Mainstem	Gaging Station	2009	28 Jan 2009	2/5/2009 9:39:14 AM
PORE	Lag 1	Bear Valley Creek	WQ Station	2008	07 Oct 2008	1/9/2009 2:28:07 PM
PORE	OLM 1	John West Fork	WQ Station	2008	01 Apr 2008	6/16/2008 3:39:36 PM
PORE	OLM 1	John West Fork	WQ Station	2008	06 May 2008	6/16/2008 4:50:18 PM
PORE	OLM 1	John West Fork	WQ Station	2008	02 Jan 2008	1/3/2008 2:45:55 PM
PORE	OLM 1	John West Fork	WQ Station	2008	04 Mar 2008	6/9/2008 3:57:13 PM

Figure SOP 2.3. Gateway to the data entry screens, for browsing and selecting from data that have already been entered.

frm_Data_Entry

The streamflow sampling event data entry form with subforms nested within separate tabs at the bottom of the form (Figure SOP 2.4). The control source is the query qfrm_DataEntry. Frm_Data_Entry is accessed from frm_Data_Gateway. The subforms include:

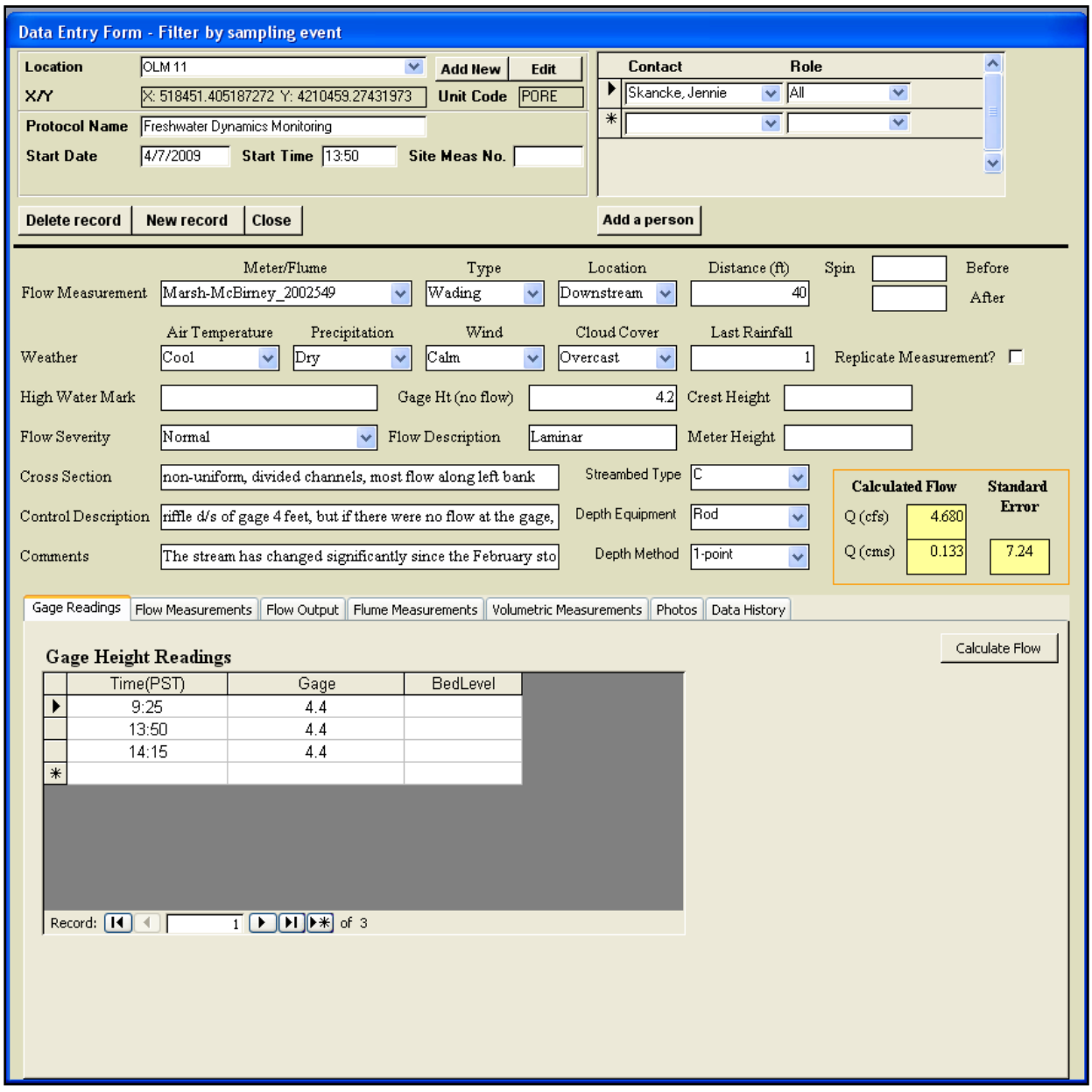


Figure SOP 2.4. Primary field data entry form, displaying the 'gage height' and 'observers' subforms.

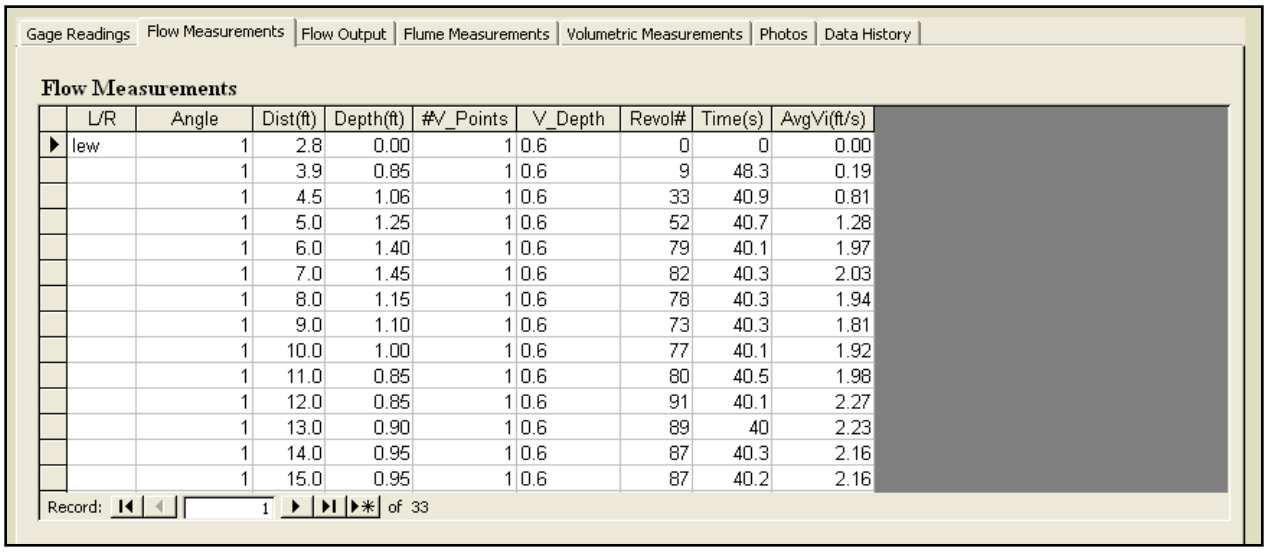
fsub_GageHeight

The gage height data entry subform of the primary field data entry form (Figure SOP 2.4). The control source is tbl_GageHeight. At Lobos Creek in the Presidio of San Francisco a permanent H-flume has been installed and is maintained by the Presidio Trust which has a water treatment

plant on the creek (see SOP 3. Stream Gage Station Locations). Streamflow can be determined by simply reading the gage height at the monitoring station. Clicking the "Calculate Flow" command button runs the macro mcr_FlumeFlow, which confirms the H-Flume as the MeterID and then populates the cumulative flow values [Q(cfs)] and [Q(cms)] in tbl_Event_Details.

fsub_FlowMeasurements

The stream depth and flow measurements data entry form (Figure SOP 2.5). The control source is tbl_FlowData.

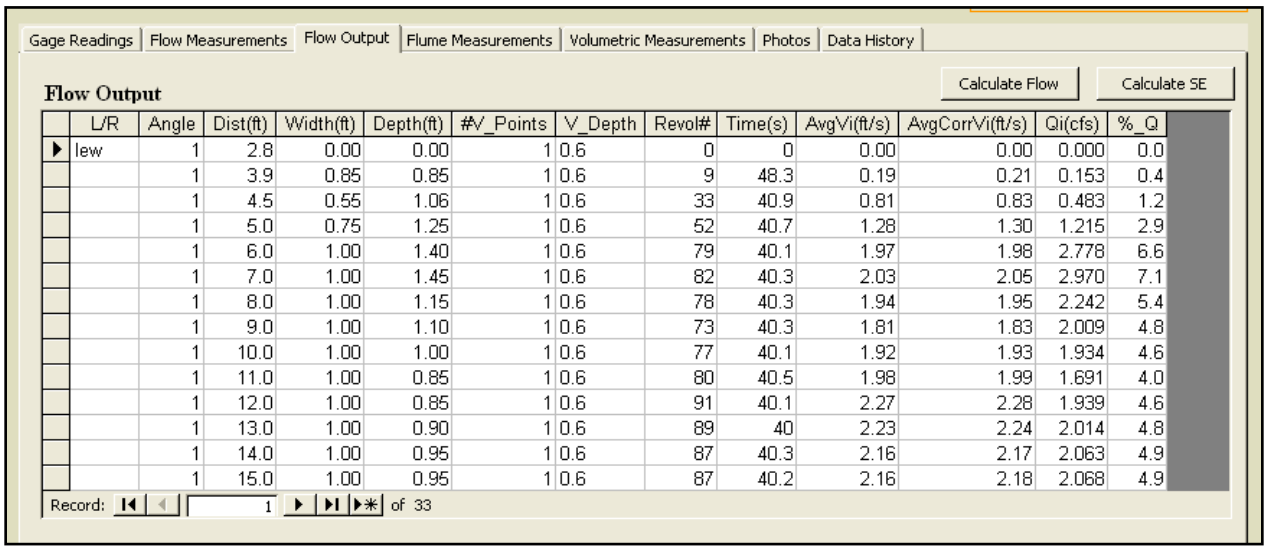


L/R	Angle	Dist(ft)	Depth(ft)	#V_Points	V_Depth	Revol#	Time(s)	AvgVi(ft/s)
lew	1	2.8	0.00	1	0.6	0	0	0.00
	1	3.9	0.85	1	0.6	9	48.3	0.19
	1	4.5	1.06	1	0.6	33	40.9	0.81
	1	5.0	1.25	1	0.6	52	40.7	1.28
	1	6.0	1.40	1	0.6	79	40.1	1.97
	1	7.0	1.45	1	0.6	82	40.3	2.03
	1	8.0	1.15	1	0.6	78	40.3	1.94
	1	9.0	1.10	1	0.6	73	40.3	1.81
	1	10.0	1.00	1	0.6	77	40.1	1.92
	1	11.0	0.85	1	0.6	80	40.5	1.98
	1	12.0	0.85	1	0.6	91	40.1	2.27
	1	13.0	0.90	1	0.6	89	40	2.23
	1	14.0	0.95	1	0.6	87	40.3	2.16
	1	15.0	0.95	1	0.6	87	40.2	2.16

Figure SOP 2.5. Subform for entering field streamflow measurements associated with sampling events.

fsub_FlowOutput

A subform that displays all measured field values along with calculated flow values (Figure SOP 2.6). The control source for the subform is the query qfrm_FlowOutput. The four calculated values - [Width(ft)], [AvgCorrVi(ft/s)], [Qi(cfs)], and [%_Q] - are not written to tbl_FlowData, but are instead dynamic values resulting from measured values stored in tbl_FlowData.



	L/R	Angle	Dist(ft)	Width(ft)	Depth(ft)	#V_Points	V_Depth	Revol#	Time(s)	AvgVi(ft/s)	AvgCorrVi(ft/s)	Qi(cfs)	%_Q
▶	lew	1	2.8	0.00	0.00	1	0.6	0	0	0.00	0.00	0.000	0.0
		1	3.9	0.85	0.85	1	0.6	9	48.3	0.19	0.21	0.153	0.4
		1	4.5	0.55	1.06	1	0.6	33	40.9	0.81	0.83	0.483	1.2
		1	5.0	0.75	1.25	1	0.6	52	40.7	1.28	1.30	1.215	2.9
		1	6.0	1.00	1.40	1	0.6	79	40.1	1.97	1.98	2.778	6.6
		1	7.0	1.00	1.45	1	0.6	82	40.3	2.03	2.05	2.970	7.1
		1	8.0	1.00	1.15	1	0.6	78	40.3	1.94	1.95	2.242	5.4
		1	9.0	1.00	1.10	1	0.6	73	40.3	1.81	1.83	2.009	4.8
		1	10.0	1.00	1.00	1	0.6	77	40.1	1.92	1.93	1.934	4.6
		1	11.0	1.00	0.85	1	0.6	80	40.5	1.98	1.99	1.691	4.0
		1	12.0	1.00	0.85	1	0.6	91	40.1	2.27	2.28	1.939	4.6
		1	13.0	1.00	0.90	1	0.6	89	40	2.23	2.24	2.014	4.8
		1	14.0	1.00	0.95	1	0.6	87	40.3	2.16	2.17	2.063	4.9
		1	15.0	1.00	0.95	1	0.6	87	40.2	2.16	2.18	2.068	4.9

Record: 1 of 33

Figure SOP 2.6. Subform for viewing flow-calculated values associated with sampling events.

The values are generated either through functions written in Visual Basic code or expressions written in SQL and are locked for editing in the subform. After entering field data in fsub_FlowMeasuremnts, the database user tabs to “Flow Output” and selects the command button “Calculate Flow”. The command button runs a macro (mcr_FinalFlow) that refreshes fsub_FlowOutput so that all of the measured and calculated values can be viewed. The command button also populates the cumulative flow values [Q(cfs)] and [Q(cms)] in tbl_Event_Details. The calculated values in the subform are automatically re-calculated when the field measurements are edited, but the cumulative streamflow must be re-calculated by selecting “Calculate Flow” again. The discharge calculations are based on USGS mid-section method (Harrelson et al. 1994).

The “Calculate SE” button generates the standard error of the discharge measurement. Clicking the button runs the macro titled mcr_StdError, which calculates the standard error and then populates that value in the Std_Error field of tbl_Event_Details. The equations for estimating standard error for Price-style pygmy and AA meters are provided in Sauer and Meyer (1992). We have derived standard error estimates for Swoffer 2100 and Marsh-McBirney Flo-Mate meters based on test data from Fulford (2001) and described further in our SOP 9-Quality Assurance Plan (see Error estimation for discharge measurements).

fsub_FlumeMeasurements

The flume data subform (Figure SOP 2.7) is only used for field surveys in which a Parshall flume was utilized to determine the streamflow. The flume measurements subform is utilized to enter the heights at point A, B, and H which are labeled on the Parshall flume. Heights A and B are used to calculate the submergence ratio which must be less than 0.60. The database will calculate the average H based on the three field measurements and the flow using the formula for the flume. The sub-ratio and average height fields in the subform are automatically calculated values. Clicking the "Calculate Flow" command button runs the macro mcr_FlumeFlow, which confirms the Parshall flume as the MeterID and then populates the cumulative flow values [Q(cfs)] and [Q(cms)] in tbl_Event_Details.

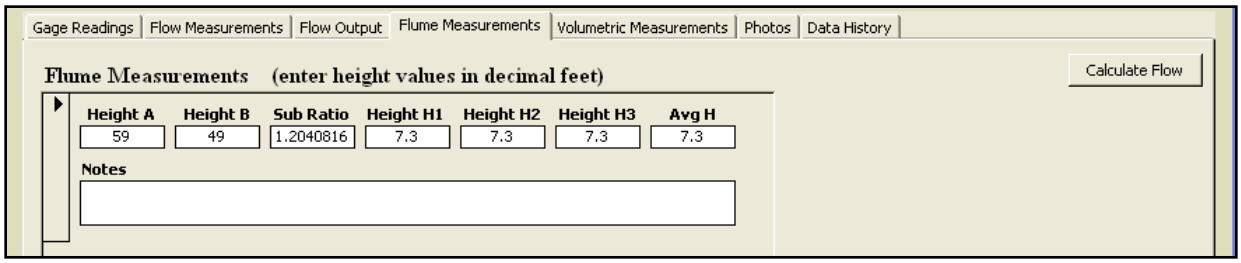


Figure SOP 2.7. Subform for entering flume measurement data.

fsub_Volumetric

The subform for volumetric flow measurements (Figure SOP 2.8) is only used occasionally when data is collected using volumetric methods during very low flow conditions (see SOP 10: Field Methods for Streamflow Measurements). The "Volumetric_Q" field is automatically calculated based on the volume, time, and unit measurement values entered. The calculation is driven by the macro mcr_VolumetricFlow. The macro mcr_ VolumetricFlow also populates the cumulative flow values [Q(cfs)] and [Q(cms)] in tbl_Event_Details, which is run by clicking the "Calculate Flow" command button. The macro confirms the method as volumetric before running the calculations.

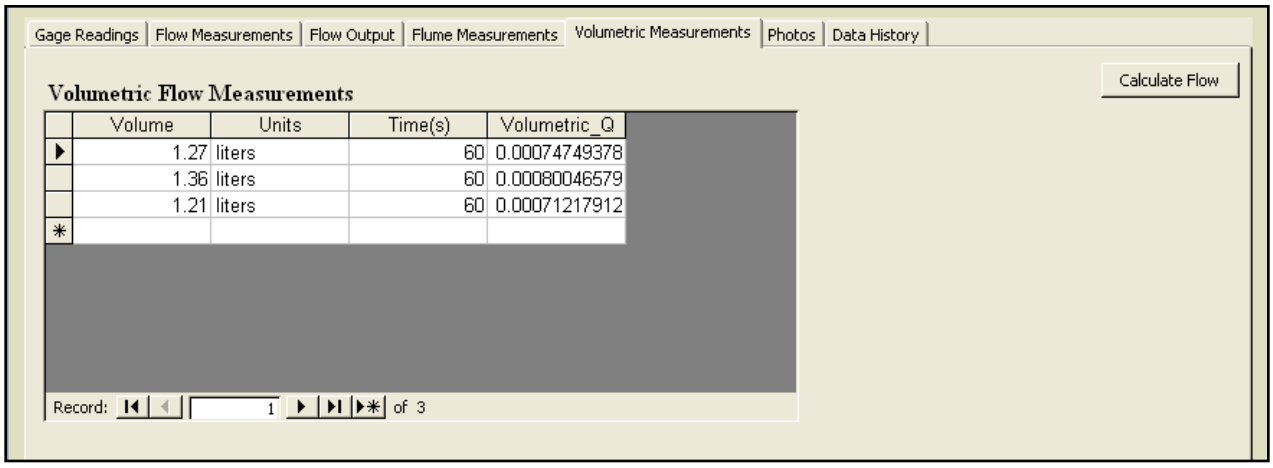


Figure SOP 2.8. Subform for entering volumetric streamflow measurement data.

fsub_Photos

The photo subform uses VBA code to display the photo identified by the directory path and photo title in the PhotoName field (Figure SOP 2.9). The Browse button opens an explorer window that allows the user to locate and select the desired photo. When selected, the entire path and file name are automatically entered into the PhotoName field. The control source for the subform is tbl_Photos.

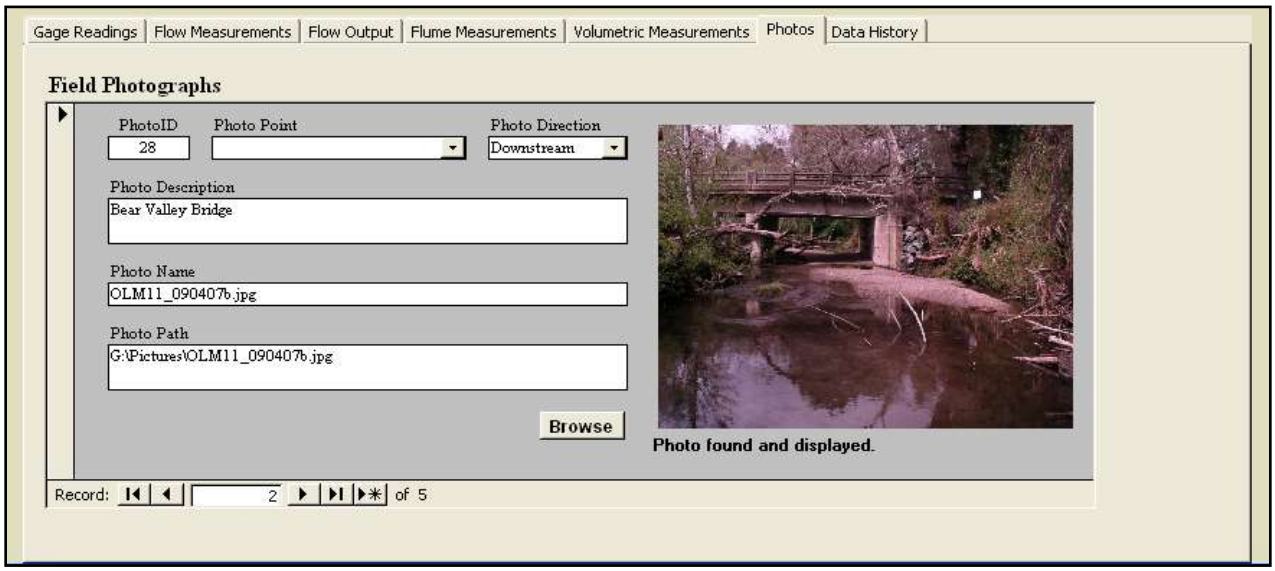


Figure SOP 2.9. Subform for entering digital photo data associated with sampling events.

fsub_DataHistory

The data history subform (Figure SOP 2.10). This subform is used to note data verification events and especially to track relevant edits to existing data. The control source is tbl_DataHistory.

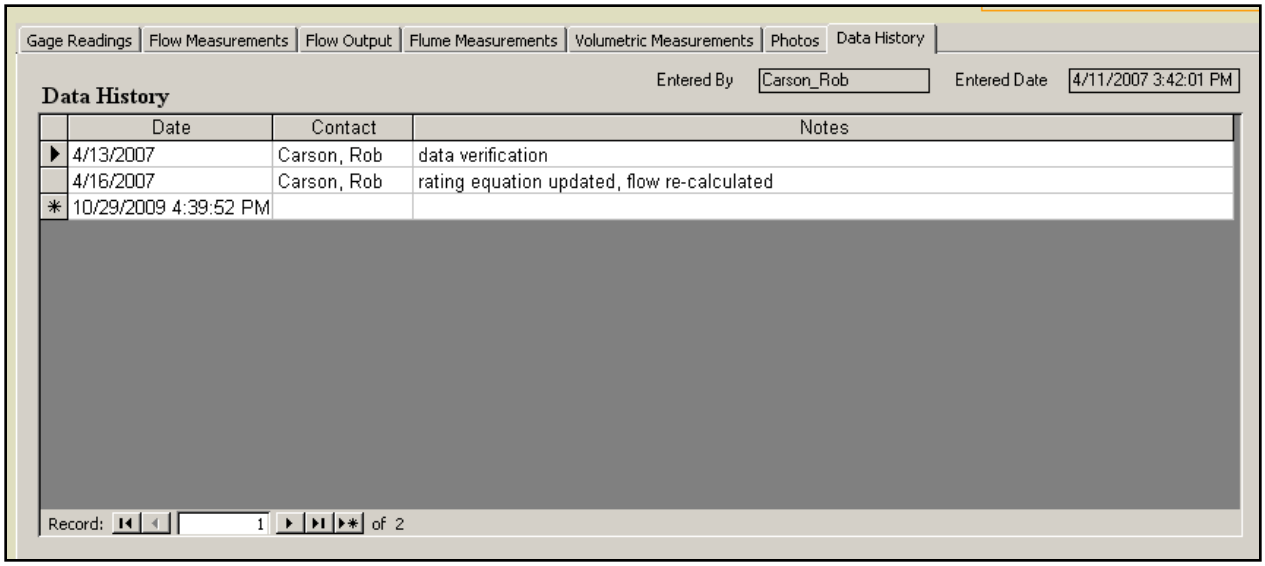


Figure SOP 2.10. Subform for entering data verification or editing events associated with sampling events.

fsub_Observers
Data entry subform for observers associated with sampling events (Figure SOP 2.4). The control source is xref_Event_Contacts.

frm_Locations
A form that allows the user to enter or edit information, including geographic UTM coordinates, for project sampling locations (Figure SOP 2.11). The control source is tbl_Locations. Frm_Locations can be accessed from frm_Data_Gateway and frm_Data_Entry.

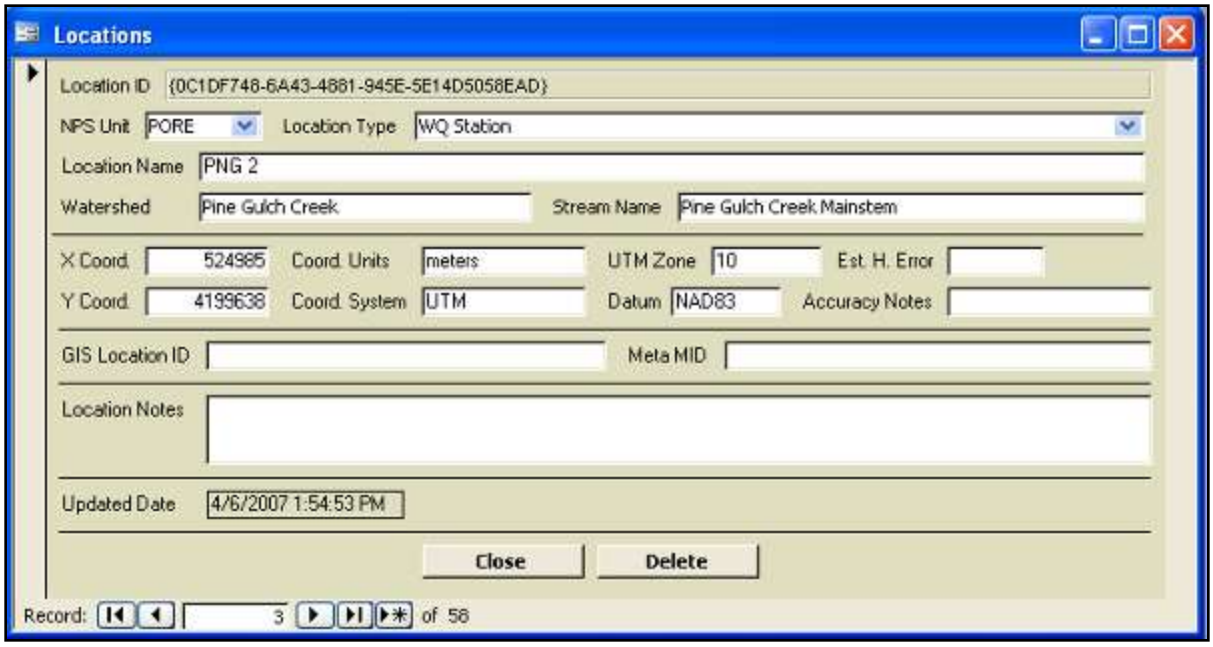


Figure SOP 2.11. Form for entering and editing project location information.

frm_QueryFlow

A form that allows the user to open a flow data query (qry_FlowQuery) based on a location and range of dates (Figure SOP 2.12). For each record that matches the entered criteria, the query displays the location, date, time, discharge in cubic feet per second, discharge in cubic meters per second, and gage height. The gage height may be displayed as a single value, an arithmetic mean, or a time-weighted average depending on how the data was collected. Data from these queries can then be exported to develop streamflow rating curves (see SOP 7). Frm_QueryFlow is accessed from frm_Switchboard. Controls for the form are set in the macro mcr_QueryFlow.

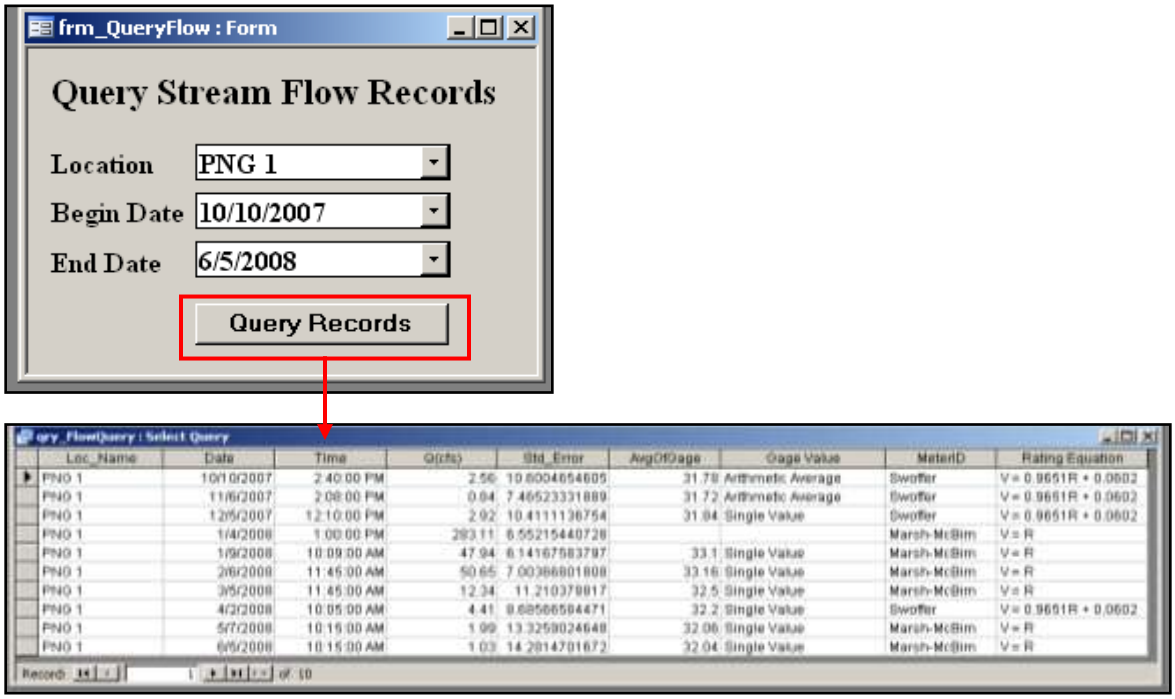


Figure SOP 2.12. Form for selecting criteria and generating summary flow queries.

frm_Contacts

A form that allows the user to enter or edit project personnel names, status, and contact information (Figure SOP 2.13). The control source is tlu_Contacts. Frm_Contacts can be accessed from frm_Switchboard, frm_Set_Defaults, and frm_Data_Entry.

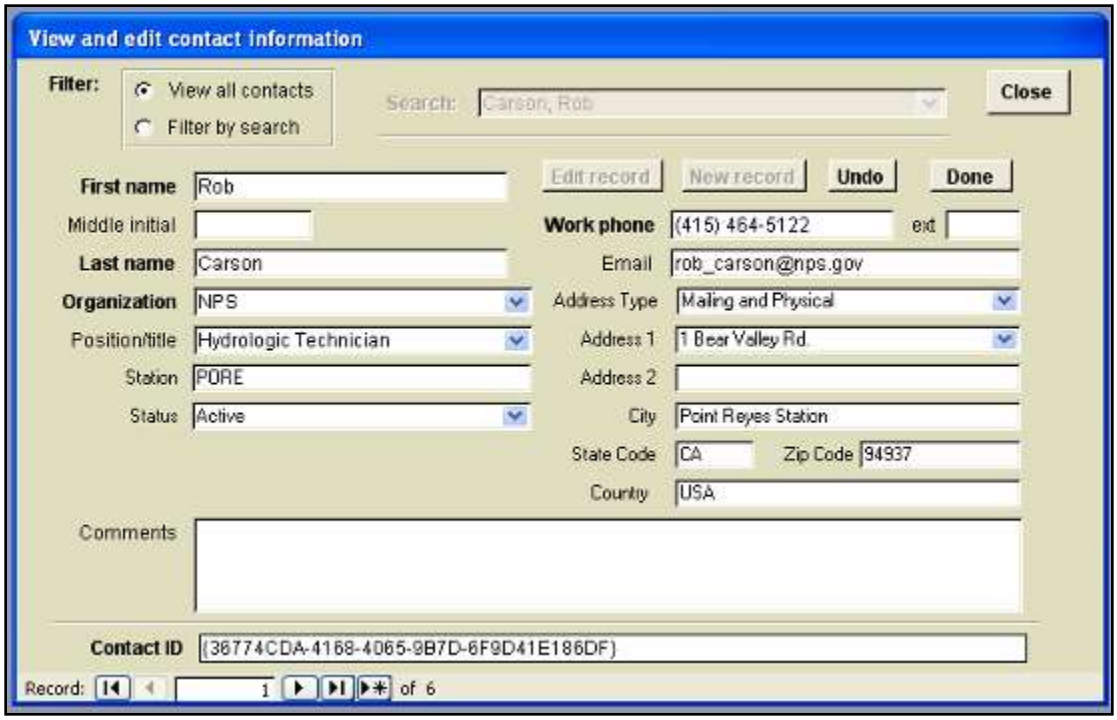


Figure SOP 2.13. Form to view and edit contact information.

frm_Meters

A form that allows the user to enter or edit metadata pertaining to the flow meters used in the field (Figure SOP 2.14). The control source is tlu_Meters. Two subforms are embedded within frmMeters, fsub_MaintLog and fsub_RatingEquations. Flow meter maintenance data is entered in fsub_MaintLog, for which the control source is tbl_MaintLog. Tbl_MaintLog also provides information regarding equipment checks such as spin-tests for mechanical meters. Flow meter rating equations are entered in fsub_RatingEquations, for which the control source is tbl_RatingEq. Frm_Meters can be accessed from frm_Switchboard.

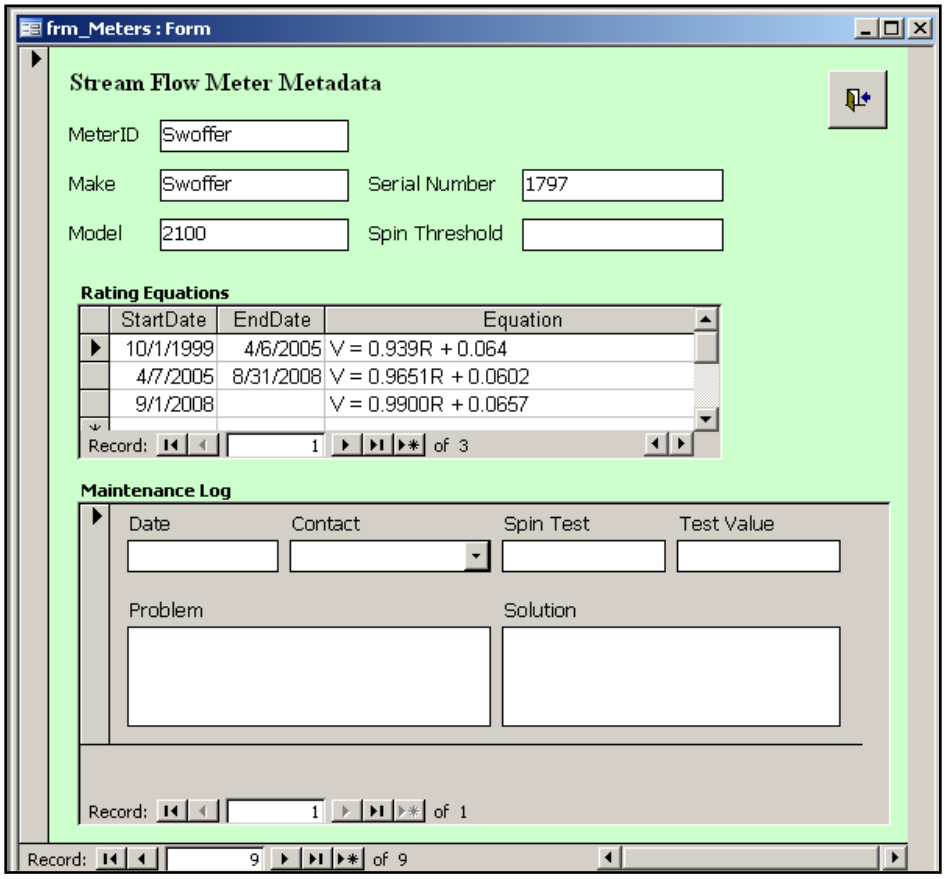


Figure SOP 2.14. Form for entering flow meter descriptions and metadata, including rating equations and maintenance logs.

frm_PhotoPoints
A form that allows users to enter or edit photo point data, including photo point descriptions and locations (Figure SOP 2.15). The control source is tlu_PhotoPoints. Frm_PhotoPoints can be accessed from frm_Switchboard. Controls for the form are set in the macro mcr_PhotoPoints.

Data Entry, Review, Verification and Validation
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.

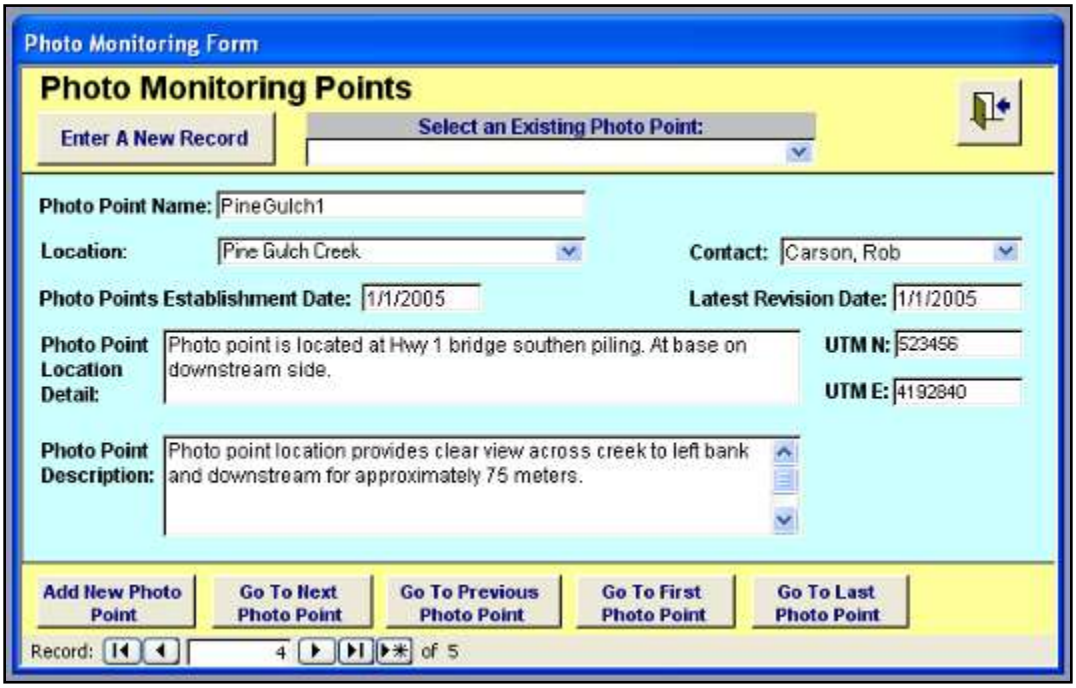


Figure SOP 2.15. Form for entering or editing photo point locations and descriptions.

There are a few important data entry items described in more detail here. These items include the following:

1. Replicate or Check Discharge Measurements
   As part of this program's data precision objective and verification procedures, replicate discharge measurements are obtained for 10% of all discharge measurements. Original and replicate discharge measurements are entered into the database separately. For replicate measurements, the entire event and discharge measurement information is entered. The 'Replicate Measurement?' check box is selected, denoting that the data is a replicate (Figure SOP 2.4).
2. Number of Vertical Measurements
   Standard velocity measurements are taken at 0.6 of the depth from the surface, and the number of vertical measurements therefore defaults to 1 in the field '#V_Points'. The

'#V_Points' field will also accept a value of 2, when measurements are taken at 0.2 and 0.8 of the depth from the surface, or 'S' for surface measurements.

3. Uncorrected, Mean Velocity
   The discharge database requires the database user to input the uncorrected velocity per vertical into the field 'AvgVi'. When there are two measurement depths in the vertical, the database user should use a calculator or other means to calculate the uncorrected, mean velocity and enter this value into the 'AvgVi' field. The database will correct the entered data using the appropriate meter rating equation.

Review and verification of data entries are 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 new water year. Once this is done, the field technician should signify that the data were checked by entering his/her name in the *Completed by* and *Checked by* fields on the *Discharge and Water Quality Measurement Form.* Furthermore, the program manager should verify discharge measurement data entries by field technicians. For new field technicians, 100 percent of discharge data entries will be done 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. Records of all data verification procedures and edits to the data should be noted in the database via the data history subform of each survey event (Figure SOP 2.10).

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 Stream Discharge 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).

Prior discharge calculations using spreadsheets by individual parks have resulted in many erroneous discharge calculations caused by copy-and-paste errors associated with meter rating equations and calculation of mid-section widths. Through the use of combo boxes and VBA code driven fields, the new database will significantly reduce the amount of data entry and calculation errors.

Despite final data verification and validation procedures, the stream discharge dataset should not be considered static in that future additions, corrections, and improvements to the data may occur. Any changes made to the dataset following final certification will be documented in tbl_DataHistory. Prior to editing a dataset, a back-up copy of the database should be created so that a record of the unedited data is kept and so that you can recover from any mistakes that may occur while editing.

File Naming Convention and File Structure

The SFAN Stream Discharge Database is currently in Version 1.04 and is named IM_Flow_Dbase_v1_04.mdb. The database is stored in the Natural Resources directory on the

PORE server (inppore05) at Bear Valley Headquarters in the Water directory under the folder "Stream Flow" (Figure SOP 2.16). Within this folder are additional "Back-Up" and "Archive" folders, which will respectively store back-up copies of the active database and archives of previous database versions. Back-up copies of the active database can be made from the "Main Menu" tab on frm_Switchboard. Alternatively, if the back-up option is checked under the "Defaults" tab, the database will prompt the user to back-up the database on exit. The back-up feature of the database stores a copy of the database in the "Stream Flow" folder with a default name based on the original file name and the date/time that the back-up was made. The format for the file name is *[Original file name]_yyyymmdd_hhmmss.mdb*, such as IM_Flow_Dbase_v1_00_20070323_133107. Back-up copies of the database can then be moved to the "Back-Up" folder.

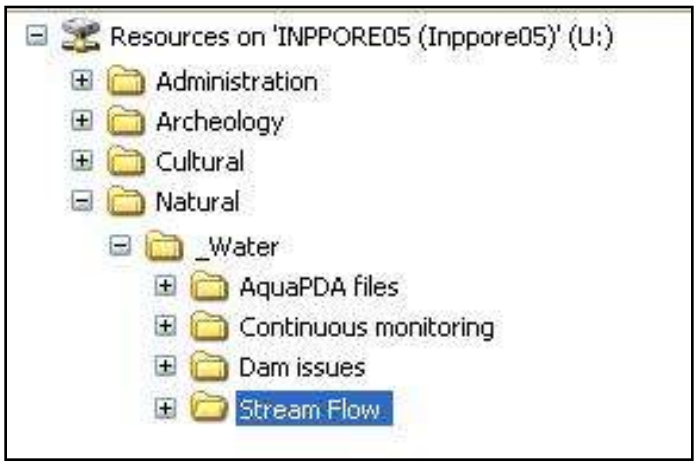


Figure SOP 2.16. File directory structure for the SFAN Stream Discharge Database.

Digital photographs associated with stream flow monitoring will be stored on the PORE server (inppore01) in their native format (e.g., its unaltered filename and format from the camera). Some photographs are shared by the NPSTORET database, and the photos are therefore stored in the NPSTORET directory in the Pictures folder (Figure SOP 2.17). The photo subform (Figure SOP 2.9) paths to photos stored within this directory.

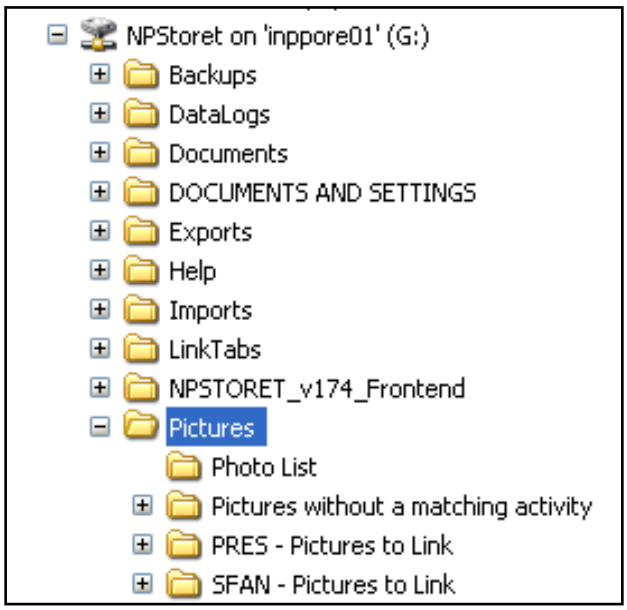


Figure SOP 2.17. File directory structure for the digital photos for network.

Archival Procedures

Once data entries have been entered and proofed, the original datasheets and field notebooks will be archived with the GOGA Park Archives (currently Bldg 667, The Presidio of San Francisco). Data will be organized for the Archives and cataloged by park and water year. Copies of datasheets will be located at offices of respective field staff in PINN, PORE, and GOGA. Datasheet copies from all sites will be stored with the program lead at Fort Cronkhite, Sausalito.

Database Metadata, Version Control Guidelines, Release and Revision Documentation

Several elements within the SFAN Stream Discharge Database help to document database metadata, release and revision history. First, the database retains two tables (tbl_Db_Meta and tbl_Db_Revisions) from the NRDT Version 3.1 for capturing metadata that are maintained by the SFAN Data Manager. The table tbl_Db_Meta is designed to facilitate metadata creation and integration with I&M metadata systems. The field Db_Meta_ID is the primary key for tbl_Db_Meta and provides the link to revision history records in tbl_Db_Revisions. The Db_Desc field is a memo field for describing the purpose of the database application. When metadata for the NRDT database is uploaded to the NPS Data Store, the Meta_MID field stores the metadata master ID generated upon upload. When metadata for the database is created using the I&M Dataset Catalog desktop metadata application, the globally unique record ID generated by the Dataset Catalog should be copied to the DSC_GUID field. The table tbl_Db_Revisions stores the application revision history. Linking tbl_Db_Revisions to tbl_Db_Meta using Db_Meta_ID facilitates accessing the revision history for inclusion in each metadata record.

Adopted from the NRDT FAB, the hidden systems table tsys_App_Releases is used to document release information for all versions of the database application. It is filled in by the SFAN Data Manager before the application is distributed. Included in tsys_App_Releases are the title, version, release date, and information about the author of the application. Associated with tsys_App_Releases is tsys_Bug_Reports, where the SFAN Data Manager can report any known bugs, such as non-working or dysfunctional features of the database. The table includes details of the problem and when / how it was fixed. The form frm_App_Releases (Figure SOP 2.18) allows the database user to view the release history and known bug information in a read-only format. The form can be accessed from frm_Switchboard's "About" tab.

Significant database re-design may require approval by the project manager and review by other data management staff. Following completion of a new database version, metadata records and online postings will be updated.

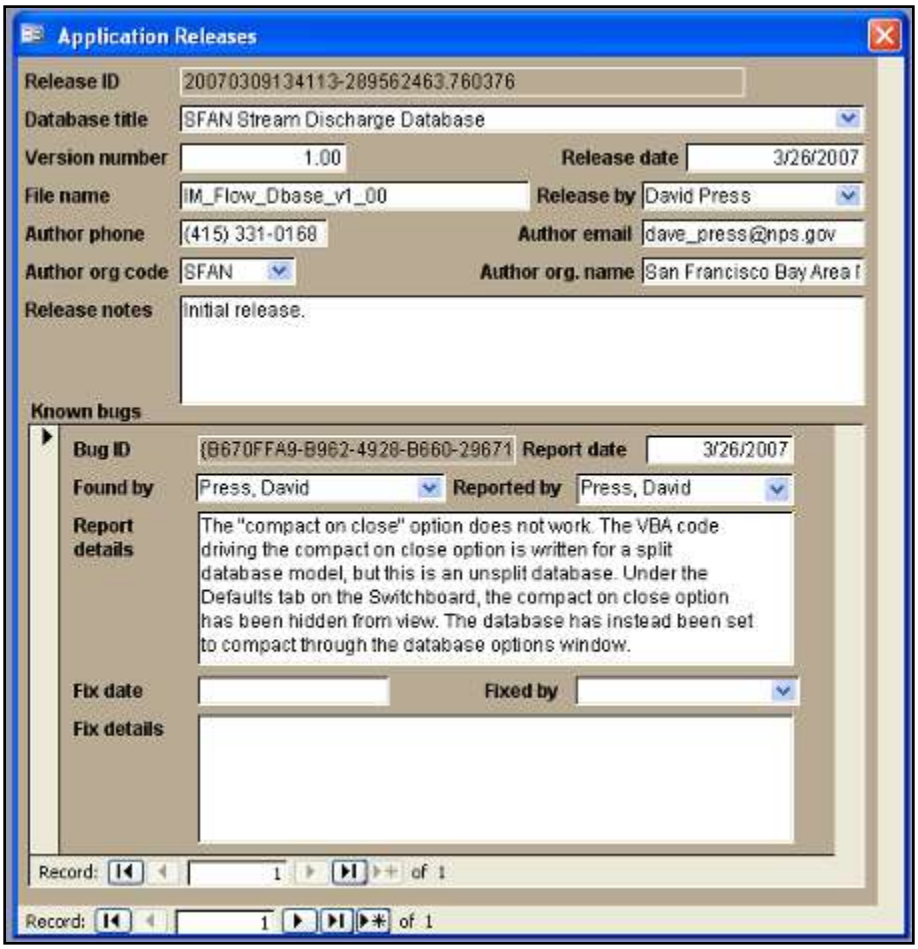


Figure SOP 2.18. Form for viewing and entering release information with a subform for known bug descriptions.

Version control guidelines for the MS Access streamflow monitoring database will follow those presented in the SFAN's Data Management Plan (Press 2005). Prior to any major changes to the database design, a back-up copy of the database should be made. Once the database design changes are complete, the database should be assigned the next incremental version number. The final copy of the previous database version should be archived with the version closing date incorporated into the database title. Version numbers should increase incrementally by hundredths (e.g. version 1_01, version 1_02, etc.) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2_0, 3_0, 4_0 …). With proper controls and communication, versioning ensures that only the most current database version is used for queries and analyses.

Raw Recording Streamgage Data Files

Each recording streamgage's 15-minute data, regardless of datalogger type (Campbell Scientific, In-Situ and Global Water), are downloaded monthly in the field using computer laptops and saved as comma-delimited text files (SOP 1). This raw dataset is similar in nature to the field data forms for individual discharge measurement. They represent data that should not be altered in any fashion after collection. Any data modifications should occur at later steps (e.g., treatment of missing data, correcting stage heights) and require documentation (See SOP 7 Data Analysis and Reporting).

File Naming Convention and File Structure: A standardized file naming convention will be used for all raw recording streamgage data files. The file name will include a 2-letter station code followed by 2-digit year code, 2-digit month code, and 2-digit date which correspond to the date of download. Campbell Scientific saves its files with *.dat extension while In-Situ and Global Water save their files with a *.csv extensions. The station letter codes are as follows (Table SOP 2.1):

Table SOP 2.1. Stream codes used for file names.

Park Unit	Stream Code	Stream Name	Location
PORE	OL	Olema Creek	Bear Valley Road Bridge
PORE	PG	Pine Gulch Creek	below Olema-Bolinas Road
GOGA	EK	Easkoot Creek	below Park entrance road
GOGA	RW	Redwood Creek	at Highway One
JOMU	FR	Franklin Creek	at Orchard Trail foot bridge
PINN	CH	Chalone Creek	At Chalone Creek Bridge
PINN	SC	Sandy Creek	At Pinnacles Campground
PINN	BG	Bear	Below Bear Visitor Center

For example, a hypothetical raw data file for a download date of February 2, 2007 at Olema Creek would be "OL070202.dat" for a Campbell Scientific datalogger.

After the raw data is downloaded, the files are transferred to the SFAN network drive. The file structure is standardized. Each streamgage has its own folder and within each folder, there is a raw data folder labeled "DAT raw files" (Figure SOP 2.19) where all raw data for the streamgage is housed.

Dataset Structure: Each of the raw data files are comma-delimited files with file naming conventions as described in the paragraphs above. Each raw data file will have data fields that differ slightly between each streamgage. However, there are core fields that are identical including date and time, raw instantaneous stage (15-minute interval), battery voltage, and rainfall (if available). Appendix SOP 2A includes the list of all field definitions for each streamgage.

Data Entry, Verification and Validation: Potential problems in the raw datasets may be identified in the field during downloading activities. Field datasheets are used to record general field conditions, work performed during the station visit, and observed conditions (e.g., stage, date, time). Observed conditions are then compared with recorded raw data from the datalogger. Potential signs of problems include low battery voltage and erroneous transducer data. Although all or portions of the raw dataset may appear to have problems, no data corrections will occur in the raw dataset. These activities are deferred to the Recording Streamgage Spreadsheets explained below.

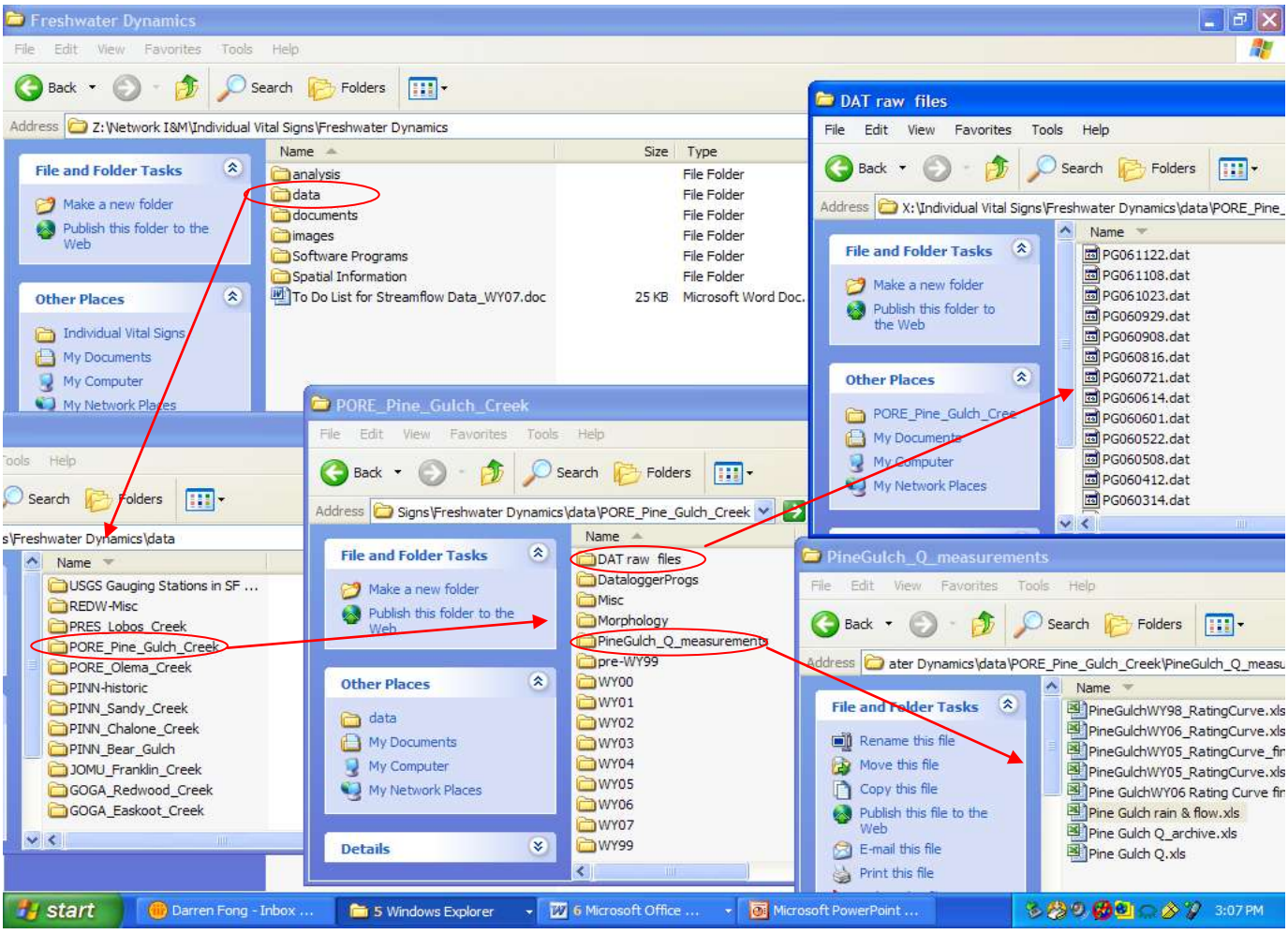


Figure SOP 2.19. Example of directory structure of streamflow files stored on the Marin Headlands server

at the Golden Gate National Recreation Area.

Recording Streamgage Spreadsheet (annual)

The raw data format stored by the dataloggers is not amenable to data analysis procedures. Microsoft Excel will be used to process and store the raw 15-minute recording streamgage data for each Water Year (WY) in a spreadsheet. The Recording Streamgage Spreadsheet file will include 6 worksheet elements. The worksheet titles and contents are as follows:

- Metadata: streamgage metadata worksheet
- FieldDescriptor: worksheet with field definitions
- SiteVisDataCorr: worksheet for documenting discharge measurements, site conditions, and data corrections (See SOP 7 Data Analysis and Reporting)
- Data: 15-minute data worksheet
- DailySum: Water Year discharge summary worksheet

This approach and data file structure is similar to what is being used by the streamflow monitoring program of Redwood National Park (R. Klein, Hydrologist, Redwood National Park, pers. comm. 2006).

Raw data files from the individual dataloggers will be imported into the 15-minute data worksheet using Microsoft Excel's [**Text Import Wizard**]. Although each streamgage may record slightly different data fields, a core set of fields will be imported for each station. These fields include date and time (Pacific Standard Time), raw water stage (instantaneous, 15-minute), and rainfall (if available).

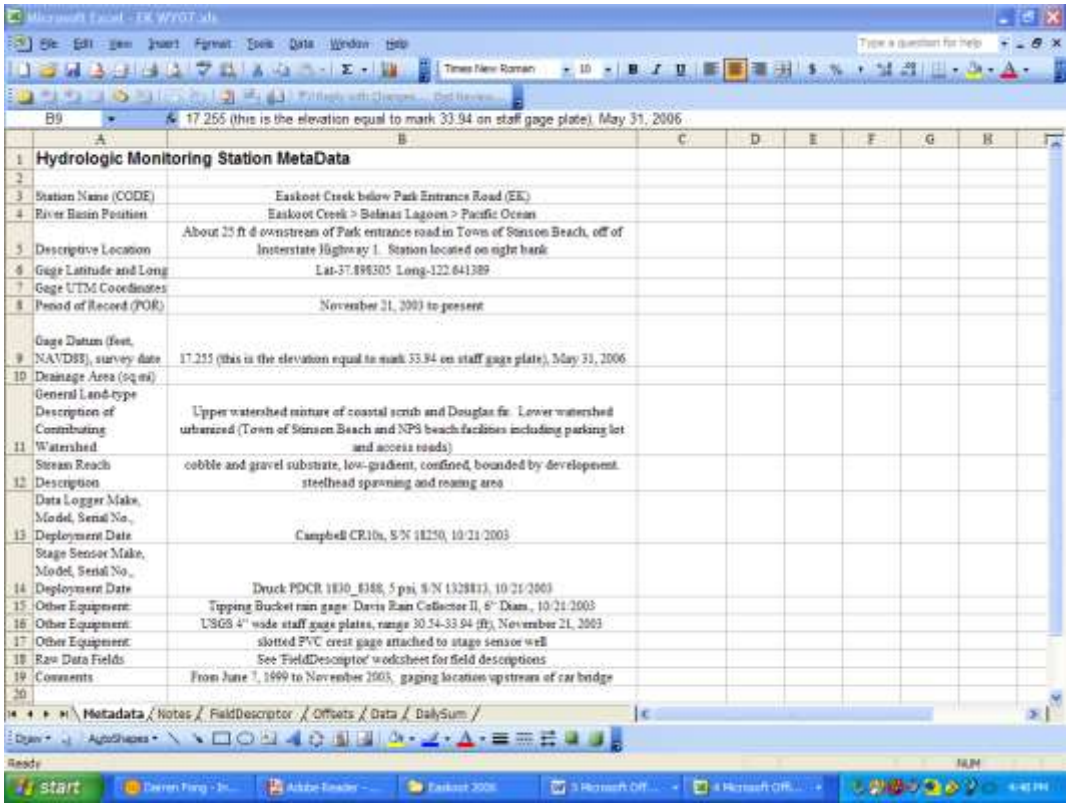
No tabulation and summary are done in the original spreadsheet except for determining corrected stage height and 15-minute discharge estimates (See SOP 7 Data Analysis and Reporting for details). This is done to prevent clutter within the spreadsheet. A "working" copy of the *Recording Streamgage Spreadsheet* is created to assist with data tabulation activities. It is deleted once calculations are checked and data summarized, generally on a monthly basis.

File Naming Convention and File Structure: A standardized file naming convention will be used for all streamgage spreadsheet files. The file name will include a 2-letter stream code and water year code. So, recording streamgage dataset for Easkoot Creek in WY07 would be "EK WY07.xls". Files that have the complete WY dataset and have been reviewed are identified through the use of the term "final" in the file name and are locked from editing (e.g., "EK WY07 final.xls").

Dataset Structure: Each streamgage spreadsheet will consist of 6 worksheets with standardized labels (Metadata, Notes, FieldDescriptor, SiteVis&DataCorr, Data, DailySum).

- *Metadata worksheet* (Figure SOP 2.20): Contains information about the streamgage, including details on deployment and type of instrumentation to a general description of the watershed. This is abbreviated information that is also provided in more detail in SOP 3 Stream Gage Station Descriptions. Although duplicative, this information is provided in

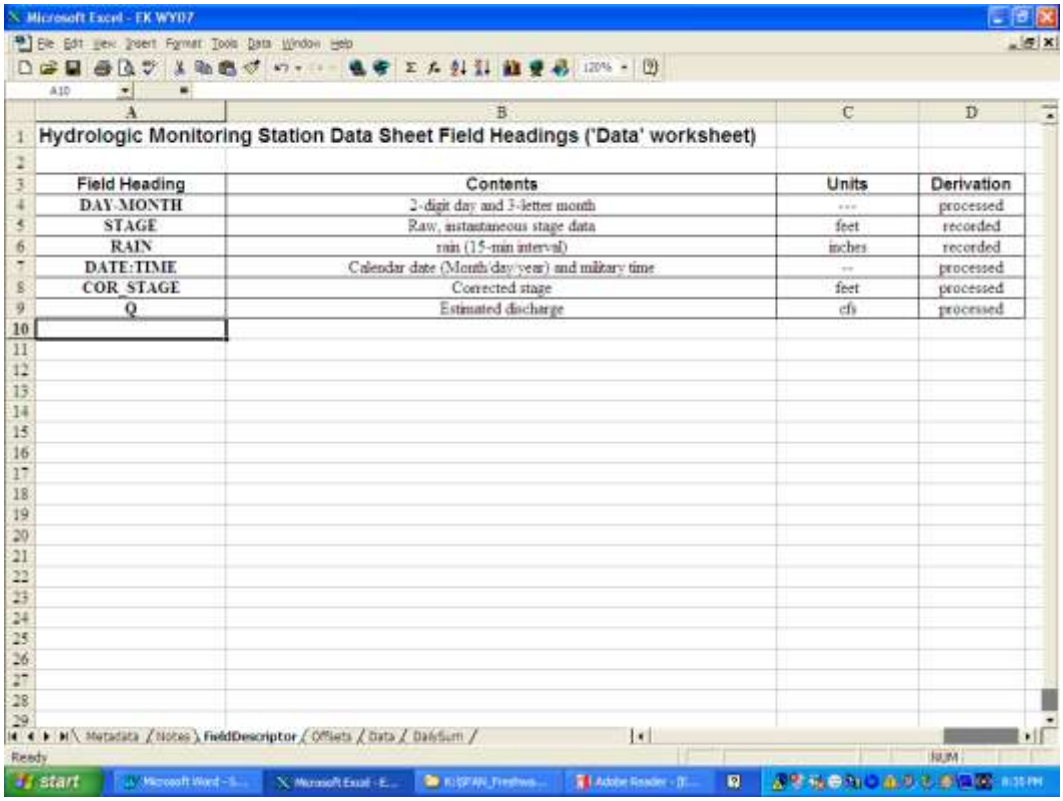
case the datasets may become separated from relevant metadata (e.g., monitoring protocol and SOP). The fields are self-explanatory. An example is illustrated from Easkoot Creek (Figure SOP 2.20).



	A	B
1	**Hydrologic Monitoring Station MetaData**	
2		
3	Station Name (CODE)	Easkoot Creek below Park Entrance Road (EK)
4	River Basin Position	Easkoot Creek > Bolinas Lagoon > Pacific Ocean
5	Descriptive Location	About 25 ft d ownstream of Park entrance road in Town of Stinson Beach, off of Interstate Highway 1. Station located on right bank
6	Gage Latitude and Long	Lat-37.898305 Long-122.641389
7	Gage UTM Coordinates	
8	Period of Record (POR)	November 21, 2003 to present
9	Gage Datum (feet, NAVD88), survey date	17.255 (this is the elevation equal to mark 33.94 on staff gage plate), May 31, 2006
10	Drainage Area (sq mi)	
11	General Land-type Description of Contributing Watershed	Upper watershed mixture of coastal scrub and Douglas fir. Lower watershed urbanized (Town of Stinson Beach and NPS beach facilities including parking lot and access roads)
12	Stream Reach Description	cobble and gravel substrate, low-gradient, confined, bounded by development. steelhead spawning and rearing area
13	Data Logger Make, Model, Serial No., Deployment Date	Campbell CR10x, S/N 18250, 10/21/2003
14	Stage Sensor Make, Model, Serial No., Deployment Date	Druck PDCR 1830_8388, 5 psi, S/N 1328813, 10/21/2003
15	Other Equipment:	Tipping Bucket rain gage Davis Rain Collector II, 6" Diam., 10/21/2003
16	Other Equipment:	USGS 4" wide staff gage plates, range 30.54-33.94 (ft), November 21, 2003
17	Other Equipment:	slotted PVC crest gage attached to stage sensor well
18	Raw Data Fields	See 'FieldDescriptor' worksheet for field descriptions
19	Comments	From June 7, 1999 to November 2003, gaging location upstream of car bridge
20		

Figure SOP 2.20. Example of an abbreviated site description or metadata worksheet and the relevant fields for Recording Streamgage Spreadsheet.

- *FieldDescriptor* (Figure SOP 2.21): Contains information on the fields used in the 'Data' worksheet including the field heading or names, definition of field heading, units of the field, and whether the data were recorded or derived. Contains information on fields used in the 'SiteVis&DataCorr' worksheet.



Hydrologic Monitoring Station Data Sheet Field Headings ('Data' worksheet)

Field Heading	Contents	Units	Derivation
DAY-MONTH	2-digit day and 3-letter month	---	processed
STAGE	Raw, instantaneous stage data	feet	recorded
RAIN	rain (15-min interval)	inches	recorded
DATE:TIME	Calendar date (Month/day/year) and military time	--	processed
COR_STAGE	Corrected stage	feet	processed
Q	Estimated discharge	cfs	processed

Figure SOP 2.21. Example of FieldDescriptor worksheet and relevant fields for Recording Streamgage Spreadsheet.

- *SiteVis&DataCorr* (Figure SOP 2.22): This worksheet is the summary of discharge measurements, site visits, and any data corrections. It contains information on the work performed at a streamgage including fields for discharge measurement and associated measurement number, date, time, personnel, and work performed. It also contains information on observed staff gage readings and corresponding recording gage measurement. The drift field describes the difference between actual measured water surface heights on the staff gage and the recording gage over time. Any drift along with other data corrections for the period is summarized in the data correction field. Treatment of data corrections (such as linear proration of drift over time) is described in the data comments field. These procedures are described in SOP 7 Data Analysis and Reporting. Two fields (Calculated # of 15 minute records and Actual # of 15 minute records) are used to determine whether there are missing records in the dataset.

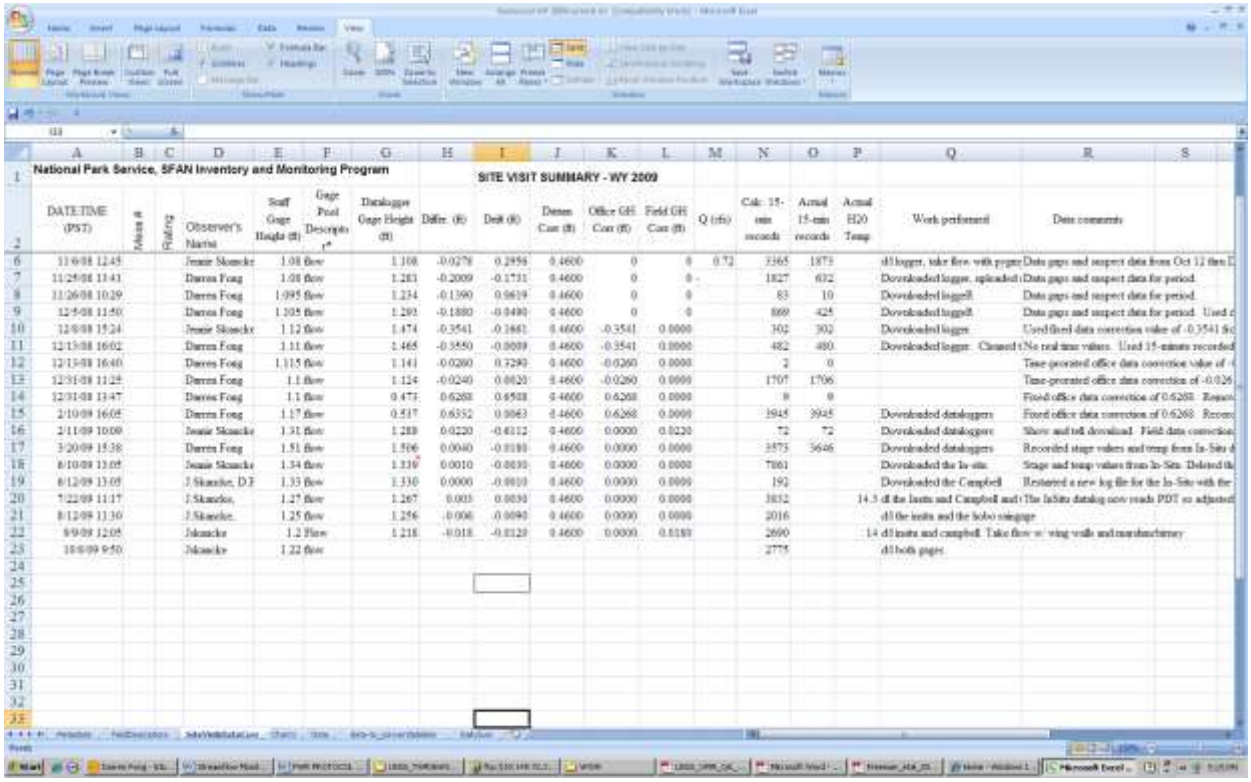
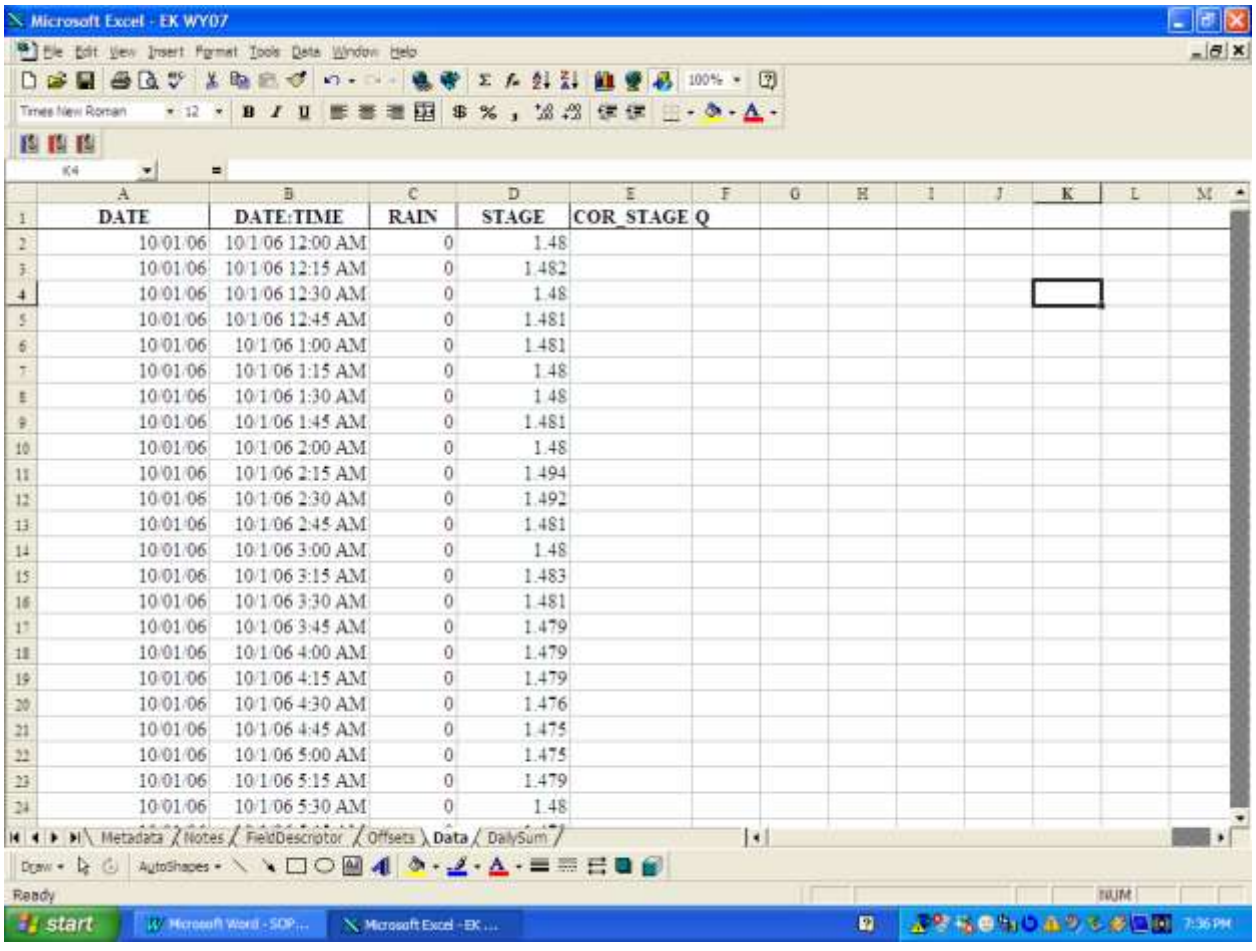


Figure SOP 2.22. Example of a site visit and data correction worksheet and relevant fields for Recording Streamgage Spreadsheet.

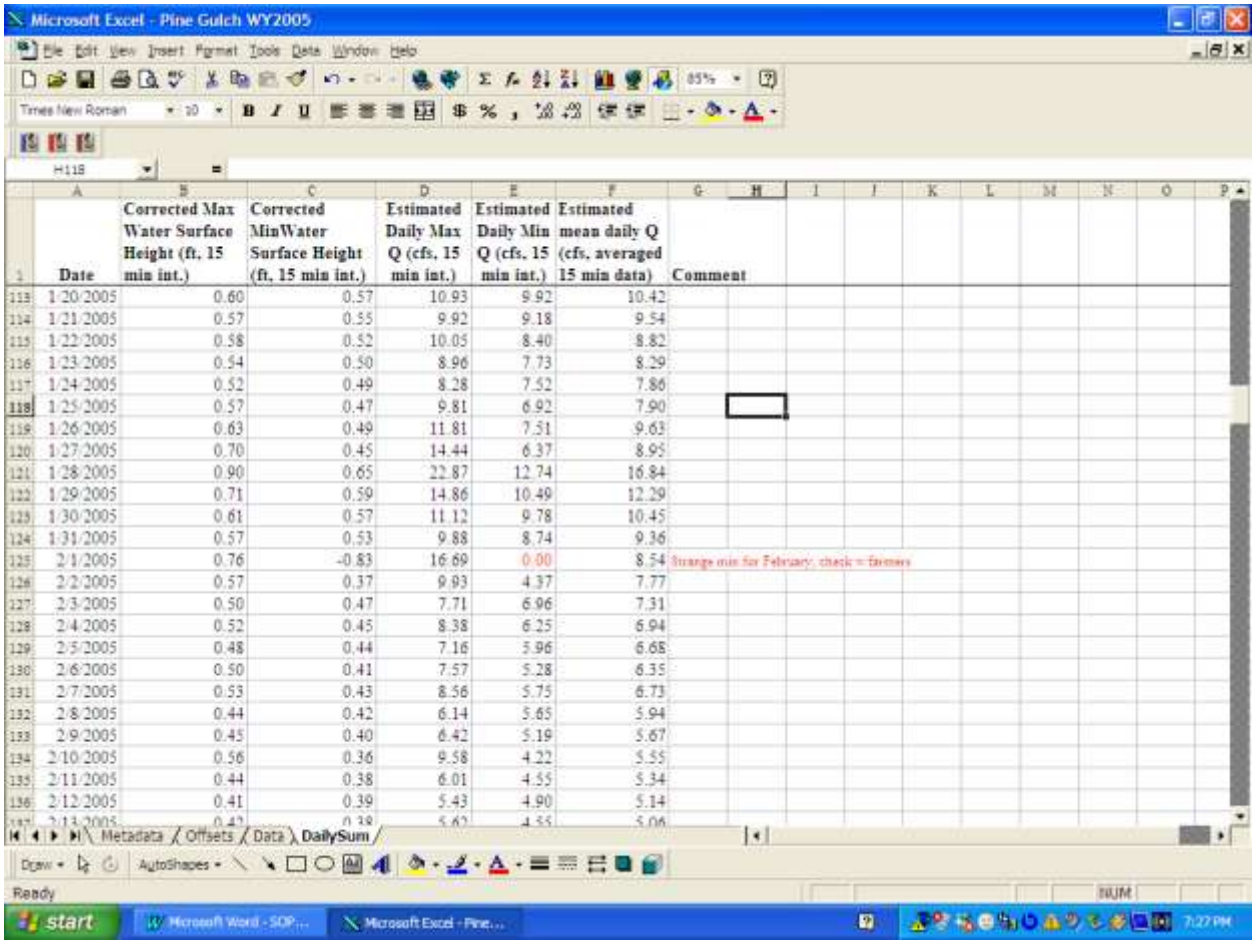
- *Data* (Figure SOP 2.23): Contains five data fields (DATE, DATE-TIME, RAIN, STAGE, COR_STAGE, and Q). These data fields form the foundation of this dataset. There are two date-time fields. The DATE field is a derived field from DATE-TIME data. It contains just the date information without any time feature to facilitate easy computation of mean daily discharge using Excel's [**Pivot Table**] feature. The DATE-TIME field is derived from the raw date and time fields from datalogger output. RAIN represents measured rainfall (inches) for the 15-minute interval. This field is only associated with Pine Gulch, Easkoot, and Redwood stations at this time. The STAGE (in feet) field represents imported data of instantaneous 15-minute water stage. COR_STAGE (in feet) represents stage data above the gage datum corrected for drift or other factors. Procedures for computing corrected stage data are described in SOP 7 Data Analysis and Reporting. Details for converting raw data into the desired format are also described in detail in the same SOP. The Q field is computed data from both 15-minuted corrected stage data and the applicable rating curve. Data is imported from the commercial rating curve software program (Aquatic Informatics Aquarius rating curve software).



	A	B	C	D	E	F
1	DATE	DATE:TIME	RAIN	STAGE	COR_STAGE	Q
2	10/01/06	10/1/06 12:00 AM	0	1.48		
3	10/01/06	10/1/06 12:15 AM	0	1.482		
4	10/01/06	10/1/06 12:30 AM	0	1.48		
5	10/01/06	10/1/06 12:45 AM	0	1.481		
6	10/01/06	10/1/06 1:00 AM	0	1.481		
7	10/01/06	10/1/06 1:15 AM	0	1.48		
8	10/01/06	10/1/06 1:30 AM	0	1.48		
9	10/01/06	10/1/06 1:45 AM	0	1.481		
10	10/01/06	10/1/06 2:00 AM	0	1.48		
11	10/01/06	10/1/06 2:15 AM	0	1.494		
12	10/01/06	10/1/06 2:30 AM	0	1.492		
13	10/01/06	10/1/06 2:45 AM	0	1.481		
14	10/01/06	10/1/06 3:00 AM	0	1.48		
15	10/01/06	10/1/06 3:15 AM	0	1.483		
16	10/01/06	10/1/06 3:30 AM	0	1.481		
17	10/01/06	10/1/06 3:45 AM	0	1.479		
18	10/01/06	10/1/06 4:00 AM	0	1.479		
19	10/01/06	10/1/06 4:15 AM	0	1.479		
20	10/01/06	10/1/06 4:30 AM	0	1.476		
21	10/01/06	10/1/06 4:45 AM	0	1.475		
22	10/01/06	10/1/06 5:00 AM	0	1.475		
23	10/01/06	10/1/06 5:15 AM	0	1.479		
24	10/01/06	10/1/06 5:30 AM	0	1.48		

Figure SOP 2.23. Example of a data worksheet and relevant fields for Recording Streamgage Spreadsheet.

- *DailySum* (Figure SOP 2.24): Contains seven data fields (DATE, Corrected Max Water Height, Corrected Min Water Height, Estimated Daily Max Q, Estimated Daily Min Q, Mean Daily Q, Comment). These fields are computed data used for the Daily Values tables in the summary report. The data can be derived using Excel's [**Pivot Table**] feature from the Data worksheet. The field descriptors are self-explanatory.



	Date	Corrected Max Water Surface Height (ft, 15 min int.)	Corrected MinWater Surface Height (ft, 15 min int.)	Estimated Daily Max Q (cfs, 15 min int.)	Estimated Daily Min Q (cfs, 15 min int.)	Estimated mean daily Q (cfs, averaged 15 min data)	Comment
113	1/20/2005	0.60	0.57	10.93	9.92	10.42	
114	1/21/2005	0.57	0.55	9.92	9.18	9.54	
115	1/22/2005	0.58	0.52	10.05	8.40	8.82	
116	1/23/2005	0.54	0.50	8.96	7.73	8.29	
117	1/24/2005	0.52	0.49	8.28	7.52	7.86	
118	1/25/2005	0.57	0.47	9.81	6.92	7.90	
119	1/26/2005	0.63	0.49	11.81	7.51	9.63	
120	1/27/2005	0.70	0.45	14.44	6.37	8.95	
121	1/28/2005	0.90	0.65	22.87	12.74	16.84	
122	1/29/2005	0.71	0.59	14.86	10.49	12.29	
123	1/30/2005	0.61	0.57	11.12	9.78	10.45	
124	1/31/2005	0.57	0.53	9.88	8.74	9.36	
125	2/1/2005	0.76	-0.83	16.69	0.00	8.54	Strange min for February; check = flatlines
126	2/2/2005	0.57	0.37	9.93	4.37	7.77	
127	2/3/2005	0.50	0.47	7.71	6.96	7.31	
128	2/4/2005	0.52	0.45	8.38	6.25	6.94	
129	2/5/2005	0.48	0.44	7.16	5.96	6.68	
130	2/6/2005	0.50	0.41	7.57	5.28	6.35	
131	2/7/2005	0.53	0.43	8.56	5.75	6.73	
132	2/8/2005	0.44	0.42	6.14	5.65	5.94	
133	2/9/2005	0.45	0.40	6.42	5.19	5.67	
134	2/10/2005	0.56	0.36	9.58	4.22	5.55	
135	2/11/2005	0.44	0.38	6.01	4.55	5.34	
136	2/12/2005	0.41	0.39	5.43	4.90	5.14	

Figure SOP 2.24. Example of DailySum worksheet and relevant fields for Recording Streamgage Spreadsheet.

Data Entry, Verification and Validation

Information regarding data downloads of the recording streamgages will be entered into the *Recording Streamgage spreadsheet* by the field technician who collected the measurements as soon as possible from the field. This information includes the description of work performed during the station visit, discharge measurements, and the recorded and observed stage measurements (SiteVis&DataCorr worksheet). The technician reviews any entered data, performs corrections if needed, and then signifies data verification in the field datasheet. This is done by marking the upper right corner of the page of the station visit entry with the first and last initials, date of data verification, and a check mark.

Data verification and validation for the continuous data are more challenging. Missing records are determined by using Excel's numeric formula functions and is described in SOP 7 Data Analysis and Reporting. Many of the data fields are computed including the corrected stage and calculated discharge. Potential errors include incorrect formulas and copy-and-paste errors. The technician should minimize errors by double-checking. The program manager should randomly select 10% to review from every imported raw dataset with a goal of 95% or greater accuracy. Less than 95% accuracy would trigger a full review and identification of factor(s) causing errors.

Potential errors in the automated stage height dataset can be identified through visual inspection of the plotted data. Typically, stage hydrographs will display a characteristic left-skewed bell curve shape (steep rising limb, less-steep receding limb). Deviations from this shape may indicate bad data (data containing errors beyond those due to sensor drift). Suspect data periods should be highlighted on the plots. Field notes should be reviewed for such periods to check for obvious sources of error (e.g., a temporary obstruction in the gaging section, evidence of rapid scour and/or fill in the channel). In addition, rainfall data may be reviewed to look for unusual patterns that may explain unusual hydrograph shapes.

Stage-Discharge Rating Spreadsheets (Pre-Water Year 2008)

The stage-discharge datasets form the backbone of this monitoring program. They include the mean gage heights and related measured stream discharges that are used to develop individual stage-discharge ratings/relationships. The datasets include basic numeric data for the stage-discharge ratings as well as derived graphics that show the linear relationship between the two variables. Before Water Year 2008, Microsoft Excel was chosen as the means for storing and working with the data. The subsections below describe the file and data management procedures for stage-discharge ratings before Water Year 2008.

File Naming Convention and File Structure: A standardized file naming convention was used for all stage-discharge ratings. Each water year has a separate spreadsheet file. The file name will start with streamgage name, followed by the water year code, and words "Rating Curve" (e.g., PineGulch WY06 Rating Curve.xls). Final rating curves for the Water Year are labeled as such and locked from editing. Example of stage-discharge rating worksheets for Pine Gulch Creek and file hierarchy can be seen in Figure SOP 2.25.

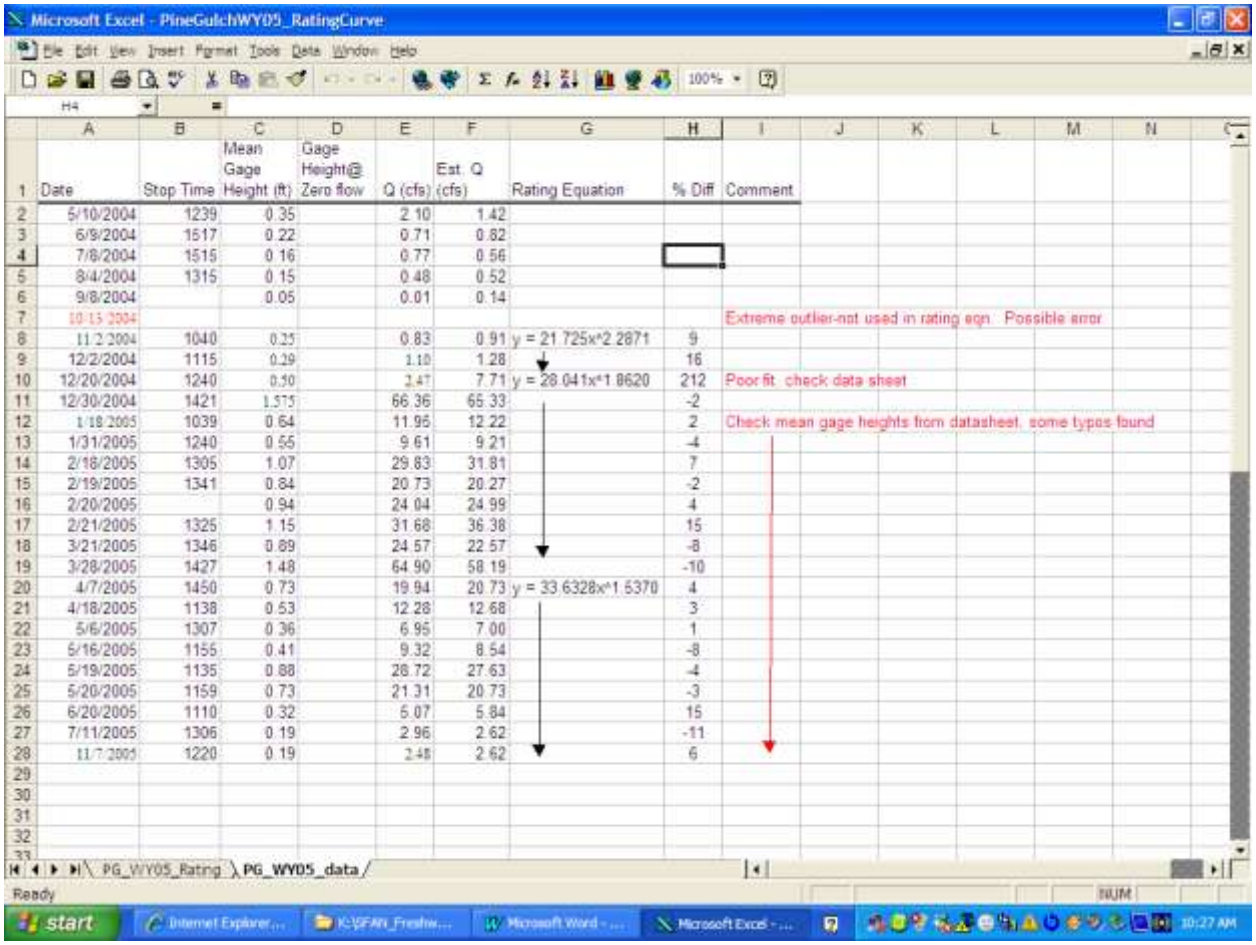


Figure SOP 2.25. Example of Stage-Discharge Rating Worksheet and relevant data fields.

Dataset Structure: The individual streamgage rating curve spreadsheets typically consist of two worksheets:

- Stage-discharge data
- Rating curve

The stage-discharge data worksheet has 10 unique data fields (Table SOP 2.2). The fields are exported from the Stream Discharge Database with the exception of derived and comment values.

Table SOP 2.2. Field names and types for pre-Water Year 2009 stage discharge worksheet.

Field Name	Field Type	Description
Date	Date/Time	Discharge measurement date
Stop Time	Number	End time for discharge measurement
Mean Gage Height	Number	Calculated mean gage height, in feet (see SOP 7. Data Analysis and Reporting)
Gage Height at Zero Flow	Number	See SOP 7 (Data Analysis and Reporting); assume constant if no values
Q (cfs)	Number	Measured discharge, in cubic feet per second
Est Q (cfs)	Number	Estimated discharge using rating equation
Rating Equation	Text	Text formulas of rating equation
Est Measurement Error	Number	The estimated individual discharge measurement error
% Diff	Number	Percent difference of calculated discharge from measured
Comment	Text	Relevant comments from field notes that related to stage or discharge values. Also, generally includes QA/QC reminders that are deleted once completed.

The rating curve worksheet consists of a graphical representation of the stage-discharge relationship. Details of the procedures are provided in SOP 7 Data Analysis and Reporting. Information for this worksheet is linked to the stage-discharge worksheet.

Data Entry, Verification and Validation: Possible errors are identified by comparing individual stage and discharge data points with the actual rating curve. Any outliers are identified and stage heights and discharge measurements checked in original field datasheets for transcriptions errors. 100% or all rating curves and associated equations are checked in this fashion

Stage-Discharge Rating Files (Water Year 2008-Present)

Per recommendations from NPS-WRD, the SFAN purchased in 2008 commercial software for rating curve development (Aquatic Informatics Aquarius rating curve software v 2.5.2). The file structure and data management is different than the prior spreadsheets. The rating curve software allows for the development of a set of rating curves for a station. Discharge measurement and stage data used for the rating curves are imported into the program. It is linked to 15-minute stage data that is stored in a comma-separated values format.

File Naming Convention and File Structure: The input file for the stage-discharge data will start with the 2-letter stream code, followed by the range of water years, and a brief text descriptor about the file content. So, an example file name for stage-discharge data from Easkoot Creek would be "EK WY05-08 Stage-Q.csv". The input file of 15-minute corrected stage data will have a similar format for each water year and streamgage. These input files will use a similar naming convention. The file name will include a 2-letter stream code and water year code. So, recording streamgage dataset for Easkoot Creek in WY07 would be "EK WY07.csv".

The Aquarius rating curve software will also have two types of files that are used to assist in managing the data and creating the discharge output. The general workflow file which includes links to the input files and the various instructions for manipulating the data to create the desired output (e.g., discharge) are saved in the program's proprietary format as *.aqw files. Each water year and streamgage will have separate *.aqw files. They will also be named in a similar way. The file name will include a 2-letter stream code and water year code. So, recording streamgage dataset for Easkoot Creek in WY07 would be "EK WY07.aqw". All stage-discharge rating measurement data is stored by the Aquarius rating curve software separately. A single master file will be used for storing and utilizing all ratings, both past and present, associated with a station. The file name will start with two-letter streamgage code, followed by the water year code of the first year used in the rating, the words "toPresentRating" and the file extension type (e.g., RW WY09toPresentRating.xml). The *.xml extension refers to the data being stored according the U.S. Geological Survey Office of Surface Water's XML standard for rating curves (Aquatic Informatics 2009).

Dataset Structure: The individual streamgage rating curve datasets will typically consist of three comma-separated values files:

- Input File: Stage-discharge data (*.csv format)
- Input File: 15-minute corrected stage data (*.csv format)
- Output File: 15-minute discharge data (*.csv format)

The stage-discharge data file will have 11 unique data fields (Table SOP 2.3). The fields will be exported from the Stream Discharge Database.

Table SOP 2.3. Field names and types for Water Year 2008 to present stage-discharge file.

Field Name	Field Type	Description
Date:Time	Date/Time	Discharge measurement date and end time for discharge measurement (Military Pacific Standard Time).
Mean Gage Height	Number	Calculated and corrected mean gage height, in feet (see SOP 7 Data Analysis and Reporting).
Gage Height at Zero Flow	Number	See SOP 7 (Data Analysis and Reporting); assume constant if no values.
Q (cfs)	Number	Measured discharge, in cubic feet per second.
Width	Number	Measured width (ft) of discharge cross-section.
Area	Number	Area of discharge measurement cross-section.
Mean velocity	Number	Mean velocity of discharge measurement cross-section.
No. verticals	Number	Number of discharge measurement verticals.
Measurement Number	Number	Discharge measurement number.
Quality	Text	Qualitative descriptor of estimated standard error using procedures in Sauer and Meyer (1992).
Condition	Text	Condition of the control.

The 15-minute corrected stage data used for generating 15-minute discharge values will be generated from the 'Data' worksheet of the *Recording Streamgage Spreadsheet* as a **.csv file***.** It will include just two fields: Date:Time (PST, military) and Cor_stage. The output file from the Aquatius rating curve software will also be a *.csv file with two fields: Date:Time (PST, military) and computed discharge (cfs).

Data Entry, Verification and Validation: Possible errors will be identified by comparing individual stage and discharge data points with the actual rating curve. Any outliers will be identified and stage heights and discharge measurements will be checked in original field datasheets for transcriptions errors. 100% or all rating curves and associated equations will be checked in this fashion.

Rainfall Data

Currently, three stations have rainfall tipping buckets that operate along with the recording streamgages (Pine Gulch, Easkoot, and Redwood; See SOP 6 Procedures for Tipping Bucket Rain Gage Stations). The 15-minute rainfall data will be stored with the 15-minute streamflow data (*Recording Streamgage Spreadsheet*). However, the daily summary table for rainfall will be stored separately. Each streamgage with a rain gage will have one daily summary spreadsheet per Water Year.

File Naming Convention and File Structure: A standardized file naming convention will be used for all rainfall data. Each water year will have a separate spreadsheet file. The file name will start with streamgage code, followed by the water year code, and words "Rainfall (e.g., EK WY06

Rainfall.xls).” Final rainfall tables for the Water Year are labeled as such and locked from editing.

Dataset Structure: There are two worksheets for each rainfall spreadsheet: Rainfall and Notes. The Rainfall Worksheet includes the total daily rainfall for the Water Year (to the nearest 0.01 inch; Table SOP 2.4).

Table SOP 2.4. Field names and types exported for Rainfall Worksheet.

Field Name	Field Type	Description
Daily	Number	Daily rainfall total (in)
Total	Number	Monthly rainfall total (in)
Mean	Number	Mean daily rainfall for the month (in)
Max	Number	Maximum daily rainfall for the month (in)
Min	Number	Maximum daily rainfall for the month (in)
Max 15-min	Number	Maximum 15-minute rainfall event for the month (in)
Water Year Total.	Number	Total rainfall (nearest 0.01 inch) for water year (in)
Note	Text	Optional notes describing data quality. Rainfall data in italics are often of questionable quality or estimated values

The Notes Worksheet provides information regarding maintenance and calibration activities related to the rain gage (Table SOP 2.5). The fields include: Date, Time, Personnel, and Work Performed.

Data Entry, Verification and Validation: The mean daily rainfall data will be reviewed to identify outliers (e.g., rainfall events in summer and fall). All data files will be cross-examined with field notebooks to identify calibration events. Any “rainfall” associated with calibration events will be removed to ensure proper rainfall totals for the year. Dates and times of outliers will be compared to field notes to ensure that data were not associated with cleaning activities at the tipping bucket. All data in summary fields will be cross-checked. For instance, daily rainfall totals reported in the draft tables will be summed to calculate monthly and yearly totals. Discrepancies in the monthly and yearly rainfall totals will be used to identify possible sources of error.

Table SOP 2.5. Field names and types for Notes Worksheet.

Field Name	Field Type	Description
Date	Date	Field visit event data
Time	Time	Field visit event data
Personnel	Text	Field personnel
Work	Text	Work performed related to rain gage

Stream Topographic Spreadsheet

Level surveys will be conducted periodically at streamgages to establish baseline conditions regarding channel and station elevations of new stations. Follow-up surveys will be done to determine whether there may have been movement of channel or gaging equipment. Data from these surveys will be recorded in the field using datasheets. The datasheets represent the long-term archival dataset of level data for the gaging equipment and stream, as only select data elements are transferred to the spreadsheet databases. Informative streamgage maps, weather conditions and survey equipment descriptions are kept only in the survey datasheets.

Level data will be stored in two fashions using spreadsheets. Field data are transferred into a single spreadsheet for each station and the inputted fields are described in Table SOP 2.6. Data for successive surveys will be stored as individual worksheets in the *Topographic Survey* spreadsheet for each station. So, a single spreadsheet will represent the history of level data for the station obtained by SFAN. A summary spreadsheet, *Level Notes*, will summarize level data specific to the streamgage (e.g., reference marks and staff gage). A single spreadsheet per station will also be used.

File Naming Convention and File Structure: A standardized file naming convention will be used for all *Topographic Survey* spreadsheets. The file name will start with the streamgage name, followed by the words "Streamgage Morphology." For example, the typical file path for Pine Gulch morphology data is illustrated in Figure 35, a hierarchical file structure illustration which is similar for all other streamgages. Similarly, the summary spreadsheet, Level Notes, will also start with the streamgage name, followed by the words "Level Notes."

Dataset Structure: Because topographic data will be collected less frequently than other data types, a single data file will contain all topographic data for a streamgage, regardless of Water Year. A single spreadsheet will be used to store individual cross-section and profile as separate worksheets for each sampling event. For example, Pine Gulch Creek profile data collected on three separate events are stored as three separate worksheets in the PineGulch Streamgage Morphology.xls file (Figure SOP 2.26).

All cross-section and profile worksheets will have a standardized structure including the following fields (Table 18):

Table SOP 2.6. Field names and types for Topographic Survey spreadsheet.

Field Name	Field Type	Description
Location	Text	Name of streamgage
River Basin	Text	If a tributary, name of larger drainage area
Investigators	Text	Name(s) of personnel conducting survey and roles (e.g., notes, rod, level)
Form Completed by	Text	Name of personnel responsible for data entry and proofing
UTM Coordinates	Number	Starting and ending coordinates of cross-section and profile using NAD 83, Zone 10 projection
Starting Location Description	Text	Description of starting location
Benchmark Description	Text	Description of benchmark and how to re-locate it. If a National Geodetic Survey benchmark, include PID number, coordinates, and elevation
Station	Text	Description of surveyed point using standard surveying nomenclature where beginning station is '0' and points at distances of 100, 200 ft respectively from starting point are labeled station '1,' and '2' and intermediate points are placed after '+' (Moffit and Bossler 1998). A surveyed point at 132.5 feet from the starting point is labeled '1+32.5'
BS	Number	Backsight (ft)
HI	Number	Height of instrument (ft)
FS	Number	Foresight (ft)
Elev	Number	Elevation (ft) based either on an established or arbitrary benchmark and datum (described in benchmark description field)
Depth	Number	Water depth (ft)
Notes	Text	Includes descriptions of surveyed points using standard abbreviations listed in spreadsheet (e.g., LEW-left edge of water)

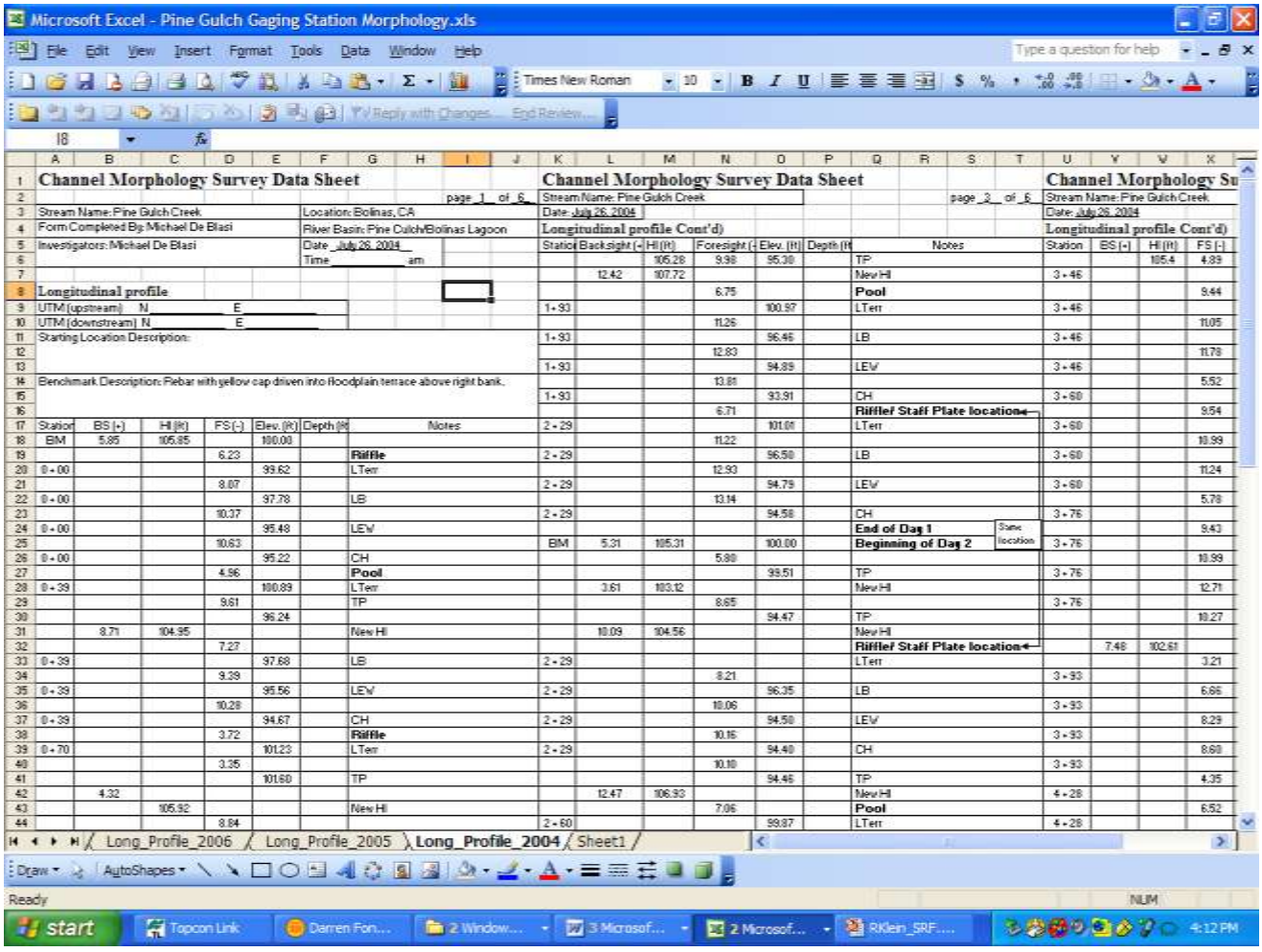


Figure SOP 2.26. Example of topographic data spreadsheet and fields for Pine Gulch Creek.

The Level Notes summary spreadsheet, will also be a single data file containing all level data for a streamgage, regardless of Water Year. The data field descriptors for this spreadsheet are provided in Table SOP 2.7.

Data Entry, Verification and Validation: Field personnel will enter topographic data from field datasheets into the Excel spreadsheets following the dataset structure described above. After data entry, field personnel will check all data entries for errors. In addition, current topographic data will be plotted and reviewed with data from prior years to identify outliers that cannot be explained by natural channel changes.

Metadata Procedures

The NPS GIS Committee recently required that all NPS GIS data layers be described with the NPS Metadata Profile, which combines the FDGC standard, elements of the ESRI metadata profile, the Biological Data Profile, and NPS-specific elements. Although no standard has been applied to natural resource databases and spreadsheets, the SFAN will complete the NPS Metadata Profile to the greatest extent possible to document databases and spreadsheets developed for the SFAN I&M program.

Table SOP 2.7. Field names and types for Level Notes spreadsheet.

Field Name	Field Type	Description
Date	Date	Date
Party	Text	Personnel conducting survey
BM	Number	Benchmark elevation
RM-1	Number	Elevation of reference mark 1
RM-2	Number	Elevation of reference mark 2
RM-3	Number	Elevation of reference mark 3
Staff Plate	Number	Elevation of staff plate at a described point
PZF	Number	Elevation of control point below gage
Recording Gage	Number	Elevation of recording gage at a described point
CSG	Number	Elevation of crest gage at a described point

Complete metadata records for the SFAN streamflow monitoring MS Access database and spreadsheets will be generated in compliance with current NPS standards by the streamflow program manager in coordination with the SFAN data manager. The metadata records are based on the FGDC standard, are formatted in XML, and can thus be imported or accessed by other standard metadata software programs (i.e., ArcCatalog). Because the location data for this project is stored as UTM coordinates within the MS Access database, there are no spatial data products associated with this protocol that require metadata records.

The metadata record for the Stream Discharge Database will initially be developed in Dataset Catalog v3.0, an MS Access metadata development and catalog tool developed by the NPS I&M Program. Dataset Catalog is currently the preferred tool to begin metadata records for MS Access databases because of its ability to harvest entity and attribute information from this database format.

The metadata record for the discharge database will be exported from Dataset Catalog as an XML file and completed in NPS Metadata Tools and Editor v1.1 (NPS MTE), thus allowing for all NPS-specific elements in the metadata record to be completed. Metadata records for Excel data files will be initiated and completed in the NPS MTE. When completed, metadata records will be posted to the NPS Data Store for public discovery and consumption. Because the discharge database and stream topography spreadsheet are continuous datasets, only metadata records and not the actual data products will be posted to the NPS Data Store. Contact information within the metadata record will direct interested parties to the SFAN lead data manager for further inquiries. Metadata records posted to the NPS Data Store will be updated annually after the new water year data has been entered and error-checked or following database revision to a new version whole number (i.e., v1_3 to v2_0, but not v2_0 to v2_1).

Data Distribution

In order for the streamflow monitoring protocol to inform park management and to share its information with other organizations and the general public, guidance documents, reports, and data must be easily discoverable and obtainable. The main mechanism for distribution of the monitoring documents and data will be the Internet. The streamflow monitoring protocol,

accompanying SOPs, and all annual reports will be made available for download at the SFAN website:
http://science.nature.nps.gov/im/units/sfan/

Although the streamflow monitoring database will not be posted for public download, as previously mentioned, metadata records for the database will be maintained at the NPS Data Store. The metadata records will direct interested parties to the SFAN Data Manager for further inquiries.

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

All documents produced by the streamflow monitoring program will be published following guidance from the NPS Natural Resource Program Center in Fort Collins, CO. The Natural Resource Publications Management home page hosts a list of all documents published through the program center. The home page can be found at:
http://www.nature.nps.gov/publications/NRPM/

Literature Cited

[EPA] Environmental Protection Agency. 2002. Guidance for quality assurance project plans. EPA QA/G-5. 2002 December. Office of Environmental Information, Washington, D.C.

Fulford, J. M. 2001. Accuracy and consistency of water-current meters. Journal of the American Water Resource Association. 37(5):1215–1224.

Press, D. 2005. San Francisco Bay Area Network Inventory and Monitoring Program Draft Data Management Plan. National Park Service. Internet address: http://science.nature.nps.gov/im/units/sfan/reportpubs.cfm

Sauer, V. B., and R. W. Meyer. 1992. Determination of errors in individual discharge measurements. U.S. Geological Survey Open-File Report 92-144, Reston, Virginia.

Appendix SOP 2 A. Data Dictionary: Raw Recording Streamgage Data Files

Description of raw output for streamgages with Campbell Scientific dataloggers (with datalogger program name in parentheses).

The outputs from the Campbell Scientific dataloggers are comma-delimited text files (numeric fields) with no field headers or descriptors. Each recording streamgage has slightly different data types and output storage locations. These are described below.

Olema Creek (OLM_2006.dld)

Field #1: Data summarization type (either 15 min, 1 hr or 24 hr)
100- 15 minute data
101- 24 hour data

15-minute Data

Field #1: Sample year
Field #2: Date- Julian calendar day
Field #3 Time- Pacific standard time (military)
Field #4: Water surface level, instantaneous (ft)
Field #5: Water surface level, max (ft)
Field #6: Water surface level, min (ft)
Field #7: Transducer output (millivolt)
Field #8: Water temperature (^{o}C)
Field #9: Water temperature (^{o}C), max
Field #10: Water temperature (^{o}C), min
Field #11: Battery voltage (V), instantaneous
Field #12: Battery voltage (V), min
Field #13: Internal datalogger temperature (^{o}C) , instantaneous

24-hour Data

Field #1: Sample year
Field #2: Date- Julian calendar day
Field #3: Time- Pacific standard time (military)
Field #4: Offset
Field #5: Slope

Pine Gulch (PNG.dld)

Field #1/: Data summarization type (either 15 min, 1 hr or 24 hr)
111- 15 minute data
222- 1 hour data
333- 24 hour data

15-minute and 1-hour Data

Field #2: Sample year
Field #3: Date- Julian calendar day
Field #4: Time- Pacific standard time (military)

Field #5: Rainfall for sample period (inch)
Field #6: Instantaneous water surface level (ft)
Field #7: Average water surface level over time period
Field #8: Max water surface level in 1-hr (ft)
Field #9: Min water surface level in 1-hr (ft)

24-hour Data
Field #2: Sample year
Field #3: Date- Julian calendar day
Field #4: Time- Pacific standard time (military)
Field #5: Battery voltage (V)
Field #6: Program number
Field #7: Rainfall for sample period (inch)
Field #8: Instantaneous water surface level (ft)
Field #9: Average water surface level over time period
Field #10: Max water surface level in 24-hrs (ft)
Field #11: Min water surface level in 24-hrs (ft)

Easkoot Creek (Program Easkoot5.dld)

Field #1: Data summarization type
  100- 15 minute data
  101- 4 hour data
  102- 4 hour data
  103- 24 hour data

15 minute data (Array ID 100)
Field #2: Sample year
Field #3: Date- Julian calendar day
Field #4: Time- Pacific standard time (military)
Field #5: Water surface level, instantaneous (ft)
Field #6: Raw output

4-hour data (Array ID 101)
Field #2: Sample year
Field #3: Date- Julian calendar day
Field #4: Time- Pacific standard time (military)
Field #5: Offset (ft)
Field #6: Slope

4-hour data (Array ID 102)
Field #2: Sample year
Field #3: Date- Julian calendar day
Field #4: Time- Pacific standard time (military)
Field #5: Battery Voltage (V)
Field #6: Signature

15-minute data (Array ID 103)
Field #2: Sample year
Field #3: Date- Julian calendar day
Field #4: Time- Pacific standard time (military)
Field #5: Rain (in)

Redwood Creek (Rwd2.dld)

Field #1: Data summarization type (either 15 min, 1 hr or 24 hr)
111- 15 minute data
222- 1 hour data
333- 24 hour data

15-minute and 1-hour Data
Field #2: Sample year
Field #3: Date- Julian calendar day
Field #4: Time- Pacific standard time (military)
Field #5: Rainfall for sample period (inch)
Field #6: Water surface level, instantaneous (ft)
Field #7: Average water surface level over time period
Field #8: Water surface level, max (ft)- 1 hour data hour
Field #9: Water surface level, min (ft) - 1 hour data hour

24-hour Data
Field #2: Sample year
Field #3: Date- Julian calendar day
Field #4: Time- Pacific standard time (military)
Field #5: Battery voltage (V)
Field #6: Program number
Field #7: Rainfall for sample period (inch)
Field #8: Water surface level, instantaneous (ft)
Field #9: Average water surface level over time period
Field #10: Water surface level, max (ft)- 24 hour
Field #11: Water surface level, min (ft) – 24 hour

Franklin Creek, Chalone Creek, Sandy Creek (Global Water)

15-minute Data
Field #1: Date:time- Month\Day\Year Pacific standard time (24-hr)
Field #2: Water surface level, instantaneous (ft)

Standard Operating Procedure (SOP) 3. Stream Gage Station Descriptions

Version 1.08

Revision History Log

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.00	3/20/06	Travis Smith	Equipment section for all Creeks	Equipment added and replaced	1.01
1.01	9/01/06	Travis Smith	Added section on Lobos	Needed to be added	1.02
1.02	2/14/07	Darren Fong, Marcus Koenen	Standardized format to match USGS Station Descriptions closer and pulled actual station descriptions. Added all site descriptions.		1.03
1.03	5/3/07	Paul Johnson	Proofreading throughout		1.04
1.04	7/28/2008	Darren Fong	Multiple edits, addition of flood frequency info, added new graphics		1.05
1.05	8/6/08	Paul Johnson	Proofreading throughout		1.06
1.06	2/11/2009	Darren Fong	General edits. Equipment changes		1.07
1.07	6/6/2010	Darren Fong, Kris Freeman, Marcus Koenen	General edits. Included USGS stations. Formatting. Equipment updates	Response to comments	1.08

Figures

Page

Figure SOP 3.1. Lobos Creek drainage basin. ..... SOP 3.11

Figure SOP 3.2. Aerial photo of Lobos Creek and streamgage. ..... SOP 3.12

Figure SOP 3.3. H-flume at Lobos Creek streamgage. ..... SOP 3.13

Figure SOP 3.4. Lobos Creek streamgage with treatment plant diversion structure (left) and bypass channel (right). ..... SOP 3.13

Figure SOP 3.5. Site map of John Muir National Historic Site, Martinez, CA. ..... SOP 3.17

Figure SOP 3.6. Location of stream gage on Franklin Creek below Highway 4, John Muir National Historic Site, CA. ..... SOP 3.18

Figure SOP 3.7. Alhambra Creek watershed (excluding Franklin Creek sub-watershed). ..... SOP 3.19

Figure SOP 3.8. Franklin Creek drainage area. ..... SOP 3.20

Figure SOP 3.9. Staff gage upstream of concrete sill on Franklin Creek (looking downstream from pedestrian bridge to left bank). ..... SOP 3.21

Figure SOP 3.10. Housing and pressure transducer underneath pedestrian bridge on Franklin Creek. ..... SOP 3.21

Figure SOP 3.11. Redwood Creek location map. ..... SOP 3.30

Figure SOP 3.12. Redwood Creek streamgage. ..... SOP 3.30

Figure SOP 3.13. Redwood Creek high flow measurement site at MBCSD pedestrian bridge. ..... SOP 3.31

Figure SOP 3.14. Redwood Creek sub-watersheds. ..... SOP 3.32

Figure SOP 3.15. Staff gage and pressure transducer (looking downstream). ..... SOP 3.33

Figure SOP 3.16. Sketch of Redwood Creek streamgage location and reference marks. ..... SOP 3.33

Figure SOP 3.17. National Geodetic Survey benchmark in foreground on concrete wingwall and RM 1 (orange spray paint) on bridge. ..... SOP 3.34

Figure SOP 3.18. Location on downstream side of HWY 1 bridge approach (above) and inset showing guard rail bolt (orange spray paint) used as RM 2. ..... SOP 3.35

Figure SOP 3.19. Redwood Creek channel slope (from Snider 1984). ..... SOP 3.36

Figure SOP 3.20. Cross-section of Redwood Creek at the Highway 1 Bridge. ..... SOP 3.37

Figure SOP 3.21. Estimated Redwood Creek flood frequency. ..... SOP 3.37

Figure SOP 3.22. Easkoot Creek at Stinson Beach. ..... SOP 3.42

Figure SOP 3.23. Easkoot Creek station location map (post-November 2003). ..... SOP 3.42

Figure SOP 3.24. Easkoot Creek watershed. ..... SOP 3.43

Figure SOP 3.25. Monitoring Equipment (November 2003 to present). Looking at right bank at staff gage, crest gage, stilling well, datalogger and rain gage (October 2006). ..... SOP 3.44

Figure SOP 3.26. Streamgage conditions (period from 1999 to October 2003), looking downstream at staff gage and stilling well on left bank (April 2000). ..... SOP 3.44

Figure SOP 3.27. Streamgage conditions (period from 1999 to October 2003), looking upstream at rain gage and datalogger in clearing on left bank (April 2000). ..... SOP 3.45

Figure SOP 3.28. Sketch of Easkoot Creek streamgage location and reference marks (post-November 2003). ..... SOP 3.46

Figure SOP 3.29. Precipitation map for Point Reyes National Seashore (adapted from Rantz 1969). ..... SOP 3.47

Figure SOP 3.30. Estimated Easkoot Creek flood frequency. ..... SOP 3.48

Figure SOP 3.31. Pine Gulch Station location map. ..... SOP 3.54

Figure SOP 3.32. Pine Gulch Creek watershed. ..... SOP 3.55

Figure SOP 3.33. Pine Gulch Creek streamgage. ..... SOP 3.56

Figure SOP 3.34. Pine Gulch Creek streamgage with new staff gage on left bank (installed May 31, 2007). ..... SOP 3.56

Figure SOP 3.35. Location of National Geodetic Survey benchmark below painted K-rail on downstream side of Olema-Bolinas road bridge. ..... SOP 3.57

Figure SOP 3.36. Estimated Pine Gulch Creek flood frequency. ..... SOP 3.57

Figure SOP 3.37. Olema Creek Watershed. ..... SOP 3.63

Figure SOP 3.38. Olema Creek streamgage at Bear Valley Road bridge: overview (above) and inset . ..... SOP 3.64

Figure SOP 3.39. Olema Creek streamgage. ..... SOP 3.65

Figure SOP 3.40. Sketch of Olema Creek streamgage location and reference marks. ..... SOP 3.65

Figure SOP 3.41. Precipitation map for Point Reyes National Seashore. ..... SOP 3.66

Figure SOP 3.42. Estimated flood frequency for Olema Creek at Bear Valley Road Bridge. ..... SOP 3.67

Figure SOP 3.43. Lagunitas Creek near Point Reyes Station streamgage location at Gallagher Ranch bridge. ..... SOP 3.69

Figure SOP 3.44. Lagunitas Creek at Samuel P. Taylor State Park streamgage location. ..... SOP 3.71

Figure SOP 3.45. Sandy Creek Watershed. ..... SOP 3.75

Figure SOP 3.46. Sandy Creek, looking upstream at triple culverts. ..... SOP 3.76

Figure SOP 3.47. Precipitation map for Pinnacles National Monument. ..... SOP 3.76

Figure SOP 3.48. Estimated flood frequency at Sandy Creek. ..... SOP 3.77

Figure SOP 3.49. Chalone Creek (looking upstream to Chalone Creek Bridge), before vegetation was present in channel. ..... SOP 3.81

Figure SOP 3.50. Chalone Creek (looking towards right bank) current condition with vegetation in channel. ..... SOP 3.82

Figure SOP 3.51. Chalone Creek watershed. ..... SOP 3.83

Figure SOP 3.52. Bear Creek watershed. ..... SOP 3.88

Figure SOP 3.53. Bear Creek staff plate and pressure transducer on upstream side of "Bridge #1" prior to crest gage installation. ..... SOP 3.89

Figure SOP 3.54. Bear Creek, looking upstream at Bridge #1. ..... SOP 3.90

Figure SOP 3.55. Estimated flood frequency at Bear Creek (unimpaired, without dam). ..... SOP 3.90

Figure SOP 3.56. Sketch Bear Creek streamgage location and reference marks……...SOP 3.90

Tables

Page

Table SOP 3.1. Drainage areas of Redwood Creek sub-watersheds. ..... SOP 3.28

Table SOP 3.2. Monthly precipitation and evaporation. ..... SOP 3.29

Table SOP 3.3. Estimated flood frequency at Redwood Creek at Highway 1. ..... SOP 3.29

Table SOP 3.4. Estimated flood frequency of Easkoot Creek below Park entrance road. ..... SOP 3.41

Table SOP 3.5. Estimated flood frequency at Pine Gulch Creek below Olema-Bolinas Road. ..... SOP 3.53

Table SOP 3.6. Estimated flood frequency at Olema Creek at Bear Valley Road bridge. ..... SOP 3.62

Table SOP 3.7. Estimated flood frequency for Sandy Creek. ..... SOP 3.74

Table SOP 3.8. Estimated flood frequency for Bear Creek (unimpaired, without dam). ..... SOP 3.87

Appendixes

Page

Appendix SOP 3A. Definition of Station Description Fields (from Kennedy 1983) ..... SOP 3.91

San Francisco Bay Area Network (SFAN) Streamflow Monitoring Protocol: SOPs

Purpose

The purpose of this standard operating procedure (SOP) is to provide guidance on the preparation, review and updating of station descriptions. The station descriptions use standard fields (Appendix SOP 3A) for existing and proposed streamgages. The station descriptions provide metadata regarding our program's streamgages. This SOP applies to streamgages with automated equipment and crest gages for stations maintained by NPS for the SFAN streamflow monitoring program.

Reference Materials

Examples of Station Descriptions and the definition of each of the fields are provided in USGS technical report, "Computation of Continuous Records of Streamflow" (Kennedy 1983, Meyer 1996). All personnel should be required to review this document.

Explanation of Station Description Fields

To the extent practicable, we are following guidance for station descriptions provided by USGS (Kennedy 1983, see Appendix SOP 3A). Two of the fields (Watershed conditions and Geology) are non-standard USGS information fields. They are included to provide a better understanding of the influences on streamflow dynamics that will be reported on.

For one of the fields (Floods), the duration of our streamgages, especially those that have yet to be installed, is insufficient to provide this information. However, such data is invaluable. Therefore, this data has been estimated using a USGS computer program for flood estimation based on regional regression procedures established for ungaged watersheds. Details of this procedure are provided in Ries and Crouse (2002) as well as in the SOP 7 Data Analysis and Reporting.

Estimation of drainage area has been determined through use of GIS software. The drainage area was determined using ArcHydro data model for ArcMap. Base map data (digital elevation model) obtained through USGS through website: http://gisdata.usgs.net/website/seamless/viewer.htm. This data downloaded as ArcGRID NAD 83 Geographic with X/Y cell Size: 00.00009 Degrees (10 Meter). Data tiles were merged, reprojected to UTM, Z10, NAD83 and then clipped to project area frame. Data processed using DEM Reconditioning utility in ArcHydro using AGREE method developed at University of Texas. For full reference see http://www.ce.utexas.edu/prof/maidment/GISHYDRO/ferdi/research/agree.html

Update Procedures for Station Descriptions

The station descriptions are written within the time that the first year's records are computed by the Program Lead and Field Technician. Station descriptions are reviewed annually and are updated as needed and become a history of the station. Any revisions are dated and the name and position of the person responsible for the changes is noted. As a station description is updated the superseded description is archived, thus the station description becomes a living document detailing the history of the station. Paper copies of current and past station descriptions should be stored with station files.

Lobos Creek, San Francisco County, California, The Presidio

Revision Date: February 22, 2010
Revised By: Darren Fong, GOGA

Location

(Figures SOP 3.1–4) – The monitoring site on Lobos Creek is located on the north side of Lincoln Boulevard in San Francisco, California. Latitude (37.788000) Longitude (122.483861). USGS Hydrologic Unit Code (18050002); Cal Water Unit: (CAR203.400LOBOS_CREEK_00). Hydrologic region name: San Francisco Bay, Hydrologic Unit Name: (San Pablo Bay), Hydrologic Sub-area name: Lobos Creek.

Directions

Drive on Lincoln Boulevard towards 25th Ave. Upon seeing the car bridge over Lobos Creek, park in the Baker Beach overflow lot to the west or the Presidio Trust Facilities Building parking lot to the east. Head downslope to creek. Water diversion structure and streamgage are behind a locked gate and fence at the downstream side of the Lincoln Boulevard bridge. Contact Presidio Trust Water Treatment Plant staff for access (415) 561-4134.

Establishment

Original station established in bypass flume on October 22, 1998. Existing station moved into box culvert of creek at Lincoln in 2001.

Elevation

Elevation within this watershed ranges from 0 ft to 250 ft above sea level (PWA 1995). Lobos exits into the Pacific Ocean through a concrete outflow structure located on Baker Beach. The headwaters of Lobos Creek start around the spring-fed Mountain Lake.

Drainage Area

Above the streamgage, Lobos Creek is a perennial stream with a drainage area of 3.84 mi^2 (2,456 acres) (planimetric) (Figure SOP 3.1). It has a three-dimensional drainage area of 3.87 mi^2 above the streamgage.

Gage

Lobos Creek flows underneath Lincoln Blvd in The Presidio in a perched box culvert. Since 2001, streamflow monitoring has been measured by a 1.5-ft high H-flume (Plasti-Fab, Inc.) (Figure SOP 3.2–3). The H-flume can measure flows up to 3.520 cfs. Water depth is measured by SIGMA 950 75 kHz Ultrasonic Flow Meter and sent to the Presidio water treatment facility via wireless radio. Currently, only mean daily flows are saved by the water treatment computer system.

History

Prior to 2001, streamflow discharge estimates from WY 1999–2000 were attempted by gaging flows in a concrete bypass channel and then adding them to metered creek withdrawals by water treatment plant (Figure SOP 3.4). Original gaging equipment included staff gage, 20-watt solar panel, Campbell Scientific CR10x datalogger (S/N X14955), 2 Druck PDCR1830, 5psig, (S/N 1088285&1088284) established by consultants (Balanced Hydrologics). There were

measurement inaccuracies due to a dynamic sandbed. The H-flume and gaging equipment were installed in 2001.

Benchmarks

There are no nearby National Geodetic Survey benchmarks nor have there been topographic surveys yet to establish local reference marks.

Watershed Hydrologic Conditions

Lobos Creek lies in a temperate-marine climate with dry summers and cool wet winters. Summers are characterized by little to no rainfall, strong afternoon winds and coastal fog. Winters are characterized by short rain storms lasting for 1 to 5 days, followed by 7 to 14 days of calm weather (BAAQMD 1985). Majority of annual precipitation occurs during and between the months of October and April, collecting on average 22 inches annually (Owenby and Ezell 1992).

Lobos Creek is a perennial stream with a planimetric surface drainage area of 3.84 mi^2. The Creek channel is approximately 1 mile long with no established tributaries. The main source of water comes from a sandy aquifer located in the Richmond district by Golden Gate Park. A smaller aquifer enters the creek downstream through fractured bedrock. Most of the creek's water enters through porous sandy soils along the south bank of the creek (along 18th–22nd Ave.) (Schanz et al. 1995, Urban Watershed Project 2001). Groundwater keeps water in the stream year-round at a stable level unlike most coastal creeks in California. During the dry summer months, water flow is around 1.5 cfs. During the rainy winter months, flows can reach 3 cfs. Little stormwater enters Lobos Creek from the surrounding, mostly urban area, except when street runoff occurs when the drop inlet structures become plugged with debris. Much of the precipitation falling onto the streets and structures around Lobos Creek are diverted into the City's wastewater treatment facility, treated, and discharged through an outfall into the Pacific Ocean.

Geology

Lobos Creek catchment area is defined by the topographical boundaries of Presidio Hill, Lone Mountain, Laurel Hill and the Pacific Ocean. The underling bedrock is Franciscan Assemblage, overlaid by Colma formation sandstone (PWA 1993). The hills forming the watershed consist of exposed Colma formations giving them their steep but short characteristics. As precipitation travels downhill, the slope decreases at the Colma/Dune interface. At this interface, Lobos Creek starts to take form. Sand dunes overlay the Colma formation and continue to the ocean where Lobos Creek enters Baker Beach.

Channel Conditions

Because of consistent baseflows and practically non-existent peak flows, much of the channel is vegetated with willows along the banks and dense areas of emergent plants such as watercress and nasturtium. Lobos Creek has no developed bars or floodplains that are present in other coastal streams. Banks of the creek are relatively steep with the south bank consisting of homeowner yards while the north bank is a mixture of willow riparian and oak woodland habitats with ubiquitous non-native vegetation. The wetted portion of the creek is generally five ft wide with depths of 0.5 to 1.0 ft and channel slopes from 0.4 to 3% (Schanz et al. 1995).

Lobos Creek is one of the few streams within San Francisco that flows mostly above ground. A majority of the streamflow is diverted to The Presidio Trust water treatment plant.

Control
The in-channel H-flume controls the stage-discharge relation at low flow discharges. Control point is the outlet of the H-flume (free-fall condition).

Discharge Measurements
TBD

Floods
Accurate measurement of peak flows is not available due to capacity of existing H-flume and upstream fish screen (See Regulation and diversion). In addition, much of the surrounding drainage area is in urban development. Much of the surface runoff is conveyed into storm drain system with eventual discharge into the Pacific Ocean.

Point Of Zero Flow
The point of zero flow corresponds to a staff gage reading of 0 and to the bottom outlet elevation of the H-flume.

Winter Flow
No ice.

Regulation and Diversion
There are no upstream diversions. The downstream diversion may affect measured flows at the streamgage when the water treatment plant is not withdrawing water. When the water treatment plant is not in operation, water backs up and the free fall of the flume is affected. This condition could potentially affect the accuracy of the rating curve. There is a ¼-inch mesh screen on the upstream side of the Lincoln Blvd culvert to trap debris and reduce fish entrainment into the water treatment plant. This screen is periodically cleaned. It likely functions as a weir or dam structure. Therefore, peak flow discharges are likely attenuated.

Cooperation
Station maintained and operated by The Presidio Trust (Presidio Water Treatment Plant). Current point-of-contact Scott Sacks, telephone (415) 561-4134, SSacks@presidiotrust.gov

Indirect Measurement Site
TBD

Land Ownership
U.S. government (GOGA)

Quadrangle
San Francisco North

Period of Record
October 22, 1998 to present



Figure SOP 3.1. Lobos Creek drainage basin.

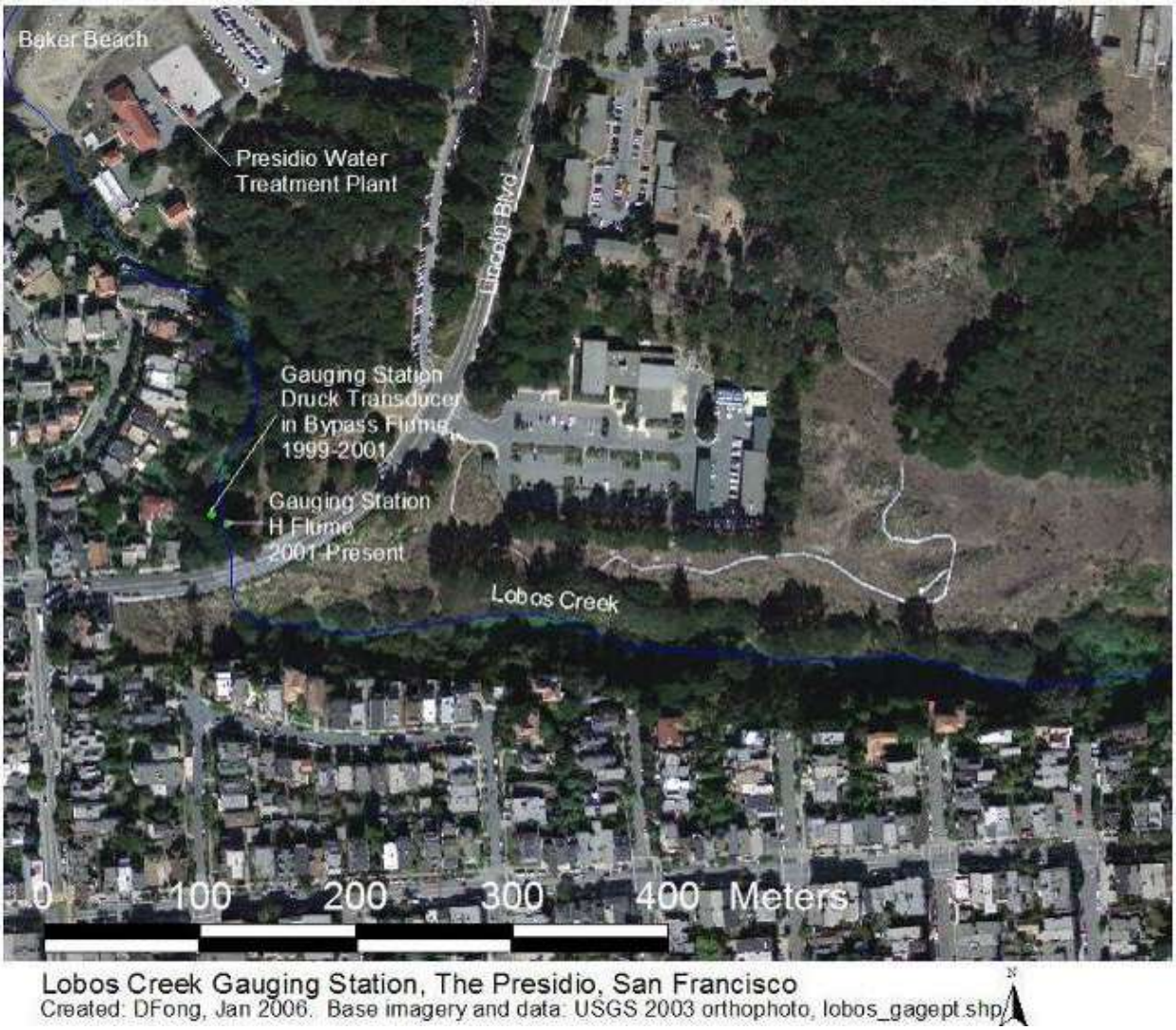


Figure SOP 3.2. Aerial photo of Lobos Creek and streamgage.



Figure SOP 3.3. H-flume at Lobos Creek streamgage.



Figure SOP 3.4. Lobos Creek streamgage with treatment plant diversion structure (left) and bypass channel (right).

Franklin Creek, Contra Costa, California, John Muir National Historic *Site*

Revision Date: March 9, 2011
Revised By: Katie Booth, SFAN

Location

(Figures SOP 3.5–10) – Latitude 37° 59' 32" N, Longitude 122º 7' 56" W. John Muir National Historical Site is located in Martinez, California. It consists of three separate land units: the House Site, the Mt. Wanda tract, and the Gravesite tract. The gaging site is at the Orchard trail footbridge near the northern boundary of the House site. USGS Hydrologic Unit Code: 18050001, Hydrologic Region: San Francisco Bay, Hydrologic Unit Name: Suisun Bay, Hydrologic Sub-unit Name: Alhambra Creek, Contra Costa County (Figures SOP 3.5–6).

Directions

I-80 to Hwy. 4 to Martinez; Exit Alhambra Ave (left) to JOMU visitor center. Site is at the Orchard trail footbridge. Gate key required for vehicle entry; separate gate combo for foot entry

Establishment

Station established in 2003 by Mary Cooprider and Greg Brown, SFAN water quality and stream fish staff, respectively.

Elevation

205 ft above sea level. The watershed ranges in elevation from 1,000 ft at the top of Franklin Ridge to 200 ft where Franklin Creek joins Alhambra Creek (Figures SOP 3.7–8).

Drainage Area

Above the streamgage, Franklin Creek is a perennial stream with a drainage area of 5.01 mi^2 (3,204 acres) (planimetric). It has a three-dimensional drainage area of 5.35 mi^2 above the streamgage.

Gage

This streamgage was discontinued and the datalogger was removed in 2008. Water level was recorded at 15-minute intervals with a Global Water WL15 data logger with a submersible pressure transducer (Figures SOP 3.9-10). A weather-resistant cylindrical enclosure housed the data logger, running on two internal 9-volt DC batteries. The Global Logger software facilitated data transfer from the logger to a laptop computer.

The data logger was housed in a 6-inch PVC pipe located 10 ft upstream from the bridge on the left bank. A 23-ft aluminum electrical conduit housed the line from the data logger to the pressure transducer. The pressure transducer was protected by a 2-inch PVC pipe resting on the creek bottom underneath the bridge. The electrical conduit and PVC pipe were held in place by rebar driven into the bank and stream bed. The staff and crest gages are mounted downstream of the bridge along the left bank.

History

There is a discontinued streamgage, #11182400 Arroyo Del Hambre on Alhambra Creek, approximately two miles downstream of the Franklin Creek monitoring station.

Benchmarks
There are no nearby National Geodetic Survey benchmarks to the site. Elevations are based on an arbitrary location

Watershed Hydrologic Conditions
Franklin Creek is the largest tributary of the Alhambra Creek watershed, which flows into the Carquinez Straits below Suisun Bay. The terrain is predominately mountainous. The creek descends southeasterly through Franklin Canyon from its origin near the 1,000 ft Franklin Ridge to approximately 200 ft at its mouth. The lower portion of the subwatershed "doglegs" so that it is flowing in a northeast direction when it joins Alhambra Creek. Franklin Creek joins Alhambra creek at about two miles below the Alhambra and Arroyo del Hambre confluence, which is about two miles from the top. Alhambra creek flows another two miles after Franklin joins it before it drains into Carquinez Straits. The Franklin Creek basin is a watershed of 5 mi^2, roughly the same size as the combined Upper Alhambra and Arroyo del Hambre basins.

Franklin Creek is predominantly spring-fed and this water stays cool even in the heat of summer. A temperature study during the summer of 1999 showed its water temperature to be consistently below 65 ºF, even when the temperature of Alhambra Creek downstream of its confluence with Franklin Creek was peaking at 72 ºF. In the summer of 2000, a follow-up study was completed measuring temperatures at several places in the Franklin basin as well as in lower Alhambra Creek. Land use in the Alhambra Creek Watershed has changed over the past 50 years in some areas from cropland and rangeland to residential subdivisions and urban development. The Franklin Creek subwatershed has escaped most of the urbanization. Franklin Creek is located in a transitional zone between the San Francisco Bay Area and the San Joaquin Valley in eastern Contra Costa County. The regional climate is Mediterranean, with warm dry summers and mild wet winters. Average annual precipitation ranges from 18 to 22 inches, with 90 percent of rainfall occurring between November and April (USDA 1997). In the summer, a steady marine wind blows through the Golden Gate and up the Carquinez Strait.

Alhambra Creek historically supported a small run of steelhead (*Oncorhynchus mykiss*) and in some years they have been seen in the creek. Barriers in the lower watershed and siltation present limitations to the amount of salmonid habitat remaining in this watershed. However, Franklin Creek is perennial, which may help support steelhead restoration in the watershed.

Geology
The bedrock of the area was originally deposited as layers of sand and mud in the deep ocean. The Briones Formation and several other geologic units have common seashell fossils. Between about 100 million and 10 million years ago, layers of sediment accumulated, were buried, compressed and turned to rock. Later, these rocks were folded and faulted and the East Bay hills uplifted. As the hills rose, erosion cut away at the rocks, carving valleys in the soft shales and leaving the harder sandstones as hills. Franklin Creek is located between the Hayward and the Concord/Green Valley Faults, which trend nearly parallel to the San Andreas Fault. Soils are generally clay and clay-loam. Rock is soft siltstone, sandstone, and mudstone. These soils will slide when undercut on moderate to steep slopes, and there is a significant local history of slope failure in developed areas. The Muir House area is generally in a flat valley; the house itself is located on a low knob. Soils are deep rich clay and clay-loam, with a long history of cultivation.

The Mt. Wanda parcel is steeply sloping on the sides, with an expanse of level terrain in the center. There is evidence that the lands in the center were graded at some time, possibly in the 1920's, to facilitate hay production. Soils on this property are loam and clay-loam 1 to 3.5 ft thick. They are impermeable, subject to erosion and can slide when undercut.

Channel Conditions

Much of Franklin Creek is underground due to the proximity of the railroad, Franklin Canyon Road and the Highway 4 Freeway. Within John Muir NHS, the channel is very constrained. After flowing through the long tunnel underneath Highway 4, Franklin Creek's channel exhibits very low sinuosity, is incised and has a thin riparian/floodplain area. A wooden bridge, part of the Orchard Trail, crosses the creek about 10 ft before the property boundary. A chain link fence gate, which is open during high flow events, crosses the creek at the property boundary and catches debris coming down the stream. At the same location is a concrete sill raised above the streambed, creating a silt-covered pool above the property boundary (Figure SOP 3.9). On either side of the pool are vertical stone riprap walls, which extend beyond the property boundary. Above the bridge, much of the riparian area has concrete riprap. Below the sill the channel bottom is lined with concrete for approximately 20 ft before a more natural channel bottom resumes.

Control

A concrete sill below the staff gage controls low flow water surface elevations (Figure SOP 3.9). At higher flow conditions, this section control may be drowned.

Discharge Measurements

Wading measurements are collected, when possible, during the monthly water quality site-visits. These visits follow a two-year rotating sampling design, which means that this site was not visited during water year 2009 or 2010 but monthly discharge measurements began again in October of 2010.

Floods

Indirect estimates of peak flow will be computed by U.S. Geological Survey's National Flood Frequency computer program (Vers. 3.2) which uses regional regression equations based on prior investigations of the relationship between watershed and climate parameters with streamflow.

Point Of Zero Flow

On March 28, 2007, the staff gage reading was 0.49 ft at zero flow. The staff gage has not been referenced to a national vertical datum.

Winter Flow

No ice.

Regulation and Diversion

TBD

Cooperation
Station maintained and operated by NPS San Francisco Area Network Inventory and Monitoring Program.

Indirect Measurement Site
TBD

Land Ownership
U.S. government (NPS - JOMU)

Quadrangle
Briones Valley

Period of Record
2003 to 1/1/06 and 3/16/06 to 2008

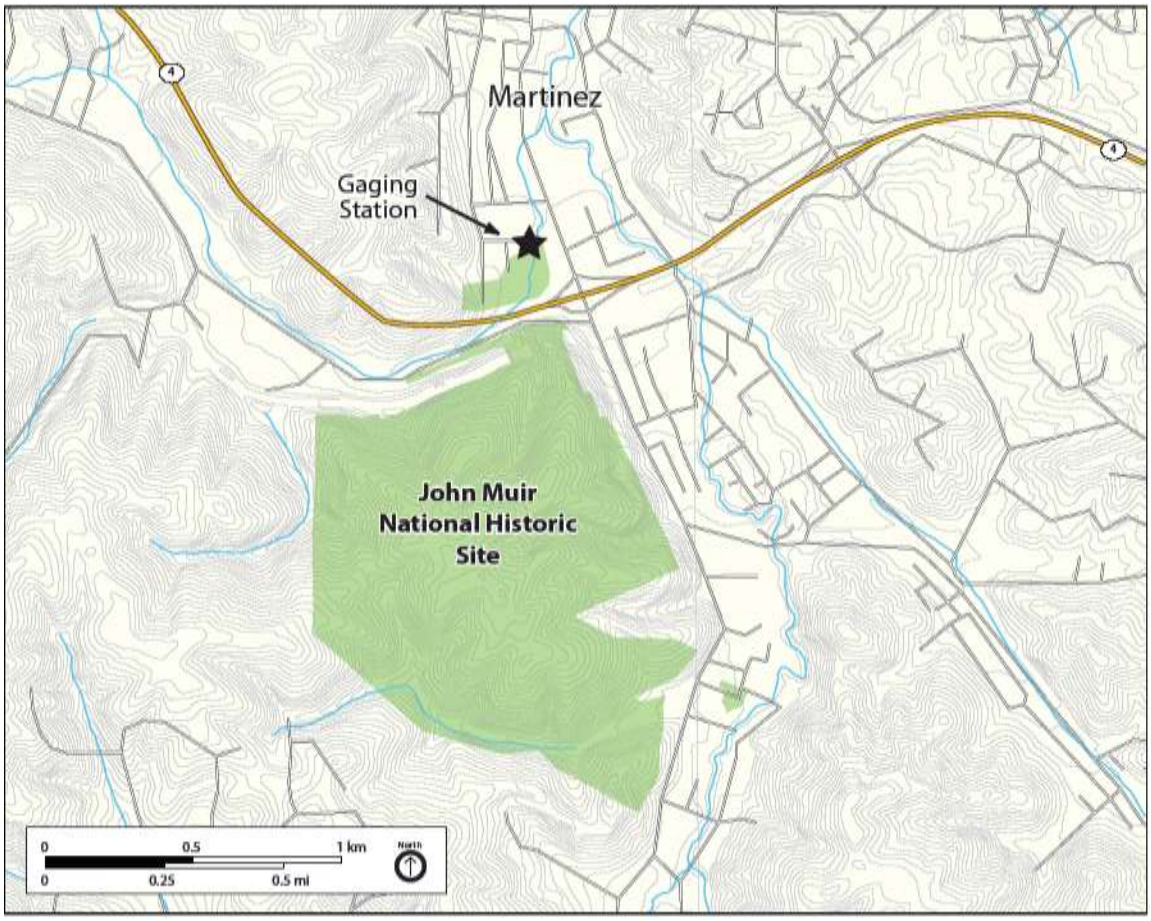


Figure SOP 3.5. Site map of John Muir National Historic Site, Martinez, CA.



Figure SOP 3.6. Location of stream gage on Franklin Creek below Highway 4, John Muir National Historic Site, CA.

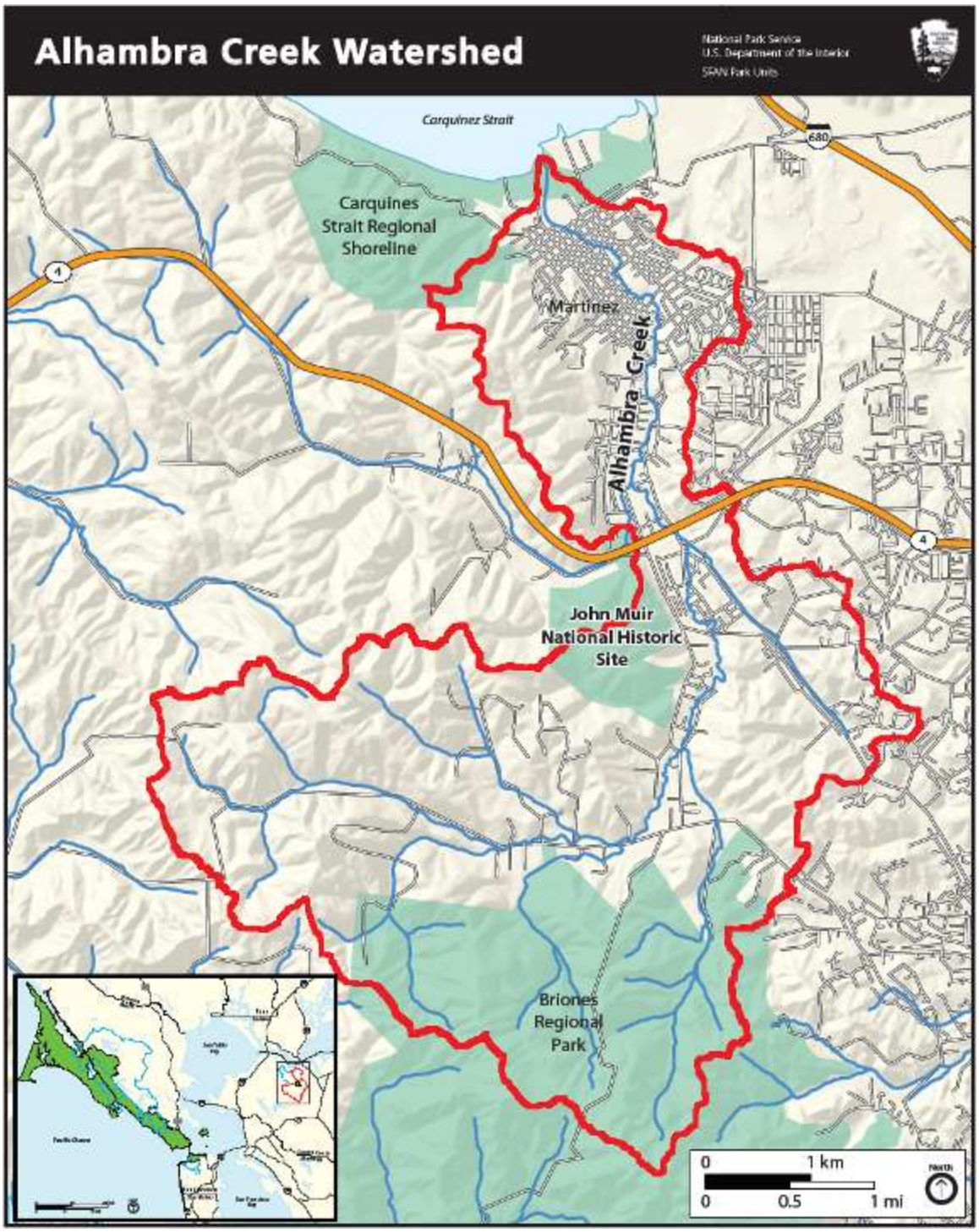


Figure SOP 3.7. Alhambra Creek watershed (excluding Franklin Creek sub-watershed).

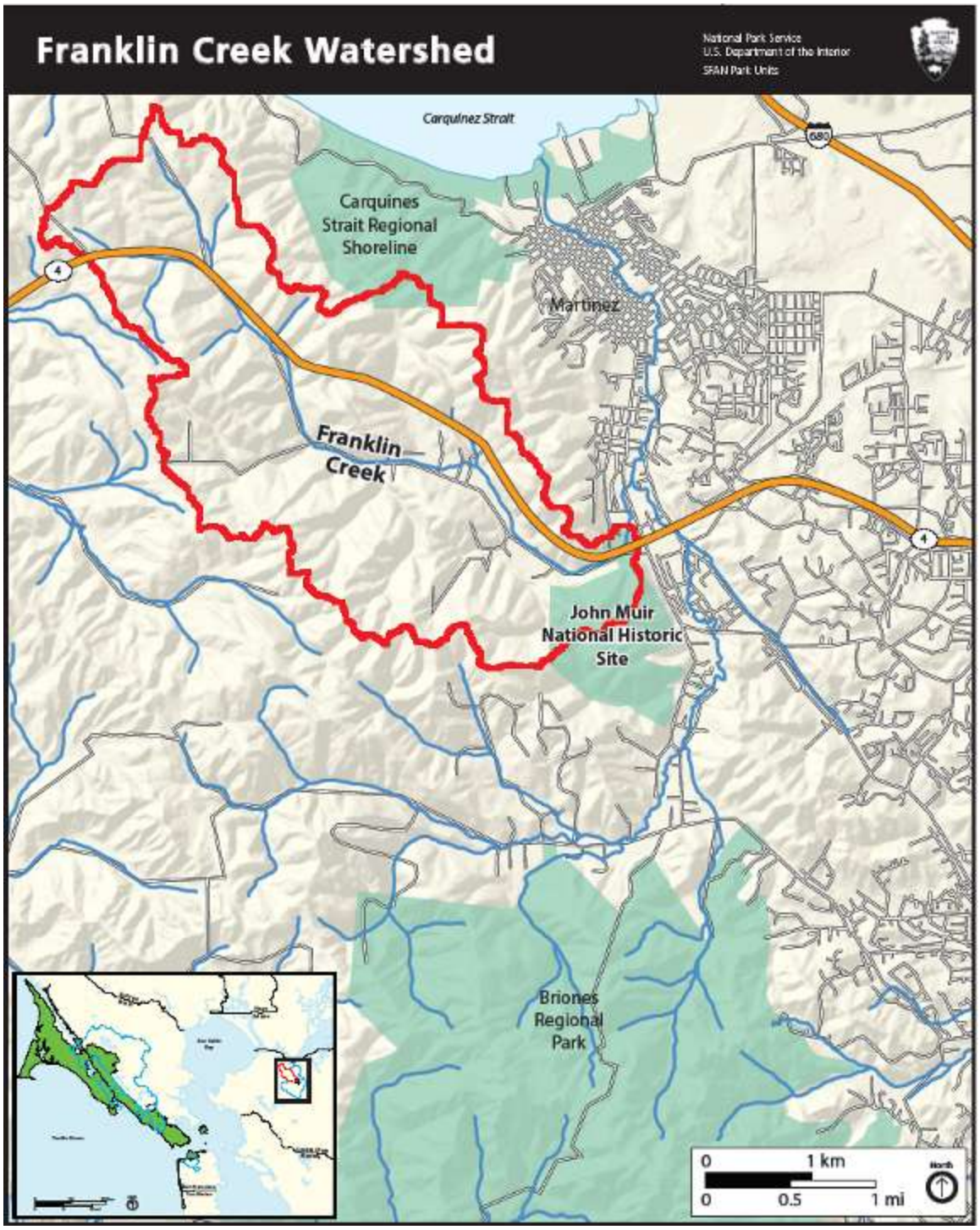


Figure SOP 3.8. Franklin Creek drainage area.



Figure SOP 3.9. Staff gage upstream of concrete sill on Franklin Creek (looking downstream from pedestrian bridge to left bank).



Figure SOP 3.10. Housing and pressure transducer underneath pedestrian bridge on Franklin Creek.

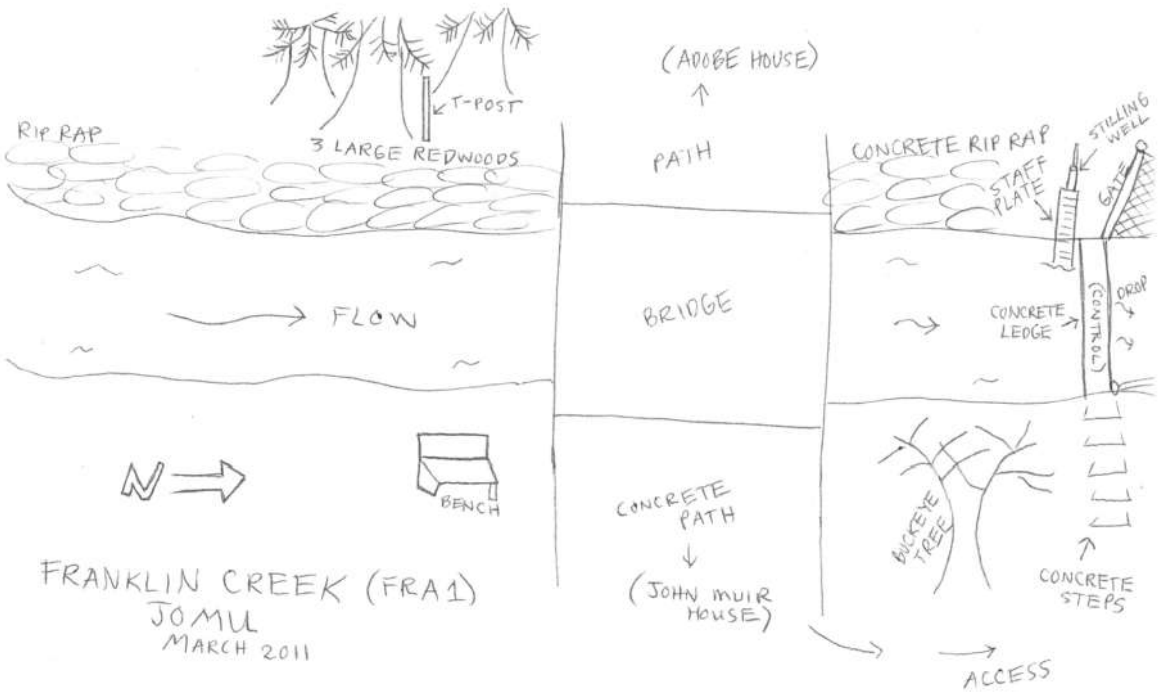


Figure SOP 3.11. Sketch of Franklin Creek streamgage location at pedestrian bridge.

Redwood Creek, Marin County, California, Golden Gate National Recreation Area

Revision Date: February 26, 2010
Revised By: Darren Fong, GOGA

Location

(Figures SOP 3.11-18) - Latitude 37°51'58.03"N, Longitude 122°34'42.61"W, in Marin County, California. The gaging site is located at the Highway 1 Bridge, on the upstream side, about 10 miles north of San Francisco. Hydrologic Unit Code: 18050005, Hydrologic Region: San Francisco Bay, Hydrologic Unit: Marin Coastal (Figures SOP 3.11–12).

Directions

The streamgage is on State Highway One, 0.1 mile southwest of the junction with Marin County's Muir Woods Road (Figure 47). To access the site, park on the side of the gravel road along the west corner of the bridge. In 2010, high flow bridge measurements will be accessed about 0.5 north of State Highway One on the county Muir Woods Road. The pedestrian bridge is located at the Muir Beach Community Service District's property (Figure SOP 3.13).

Establishment

The existing streamgage was set-up by Brannon Ketcham, formerly the Coho and Steelhead Restoration Project hydrologist, in November 1997.

Elevation

Approximately 23 ft above sea level. The watershed ranges in elevation from 2,575 ft (784 m) at the peak of Mt. Tamalpais to sea level at Big Lagoon.

Drainage Area

Above the streamgage, Redwood Creek is a perennial stream with a drainage area of 7.12 mi^2 (4,557 acres) (planimetric) (SOP 3.14). It has a three-dimensional drainage area of 7.77 mi^2 above the streamgage. The stream distance to the drainage divide is 5.66 miles (9,110 m). The drainage area at the current high flow measurement site is 6.66 mi^2 (planimetric) and a three-dimensional drainage area of 7.23 mi^2. The high flow site represents 94% of the drainage area of the streamgage.

Gage

Starting in December 31, 2008, stream water level and temperature were measured continuously and recorded as 15-minute instantaneous values using a combined datalogger and transducer system (In-Situ Level Troll 500). Starting in November 26, 2008, rainfall is measured in a stand-alone tipping bucket (Onset Computer Corp., Model RG-2) in a grassland-shrub habitat near the streamgage. The previous rain gage was located in a small opening in the riparian forest that was starting to have canopy closure. Measurements at this site have since been discontinued.

From 1998 to December 31, 2008, stream water level was measured continuously and recorded as 15 minute instantaneous values using an Instrumentation Northwest PS9105 pressure transducer to the nearest 0.01 ft. After this period, the equipment is being used as a backup to the In-Situ Level Troll 500. Hourly and daily average, maximum and minimum water levels are also recorded. The transducer is housed in a 12-ft long galvanized stilling well that was driven approximately 2 ft into the streambed attached to the upstream center support leg of the Highway

1 bridge (Figure SOP 3.15). The lead attaching the transducer is run through a half-inch aluminum electrical conduit running from the well to a weatherproof box mounted to a wooden post approximately 20 ft away on the right side of the creek.

A Campbell Scientific instrument CR10x data logger is housed in the weather proof box and is powered by a solar charging unit. Data is collected using the PC208W Program.
Until November 2008, rainfall was measured with a Campbell Scientific Instruments TE525 tipping bucket rain gage (to the nearest 0.01 inch). The gage is mounted in an open area approximately 40 ft northeast of the bridge next to the solar panel. Connecting cables are housed in a ½ inch aluminum electrical conduit for protection.

A crest gage is attached to the top of the galvanized stilling well to record high flows. The original gage datum was the '0' of the gage tape that was placed on the stilling well in 1997. The gage datum elevation of '0' was 14.12 feet (NAVD 88) (Surveyed 07 November 2005). On October 31, 2005, an enamel staff gage was mounted next to the well using marine epoxy to the center support pier of the bridge. The 0.00 feet on the staff gage plate is 14.58 ft (NAVD88) (Surveyed 04 October 2007). A datum correction of 0.46 feet is required to normalize current staff gage measurements to the original gage datum.

History

From 1962 to 1973, the USGS measured annual peak flows in Redwood Creek at the Frank Valley Bridge (contributing area = 6.38 mi^2). From 1986 to 1988, the USGS quantified "summer" and "winter" flows at the Pacific Way Bridge, at the downstream boundary of Muir Woods National Monument, and Green Gulch Creek. From March 1992 to September 1993, daily flow was monitored continuously in Redwood Creek at the Pacific Way Bridge using an automatic water level recorder (PWA 1994). The NPS has been monitoring flow, with some data gaps, at the Highway One Bridge since 1998. From 1998 to 2000, USGS measured streamflows and obtained water quality data for 13 events at the existing streamgage.

Benchmarks

A sketch map of benchmark and reference marks is provided in Figure SOP 3.16.

Elevations for the streamgage are based on National Geodetic Survey marker (PID HT1707) established in 1970 and located in the top of the concrete wingwall of the Highway 1 bridge (Figure SOP 3.17, upstream, left bank wingwall looking downstream). Benchmark disk is stamped "W480 Rest 1970" Latitude 37°51'59" and Longitude 122°34'41". Benchmark elevation of 25.5 ft (NAVD 88).

RM1 is steel bolt set into State Route 1 bridge guard rail and painted orange (Figure SOP 3.17). Bolt on left bank, upstream side of bridge and 9.7 feet from NGS W480 benchmark. Elevation 27.515 ft, NAVD88 (Levels of June 11, 2008).

RM2 is steel bolt set into State Route 1 bridge guard rail and painted orange (Figure SOP 3.18). Bolt on left bank, downstream side of bridge. Elevation 27.025 ft, NAVD88 (Levels of June 11, 2008).

RM3 is south-eastern most pressure-treated 4x4 wood post supporting Campbell Scientific Datalogger on the left bank upstream of bridge. Elevation 28.60 ft, NAVD88 (Levels of June 11, 2008)-top of wood post.

Watershed Hydrologic Conditions

The Redwood Creek watershed is 8.9 mi^2 (5,568 acres) making it the largest drainage in the Golden Gate National Recreation Area (GOGA). The creek begins as springs on the south face of Mount Tamalpais and flows approximately 6 miles through a heavily forested watershed in Mount Tamalpais State Park and Muir Woods NM, underneath Highway 1, and then drains into the Pacific Ocean at Muir Beach. The terrain is predominantly mountainous, rising from sea level to approximately 2,600 ft. Redwood Creek's watershed is located in the Coast Ranges, which were formed by the subduction of the Farallones plate under the western edge of the North American plate. The watershed is predominantly underlain by the Franciscan complex, which contains highly deformed beds of late Jurassic and Cretaceous sedimentary, metamorphic and igneous rock and Quaternary era sand, silt and gravel. The San Andreas Fault lies just offshore.

Redwood Creek is 5.9 miles long, approximately 1 mile of which is within the coastal zone, while the tributaries total 14.2 miles. The larger tributaries of Redwood Creek include Bootjack, Rattlesnake, Spike Buck, Fern, Kent and Green Gulch Creeks. Green Gulch Creek enters immediately upstream of Redwood Creek entering Big Lagoon (Figure SOP 3.14, Table SOP 3.1). Vegetation is composed of mixed conifer forests in the upper valleys, mixed hardwoods, chaparral and grasslands on the slopes, and a corridor of riparian vegetation (willows and alders) along Redwood Creek.

Redwood Creek watershed is located in Northern California's zone of Mediterranean-type climate, which exhibits mild, wet winters, and warm, dry summers. About 60% of the rainfall is lost to evapotranspiration. Daily rainfall has been recorded at the Muir Woods National Monument since 1941, and monthly average data is available from Lagunitas Reservoir from 1879. Average annual rainfall is 37.5 in (95.2 cm.), with 95% of the precipitation falling from October to April (PWA 2000). Precipitation increases with elevation ranging from 28-30 inches at sea level to 28-50 inches at around 2,000 ft (Snider 1984). Average monthly rainfall values vary from 7.60 inches in January to 0.07 inches in July (Table SOP 3.2). Fog drip has been shown to contribute one-third of total annual precipitation in Northern California redwood forests (Dawson 1998).

The hydrologic regime of Redwood Creek is similar to that of many northern California coastal streams. Seasonal flow patterns in Redwood Creek are characterized by summer and fall low flows, low-to-moderate winter baseflows and sharp, short-duration winter storm peaks. Early season storm flows are comprised primarily of direct storm runoff and recede quickly after rainfall ends. By January, groundwater storage is sufficient to maintain high baseflows, and post-storm recessions can last for over 7 days. Flows in the late spring and summer dry season are derived from groundwater and springs in the upper watershed. Limited groundwater storage is available in the alluvial deposits in the lower valleys, and during the dry season, the creek commonly loses water to groundwater in the lower reaches in Frank Valley (PWA 1995). By the end of the summer dry season, the creek can have virtually no surface flow.

Geology

The Redwood Creek watershed is located in the Coast Ranges, which were formed by the subduction of the Farallones tectonic plate under the western edge of the North American plate. The geology of the watershed includes Mesozoic era Metasandstone and mélange and Quaternary era sand, silt and gravel. Sheared greywacke and shale, greenstone, chert, and metamorphic rock outcrops are dispersed throughout the watershed. The Coastal Belt Franciscan Complex, a highly sheared mixture of sedimentary, metamorphic and igneous rocks of Late Jurassic and Cretaceous age, with stacked thrust sheets composed of Cretaceous greenstone, greywacke, shale, and chert underlies the watershed (Blake et al. 1974, Jennings 1977, Warhaftig 1984, Martin 2000). Redwood Creek has downcut through these rocks to form Redwood Canyon and Frank Valley. Frank Valley has been subsequently filled with unconsolidated alluvial deposits (Martin 2000). The depth of alluvial fill is at least 37 ft (Martin 2000) and could be as much as 90 ft (Laudon 1988). There is also a prominent tract of alluvium through the Green Gulch sub-watershed and a Holocene beach and sand deposit known as Muir Beach at its mouth.

The rocks weather to a thin (1 ft) gravelly loam layer in the headwater reaches sitting directly on bedrock (Stillwater Sciences 2004). Permeability is low to moderate, and the potential for runoff and erosion is high. Lower in the watershed, clay-loam soils give way to clay at depth with low permeability, prior to bedrock. Runoff and erosion potential on the alluvial soils are low, primarily because of the low slopes (2 to 5%).

Channel Conditions

There are 122 km (75.8 mi) of channel within the watershed, giving a drainage density of 5.4 km/km^2. A series of narrow sub-watersheds rise on the steep southern slopes of Mt. Tamalpais before joining the Redwood Creek main stem in Redwood Canyon (Figure SOP 3.14). These channels have step-pool morphology, with channel beds composed of boulders with gravels held locally in small pools. Redwood Creek becomes a second-order channel at the confluence of Fern and Upper Redwood creeks and then flows 7.6 km to the mouth of the basin. The channel is gravel-bedded and, at the downstream end of Redwood Canyon, turns from a southeasterly flow direction to the southwest and gains a significant alluvial floodplain through the Frank Valley mid-reaches where a series of short, steep tributaries discharge across alluvial fans to the main stem. The confluence with Kent Canyon (2.5 km^2) is at this point. Exposures indicate the floodplain to be composed largely of fine loam, interspersed with layers of small gravel that increase in frequency and grain size with depth. In Lower Frank Valley, the channel turns southeasterly again before draining into Big Lagoon. The other tributary of note is Green Gulch (2.9 km^2), which drains directly into Big Lagoon. Redwood Creek continues to be gravel-bedded into Big Lagoon (Stillwater Sciences 2004).

In the upper portion of the watershed, the tributary creeks (Bootjack, Rattlesnake, Spike Buck and Fern) flow through deep incised canyons into Franciscan Complex mélange. In these canyons, the channel slope is four percent or greater (Figure SOP 3.19). When Redwood Creek reaches the Muir Woods National Monument, channel slope is around one percent. Downstream of Redwood Canyon, channel slope in the Frank Valley ranges from 0.9 percent at the upper end to 0.4 percent near the Highway 1 Bridge (Figure SOP 3.19). The present-day Redwood Creek main stem channel is incised below its former floodplain surface, leaving a series of horizontal surfaces preserved as inset fill terraces. The incised channel extends downstream of the

channelized section through Muir Woods National Monument, to the Highway 1 bridge near Big Lagoon.

The bridge spans 60 feet and mimics a large box culvert with flow being concentrated into two chambers (Ketcham 1998). The bridge confines flows into three culvert sections that total about 38 feet (Figure SOP 3.20). At low flow the stream is concentrated in the right section. At higher flows the other sections transmit water, the left section acting as a large eddy. The resulting silt deposition is a key reason why the low flow is concentrated to the right bridge section. Upstream of the bridge, flows are confined until water surface elevations reach around 26 ft NAVD88. This corresponds to the top of the bridge wing walls and elevation of the dirt spur road and Highway One.

In the fall of 2003, Philip Williams and Associates (PWA) completed a restoration project (Banducci site) on a 1.1-mile reach of Redwood Creek just upstream of the gaged site, installing several channel spanning weir structures into the banks and lowered channel banks that confined flood flows.

Control

Under low flow conditions, a pool tailout comprised of gravel, approximately 60 ft downstream from the upstream edge of the bridge serves as the section control. During the fall, deciduous tree leaves and twigs may collect at tailout and raise water surface levels. Under bankfull conditions, the channel control is a bend in the creek downstream of the gravel section control. There is also an unknown backwater effect caused by the two bridge supports under high flow conditions.

Discharge Measurements

Wading measurements are made 40 feet downstream of Highway One bridge. Low flow flume measurements are done 30 feet upstream of Highway One bridge. High water measurements are made off Highway One bridge using cable deployment. Under high water, the stream is all one channel in immediate proximity of the bridge. A heavy weight (30-50 lb) for the cable deployment is required to avoid vertical angles. An eddy is generally present at the left bank where a persistent gravel bar exists (Figures SOP 3.15, 3.20). For safety, starting in WY 2010, high water measurements will be made off a new pedestrian bridge at the Muir Beach Community Service District's (MBCSD) well site.

Floods

Indirect estimates of peak flow have been computed by U.S. Geological Survey's National Flood Frequency computer program (Vers. 3.2) which uses regional regression equations based on prior investigations of the relationship between watershed and climate parameters with streamflow. Redwood Creek watershed is near the interface between the Central Coast and North Coast regions. Estimates reported below (Table SOP 3.3, Figure SOP 3.21) were run using regional regression for Central Coast because altitude index was outside computation range for the North Coast region. In addition, the computed estimates are similar to values at a nearby station. At 1.2 km upstream of the current streamgage, Lehre (1974) derived a flood-frequency relationship for Redwood Creek based on 12 years of peak flow measurements collected at the Franks Valley Bridge. Based on this, the 100-year flood in Redwood Creek will have a peak discharge of about 3,300 cfs. The 10-year peak would be about 2,000 cfs, and the two-year peak would be about 800 cfs.

Point Of Zero Flow
For WY08, the point of zero flow was determined to be 1.40 feet (gage datum). This was based on near disconnected pool conditions on September 19, 2008.

Winter Flow
No ice.

Regulation and Diversion
The MBCSD obtains water from a shallow well adjacent to the creek. Assessments by NPS have indicated a hydrologic connection between the well and creek. The MBCSD has water rights to a maximum of 50.6 acre feet per year with maximum diversion rates of 0.07 cfs.

Cooperation
Station maintained and operated by NPS.

Indirect Measurement Site
TBD

Period of Record
Brannon Ketcham, Point Reyes National Seashore hydrologist, installed the original data logger and transducer in 1997 for the Coho and Steelhead Restoration Project. (1997-present)

Land Ownership
Ninety-five percent of the Redwood Creek watershed is publicly owned. Marin Municipal Water District owns 17% of the watershed, California Department of Parks and Recreation owns 52% (Mt. Tamalpais State Park), and the Golden Gate National Recreation Area owns 26% (Golden Gate National Recreation Area and Muir Woods National Monument). The remaining 5% includes roads owned by the California Department of Transportation, the County of Marin, local service districts, and private entities (Stillwater Sciences 2004).

Quadrangle
Pt. Bonita

Table SOP 3.1. Drainage areas of Redwood Creek sub-watersheds.

	Drainage Area	
Sub-watershed	**km^2**	**mi^2**
Upper Redwood Creek	5.12	1.98
Fern Creek	2.83	1.09
Kent Creek	2.54	0.98
Camino del Canyon	0.75	0.29
Green Gulch	2.85	1.10
Redwood Canyon	1.96	0.76
Upper Frank Valley	3.91	1.51
Lower Frank Valley	2.15	0.83
Total Watershed	22.69	8.76

Table SOP 3.2. Monthly precipitation and evaporation.

Month	Mean Precipitation[a] (in)	Mean Evaporation[b] (in)	Mean PET[c] (in)	Available Water[d] (in)
Oct	2.08	2.39	1.67	0.41
Nov	5.42	0.98	0.69	4.73
Dev	6.75	0.53	0.37	6.38
Jan	7.69	0.39	0.27	7.42
Feb	6.15	0.84	0.59	5.56
Mar	4.99	2.68	1.88	3.11
Apr	2.36	3.71	2.60	0.00
May	1.05	5.53	3.87	0.00
Jun	0.39	6.42	4.49	0.00
Jul	0.07	7.30	5.11	0.00
Aug	0.15	5.68	3.98	0.00
Sep	0.43	3.91	2.74	0.00
Total	37.52	40.36	28.26	9.26

[a]Precipitation data from Muir Woods' daily records from water years 1942-1986, 1989-2002.
[b]Evaporation data from Lagunitas Reservoir Pan.
[c]Potential Evapotranspiration (PET) computed from Pan Evaporation using a pan coefficient of 0.7.
[d]Available water is the water left after evapotranspiration losses, Mean Precipitation – Mean PET.

Table SOP 3.3. Estimated flood frequency at Redwood Creek at Highway 1.

Recurrence Int. (yrs)	Peak cfs	Standard Error (%)
2	773	110
5	1,330	86
10	1,760	78
25	2,290	78
50	2,760	85
100	3,150	93
500	4,220	

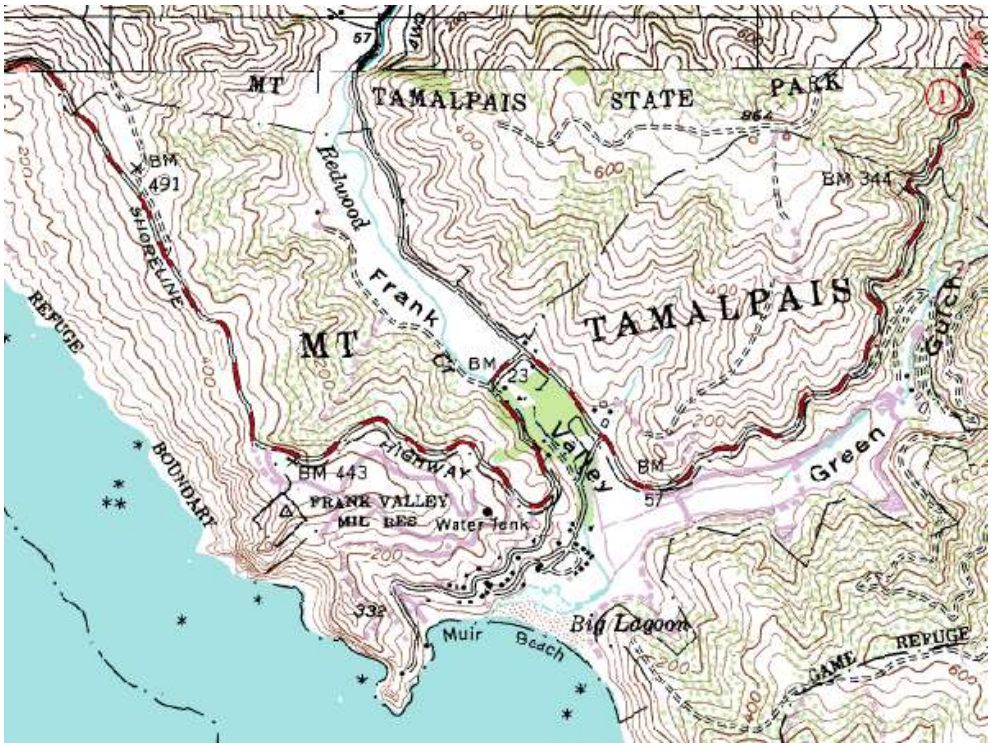


Figure SOP 3.11. Redwood Creek location map.

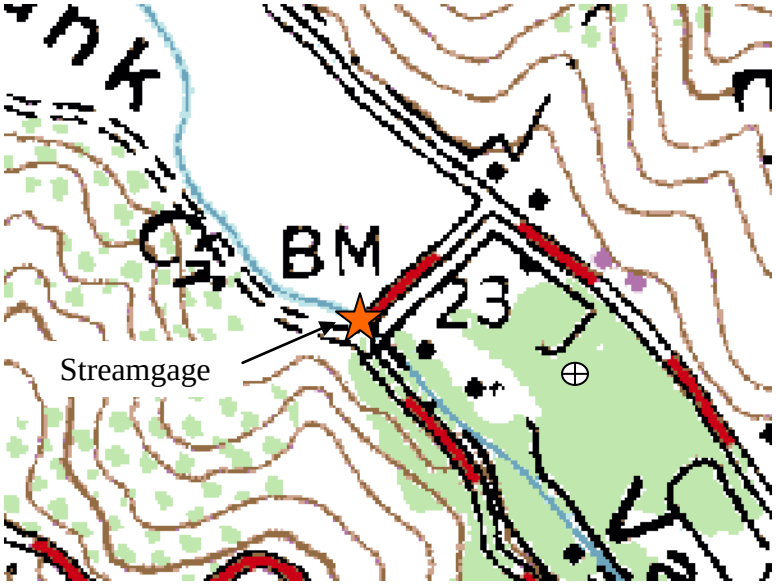


Figure SOP 3.12. Redwood Creek streamgage.

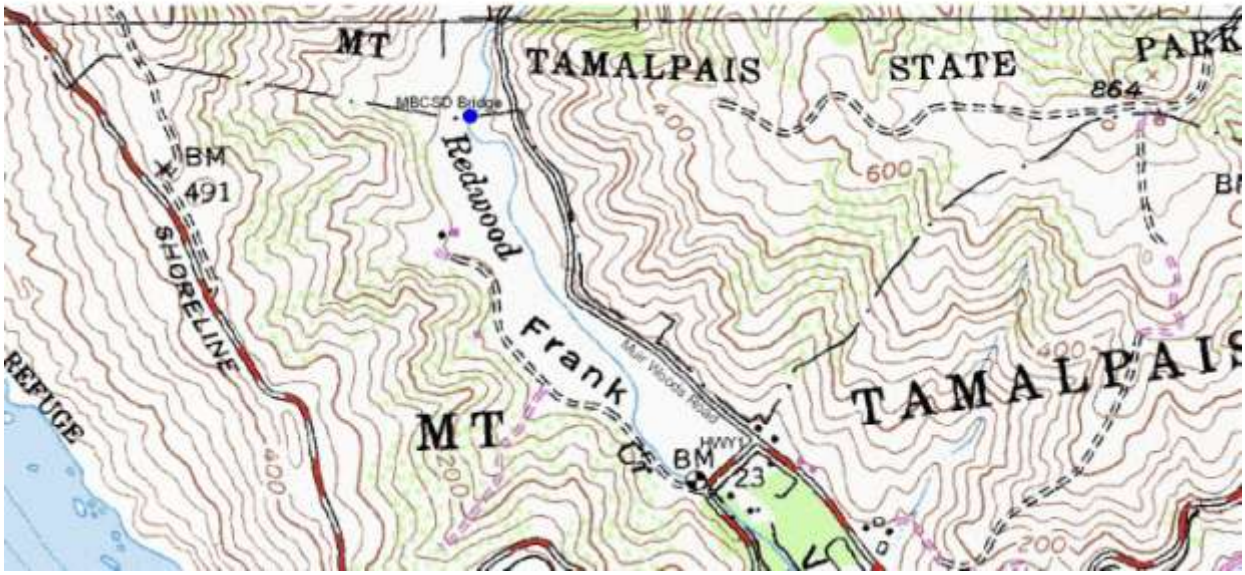


Figure SOP 3.13. Redwood Creek high flow measurement site at MBCSD pedestrian bridge.

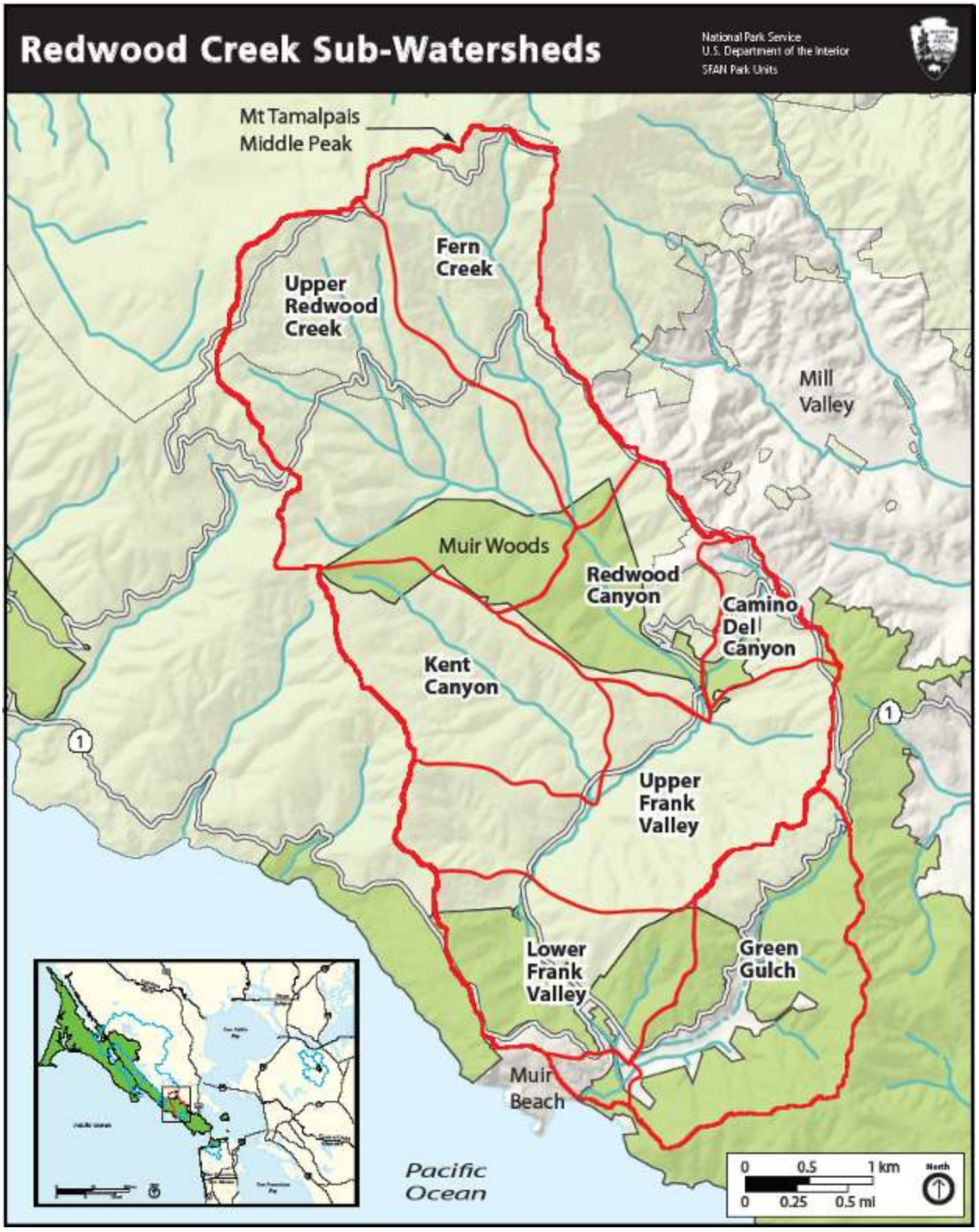


Figure SOP 3.14. Redwood Creek sub-watersheds.



Figure SOP 3.15. Staff gage and pressure transducer (looking downstream).

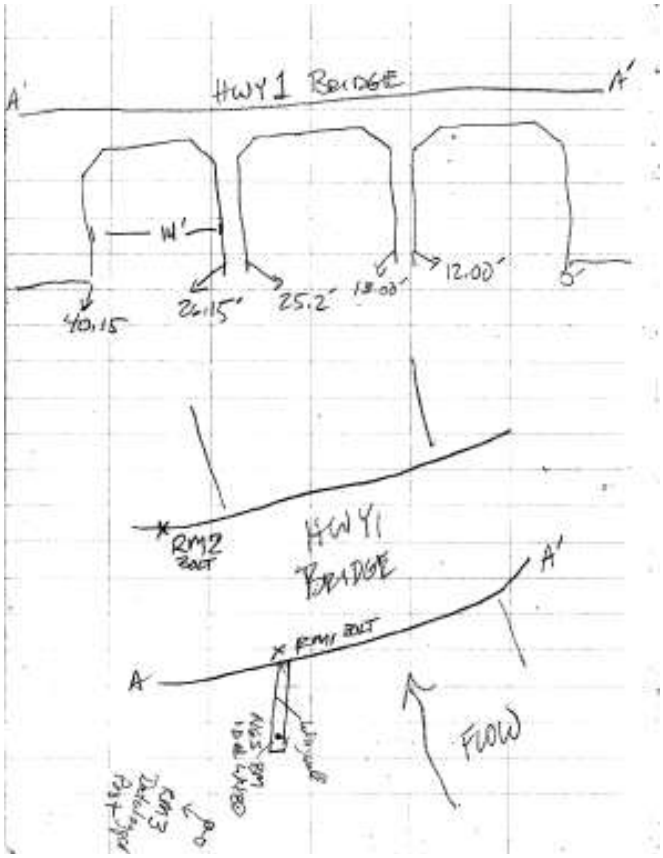


Figure SOP 3.16. Sketch of Redwood Creek streamgage location and reference marks.



Figure SOP 3.17. National Geodetic Survey benchmark in foreground on concrete wingwall and RM 1 (orange spray paint) on bridge.

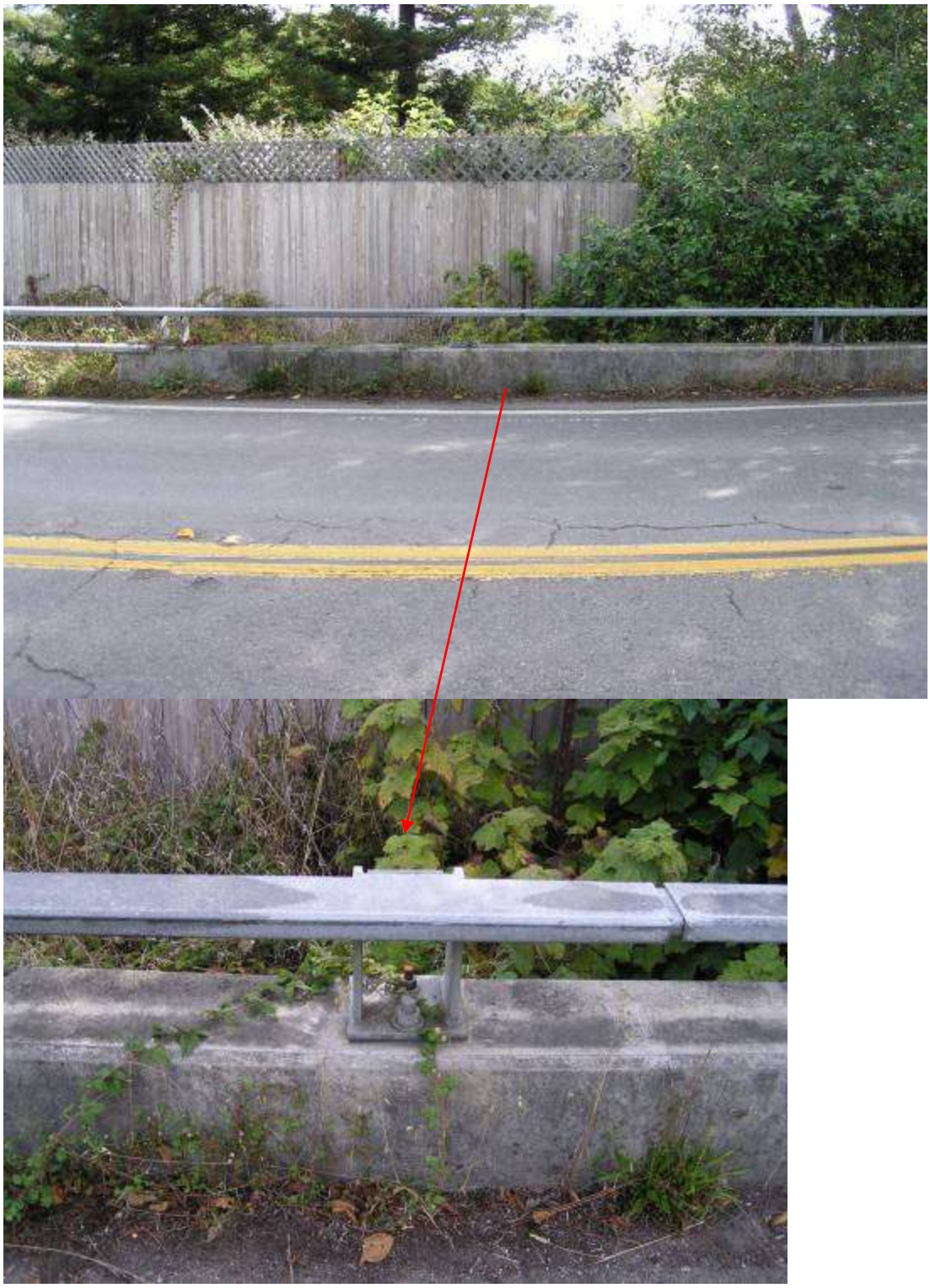


Figure SOP 3.18. Location on downstream side of HWY 1 bridge approach (above) and inset showing guard rail bolt (orange spray paint) used as RM 2.

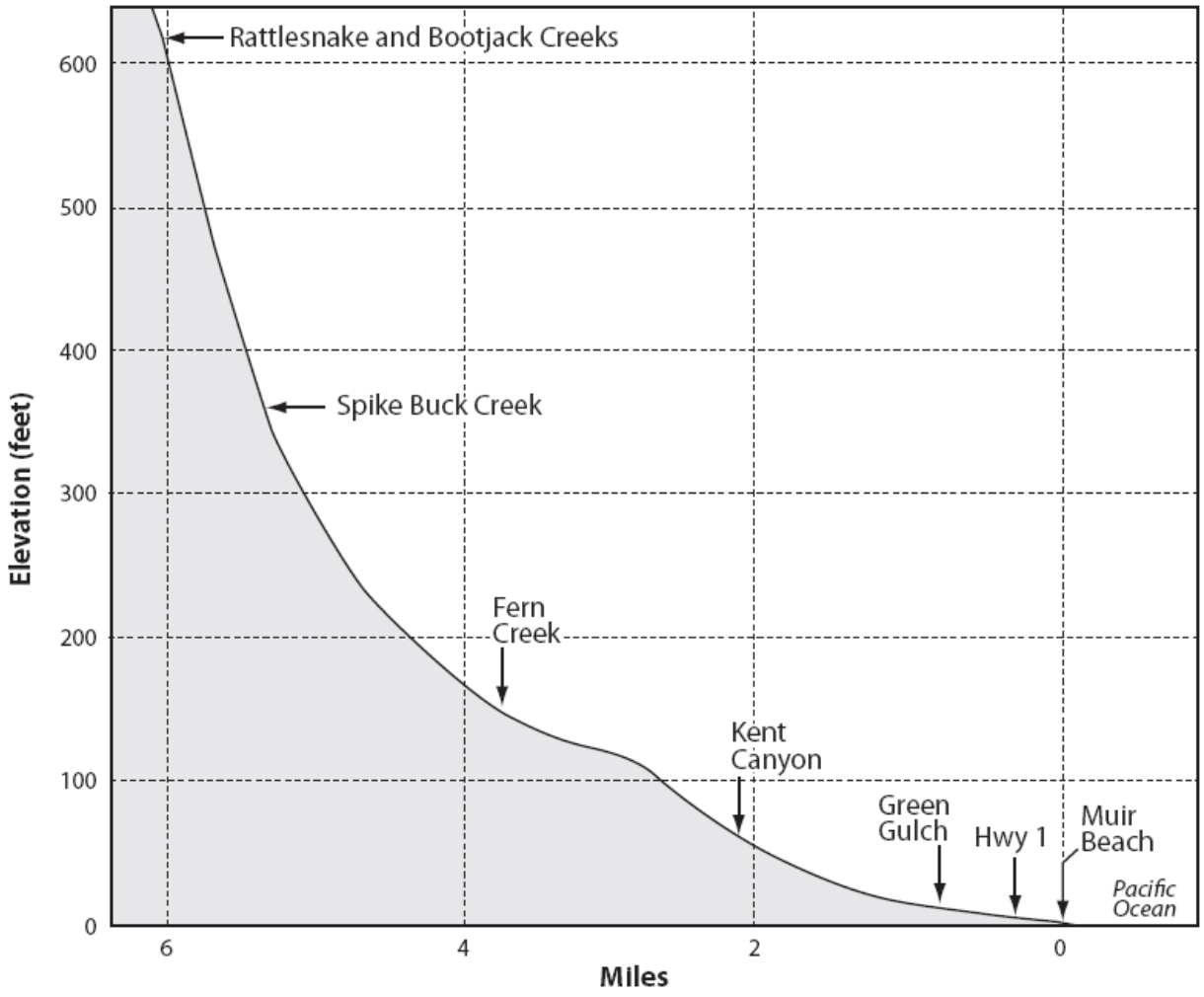


Figure SOP 3.19. Redwood Creek channel slope (from Snider 1984).

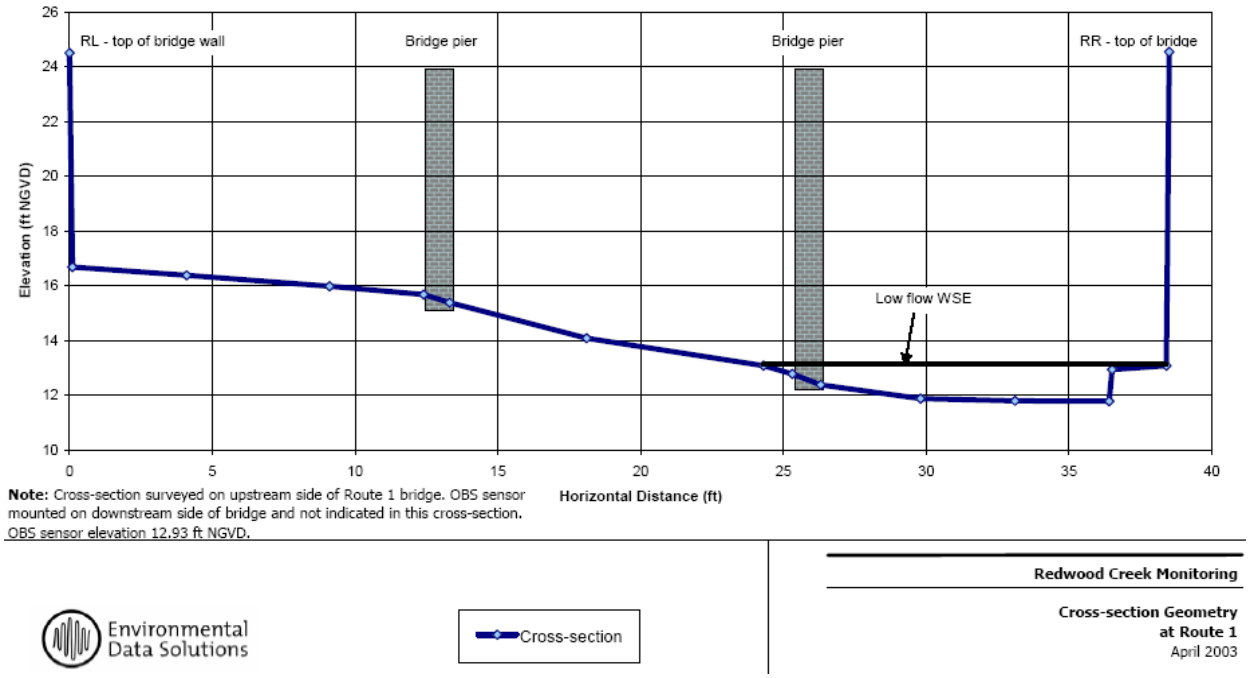


Figure SOP 3.20. Cross-section of Redwood Creek at the Highway 1 Bridge.

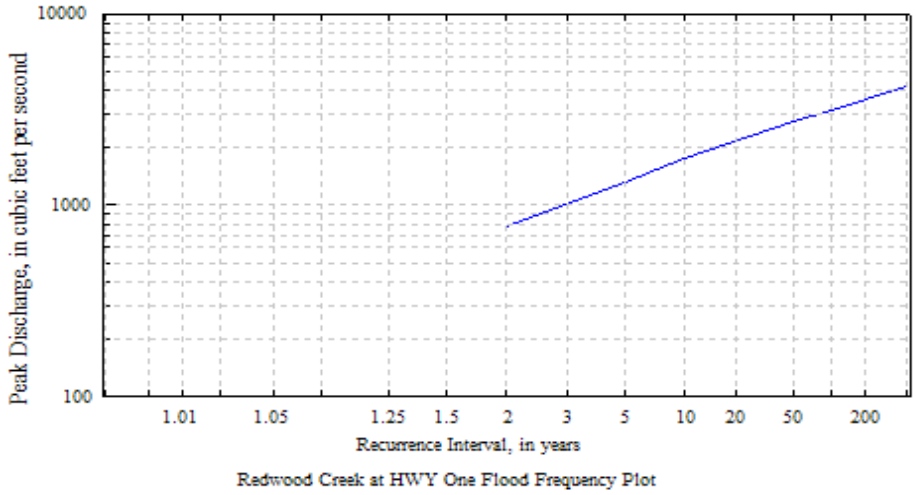


Figure SOP 3.21. Estimated Redwood Creek flood frequency**.**

Easkoot Creek, Marin County, Golden Gate National Recreation Area

Revision Date: February 9, 2010
Revised by: Darren Fong, GOGA

Location

Latitude 37°53'53.9" N, longitude 122°38'29" W, in Marin County, California. The streamgage is approximately 25 ft below the entrance bridge into Stinson Beach Park. Stinson Beach Park is located twelve miles northwest of San Francisco. USGS Hydrologic Unit Code: 18050005, Hydrologic Region: San Francisco Bay, Hydrologic Unit: Marin Coastal (Figures SOP 3.22–23)

Directions

In the town of Stinson Beach on Highway One, enter Stinson Beach Park and park in the north lot. The streamgage is approximately 25 ft below the entrance bridge on the right bank (Figure SOP 3.23).

Establishment

June 7, 1999 by NPS-Water Resources Division

Elevation

The streambed elevation at the staff gage was 15.095 ft NAVD88 (survey date May 31, 2006). Staff gage elevation was 17.255 ft (this is the elevation equal to mark 33.94 on staff gage on May 31, 2006)

Drainage Area

Easkoot Creek, above the streamgage, is a perennial stream has a drainage area of 1.42 m^2 (911 acres) (planimetric). It has a three-dimensional drainage area of 1.58 mi^2above the streamgage. (Figure SOP 3.24). The stream distance to the drainage divide is 1.58 mi (2,545 m).

Gage

Stream water level is measured continuously and recorded at 15 minute intervals using a Druck PDCR 1830 5.0 psig submersible pressure transducer (S/N 1328813) to the nearest 0.01 ft. Hourly and daily average, maximum and minimum water levels are also recorded. The transducer lead is housed in half-inch aluminum electrical conduit leading to a 2-ft long, 1.25-inch-diameter well point (Johnson stainless well screen, 0.01 inch diameter slot spacing) in which the transducer is housed. The well tip is topped with a 2-ft galvanized pipe extension and then was driven approximately 2 ft into the streambed. There is a 4-inch wide, ceramic staff gage (range 30.54 to 33.94 ft) and a 5-ft crest gage mounted on a wooden board attached to a steel T-post near the right bank (Figure SOP 3.25). The Campbell Scientific CR10x data logger (S/N 18250) is contained in a weatherproof box mounted to a steel T-post approximately 15 ft from the stream on the right bank. The data logger is powered by a solar charging unit, which is mounted on top of the T-post (Figure SOP 3.25). The data logger output is retrieved monthly using the PC208W program.

History

The NPS-Water Resources Division installed a continuous-recording stage gage on June 7, 1999. This former streamgage was located at Latitude 37°53'53" N, Longitude 122°38'19" W (Figures SOP 3.26–27). A rain gage and air and water temperature probes were added on April 3, 2000.

The temperature probes were removed on September 25, 2000. The streamgage was moved after a tree fell on the equipment and was re-established at current location on November 21, 2003 after a stream restoration project. Up to WY 2006, rainfall was measured with a Davis Rain Collector II tipping-bucket rain gage (to the nearest 0.01 of an inch) that was placed in an open riparian area at 2.75 ft above ground surface. Riparian growth around the tipping bucket after this time has prevented accurate data collection.

Benchmarks

Elevations for the streamgage are based on National Geodetic Survey marker (PID HT1718) established in 1951 and located on a boulder just southwest of Highway One in the Town of Stinson Beach near the intersection with Calle del Sierra Street. Latitude 37°53'59" and Longitude 122°38'34". Benchmark a round disk set in rock outcrop about 5 ft above road. Benchmark elevation of 20.7 ft (NAVD 88).

RM1 is a stainless steel mag nail set in a metal disk at the south edge of the entrance kiosk curb. Elevation 17.715 ft NAVD88 (Levels of August 16, 2004). UTM coordinates: 4194526.5N 531561.7E NAD83 Zone10S

RM2 is a nail set in the asphalt pavement near the inbound lane of the entrance kiosk. Elevation 19.275 ft NAVD88 (Levels of December 8, 2009). UTM coordinates: 4194554N 531538E NAD83 Zone10S

A sketch of the creek and RMs is provided in Figure SOP 3.28.

Watershed Hydrologic Conditions

Easkoot Creek is a perennial stream in a 1.7 mi^2 (1,062 acre) watershed draining to Bolinas Lagoon to the north. The terrain is predominately mountainous, rising from the coast to 2,071 ft at the highest point, and is composed of a sandstone, shale, chert and conglomerate formation of Mesozoic age, except for the terrain along the final 3,000 ft of the stream, which is composed of recent dune sand and beach deposits. Mean annual precipitation at the streamgage estimated at 27.5 inches (69.85 cm) per year (Rantz 1969, Figure SOP 3.29). June through September is the dry season with the least precipitation falling in July and the most occurring in January. Mean annual runoff for the watershed is estimated from Rantz (1974) as 13 inches, or 1.6 cfs. Much of the upper watershed is publicly owned while the lowest reach flows through mostly private ownership. Easkoot Creek descends rapidly from Bolinas Ridge and flattens on a plain before it enters Bolinas Lagoon. Bolinas Lagoon is a 1400-acre tidally-influenced estuarine area. The extent of tidal influence upstream from the lagoon is unknown. Easkoot Creek supports remnant population of steelhead trout.

Geology (from NPS-GOGA 2003)

The topography of the Easkoot Creek watershed reflects the ancient erosion of hard bedrock and the recent deposition of sand dunes. Topographic relief in the watershed ranges from sea level to over 2000 ft. Easkoot Creek watershed begins in the bedrock western slopes of Mt. Tamalpais along the Bolinas Ridge and flows as three small tributaries called Black Rock, Laurel and Fitzhenry Creeks. These tributaries join above Highway 1 near the fire station, and flow through town until reaching Bolinas Lagoon. In the Stinson Beach area, younger deposits and sand dune

deposits of the late Pleistocene and Holocene cover these older rocks. Lower Easkoot Creek is located behind the foredune of this coastal sand beach deposit.

Channel Conditions

The active stream channel at the streamgage is a trapezoidal shape approximately 4 ft wide at the base and 2 ft deep from the thalweg to the top of the bank. The left bank rises to a berm at approximately 4.5 ft above the thalweg. The right bank is steep and rises to a height greater than the left bank berm. The channel slope around the streamgage is 0.0125 averaged over 1,000 ft. The streambed is composed of gravel and small cobbles. Overbank areas are vegetated with grasses, forbs, and willow out to about 50 ft from the left bank, after which begins a paved parking lot. The vegetated buffer along the right bank is larger. In 2003, the Golden Gate National Recreation Area undertook a restoration of the channel where the creek flows through Stinson Beach Park. In the park, the riparian area along the left bank is limited in size because of parking facilities.

Control

Boulder weir structure about 10 ft downstream of gage serves as section control point under low flow conditions. As of October 6, 2005, the elevation of the section control point was 14.245 ft (NAVD 88). Weir structure may catch deciduous leaves and debris in the fall resulting in slightly elevated water surfaces. Because of the relative close proximity to Bolinas Lagoon, extreme high tides may also control observed water surface elevations at the gage site. The extent of this influence is unknown at this time.

Discharge Measurements

Wading measurements have been conducted within a couple feet of the gage.

Floods

Indirect estimates of peak flow have been computed by U.S. Geological Survey's National Flood Frequency computer program (Vers. 3.2) which uses regional regression equations based on prior investigations of the relationship between watershed and climate parameters with streamflow. Easkoot Creek watershed is near the interface between the Central Coast and North Coast regions. Estimates reported below (Table SOP 3.4, Figure SOP 3.30) were run using regional regression for Central Coast because the altitude index was outside computation range for the North Coast region.

Point Of Zero Flow

The staff gage height at zero flow was 30.93 ft on October 6, 2005. Significant aggradation along length of channel during winter and spring of WY2006 has likely changed point of zero flow.

Winter Flow

No ice.

Regulation and Diversion

There are three known diversions upstream of the streamgage by the Stinson Beach County Water District (Black Rock Creek, and Fitzhenry Creek #1-2). There may be additional diversions by adjacent owners under riparian rights. The diversions in calendar year 2002 by the district in this watershed amounted to 13.1 million gallons mainly during months of January

through June (Stetson Engineers 2003). No known instream ponds are present in the watershed that will affect hydrograph.

Cooperation
Station maintained and operated by NPS.

Indirect Measurement Site
TBD

Land Ownership
U.S. government (GOGA)

Quadrangle
Bolinas

Table SOP 3.4. Estimated flood frequency of Easkoot Creek below Park entrance road.

Recurrence Int. (yrs)	Peak (cfs)	Standard Error (%)
2	53.9	150
5	133.0	110
10	203.0	96
25	303.0	96
50	387.0	110
100	482.0	120
500	708.0	

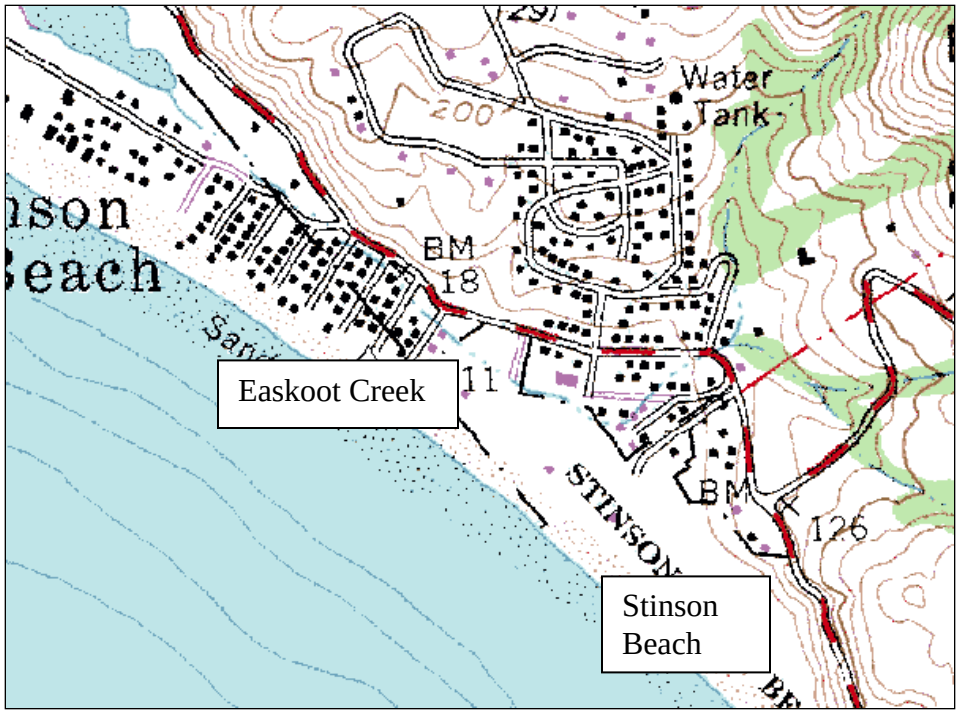


Figure SOP 3.22. Easkoot Creek at Stinson Beach.

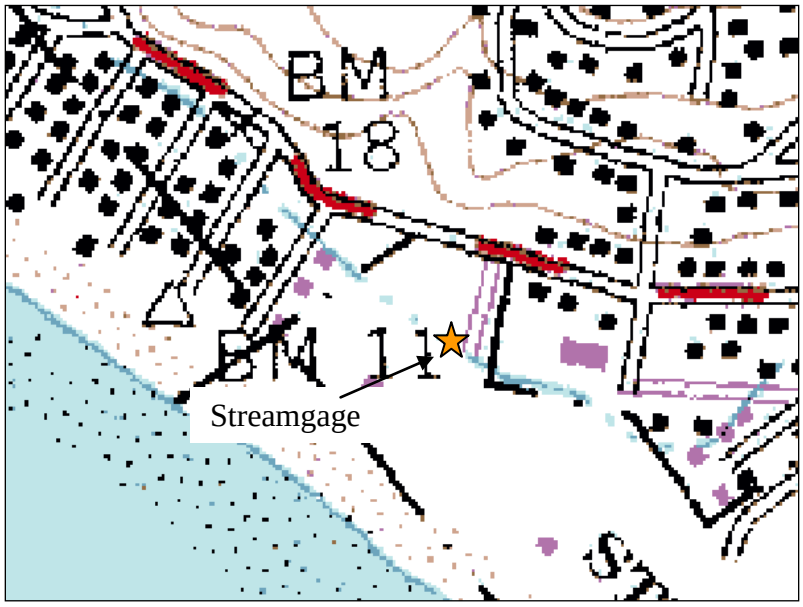


Figure SOP 3.23. Easkoot Creek station location map (post-November 2003).



Figure SOP 3.24. Easkoot Creek watershed.



Figure **SOP 3.25**. Monitoring Equipment (November 2003 to present). Looking at right bank at staff gage, crest gage, stilling well, datalogger and rain gage (October 2006).



Figure SOP 3.26. Streamgage conditions (period from 1999 to October 2003), looking downstream at staff gage and stilling well on left bank (April 2000).



Figure SOP 3.27. Streamgage conditions (period from 1999 to October 2003), looking upstream at rain gage and datalogger in clearing on left bank (April 2000).

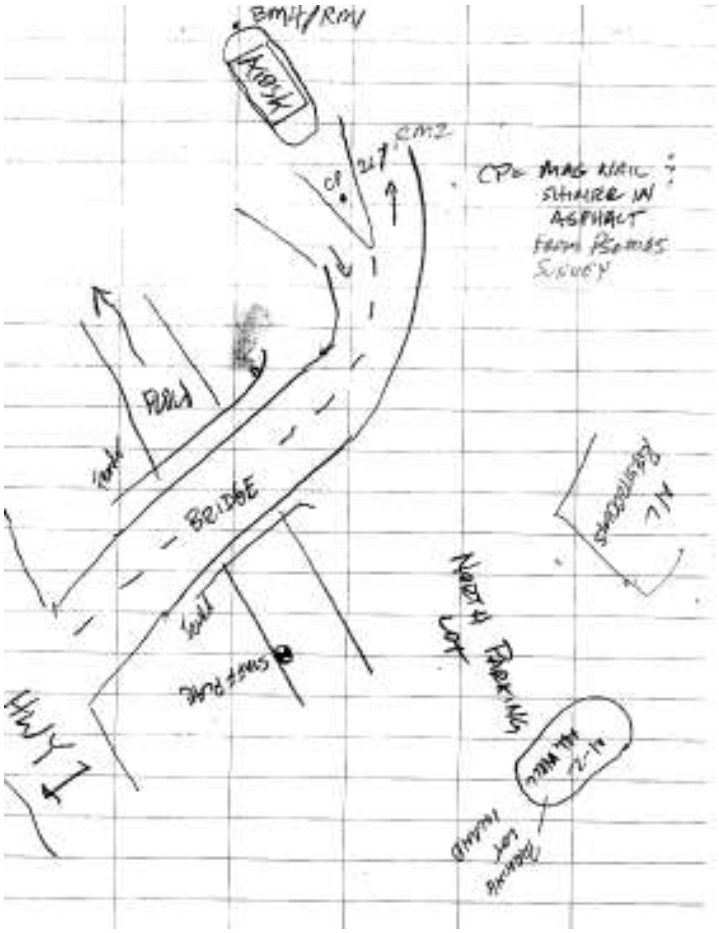


Figure SOP 3.28. Sketch of Easkoot Creek streamgage location and reference marks (post-November 2003).

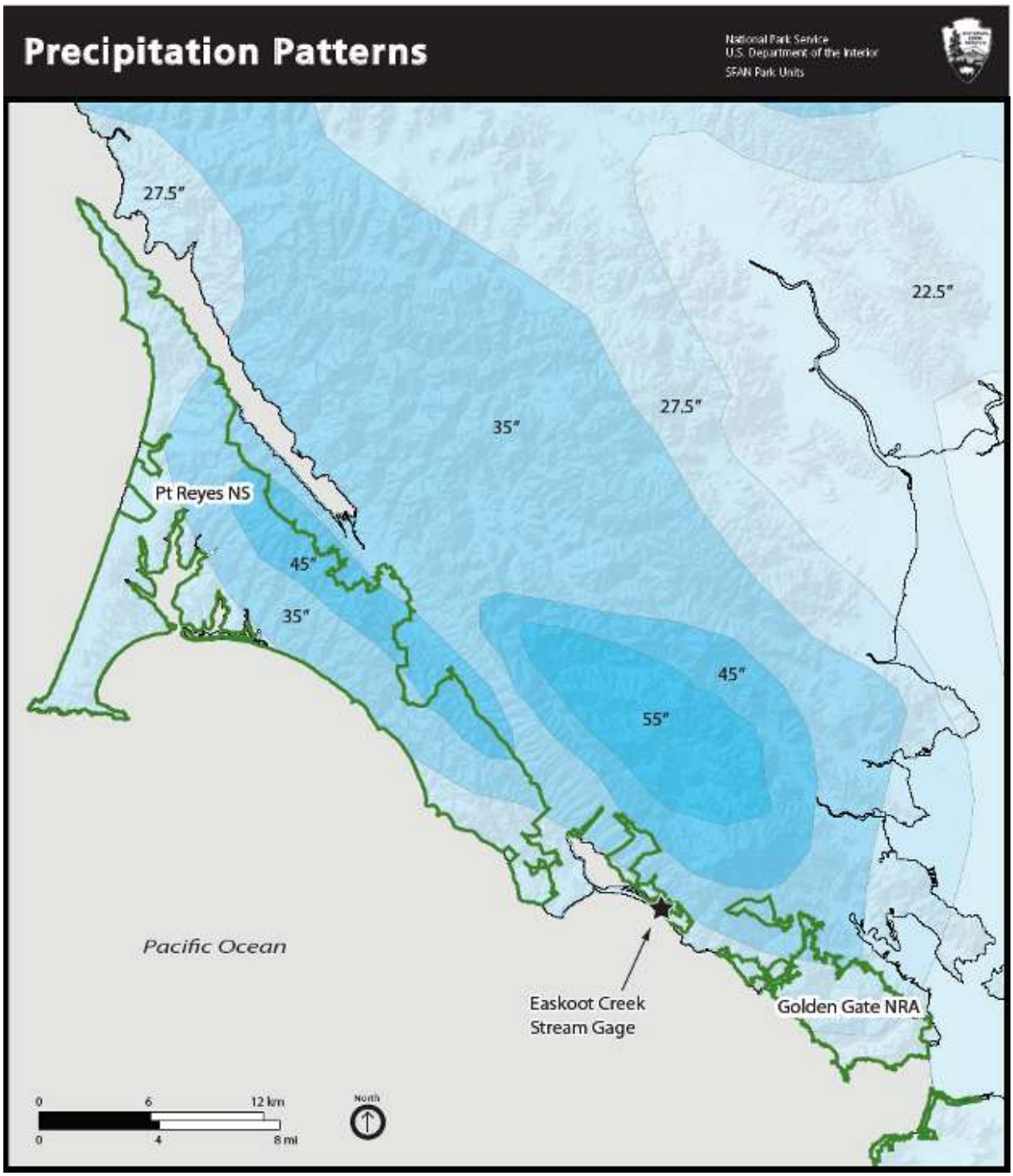


Figure SOP 3.29. Precipitation map for Point Reyes National Seashore (adapted from Rantz 1969).

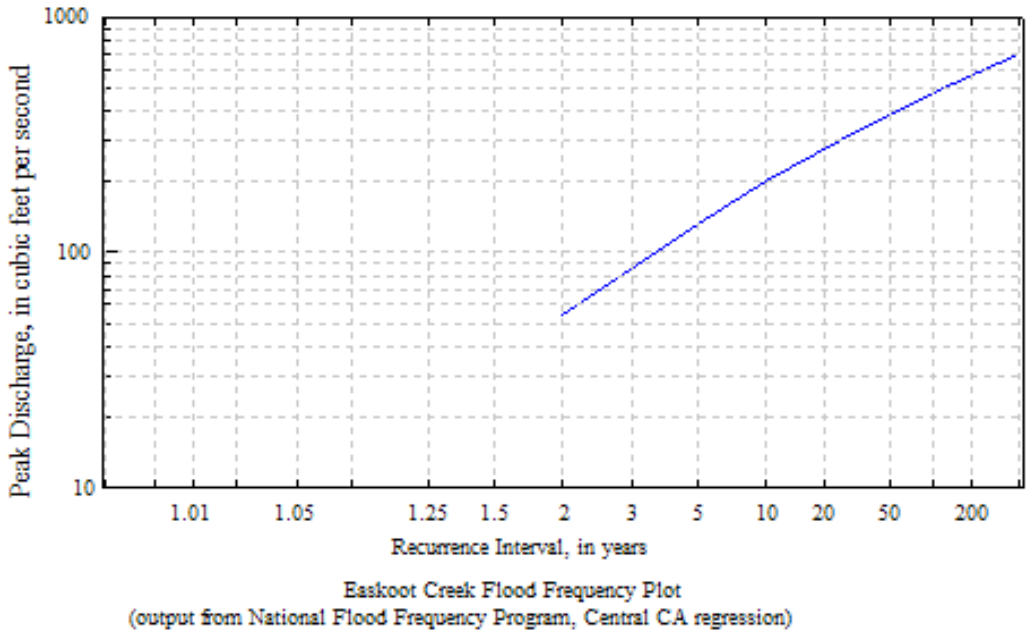


Figure SOP 3.30. Estimated Easkoot Creek flood frequency.

Pine Gulch Creek, Marin County, California, Point Reyes National Seashore

Revision Date: February 1, 2010
Revised By: Darren Fong, GOGA

Location

Latitude 37°55'11.1138" N (37.919754), Longitude 122°41'30.6744" W (-122.691854), in Marin County, California, The site is located 328 ft (100 m) downstream of the Olema-Bolinas Road Bridge. The site is located on private property (Gospel Flat Farm, Don Murch). USGS Hydrologic Unit Code 18050005; CalWater Unit 220130011 Hydrologic Region name: San Francisco Bay, Hydrologic Unit name: Marin Coastal, Hydrologic Area name: Bolinas Lagoon (Figures SOP 3.31–32).

Directions

From Highway One, go southwest on Olema-Bolinas Rd towards the Town of Bolinas. Pine Gulch Creek is within 3 km from turnoff at County Milepost 1.30. After crossing small road bridge (with colorful graffiti), turn left into unpaved driveway of Gospel Flat Farm. Streamgage is just downstream of footbridge.

Establishment

The existing recording streamgage was established by Brannon Ketcham in 1997.

Elevation

Approximately 15 ft. The watershed elevation ranges from 1,566 ft at the headwaters of Copper Mine Gulch on Bolinas Ridge east of the San Andreas Fault to sea level at its mouth in Bolinas Lagoon.

Drainage Area

Above the streamgage, Pine Gulch Creek is a perennial stream with a drainage area of 7.82 sq. miles (5005 acres) (planimetric) (Figure SOP 3.32). It has a three-dimensional drainage area of 8.51 sq. miles. The stream distance to the drainage divide is 7.40 miles (11,906 m).

Gage

Stream water level is measured and recorded at 15-minute intervals using a Global Logger WL 15 submersible pressure transducer (nearest 0.01 ft) (Installed December 4, 2009). The pressure transducer is housed in a PVC well on the right bank attached to a tree. The rain gage is located adjacent to an agricultural field approximately 100 ft west from the data logger. A stand-alone, event-based, rainfall tipping bucket (Onset RG-2) has replaced the prior rain gage which kept on getting data cable severed by farm equipment (Installed February 2009).

A tape staff gage is attached to the PVC well (Figure SOP 3.33). A 5-ft crest gage is attached to measure high flows during large storm events. The tape staff gages elevation of '0' at 9.1 ft NAVD88. Because of wear, the tape staff gage was replaced with enamel staff plates mounted on wood boards and attached to metal t-posts on the left bank of the channel. The range of the enamel staff plates is 30.54 to 37.34 feet. Installation was completed by May 31, 2007 (Figure SOP 3.34). The new staff gage elevation of '0' at 10.61 ft NAVD88.

History

A USGS monitoring station (11460170) was operated upstream of the existing station from Water Years 1967-70 on the since-replaced Olema-Bolinas Road Bridge. The USGS information is available as daily mean flow, with calculations of daily, monthly, and annual water production for the watershed. It was operated as part of a larger sediment input study to Bolinas Lagoon. In 1997, the NPS chose not to install a monitoring station at the Olema–Bolinas Road Bridge, the location of the USGS station, as the site is an access point for the county to conduct maintenance dredging.

Initial streamgage equipment has been replaced due to failure. Until 2009, stream level data was collected by Druck PDCR 1830 5.0 psig submersible pressure transducer (nearest 0.01 ft) and Campbell Scientific CR10X data logger. This logger was housed in a weatherproof box mounted to wooden apparatus approximately 20 ft from the stilling well on the right bank. A solar charging unit, mounted on top of an aluminum tube, powers the data logger (Figure SOP 3.33).

Until 2009, rainfall was measured with a Texas Electronics TR-525 rain gage (mounted four feet above ground) with data recorded every 15 minutes. The data logger output was retrieved monthly using the PC208W program.

Benchmarks

Elevations for streamgage based on National Geodetic Survey marker (PID HT3827) established in 1985 on Olema-Bolinas Road Bridge at Latitude 37°55’07” and Longitude 122°14’34”. Benchmark a round disk set in concrete bridge deck level with road at southwesterly corner of deck. Currently, the benchmark disk sits below an image of a painted snake (Figure SOP 3.35). Benchmark elevation of 18.0 ft (NAVD 88).

RM1 (temporary) is a red, steel t-style fence post at the edge of the field along the farm road on the right bank. Elevation 15.57 ft, NAVD88 (Levels of May 21, 2007)

RM2 (temporary) is the left bank metal rebar cross-section marker. The cross-section is at the downstream section control. Elevation 14.81 ft, NAVD88 (Levels of May 21, 2007)

RP1 is staff gage value of 37.34. Elevation 14.98 ft NAVD88 (Levels of December 17, 2007). UTM coordinates: 4196961.8N 527086.3E NAD83 Zone 10S

Watershed Hydrologic Conditions

Pine Gulch Creek, the only perennial and significant tributary to enter Bolinas Lagoon from the west, is a 12.42 mi^2 (7,944 acre) watershed. The mainstem length is 7.6 miles and the tributaries total 16.2 miles. The creek, draining approximately half of the Bolinas Lagoon basin follows the San Andreas Rift Valley flowing south and forms a delta in the Lagoon. Approximately 75% of the watershed is west of the Fault. The geology west of the Fault includes Santa Cruz mudstone and Merced Formation, creating deep soils with high infiltration capacities. Pine Gulch Creek joins McCormick Creek, flows through Paradise Valley west of Horseshoe Hill, and enters Bolinas Lagoon about midway between the head of the lagoon and Kent Island. Bolinas Lagoon is a 1400-acre estuarine area composed of salt water, tidal flooded by high tides. The terrain is a combination of mountainous headwaters and low elevation/slope coastal lands. Seventy-five

percent of the water draining into Pine Gulch Creek flows off Inverness Ridge. These perennial tributaries provide water to the mainstem, but climb quickly from the valley bottom, providing little to no salmonid habitat. Tributaries draining from Bolinas Ridge have topography and stream profiles appropriate to support salmonids. The Ridge, made up of the Franciscan Complex, has very thin soils and low infiltration capacity. Except for McCurdy Creek, all eastern tributaries are intermittent. Recorded flows have varied from a high of 715 cfs to periods of no recorded late summer surface flow during very dry years. The mean flow appears to be around 2 cfs.

The National Park Service manages the upper 75 percent of the Pine Gulch Creek watershed as a part of the Point Reyes National Seashore and Golden Gate National Recreation Area, which provides good habitat for steelhead (*Oncorhynchus mykiss*) and for populations of coho salmon (*O. kisutch*). The lower quarter of the watershed is under private ownership, with five commercial organic agriculture operations as the primary land use.

Pine Gulch Creek watershed is located in Northern California's zone of Mediterranean-type climate, which exhibits mild, wet winters, and warm, dry summers. Most rainfall (95%) occurs between November and April while fog drip is an important source of yearly precipitation and causes significant reduction in rates of evapotranspiration. Areas affected by coastal fog also exhibit a relatively low season evapotranspiration fluctuation. Seasonal flow patterns are characterized by summer and fall low flows, low-to-moderate winter baseflows and sharp, short-duration winter storm peaks. Precipitation generally ranges from about 25 inches near the coast to over 50 inches at higher elevations. The watershed's average annual rainfall is 37.5 in (95.2 cm.), while mean annual precipitation at the streamgage is 27.5 inches (69.9 cm) per year (California Spatial Information Library).

Geology: The major geologic feature in the area is the San Andreas Fault zone, which trends in a northwesterly direction through Bolinas Lagoon. The Fault cuts through Tomales Bay, Olema Valley, Bolinas Lagoon, westerly into the Pacific Ocean, and then returns east and inland just south of San Francisco. The terrain is a combination of mountainous headwaters and low elevation/slope coastal lands. On average, the Pacific Plate moves in a northwesterly direction 1-2 inches per year. The rest of California is part of the slower, westerly moving North American Plate, which results in periodic seismic activity along the San Andreas Fault.

Approximately 75% of the watershed is west of the Fault. The geology west of the Fault includes Santa Cruz mudstone and Merced Formation, creating deep soils with high infiltration capacities (Clark et al. 1984). Tributaries from this portion are perennial. The remaining land drains from Bolinas Ridge on the east side of the Fault. The geology east of the Fault has deep to moderately deep soils with high infiltration capacities. The Ridge, made up of the Franciscan Complex, has very thin soils and low infiltration capacity. The Franciscan Complex is an assemblage of sandstones, shales, cherts, limestones, conglomerates, and basalts that have been deformed intensively (Galloway 1977, Boudreau 1979). The only perennial tributary east of the Fault is McCurdy Creek.

Channel Conditions

The main stem of Pine Gulch Creek is 12 km (7.2 mi) long. Based on July 2004 survey data, the active stream channel at the streamgage is a wide trapezoidal shape approximately 15 ft wide at

bankfull and 2.4 ft deep from the thalweg to the high water elevation. The right bank rises to a bench approximately 8 ft above the thalweg. The right and left banks are steep. It is possible that the banks are artificially high to prevent the adjacent farmlands from flooding. The channel slope near the streamgage averaged over 600 ft is 0.29%. The streambed is composed of gravel and small cobbles. Overbank areas are vegetated with grasses and thick shrubs up to the top of the slope along with mature Alder trees. At the mouth of Pine Gulch, north of the unincorporated town of Bolinas, is an extensive delta. Upstream of the existing streamgage, stream banks are lower and Pine Gulch has overbank flows in Paradise Valley under situations where confined flow is present at existing streamgage.

Control

The downstream, low flow section control for the Pine Gulch Creek streamgage is a gravel riffle (as of December 5, 2005). It is 10 ft below the gage. The elevation of the control is 8.41 ft (NAVD88, surveyed December 5, 2005). This section control may be affected by leaves collecting on a deer-exclosure fence 200 feet downstream of the gage that spans the channel causing backwater conditions under low flows. The fence is in place from April-December of each year (Mickey Murch, Gospel Flat Farm, pers. comm., 2008)

Discharge Measurements

Wading measurements are taken near the gage. High water measurements are done at the Olema-Bolinas Rd Bridge upstream of the streamgage. The bridge crosses the creek at an angle, so high flow measurements previously taken off this bridge are likely skewed erroneously high.

Floods

Indirect estimates of peak flow have been computed by U.S. Geological Survey's National Flood Frequency computer program (Vers. 3.2) which uses regional regression equations based on prior investigations of the relationship between watershed and climate parameters with streamflow. Pine Gulch Creek watershed is near the interface between the Central Coast and North Coast regions. Estimates reported below (Table SOP 3.5, Figure SOP 3.36) were run using regional regression for Central Coast because the altitude index was outside computation range for the North Coast region.

Point Of Zero Flow

TBD

Winter Flow

No ice.

Regulation and Diversion

Historically, Pine Gulch Creek had up to 7 permanent and seasonal on-stream dams within the watershed. While there are no diversion dams within the Pine Gulch Creek watershed today, there were in-stream permanent and seasonal dams in the mid to late 1970's. The last instream dam was removed in the early 1990's prior to the exiting monitoring program (B. Ketcham, PORE Hydrologist, pers. comm. 2007)

Cooperation
Station maintained and operated by NPS. Access permission through Don Murch, Gospel Flat Farm.

Indirect Measurement Site
TBD

Period of Record
1998 to the Present

Land Ownership
Private, Gospel Flat Farm, Don and Mickey Murch. 140 Olema/Bolinas Road, Bolinas, CA 94924. (415) 868-0921

Quadrangle
Bolinas

Table SOP 3.5. Estimated flood frequency at Pine Gulch Creek below Olema-Bolinas Road.

Recurrence Int. (yrs)	Peak cfs	Standard Error (%)
2	806	
5	1,420	110
10	1,830	96
25	2,320	96
50	2,700	110
100	3,040	120
500	3,790	



Figure SOP 3.31. Pine Gulch Station location map.

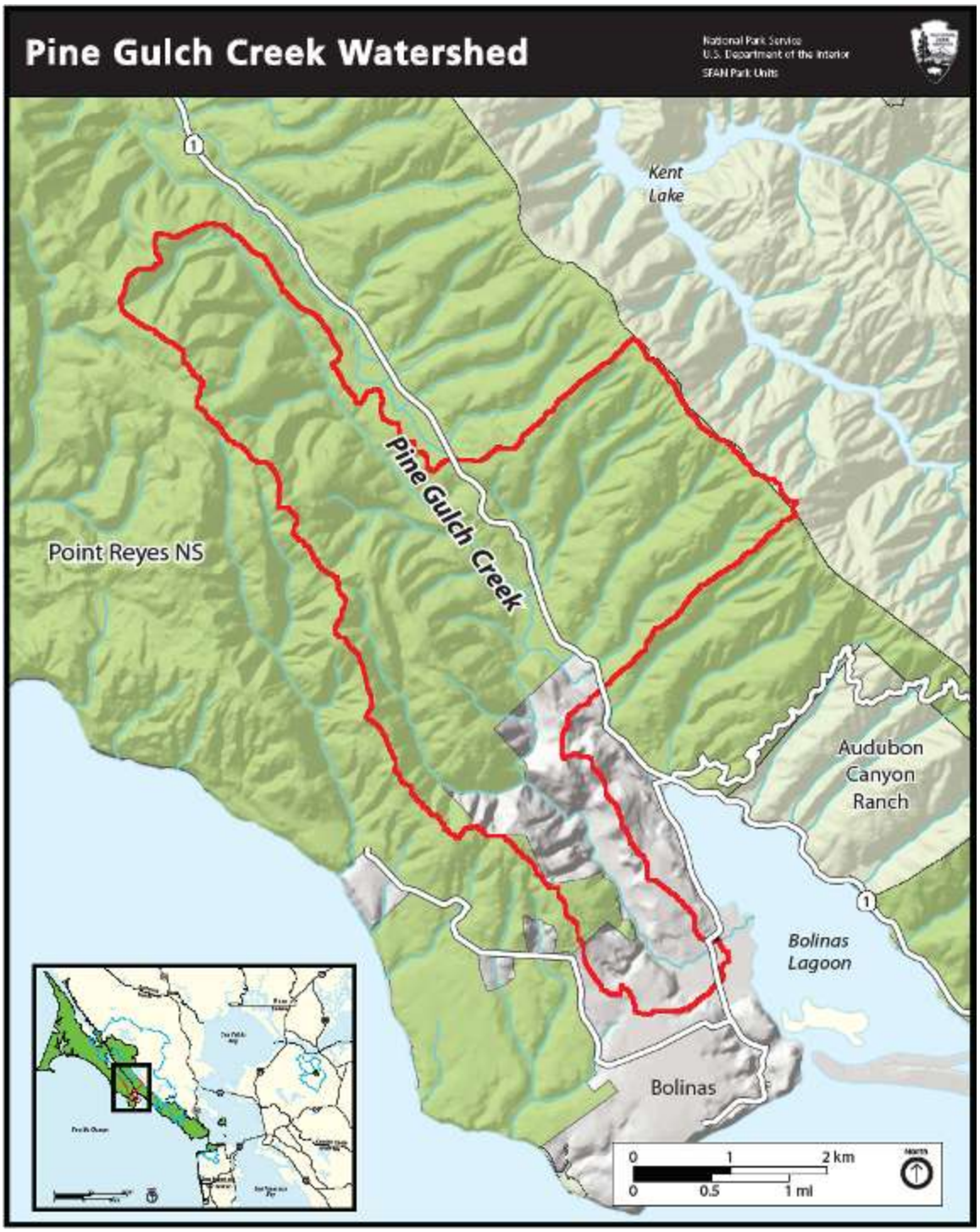


Figure SOP 3.32. Pine Gulch Creek watershed.

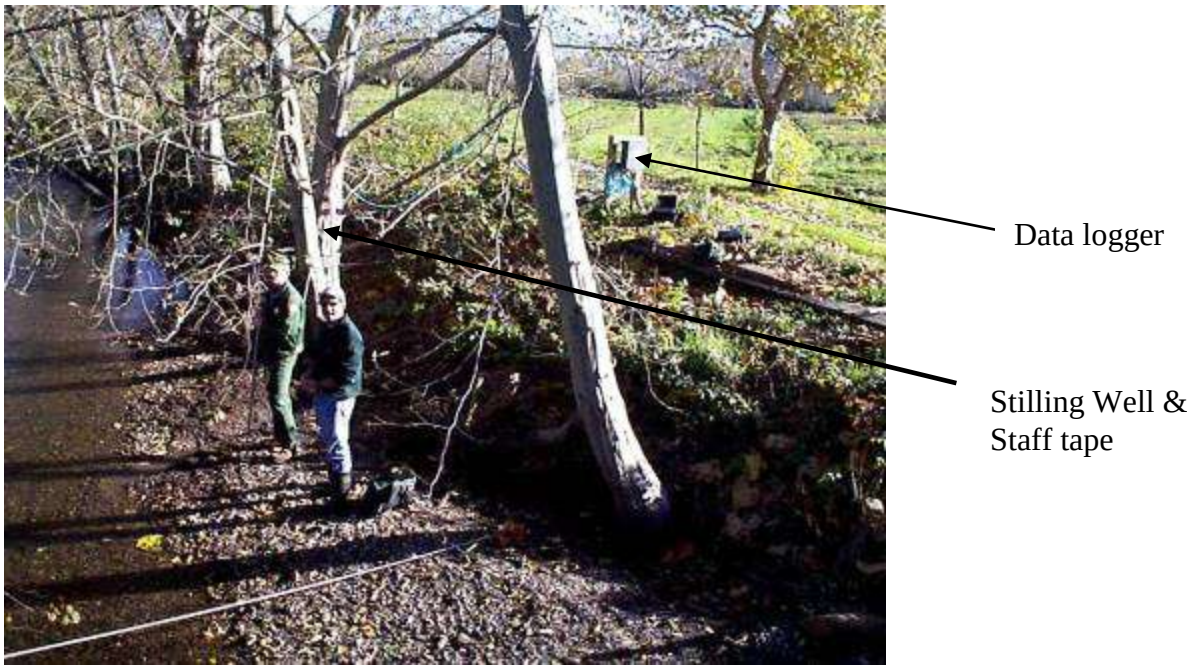


Figure SOP 3.33. Pine Gulch Creek streamgage.



Figure SOP 3.34. Pine Gulch Creek streamgage with new staff gage on left bank (installed May 31, 2007).



Figure SOP 3.35. Location of National Geodetic Survey benchmark below painted K-rail on downstream side of Olema-Bolinas road bridge.

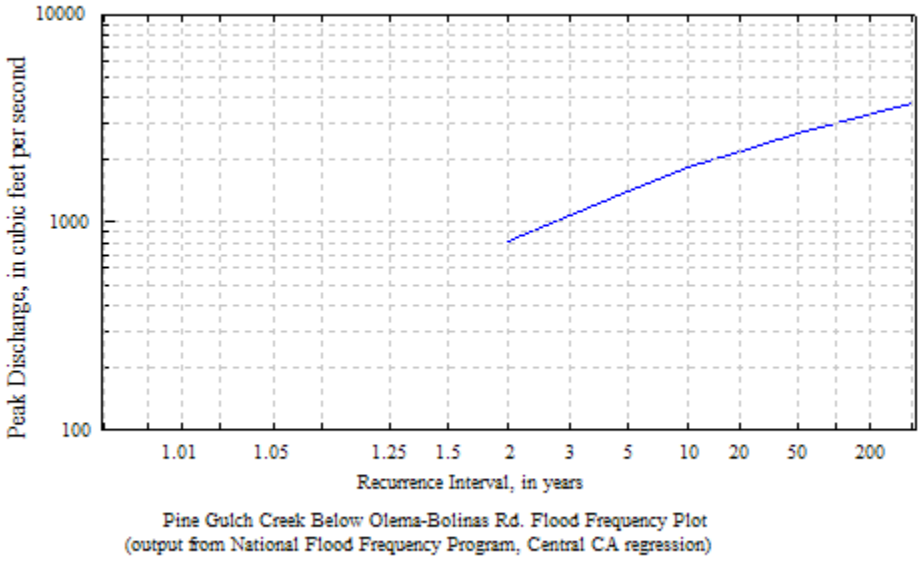


Figure SOP 3.36. Estimated Pine Gulch Creek flood frequency.

Olema Creek, Marin County, California, Point Reyes National Seashore

Revision Date: March 9, 2011
Revised By: Katie Booth, SFAN

Location

The monitoring site is located immediately upstream of Bear Valley Road bridge in Marin County, California. Latitude 38° 2' 30" N (38.041670), Longitude 122° 47' 23" W (122.789722). USGS Hydrologic Unit Code 18050005; CalWater Unit: 220113030. Hydrologic Region name: San Francisco Bay, Hydrologic Unit name: Marin Coastal, Hydrologic Area name: Tomales Bay, Hydrologic Sub-area name: Lagunitas Creek (Figures SOP 3.37–38).

Directions

In the Town of Olema, go west on Bear Valley Rd off of Highway One. Park in pull-out on north side of Bear Valley Rd (west of creek).

Establishment

The existing recording streamgage was established by Brannon Ketcham, formerly the NPS Coho and Steelhead Restoration Program in 1997.

Elevation

Approximately 40 ft above sea level. The watershed elevation ranges from 1,456 ft above sea level on Bolinas Ridge east of the San Andreas Fault to approximately 15 ft at the confluence with Lagunitas Creek.

Drainage Area

Above the streamgage, Olema Creek is a perennial stream with a drainage area of 12.63 sq. miles (8,082 acres) (planimetric). It has a three-dimensional drainage area of 13.36 sq. miles. The stream distance to the drainage divide is 9.40 miles (15,130 m).

Gage

A new datalogger and transducer system (In-Situ Level Troll 500) was installed in April 2010 in order to adjust to the channel's migration towards the left bank and to update to newer technology. This logger collects stream water level and temperature data continuously at 15-minute intervals. A new staff plate was installed on the downstream face of the left bank bridge support, and a level survey was conducted on May 3, 2010. The new transducer is housed in a 12-foot long PVC stilling well on the downstream-facing edge of the concrete bridge support, in order to avoid damage from floating debris. Flexible PVC conduit protects the cable that travels from the stilling well to a weatherproof box containing the datalogger (Figure 3.39).

The old system is still in place and will be used as a back-up; this datalogger records stream water level at 15-minute intervals using a Druck PDCR 1830 pressure transducer (S/N 1418339) to the nearest 0.01 ft. Water temperature is recorded similarly using a Druck thermistor to nearest 0.01 ^{o}C. The transducer lead is housed in electrical conduit leading to a 12-ft long galvanized pipe in which the transducer is housed. This is driven approximately 2 ft into the streambed. This housing and the staff gage are mounted against the right bridge support. The Campbell CR10x data logger (S/N X3582) is housed in a weatherproof box above the right bridge support wall. A

solar charging unit, mounted on top of the T-post, powers the data logger. The data logger output is retrieved monthly using the PC208W program.

History

Limited historic continuous, streamflow data are available through PORE. Mean daily flow data were collected from 1986–1989 by Questa Engineering (Ketcham 1998). These were pretty dry years ~60 % of normal rainfall. A new data collection system was installed by the SFAN water quality specialist in 2004 to combine streamflow data collection with turbidity monitoring.

Benchmarks

Elevations for streamgage based on National Geodetic Survey marker (PID JT9507) established in 1987 on State Highway One at Latitude 38°02'36" and Longitude 122°47'19". Benchmark is the top of a stainless steel metal rod set in a 5-inch logo cap. The benchmark is on the east side of the State Highway One adjacent to a survey witness post. It is 133.5 ft north of the extended center of a driveway leading west into Olema Ranch campground Benchmark elevation of 54.44 ft (NAVD 88).

RM1 is a mag nail set in marine epoxy on the left bank, upstream wingwall of the Bear Valley Bridge. Elevation 51.81 ft, NAVD88 (Levels of December 8, 2009). UTM coordinates: 4210481.5N 518453.4E NAD83 Zone10S

RM2 is the upstream most corner of the steel datalogger housing closest to the creek. The datalogger is on the upstream side of the Bear Valley Bridge on the right bank. Elevation 55.158 ft, NAVD88 (Levels of December 8, 2009). UTM coordinates: 4210483.1N 518472.2E NAD83 Zone 10S

RM4 is a brass NPS property cap set in a metal post driven into the ground. The post is located adjacent to the left bank, upstream wingwall Elevation 50.80, NAVD88 (Levels of December 8, 2009).

RP1 has a value of 13.32 on the old staff plate (right bank). Elevation 51.765 ft NAVD88 (Levels of December 17, 2007). UTM coordinates: 4210483.1N 518464.1E NAD83 Zone 10S

A sketch map of the reference marks and point is provided in Figure SOP 3.40.

Watershed Hydrologic Conditions

The mainstem length is 9.9 miles while the tributaries total 27.8 miles. The terrain is a combination of mountainous headwaters and low elevation/slope coastal lands. The Olema Valley ranges in width from 1,500 to 7,000 ft. The streamflows northwesterly along the San Andreas Fault joining with Lagunitas Creek before the combined flow enters Tomales Bay at the northern end of the Point Reyes peninsula. Olema Creek is the largest undammed tributary to Lagunitas Creek. Approximately two-thirds of the watershed is east of the Fault. The geology east of the Fault has moderately deep to deep soils with high infiltration capacities. Five seasonally flowing creeks empty into Olema Creek within a 1-mile section near the "Five Brooks" trailhead. The creek provides critical habitat to the federally listed coho (*Oncorhynchus kisutch*) and steelhead salmon (*O. mykiss*).

There have been substantial modifications along Olema Creek (PWA 1993). Levees were built for a road in Olema Marsh and the mouth of Olema Creek around the turn of the century. In the early 1900s, several artificial channels were excavated in the Olema Creek watershed. In the early 1920s, Olema Creek was straightened into a 1.9-mile long canal between the town of Olema and its confluence with Lagunitas Creek. The canal drained the surrounding land for agricultural production, and feed crops and vegetables were planted. This area has also been used for cattle grazing. Point Reyes NS managers have restored the historical conditions and the creek again floods this area.

The climate is "Mediterranean", which exhibits mild, wet winters, and warm, dry summers. Most rainfall occurs between November and April and about 60% of the rainfall is lost to evapotranspiration. Mean annual precipitation at the streamgage is 35 inches (88.9 cm) per year while the average for the entire Peninsula is approximately 36 inches (91.4 cm) per year (California Spatial Information Library) with considerable inter-annual and seasonal variation (Figure SOP 3.41). Seasonal flow patterns are characterized by summer and fall low flows, low-to-moderate winter baseflows and sharp, short-duration winter storm peak.

Geology

Olema Creek is located in a fault-controlled valley, which exists along and is defined by the San Andreas Fault. The creek is the only example of an offset stream (a laterally or vertically displaced stream caused by faulting) on the Point Reyes peninsula. The fault cuts through Tomales Bay, Olema Valley, Bolinas Lagoon, westerly into the Pacific Ocean, and then returns east and inland just south of San Francisco. The rest of California is part of the slower, westerly moving North American Plate, which results in periodic seismic activity along the San Andreas Fault. On average, the Pacific Plate moves in a northwesterly direction 1-2 inches per year. The most notable geologic difference between the Point Reyes Peninsula and the remainder of the California Coast is the presence of igneous plutonic granitic rock with variations and the absence of the Franciscan Formation found west of the San Andreas Fault.

The Peninsula's granite rock and the Franciscan Formation are believed to be from the late Jurassic and Cretaceous age. However, the granite probably originated from much deeper in the earth and several hundred miles south of its current location (Shuford and Timossi 1989, Evens 1993). The salt and pepper texture and visible crystals of granite rock are typical of this unit. The salt and pepper rock is granodiorite, the white rock is marble, and the streaked gray rock is gneiss. This is called the “Sur” Series because similar rocks are exposed in Big Sur far to the south (Wright 2000). Some of the other wide-spread geologic formations found on the peninsula include Laird sandstone and Monterey shale. A formation of clay and mudstone called the Olema Creek Formation is found in the San Andreas Fault zone valley. The geology east of the Fault has deep to moderately deep soils with high infiltration capacities.

Channel Conditions

The active channel at the streamgage is a wide trapezoidal shape. The width of the channel at bankfull is approximately 32 ft (9.75 meters) and the depth is 3.73 ft from the thalweg to the high water elevation. The right bank rises to a bench at approximately 15 ft above the thalweg. The right and left banks are steep. The channel slope at the streamgage averaged over 610 ft is 0.44%. The streambed is composed of gravel and sand. Overbank areas are vegetated with

grasses and thick brush up to the top of the slope. A bridge crosses the stream at the site of the streamgage.

At the monitoring site, the Bear Valley Road Bridge mimics a large box culvert with flow concentrated into two chambers (Ketcham 1998). There are two sections: 20 ft wide, 12 ft high and 24 ft long (6.2 m, 3.7 m and 7.3 m). Below the bridge the channel turns to the left. The center bridge support disturbs flow because it is at a point where the channel transitions from a relatively straight run into a bend. Because of this the bed around the bridge changes dramatically after high flows, as does the section that contains the majority of discharge at low flow. The bridge support also intercepts large woody debris as it flows downstream exacerbating the channel bed changes.

Control
Immediately downstream of the Bear Valley Bridge, a gravel riffle serves as a section control. In some years, the low flow channel may become braided due to aggradation of fine sediments between debris and vegetation. Under moderate flows, a downstream gravel formed by debris collecting on the upstream side of leaning riparian trees likely causes water to backup. Under higher flows, the piers of the bridge typically trap debris and also cause a backwater effect.

Discharge Measurements
Location of wading measurements is variable because of dynamic channel conditions under low flows. The locations are generally within 50 feet of the streamgage. Cable deployed measurements are done from the existing Bear Valley Road bridge under high water conditions. The quality of high flow measurements is affected by high velocities causing vertical angles and flows not entirely parallel through bridge.

Floods
Indirect estimates of peak flow have been computed by U.S. Geological Survey's National Flood Frequency computer program (Vers. 3.2) which uses regional regression equations based on prior investigations of the relationship between watershed and climate parameters with streamflow. Olema Creek watershed is near the interface between the Central Coast and North Coast regions. Estimates reported below (Table SOP 3.6, Figure SOP 3.42) were run using regional regression for both Central Coast and North Coast region. The Park hydrologist has indicated that observed peak streamflows and frequency match better with the North Coast regression based on channel field indicators (Brannon Ketcham, PORE Hydrologist, pers. comm., 2008).

Point Of Zero Flow
TBD

Winter Flow
No ice.

Regulation and Diversion
No dams are present on mainstem Olema Creek above the streamgage. Approximately 6 stock ponds are present on tributaries with a cumulative storage less than 100 acre-feet (Brannon Ketcham, PORE Hydrologist, pers. comm. 2007). There are two minor diversions on the

mainstem by a rancher at John West Fork confluence and a residential diversion at Lupton's (Brannon Ketcham, PORE Hydrologist, pers. comm. 2007). Some minor diversions are present on tributaries (Vedanta tributary and springs by Stewart Horse Camp at Five Brooks).

Cooperation
Station maintained and operated by NPS.

Indirect Measurement Site
TBD

Period of Record
1998–11/2005, 2/2006–Present

Land Ownership
U.S. government (PORE), Bear Valley bridge within Marin County right-of-way

USGS Quadrangle (7.5 minute)
Inverness

Table SOP 3.6. Estimated flood frequency at Olema Creek at Bear Valley Road bridge.

Central CA			North Coast		
Recurrence Int. (yrs)	Peak cfs	Standard Error (%)	Recurrence Int. (yrs)	Peak cfs	Standard Error (%)
2	2,260	150	2	1,520	66
5	3,470	110	5	1,950	60
10	4,090	96	10	2,260	60
25	4,760	96	25	2,460	60
50	5,260	110	50	2,630	63
100	5,640	120	100	2,640	66
500	6,350		500	2,860	

.



Figure SOP 3.37. Olema Creek Watershed.

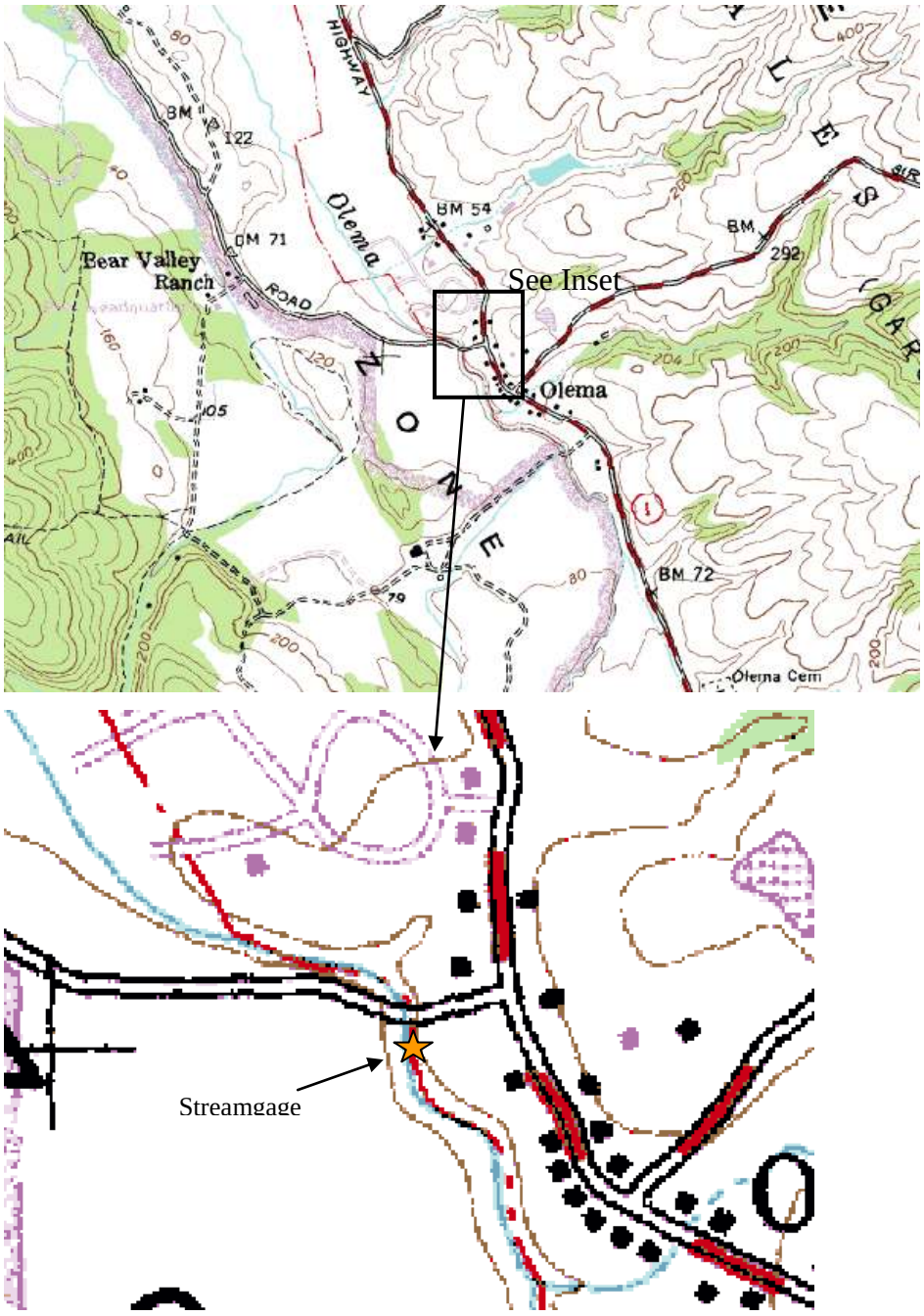


Figure SOP 3.38. Olema Creek streamgage at Bear Valley Road bridge: overview (above) and inset.



Figure SOP 3.39. Olema Creek streamgage (datalogger in upper right-hand corner).

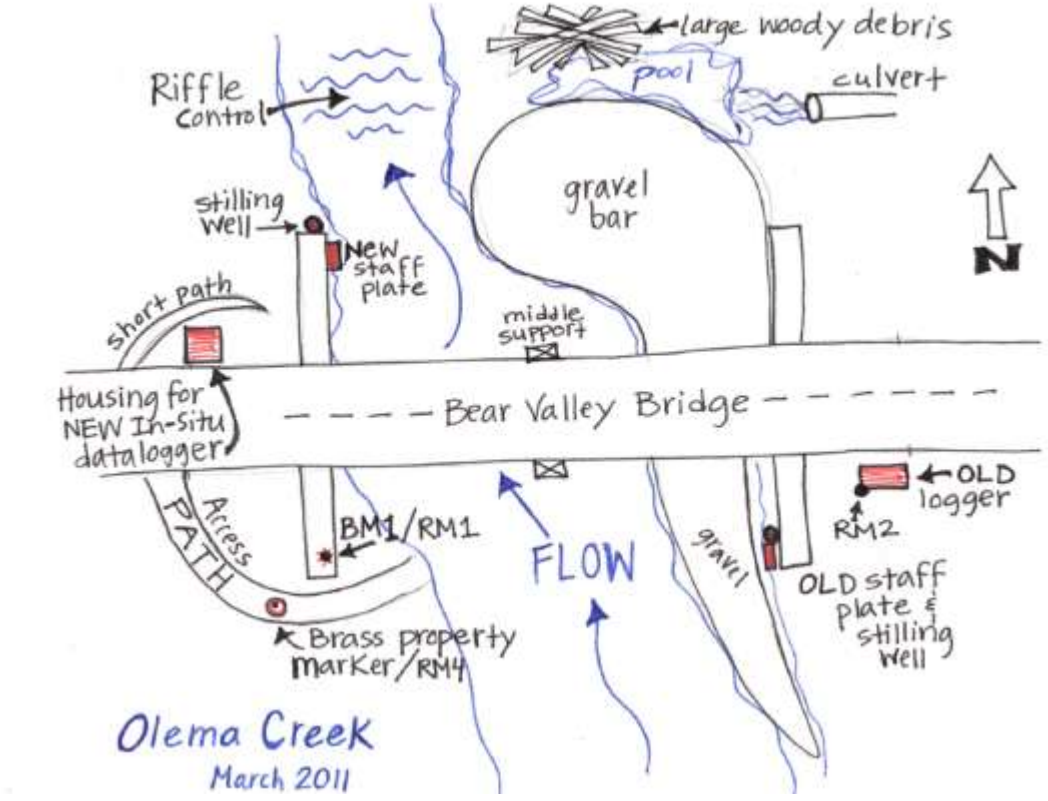


Figure SOP 3.40. Sketch of Olema Creek streamgage location and reference marks.

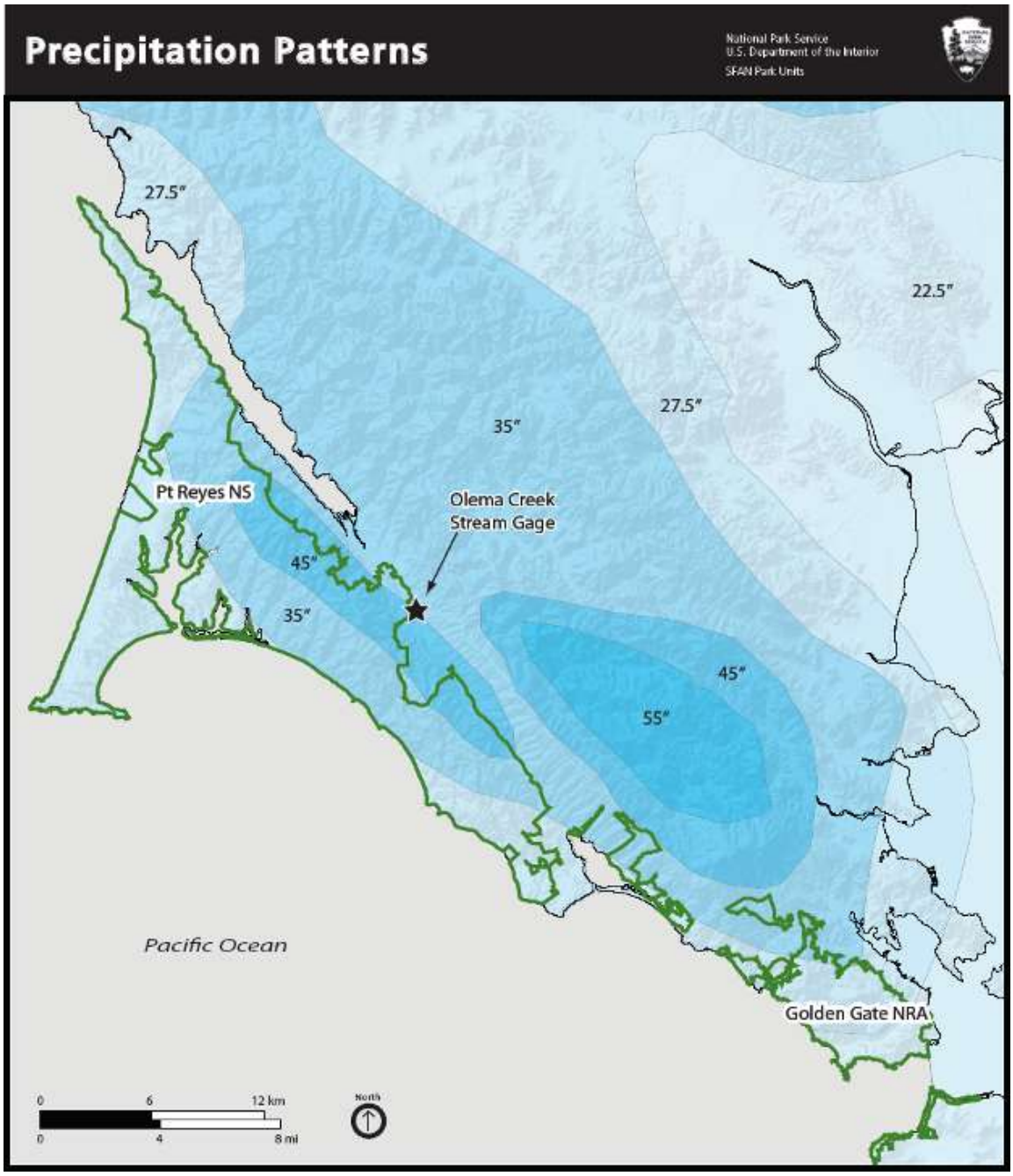


Figure SOP 3.41. Precipitation map for Point Reyes National Seashore.

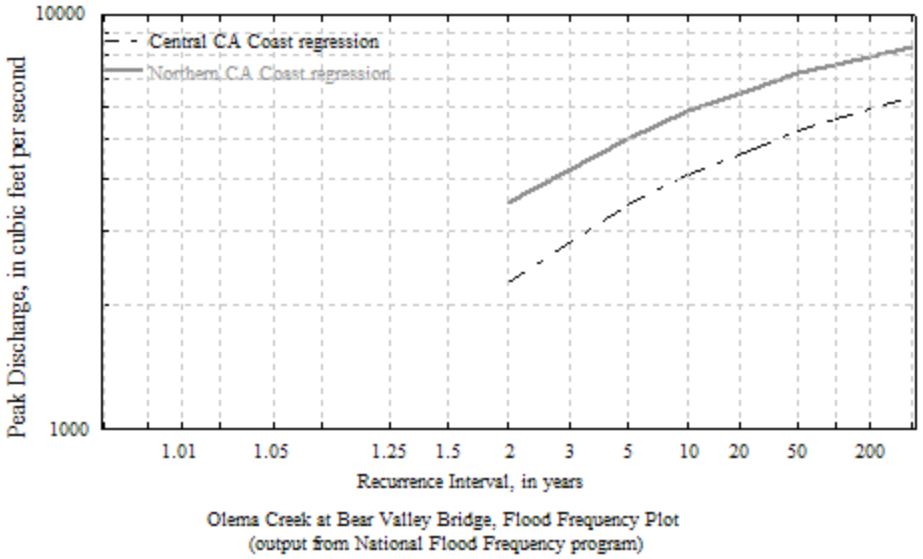


Figure SOP 3.42. Estimated flood frequency for Olema Creek at Bear Valley Road Bridge.

Lagunitas Creek near Point Reyes Station, Marin County, California (From USGS)

Revision Date: 1/12/2009
Revised by: mwebster, USGS

Location

Lat 38°04'49", long 122°47'00" referenced to North American Datum of 1927, Marin County, CA, Hydrologic Unit 18050005, in Nicasio (Black) Grant, on right bank, at upstream side of road bridge, 300 ft downstream from small right-bank unnamed tributary, 1.4 mi northeast of town of Point Reyes Station, and 2.5 mi downstream from Nicasio Dam (Figure SOP 3.43).

Drainage Area

81.7 mi^2.

Period of Record

October 1974 to current year.
CHEMICAL DATA: Water years 1977, 1999-2001.
WATER TEMPERATURE: Water year 1990.
SEDIMENT DATA: Water years 1990, 1999-2001, 2004-06.

Revised Records

WDR CA-79-2: 1975, 1978. WDR CA-82-2: 1975 (instantaneous maximum discharge), 1978 (instantaneous maximum discharge), 1980 (instantaneous maximum discharge).

Gage

Water-stage recorder and crest-stage gage. Datum of gage is 13.31 ft above NGVD of 1929.

Remarks

Flow regulated by Nicasio Reservoir, capacity, 22,450 acre-ft, Kent Lake, capacity, 16,680 acre-ft, Alpine Lake, capacity, 8,890 acre-ft, and Bon Tempe Lake, capacity 4,296 acre-ft, all of which divert water for domestic and industrial use in Marin County.

Extremes for Period of Record

Maximum discharge, 22,100 ft^3/s, Jan. 4, 1982, gage height, 26.96 ft, from rating curve extended above 7,500 ft^3/s, on basis
of slope-area measurement of peak flow; minimum daily, 0.01 ft^3/s, Sept. 26, 1977.

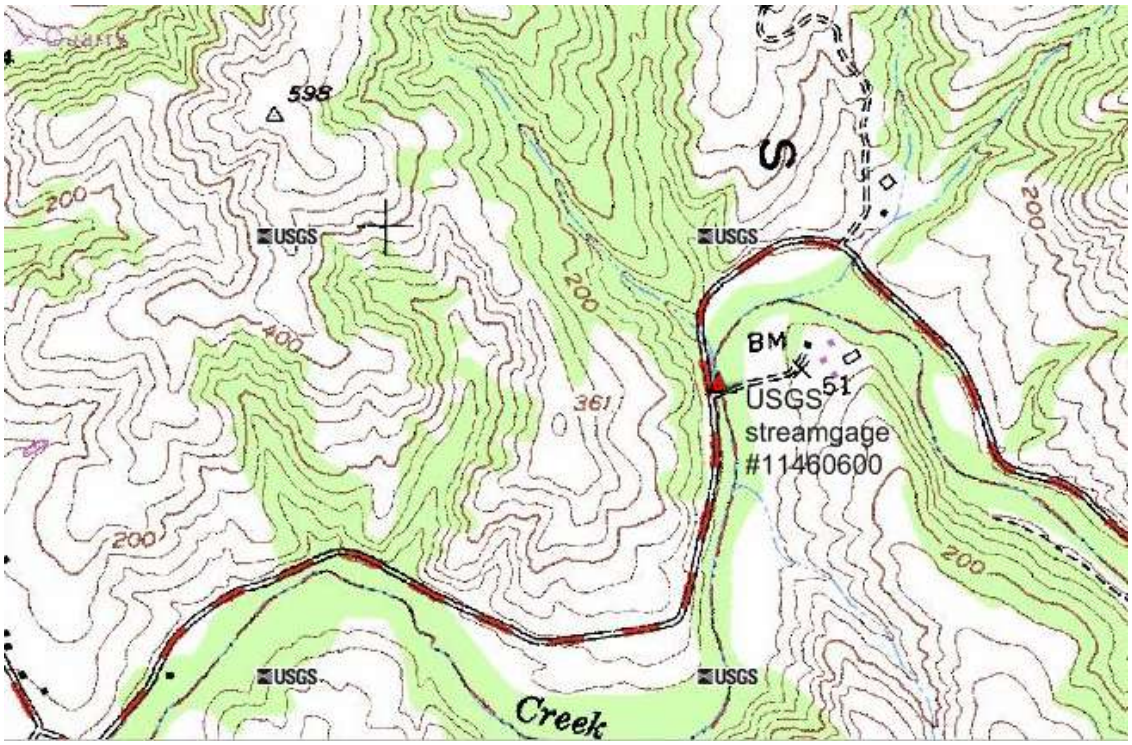


Figure SOP 3.43. Lagunitas Creek near Point Reyes Station streamgage location at Gallagher Ranch bridge.

Lagunitas Creek at Samuel P. Taylor State Park, Marin County, California (From USGS)

Revision Date: 2/12/2008
Revised by: kengelki, USGS

Location

Lat 38°01'37", long 122°44'07" referenced to North American Datum of 1927, Marin County, CA, Hydrologic Unit 18050005, in Samuel P. Taylor State Park, on left bank, 300 ft upstream from Deadman's Gulch, 0.9 mi downstream from park entrance, 2.1 mi northwest of Lagunitas, and 3.4 mi downstream from Kent Lake (Figure SOP 3.44).

Drainage Area

34.3 mi^2.

Period of Record

December 1982 to current year.
WATER TEMPERATURE: Water year 2004-06.
SEDIMENT DATA: Water year 2004-06.

Gage

Water-stage recorder and crest-stage gage. Datum of gage is 102.89 ft above NGVD of 1929.

Remarks

Flow regulated by Kent Lake, capacity, 32,900 acre-ft, Alpine Lake, capacity, 8,890 acre-ft, and Bon Tempe Lake, capacity, 4,300 acre-ft, which divert water for domestic and industrial use in Marin County.

Extremes for Period of Record

Maximum discharge: 10,200 ft^3/s, Dec. 31, 2005; gage height: 13.21 ft; minimum daily: 3.8 ft^3/s, Oct. 16–18, 1986.

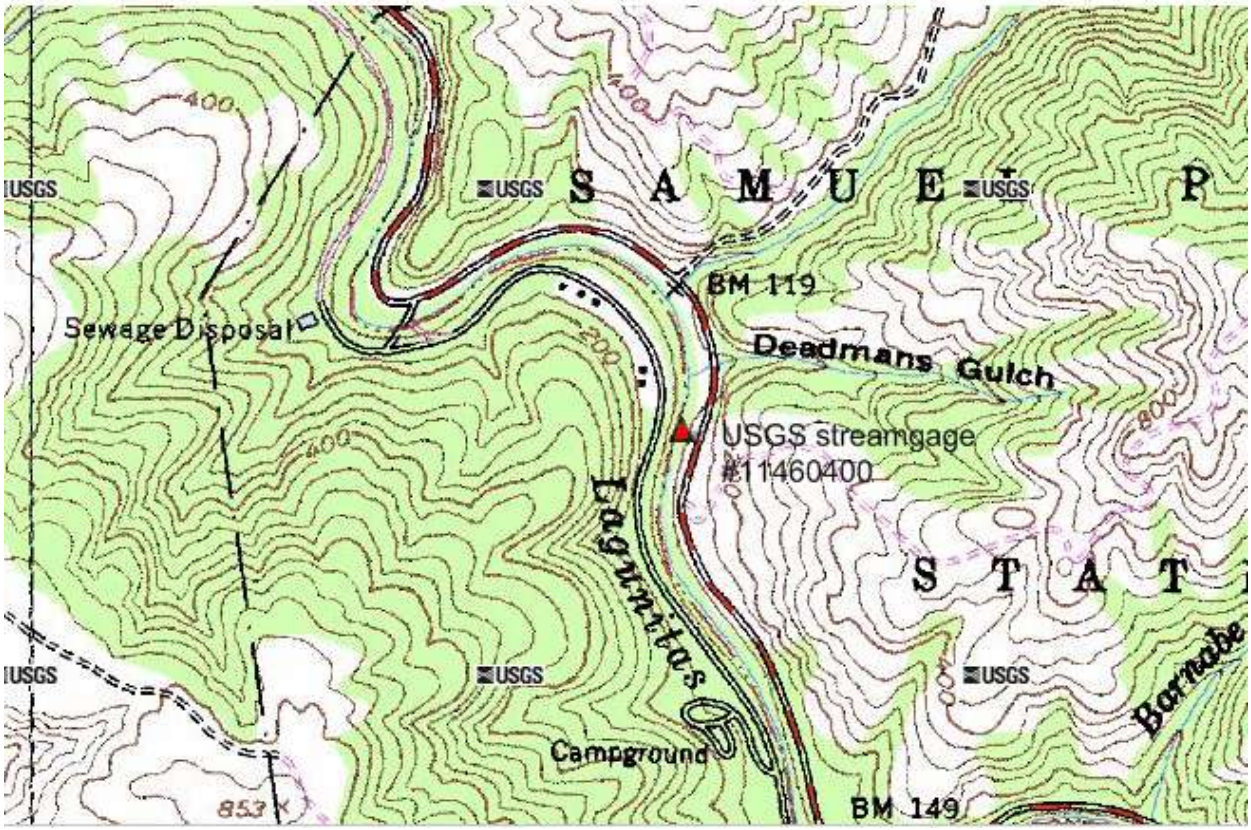


Figure SOP 3.44. Lagunitas Creek at Samuel P. Taylor State Park streamgage location.

Sandy Creek, Pinnacles National Monument

Revision Date: 8/6/2008
Revised by: Paul Johnson, PINN

Location (proposed)

Latitude 36°29'32"N, Longitude 121°08'48"W, in NE ¼ SW ¼ sec. 31, T. 16 S, R. 8 E., on downstream side of center culvert at triple culvert road crossing in Pinnacles Campground in San Benito County, California (Figures SOP 3.45–46). Hydrologic Unit Code: 18060005, Hydrologic Region: Central California Coastal, Hydrologic Unit: Salinas.

Directions

Take Highway 101 south through Gilroy, exit onto Highway 25, continue approximately 42 miles to Highway 146. Take Highway 146 west 1.8 miles to the Pinnacles Campground. Turn left into the campground, in 300 ft take the first right and then in another 300 ft the first left. The triple culvert crossing is immediately ahead of you, so park in the first campsite on the right (sites P and Q). At low water, walk down the road toward the crossing, then down the bank on the left to the upstream side of the culverts. Walk inside the right culvert to the downstream end where the gage will be established.

Establishment

TBD

Elevation

Approximately 1,100 ft above sea level. The watershed ranges in elevation from approximately 2,690 ft (820 m) at its headwaters near the Monterey/San Benito County line to 900 ft (274 m) at its confluence with Chalone Creek.

Drainage Area

Sandy Creek is an intermittent stream with a drainage area of 19.85 sq. miles (12705 acres) (planimetric). It has a three-dimensional drainage area of 21.06 sq. miles. The distance to the drainage divide is 12.09 miles (19,463 m; Figure SOP 3.45)

Gage

This installation will be very similar to the Bear Creek streamgage. The composite board will be buried in the streambed and anchored to the downstream right side of the leftmost culvert.

History

There are no existing streamgages within this watershed.

Benchmarks

There are no nearby National Geodetic Survey benchmarks to the site.

Watershed Hydrologic Conditions

Mean annual precipitation is estimated to be 14 inches (Figure SOP 3.47). Most of the watershed is covered by chaparral vegetation, although more grassland and valley/blue oak woodland is found here than in the other two Pinnacles watersheds discussed. Other vegetation types include buckwheat shrubland, desert wash type vegetation, and likely other vegetation types than are

found within PINN. Most of the stream length is seasonal, with a perennial section running from 1 to 4 miles upstream of the confluence with Chalone Creek. The terrain is mostly mountainous, though less steep than in the other two watersheds, and with a relatively high proportion of wide, gentle valleys.

The creek provides critical habitat to the federally threatened California red-legged frog (*Rana aurora draytonii*) which breeds in perennial reaches within approximately 1 mile upstream and downstream of the gaging site. The most consistently used breeding site is the pool at the gaging site. Care should be taken to avoid disturbing frogs, eggs, or habitat at this site.

Geology

The watershed is primarily underlaid by the sedimentary Monterey Formation. Some portions are underlaid by decomposable granite, and the portion just upstream of the confluence with Chalone creek is mostly volcanic rhyolite. Portions of the headwaters may also lie upon rhyolite. Although much of the terrain is not as steep as for Bear and Chalone Creek, Sandy Creek has a fairly flashy response to precipitation.

Channel Conditions

The channel crosses a campground road in a corrugated steel culvert, which is rusted through near the downstream end. At low flows, this does not affect flow, but at moderate and higher flows, some flow will be diverted through these holes before reaching the end of the culvert. The stream channel at the culvert is clear of vegetation at low flow, but the inlets of the other culverts may be blocked by vegetation/debris at higher flows. The stream is single channel at low flows, double channel at high flows, and triple channel at flood. The main channel is straight above and below the site.

The channel consists of three parallel corrugated culverts 6 ft in diameter and approximately 40 ft long. The culverts are at different heights at the inflow, with the center one lowest, the right one several inches higher, and the left one several inches higher again. The bottom third of the left culvert is currently blocked by dirt and debris. The right culvert is partially blocked by rip rap.

Control

The channel immediately downstream of the culverts has a significant amount of vegetation and debris with no stable section control. High flows may cause shifts in the control.

Discharge Measurements

TBD

Floods

An estimated 40-year event on Feb. 3, 1998 based on high water marks resulted in 1,100 cfs in Sandy Creek approximately 0.75 mile downstream of the proposed gaging site (Chad Moore, former-PINN physical scientist, pers. comm. 2006),. This flow is likely only slightly higher than would be expected at the proposed gaging site, due to a small input from McCabe Canyon.

Indirect estimates of peak flow have been computed by U.S. Geological Survey's National Flood Frequency computer program (Vers. 3.2) which uses regional regression equations based on

prior investigations of the relationship between watershed and climate parameters with streamflow. Estimates reported below for Sandy Creek (Table SOP 3.7, Figure SOP 3. SOP 3.48) were run using regional regression for Central Coast.

Point Of Zero Flow
TBD

Winter Flow
No ice.

Regulation and Diversion
No known in-stream diversions. Various small stock ponds with earthen dams, four NPS-owned, the rest private. Culverts at multiple road crossings.

Cooperation
TBD

Indirect Measurement Site
TBD

Land Ownership
The campground and surrounding lands are managed by the National Park Service. The majority of the watershed is privately owned.

Quadrangle
North Chalone Peak 1:24000 (1984).

Period of Record
TBD

Table SOP 3.7. Estimated flood frequency for Sandy Creek.

Recurrence Int. (yrs)	Peak cfs	Standard Error (%)
2	48.3	150
5	219.0	110
10	456.0	96
25	932.0	96
50	1,490.0	110
100	2,170.0	120
500	4,610.0	



Figure SOP 3.45. Sandy Creek Watershed.



Figure SOP 3.46. Sandy Creek, looking upstream at triple culverts.

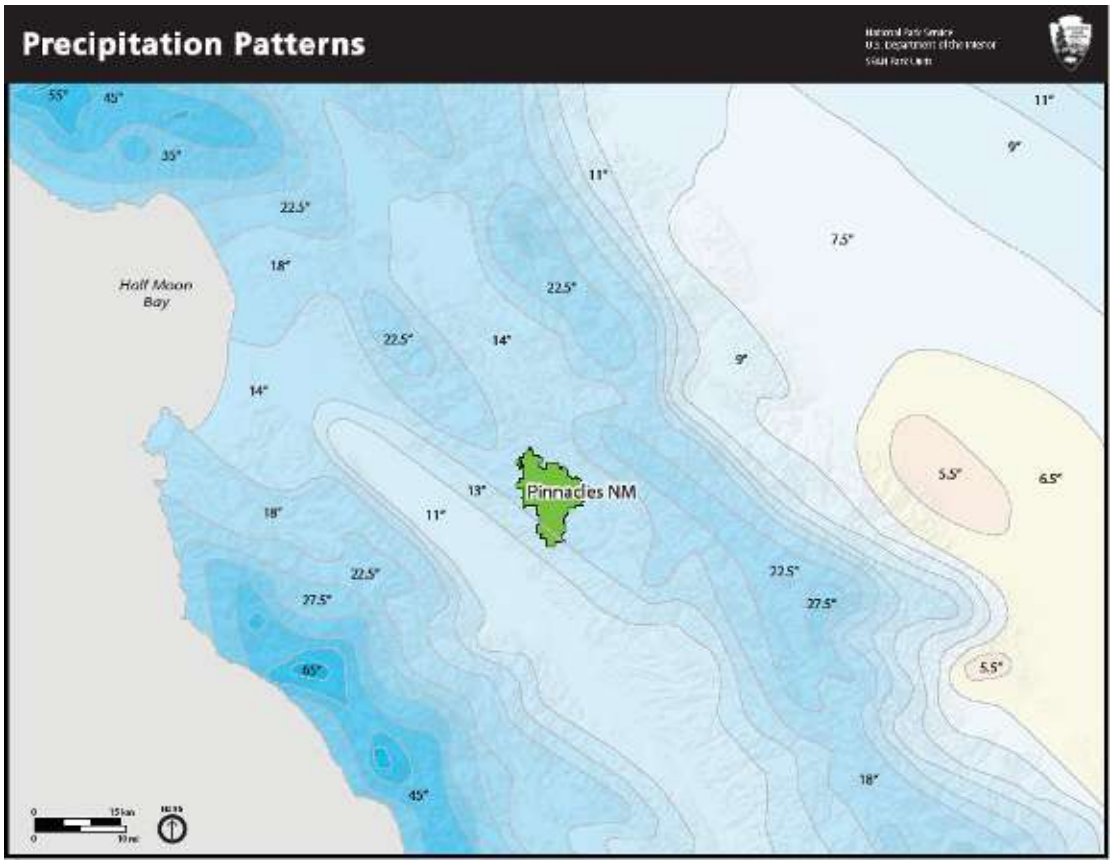


Figure SOP 3.47. Precipitation map for Pinnacles National Monument.

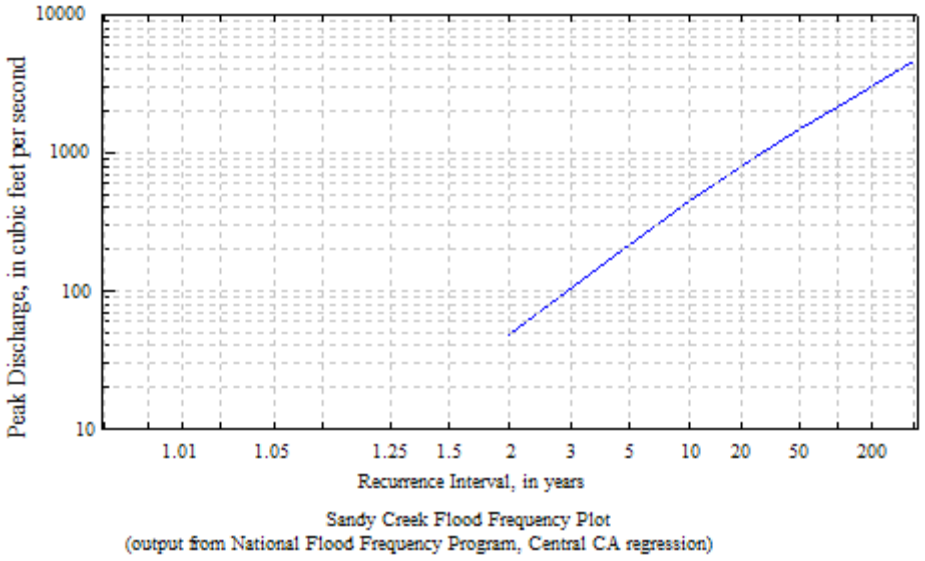


Figure SOP 3.48. Estimated flood frequency at Sandy Creek.

Chalone Creek, Pinnacles National Monument

Revision Date: 8/6/2008
Revised By: Paul Johnson, PINN

Location (proposed)

Latitude 36°29'13"N, Longitude 121°10'10"W, in San Benito and Monterey Counties, California. In NW ¼ NW ¼ sec. 1, T. 17 S, R. 7 E., on downstream left side of bridge, 0.75 mile NE Bear Visitor Center, 1,750 ft upstream of the confluence with Bear. The gaging site is located on the Chalone Creek Bridge on the road leading to the Bear Visitor Center (Figures SOP 3.49–50). Hydrologic Unit Code: 18060005, Hydrologic Region: Central California Coastal, Hydrologic Unit: Salinas.

Directions

Take Highway 101 south through Gilroy, exit onto Highway 25, continue approximately 42 miles to Highway 146. Take Highway 146 west 3.5 miles to a pullout on the right. Park here and walk 0.2 miles farther along the road to the Chalone Creek Bridge, to the left just past the turnoff to the Chalone Area. From here, proceed down to the creek bed and follow the creek upstream 900 ft.

*Estab*lishment

TBD

Elevation

Proposed site is approximately 980 ft above sea level. The watershed ranges in elevation from 3,304 ft (1,007 m) at North Chalone Peak to 328 ft (100 m) at its confluence with the Salinas River.

Drainage Area

Chalone Creek is an intermittent stream with a drainage area of 25.44 sq. miles (16,282 acres) (planimetric) (Figure SOP 3.51). It has a three-dimensional drainage area of 27.52 sq. miles.

Gage

A single 3.3-ft staff plate will be attached to a composite board and buried in the streambed. If possible, the board will be anchored to the vertical dirt bank by attaching it to rebar or a T-stake driven horizontally into the bank.

History

There are no existing streamgages within this watershed.

Benchmarks

There are no nearby National Geodetic Survey benchmarks to the site.

Watershed Hydrologic Conditions

Mean annual precipitation is estimated to be 14 inches (Figure SOP 3.47). The Chalone Creek watershed includes the Bear Creek and Sandy Creek watersheds, discussed in other sections to this document. The watershed is dominated by chaparral, with tracts of grassland and valley/blue oak woodland. Other upland vegetation includes gray pine woodland, California buckeye

woodland, California buckwheat shrubland, coastal sage scrub, and rock-scree areas dominated by club moss and tiny annuals. Along many stream reaches with seasonal flow the riparian vegetation is essentially identical to that of the adjacent uplands, although in some cases the associated sandy/gravelly flood plains and alluvial fans support plant associations reminiscent of desert washes. Willows are associated with many riparian areas, and wetter areas support live oaks, cottonwoods, and sycamores. The terrain is dominated by steep mountains with a few wide valleys. The creek provides critical habitat to the federally threatened California red-legged frog (*Rana aurora draytonii*) which breeds in perennial reaches from just upstream of the site to the PINN boundary downstream.

Geology
Much of Chalone Creek and its tributaries (except for Sandy Creek) are underlaid by volcanic rhyolite. Portions of small tributaries to Chalone Creek (east of the Chalone Creek fault) are underlaid by sedimentary and granitic substrate. As described in the section on Sandy Creek, this major tributary is underlaid mainly by the sedimentary Monterey formation. It should be noted that Sandy Creek and Bear enter Chalone Creek below the gaging site. The soils are poorly developed and the terrain is steep, so response to precipitation tends to be flashy.

Channel Conditions
The stream is one channel at low stages, two at higher flows. The main channel is straight above and below site. The Chalone Creek Bridge has vertical abutments with earth and rip rap against them, and a single central piling 4 ft in diameter. The bridge deck is curved with the center facing upstream. The right bank is sand/gravel to the foot of a 45° rip-rap slope (rip-rap is approximately 18 inches in size). Halfway up the rip-rap slope is a foot trail 4 ft wide. At the top of the rip-rap is a flat area extending 10 ft to the base of the vertical concrete bridge abutment. Left bank is sand/gravel to foot of 45° rip rap slope. Rip-rap is approximately 18 inches in size. At top of rip-rap is a flat area extending 9 ft to the base of the vertical concrete bridge abutment. Bankfull width is 20 ft, width between bases of rip-rap slopes is 56 ft, and width between abutments is 110 ft.

Control
At low water, the proposed gaging site is controlled by a pool tail/riffle. During high water and floods, gravel bar and channel control. The stream channel is moderately filled with shrubs (*Salix* and *Baccharis*) 5–20 ft in height, plus some small blackberry and sedge on the banks.

Discharge Measurements
TBD

Floods
Estimated 50-year event on Feb. 3, 1998 resulted in 2,500–3,000 cfs at the Chalone Creek bridge based on high water marks (Chad Moore, former-PINN physical scientist, pers. comm. 2006).

Point Of Zero Flow
TBD

*W*inter Flow
No ice.

Regulation and Diversion
Privately-owned dam on Gloria Lake, a large stock pond, present in the headwaters of Chalone Creek outside PINN. Water is only released in extremely high flow events (such as in Feb. 1998). Very small earthen dam on stock pond is in Marion Canyon, off of North Fork Chalone Creek. No in-stream diversions are known.

Cooperation
TBD

Indirect Measurement Site
TBD

Land Ownership
Parts are owned by the U.S. Government (National Park Service, PINN) and the California Department of Transportation. A small portion is privately owned.

Quadrangle
North Chalone Peak 1:24000 (1984).

Period of Record
To be determined.



Figure SOP 3.49. Chalone Creek (looking upstream to Chalone Creek Bridge), before vegetation was present in channel.



Figure SOP 3.50. Chalone Creek (looking towards right bank) current condition with vegetation in channel.

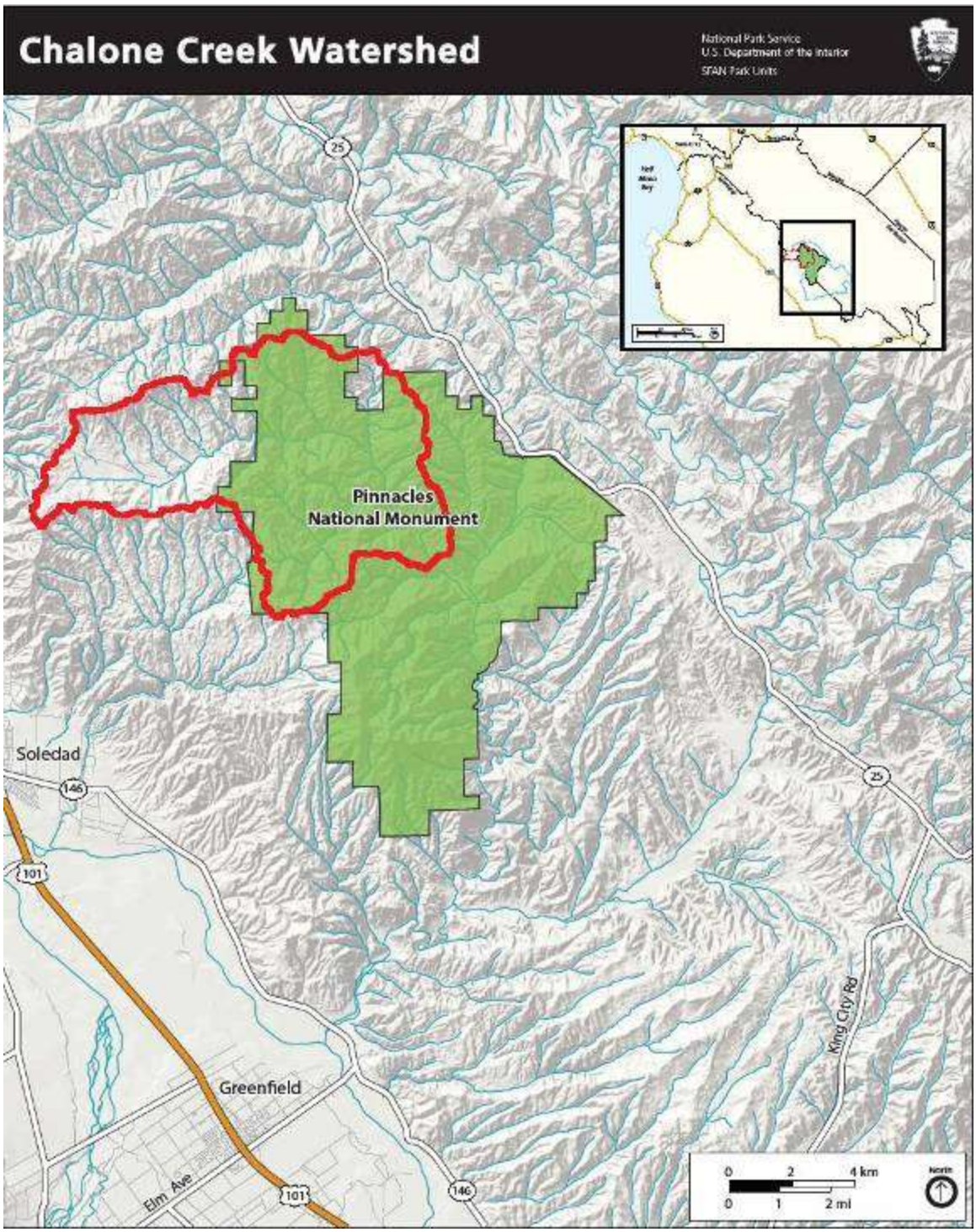


Figure SOP 3.51. Chalone Creek watershed.

Bear Creek, Pinnacles National Monument

Revision Date: 10/8/2009
Revised By: Paul Johnson, PINN

Location

Lat. 36°28'56"N, Long. 121°10'47"W, in SW ¼ NE ¼ sec. 2, T. 17 S, R. 7 E., on downstream side of first footbridge ("Bridge #1") on Bear Trail, 600 ft NE Bear Gulch Visitor Center/Condor Gulch confluence (Figures 86-87). Hydrologic Unit Code: 18060005, Hydrologic Region: Central California Coastal, Hydrologic Unit: Salinas.

Directions

Take Highway 101 south through Gilroy, exit onto Highway 25, continue approximately 42 miles to Highway 146. Take Highway 146 west 4.7 miles to the Bear Gulch Visitor Center. Park in the main lot and walk down the Bear Gulch Trail (trailhead is near the stop sign) approximately 600 ft to the first footbridge.

Establishment

The streamgage was set up by Paul Johnson (PINN) and Rick Inglis (NPS-WRD) in November, 2008.

Elevation

Proposed site is approximately 1,230 ft above sea level. The watershed ranges in elevation from approximately 2,800 ft (853 m) on the ridge one mile north of North Chalone Peak to 970 ft (296 m) at its confluence with Chalone Creek.

Drainage Area

Bear Creek is a perennial stream with a drainage area of 2.78 sq. miles (1,776 acres) (planimetric) (Figure SOP 3.52). It has a three-dimensional drainage area of 3.11 sq. miles. The stream distance to the drainage divide is 2.34 miles (3,765 m).

Gage

Stream water level is measured periodically every 15 minutes using a Global Water WL 16U pressure transducer/datalogger to the nearest 0.01 ft. The transducer is housed in a 3-ft long ABS pipe installed perpendicular to the bank and angled downward at approximately 30 degrees. The pipe is attached with a bracket to the downstream edge of the composite board to which the staff plate is attached. The ABS pipe is pinned to the shore with two 1-ft sections of rebar driven into the ground at an angle over the pipe. From there, the lead runs inside ABS pipe as it bends several times and continues up the bank to an ABS sprinkler box approximately 20 feet away. The ABS pipe sections and joints are pressure-fitted and pinned at several points with rebar, and buried under dirt and/or rocks. The datalogger is housed inside a larger diameter ABS pipe, and this in turn is inside the sprinkler box. This sprinkler box is situated on the downstream side of a larger concrete box.

The staff plate consists of two 3.3-ft sections, for a total of 6.6 ft. The bottom 1.5 ft of the staff plate is buried in the streambed. This board is in turn attached with brackets to the bridge, with galvanized wire to T-stakes driven 2 ft into the streambed on the up- and downstream sides of

the board, and the board itself is buried 2 ft in the streambed (Figure SOP 3.53). A crest gage will also be attached to the composite board with the staff plate, in order to record high flows.

History
There are no existing streamgages within this watershed.

Benchmarks
There are no nearby National Geodetic Survey benchmarks to the site.

Watershed Hydrologic Conditions
The watershed is dominated by chaparral with small patches of woodland (blue oak, gray pine, and California buckeye), rock-scree, California buckwheat shrubland, and coastal sage scrub. Riparian vegetation in the lower reaches of the watershed is characterized by a dense canopy of coast live oak and sycamore. The upper stream reaches are mainly seasonal, so they do not generally support riparian vegetation. The terrain is dominated by steep mountains, although the upper Bear Creek valley is somewhat wide and gently sloping.

Bear Creek stretches from just outside PINN's western boundary, approximately three miles eastward to Chalone Creek. Its upper reaches are seasonal, with the first perennial water occurring in the Bear Gulch Reservoir. There is apparently a small set of springs in the headwaters outside of PINN. Another small spring flows beneath the reservoir, though it is unknown whether it flows enough to have maintained perennial streamflow before the Bear Gulch Dam was constructed. Below the dam, Bear Creek alternates between intermittent and perennial sections. The terrain is predominantly mountainous, rising from 970 to 2,800 ft. The watershed is located in the Coast Ranges, which were formed by subduction of the Farallones plate under the western edge of the North American plate. The watershed is primarily underlain by Miocene volcanics dominated by rhyolite. The Chalone Creek and San Andreas Faults lie just to the east.

The creek provides critical habitat to the federally threatened California red-legged frog (*Rana aurora draytonii*) which breeds in the Bear Gulch Reservoir and also inhabits the stream from the reservoir downstream to Chalone Creek. Although males have been heard calling in the stream near the Bear Gulch Visitor Center, no reproduction has been documented in the stream either currently or historically.

The largest tributary of Bear Creek is Condor Gulch, which drains the High Peaks formation to the north. Other tributaries are relatively small. Vegetation is composed of grassland and blue oak woodland in the upper valley (burned in 1995); chaparral, blue oak woodland, California buckwheat shrubland, coastal sage scrub, gray pine woodland, and California buckeye woodland on the slopes; and dense riparian vegetation dominated by coast live oak and sycamore in middle and lower Bear Creek.

Geology
The underlying geology of the watershed is almost entirely volcanic in origin, consisting mostly of rhyolite. The soils are poorly developed and the terrain is steep, so response to precipitation tends to be flashy.

Channel Conditions
At the gaging site, the stream substrate is mainly gravel, sand, and cobble with seasonally heavy leaf litter (Figure SOP 3.54). The low-water channel is clear of vegetation. The stream is a single channel except in very high flood stages, when it also flows around the left side of the bridge. The main channel is straight above and below the gaging site. The banks are roughly symmetrical bridge abutments consisting of concrete and rock. The channel width is 10 ft at low water, 13 ft at bankfull.

Control
At low water, the tail of pool/start of glide is 12 ft downstream. There is no vegetation in low water channel, moderately dense low vegetation on banks, and a few large sycamore trees in channel. During high water and floods, gravel bar and channel control.

Discharge Measurements
Gage maintenance and wading discharge measurements will occur once per month during the water quality site-visits of water year 2011 and 2012.

Floods
The estimated 40-year event on Feb. 3, 1998 resulted in 500 cfs at Bridge #1 based on high water marks (Chad Moore, former-PINN physical scientist, pers. comm. 2006). Indirect estimates of peak flow have been computed by U.S. Geological Survey's National Flood Frequency computer program (Vers. 3.2) which uses regional regression equations based on prior investigations of the relationship between watershed and climate parameters with streamflow. Estimates reported below for Bear Creek (Table SOP 3.8, Figure SOP 3.55) were run using regional regression for Central Coast. The estimates are based on unimpaired conditions (no upstream dam).

Point Of Zero Flow
To be determined

Winter Flow
No ice.

Regulation and Diversion
There are no known in-stream diversions above the proposed gaging site. The Bear Gulch Dam approximately 1 mile upstream likely attenuates peak events. The dam has small leaks, and occasionally water is released in the fall to exercise valves. There are several culverts at road crossings of Bear Creek and tributaries.

Cooperation
TBD

Indirect Measurement Site
TBD

Land Ownership
Parts are owned by the U.S. Government (National Park Service, PINN). Ranch lands in the low saddle at the headwaters of Bear Creek are privately owned.

Period of Record
TBD

Table SOP 3.8. Estimated flood frequency for Bear Creek (unimpaired, without dam).

Recurrence Int. (yrs)	Peak cfs	Standard Error (%)
2	7.86	150
5	36.4	110
10	77.4	96
25	161.0	96
50	258.0	110
100	385.0	120
500	833.0	

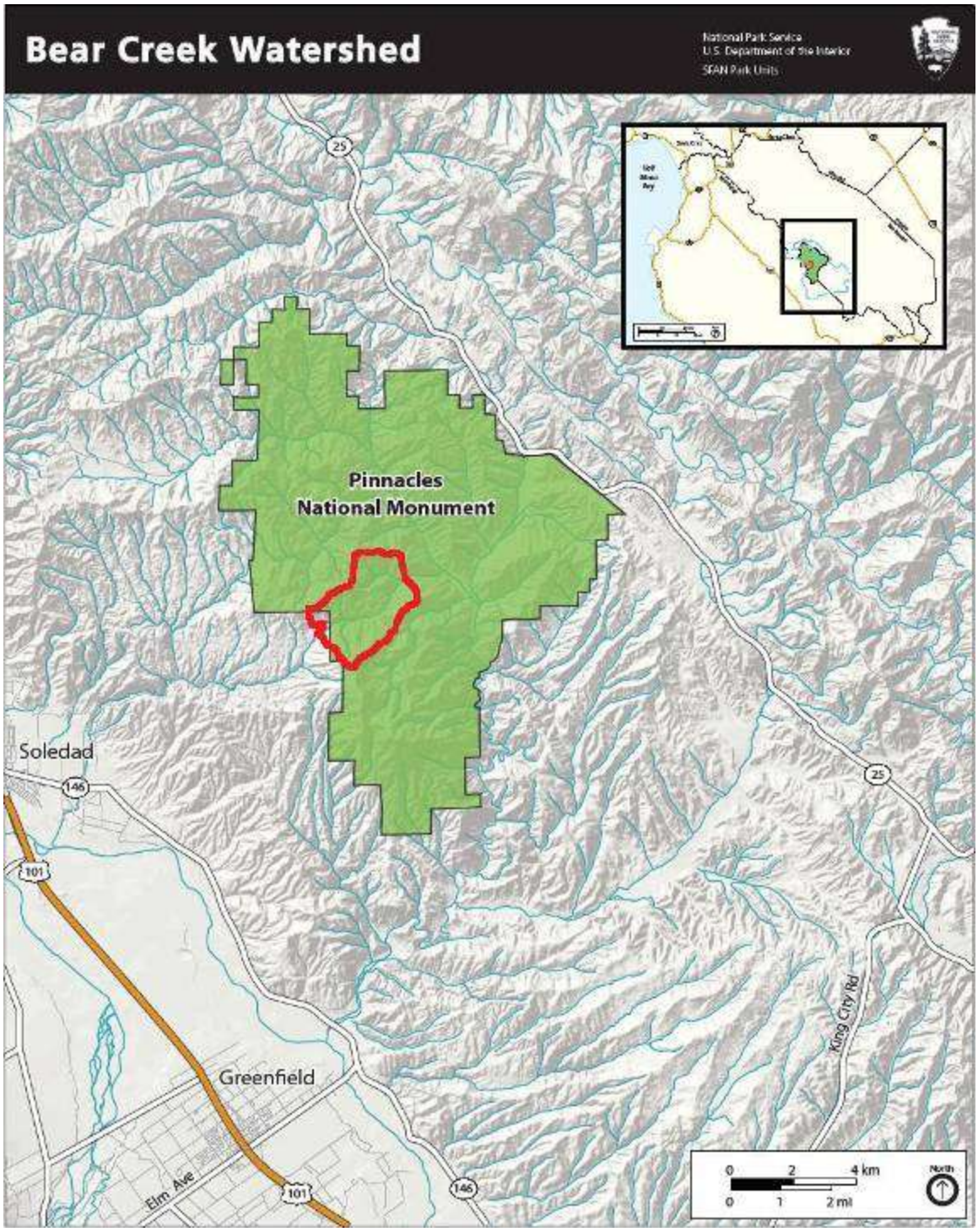


Figure SOP 3.52. Bear Creek watershed.



Figure SOP 3.53. Bear Creek staff plate and pressure transducer on upstream side of “Bridge #1” prior to crest gage installation.



Figure SOP 3.54. Bear Creek, looking upstream at Bridge #1.

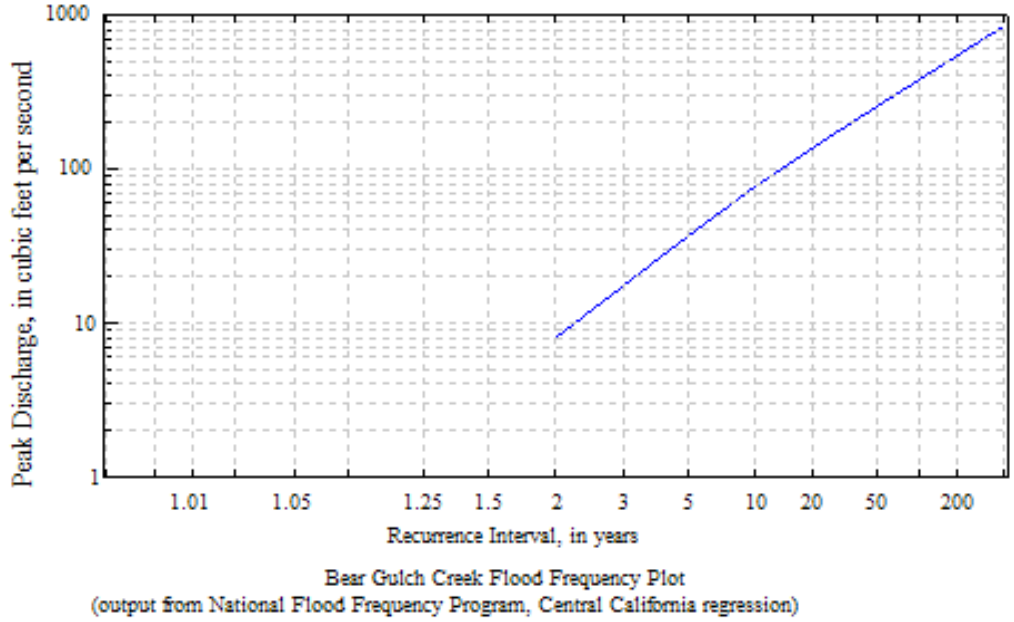


Figure SOP 3.55. Estimated flood frequency at Bear Creek (unimpaired, without dam).

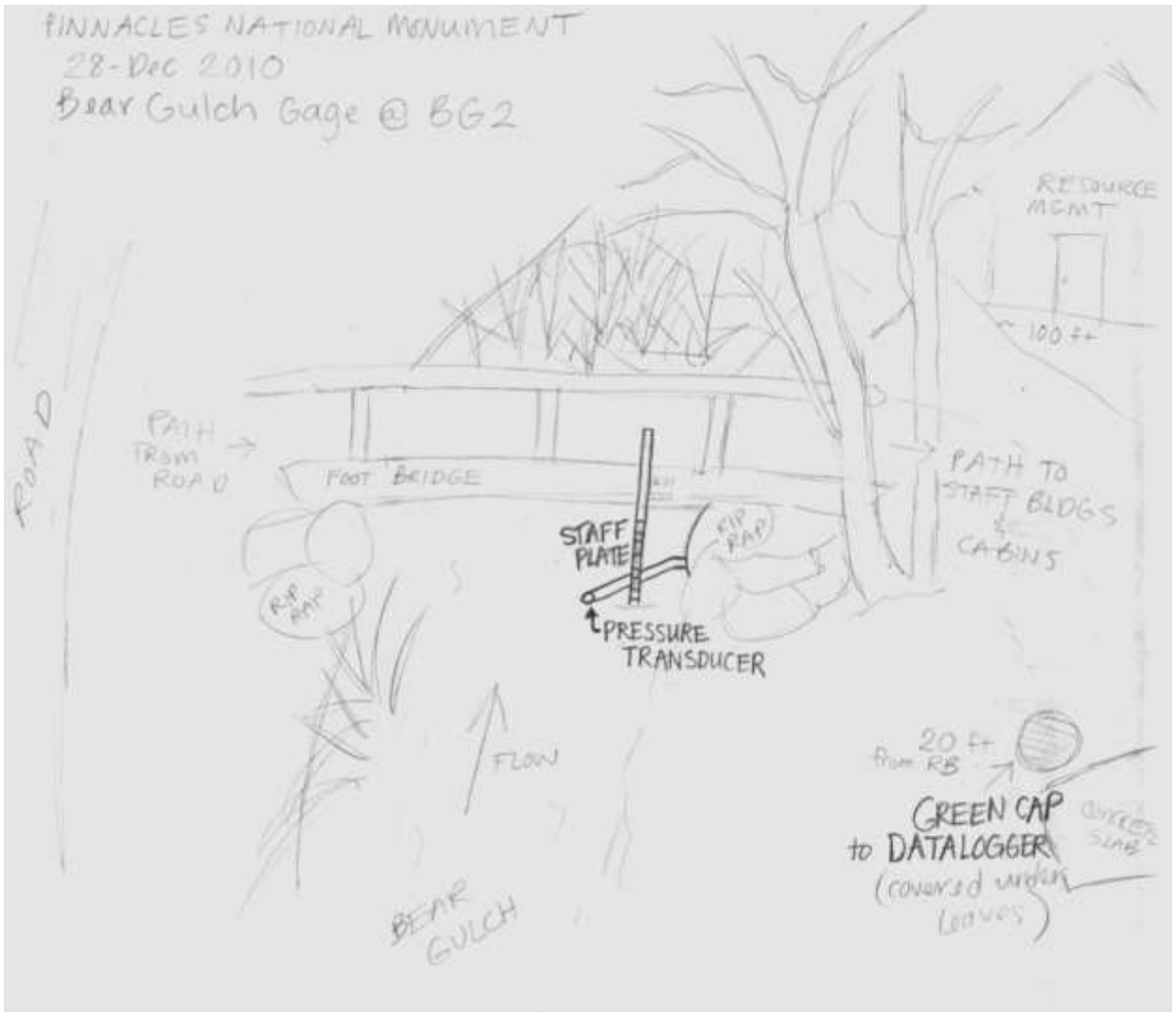


Figure SOP 3.56. Sketch Bear Creek streamgage location and reference marks.

Literature Cited

Blake, M. C. Jr., J. A. Bartow, V. A. Frizzell Jr., J. Schlocker, D. Sorg, C. M. Wentworth, and R. H. Wright. 1974. Preliminary geologic map of Marin and San Francisco Counties and parts of Alameda, Contra Costa and Sonoma Counties, California. U.S. Geological Survey Miscellaneous Field Studies Map MF-574. Scale 1:62,500.

Boudreau, E. H. 1979. Geology and Ground Water Potential of the Stinson Beach Area. Report to Stinson Beach County Water District. 1979 July 23.

Clark, J.C., E. E. Brabb, H. G. Greene, and D. C. Ross. 1984. Geology of Point Reyes Peninsula and implications for San Gregorio fault history. Pages 67–86 *in* J. K. Crouch and S. B. Bachman, editors. Tectonics and sedimentation along the California margin. Society of Economic Paleontologists and Mineralogists, Pacific Section, Los Angeles.

Evens, J. G. 1993. The natural history of the point reyes peninsula. Point Reyes National Seashore Association, Point Reyes, California.

Galloway, A. J. 1977. Geology of the Point Reyes Peninsula, Marin County, California. California Division of Mines and Geology Bulletin 202. Scale 1:48,000.

Jennings, C. W. 1977. Geologic map of California. California Geologic Data Map Series. California Division of Mines and Geology. Sacramento, California.

Kennedy, E. J. 1983. Computation of continuous records of streamflow. Chapter A13 *in* Techniques of water-resources investigations of the United States Geological Survey. Book 3. U.S. Geological Survey, Washington. D.C. Online. (http://www.ecy.wa.gov/programs/eap/models/usgs_twri.html). Accessed 30 March 2010.

Ketcham, B. 1998. Hydrologic Monitoring Station Information Summary. National Park Service, Point Reyes National Seashore, Point Reyes Station, California.

Laudon, J. 1988. Redwood Creek underflow, Marin County. [Memorandum]. California State Water Resources Control Board, Division of Water Rights.

Lehre, A. K. 1974. The climate and hydrology of the Golden Gate National Recreation Area. *In* The terrestrial environment of the Golden Gate National Recreation Area with proposals for resource management and research. National Park Service, Golden Gate National Recreation Area, San Francisco, California.

Martin, L. 2000. Hydrogeology of the Muir Beach Community Services District Well Site Frank Valley, Redwood Creek, California, Golden Gate National Recreation Area. National Park Service Water Resources Division Technical Report NPS/NRWRD/NRTR-2000/265. National Park Service, Fort Collins, Colorado.

Meyer, R. W. 1996. Surface-water quality-assurance plan for the California district of the U.S. Geological Survey. Open-File Report 96-618. U.S. Geological Survey, Sacramento, California.

Owenby, J. R. and D. S. Ezell, editors. 1992. Monthly station normal of temperature, precipitation, and heating and cooling degree days 1961–1990. National Oceanic and Atmospheric Administration. Richmond/Sunset Climatic Station.

[PWA]Philip Williams and Associates, Ltd., Wetlands Research Associates, Strong Associates [Butler, L. J.]. 1993. An evaluation of the feasibility of wetland restoration on the Giacomini Ranch, Marin County. Prepared for the National Park Service.

[PWA]Philip Williams and Associates, Ltd. 1995. Analysis of Land Use Impacts on Water Quality and Quantity in Redwood Creek. Prepared for The National Park Service, Golden Gate National Recreation Area. 1995 January. National Park Service, Golden Gate National Recreation Area, San Francisco, California.

Rantz, S. E. 1969. Mean annual precipitation in the California region: U.S. Geological Survey Open-File Map (Reprinted 1972, 1975). [Digital isohyetal precipitation data covering the period 1900–1960 from California Department of Forestry and Fire Protection.]

Rantz, S. E. 1974. Mean annual runoff in the San Francisco Bay Region, California, 1931–1970. U.S. Geological Survey miscellaneous field studies map. U.S. Geological Survey, Menlo Park, California.

Ries, K. G., and M. Y. Crouse. 2002. The national flood frequency program: A computer program for estimating magnitude and frequency of floods for ungaged sites. Version 3. U.S. Geological Survey Water-Resources Investigations Report 02-4168. U.S. Geological Survey, Washington, D.C.

Schanz, R.W., K. Julin, S. Bull, and G. Odaffer. December 1995. Restoration plan for Lobos Creek. Golden Gate National Recreation Area Unpublished Report. San Francisco, California.

Shuford, D. W., and I. C. Timossi. 1989. Plant Communities of Marin County. Sacramento, California: California Native Plant Society.

Snider, W. M. 1984. An Assessment of Coho and Steelhead Resource Requirements in Redwood Creek, Marin County. Environmental Services Branch Stream Evaluation Program Administrative Report 84-1.

Stetson Engineers, Inc. 2003. Urban water management plan: Stinson Beach County Water District. Stinson Beach County Water District Unpublished Report.

Stillwater Sciences. 2004. Sediment Budget for Redwood Creek Watershed, Marin County, California. Golden Gate National Recreation Area, San Francisco, California.

Urban Watershed Project. 2001. Lobos Creek water quality investigation and management plan. Presidio of San Francisco Gate National Recreation Area Unpublished Report, San Francisco, California.

[USDA]United States Department of Agriculture, Natural Resources Conservation Service, and U.S. Forest Service. 1997. Alhambra Creek Watershed Resources Inventory. Contra Costa Resource Conservation District.

Warhaftig, C. 1984. Structure of the Marin Headlands Block, California: A progress report. *In* M. C. Blake, Jr., editor. Franciscan Geology of Northern California. Society of Economic Pelontologists and Mineralogists, Pacific Coast Section, Bakersfield, California.

Wright, T. 2000. Overview of Point Reyes geology. Sonoma State University. Sonoma, California.

Appendix SOP 3A. Definition of Station Description Fields (from Kennedy 1983)

Location.--Lat-long.; land-line location (public-land surveyed states); county; distance from bridges, dams, falls, highways, tributaries, towns, etc.; and river mile or distance from mouth. How reached. Give highway routes and road logs for normal and high water access. Same information for slope station auxiliary gage.

Establishment.--Date of first record published by U.S.G.S. that is equivalent to present record, and the name of the organization that installed the gage.

Drainage area.--Size of total area, size and type of noncontributing area, source of figures, method of computation, coordination information, and name of coordinating agency.

Gage.--Decription, manufacturer and type of recorder, gage heights of components (intakes, doorsills, maximum recordable stage, shelter roof, etc.), principal gage, reference gage, description and location of outside gage and other supplementary gages, unusual features of equipment, elevation (or altitude) of gage datum above N.G.V. Datum. Same information for a slope-station auxiliary gage.

History.--Brief descriptions, in chronological order by date of start of record collection, of all gages with equivalent records operated at or near the site. Include major additions or changes to the equipment.

Reference and benchmarks.--Include at least three and no more than five RM's for a base gage, no more than three for a slope-station auxiliary gage, and one for a supplementary site. Describe RM and its location fully. Show latest elevation above gage datum at the time the description is prepared and note the most permanent mark. Name and number of NGS or U.S.G.S. benchmark used for N.G.V.D. tie, its latest published or listed elevation above N.G.V.D., the adjustment or datum date, and its elevation above gage datum.

Channel and control.--Character (rock, sand, gravel, clean, vegetation prone, permanent, shifting, etc.) and alignment of channel in the gage vicinity, character of banks and stage when overflow starts on each bank, extent of overflow at a specific high stage for each bank, the character of the flood plain, and number of channels at high and low stage.

Character, type, and location of low-water and high-water controls, sensitivity to ice effect, permanency, and any special conditions.

Discharge measurements.--Location, maximum depth (gage height + ___ ft), and velocities at the best wading sections and the high-water measuring sections. Measuring conditions, anticipated accuracy, and special hazards. Location of culverts or bypass sections not evident during floods. Stage of the start of road overflow in the measuring section. Alternate high-water measuring sites, stored boats or equipment, special measuring problems or methods. For cableways; safety precautions, location, type and height of A-frames or towers, size of anchorages, length, diameter and type of cable, type of connectors (sockets, clips, etc.), unloaded sag, sag marks on A-frames, stationing, and initial point. For bridges; safety precautions, bridge occupancy limitations by police or highway officials, location, stationing details, horizontal angle coefficients. For boat ranges; safety precautions, width, permanent alignment or triangulation targets, availability of boats, etc.

Give the locations of any sites that have been used for slope-area, contracted-opening, or other indirect measurements or of sites that appear promising for the purpose.

Floods.--Narration of historic data search, (date, name of investigator, names of sources of information, nature of information, authority of informant, etc.). Interpretation of information. Include all historic floods, but only the notable ones within the period of station operation.

Point of zero flow.--Location, gage height, probable accuracy, permanency. Recommend frequency of observations.

Winter flow.--Ice effect likely to be more severe or less than at other stations in the area. Why?

Regulation and diversion.--Location, description, and probable effect of dams, lakes, power plants, reservoirs, swamps, unusual land use, above or just below the station. If the station is one of several on a regulated stream, refer to the next gage upstream and describe in detail only those regulations and diversions between the gages.

Accuracy.--Anticipated accuracy, with all equipment working, for the different seasons and ranges of flow.

Cooperation.--Each agency involved, the proportion of its support (financial and technical), and the dates.

Sketch.--Page size sheet with enough detail to enable one unfamiliar with the locality to reach the station, park a vehicle, and locate principal features with minimum effort. Include gage, measuring sections, and any paths or trails used to reach them. An additional large scale sketch may be needed to illustrate an obscure site.

Photographs.--File with photographs of principal features (close view of gage and shelter, general view showing control, measuring equipment, etc., and stereo slides of the channel).

Observer.--Name, address, phone number, occupation, place where usually contacted during the day, gage duties, and rate of pay.

FIGURE 1.—Outline of a field-station description.

Standard Operating Procedure (SOP) 4. Field Equipment for Flow Measurements and Station Maintenance

Version 1.05

Revision History Log

Prev. Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.0	4/3/06	Travis Smith			1.00
1.0	6/5/06	Travis Smith			1.01
1.01	2/6/07	Darren Fong			1.02
1.02	5/7/07	Paul Johnson	proofreading		1.03
1.03	8/6/08	Paul Johnson	proofreading		1.04
1.04	06/03/10	Darren Fong, Kris Freeman, Marcus Koenen	add/remove equipment, formatting		1.05

Tables

Page

Table SOP 4.1. Safety equipment. ..... SOP 4.4

Table SOP 4.2. Basic equipment. ..... SOP 4.5

Table SOP 4.3. Equipment needed for maintenance and downloading of recording streamgages[1] ..... SOP 4.6

Table SOP 4.4. Streamflow equipment. ..... SOP 4.7

Table SOP 4.5. Maintenance of tipping rain buckets. ..... SOP 4.7

Table SOP 4.6. Topographic survey equipment. ..... SOP 4.8

Appendixes

Page

Appendix SOP 4A. Equipment Maintenance Procedures ..... SOP 4.9

Purpose

This Standard Operation Procedure gives a detailed list of field equipment that will be used by the field personnel for obtaining streamflow measurements as well as maintaining streamgages. Each task that the field personnel perform requires a list of job-specific equipment. Each streamgage is mildly different from the others; a list below shows what equipment is necessary when visiting specific stations.

Scope and Applicability

This SOP applies to basic and task-specific field equipment using for the SFAN streamflow monitoring program. The storage locations apply for field work conducted for PRES, GOGA, and PORE. Because of the long distance to PINN from the other SFAN parks, duplicate equipment and separate equipment storage locations will need to be secured.

Reference Materials

Copies of various equipment manuals should be reviewed and made available so that field personnel are familiar with specific equipment. Field laptops should also include electronic copies of equipment manuals. All electronic copies of manuals have been placed on the network drive (X:\Individual Vital Signs\Streamflow\documents) in the Equipment Operator's Manual folder. They include the following manufacturers: Campbell Scientific, Druck, Gurley, Global Water, In-Situ Inc., Instrumentation Northwest, Marsh-McBirney, Onset Computer, and Swoffer.

Basic Field Equipment

There is a basic set of items that should be carried by the technician at all times. These items are to help with troubleshooting, basic maintenance, and safety protection. Because of the time required to gather these items for each field visit, it is recommended that the equipment be segregated by type and placed in large plastic tubs for easy access and transport. The basic equipment will be stored in the vehicle and backpack of the field technician, except for items that are seasonal in nature (e.g., high flow discharge equipment, traffic safety equipment for inclement weather). When not in use, the basic field equipment is housed at the Golden Gate National Recreation Area, Building 1063, Fort Cronkhite (1st Floor Aquatic Ecologist Storage Room); see Tables SOP 4.1–2.

Table SOP 4.1. Safety equipment.

Equipment	Purpose
Sun screen	UV protection
Mosquito repellent	Mosquito protection
Cell Phone and phone list	Keep a cell phone with emergency numbers (including all Park dispatch numbers) with you at all times in the field. See SFAN SOP Field Safety (X:\Shared\Standard Operating Procedures\SFAN Field SOPs\Standard Operating Procedures)
Life Vest	Life vest should be worn when wading in water over knee height.
Wading belt	Wading belt should be worn over waders to prevent water from filling waders should the wearer fall in the creek
Orange Traffic Vest	Should be worn when taking bridge measurements in bad weather and limited visibility.
Traffic Cones and Safety Signs	Should be placed in road when making bridge measurements. Cones will be placed on the road far enough away from the vehicle so that oncoming traffic from both ends can see the cones and signs and slow down to avoid personnel working from bridges. Weather conditions and average traffic speeds should be considered when setting up cones.

Table SOP 4.2. Basic equipment.

Equipment	Purpose
Digital Camera	Streamgage photos (normal and flood conditions).
Flashlight (water-resistant)	You never know when it might come in handy!
Charged, extra batteries (9 Volt, 3 Volt lithium, 1.5 Volt "D", 12 Volt lead-acid)	For CR10X, WL14-16, Marsh McBirney, Swoffer 2100, and tipping buckets
Small water bottle	Cleaning rain gage
Funnel	Cleaning out crest-gage
Granulated cork	Refilling crest-gage
Capped PVC-pipe (>4 ft)	Calibration of transducers
Rain pants and coats	Bad weather gear
Brush clippers	Clearing area around and to field equipment
Work gloves	Removing brush
Extra pencils	Writing equipment (pens don't work on write-in -the - rain paper)
Bright color waterproof markers	Marking cables, etc.
Desiccant (blue indictor type)	For loggers
Plastic bags/containers	Transfer spent desiccant to lab
Utility knife (e.g., Leatherman style)	Miscellaneous purposes
Allen wrench set	
Pocket measuring tape (engineer scale)	Read gage height for flume and when staff plate is hard to read at some locations
Duct tape	Miscellaneous purposes
Cable ties (various lengths)	Secure wires/crest gages
Wire	Secure wires/crest gages
Hose clamps (various lengths)	Secure materials
Binoculars	Reading staff plate at high flow
Equipment manuals/monitoring protocol/SOPs	Keep in vehicle for trouble shooting
Shovel	
Abrasive sponge	Cleaning off staff plate

Task-Specific Equipment

Specialized equipment is needed for a series of tasks including downloading and maintenance of recording streamgages, direct measurements of streamflow, maintenance and calibration of tipping rain buckets, and collection of topographic survey data (see Tables SOP 4.3–6; Appendix SOP 4A). As with the basic equipment described above, these items should be segregated by task and readily accessible. Much of the task-specific equipment has been purchased by individual parks (GOGA and PORE), and is available for use by the SFAN monitoring program. As with the basic equipment, most of this equipment is housed at the Golden Gate National Recreation Area, Building 1063, Fort Cronkhite (1st Floor Aquatic Ecologist Storage Room).

Table SOP 4.3. Equipment needed for maintenance and downloading of recording streamgages[1]

Equipment	Olema Creek	Pine Gulch Creek	Easkoot Creek	Redwood Creek	Lobos Creek	Sandy Creek	Bear
Datalogger program	PC208W program	PC208W program	PC208W program	Win-Situ5		Global Logger	Global Logger
Data Cables	Campbell Scientific SC929	Campbell Scientific SC929	Campbell Scientific SC929	In-Situ USB Twist-Lock connector cable	N.A.	RS232C	RS232C
Batteries	12 Volt Lead-acid	12 Volt Lead-acid	12 Volt Lead-acid	N.A.	N.A.	9 Volt	9 Volt
Desiccant	loose	loose	loose	loose	N.A.	Silica Mini-pack	Silica Mini-pack

[1]Common equipment for all datalogger loggers: fully charged laptop, individual streamgage logbooks, putty (seal holes), and volt meter (check battery).

Each station, because of differences in datalogger brands, requires a specific cable and computer program to communicate between the laptop and datalogger. Campbell Scientific, In-Situ and Global Water each have their own connection cable for communication between the laptop and the datalogger. Each station is powered by different battery sources and requires different packaging of desiccant. Global Water dataloggers require small desiccant packs due to their small size. Small cups or bags (made from panty hose) can be used to hold loose desiccant in the Campbell datalogger enclosures. The In-Situ Level Troll 500 has an attached desiccant tube on the end of the logger's data cable that can be replenished with loose desiccant. A fully charged laptop with all the required cables, logbooks, and programs should be brought to each station.

Table SOP 4.4. Streamflow equipment.

Equipment	Occasion	Purpose
Hip-boots/waders	All	For wading flow measurements
Discharge datasheets (NPS WRD Vers. 1999 or latest vers.)	All	Keep in truck or clipboard
Field clipboard	All	Store flow sheets and writing surface
Calculator (plastic bag)	All	Calculating discharge
Past streamgage rating curves (laminated)	All	Check accuracy of field discharge measurement or rating shift
Synchronized wrist watch	All	Keep track of time and verify time on dataloggers. Needs to be synchronized regularly with National Institute of Standards and Technology (see webpage)
Measuring tape (engineering scale)	All	Measures cross-section
Stakes	All	Holds down measuring tape
Top-setting wading rod	Wading	
Swoffer 2100 (meter and rod)	Wading	
Pygmy meter (rod, headset, hanger, oil, meter)	Wading	
Marsh McBirney Flo-mate 2000	High flow	
Screwdriver/utility knife	High flow	
Price AA (meter, vane)	High flow	
Bridge Board	High flow	
Weights (various)	High flow	
Bridge board reel with extra butterfly nuts	High flow	
Safety equipment	High flow	See Table SOP 4.1.

Table SOP 4.5. Maintenance of tipping rain buckets.

Equipment	Purpose
Cotton swabs	Clean tipping bucket mechanism
Carpenter's level (>6-inch)	Check level of tipping bucket
Old rags	Clean bird poop from tipping bucket
500 ml Nalgene bottle with pin hole in bottom	Calibrates rain gage if needed
250 or 500 ml volumetric flask	Calibrates rain gage if needed
Allen wrench set	Adjusts rain gage calibration

Table SOP 4.6. Topographic survey equipment.

Equipment	Purpose
Map and elevation of existing benchmarks	Assist in finding existing benchmarks
Properly functioning level (laser[1] or optical autolevel[2])	Obtain elevation
Peg test datasheets	Level QA/QC datasheets
Tripod	Holds levels
Stadia rod	Records elevation
Measuring tape (engineering scale)	Measure cross-section and thalwag
Tape stakes	Anchor tape
Wood stakes and mallet/hammer	For turning points
Single topographic field book	Record topographic survey data

[1]GOGA's Laser Beacon Model 3900 (S/N 3920-28794). Internal rechargeable battery good for 8-hr survey fully charged. Receiver needs 9-volt battery.
[2]GOGA's Topcon AT-G2 (S/N TG2689). Do not use GOGA's David White transit level- does not level properly.

Appendix SOP 4A. Equipment Maintenance Procedures

Proper maintenance not only lengthens the life of monitoring equipment, it also helps in limiting error in collected data and streamflow models. Furthermore, care should be taken in the transport of the equipment to prevent damage.

Swoffer Instruments Model 2100 (from Swoffer Instruments N.D.)

A 9-volt battery powers the Swoffer Instruments Model 2100 Indicator as well as the photo-diode and the phototransistor in the sensor. The battery compartment at the back of the indicator can be opened by use of the four thumbscrews at the corners of the case back. Inside there is room for both the operating battery and a spare. Depending on the level of use, a fresh battery can last as long as several months. Be sure to return the selector switch to one of the **OFF** positions after completing a velocity transect and always have a fresh spare battery. One way to determine battery strength is to check the calibration number held by the indicator. Rotate the selector switch to the **CALIBRATE** position. Replace the battery if the displayed calibration number is much lower than it should be. (The sensor must be connected to the indicator and the rotor positioned so that the optics trigger an "on" condition. Only then will maximum battery drawdown achieved.) Do not use a battery with less than 5 volts remaining because below this the battery will power the indicator electronics but not the sensor circuit. The sensor will not be able to transmit a signal to the indicator or will transmit only an occasional signal, which will give erroneous readings.

Swoffer Instruments provides procedures for self-calibration of its meters. However, laboratory tests by USGS-HIF have found that its calibration procedures still resulted in measurement values outside of limits established for standard Price mechanical meters (Fulford 2001). The following calibration procedures should only be done as a check to determine if the meter has been damaged or requires a new calibration by a certified laboratory facility.

The Swoffer test is performed by turning the dial on the unit to the **CALIBRATE** position. Calibration numbers correctly matching a rotor assembly to a 2100 Indicator can vary greatly depending on many factors; bearing surface condition in the rotor, make-up of the water being measured (amount of suspended particulates), any damage to the propeller, rotor, shaft, thrust-bearing nut, etc. The value should be about 186 when measuring velocity in feet (610 when measuring in meters). If the displayed figures are much lower than these figures, check the battery. A weak battery can allow the calibration numbers to "drift" downward slightly and will cause errors in measurements.

To determine a reliable calibration number for the Swoffer, perform the following test (This is something you must do if you are working with slow flows [> 1.5 FPS] and for measurements taken in very shallow streams): 1. Mark a straight course of 10 to 20 feet in length in a body of calm, current-free water (a swimming pool or lake work best) along which the sensor can be towed by walking the course. 2. Rotate the selector switch to the **COUNT** position. If the display does not display all zeros, press and release **RESET**. (The decimal point does not show in the count mode.) 3. Place the sensor in the water a few feet before the beginning of the course, 0.5-1.0 feet below the surface. 4. Begin walking the sensor through the course at a rate close to that

which you will be measuring. (If shallow flows are to be encountered, try to duplicate those conditions when making calibration checks.) 5. Using the wand rather than the sensor as a guide, press and release the **RESET** button at the moment the wand enters the course. The indicator will begin counting the number of sensor pulses generated as you walk. 6. At the end of the course, press and release the **START/STOP** button. The display now shows (and will hold) the number of pulses generated through the course length. Several passes through the course in both directions are recommended to develop a reliable average figure. Press and release **RESET** each time a run is completed to zero the display.

Determine the average number of pulses generated through the course. If your course length is not 10 feet, compute the number of pulses that the sensor would generate if the course were exactly 10 feet. This will be the Calibration Number that the Swoffer Indicator should hold for accurate measurements with that rotor assembly (in feet per second):
FEET CAL. #. = (10 x AVERAGE #. OF PULSES) / (COURSE LENGTH (ft))
(This number can then be multiplied by 3.281 (the number of feet in one meter) to determine the calibration number for meters.)

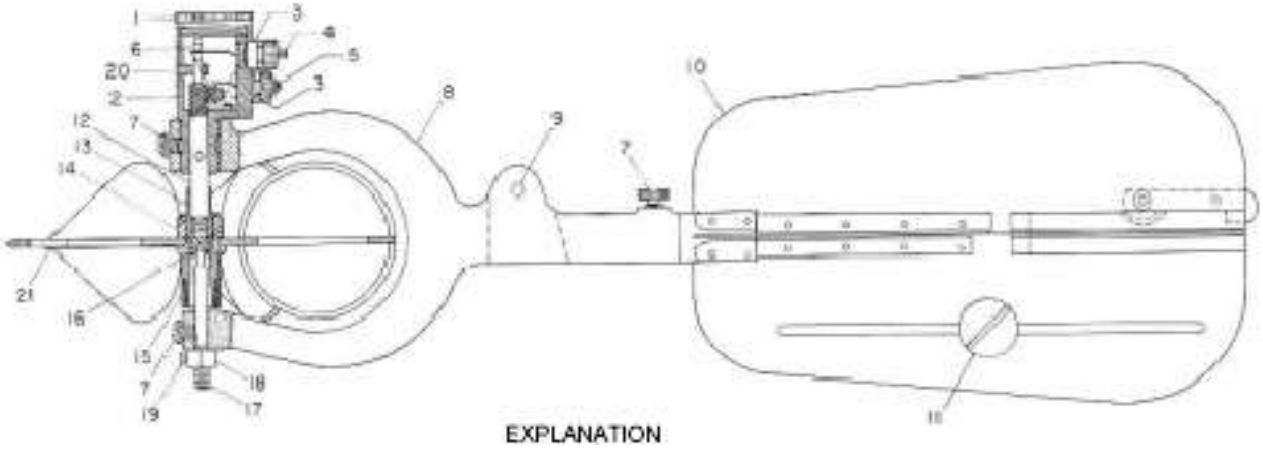
Next, rotate the selector switch to the **CALIBRATE** position. Put the **FEET/METERS** switch (in battery compartment) in the **FEET** position and the indicator will display the Calibration Number it presently holds for measuring in fps. With a good battery, it should be 180-186 (2”props only).

If the 2100 indicator falls into the stream, open the battery compartment as soon as possible and dry the battery terminals and the cable connections. The foam lining is closed-cell so water will not absorb into more than just its surface. Allow the compartment to air dry or use a hair dryer if available before replacing cover. Always make sure that the calibration adjustment cover screws located at the bottom end of the indicator are fitted tightly. These provide direct access to the circuit board, and if loose, will allow water to enter the indicator.

Clean the indicator only with a solution designed for plastics. The indicator lens is made of acrylic and can be easily scratched if an abrasive cloth is used. The indicator case is ABS and there are many chemicals, which act as solvents for ABS, severely affecting its appearance if they make contact. Periodically check the condition of the pins and sockets in the connector. Keep the contacting surfaces clean and bright and make sure the pins are not bent and that the sockets still fit the pins snugly. Avoid sharp bending and re-bending of the connection cable and do not suspend the wand or indicator by it.



Swoffer Model 2100 Current Meter Indicator



Price AA Current Meter

1. Cap for contact chamber
2. Contact Chamber
3. Insulating bushing for binding post
4. Single-contact binding post
5. Penta-contact binding post
6. Penta gear
7. Set Screws
8. Yoke
9. Hole for hanger screw
10. Tail piece
11. Balance weight
12. Shaft
13. Bucket-wheel hub

14. Bucket-wheel hub nut
15. Raising nut
16. Pivot bearing
17. Pivot
18. Pivot adjusting nut
19. Keeper screw for pivot adjusting nut
20. Bearing lug
21. Bucket wheel

Release raising nut (15) by unscrewing nut. Holding the nut and spinning bucket wheel (21) to unscrew lifting nut by will bend the meter's shaft (12). Spin the bucket wheel (21) to determine if the bucket-wheel frame is bent. If the bucket-wheel frame wobbles, determine if the bucket-wheel hub (13) is also wobbling. If the upper portion of the bucket-wheel hub wobbles more than the lower portion, the shaft is bent and must be replaced. If the lower section of the bucket-wheel hub wobbles, the pivot bearing (16) is worn and the bucket-wheel hub should be replaced. If the bucket-wheel hub is not wobbling and the bucket wheel is, the frame is bent. If the frame is bent, replace the bucket wheel before putting back into service.

Remove contact-chamber cap (1) but not with the raising nut engaged because that will bend the shaft (12). Looking down into the contact chamber, spin the meter to ensure there is not a wobble in the upper shaft. A wobble of the upper shaft is an indication of a bent shaft that should be replaced. While removing the contact chamber (2) make sure that the penta-gear assembly (6) does not bind when lifting the chamber off the yoke (8) and shaft.

Remove pivot (17) and the shaft by inserting a small Allen wrench into the hole in the shaft and unscrewing. Clean the shaft and acme threads (threads that penta-gear engage into). If the contact edge shows signs of nicking, if any portion is bent, or if there are burrs in the acme threads, replace shaft. Rolling the shaft on a flat surface will reveal if the shaft is bent. (The vast majority of bends have been found in the reduced diameter section, bearing and contact area.)

Clean pivot and check for deformations on the point of the pivot. The majority of AA meters found with burrs on the pivot will not fit within the allowable limits of the standard rating equation. . Also, check to see if the pivot is magnetized. To do this, touch the pivot on a paper clip. If the pivot lifts the paperclip, demagnetize using a bulk magnetic tape eraser or a tape player head demagnetizer. Pivots with rounded points or that are magnetized should be replaced.

To clean pivot bearing (16) remove some of the cotton on the sides of the swab and make a point of the cotton on the end to reach into the bottom of the pivot bearing. A clean pivot bearing will usually shine when clean. If there is hardened material in the pivot bearing, a drop or two of meter oil left sitting for a couple minutes will help in the cleaning.

Clean contact chamber. If the contact chamber does not have sediment in it and there is not a great deal of old oil in the chamber, the chamber can be cleaned by using a lint free swab or paper-towel covered rod. Pay particular attention to cleaning the bearing surface of the bearing lug (20) and the edges of the penta gear. If there is sediment or excessive oil in the contact chamber, the penta gear may have to be removed and the chamber and penta gear cleaned with a

cleaning fluid. (Removal of the penta gear should be avoided if at all possible. If the penta gear is removed, the cat whiskers (4 and 5) should be removed and the position of the penta gear noted. The reinstallation of the penta gear will require some trial and error adjustment to insure that the penta gear and the shaft do not bind.) A spray cleaning fluid like WD40 can be used with moderate success. All parts should be allowed to fully dry before reassembly.

Check yoke with yoke-alignment tool (HIF stock number 1101058). Do not force the alignment tool into the yoke, as it should slide easily in, all the way down. Do not use the alignment tool to straighten the yoke. To straighten the yoke, use a rubber hammer to move the yoke arms gently back into alignment. Forcing the yoke to move too far will weaken the yoke and may crack it.

If the pivot bearing should be replaced, replace bucket-wheel hub, which contains the bearing. Unscrew the bucket-wheel hub nut (14) to remove the bucket wheel. To replace bucket wheel, remove the hub nut (14) and change the bucket wheel. The letter and number on the bucket-wheel frame (such as S90) should face up. The alignment pin on the hub should be inserted into the key slot of the bucket wheel frame. This will ensure that the bucket wheel will not slip on the hub during use. If the alignment pin is missing or damaged, replace the bucket wheel hub.

Individual cups of the bucket wheel can be repaired if they are not too badly bent. A device with a hard curved edge will work okay for this procedure. (A handle of a pair of pliers wrapped in a soft rag can be used if proper tools are not available.) Replace the bucket wheel if the cup cannot be brought back to its original shape, if the plating is popped off of the base metal, or if the bucket-wheel frame is bent.

Oil pivot bearing with one drop of meter oil. Too much oil will attract sediment. (One can dip the end of a straightened paper clip into the meter oil and transfer the drop that accumulates to the pivot bearing.) Vegetable-based oils, like 3-in-1 oil, and silicon based oils should not be used. Vegetable-based oils emulsify too easily, and silicon-based oils hold sediment and are difficult to clean.

Align bucket-wheel assembly in the yoke and install shaft by screwing the shaft back into the top of the bucket wheel hub using a small Allen wrench or rod. The shaft should be snug but not so tight that to remove it will bend the wrench or rod being used.

Insert pivot through the bottom hole in the yoke. Using the pivot set screw (7), not adjusting nut (18), set the pivot so that the bucket-wheel hub is just touching the lower yoke arm (this is to ensure that when installing the contact chamber cap that the shaft is not too high). The pivot will be adjusted as needed later.

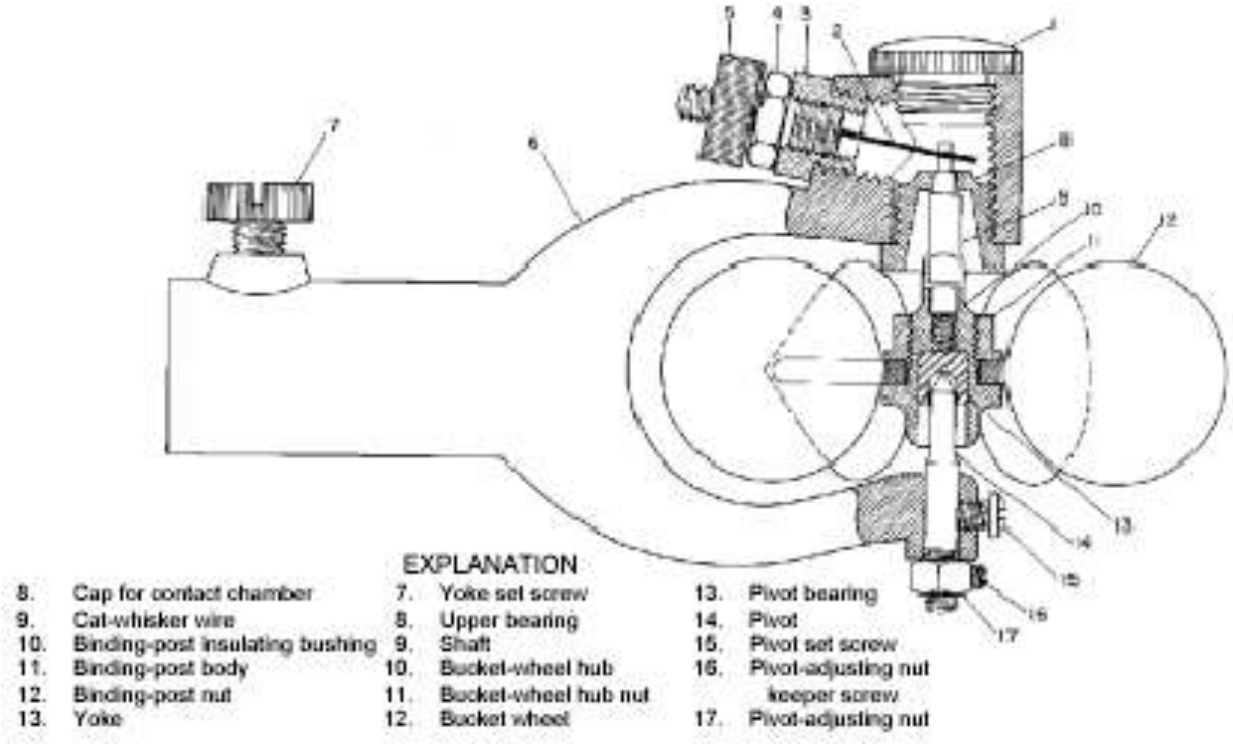
Install contact chamber. Insert contact chamber over shaft without force the chamber onto the shaft and yoke. Twisting back and forth is sometimes needed to get the chamber to fit into place. Align marks on the front of the contact chamber and yoke or binding posts with the back of the yoke and tighten set screw. While slowly spinning the bucket wheel, screw on the contact chamber cap slowly making sure that the shaft does not bind on the cap. The bucket wheel will stop spinning abruptly if the shaft hits the cap. Set the pivot, if needed. Follow the directions in table 1 (below) for setting the pivot.

After the pivot has been set, remove the contact-chamber cap and set the cat whiskers; both penta and single count. Set both to get a strong, even click (scratch). Oil on a cat whisker wire or an old worn wire will not give a clean enough contact for electronic counters. For electronic counters, setting the single count cat whisker to make contact for about the rotational distance of 1/2 of one bucket (approximate dwell angle of 30 degrees) and the penta-count cat whisker to make contact for approximately 1/2 to 3/4 wheel revolutions (180- to 270-degree dwell angle) results in good, clean signals.

Oil shaft and penta gears. Oil lug bearing with one drop of oil. Place one drop of oil on the top of the shaft. Place one drop of oil on each side of the penta gear. Place one to two drops of oil on the acme threads on the shaft. Be warned that applying too much oil in the contact chamber could possibly contaminate the cat-whisker contact wires making the meter unusable with electronic counters. Replace contact-chamber cap.

Spin test the meter. Spin limits are given in OSW Technical Memorandum No.89.07. All timed spin tests should be conducted with the meter level and the shaft vertical and in a location with NO air currents. Minimum spin time is 2:00 minutes; optimum spin time is more than 4:00 minutes. Lift the bucket-wheel assembly off the pivot using the raising nut to complete the task. DO NOT spin the bucket wheel to engage the raising nut.

Gurley Pygmy Meter



Remove the shipping plug and insert the pivot (14). (If the working pivot has a burr, use a new pivot in its place for the meter checkup.) Visually inspect the meter for pivot alignment problems. If the pivot does not line up with the shaft (9) of the meter, this is an indication of the yoke (6) being out of alignment.

Rotate the bucket wheel (12) and check for wobble. If wobbling occurs, the bucket-wheel frame is bent, one of the buckets is bent, or the pivot bearing (13) is worn. Replace the bucket wheel if the frame or one of the buckets is bent. To determine if the pivot bearing is worn, look to see if the lower section of the bucket-wheel hub (10) wobbles when the bucket wheel is slowly rotated. If the hub wobbles, replace the hub.

Check the upper bearing (8) and shaft (9) for excessive wear by taking the contact-chamber cap (1) off and observing the shaft as the bucket wheel is rotated slowly. As the cat-whisker wire (2) slides over the contact lobe of the shaft, there should be no discernible movement of the shaft away from the cat whisker. If movement is observed, replace the upper bearing.

Visually check the shaft (9) to see if it is bent. Rotate the bucket wheel slowly to see if the upper section of the shaft in the contact chamber wobbles (not associated with a worn upper bearing). If the upper section of the shaft wobbles, replace it.

Visually inspect the cat-whisker wire and replace if it is kinked, twisted, or coated with an oil film. To remove/replace the cat whisker, use a thin wrench to unscrew the cat-whisker wire and

binding post (4). Use a pair of pliers to remove the binding-post insulator (3) if it does not come off with the binding post by hand. Install the new cat whisker, binding post and insulator by tightening until snug.

Remove the bucket-wheel assembly (bucket wheel (12), hub (10), and shaft (9)) by loosening the pivot set screw (15) and removing the pivot and then bucket-wheel assembly. Do not force the assembly. Some of the older pygmy meter yokes have limited clearance between the yoke arms. Subsequently, the bucket-wheel assembly will come out in only one position. Rotate the assembly until finding the one position that will allow its removal.

To remove the bucket wheel from the hub, either use a deep 5/16" socket to slip over the shaft and loosen the bucket-wheel hub nut (11), or remove the shaft by unscrewing with a pair of pliers or a small adjustable wrench (preferred method) and using a standard 5/16" socket to loosen the bucket-wheel hub nut. The bucket wheel should slide off the hub. (If the bucket wheel will not easily slide off the hub, replace the hub nut a couple threads place the socket on the nut, flip upside down and gently hit the back of the socket on a hard surface while cradling the bucket wheel in your hand. Make sure there is a gap between the bottom of the nut and the top of the bucket wheel.) Install a new bucket wheel by inserting the hub assembly into the bottom of the center hole of the bucket wheel. (The top of the bucket wheel frame is marked with an "Sxx", where the “xx” is the year it was manufactured. If there are no markings, the bucket wheel must be installed such that the bucket wheel will rotate in the counterclockwise direction when looking down on it. The standard rating does not apply for a bucket wheel without an "Sxx". It must have an individual rating.) Tighten the bucket-wheel retaining nut snugly.

To clean the pivot bearing (13) remove some of the cotton of a swab making a point of the cotton on the end will usually get into the bottom of the pivot bearing. A clean pivot bearing will usually shine when clean. If there is hardened material in the pivot bearing, a drop or two of meter oil left sitting for a couple minutes will help in the cleaning.

Oil the pivot bearing with one drop of meter oil. Too much oil will attract sediment. (Hint: Dip the end of a straightened paper clip into the meter oil and transfer the drop that accumulates to the pivot bearing.) Vegetable-based oils, like 3-in-1 oil, and silicon based oils should not be used. Vegetable-based oils emulsify too easily, and silicon based oils hold sediment and is difficult to clean off. Clean the shaft and upper bearing.

Clean the pivot (14) and replace it if a burr is found or if the pivot point is rounded. Touch the pivot with a paper clip to check if it is magnetized. If the pivot lifts the paper clip, the pivot is magnetized; demagnetize using a bulk magnetic tape eraser or a tape player head demagnetizer, or replace the pivot.

Screw the shaft into the top of the hub assembly using a pair of pliers or a small adjustable wrench (preferred method). Use the pliers to remove the upper bearing, but be careful not to crush the upper bearing when attempting to remove. Gently screw a new bearing into the underside of the upper yoke arm using a small pair of pliers to install an upper bearing. It is better to have the pliers slip than to crush or deform the upper bearing. The bearing is fully

inserted when the lower lip of the bearing makes contact with the lower surface of the upper yoke arm.

Yoke alignment check. Screw the alignment tool into the top of the yoke until the lower pin is about to enter the pivot hole in the lower yoke arm. Visually check to see if the lower pin will slide into the pivot hole. (Do not force the lower pin into the pivot hole by screwing the alignment tool all the way down without visually checking the alignment first. If the lower arm of the yoke is moderately to severely out of alignment, forcing the alignment tool into the pivot hole will either bent the alignment tool or deform the pivot hole, making the yoke unusable.) NOTE: To insert the pygmy yoke alignment tool (HIF stock number 1103028) the upper bearing (8) and the cat-whisker wire (2) must be removed. Align the yoke as needed using a rubber hammer. Once you are satisfied that the alignment is okay, or only slightly out of alignment, then gently screw the alignment tool down until the lower pin completely inserted into the pivot hole. WARNING: There is no machined stop on the pygmy alignment tool similar to the AA alignment tool. You must stop screwing the alignment tool whenever the lower pin is fully inserted into the pivot hole. Forcing the alignment tool beyond this point or forcibly screwing the alignment tool into the lower yoke arm will damage the yoke beyond repair.

Insert the bucket-wheel assembly into the yoke by inserting the shaft into the upper bearing hole and wiggling until the assembly slides into place. Do not force the assembly. Some of the older pygmy meter yokes have limited clearance between the yoke arms. Subsequently, the bucket-wheel assembly will insert in only one position. Rotate the assembly until finding the one position that will allow its insertion.

Insert the pivot and adjust as needed. To adjust the pivot correctly, perform the following steps.

1. Make sure the meter has been oiled properly; then, hold meter in inverted position with pivot up.
2. Release the keeper screw (16) for pivot-adjusting nut (17) and unscrew the nut a few turns.
3. Release set screw (15) and advance pivot until all vertical play of the hub assembly is eliminated.
4. Tighten set screw (15) temporarily and advance pivot-adjusting nut (17) until it touches the yoke.
5. Release set screw (15) (not too far because the pivot should not revolve) and advance the pivot adjusting nut one-fourth turn. Then, tighten the keeper screw (16).
6. Push the pivot inward as far as it will go and tighten set screw (15).
7. Adjust the cat whisker as needed to obtain a strong click (scratch). For electronic counters, the OSW Hydraulics Laboratory personnel have found that setting the contact wire to make contact for about the rotational distance of one bucket (approximate dwell angle of 60 degrees) results in a good clean signal.
8. Oil the upper bearing and shaft contact point with one drop of oil only.
9. Replace the contact-chamber cap.

10. Spin test the meter. Spin limits are given in OSW Technical Memorandum No. 89.07. All timed spin tests should be conducted with the meter level and the shaft vertical and in a location with NO air currents. Minimum spin time is 45 seconds; optimum spin time is more than 1:30 minutes. NOTE: If the bucket wheel "chatters" when spun hard, this is a sign that the pivot bearing is worn. Replace the hub (10) if chattering occurs during spin testing.
11. Replace the pivot with the shipping plug to make the meter ready for storage or transport.

Standard Operating Procedure (SOP) 5. Training and Resources

Version 2.05

Revision History Log

Prev. Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.0	2/23/06	Travis Smith	Wording and depth	Second draft	1.01
1.01	4/3/06	Travis smith		Third draft	1.02
1.02	6/6/06	Travis Smith			1.03
1.03	7/07/06	Travis Smith		Forth draft	1.04
1.04	1/2/07	Darren Fong		Major revision	2.0
2.0	5/7/07	Paul Johnson	Proofreading		2.01
2.01	5/11/07	David Press	Proofreading		2.02
2.02	8/6/08	Paul Johnson	Paul Johnson	Proofreading	2.03
2.03	1/30/2009	Darren Fong	Edited contacts		2.04
2.04	6/6/2010	Darren Fong, Kris Freeman, Marcus Koenen	General edits, formatting	Review comments	2.05

Tables

Page

Table SOP 5.1. Personnel familiar with SFAN stream gaging operations who can provide technical support and historic information. ..... SOP 5.3

Table SOP 5.2. Equipment manufacturers..... SOP 5.4

Purpose

This standard Operating Procedure summarizes and lists training resources that are available for field staff in order to implement the streamflow monitoring protocol. Basic training can be found in the tutorials on the Internet based resources. More detailed training on the use of field equipment specific to this monitoring protocol and data management is also provided below.

The U.S. Geological Survey (USGS) has been the benchmark standard for streamflow monitoring protocols. As such, their procedural manuals are required reading for all technicians and program leads for this monitoring protocol. The publications listed below illustrate the concepts of streamflow monitoring as well as detailed descriptions for field measurements, data analysis, and report generation.

Training can be provided to staff to ensure proper collection and management of data. However, good performance is best-ensured if field personnel involved in data collection have appropriate educational and/or professional background so that the training process is merely an overview rather than a new introduction of ideas and procedures. Appropriate backgrounds also ensure that the training process does not become burdensome on existing personnel. Performance audits should be required and be made a part of the annual performance review of technical staff implementing this monitoring protocol.

In addition to the training and reference material provided in this SOP, Table SOP 5.1 lists contacts that are knowledgeable about flow monitoring and have provided technical assistance in the past. Table SOP 5.2 provides a list of contact information for equipment suppliers that may be a resource for repair or troubleshooting.

Table SOP 5.1. Personnel familiar with SFAN stream gaging operations that can provide technical support and historic information.

Name	Title and Contact Information
Darren Fong	GOGA Aquatic Ecologist, (415) 331-8716, darren_fong@nps.gov
Vacant	SFAN Water Quality Specialist, (415) 464-5122,
Brannon Ketcham	PORE Hydrologist, (415) 464-5192, brannon_ketcham@nps.gov
Gwen Gerber	NPS-WRD, Hydrologist, (970) 267-2144, gwen_gerber@nps.gov
Chris Gable	NPS-WRD, Hydrologist, (970) 225-3529, chris_gable@nps.gov
Randy Klein	REWD, Hydrologist, (707) 825-5111; Randy_Klein@nps.gov
Rob Carson	former SFAN Water Quality Specialist, robcarson@tomalesbaywatershed.org
Karl Davidek	USGS, Office (707) 468-4046, kdavidek@usgs.gov
Mike DeBlasi	former SFAN Hydrological Technician (2005) mdeblasi@pcweb.net

Table SOP 5.2. Equipment manufacturers.

Manufacturer	Contact Information
Campbell Scientific Inc.,	Phone (435) 753-2342, Fax (435) 750-9540 815 W 1800N, Logan, UT 84321 www.campbellsci.com
Global Water	Phone 1-800-876-1172, Fax (916) 638-3270 11390 Amalgam Way, Gold River, CA 95670 www.glabalw.com
Swoffer Instruments Inc	Phone (206)575-1016, Fax (206) 575-1329 1048 Industry Drive, Seattle, WA 98188 www.swoffer.com
Marsh-McBirney Inc	Phone: 1-800-368-2723, Fax (301) 874-2172 4539 Metropolitan court, Fraderick, MD 21704-9752 www.marsh-mcbirney.com
Gurley Precision Instruments	Phone 1-800-759-1844, Fax (518)-274-0336 514 Fulton St., Troy, NY 12181 www.gpi-hydro.com

Educational Resources

Electronic Resources

The USGS has developed online courses that provide step by step guidance with visual and audio aids. The following link offers a variety of basic classes that cover an introduction for operating streamgages.
http://wwwrcamnl.wr.usgs.gov/sws/SWTraining/FlashFandR/Index.html

The most important classes that should be looked at are:

- Surface Water Field Methods: This on-line course is oriented to the work being performed in the field. The class covers what to look for and what not to look for in selecting a stream site, what pool-forming controls are, and how to perform stage and discharge measurements.
- Stage-Discharge Relations -- Basic Concepts: This on-line course is more quantitative, looking at the relationships between stream stage and discharge. This class will go over the office work and responsibilities of developing the raw data collected in the field. Topics covered in this class include: rating controls, rating scales, rating offsets, developing shifts to ratings, applying shifts, and developing new ratings.
- Overview of Data Collection at Streamgages.

The field staff should be required to take and satisfactorily pass the tests for these on-line tutorials.

In addition to these Internet-based resources, there are a series of CD-based tutorials that will also be useful to review.

- Measurement of Stream Discharge by Wading
- Levels at Streamflow Streamgages -- A CD-ROM Based Training Class
- Care and Maintenance of AA and Pygmy Meters

- Introduction to Suspended-Sediment Sampling

Published Resources

A variety of published documents is available and should be reviewed by new or interested field staff prior to conducting field work or data analyses. The USGS is the nation's premier agency responsible for monitoring the nation's streams and rivers. The primary standard resources for our streamflow monitoring program should be USGS's "Techniques of Water-Resources Investigations of the United States Geological Survey." This is a long-running series of technical publications that cover standard procedures for measurement of streamflow parameters much in the manner that American Public Health Association's "Standard Methods for the Examination of Water and Wastewater" has been the standard procedural manual for water quality monitoring. In addition, technical updates and internal-USGS policy related to their streamflow monitoring program are provided in the Office of Surface Water Policy as memorandums. Most of these publications are available electronically by USGS on the Internet.

- USGS Techniques of Water Resources Investigation (TWRI) reports (http://pubs.er.usgs.gov/usgspubs/)
- USGS Water Resources Discipline and Office of Surface Water Policy Memoranda (http://water.usgs.gov/admin/memo/)

For staff of the SFAN network, digital versions for the key published USGS resources have been obtained and are stored on the Golden Gate National Recreation Area Marin Headlands network drive (X:\Individual Vital Signs\Streamflow\documents\ReferenceLibrary of Hydro Docs). The standard file nomenclature requires the primary author's Last Name (including "et al" for additional authors), Date, and shortened Title Name. As new literature becomes available, digital versions should be added to the SFAN network using this file naming convention.

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 other federal employees. A listing of these resources is available via the Internet. Many of these courses cover basic procedures (e.g., surface-water records computation) as well equipment specific techniques (e.g., stream measurements using acoustic doppler profiling equipment).

Opportunistic Training

Training opportunities may be available through temporary details with agencies performing surface water monitoring (USGS, California Department of Water Resources), paid consultant training, or volunteer opportunities.

Topographic Surveys

Training

Ideally, field personnel would have taken standard undergraduate coursework in surveying. Engineering programs at the local universities typically offer surveying courses. At City College of San Francisco, surveying courses are usually offered every semester, often in the evenings for

working individuals. They provide a rigorous grounding in surveying principles, surveying equipment and techniques, and quality assurance/control procedures. Alternately, review of surveying reference materials (see section below) as well as on-the-job training would be an adequate substitute.

Reference Materials

Topographic surveys are required to document any changes in the stream profile and cross-section at streamgages as well as any required datum due to settlement or uplift of the gage. Basic information on surveying can be found in standard surveying text books (e.g., Moffit and Bossler 1998) and help provide information on unknown surveying terms or adjustment of instruments. A good and easy to understand guide to survey techniques for streams can be found in Stream Channel Reference Sites: An Illustrated Guide to Field- Chapters 5, 6, and 8 (Harrelson et al. 1994). Additionally, USGS's CD-ROM training program for running levels should be reviewed as well.

Topographic information for each streamgage can be found in the station descriptions and annual station analyses for each streamgage. In addition, topographic surveys conducted by NPS staff are recorded in standard level books located at the SFAN office (Fort Cronkhite, Bldg. 1063, Sausalito, CA 94965). These level books should be reviewed to understand benchmark locations, ideal instrument setup locations, and other surveying peculiarities for each streamgage prior to conducting new topographic surveys.

Streamflow Measurements

Training

Standard streamflow measurements should follow standardized procedures as described in the Water Quality SOP 9 Flow Measurements and personnel should be properly trained to carry out field procedures. Ideally, field personnel should have had coursework in surface water hydrology that introduces hydrologic concepts. Field personnel can also learn field techniques through the various educational resources described previously. New personnel will be required to accompany existing staff to understand network procedures and protocols.

High flow measurements are typically concentrated during a short-time period during the year and because they are done infrequently, it is likely that trained field personnel may forget sampling procedures. However, high flow measurements are the most time-critical field measurement of this monitoring protocol and the most unforgiving for unprepared personnel. Personnel need to be ready to take streamflow measurements when peak streamflow conditions arrive. Consequently, field personnel should ensure prior to the winter season that all field gear for high flow measurements are in good working order and organized for quick deployment. In the field, high flow measurements need to be taken quickly and efficiently. Consequently, field personnel should review pertinent sections of the Water Quality SOP 9 Flow Measurement and Rantz et al. (1982a) related to high flow measurements prior to the winter season. In addition, "dry lab" operation of bridge board, reel, and meter are highly recommended to ensure that personnel are familiar with equipment and its operation.

Reference Materials

Four different meters can be used to determine stream velocity Swoffer 2100, Gurley pygmy, Marsh-McBirney Flo-Mate, and Price AA meters). In addition, two flumes are used to obtain direct measurements of discharge (3-inch modified Parshall flume and 1.5 foot H-flume). The discharge measurement SOP provides an overview of the streamflow measurement procedures and appropriate conditions for use of each meter or flume. The best reference that describes use and care of these meters and flumes can be found in the two-volume USGS reference streamflow reference guide by Rantz et al. (1982a, b). In addition, manuals for each piece of equipment provide additional information for calibration and maintenance. They are found on the Golden Gate National Recreation Area Marin Headlands network drive: X:\Individual Vital Signs\Streamflow\documents\Equipment Operator's Manual. Smoot and Novak (1968) provide detailed maintenance information for the vertical axis meters.

Streamgage Operations

Training

For new employees, back-up dataloggers and transducers (e.g., Campbell CR10x and Global Water WL-15/16) are available at the network for office testing. New employees should follow procedures within SOP 1 and equipment-specific manuals for set-up, operating, calibrating, and trouble-shooting the equipment prior to field work. New employees should feel comfortable with operation of dataloggers and related equipment prior to starting field activities.

In addition, training on operation of recording streamgages may best be done by accompanying and assisting existing SFAN field personnel associated with this monitoring program. The monitoring protocol and related SOP's provide a complete description of how to maintain and operate our existing stations.

Reference Materials

As with most of the streamflow monitoring procedures, the two-volume USGS reference streamflow reference guide by Rantz et al. (1982a, b) is the best and most complete source of information on standard streamgage procedures. However, this reference guide is generic. General procedures on use of submersible pressure transducers including installation, sources of error, and routine trouble-shooting can be found in a recent USGS publication by Freeman et al. (2004).

Hard-copy manuals of the Campbell Scientific datalogger are stored at the SFAN offices (Fort Cronkhite, Building 1063, Sausalito, CA 94965). It should be noted that the Campbell Scientific software (PC 208W) and hardware are not very user-friendly. We have routinely received assistance from staff with NPS Water Resources Division (NPS-WRD) to assist with various technical issues throughout the years.

Data Management, Analysis and Reporting

Training

The data management, analysis and reporting procedures will take up a lot of time and require a basic understanding of key computer software programs. The monitoring protocol and related SOP's provide a complete description of how to conduct data management, analysis and

reporting. Personnel working with the streamflow dataset should be familiar and comfortable with the use of Microsoft Access and Excel. Familiarity with MS Excel should include the ability to plot graphs using log scale, the ability to use formulas in Excel for computation, and the ability to summarize data using pivot tables. Familiarity with MS Access should include the ability to enter data into tables, to import/export MS Access data into various formats, and to conduct queries. Development of stage-discharge ratings requires understanding of software program (Aquatic Informatics Aquarius rating curve program) as well as a good understanding of rating procedures. The USGS offers a week-long training course in developing ratings. They also provide good web-based tutorials as described previously. Aquarius' web-based software tutorials can assist new personnel to develop sufficient understanding of software capabilities to analyze the streamflow dataset.

Reference Materials

As with most of the streamflow monitoring procedures, the two-volume USGS reference streamflow reference guide by Rantz et al. (1982a) is the best and most complete source of information on general data management, analysis and reporting. Past station analysis reports and datasets are helpful templates. The Data Management SOP 2 provides the detailed instructions for managing and reporting data.

Literature Cited

Moffit, F. H. and J. D. Bossler. 1998. Surveying. Tenth edition. Addison-Wesley, Menlo Park, California.

Rantz, S. E., et al. 1982a. Measurement of stage and discharge. Volume 1 *in* Measurement and computation of streamflow. US Geological Survey Water-Supply Paper 2175. US Government Printing Office, Washington, D.C.

Rantz, S. E., et al. 1982b. Computation of discharge. Volume 2 *in* Measurement and computation of streamflow. US Geological Survey Water-Supply Paper 2175. US Government Printing Office, Washington, D.C.

Standard Operating Procedure (SOP) 6. Procedures for Tipping Bucket Rain Gage Stations

Version 1.03

Revision History Log

Prev. Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
	3/24/07	Marcus Koenen	Adapted from draft Weather Protocol		1.0
1.0	5/7/07	Paul Johnson	Proofreading		1.01
1.01	8/6/08	Paul Johnson	Proofreading		1.02
1.02	6/5/2010	Darren Fong, Kris Freeman, Marcus Koenen	Equipment changes, formatting	Review comments	1.03

Figures

Page

Figure SOP 6.1. Davis Instruments Rain Collector II tipping bucket rain gage showing tipping mechanism. ..... SOP 6.4

Figure SOP 6.2. Tipping bucket adjustment screw..... SOP 6.9

Tables

Page

Table SOP 6.1. Precipitation data collection sites in the San Francisco Bay Area Network near stream streamgages. ..... SOP 6.5

Table SOP 6.2. Weather station metadata. ..... SOP 6.6

Table SOP 6.3. Tipping bucket specifications..... SOP 6.7

Purpose

The purpose of this standard operating procedure (SOP) is to provide standardized guidance on installation, operation, and maintenance of precipitation measurement devices associated with the streamflow monitoring program in the SFAN network. Precipitation data will assist with interpretation of the streamflow record.

Scope and Applicability

This SOP applies to collection of rainfall-derived precipitation using commercially available tipping buckets that are connected to streamgage dataloggers. In the future, this protocol may be revised to include collection of fog-derived precipitation.

Reference Materials

USGS released a technical memorandum governing collection of precipitation data (Blanchard 2005) entitled "Collection, Quality Assurance, and Presentation of Precipitation Data." This document provides useful and comprehensive information that has been incorporated into precipitation data collected for this program. However, this memorandum does not cover collection of fog-based precipitation. Manuals for particular tipping buckets are also available in hard copy and electronically on the SFAN network (Network I&M\Individual Vital Signs\Streamflow\documents\Equipment Operator's Manual).

Selection of Equipment

Information is desired regarding rainfall intensity and total annual rainfall within the watershed where SFAN streamgages are present. The USGS has reviewed several different types of precipitation gages and recommend tipping bucket rain gages as the best choice for accuracy (Blanchard 2005). However, tipping buckets may underreport precipitation during periods of intense precipitation (Blanchard 2005). We have decided to use tipping buckets because they are relatively inexpensive and provide reasonably accurate data. The two current tipping bucket brands include Davis Instruments and Onset Computer Company, although other brands would be acceptable as well.

Tipping buckets operate by collecting precipitation in a funnel-shaped container of standard diameters (typically 6 or 8 inch). Collected rainfall is directed by the funnel to one of two small "buckets" on a fulcrum. Each bucket collects the equivalent of 0.01 inches (0.3 mm) of precipitation, tips to empty its contents and brings the other bucket into position under the funnel. Each tip of the bucket closes an electrical contact, which sends a signal to a signal conditioner for digital recording. A typical tipping bucket is shown in Figure SOP 6.1. The specifications of the tipping bucket used by this program are provided in Table SOP 6.3.



Figure SOP 6.1. Davis Instruments Rain Collector II tipping bucket rain gage showing tipping mechanism.

Site Selection and Installation for Tipping Buckets

Ideally, rainfall would be collected and managed by an entity with expertise in climatological data collection such as NOAA's Climatic Data Center or the National Interagency Fire Center (which manages the Remote Automated Weather Stations or RAWS). We determined that adequate precipitation data was being collected within the Olema Creek watershed (RAWS station), Lobos Creek (Crissy Field weather station, Golden Gate National Parks Conservancy), Franklin Creek (National Weather Service station), and for some of the PINN stations. At these locations, no additional precipitation gages will be installed.

At sites lacking precipitation data, a tipping bucket is installed on level ground so the mouth is horizontal and open to the sky. The overstory vegetation circling the raingage should be kept back at a 45 degree angle from the horizon. The vegetation of the underlying surface should be short grass or gravel. The height of the opening should be as low as possible (minimum: 30 cm), but should be high enough to avoid splashing in from the ground and disturbance from wildlife. The tipping bucket may be mounted on top of a wooden post or attached to a t-post with the top of the funnel perfectly level. The bucket should be placed on a sturdy structure that does not shake in the wind causing unintentional bucket-tips (Blanchard 2005). Nearby obstructions that can create adverse effects on precipitation measurements (e.g., funneling, reflection, and turbulence) should be avoided. Every effort should be made to minimize the wind speed at the mouth opening of a precipitation gage. In sheltered areas where the height of the objects and their distance to the instrument is uniform, their height above the instrument should not exceed twice the distance from the instrument. In open areas, the distance to obstructions should be at least two, preferably four, times the height of the obstruction. The lip of the tipping bucket should be leveled in all directions using a carpenter's level. The cable from the tipping bucket to the datalogger should be placed in conduit to prevent animal activity from damaging the cable.

Information regarding the location of the precipitation data collection sites is provided in Table SOP 6.1. Additional data regarding the dates of operation, equipment, and data storage locations are provided in Table SOP 6.2.

Table SOP 6.1. Precipitation data collection sites in the San Francisco Bay Area Network near stream streamgages.

Station Name	Manager	Location	Elev. (ft MSL)	Longitude	Latitude
Crissy Field	Golden Gate National Parks Conservancy	On top of Crissy Center at Crissy Field, The Presidio	~40	-122º 27’ 31” W	37º 48’ 10” N
Martinez 2 S	National Weather Service	Within town of Martinez	230	-122° 07’39” W	37° 58’12” N
Redwood Creek	This program	Along Highway 1 bridge near Muir Beach	~40	-122° 34' 46.272"W	37° 51' 58.1394" N
Easkoot Creek	This program	Near Stinson Beach Park entrance	~10	-122° 38’ 28” W	37° 53’ 53” N
Pine Gulch Creek	This program	Adjacent to an organic farm north of Bolinas, CA	~20	-122° 41’54” W	37° 55’18” N
Olema Valley	PORE	Nr NPS administrative headquarters at Bear Valley	37	-122° 47’45” W	38° 02’33” N
Pinnacles Station 2	PINN	Behind Chaparral Visitor Center	1,400	-121° 14’ 12” W	36° 30’ 19” N
Pinnacles Air Quality Station	PINN/NPS-Air Resources Div	2.5 mi SW of Hwy25/Hwy 146 junction	1,200	-121°09’18” W	36° 28’ 55” N

Table SOP 6.2. Weather station metadata.

Station	Period of Record	Software	Hardware	Archival Location
Crissy Field	2001–Present	WeatherLink 5.0	Davis Instruments Vantage Pro	Network I&M\Individual Vital Signs\Weather\data\WS_data\crissy field
Martinez 2 S	1948–Present	N.A.	FISCHER/PORTER RRNG	http://www.ncdc.noaa.gov/oa/climate/stationlocator.html
Redwood Creek	1999–Present	Boxcar Pro 4.3	Texas Electronic Tipping Bucket TR 525 (1997-2008) Onset RG-2 (2008-)	Network I&M\Individual Vital Signs\Streamflow\data\GOGA_Redwood Creek
Easkoot Creek	1999–Present	PC208W	Davis Instruments Tipping Bucket	Network I&M\Individual Vital Signs\Streamflow\data\GOGA_Easkoot_Creek
Pine Gulch Creek	1997–Present	Boxcar Pro 4.3	Texas Electronic Tipping Bucket TR 525 (1997-2008) Onset RG-2 (2008-)	Network I&M\Individual Vital Signs\Streamflow\data\PORE_Pine_Gulch_Creek
Olema Valley	2004–Present	N.A.	N.A.	1) http://www.wrcc.dri.edu/cgi-bin/rawMAIN.pl?caCOLV 2) Contact PORE hydrologist
Pinnacles Station 2	1998–Present	WeatherLink v4.02	Davis Instruments Weather Monitor II	Contact PINN Natural Resources Div
Pinnacles Air Quality Station	11/2/1999–Present	N.A.	NA	1) http://nadp.sws.uiuc.edu/sites/siteinfo.asp?id=CA66&net =NADP 2) Contact PINN Natural Resources Div

Tipping Bucket Weather Station Descriptions

Currently, there are tipping buckets directly connected to three streamgages including Pine Gulch Creek, Easkoot Creek, and Redwood Creek. All tipping buckets are connected to the same Campbell Scientific data loggers that collect the stream gaging data. The download procedures for collecting stream gaging data will also retrieve collected precipitation data (see SOP 1 Procedures for Selection and Operation of Streamgages. Rainfall at all stations is recorded every 15 minutes, and summarized by one-hour and 24-hour totals.

- Pine Gulch Creek: This station is associated with a stream monitoring station located above the right bank of Pine Gulch below the Olema-Bolinas Road Bridge. There is a Onset Computer Company RG-2 tipping bucket rain gage (four feet above ground) located adjacent to a farm field near the creek.
- Easkoot Creek: This station is associated with a stream monitoring station located below the Stinson Beach Park entrance bridge. There is a Davis Instruments Rain Collector II tipping bucket rain gage located approximately five meters west of the data logger site.
- Redwood Creek: This station is associated with a stream monitoring station located above the left bank of Redwood Creek on the upstream side of the Highway 1 Bridge. There is a Onset Computer Company RG-2 tipping bucket rain gage located in a clearing approximately ten meters northeast of the creek.

Table SOP 6.3. Tipping bucket specifications.

Model	Ht.	Funnel Dia.	Software	Range	Accuracy		Limits	Resolution
Texas Instruments TR-525	10.0"	6.06"	Campbell Scientific PC208W	Infinite in 0.01" increments	≥1"/hr 1–2"/hr 2–3"/hr	±1% +0, -3% +0, -5%	Temperature: 0–50º C Humidity: 0–100%	1 Tip = 0.01"
Davis Instrument	9.5"	6.06"	Campbell Scientific PC208W	Infinite in 0.01" increments		±4%		1 Tip = 0.01"

Rain Gage Operation and Maintenance

Regular maintenance of the rain gage equipment is essential to obtain accurate data. The field personnel responsible for the streamgages will also be responsible for ensuring that rain gage equipment is in good working condition. Field inspection of equipment will occur concurrently with routine stream gage visits, at roughly one-month intervals. Minimal equipment is needed and includes the following:

- Rags, towels, and cotton swabs for cleaning
- Carpenter's level
- Water bottle
- Allen wrench set
- Volumetric flasks and 500 ml Nalgene Bottle or Novalynx™ calibration bottle
- Streamgage field book

This information is also provided in SOP 4 (Field Equipment for Flow Measurements and Station Maintenance).

During the site visit, the following are conducted (from Blanchard 2005):

- Visual check for 45-degree clearance above collector.
- Note cup, debris screen, drain holes, and funnel condition (clean or dirty).
- Clean cups, screen, drain holes, and funnel, if necessary, and note.
- Re-level the instrument if necessary (collector must be vertical).
- Lubricate the pivot hinge with a plastic-safe lubricant or silicone oil (as recommended by the manufacturer).
- Make sure the small drain holes at the bottom of the gage are not plugged with dirt or other material (drill them larger if problem becomes chronic). Record water levels in accumulation can and empty it.
- During warm weather site visits, the collector funnel and tipping buckets should be waxed (liquid car wax). This will reduce corrosion and decrease the number of water droplets that might cling to the side/bottom of the collector.

- Perform a manual test tip procedure to check the integrity and operation of the gage sensor and wiring.
- Fill out streamgage field book

The field book is an important record of condition and actions associated with the rain gage. Documentation of all rain gage equipment should include a description of the system “as found”, details of any adjustments to the instrument, and a description of the system “as left”. This documentation is a vital part of the "paper-trail" for any claims of data validity.

Rain Gage Calibration

Calibration tests must be performed annually (Blanchard 2005). For the SFAN monitoring program, these tests should be performed at similar times and preferably before the start of the rainy season (e.g., in early November). Calibration tests are performed using accurate and known volumes of water that are released into the tipping rain gage using a plastic calibration container. This is compared to the number of tips recorded by the datalogger where one tip is equivalent to 0.01 inches distributed evenly over the area of the funnel. This plastic calibration container has a small hole that controls the release rate of water. Commercial products are available and the SFAN has purchased a NovaLynx unit for this purpose. Alternatively, tipping bucket manufacturers recommend use of a plastic bottle with a small hole drilled into the bottom to release water at a controlled rate. A nozzle size should be selected that results in a release rate of 2 inches/hr (Blanchard 2005). Because of the time required, no more than 500 ml of water should be used (approx. 30 minutes). A volumetric flask should be used to deliver an exact amount of water to the plastic calibration bottle.

The actual rainfall amount (inches) per fixed volume of water can be determined with simple algebra. Actual rainfall (inches) is calculated as the volume of water (cubic inches) divided by the surface area of the funnel above the tipping bucket (square inches).

Adjustments are required when tipping bucket data are not within 5% of actual volume (Blanchard 2005). Adjustments may involve leveling the gage, adjusting the tipping mechanism, lubrication of tipping mechanism, and waxing of collection surface to improve runoff. Should the tipping mechanism require adjustment, turn adjusting screws located on the bottom adjacent to the large center drain hole. Davis Instrument II adjustment screws are shown in Figure SOP 6.2. One-half turn of both screws causes a 2–3% change. Both screws need to be turned in the same direction and the same number of turns. Moving the screws in the positive (+) direction causes the bucket to tip more times (i.e. give a larger count) for a given amount of water.

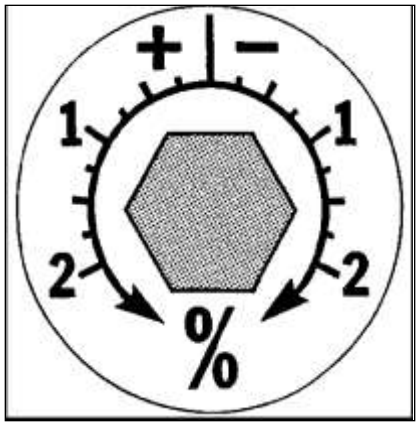


Figure SOP 6.2. Tipping bucket adjustment screw.

Once adjustments are made, a second calibration check should be conducted to ensure that actions improved accuracy. All actions and results shall be recorded in the streamgage field logbook. Field personnel will be required to review the USGS technical memorandum on collection and quality assurance of precipitation data.

Equipment Repairs, Replacements and Upgrades

For tipping rain buckets, we do not have a recommended replacement schedule. Generally, the equipment will be used until failure. Routine data checks after monthly downloads combined with annual field cleaning and calibration will be used to determine whether equipment needs replacement or repair.

Literature Cited

Blanchard, S. 2005. Collection, quality assurance, and presentation of precipitation data. US Geological Survey Office of Surface Water Technical Memorandum No. 2006.01. 2005 December 28.

Standard Operating Procedure (SOP) 7. Data Analysis and Reporting

Version 1.04

Revision History Log

Prev. Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
	1/05/2007	D. Fong	1st version of SOP		1.0
1.0	5/7/07	Paul Johnson	Proofreading		1.01
1.01	7/24/2008	D. Fong	Revisions of various sections		1.02
1.02	8/6/08	Paul Johnson, Marcus Koenen	Proofreading		1.03
1.03	6/4/10	D. Fong, Kris Freeman, Marcus Koenen	Added long-term analyses, formatting	Addressed comments from Jim Agee, Gwen Gerber and Rick Inglis.	1.04

Figures

Page

Figure SOP 7.1. Midsection method of discharge measurement (from Rantz et al. 1982a). ..... SOP 7.6

Figure SOP 7.2. A generalized workflow chart of data processing procedures for determination of instantaneous stream discharge, SFAN streamflow monitoring program. ..... SOP 7.10

Figure SOP 7.3. Combining date and time fields into a single date:time field..... SOP 7.11

Figure SOP 7.4. Printout of recorded stage data and observed stage for error checking. ..... SOP 7.14

Figure SOP 7.5. Counting stage records in Excel..... SOP 7.15

Figure SOP 7.6. Example of drift correction through linear interpolation in the MS Excel *Recording Streamgage* Spreadsheet..... SOP 7.17

Figure SOP 7.7. Rating shift at the Redwood Creek (GOGA) streamgages (from Stillwater Sciences 2005)..... SOP 7.19

Figure SOP 7.8. Rating curve for Easkoot Creek, Water Year 2001 (from NPS-WRD)..... SOP 7.22

Figure SOP 7.9. Mean daily discharge and rainfall for Olema Creek at Bear Valley Bridge, Marin Co., CA. Water Year 1998 (Example)..... SOP 7.30

Figure SOP 7.10. Little Lost Man Creek, log-Pearson type III flood-frequency distribution (from Klein 2005)..... SOP 7.32

Tables

Page

Table SOP 7.1. NPS - SFAN water year discharge computation checklist. ..... SOP 7.8

Table SOP 7.2. Measurement and site summary worksheet. ..... SOP 7.9

Table SOP 7.3. Example Level Notes Worksheet (from NPS-WRD)..... SOP 7.12

Table SOP 7.5. Annual hydrologic summary statistics. ..... SOP 7.23

Table SOP 7.6. Mean daily discharge (Example). ..... SOP 7.28

Table SOP 7.7. Daily rainfall (Example). ..... SOP 7.29

Table SOP 7.8. Annual peak discharges and recurrence intervals (RI) for Little Lost Man Creek (LLM), Prairie Creek above Brown Creek (PRU), and Prairie Creek above May Creek (PRW) (from Klein 2005). ..... SOP 7.31

Appendixes

Page

Appendix SOP 7A. Example Station Analysis (from NPS-WRD)..... SOP 7.37

Purpose

The objectives of this SOP are to describe procedures for:

1. Processing data needed for this protocol
2. Developing annual summaries of streamflow conditions
3. Conducting long-term assessments of flood frequency and flow duration that are anticipated for our long-term reports.

The procedures include 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. The standard procedures for discharge data analyses have been developed and tested by the USGS to analyze records from over 7,000 streamgages nationwide. The intent of this SOP is to refer to or summarize these procedures rather than to adopt new data analysis methods. Much of the analyses will be conducted using Microsoft Excel spreadsheets. The annual report format borrows heavily from established USGS formats for summarizing water year data.

Other important elements such as quality assurance procedures are dealt separately in stand-alone SOPs. Quality assurance procedures are briefly mentioned in this SOP but the reader is referred to SOP 9 for greater details. See also SOP 2 Data Management, especially sections on data validation for details of how data are managed and archived.

Reference Materials

Procedures for stream discharge analyses have been obtained from three main USGS reference documents: Kennedy (1983), Rantz et al (1982b), and (Sauer 2002). These documents are available electronically on the Internet and the reader is referred to those documents for a more specific description of methods.

Individual Discharge Computations

The procedures used to calculate measured discharges are specific to the particular field sampling techniques and include the USGS's mid-section (for flow meters), float, volumetric, and flume methods. These computational procedures are used in the SFAN Stream Discharge Database.

Mid-section Method

For current meter measurements, individual discharge measurements will be calculated using USGS's mid-section method. This method divides the channel into sections. The discharge is the sum of the partial discharge estimates for all the sections and is based on the section's width, depth, and average velocity (Figure SOP 7.1). The basic formula is

$$Q = \sum (a\bar{V})$$

where $\boldsymbol{a}$ is the rectangular area of the subsection (product of depth and width) and $\bar{V}$ is the mean velocity in a subsection (Harrelson et al. 1994). The width of each section is the distance between the mid-points of two adjacent points ($\mathbf{b_{n+1} - b_n}$) (Figure SOP 7.1). The mid-section method does not include the triangular section of channel next to each bank and assumes that partial discharge in these sections is negligible.

A variety of adjustments may be needed to compute discharge. Usually these adjustments are associated with determining the mean velocity in the vertical. Both vertical and horizontal angle corrections may be used to correct measured velocity when flow lines are not perpendicular to the plane of measurement. For the one-point method, the mean velocity is equal to the point velocity at the 0.6 depth. For the two-point method, the mean velocity is equal to a mean of the point velocities for the 0.2 and 0.8 depths. In certain situations, when only a point velocity just below the surface may be available (under high flow bridge deployments), a surface correction coefficient of 0.86 (Rantz et al. 1982a) would be used.

A Microsoft Access database (see SOP 2 Data Management) has been developed to enter field discharge measurement data for archival purposes as well as to calculate individual discharge measurements based on meter ratings as well as to adjust velocity measurements in the vertical as described above. The discharge database uses the basic formula listed above to calculate discharge.

Float Method (Adapted from Leopold 1997)

Discharge estimates using the float method are the product of the mean cross-sectional area for the channel reach and mean velocity for the stream. The cross-sectional area at the streamgage is either computed from recent field measurements or from a regression equation relating gage height to cross-sectional area. The mean cross-sectional area is the average of the streamgage data and the area at the start or finish line. The individual float distance and travel times are used to calculate surface velocities for each measurement. Surface velocities are converted to mean in vertical by multiplying velocity estimates by 0.8 (Leopold 1997). As with other discharge measurements, data are entered into the SFAN Stream Discharge Database. The database calculates the mean velocity as a grand mean.

Volumetric Method

Estimating discharge using the volumetric method may be the easiest and most accurate discharge measurement procedure. Discharge is calculated as $\frac{Sample\_volume\_(ft^3)}{Time\_(\text{secs})}$. The mean discharge estimate from three replicate samples is entered into the SFAN Stream Discharge Database. The individual discharge measurement values are entered in the Notes field.

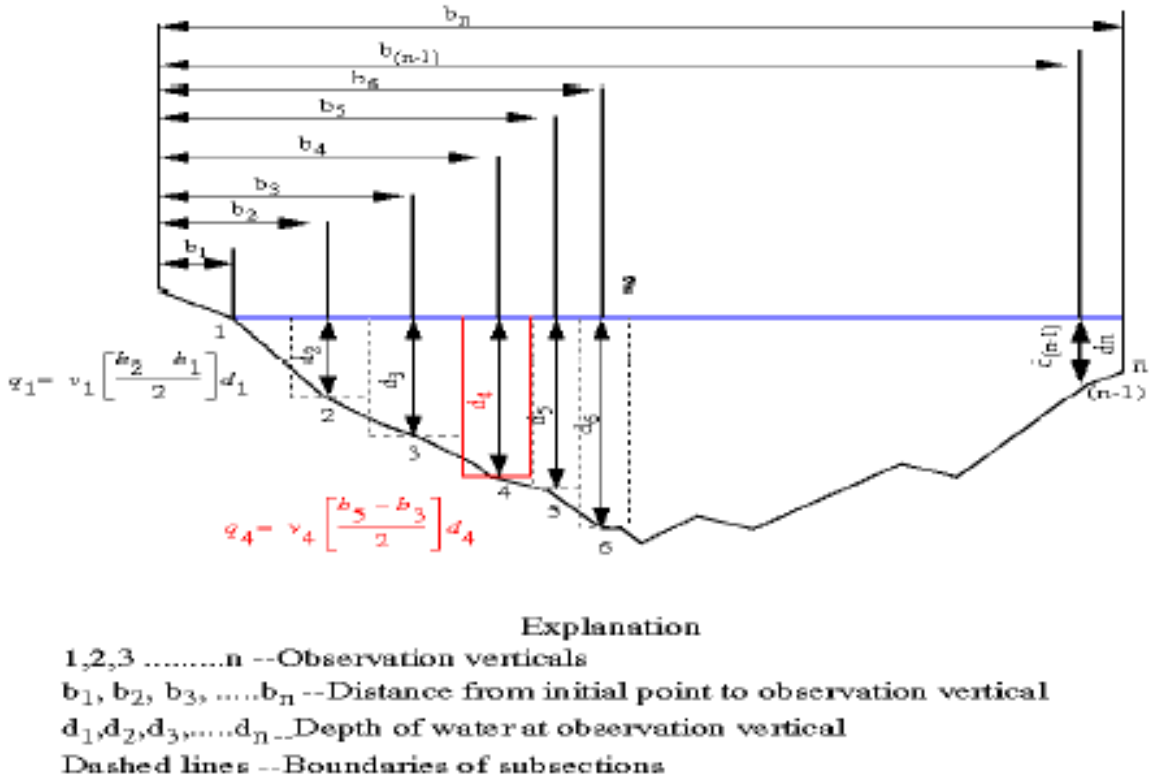


Figure SOP 7.1. Midsection method of discharge measurement (from Rantz et al. 1982a).

Flumes and Thin-plate Weirs

A variety of flumes or thin-plate weirs may be used for measuring discharge. Individual discharge measurements are calculated based on the height of water measured within the flume or at the weir notch. The SFAN Stream Discharge Database should be updated periodically with the rating equations for currently used flumes and weirs. The mean height is entered in the database with individual measurements added in the Notes field.

Preparation of Recording Streamgage Data for Analysis

The raw data downloaded using procedures in SOP 1 Procedures for Selection and Operation of Streamgages need processing before they are useful for data analyses. The procedures described below include step by step instructions for processing of recording streamgage data. An overview of this process, including how these data are integrated with stage-discharge rating curves, is provided in flowchart format in Figure SOP 7.2. In addition, the QA/QC checklist procedures for ensuring the production of good data are provided in Table SOP 7.1.

Raw Data Importation

Each recording streamgage's 15-minute data for a Water Year (WY) will be imported from individual data loggers and stored in separate Microsoft Excel spreadsheets (See SOP 2. Data Management). Although each station may record slightly different data fields, a core set of fields will be imported for each station. These fields include date and time (Pacific Standard Time), raw water stage (instantaneous, 15-minute), and rainfall (if available). Only the sampled or instantaneous stage data will be used for analysis.

Campbell Scientific data can be opened in a "working" spreadsheet as comma delimited data. The descriptions of the data fields for each station are given in SOP 2 (Data Management).

Excel Tips for Preparing Raw Date:Time Fields from Datalogger

The raw datalogger date and time fields are combined in the *Recording Streamgage Spreadsheet* as a single date:time field. Excel stores dates as sequential whole numbers starting from January 1, 1900 while hours and minutes are stored as fractional values. The Excel formula to transform year, Julian date, and time to a composite Date:Time format (e.g., 3/31/2005 13:45 hr):

> Date:Time = Excel Date + Julian day + (**TRUNC**(Time/100)/24) + ((**RIGHT**(Time,2)/60)/24)

where Excel Date is the numeric format for December 31 of prior year, [**TRUNC**] and [**RIGHT**] commands converts hours and minutes, respectively to decimal day. The general formula can also be found in Figure SOP 7.3 which includes a screenshot of the Excel spreadsheet.

Correcting Water Stage Data

The water level information is converted to discharge data through application of stage-discharge relations. Ensuring the accuracy of gage-height record is, therefore, a necessary component of ensuring the accuracy of computed discharges. Preparatory work is needed to adjust datalogger output to corrected water level stage. Often, datalogger records may not reflect actual water level stage due to movement of sensor (e.g., cleaning and calibration checks of transducer), the need for datum corrections, missing data, erroneous data, or sensor reading drift. Procedures to adjust and check raw water stage data are described below.

It is important to document any corrections to the stage record for both program staff and others that may be using the data. The SFAN program will be using a Water Year Discharge Computation Checklist (Table SOP 7.1) and a Measurement and Site Summary worksheet (based on USGS Standard Form 9-207 developed by NPS-WRD staff; Table SOP 7.2). These forms track changes including key site visit information, summary of discharge measurements and corresponding gage heights, and any data corrections by station and water year. This information is essential for the annual Station Analyses (see description below).

Table SOP 7.1. NPS - SFAN water year discharge computation checklist.

STATION NO._____STATION NAME _____PARK _____WATER YEAR _____

CHECKS	COMPUTED & CHECKED BY QUARTER				Processed by W.Year	2nd Review
	10/1 to 12/31	1/1 to 3/31	4/1 to 6/30	7/1 to 9/30		
Re-check level notes. Put copies of level summary in field and office folders. Enter data in *Level Survey Summary* Spreadsheet template						
Enter, compute and check discharge measurements and notes into Access database						
Enter measurements and site visit data on *Recording Streamgage Spreadsheet*, including staff gage and datalogger readings.						
Import core raw continuous data into *Recording Streamgage Spreadsheet* template						
Identify periods of missing data. Compare # of actual 15-min records with calculated #. Plot raw unit values						
Identify erroneous data by plotting raw unit values against rainfall and unit data from nearby streamgages						
Identify observer errors in staff gage height (including field GH corrections). Plot GH vs. datalogger readings.						
Determine gage height corrections.						
Determine datum corrections needed according to level summary data						
Enter data corrections and datum corrections						
Look at photos, level data, point of zero flow, and bed level at gage to determine period of channel adjustments						
Run Rating Offset and Shift Analyses						
Plot measurements on working rating curve						
Verify existing rating or develop new rating if necessary						
Re-compute percent differences (using shifts) and update measurements						
Write preliminary Station Analysis through rating paragraph						
Estimate Daily Values for missing data periods (optional)						
Print copy of primary computation table						
Check and correct primary for errors (values exceeding rating, drift criteria)						
Pencil note on primary: measurements, observed gage heights. Check accuracy of shifts and corrections						
Update final shifts and G.H. corrections as needed; Rerun primary, if necessary.						
Print copy of discharge measurement summary; put copies in office, field and annual folders						
Print end of year summary; confirm peaks and high flows with GH / discharge record						
Print copy of updated daily values table with statistical summaries						
Print annual hydrograph of daily means with measurements also plotted						
Create / update manuscript page – insert daily values table and print						
Complete Station Analysis & print a clean copy						
Review and update Station Description						
Scan and upload discharge field datasheets and field notebooks to server at end of WY						

Table SOP 7.2. Measurement and site summary worksheet.

United States Department of the Interior
National Park Service
Water Resources Division

SITE VISITS, DISCHARGE MEASUREMENT, AND DATA CORRECTION SUMMARY
WY2007 and 1st Quarter of WY2008

Saguaro National Park
Rincon Creek Near Madrona
Ranger Station #320745110365701

Date	Meas #	Rating	Time (LST)	Observer's Name	Staff GH[1]	Gage Pool Descriptor[2]	Datalogger GH	Staff Gage / Datalogger difference	Data Correction Applied	Q (cfs)	Applied Shift	% diff from shifted rating	Remarks
09/27/06			9:04	Chuck Perger	2.06	FLOW	2.08	-0.02	0.00				No data corrections applied because DCP stopped logging data after 8/16/08 at 15:00. DCP eventually sent into Design Analysis for repair, re-installed on 1/23/07.
10/04/06			8:49	Chuck Perger	2.04	FLOW	2.04	0.00	0.00				
01/10/07			9:37	Chuck Perger	2.02	FLOW	ND	ND	ND				sediment=1.38
01/26/07			9:36	Chuck Perger	2.00	FLOW	1.90	0.10	7.00				No data correction made levels fluctuating more than 0.10 due to leak in airline found on 3/14/07. Data logger reset @ 9:41.
			9:41				2.00		0.00				
04/18/07			8:39	Chuck Perger	2.07	FLOW	2.06	0.01	0.01				transitional data correction from 0.00 on 4/4 at 9:12 to 0.01 on 4/18 at 8:39.
06/13/07			8:17	Chuck Perger	1.93	FLOW	1.91	0.02	0.02				continuous correction of 0.02 from 5/2 @ 9:58 to 6/13 @ 8:17
06/18/07			9:02	Filippone/Perger	1.86	POOL	1.82	0.04	0.04				transitional data correction of 0.02 on 6/13 at 8:17 to 0.04 on 6/18 @ 9:02. staff gage level very close to the PZF
06/27/07			8:12	Chuck Perger	<1.64	WET	1.43	NA	NA				sediment = 1.64
07/11/07			8:20	Chuck Perger	<1.64	DRY	0.70	NA	NA				sediment = 1.64
07/25/07			9:48	Don Swann	1.54	POOL	1.50	0.04	0.04				continuous correction of 0.04 from 6/18 @ 9:02 to 7/25 at 9:48. Staff plate viewed from opposite bank, with turbulence staff reading may be at ±0.02.
08/08/07			8:55	Chuck Perger	3.14	FLOW	3.05	0.09	0.09				Transitional data correction from 0.04 on 7/25 at 9:48 to +0.09 on 8/8 at 8:55.
08/10/07	22	G	10:00	Filippone/Perger	2.65	FLOW	2.57	0.08	0.08	7.355	-0.30	-0.4	Transitional data correction from +0.09 on 8/8 at 8:55 to +0.08 on 8/10 at 10:00.
08/22/07			7:50	Chuck Perger	2.40	FLOW	2.39	0.01	0.01				Transitional correction of 0.08 on 8/10 at 10:00 to 0.01 on 8/22 at 7:50
09/05/07			7:32	Chuck Perger	2.12	FLOW	2.17	-0.05	-0.05				Transitional correction of 0.01 on 8/22 @ 7:51 to -0.05 on 9/5 @ 7:32. End correction at 7:53. Reset datalogger at 7:53.
			7:53	Chuck Perger			2.12		0.00				
09/19/07			7:50	Chuck Perger	2.10	FLOW	2.12	-0.02	-0.02				Transitional correction of 0.00 at 9/5 at 7:54 to -0.02 on 9/19 at 7:50.
see water year folder 2008 for remaining site visit summary data													
03/06/08	23	G	16:22	Chuck Perger	2.53	FLOW	NR	NA	NA	1.898	-0.46	-2.8	

Note: - Data source is from Levels, Download and Discharge Measurement forms located in Section 2 of the WY folder
ND - No Data DCP stopped logging data after 8/16/08 at 15:00. DCP sent into Design Analysis for repair, re-installed on 1/23/07.
NA - Not applicable
NA* - Datalogger data not recorded during site visit. DCP GH taken from site visit UV tables.
Staff GH[1] - The "<" symbol indicates no level recordable by staff plate. Water level is less than (<) aggradation line (AL, or sediment line) on the staff plate.
Gage Pool Descriptor [2] - **FLOW**: Creek is still flowing (flow into and/or out of pool is evident); **POOL**: Creek has stopped flowing but there is water in the Pool at the listed staff plate reading; **WET:** There is still water in the pool but is not recordable by the staff plate (lower than the staff plate or aggradation line); **DRY**: Pool is completely dry

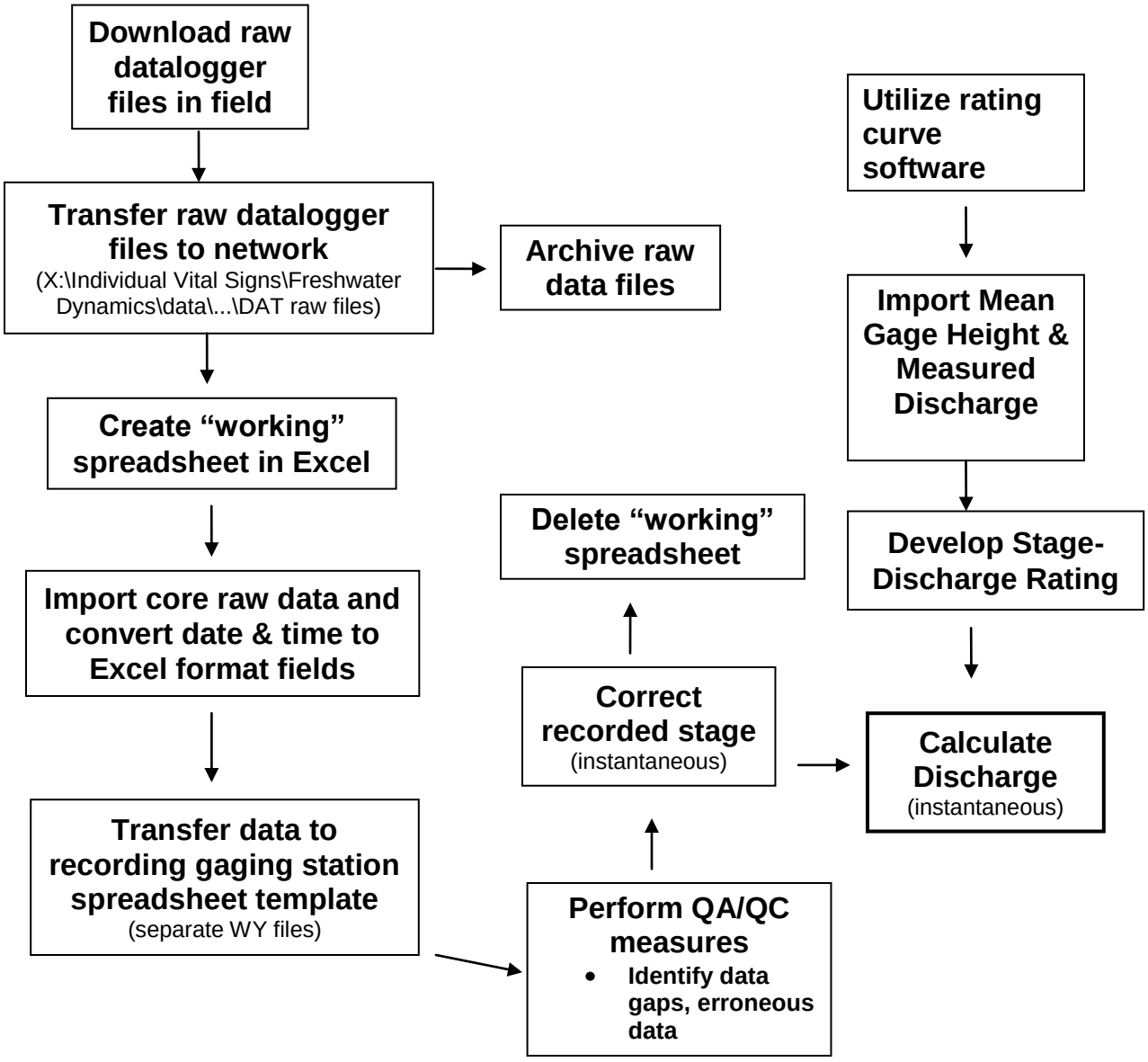
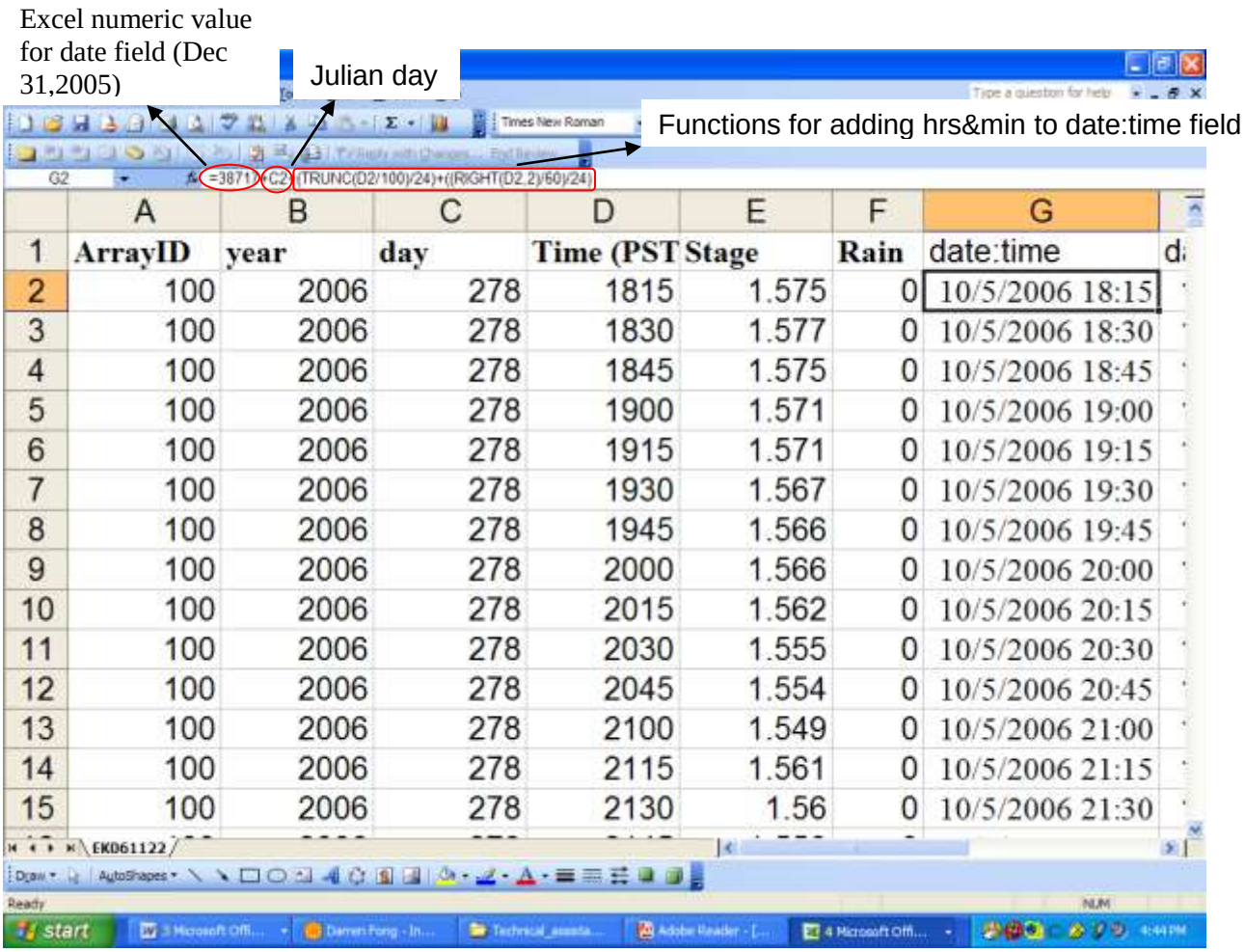


Figure SOP 7.2. A generalized workflow chart of data processing procedures for determination of instantaneous stream discharge, SFAN streamflow monitoring program.

Sensor Movement

The position of the sensor in the piezometer may change due to deliberate actions such as cleaning and calibration checks or from accidental actions such as tripping over conduit and pulling the sensor upward in the piezometer. The change in sensor position can be determined by comparing water stage data to staff plate readings prior to and after expected sensor movement. This difference can be used to adjust the offset and recorded water stage by simple addition or subtraction.



	A	B	C	D	E	F	G
1	ArrayID	year	day	Time (PST	Stage	Rain	date:time
2	100	2006	278	1815	1.575	0	10/5/2006 18:15
3	100	2006	278	1830	1.577	0	10/5/2006 18:30
4	100	2006	278	1845	1.575	0	10/5/2006 18:45
5	100	2006	278	1900	1.571	0	10/5/2006 19:00
6	100	2006	278	1915	1.571	0	10/5/2006 19:15
7	100	2006	278	1930	1.567	0	10/5/2006 19:30
8	100	2006	278	1945	1.566	0	10/5/2006 19:45
9	100	2006	278	2000	1.566	0	10/5/2006 20:00
10	100	2006	278	2015	1.562	0	10/5/2006 20:15
11	100	2006	278	2030	1.555	0	10/5/2006 20:30
12	100	2006	278	2045	1.554	0	10/5/2006 20:45
13	100	2006	278	2100	1.549	0	10/5/2006 21:00
14	100	2006	278	2115	1.561	0	10/5/2006 21:15
15	100	2006	278	2130	1.56	0	10/5/2006 21:30

Figure SOP 7.3. Combining date and time fields into a single date:time field.

Datum Corrections

A correction applied to gage-height readings to compensate for the effect of settlement or uplift of the gage is usually measured by levels and is called a "datum correction" (Kennedy 1983). Datum corrections are applied to gage-height record in terms of magnitude (in feet) and in terms of when the datum change occurred. In the absence of any evidence indicating exactly when the change occurred, the change is assumed to have occurred gradually from the time the previous levels were run, and the correction is prorated with time (Rantz et al. 1982b). Datum corrections are applied when the magnitude of the vertical change is equal to or greater than 0.02 ft (Sauer 2002). Field information about changes in the gage datum, reference marks, and other key topographic points are kept in the *Level Notes Worksheet*. Every station will have a *Level Notes Worksheet* associated with it. The template used by NPS-WRD for maintaining level notes will also be adopted by this program (Table SOP 7.3).

Table SOP 7.3. Example Level Notes Worksheet (from NPS-WRD)

POOL A LEVELS (FINAL TABLE)

Date	Party	Ground rod (base)	RM-1	RM-2	RM-3	OVS 1 (lower staff plate)	OVS 2 (upper staff plate)	Orifice	PZF	CSG	Remarks
06/11/03	Grover / Filippone	9.33				3.08	5.51	0.55			
06/25/04	Gerber / Albright	9.33	6.61	4.95	5.62	3.08	5.51	0.57	1.41		RM-1, RM-2, and RM-3 established on this day
05/24/05	Gerber / Daniels	9.33	6.62	4.96	5.63	3.09	5.51	0.56	1.65	4.95	Preliminary survey completed on 5/23/05 to raise OVS-2 (tree fell on it during 2/12/05 high flow event). CSG installed on 5/24/05.
08/03/06	Gerber / Perger	9.33	6.61	4.95	5.62	3.09	5.48				CSG lost in 07/31/06 high flow event; orifice buried under 2 feet of course sand and fine gravel; no PZF remaining, pool has filled in with sand. OVS-2 has canted slightly due to high flows and is considered slightly unstable due to the -0.02 shift overnight in response to flows which increased to over 7 feet in response to an event after our survey on 8/3/06.
08/04/06	Gerber / Perger						5.46				
4/25/2007	Gerber / Perger	9.33	6.61	4.96	5.62	3.09	5.50				Survey completed relating Pool A gage datum to RC-1. Elevation survey completed. Elevation of OVS-1 at 0.00 feet is 3155.51.
03/26/08	Gerber / Perger	9.33	6.61	4.95	5.62	3.09	5.50				

Missing or Erroneous Data: The raw 15-minute record needs review to identify if data may not have been recorded due to datalogger failure or if erroneous data are present. Graphical analysis of raw data using hydrographs as noted in SOP 2 Data Management will assist in identifying potential data errors including data gaps or stage data that is suspect. Evaluation of hydrographs is an effective means for evaluating the validity of datum or gage-height correction applications, identifying periods of faulty gage-height data, and estimating discharges for periods of missing record or periods of no stage-discharge relation Rantz et al. (1982b). Figure SOP 7.4 shows a time-series of stage data from Redwood Creek and some of the potential data gaps and errors. In addition, the actual number of data records that might be missing from in the 15-minute record can be identified using the Excel spreadsheet. To do this, the actual number of data records is compared to the expected number. The actual number of stage records saved by the datalogger is counted by highlighting the 'Stage' field, right-clicking the bottom menu bar, and selecting [**Count Nums**]. Figure SOP 7.5 shows a computer screen image of this process. In the case of our WY07 Easkoot Creek dataset, we have 2155 records between October 1, 2006 12:00 am to October 23, 2006 10:30 am. To calculate the expected number of 15-minute records between this time, subtract the last and first date:time fields to obtain the decimal days. Convert the decimal days to number of 15-minute records:

$$EN = TRUNC\left[DD\left(\frac{24\text{hr}}{\text{day}}\right)\left(\frac{60\text{ min}}{1\text{hr}}\right)\left(\frac{1\text{record}}{15\text{min}}\right)\right]$$

where ***EN*** is the expected number of 15-minute records, ***DD*** is the decimal days, and ***TRUNC*** is just an Excel formula that truncates values to an integer. If the expected number of records does not match up with the actual number of records, you probably have some missing records that you need to find and document. Excel's [**Pivot Table**] feature should be used to display the number of 15-minute records per day. Any day with less than 96 records has missing data.

Missing records are documented in two locations: the station's Water Year data file and the annual station report or analyses. Should a substantial portion of a day's record be missing and the stage appears to be rapidly changing, the remaining stage values for that day can be converted to text values. Conversion to text values will prevent mean daily discharge and stage from being calculated from just a few values. In each case of missing data all affected data files, whether they be recorded data or summaries based thereon, should be clearly marked to identify the period of missing data.

In some cases, it may be important to fill in missing data. However, an attempt to fill in missing data should be only made if there are reasonably accurate means available to do so. In some situations, a backup recording streamgage can be used to replace missing or erroneous data. Lacking backup data, linear or non-linear interpolation can provide a good and simple means to fill in a string of missing data. However, this can only be applied to periods of regular rise or fall of the hydrograph (rising or falling limb of storm hydrograph) and is not useful for estimating peak stages. In the case of missing peaks, a thorough field inspection soon after a flood for which data are missing can be instrumental in re-creating a missing storm peak. Often, high water marks (HWM) recorded by crest gages at the streamgage can approximate the peak stage. From

this, a missing hydrograph can be filled in to conform to the HWM data. Note that HWM 'age' rather quickly, so it is important make a field inspection soon after a problem is discovered.

Lacking a reliable HWM, the next best method for synthesizing missing data is to use data from a nearby gage that is similar in basic hydrologic responses to rainfall and had similar rainfall during the subject event. Regression analysis is used to develop a predictive relationship from a period of similar hydrology when both gages were operational (either before or after the period of missing data), then the missing data is filled in with stages predicted by the operational gage using the regression equation. The rationale and procedures for synthesizing data needs to described in the annual Station Analyses report.

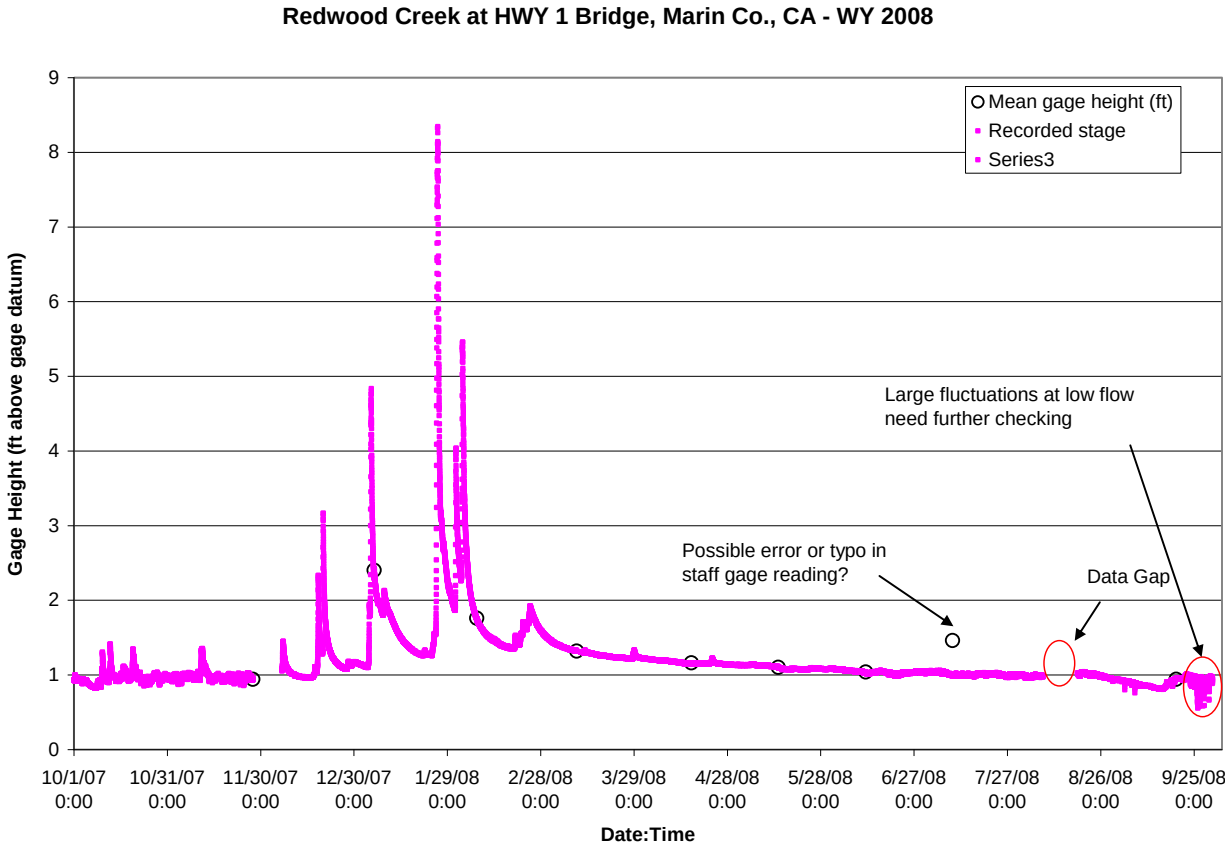


Figure SOP 7.4. Printout of recorded stage data and observed stage for error checking.

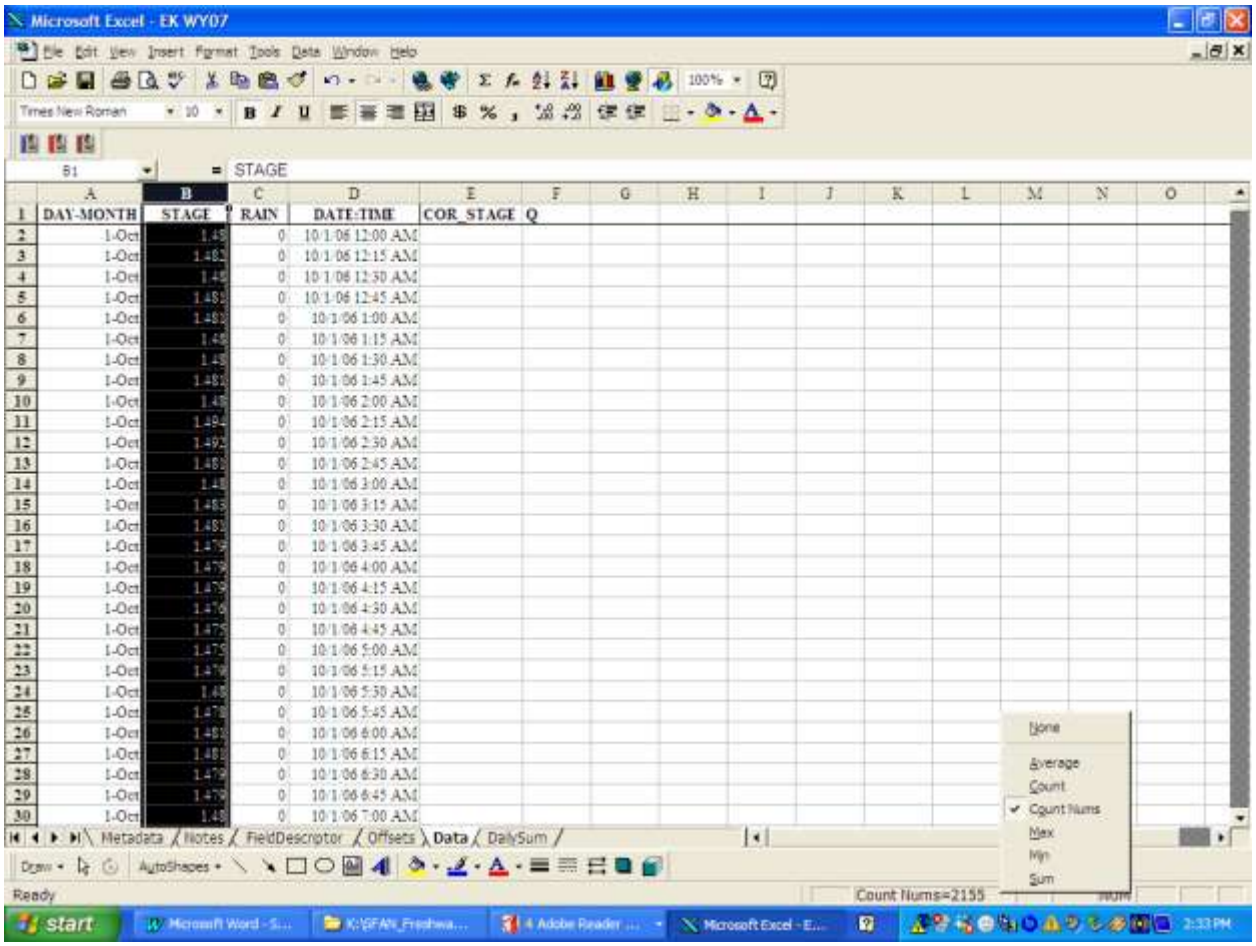


Figure SOP 7.5. Counting stage records in Excel.

If no suitable 'surrogate' gage data are available, and the missing data are of substantial importance in the monitoring program, then other more intensive techniques may be applied, such as rainfall-runoff models that use unit hydrograph or other approaches (see Dunne and Leopold 1978). Simple models can be manually applied while more sophisticated models are better applied using computer software (e.g., HEC-HMS). Only those experienced, or advised by experienced staff, should attempt to apply complex models.

Identifying Erroneous Data: It is extremely important to ensure that electronic stage data are as accurate as possible. Because of the exponential relationship between stage and discharge, small errors in stage result in large errors in estimated discharge. USGS's Office of Surface Water memorandum 93.07 (Boning 1992) notes that a 1 percent error in the effective stage input to the rating would translate into a 3 percent error in the computed discharge.

Once gage height corrections have been applied to the dataset, the preliminary corrected stage data can be checked to identify erroneous data. Peak values for electronic stage data can be compared to observed high marks and crest gage data (Boning 1992). The minimum stage values in the electronic data should also be reviewed for accuracy. Occasionally, negative stage values

may occur due to equipment error or user error (e.g., pulling transducer from piezometer for cleaning and forgetting to accurately document time of actions).

If after initial review the suspect data still appear to be erroneous, the suspected data fields should be deleted and action noted in recorded data files and summary reports. If the data for this period are essential (e.g., occurring during peak storm event), new data can be synthesized using the approach described for missing data. In all cases of corrected data, all affected data files, whether they be recorded data or summaries based thereon, should be clearly marked with notations on the period of corrected data and how that period was dealt with (e.g., the method of correction used and data sources used to assist corrections, who did the corrections and when, and so forth).

Gage-height/stage Corrections: A correction applied to gage-height readings to compensate for differences between the recording gage and the base staff gage is called a "gage-height correction" (Rantz et al. 1982b). Gage height corrections are applied so that the recorded data agree with the base-gage data. In some situations, recording gage heights may represent more accurate information about stream stage than staff gage observations (e.g., surging flows). In these situations, SFAN staff will have to determine whether data corrections are warranted.

Gage-height corrections are generally applied when the gage-height difference between the recording gage and the base gage is equal to or greater than 0.02 ft, or for as small a difference as 0.01 ft when warranted due to low-water conditions when the percent difference from the rating is excessive. The typical gage height correction is associated with sensor drift. Between data downloads the readings from the pressure transducers may "drift," so that they will no longer be in agreement with the base gage (our staff plates). A drift correction—usually a linear proration with time—is applied to compensate for drift in the transducer's offset calibration (Rantz et al. 1982b).

To rectify the difference, calculate the difference between the staff plate and recorded water stage at the beginning and the end of the logging period. If the difference is less than 0.01 ft, there is no need for correction because of the accuracy of staff plate reading is no better than 0.01 ft. The more frequently the staff plate is recorded the better the chance of knowing when the drift began. To correct for drift, the amount of drift must be distributed over the applicable time period by linear interpolation.

Microsoft Excel is used for drift correction. The linear interpolation is calculated for each 15-minute data record and used to correct the raw stage height. An example of how this is calculated in the *Recording Streamgage Spreadsheet* (*Data Worksheet* and *Offset Worksheet*) is found in Figure SOP 7.6.

Any data correction needs to be documented. For SFAN, records of these corrections are stored in the *Measurement and Site Summary Worksheet* (see below).

Datum Conversion: Currently, the corrected water stages are reported as water heights above our gage datum. Many of the gage datums are tied to a local reference mark of an arbitrary elevation and not to a known national vertical datum. Because many of these gages are located

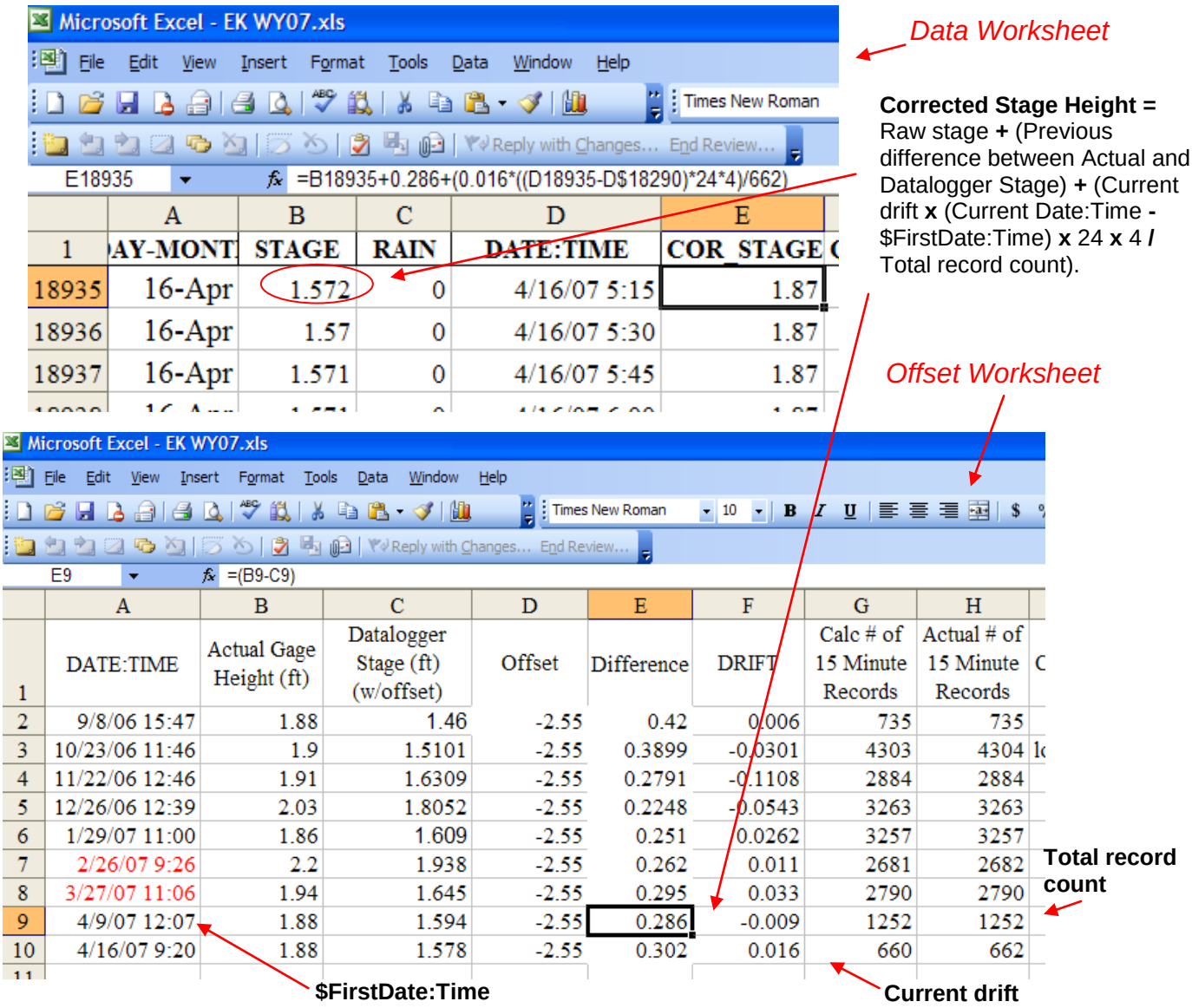


Figure SOP 7.6. Example of drift correction through linear interpolation in the MS Excel *Recording Streamgage* Spreadsheet.

in the active channel, there is a likelihood of losing both the gage and associated reference marks during a flood event. Where possible, it has been strongly recommended that all streamgages be tied to NAVD88 (National Geodetic Vertical Datum) which is also the U.S. Geological Survey's official vertical datum (D.Phil Turnipseed, USGS, pers. comm. 2008). Use of a national vertical datum will allow for long-term comparison of datasets.

Determining Instantaneous Discharge

Once the instantaneous (15-minute) water stage data has been corrected, additional steps are needed to convert water stage data to discharge. These steps include computation of mean gage height, the establishment of stage-discharge relationship, and finally, computation of 15-minute and mean daily discharges.

Computation of Mean Gage Height

Occasionally, discharge measurements are made during periods of stage changes. Under these conditions, the computation of the mean gage height is required and described in detail by Rantz et al. (1982a). When stage changes during the discharge measurement period are small (<0.15 ft) and uniform, the individual gage heights can be averaged. If the change in stage is greater than 0.15 ft (0.05 m) or if the change in stage has not been uniform, the mean gage height is obtained by weighting the gage heights corresponding to the clock-time observations. The SFAN Stream Discharge Database incorporates these guidelines for its computation of mean gage heights.

Establishing Stage-Discharge Relationships

The development of the stage-discharge relation, also called the rating, is one of the principal tasks in computing discharge records. The rating is usually the relation between gage height and discharge (simple rating). Ratings for some special sites involve additional factors, such as rate of change in stage or fall in slope reach (complex ratings) (Kennedy 1983). Procedures for the development, modification, and application of ratings are described in Kennedy (1984), and guidelines pertaining to rating and records computation are presented in Kennedy (1983) and in Rantz et al (1982b).

A rating curve or stage-discharge relationship is then developed from numerous stage and discharge measurements computations made at the site over a range in flows by plotting stage versus discharge (typically gage height in feet versus discharge in cubic feet per second) on log-log paper. The more points, the more precise the rating curve is likely to be. A minimum of 10 per year is recommended initially. However the rating curve may shift over time and periodic measurements are necessary after the first year to either confirm the permanence of the rating or to follow changes/shifts in the rating. In order to be most accurate, it is important that the rating curve include measurements made at flow extremes, under both flood conditions and extreme low flow conditions. Extrapolating values for discharge outside of the range of actual stage/discharge measurements can introduce error.

With the exception of Lobos and Franklin Creeks, all streamgages are located on streams with unstable beds. Stage-discharge relationships, particularly for low and mid-flow conditions, may only be consistent for a few years before changing due to bed conditions. As an example, Stillwater Sciences, a hydrologic consultant firm, evaluated streamflow monitoring data at Redwood Creek and noticed rating shifts under all flow conditions (Figure SOP 7.7). When possible, rating shift adjustments will be applied for short-term departures (e.g., less than 2 months) from current rating curves (Rantz et al. 1982b). New rating curves will be used for long-term shifts for each of the streamgages.

Shifts are identified by graphically examining plots of recent discharge and stage measurements overlain on an existing rating curve. If groups of sequential data points plot to the right or left of the existing rating curve, a shift in the rating has occurred (Rantz et al. 1982b).

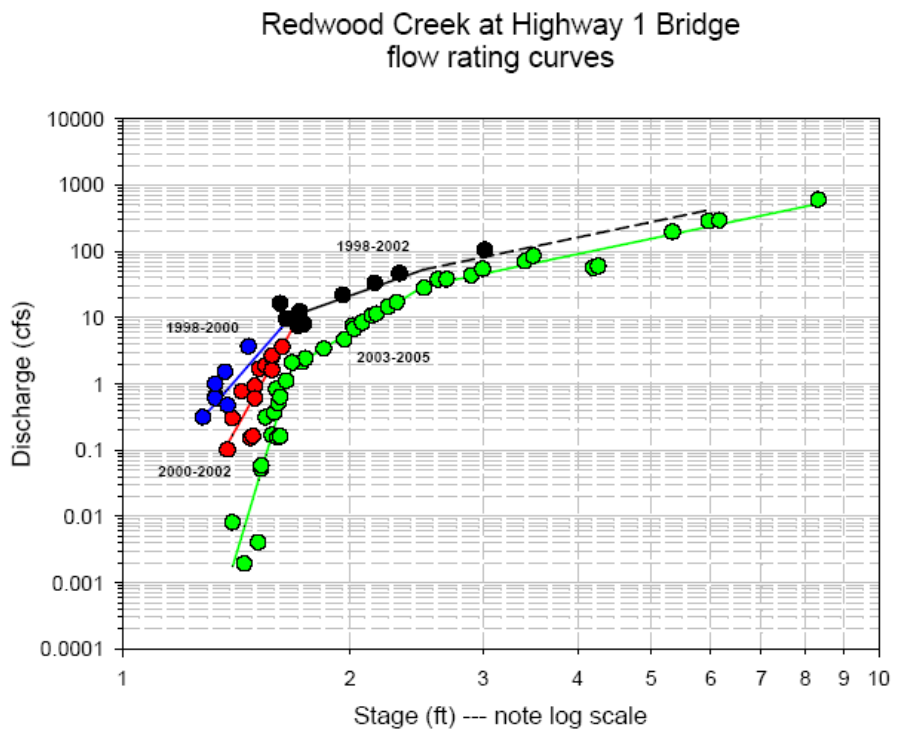


Figure SOP 7.7. Rating shift at the Redwood Creek (GOGA) streamgages (from Stillwater Sciences 2005).

SFAN Guidelines for Stage-Discharge Rating Curves: Commercially available software will be used to create stage-discharge rating curves. NPS Water Resources Division has recommended a software package that has been developed in conjunction with the U.S. Geological Survey and follows their guidance for stage-discharge relationships (Aquarius Rating Curve™). Because of the details involved with use of this software, SFAN staff that will use the Aquarius rating curve software are referred to the software-specific instructions in the manual (Aquatic Informatics 2009). Only the general rating curve guidelines are provided below.

In the past, rating curves were developed for each recording streamgage using a spreadsheet. In this spreadsheet, individual discharge measurements and related gage heights for periods where the stage-discharge relationships have not changed were used to generate equations that related discharge to stage. Use of mathematical and/or statistical methods for defining rating curves, as what we have done in the past, is not recommended, because rating curves are hydraulic functions (Sauer 2002).

Data is prepared for the rating curve software by saving individual discharge measurements for the rating as comma-separated values. The file fields should include date:time, measured discharge, measurement number, measurement quality (the estimated standard error for discharge measurement), mean gage height, and stream condition. All these fields can be exported from the SFAN Stream Discharge Database.

A rating curve or segment of it that plots as a straight line on logarithmic paper can be described by the following equation (Rantz et al. 1982b):

$$Q=p(G-e)^N$$

where Q represents discharge, G represents gage height or water surface elevation, e is gage height at zero flow, p is a constant and N is the slope of the rating curve regression coefficients (Rantz et al. 1982b). An example of a typical rating curve for our program is provided in Figure SOP 7.8. Often segments of the rating curve may be plotted as a straight line on logarithmic paper.

As water levels rise, the relationship between stage and discharge may change. Under low flow conditions, a downstream riffle (section control) may control stage-discharge relationship. At higher flows this riffle may be submerged and a channel control becomes effective. In these situations, the breaks or changes in the slope of the rating curve are determined by examining topographic data for the streamgage and distribution of plotted stage-discharge points. Generally, the slope of the rating curve is greater than 2 for section controls and less than two for overbank or channel controls (Sauer 2002). For each station, the break points will be used to describe the best relationship between stage and discharge for each segment of the rating curve. In the case of Redwood Creek, there are often two break points that delineate different relationships at low, moderate and high flows. The software rating program allows the user to graphically linearize the measurement data in logarithmic scale for each rating segment using offsets. It computes the offset using the Johnson's method (Aquatic Informatics 2009).

As discharge approaches zero, Rantz et al. (1982b) recommend rectilinear plotting of the data because zero cannot be plotted on logarithmic paper. Extreme low flow rating equations require gage height at zero flow. The software program allows the user to develop ratings that are for defined period as well as for changes in the slope of the stage-discharge relationships.

Shifts or gage-height adjustments may be used to account for temporary changes to rating curves, without having to re-define the rating curve (Sauer 2002). Measurements that plot above an existing rating generally indicate aggradation at the control while measurements that plot below indicate degradation or erosion. This program will not have a fixed guideline for applying shifts based on a percent departure of discharge measurements from an existing rating. Shifts will be determined based on consideration of the relative accuracy of the measurements, the number of measurements consistently different from the rating, as well as the percent departure from the rating. For instance, a preponderance of measurements plotting to one side of the rating warrants a shift regardless of the perceived accuracy of the measurements or the relatively small magnitude of the shift (Meyer 1996). The software program allows the user to use USGS-style shift variable diagram to identify the magnitude of the potential shift of selected measurements from the existing rating over a range of stages. The program documents the time period for which a shift is used, the applicable stages, and the person responsible for the shift.

Rating curves for a station will be plotted on log-log paper with separate plots of low-flow sections on a rectilinear scale. By convention, discharge is plotted on the X-axis and stage height on the Y-axis. Individual discharge measurements will be included on the rating curves and the measurement numbers included. An example of a rating curve for an existing station is illustrated in Figure SOP 7.8, with rectilinear rating curve at low flows as an inset.

An evaluation of the predicted and actual discharge measurements can be done to check the suitability of the rating equation at various gage heights. Past ratings have indicated a poor fit between measured discharges and gage heights during the late fall for many SFAN streams under low flow conditions. Assuming that the discharge measurements were accurate, the poor fit may reflect a temporary, shifting control over this period. During late fall, leaf packs often form at the control points of the streamgages, temporarily raising water surface elevations. In this situation, field datasheets should be checked to see if the notes indicate this phenomenon and to make sure that gage height at zero flow had been recorded and entered into the discharge database. Similar problems may also be avoided by more frequent discharge measurements using techniques more sensitive to low flows (e.g., Parshall flume).

Extrapolation of a stage-discharge relation beyond twice the measured discharge at a streamgage is undesirable and possibly unreliable (Rantz et al. 1982b). Data screens will be conducted to flag any derived discharge values that exceed twice the measured discharge used for the stage-discharge rating. Due to program limitations, SFAN staff will not attempt to synthesize discharge measurements using indirect methods to extend the high end of stage-discharge ratings.

Computation of 15-minute and Mean Daily Discharge

Once the stage-discharge relationship has been defined, 15-minute stage data are converted to discharge. The rating software program will be used to output 15-minute derived discharge data based on the inputted stage-discharge relationship and rating curve. The output file is saved in a comma separated value format. This data can then be copied and pasted back into our *Recording Streamgage Spreadsheet*. Mean daily discharge estimates can then be computed using Excel's [**Pivot Table**] feature. The [**Help**] feature on Excel's menu bar provides a good and quick overview of how to use the [**Pivot Table]** for summarizing data.

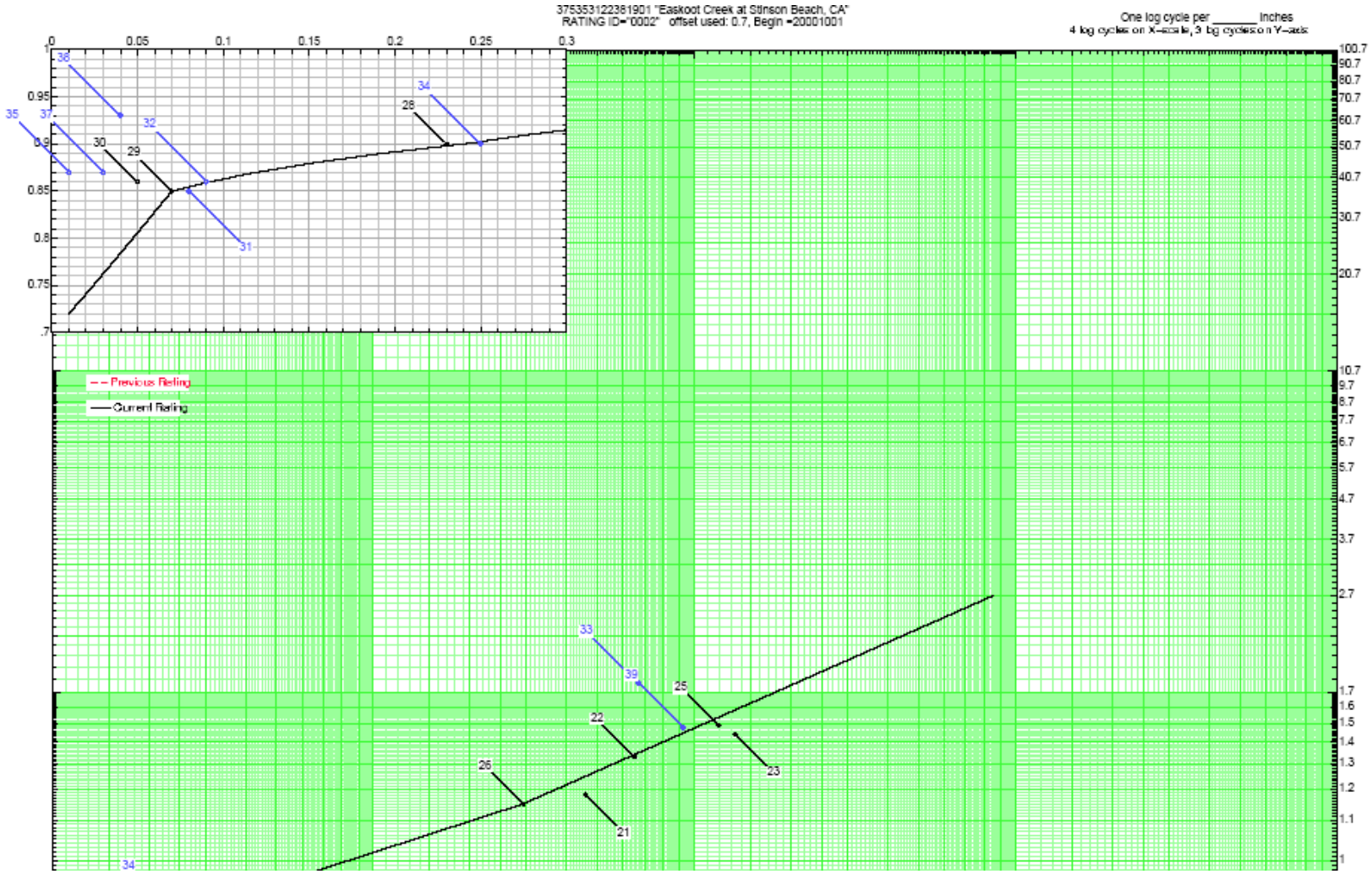


Figure SOP 7.8. Rating curve for Easkoot Creek, Water Year 2001 (from NPS-WRD).

Computation of Discharge Summary Statistics

A variety of discharge summary statistics are necessary to evaluate change over time. These summary statistics have been identified by Richter et al. (1996) as being biologically relevant hydrologic attributes sensitive to hydrologic alterations or attributes used by Lins and Slack (1999, 2005) to document hydrologic responses to climatic changes. These summary statistics are listed in Table SOP 7.5. They will be compiled annually for each Water Year.

Table SOP 7.5. Annual 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 WY (> 75th percentile)	Magnitude/Frequency
Julian date of first high pulse	Timing
Julian date of last high pulse	Timing

Summary statistics based on daily values can be generated in Microsoft Excel or exported to a stand-alone, freeware software, Indicators of Hydrologic Alteration (The Nature Conservancy 2007). Annual quantile streamflow values are computed by ranking the daily mean streamflows and selecting the respective values. 7-, 30- and 90-day mean streamflow duration statistics are computed using moving average procedures (Helsel and Hirsch 2002). The software simplifies many of the calculations such as the moving averages. The current software version imports daily mean values in three different formats; however, the easiest format is the two-field format with the first field being the date values separated by a delimiter (e.g., comma, space) and the second field being mean daily discharge (cfs) (The Nature Conservancy 2007). Output is generated using simple menus for selecting various summary statistics. The single instantaneous maximum values are computed in the spreadsheet program. The annual instantaneous peak streamflows are derived from the single highest recorded stream stage during a given water year (Stogner 2000). A secondary peak flow or pulse is defined using guidelines described by Novak (1985), and are given as follows: "two peaks are considered independent if the hydrograph recedes to a well-defined trough between the peaks. Publish both peaks if the instantaneous

discharge of the trough is equal to or less than 75 percent of the instantaneous discharge of the lower peak; otherwise publish only the higher peak. For small, highly responsive watersheds, only the highest peak discharge resulting from an obvious single storm event should be reported regardless of the trough configuration or magnitude between peaks."

Routine Data Summaries for Annual Report

Once the recording stream gage data have been processed, several routine analyses are performed in order to summarize hydrologic characteristics for each complete water year by station. The data are compiled in annual reports. The hydrologic information specific to each streamgage (abbreviated station descriptions, station analysis, daily values table, hydrograph, rating curves, indicators of hydrologic alteration, and key photographs) will be placed in the appendices and organized by streamgage. These analyses include many of the same summaries used by the USGS, including: 1) annual yield data (acre-feet), 2) minimum, maximum and mean daily discharge, 3) minimum, peak, and mean monthly discharge, and 4) minimum, peak, and mean annual discharge. These data will be presented in Daily Values table in a format similar to USGS's tabular summaries (see Tables SOP 7.6–7).

Annual reports follow the standard content presented in the *Data Management Plan: Appendix C Data Deliverables* (X:\Shared\Standard Operating Procedures). The format follows guidelines prepared by the Natural Resources Production Management program: http://www.nature.nps.gov/publications/nrpm/finalreport.cfm.

Abbreviated Station Description

Because the annual reports are intended to be stand-alone documents, very brief information regarding the streamgages will be provided. These are intended to be one-page or less summaries of the location, watershed area, and equipment for each gaging station. This data will be exported from the Metadata worksheet of *Recording Gaging Station* spreadsheet (Figure SOP 2.20).

Station Analysis

Annual station analysis summaries are prepared that synthesize discharge information including station equipment, description of rating procedures, and recommendations. The station analysis will also include a synthesis of data quality procedures and data quality issues for that water year. The station analysis will include information on whether measurement quality objectives were met for measurement precision, bias, sensitivity, and data completeness (See SOP 9 Quality Assurance Project Plan). The station analysis should include information regarding estimated or synthesized records including the potential cause and explanation of the estimation process. The analysis provides a basis for review and to serve as a reference in case questions arise about the record at some future date (Rantz et al. 1982b). The standardized content for these station analysis summaries is provided by the USGS (Rantz et al. 1982b, Meyer 1996, and USGS 2006). NPS-WRD has provided a template of a standard station analysis (Appendix SOP 7A). We plan on using the same format for our future station analyses.

Daily Values Table

For all recording streamgages, a daily mean discharge value table is prepared for each Water Year (Table SOP 7.6). The table has basic data about the station (e.g., station name and coordinates). It also includes summary information such as annual and monthly yield data above the streamgage (acre-feet), daily, monthly and instantaneous peak discharge values. For

streamgages with tipping rain buckets, an additional daily precipitation table will be prepared in a similar format (Table SOP 7.7).

Indicators of Hydrologic Alteration

Annual summary data that is based on the Nature Conservancy's Indicators of Hydrologic Alteration will also be displayed in tabular form for the annual reports.

Management Triggers

Because the management triggers are related to individual park issues, we felt that it would be appropriate for the parks themselves (as well as their cooperators such as water agencies) to use the provided SFAN data as they see fit. In addition, some of the management triggers require additional data that the individual parks should be responsible for. For instance, Lobos Creek (PRES) has an instream flow trigger downstream of a diversion and downstream from the streamgage. Assessment of any exceedences from this trigger requires stream withdrawal data from the Presidio water treatment plan to be subtracted from mean daily flow. The SFAN intends on providing streamflow data in a timely manner to parks so that they can determine the frequency and magnitude of trigger exceedences for the water year in question.

Hydrographs

A discharge hydrograph is a plot of daily mean discharges (vertical axis) versus time (horizontal axis) (Figure SOP 7.9). Where data are available, daily precipitation information is superimposed on the same graph. All hydrographs are plotted in a consistent format so that a plot for one station can be compared directly to that of another station or another Water Year. Information placed on the hydrograph for each station includes station name, water year, date the hydrograph was plotted, drainage area, plot of daily mean discharge data, plots of measurements, and any other information that may be of importance (USGS 2006). Any estimated discharges may be indicated in red.

Rating Tables and Curves

The development of the stage-discharge relation, also called the rating, is one of the principal tasks in computing discharge record. The annual summary reports will include graphs of rating curves for each streamgage by Water Year on logarithmic scale with insets for rectilinear plots of low flows. The base rating curve should have a rating number, the dates of application, date of rating development and approval, and name(s) of the person(s) responsible for developing and approving each plotted rating (Sauer 2002). The graphs will include the base rating along with any shift curves used for the Water Year. Shift curves can be numbered to match same the integer rating number as the base rating curve, but with decimals to denote their association with the particular rating curve. The rating curves will display all measurements that were used to develop the rating. Measurements will be displayed as open circles and identified by a measurement number (Sauer 2002).

Photographs

Photographs are taken by field personnel for the purpose of documenting important conditions at the streamgage and creek. Photographs that document important conditions (e.g., changes in control, flood conditions, or drought conditions) will be included in the annual report for each streamgage.

Infrequent Data Summaries for Long-term Report

The long-term monitoring objectives will be addressed specifically in the long-term trend reports. The data analyses will naturally focus on our SFAN streams. Explanations of noted trends will be of interest to other vital signs monitoring programs that are strongly linked to streamflow, particularly, the salmonid monitoring effort. In addition, regional and broader geographic scale analyses done by others (e.g., USGS) will serve to determine whether our observed changes are consistent with these broader trends. To facilitate these comparisons, we selected the same data metrics that current peer-reviewed USGS articles have used to analyze hydrologic time series data (e.g., Lins and Slack 1999).

The first long-term report will be initiated in WY2018 and at 10-year intervals thereafter. Trend detection requires long-term datasets. In their evaluation of streamflow trends in the United States, Lins and Slack (1999) analyzed data from stations that had at least 30 years of continuous daily records. 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. Local hydrologic consultants have also indicated that such long-term datasets are also needed to separate out any anthropogenic streamflow influences from changes associated with the influence of El Nino–southern oscillation events. By WY2008, many of the streamgages established by GOGA and PORE will have been in operation for about 10 years and by 2018, a 20-year dataset will be available for analysis.

The long-term report will provide a brief summary of each of the streamgages including any major changes for the period of record. However, detailed accounting of the stations will still be contained in the station summary. The report will include a tabular summary of the annual streamflow summary statistics for the period of record, including the applicable recurrence interval. As an example, annual instantaneous peak flow data and recurrence interval will be summarized as in a similar fashion to this table from REDW (Klein 2005). Supplementary graphics (Table SOP 7.8, Figure SOP 7.10) will be used to describe the log-Pearson Type III frequency distribution analyses needed to estimate the recurrence interval.

The report will also include a summary of trend analyses computed for the various summary statistics (see below) as well as flow duration and low-flow and flood frequency analyses (see below). Significant departures from normal conditions will result in identification of potential causative factors.

Assessing Long-term Trends in Discharge Estimates

This section will demonstrate analyses that will address the first monitoring objective:

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 in GOGA, JOMU, PRES, PINN, and PORE.

As described in the protocol narrative, trend analyses will be used to determine whether a significant change has occurred in the identified hydrologic summary statistics (e.g., annual instantaneous peak streamflow) (Table 3, protocol narrative). These 20 hydrologic summary

statistics have been identified by the Nature Conservancy as being good indicators of hydrologic alteration (Richter et al 1997).

Trend analyses of streamflow data are difficult. A variety of approaches have been done, depending upon interests. The Nature Conservancy, because of its interest in teasing out anthropogenic responses, breaks datasets into pre- and post- impact groups and tests whether the central tendency of the pre- and post-impact hydrologic parameter is significantly different (Richter et al 1996). USGS researchers often use a non-parametric trend test for entire streamflow datasets (Lins and Slack 2005). Finally, others stratify hydrologic parameters based on water year types before data analyses (e.g., critically dry, dry, normal, wet, extremely wet years; McBain and Trush 2007). This stratification removes some of the influence of climatic changes in detecting trends.

Our assessment of change will use a stratified analysis of data. In most cases, we will not be able to parse SFAN streamflow datasets into pre- and post- impact groups with any certainty. So, it would not be appropriate to use The Nature Conservancy data analysis approach. Therefore, we propose to use long-term precipitation records near streamgages to group water year datasets into "dry," "normal," and "wet" categories on an equal percentile basis. The precipitation datasets will be at least 50 or more years in length.

Table SOP 7.6. 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 STREAM SOURCE
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 WATER YEAR 2000
HIGHEST DAILY MEAN 65 Feb 13 2000
LOWEST DAILY MEAN 0.01 Oct 17 2000
ANNUAL SEVEN-DAY MINIMUM 0.01 Oct 01 2000
INSTANTANEOUS PEAK FLOW 108 Feb 13 2000 1930 hr
INSTANTANEOUS PEAK STAGE 2.40 Feb 13 2000 1930 hr
INSTANTANEOUS LOW FLOW 0.01 Oct 17 0000 1230 hr

Table SOP 7.7. Daily rainfall (Example).

UNITED STATES DEPARTMENT OF THE INTERIOR - NATIONAL PARK SERVICE – GOLDEN GATE NATIONAL RECREATION AREA
Easkoot Creek Below Entrance Station RoadWater Year 2006Daily 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	1.1	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	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	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.

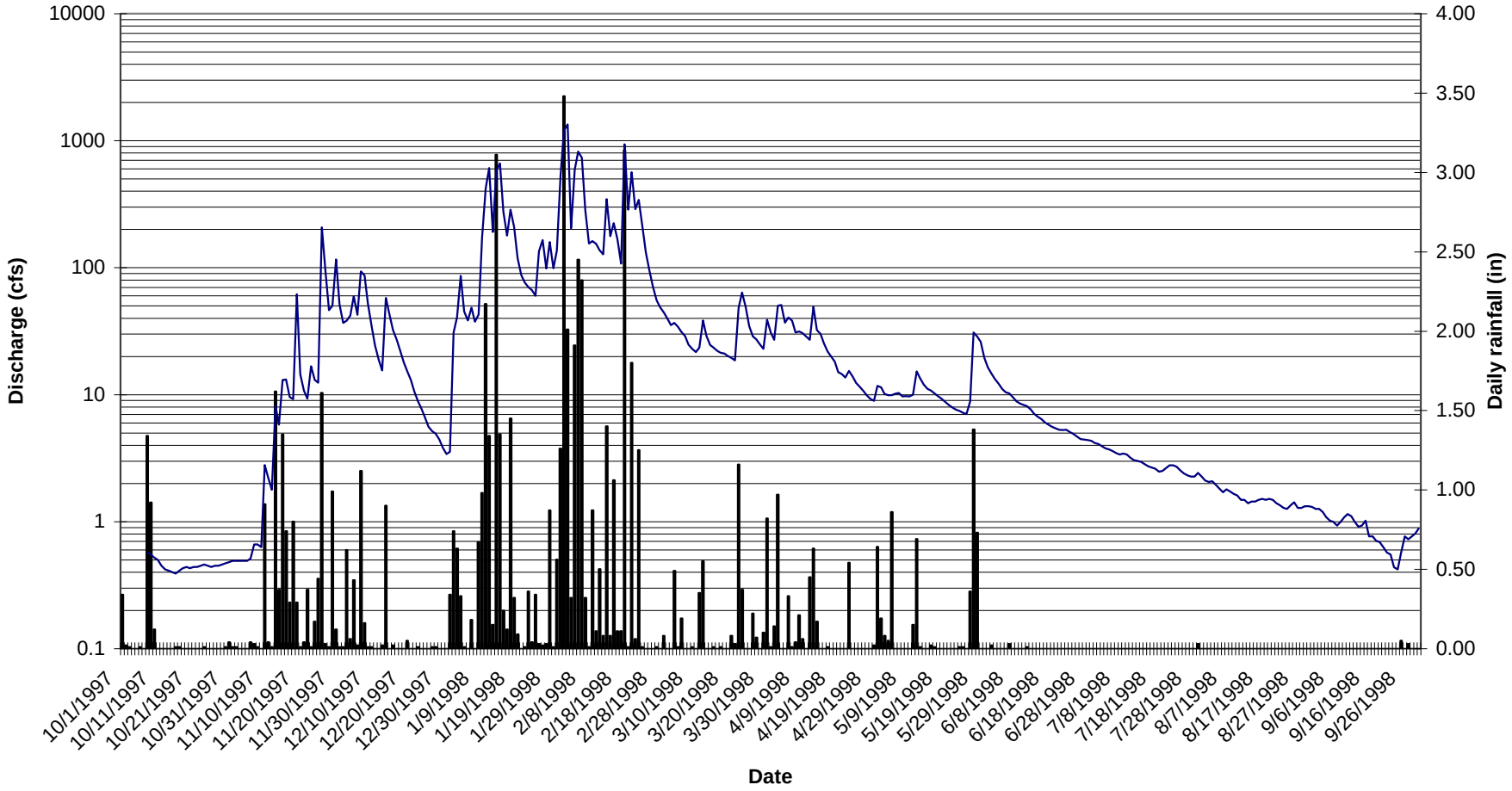


Figure SOP 7.9. Mean daily discharge and rainfall for Olema Creek at Bear Valley Bridge, Marin Co., CA. Water Year 1998 (Example).

Table SOP 7.8. Annual peak discharges and recurrence intervals (RI) for Little Lost Man Creek (LLM), Prairie Creek above Brown Creek (PRU), and Prairie Creek above May Creek (PRW) (from Klein 2005). (Note: peak discharge for LLM for WY2003 is preliminary and may change substantially upon final analysis; blank cells indicate no data available.)

	LLM			**PRU**			**PRW**		
WY	cfs	cfs/mi^2	RI (yrs)	cfs	cfs/mi^2	RI (yrs)	cfs	cfs/mi^2	RI (yrs)
1975	808	234	9.0						
1976	165	48	1.4						
1977	88	25	1.1						
1978	391	113	2.7						
1979	177	51	1.4						
1980	230	66	1.7						
1981	240	69	1.7				531	42	1.7
1982	486	140	3.6				766	61	2.6
1983							1315	104	6.5
1984							1426	113	7.9
1985	252	73	1.8				683	54	2.2
1986	787	227	8.5				994	79	3.8
1987	76	22	1.1				208	17	1.0
1988	301	87	2.1				664	53	2.2
1989	471	136	3.4				595	47	1.9
1990				93	23	1.1	300	24	1.2
1991				153	38	1.6	261	21	1.1
1992				125	31	1.4	241	19	1.1
1993	143	41	1.3	169	42	1.8	451	36	1.5
1994	102	29	1.2	113	28	1.3	307	24	1.2
1995	370	107	2.5	241	59	3.0	773	61	2.6
1996	393	114	2.7	346	85	6.2	1404	111	7.6
1997	639	185	5.5	348	86	6.3	1767	140	14.1
1998	382	110	2.6	234	58	2.9	887	70	3.2
1999	987	285	15.8	313	77	5.0	1336	106	6.8
2000	328	95	2.2	332	82	5.7	687	55	2.2
2001	33	10	1.0	29	7	0.7	90	7	0.8
2002	294	85	2.0	205	50	2.4	880	70	3.1
2003	*912*	264	12.2	239	59	3.0	1220	97	5.6
2004	510	147	3.8	245	60	2.60	1815	144	

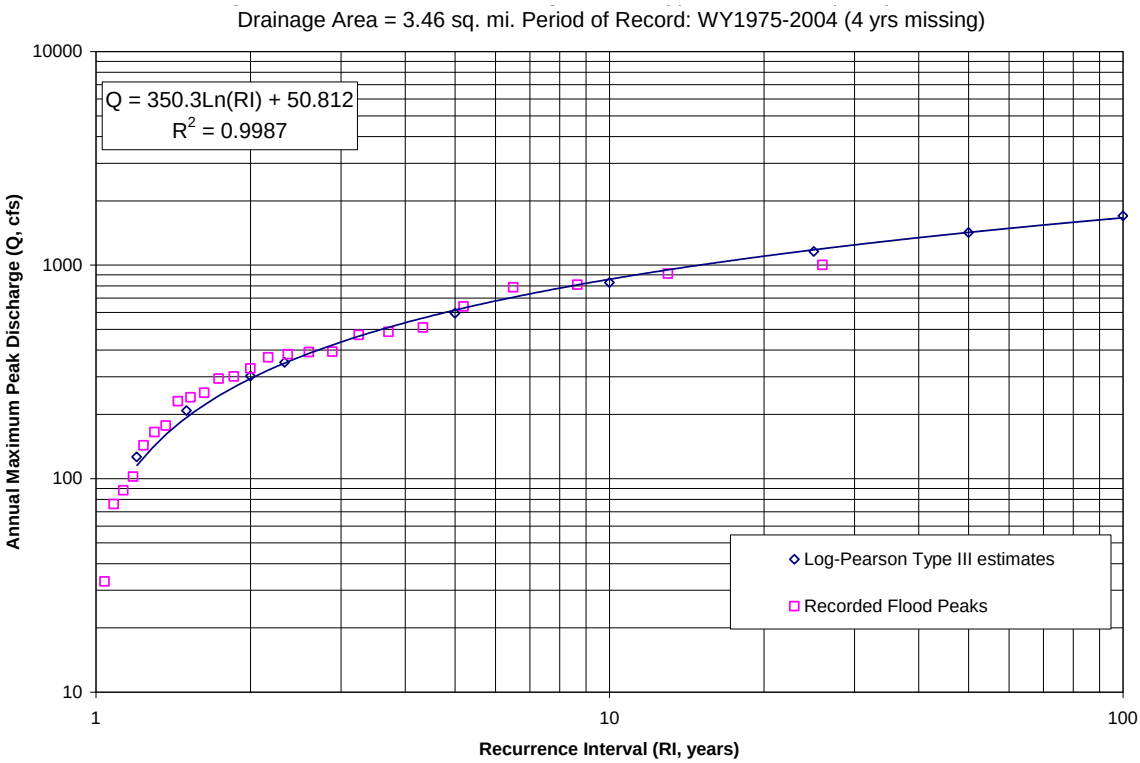


Figure SOP 7.10. Little Lost Man Creek, log-Pearson type III flood-frequency distribution (from Klein 2005).

Within these precipitation categories, analysis of parameters will involve use of the non-parametric Mann-Kendall trend test (Helsel and Hirsch 2002; Fenelon and Moreo 2002). The Mann-Kendall method is a nonparametric trend test that determines whether a statistically significant upward or downward change in water level or discharge parameter has occurred over the period of record. The method does not imply anything about the magnitude of the change or whether the change is linear (Fenelon and Moreo 2002). It is a rank-based procedure, resistant to the influence of extremes, outliers, and good for use with skewed variables and monotonic data. When a dependent variable (e.g., discharge or water level) generally increases or decreases as the independent variable (e.g., time) progresses, the two variables are said to possess a monotonic correlation (Helsel and Hirsch 2002). No assumption of normality is required although there must not be any serial correlation for the resulting p-values to be correct (Helsel and Hirsch 2002; Hirsch et al. 1993). These characteristics make it particularly appropriate for use with streamflow data sampled up to one year apart.

The paired data (e.g., time and discharge) are ordered from oldest to most current. Each dependent variable is compared to all subsequent data values. The initial value of the Mann-Kendall statistic, *S*, is assumed to be 0 (*e.g.*, no trend). If a data value from a later time period is higher than a data value from an earlier time period, *S* is increased by 1. On the other hand, if the data value from a later time period is lower than a data value sampled earlier, S is decreased by 1. The net summation of all such increments and decrements yields the final value of *S*.

Let *n* represent the total number of data points while *x* represents the variable of interest (e.g., discharge). Then the Mann-Kendall statistic (*S*) is given by:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \mathrm{sgn}(x_j - x_k),$$

where x_j and x_k are the annual values in years j and k, $j > k$, respectively, and

$$\mathrm{sgn}(x_j - x_k) = \begin{cases} 1 & \text{if } x_j - x_k > 0 \\ 0 & \text{if } x_j - x_k = 0 \\ -1 & \text{if } x_j - x_k < 0 \end{cases}.$$

(from Salmi et al. 2002).

A very high positive value of *S* is an indicator of an increasing trend, and a very low negative value indicates a decreasing trend. However, it is necessary to compute the probability associated with *S* and the sample size, n, to statistically quantify the significance of the trend.

For our purposes, $\alpha = 0.05$ and significant trends will be identified when p-values are less than this value (Helsel and Hirsch 2002). For situations where n is 9 or less, the absolute value of *S* is compared directly to the theoretical distribution of *S* derived by Mann and Kendall for a two-tailed test (Salmi et al. 2002). If n is equaled to 10 or more, the normal approximation test is used (Salmi et al. 2002). The calculations for these tests can be done using an Excel template (file name MAKESENS_1_0.xls) designed by Salmi et al. (2002).

Should significant trends in any of these streamflow summary statistics be identified, the network program will work with individual Parks to try to identify possible changes in stream condition and causative factors, particularly if adverse management activities are a possible cause. As an example, John Muir NHS is located in a watershed (Franklin Creek) that may be subject to increased urban development pressures in the future. A significant increasing trend in annual instantaneous peak streamflow will trigger an assessment of stream condition (e.g., is there more channel incision or overbank flooding or BLM's Proper Functioning Condition) followed by discussion of management options

Flood or Low-Flow Analyses

This section will demonstrate analyses to meet the second and third monitoring objectives:

> 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 in GOGA, JOMU, 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 at GOGA, PORE, and PINN.

Flood and Low Flow Frequency: The flood frequency analyses allow hydrologists to assess the probability of a certain size of flood or greater occurring in any year. Similarly, the probability of a low-flow event of a certain size may also be assessed using similar methods. Both analyses require sufficiently long datasets to provide meaningful information. Riggs (1982) notes that less than 10 annual events are inadequate to define a relation of better than 0.8 correlation with the concurrent part of a longer record.

The Weibull's formula is used to calculate the return period (or recurrence interval) and probability of occurrence (Linsley et al. 1982) where $p = \frac{m}{n+1}$ and p = probability, n is the number of years of record and m is the rank of the event in order of magnitude. The recurrence interval or return period is the number of years within which a flood or low-flow event of a given magnitude is likely to occur. It is calculated as the inverse of p. For flood frequency analyses, the largest event is assigned rank of 1. For low-flow analyses, the smallest event is assigned rank of 1 (Riggs 1982). Once the data is assembled, frequency distributions can be fitted to the data by assuming a theoretical frequency distribution. In the United States, the log-Pearson Type III distribution has been most frequently used to describe flood and low-flow frequencies (Linsley et al. 1982, Riggs 1982). Specific procedures for fitting a frequency curve are also found in Linsley et al. (1982) and Riggs (1982).

In the examples used by Riggs (1982), the shape of the low-flow frequency curve as well as the presence of extreme outliers can be used to identify potential departures from normal conditions. Typical fitted low flow frequency curves for streams that do not go dry are smooth and concave upward on log-Gumbel plots.

Flow Duration: A flow-duration curve is a semi-logarithmic plot of discharge versus the percentage of the time in a given year that a given discharge is equaled or exceeded. If the curve has an overall steep slope, the catchment has a large amount of direct runoff. If the curve is relatively flat, there is substantial storage within the catchment, either as surface or groundwater (Morisawa 1968). Flow duration analyses can be conducted on, at a minimum, a single year's worth of average daily discharge data, but the data must be complete (e.g., no missing values). Thus where segments of missing or unreliable data exist, those records must be synthesized for flow duration analyses to be performed. Methods to be followed for analyzing flow duration (exceedence probabilities) and flood recurrence intervals (flood frequency analyses) are described in Dunne and Leopold (1978) and Linsley et al. (1982). Analyses can be easily completed using Microsoft Excel.

Station Descriptions

Station descriptions provide a living overview of the streamgage from operational logistics to measured parameters. A full description of each streamgage is provided in SOP 3 Stream Gage Station Descriptions. An abbreviated version of the station descriptions is also provided in the 'Metadata' worksheet of the *Recording Streamgage* spreadsheet that contains the 15-minute data for individual streamgage by WY. Until a sufficiently long dataset is acquired (about 20 years), one data field, "floods" will be estimated using regional regression equations. The regression equations used for our stations are for estimating peak discharges (Q_T) having recurrence

intervals T that range from 2 to 100 years (Ries and Crouse 2002; Jennings et al. 1994). The explanatory basin variables used in the equations are drainage area (A), in square miles; mean annual precipitation (P), in inches; and an altitude index (H), which is the average of altitudes in thousands of feet at points along the main channel at 10 percent, and 85 percent of the distances from the site to the divide. We determined distance along the main channel and longest tributary by screen digitizing at 1:24,000 scale. Drainage areas are computed using the ArcHydro data model for ArcMap (GIS software). H is determined from topographic maps. Mean annual precipitation (P) is determined from digital isohyetal data derived from Rantz (1969). The regression equations were developed from peak-discharge records of 10 years or longer, available as of 1975, at more than 700 streamgages throughout California (Jennings et al. 1994). The regression equations are applicable to unregulated streams. The standard errors of estimate for the regression equations for various recurrence intervals and regions range from 60 to over 100 percent.

Literature Cited

Aquatic Informatics Inc. 2009. Aquarius time-series software help manual. Release 2.4. 377 p.

Boning, C. W. 1992. Policy statement on stage accuracy. USGS Office of Surface Water Technical Memorandum No. 93.07. 1992 December 4. Washington, D.C.

Dunne, T., and Leopold, L. B. 1978. Water in environmental planning. WH Freeman and Company, San Francisco, California.

Fenelon, J. M., and M. T. Moreo. 2002. Trend analysis of ground-water levels and spring discharge in the Yucca Mountain region, Nevada and California, 1960–2000, Water-Resources Investigations Report 02-4178. U.S. Geological Survey, Denver Federal Center, Denver, Colorado. Online. (http://pubs.usgs.gov/wri/wrir024178/). Accessed 24 March 2010.

Helsel, D. R., and R. M. Hirsch. 2002. Statistical methods in water resources. Chapter A3 *in* Techniques of water-resources investigations of the United States Geological Survey. Book 4. U.S. Geological Survey, Washington. D.C. Online. (http://www.ecy.wa.gov/programs/eap/models/usgs_twri.html). Accessed 30 March 2010.

Hirsch, R. M., D. R. Helsel, T. A. Cohn, and E .J. Gilroy. 1993. Statistical analysis of hydrologic data. Pages 17.1–17.55 *in* D. R. Maidment, editor. Handbook of hydrology. McGraw-Hill, Inc.

Huh, S., D. A. Dickey, M. R. Meador, and K. E. Ruhl. 2005. Temporal analysis of the frequency and duration of low and high streamflow: years of record needed to characterize streamflow variability. Journal of Hydrology 310:78–94.

Jennings, M. E., W. O. Thomas, Jr., and H. C. Riggs. 1994. Nationwide summary of U.S. Geological Survey regression equations for estimating magnitude and frequency of floods for ungaged sites, 1993, U.S. Geological Survey Water Resources Investigation Report 94-4002. (http://onlinepubs.er.usgs.gov/djvu/WRI/wrir_94_4002.djvu). Accessed 24 March 2010.

Kennedy, E. J. 1983. Computation of continuous records of streamflow. Chapter A13 *in* Techniques of water-resources investigations of the United States Geological Survey. Book 3. U.S. Geological Survey, Washington. D.C. Online. (http://www.ecy.wa.gov/programs/eap/models/usgs_twri.html). Accessed 30 March 2010.

Kennedy, E. J. 1984. Discharge ratings at gaging stations. Chapter A10 *in* Techniques of water-resources investigations of the United States Geological Survey. Book 3. U.S. Geological Survey, Washington. D.C. Online. (http://www.ecy.wa.gov/programs/eap/models/usgs_twri.html). Accessed 30 March 2010.

Klein, R. 2005. Rainfall, streamflow, turbidity, and suspended sediment yield in the Redwood Creek watershed. A progress report on Redwood National and State Park's hydrologic monitoring program. Unpublished report. 22 pp.

Leopold, L. B. 1997. Rainfall and stage data needed: Napa River Basin instructions for construction of a wire weight gage, for recording data, for measuring stream velocity with floats, and for analysis of these data. Unpublished Report.

Lins, H. F., and J. R. Slack. 1999. Streamflow trends in the United States. Geophysical Research Letters 26(2):227–230. (http://water.usgs.gov/osw/lins/streamflowtrends.html) Accessed 24 March 2010.

Lins, H. F., and J. R. Slack. 2005. Seasonal and regional characteristics of U.S. streamflow trends in the United States from 1940 to 1999. Physical Geography 26(6):489–501.

Linsley, R. K., M. A. Kohler, and J. L. H. Paulhus. 1982. Hydrology for engineers. Third edition. McGraw-Hill, New York.

McBain and Trush, Inc. 2007. Pulse flow guidelines: Managing the annual snowmelt hydrograph and winter floods in regulated boulder-bedrock Sierra Nevada rivers. Report prepared for the California Energy Commission-Public Interest Energy Research Program.

Meyer, R. W. 1996. Surface-water quality-assurance plan for the California district of the U.S. Geological Survey. Open-File Report 96-618. U.S. Geological Survey, Sacramento, California.

Novak, C. E. 1985. WRD data reports preparation guide: U.S. Geological Survey Open-File Report 85–480. U.S. Geological Survey, Reston, Virginia.

Rantz, S. E. 1969. Mean annual precipitation in the California region: U.S. Geological Survey Open-File Map (Reprinted 1972, 1975). [Digital isohyetal precipitation data covering the period 1900–1960 from California Department of Forestry and Fire Protection.]

Rantz, S. E., et al. 1982a. Measurement of stage and discharge. Volume 1 *in* Measurement and computation of streamflow. U.S. Geological Survey Water-Supply Paper 2175. U.S. Government Printing Office, Washington, D.C.

Rantz, S. E., et al. 1982b. Computation of discharge. Volume 2 *in* Measurement and computation of streamflow. U.S. Geological Survey Water-Supply Paper 2175. U.S. Government Printing Office, Washington, D.C.

Richter B. D., J. V. Baumgartner, J. Powell, and D. P. Braun. 1996. A method for assessing hydrologic alteration within ecosystems. Conservation Biology 10:1163–1174.

Richter, B. D., J. V. Baumgartner, R. Wigington, and D. P. Braun. 1997. How much water does a river need? Freshwater Biology 37**:**231–249.

Ries, K. G., and M. Y. Crouse. 2002. The national flood frequency program: A computer program for estimating magnitude and frequency of floods for ungaged sites. Version 3. U.S.

Geological Survey Water-Resources Investigations Report 02-4168. U.S. Geological Survey, Washington, D.C.

Riggs, H. C. 1982. Low-flow investigations. Chapter B1 in Techniques of water-resources investigations of the United States Geological Survey. Book 4. U.S. Geological Survey, Washington, D.C. Online. (http://www.ecy.wa.gov/programs/eap/models/usgs_twri.html). Accessed 30 March 2010.

Salmi, T., A. Maatta, P. Anttila, T. Ruoho-Airola, and T. Amnell. 2002. Detecting trends of annual values of atmospheric pollutants by the Mann-Kendall test and Sen's slope estimates-the Excel template application MAKESENS. Finnish Meteorological Institute Publications on Air Quality No. 31, Helsinki. 35 pp.

Sauer, V. B. 2002. Standards for the analysis and processing of surface-water data and information suing electronic methods. U.S. Geological Survey Water-Resources Investigations Report 01-4044.

Stogner, R. W. 2000. Trends in precipitation and streamflow and changes in stream morphology in the fountain Creek watershed, Colorado, 1939–1999. U.S. Geological Survey, Water-Resources Investigations Report 00-4130. U.S. Geological Survey, Washington, D.C.

The Nature Conservancy. 2007. Indicators of hydrologic alteration. Version 7 user's manual. Arlington, Virginia.

[USGS]United States Geological Survey. 2006. Guidelines for the collection, preparation, and standardization of streamflow data. USGS Unpublished Report, Washington, D.C.Wager, R. J., R. W. Boulger, Jr., C. J. Oblinger, and B. A. Smith. 2006. Guidelines and standard procedures for continuous water-quality monitors; station operation, record computation, and data reporting. U.S. Geological Survey Techniques and Methods Report 1-D3. U.S. Geological Survey, Reston, Virginia. Online. (http://pubs.usgs.gov/tm/2006/tm1D3/). Accessed 23 March 2010.

Appendix SOP 7A. Example Station Analysis (from NPS-WRD)

SURFACE WATER STATION ANALYSIS – WATER YEAR XXXX
STATION NAME – STATION NUMBER
FULL PARK NAME

Prepared by:_____ Date:_____
Reviewed by: _____Date:_____
Reviewed by: _____Date:_____
Approved by:_____Date:_____

Equipment

- Short description of equipment (type of gage [transducer, bubbler or float], recorder, etc.)
- Artificial control (if any)
- Calibration Parameters (sensor ratings with offsets – slope and time interval)
- Report equipment changes that may affect accuracy of record
- Review station description and revise if necessary. Include the statement, "Equipment conforms to station description data….".

Hydrologic Conditions

- Describe changes that might affect runoff regime (i.e. fire, urban development, logging, road building operations, weather, and seismic events). Provide date and extent of effect.
- Note if no changes occurred in current year

Gage Height Record

- Completeness of gage height record for water year
- List periods of missing record, cause and corrections.
- Discuss instrument errors and if corrected

Data and Datum Corrections

- Brief summary of data and datum corrections. Information will be contained in a site visit summary table

National Park Service, SFAN Inventory and Monitoring Program — REDWOOD CREEK at HWY ONE SITE VISIT SUMMARY - WY 2009

DATE TIME (PST)	Minus #	Reading	Observer's Name	Staff Gage Height (ft)	Gage Pool Descript or*	Datalogger Gage Height (ft)	Differ (ft)	Drift (ft)	Datum Corr (ft)	Office GH Corr (ft)	Field GH Corr (ft)	Q (cfs)		Calc 15-min records	Actual 15-min records	Actual H20 Temp	Work performed	Data comments
8 26 08 11:38				0.99		1.322	-0.3320			-0.31								
9 19 08 7:30			Darren Fong	0.94	pool	1.268	-0.3280	0.0040	0.4600	-0.32	0	0.00		2287			Downloaded logger, measur	Fixed data correction value of -0.32. Mea
10 2 08 11:24			Jennie Skanc	0.96	pool	1.283	-0.3234	0.0046	0.4600	-0.32	0	0.00		1263	1236		Downloaded logger twice, h	Fixed data correction value of -0.32. Dat
11 6 08 12:43			Jennie Skanc	1.08	flow	1.108	-0.0278	0.2956	0.4600	0	0	0.72		3365	1879		dl logger, take flow with pr	Data gaps and suspect data from Oct 12 th
11 25 08 13:41			Darren Fong	1.08	flow	1.281	-0.2009	-0.1731	0.4600	0	0	-		1827	632		Downloaded logger, upload	Data gaps and suspect data for period.
11 26 08 10:29			Darren Fong	1.095	flow	1.284	-0.1890	0.0619	0.4600	0	0			83	10		Downloaded loggeR.	Data gaps and suspect data for period.
12 5 08 11:50			Darren Fong	1.105	flow	1.293	-0.1880	-0.0490	0.4600	0	0			869	425		Downloaded loggeR.	Data gaps and suspect data for period. Use
12 8 08 15:24			Jennie Skanc	1.12	flow	1.474	-0.3541	-0.1661	0.4600	-0.3541	0.0000			302	302		Downloaded logger.	Used fixed data correction value of -0.354
12 13 08 16:02			Darren Fong	1.11	flow	1.465	-0.3550	-0.0009	0.4600	-0.3541	0.0000			482	480		Downloaded logger. Cleane	No real time values. Used 15-minute reco
12 13 08 16:40			Darren Fong	1.115	flow	1.141	-0.0260	0.3290	0.4600	-0.0260	0.0000			2	0			Time-prorated office data correction valu
12 31 08 11:25			Darren Fong	1.1	flow	1.124	-0.0240	0.0020	0.4600	-0.0260	0.0000			1707	1706			Time-prorated office data correction of -0
12 31 08 13:47			Darren Fong	1.1	flow	0.473	0.6268	0.6508	0.4600	0.6268	0.0000			9	9			Fixed office data correction of 0.6268. R
2 10 09 16:05			Darren Fong	1.17	flow	0.537	0.6332	0.0063	0.4600	0.6268	0.0000			3845	3845		Downloaded dataloggers	Fixed office data correction of 0.6268. R
2 11 09 10:09			Jennie Skanc	1.31	flow	1.288	0.0220	-0.6112	0.4600	0.0000	0.0220			72	72		Downloaded dataloggers	Then- and tell download. Field data correct
3 20 09 15:38			Darren Fong	1.51	flow	1.506	0.0040	-0.0180	0.4600	0.0000	0.0000			3573	3646		Downloaded dataloggers	Recorded stage values and temp from In-Si
6 10 09 13:05			Jennie Skanc	1.34	flow	1.339	0.0010	-0.0030	0.4600	0.0000	0.0000			7861			Downloaded the In-situ	Stage and temp values from In-Situ. Delet
6 12 09 13:05			J.Skancke, D	1.33	flow	1.330	0.0000	-0.0010	0.4600	0.0000	0.0000			192			Downloaded the Campbell	Restarted a new log file for the In-Situ wit
7 22 09 11:17			J.Skancke,	1.27	flow	1.267	0.003	0.0030	0.4600	0.0000	0.0000			3832		14.3	dl the Insitu and Campbell	The Insitu datalog now reads PDT so adju
8 12 09 11:50			J.Skancke,	1.25	flow	1.256	-0.006	-0.0090	0.4600	0.0000	0.0000			2016			dl the insitu and the hobo raingage	
9 9 09 12:05			Jskancke	1.2	Flow	1.218	-0.018	-0.0120	0.4600	0.0000	0.0180			2690		14	dl insitu and campbell. Take flow w	wing walls and marshorthorney
10 8 09 9:00			Jskancke	1.22	flow									2776			dl both gages	

Level Surveys

- Dates for level surveys. Explain if no levels for water year.
- Summary of changes in primary control points (RM's, RP's, staff plates, and stilling wells).

Channel and Control

- Description of control and type at various stages. For example: *Stage-discharge rating control at low to moderate flows is a riffle 75' downstream of the gage transect. Riffle is predominately gravel-cobble, with a scour-fill cycle typically beginning with spring runoff and lasting until early summer. Stage-discharge is channel controlled at a stage of about 3.42, when well vegetated banks (willow and alder) are inundated.*
- Summarize measurements of low point on section controls and calculated GZF's. Quality depends on length of record, number of discharge measurements, surveys, and paired observations of sensor and staff plate readings.

Discharge and Rating

- Total number of discharge measurements with their respective numbers and range of discharge. For example: Ten discharge measurements (numbers 35-44) were made ranging from 42.8 cfs (no. 44) to 437 cfs (no. 36).
- Rating used. If a new rating was developed, give reasons why. Explain (individually or by groups) how measurements plotted with respect to the rating. Explain reasons for any significant deviations (> t5% in the abscissa or discharge axis).
- Additional information necessary to help a reviewer understand rating.
- Ratings (number) and types of shift adjustments used by period. Include a shift table for those periods when a shift curve was applied to the gage height record. An example shift table follows:

Rating STGQ # 0002

SHIFT CURVES
10/01/2006 - 09/30/2007
DD 6, Discharge (cfs)

	STARTS	ENDS	INPUT	SHIFT	INPUT	SHIFT	INPUT	SHIF
PRV:	10/23/2006 09:38:00 PST transition from 0.00 shift to 2007 shift		1.40	0.00	2.50	0.00		
1	10/23/2006 09:38:00 PST transition from 0.00 shift to 2007 shift		1.40	0.00	2.50	0.00		
2	12/26/2006 11:06:00 PST 2007 fill post 12/2006 event		1.78	-0.14	2.22	-0.05	2.50	0.(

Special Computations

- Periods requiring special computations
- Describe special computation/s
- List stations used for hydrographic comparison (quality assurance, reconstructing missing record, or adjusting questionable record).

Water Quality

- Water quality parameters (water temperature, pH, conductivity, etc.) collected with gage height
- Summarize data and include location of collection points in relation to the gage
- Report interval and completeness of record

Maximum and Minimum

- Description of instantaneous and mean daily max/min stage and discharge for current year determined from the End of Year Summary. The description can be written or in table format. The description should include the maximum and minimum instantaneous and mean daily stage and discharge. The number of days or date the maximum and minimums occurred must accompany the stage and discharge values.

Examples:

- ✓ Maximum instantaneous depth below land surface is 354.83 ft on 09/20/2004. Maximum mean daily computed depth below land surface is 354.83 ft on 09/21/2004.

- ✓ Table of Maximum and Minimum Discharge and Stage

	Water Year 2002	
	Date / Time	Value
Maximum Instantaneous Discharge	09/07/2002 at 19:00:00	3.0 cfs
Minimum Instantaneous Discharge	Many	1.7 cfs
Maximum Instantaneous Stage	09/07/2002 at 19:00:00	0.90 feet
Minimum Instantaneous Stage	08/09/2002 at 16:00:00	0.75 feet

- ✓ Table of instantaneous mean, maximum and minimum discharge and gage heights for CY 2004 are listed below.

	TIME	Discharge		Gage height	
DATE	HH MM SS	(CFS)	(CMS)	(FT)	(M)
MAXIMUM INSTANTANEOUS					
11/26/2004	03:15:00	0.50	0.01	0.64	0.20
MINIMUM INSTANTANEOUS					
Various*		0.40	0.01	0.56	0.17

*There were 119 days out of a total of 365 days that had this same minimum instantaneous value.
See the complete record in the 2004 calendar year folder, Section 6- End of Year Summary.

MAXIMUM DAILY Discharge					
Various*		0.45	0.01		

*There were 83 days out of a total of 365 days that had this same maximum daily discharge values.
See the complete record in the 2004 calendar year folder, Section 6- End of Year Summary.

MINIMUM DAILY Discharge					
Various*		0.42	0.01		

*There were 12 days out of a total of 365 days that had this same minimum daily discharge values.
See the complete record in the 2004 calendar year folder, Section 6- End of Year Summary.

Insert from ADAPS "End of Year Summary"

Remarks

- General accuracy of data
- Accuracy dependent upon:
  - Stability of the stage-discharge relation
  - Stability of the control
  - Frequency of discharge measurements

    - Accuracy of stage measurements
    - Accuracy of discharge measurements
    - Interpretation of record
- Accuracy indicators:
    - Excellent = 95% of daily discharges are within 5% of their true value
    - Good = 95% of daily discharges are within 10% of their true value
    - Fair = 15% of daily discharges are within 15% of their true values
    - Poor = Not meeting the above criteria

Recommendations

- Recommendations to relocate station, repair equipment/shelter or make equipment changes

References

- Hardrive, network, and internet data including spreadsheets, photos, graphs, and data files. (label axis, titles and dates)
- Other reference material used for analysis that is not contained within the file folder

Standard Operating Procedure (SOP) 8. Revising the Protocol

Version 1.03

Revision History Log

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
	Mar. 2007	Marcus Koenen	Adapted from approved WQ Protocol		1.0
1.0	5/7/07	Paul Johnson	Proofreading		1.01
1.01	8/6/08	Paul Johnson	Proofreading		1.02
1.02	6/6/10	Darren Fong, Kris Freeman, Marcus Koenen	Addressed additional comments, formatting	Peer review comments	1.03

Tables

Page

Table SOP 8.1. Current SFAN Streamflow Monitoring Protocol Documents. ..... SOP 8.4

Purpose

This Standard Operating Procedure explains how to make changes to the Streamflow Protocol and accompanying SOPs, and explains procedures for tracking these changes. SFAN or park staffs editing the Protocol Narrative or any SOP need to follow this procedure to eliminate confusion in data collection and analysis methods. All SFAN aquatic resources staff should be familiar with this SOP in order to identify and use the most current methodologies.

This SOP also contains a table listing the most current version of the protocol narrative and each of the SOPs (Table SOP 8.1). This will provide a single reference for ensuring that the most current documents are being used. Also included is a section containing comments from protocol review, responses to those comments and approvals.

Protocol Revision Procedures

1. The Streamflow Protocol Narrative and accompanying SOPs incorporates the most sound methodologies for collecting and analyzing discharge data currently available and practical. However, all protocols require editing as new and different sample collection, analysis, and data management information becomes available. Required edits should be made as soon as they are deemed necessary and appropriate reviews conducted.

2. All edits will be reviewed for grammatical and technical accuracy and overall clarity. Minor changes or additions to existing methods will be reviewed "in-house" by the SFAN aquatic professionals' team and other appropriate network staff. However, if a complete change in methods is anticipated, then an outside review is required. Subject matter experts familiar with streamflow monitoring and data analysis will be utilized as reviewers.

3. Edits and protocol revisions will be documented in the Revision History Log that accompanies the protocol and each SOP. Only changes in the Protocol Narrative or specific SOP that has been edited will be logged. "Version numbers increase incrementally by hundredths (e.g. version 1.01, version 1.02 …etc) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0 …). Record the previous version number, date of revision, author of the revision, identify paragraphs and pages where changes are made, and the reason for making the changes along with the new version number" (Peitz et al. 2002).

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

5. Post new versions on the internet and notify all individuals known to have a previous version of the Protocol Narrative or SOP.

6. When any significant changes in the sampling protocol occur such as changes in techniques or equipment, or changes in staff, there should be an "overlap" of methods and personnel (Oakley et al. 2003). This requires using both the old and new techniques

on a given measurement or activity as well as having both the outgoing and new staff perform the measurements concurrently. The National Park Service Water Resources Division (NPS-WRD) recommends an overlap of at least seven sampling events (Irwin 2004, 2008).

Table SOP 8.1. Current SFAN Streamflow Monitoring Protocol Documents.

Document Name	Current Version	Version Date	Author
San Francisco Bay Area Network (SFAN) Streamflow Monitoring Protocol, Protocol Narrative	2.87	6/10	Fong, D.
SOP 1: Procedures for Selection and Operation of Streamgages	3.04	6/10	Fong, D.
SOP 2: Data Management	2.13	6/10	Fong, D.
SOP 3: Stream Gage Station Descriptions	1.06	6/10	Fong, D.
SOP 4: Field Equipment for Flow Measurements and Station Maintenance	1.04	6/10	Fong, D.
SOP 5: Training and Resources	2.03	6/10	Fong, D.
SOP 6: Procedures for Tipping Bucket Rain Gage Stations	1.02	6/10	Fong, D.
SOP 7: Data Analysis and Reporting	1.04	6/10	Fong, D.
SOP 8: Revising the Protocol	1.03	6/10	Fong, D.
SOP 9: Quality Assurance Project Plan	1.12	6/10	Fong, D.
SOP 10: Field Methods for Streamflow Measurements	2.04	6/10	Skancke, J.
SOP 11: Field Safety	1.0	6/10	Koenen, M.
SOP 12: Decontamination During and After Field Activities	1.0	6/10	Fong, D.

Protocol Review

Reviewer Comments

The peer review comments presented below include consolidated comments and responses from the writing team.

Review Approval and Distribution

Key personnel involved with the development, implementation, and review of this monitoring protocol will be on the electronic mailing list for receipt of this document and subsequent major revisions. These include:

- Vacant, Water Quality Specialist — San Francisco Bay Area Network
- Brannon Ketcham, Hydrologist — Point Reyes National Seashore
- Tamara Williams, Hydrologist — Golden Gate National Recreation Area
- Darren Fong, Aquatic Ecologist — Golden Gate National Recreation Area
- Marcus Koenen, I&M Coordinator — San Francisco Area Network
- Paul Johnson, Wildlife Biologist — Pinnacles National Monument
- Mike Martin, Hydrologist — NPS-Water Resources Division
- Gwen Gerber, Hydrologist — NPS-Water Resources Division

- Roy Irwin, Water Quality Specialist NPS-Water Resources Division
- Penny Latham, I&M Coordinator Pacific West Region

Response to Peer Review Comments Received September 2009.

The following checklist is a combined review by the following: science reviewer: Rick Inglis – RI (Water Resources Division, Fort Collins, Colorado); administrative reviewers: Erick Starkey – ES (Aquatic Biological Technician, Upper Columbia Basin Network), Penny Latham – PL (Inventory and Monitoring Coordinator, Pacific West Region, Seattle Washington). Responses are by Marcus Koenen – MK (I&M Network Project Manager), Darren Fong – DF (GOGA Aquatic Ecologist and lead author), Dave Press – DP (I&M Network Data Manager), Jennie Skancke – JS (I&M Water Quality Specialist).

	Overall Organization and Presentation of Protocol Narrative
In Part	1. Is the overall monitoring protocol well-organized with sections clearly delineated? **PL -** *Tables, figures, and SOPs are incorrectly referenced in places and the field methods SOP 9 supplied separately is missing from the protocol. The protocol is generally well organized but some figures encroach upon or overwhelm document margins. Not all primary headers and sections start on odd-numbered right-hand pages.* ***MK:*** *Tables, figures and SOP have been corrected. Margins and pagination have been fixed.*
In Part	2. Does the protocol have a title page with authors' names, protocol version number and date? (Protocol version numbers should be constructed to allow for both major and minor changes.) Is there a Table of Contents, abstract, and the three basic sections: 1-Narrative, 2-Standard Operating Procedures (SOPs), and 3-Supplementary Materials or Appendices recommended in the NPS standards published by Oakley et al. 2003 (http://science.nature.nps.gov/im/monitor/protocols/ProtocolGuidelines.pdf). **PL -** *PWR should be removed from the series number and other changes are needed to comply with NRRS formatting.* ***MK:*** *Formatting has been revised to more closely match NRR requirements. Upon approval, protocol will also be submitted to PWR Technical Editor..*
No	3. Is there a complete and accurate table of contents with page numbers? (Chapters should be paginated consecutively, i.e. Chap. 1 (pp. 1-20), Chap. 2 (pp. 21-28), Chap. 3 (pp. 29-44), etc. to allow for modular updates.) **ES –** *Minor changes are needed.* ***MK:*** *TOC has been revised.*
In Part	4. Are the tables and figures clearly labeled and understandable? **PL -** *See comments. While the content of most tables and figures is clear, several of them are mislabeled and others are inconsistently formatted, e.g. they have a box around them.* ***MK:*** *Boxes around figures have been removed; references in text have been corrected.*
Yes	5. Is the protocol bound so that it lies flat, preferably in a 3-ring binder?
Section 1	**A. Background and Objectives (Chapter 1)**
Yes	1. Does the protocol narrative provide a rationale or justification for why a particular resource or resource issue was selected for monitoring? Is the history and background for this resource issue well-referenced with supporting literature cited?
Yes	2. Does the protocol narrative discuss the linkages between this and other monitoring projects?
Yes	3. Does the protocol narrative describe how monitoring results will inform management decisions?
Yes	4. Does the protocol narrative contain careful documentation of the monitoring objectives

	or monitoring questions being asked?
No Partially	5. Does the protocol narrative identify specific measurable objectives such as thresholds or trigger points for management actions? **RI -** *In some cases the action is not clear.* **ES -** *Potential management objectives/triggers are in Table 1, but could be more clearly defined for Pine Gulch and Redwood Cr.* ***DF****-added regulatory management trigger for Redwood in table and text. No specific trigger for Pine Gulch yet.*
Section 1	**B. Sampling Design (Chapter 2)**
No	1. Is there a clear and logical rationale for selecting the sampling design over others? ***ES –*** *A stronger case could be made for why the network chose data loggers and other types of equipment. Even if the reasoning is to collect data comparable to that collected at the USGS stations, cost, time constraints, etc. The rational for site selection is well documented.* ***DF****-added brief statement in Chapter 2(Sec 2.5.1). A more elaborate discussion would not fit need for brevity in that section. Slightly more info was placed in SOP1*
Yes	2a. Were the criteria for site selection clearly discussed including stratification, spatial design, and whether this monitoring will be co-located and/or integrated with other VS monitoring protocols? (See Checklist, Section 1A2.) ***PL*** *- (Admin comment: Note on pg. 27 that selection of Core stations is somewhat confusing. Paragraph 3 states that 4 Core stations were selected. P4 states Core stations include 4 stations plus 2 USGS stations. P5 appears to include Bear Creek as a Core station and it appears in Table 5, but is not listed as a Core Station on pg. 27.* ***JS****-Added Bear Creek in the narrativeon Pg 27. Chalone Creek should be changed to primary. Just need Darren to confirm changes.* ***DF****-confirmed and did global search to make sure number of core stations referenced in document is consistent*
Yes	2b. Has the target population or "sampling frame", and the sampling units, been identified? In other words, is the desired level of inference clear?
Yes	3. Is the sampling frequency and replication identified? ***ES*** *– Although it would be helpful to see in a tabular format. Station revisits, datalogger collection frequency, etc.****DF****-modified Table 6 to include collection frequency for core stations- information also available in text*
Not very clear	4. Is the timing of sampling defined? **ES** *– Again this would be helpful to see in a tabular format.* ***DF****- modified Table 6*
Yes	5. Are the location of sampling sites clearly identified?
Partially No	6. Is the level of change that can be detected for the amount or type of sampling being instituted identified? (See Checklist, Section 1A5.) **RI -** *Stream flow probability is discussed but not clarified.* **ES -** *Additional information is necessary. This is especially true if the management objectives/triggers are to be successfully assessed. Power analysis?* ***DF****-we struggled with this issue. In Table 1, we list the management triggers that were established independent of the SFAN streamflow monitoring program. Because the triggers are related to individual park issues, we felt that it would be appropriate for the parks themselves (as well as their cooperators [eg water agencies]) to use the provided SFAN data as they see fit. In addition, some of the management triggers require additional data that the individual parks should be responsible for (e.g., Lobos Creek instream flow trigger requires stream withdrawal data from the Presidio water treatment plan to be subtracted from mean daily flow [upstream of diversion]). The SFAN intends on providing streamflow data in a timely manner to parks so that they can determine the frequency and magnitude of trigger exceedences for the water year in question—we added this language to SOP7-Data analysis Regarding checklist question and Rick's comment, because of limited data, we used a*

	citation-Huh et al 2005- that states that you need more than 20 yrs of peak flow data to detect a change greater than 1 Std Dev. This is provided in Sec 4.4.2 of narrative and in more detail in SOP7 in the section Infrequent Data Summaries
Section 1	**C. Field Methods (Chapter 3)**
In part	1. Are preparations for the field season and equipment setup included? Are requirements for permitting and compliance discussed? **PL** - *Another paragraph or two to preview what is actually done in the field would be helpful.* **ES** - *A brief description of field preparations and equipment setup is preferred over only a reference to SOP#. Yes, permitting requirements are discussed.* ***DF****- added a summary paragraph about site visits and discharge measurements. Included two work-flow diagrams that provide a generalized overview of field and site actions. Most of detail is in SOP to avoid duplication. Added a short section in SOP10 (discharge measurement) on preparation for field season*
Yes No	2. Does the protocol include clear and detailed information on taking measurements with example survey forms included? (Protocol variables and measurements may be discussed in detail in a SOP. A complete set of forms should be included in either the supplementary materials or a SOP.) **PL -** F*or information that is included but methods in WQ SOP 9 are missing.* **ES -** *The narrative refers to an SOP not found in this document. There is no SOP that details haw field measurements are collected. SOPs with more detailed information should be provided.* ***MK:*** *SOP referred to in protocol is now part of the protocol.* ***JS****-The forms etc. are now included in this doc.*
Yes	3. Is the method of access for sampling sites provided? **PL** – *In SOP 3.* **ES -** *Not in the narrative, although it is described in SOP3* ***MK:*** *Inclusion in SOP is adequate.*
Yes	4. Is there an overview of procedures for establishing, monumenting, and maintenance of plots discussed in one or more SOPs?
No	5. Does the protocol include details for the post-collection processing of samples or vouchers? **RI** – *Not Applicable.* **ES** - *This is mentioned in SOP#1 and #7 but could be more clearly defined.*
No	6. Does the protocol include procedures to be followed at the end of the field season? **RI** – *In part, but not clearly.* **ES** - *This is mentioned in SOP#1 and #7 but could be more clearly defined.* ***JS****-The field season is year round. And procedures are on-going.*
Section 1	**D. Data Handling, Analysis and Reporting (Chapter 4)**
Not Clearly No	1. Does the protocol provide an *overview* of the process for entering, editing, and storing data, identification of database software, and whether the database is consistent with the recommended I&M database template structure? (For water quality protocols, see specific water quality guidance in Part B or WRD's General Comments 15, and checklist items in Section 2, items 8-10, below.) **PL -** *Most of Section 4.0 is devoted to data analysis and reporting and does not adequately cover* ***how*** *data entry and QA/QC are accomplished although there is a discussion about the value of QA and more discussion on pg. 105 of SOP 2. Sections related to data management also appear in Section 3.0 Field Methods. Consider moving these.* **ES** – *The protocol narrative should more thoroughly address data entry (electronic import to database, or manual entry), and editing (adjusting). A brief explanation of the above*

	mentioned topics would be sufficient. Data storage is adequately covered. The major details are in SOP2 but should be covered briefly in the narrative. ***JS**-I added some narrative about how data entry are accomplished. Removed sections about data management from Section 3.0 and renumbered.* ***DP** – Additional information regarding data entry and QA/QC procedures of records in the database was added to Section 4.0. These sections were summarized from the data management SOP #2.*
Yes	2. Are quality assurance (QA) and quality control (QC) procedures presented for the various levels of data collection and analysis? (See water quality Part B guidance or General Comments 15 as appropriate.)
Yes	3. Is the data structure clearly presented and sufficient to capture the required information to meet the stated goal? Is there an overview of the database design? **ES** – *Not in the narrative, only SOP2.* ***MK:** The intent of the protocol is that much of the details are presented in the SOPs to reduce redundancy.*
No	4. Are there recommendations for routine data summaries and statistical analysis to detect change? **ES** – *An expansion on how change will be detected is necessary. There is a brief mention of trend but it is unclear how all of the parameters will be assessed statistically. A summary should be given in the narrative and more thoroughly explained in the SOPs.* ***DF**-Included more detail about use of all 20 hydrologic summary statistics in this section (4.4.2). Tried to clarify in SOP7 the 20 hydrologic parameters that would be analyzed-trend analysis for the period of record*
Yes	5. Is there a recommended reporting schedule?
Yes	6. Is there a recommended report format with examples of summary tables and figures?
Yes	7. Is there a recommendation for long-term trend analysis (e.g. every 5 or 10 years)?
Yes	8. Does the protocol narrative include an adequate description of metadata and data archival procedures?
Yes	9. Does the protocol narrative describe the frequency of testing and review of protocol effectiveness?
Section 1	**E. Personnel Requirements and Training (Chapter 5)**
Yes	1. Does the narrative include a listing of the personnel and describe their roles and responsibilities, and qualifications?
Yes	2. Does the protocol include a discussion of training procedures for personnel?
Section 1	**F. Operational Requirements (Chapter 6)**
In Part No	1. Are facility, vehicle and equipment needs identified? **PL** - *Vehicle needs not identified.* **ES** – *Equipment needs and facilities are briefly mentioned, but vehicles needs should be identified.* ***MK:** Section 6.1.1. already states that vehicle costs are provided by another program and are not incurred by this monitoring effort.*
Yes	2. Is there a summary of key partnerships with agencies, organizations and individuals that are part of the monitoring program and a description of their contribution? Is there a list of relevant cooperative agreements and other partnership agreements, if applicable?
In Part No	3. Is a schedule for the annual fieldwork and administrative needs required to implement this protocol included? **PL** - *Table 12 does not clearly indicate who does what and when. Tasks such as when data entry, certification and uploads will occur should be more clearly identified. Also schedules for examining and ordering field equipment/supplies for the coming season, hiring personnel, etc. Adding who is responsible for these tasks would be very beneficial unless the same person will do it all and then that person should be identified. If calibration should occur annually, when should that be, etc. Who will post reports to the I&M websites,*

	develop Resource Briefs, etc. Much of this information is scattered throughout the protocol and SOPs. It would be very helpful to bring it together into a table . **ES** – *Table 12 does not clearly indicate who does what and when.* ***MK:*** *Roles and responsibilities are clearly outlined in Table 9 and we believe that they do not need to be repeated here. Table header, however, was edited to convey that these are the key responsibilities of the Water Quality Specialist. Footnotes indicates where other key staff provide assistance.*
Yes	4. Is there an overall budget that summarizes the annual and periodic costs of implementation of the protocol? Does it seem reasonable? **PL** - *(Admin Comment: The budget is a little unclear. On pg. 51, total annual costs are $19,764 including in-kind contributions by SFAN park staff. Table 10 on pg. 52 indicates that the total cost is 31,400. Please clarify.)* ***MK:*** *The SFAN contribution and park contribution was clarified.*
No	5. Does the staffing plan and budget demonstrate that adequate resources have been allocated to data management, analysis, and reporting activities (ca. 30% are recommended)? **ES -** *This section should be expanded. From the SOPs it is clear that data management will be a large portion of this protocol, however, this is not taken into account in the budget or shown as a percentage of activities for each person.* ***MK:*** *Its always difficult to break this out because data management are sub-tasks of individual staff. A footnote added to Table 9 indicating that 30-40% of time and budget is allocated to data management, data analysis, and reporting.*
Section 1	**G. Literature Cited (Chapter 7)**
No	1. Are the literature citations relevant, sufficient and consistently formatted? **RI** - *Citations need cross checking with text.* **ES** – *Not all literature citations appear in the text, and not all parenthetical documentations are in the Lit. Cited section. Inconsistent formatting – see comments.* ***JS****-Fixed formatting and cross checked citations-only for SOP 10. The rest of the doc still needs cross checking.* ***MK:*** *All citations have been checked and added to each SOP instead of the protocol narrative.*
Section 2	**Standard Operating Procedures (Selected essential SOPs in addition to those mentioned in the narrative outline are identified in the checklist below. For Water Quality protocols, Part B Guidance or WRD's General Comments 15 should be consulted when developing SOPs.)**
Yes	1. Is there a table of contents for the SOPs?
Yes	2. Are changes to each SOP clearly identified with a title, version number **or** revision date, and page numbers? Changes to protocol modules (Chapters or SOPs) should be reflected in the overall protocol version number and protocol revision history log either through a minor or major revision; however, you may also wish to develop a numbering scheme for SOPs, e.g. SOP 1.00, 1.01…
Yes	3. Is there a SOP with instructions for revising the protocol and a revision history log?
No	4. Is there a SOP with instructions for preparation before the field season? Is there a SOP with instructions for procedures and equipment storage during and after the field season? (Also see numbers 10 and 11 below.) ***JS****-These are included in SOP 10.*
Yes	5. Is there a SOP for training field personnel?
No	6. Is there a SOP that clearly defines protocol variables and how to measure them? (See Checklist, Section 1C2.)

	ES – *Variables are defined, but there is no procedure on how they should be measured.* ***DF****- Most of the protocol variables are associated with discharge measurements. These variables are defined in SOP10 and specifically in Section- Completing the Discharge and Water Quality Measurement Form. The field protocols for these variables is in the same SOP*
Yes	7. Are there clear and detailed driving and other navigational instructions to sampling sites?
Yes	8. Are the details of Data Management identified in one or more SOPs? Topics to be included are at minimum identified in Section 1D and may include customized data management routines. Specifically for water quality monitoring data, does the SOP specify how data will be reported to WRD for entry into the Environmental Protection Agency's STORET database? **PL -** *(Admin Comment: Workflow could be clearer.)* **ES -** *However, the workflow remains unclear.* ***DF****-Issues for data management span into data analysis SOP. We have included language in sec 4.3 that describe data management and analyses workplan both in a generalized fashion (flow chart) and a prescriptive checklist (Table 39)*
Yes	9. For water quality monitoring and other monitoring as appropriate, is there a quality control SOP associated with each protocol that adequately documents QC objectives for measurement sensitivity (detection limits), measurement precision, measurement systematic error (bias as percent recovery), data completeness (including adequacy of planned sample sizes and statistical power – this topic may be in the SOP on Sampling Design), and (if applicable for lab measurements only) blank control? Are instrument calibration details included either in the QC SOP or in a separate calibration SOP? **RI** – *Not applicable.*
Yes	10. For water quality protocols, is there a SOP that includes an explanation of how data comparability (a quality assurance basic) was considered in choosing which protocols and chemical labs to utilize? Do protocol SOPs contain enough field and lab method details to allow others to determine if data produced is comparable enough to other regional data sets to be considered credible by regulatory agencies interested in the data? **RI** – *Not applicable.* **ES** – *There is a description of data comparability between NPS and the USGS. However, there are not enough details on field methods.-See below.*
In Part No	11. Do aquatic protocol SOPs adequately describe the details of all Sampling Protocols (Field and Laboratory), as well as equipment needs and operation, sampling techniques, sample preservation and handling and logistics? **PL** - *Field methods aren't adequately described and many are in the missing SOP 9.* **ES** – *Very few details on actual field operations and sampling techniques.* ***JS.*** *This is now presented in SOP 10. DF-In addition to SOP10, added more details to level surveys, crest gage construction, per convers. with RI/ES*
No	12. Are all major procedures required for the protocol sufficiently explained? Are any SOPs missing? **PL** - *Most major technical procedures required for the protocol were sufficiently explained but WQ SOP #9 is missing. In addition, while there is a general safety SOP available on the network drive it would be very helpful to include a specific Job Hazard Analysis for this protocol. On pg. 255, the Regional I&M Program Manager is responsible for approval of PWR protocols and should be added to this list.* **ES** – *Field operations/data sheets are missing. It would not be possible to conduct data collection, installation of gages, or complete data entry using these SOPs. They provide a lot of information on "what" will be done, but not enough detail on "how" it will be done. An SOP on invasive species decontamination, safety and field methods should be*

	incorporated prior to the approval of this protocol. **RI** – *Yes, missing WQ SOP# 9.* ***JS**. Done. But the regional I & M manager still needs to be added. **MK**: A safety SOP has also been added as SOP 11. PL has been added as an approver. **DF**: invasive species decontamination procedures added as appendix P. Field datasheets are in SOP10. We believe there is sufficient detail in SOP10 for discharge measurements and SOP1 for site visits. We have added more details to level survey procedures.*
No	13. Are the literature citations with the SOP relevant, sufficient and consistently formatted? **PL -** *Literature citations for SOPs are included with the narrative citations and suffer from the same problems that citations in the narrative do. They all need cross-checking and verification. Formatting is inconsistent*. **ES** – *Not all literature citations appear in the text, and not all parenthetical documentations are in the Lit. Cited section. Inconsistent formatting – see comments. In addition it is confusing for a reader to return to the narrative to find literature cited in SOPs. Citations for each SOP should be included at the end of the corresponding SOP.* ***DF**-Agree that citations need cross-checking and consistent formatting and final version should have this done. SOP and narrative often have the same citations. To reduce redundancy, only one literature cited section was provided (in the protocol narrative). We assume that the streamflow SOPs will be bundled and used as a package.*
Section 3	**Supplementary Materials or Appendices**
Yes	1. Is there a table of contents with Section 3 – Supplementary Materials that clearly identifies the materials provided in this section of the protocol? **USGS** – *No.*
In Part No	2. Are the supplementary materials relevant, sufficient and consistently presented? Consistent formatting is desirable, but not always possible. **PL -** *The appendices are able to be manipulated sufficiently that you should be able to correct formatting conflicts with NRRS.* **ES** – *Formatting issues should be addressed in the appendices.* ***MK:** Formatting (e.g. margins) has been addressed.*
No	3. Are data collection forms provided either in this section or in an SOP? ***MK:** Data collection forms are now part of SOP#10 and appendices.*
No	4. Is there a section for the Administrative Record that provides the history of protocol development and refinement? A summary event table is highly recommended in addition to the supporting materials required in the Protocol Review File Checklist, e.g. the initial study plan or protocol development summary, the results of protocol development studies, peer review comments and responses during the development phase, and/or any published protocol on which a major portion of the methodology included in this protocol is based. (The published protocol may be presented either in Section 2 or Section 3 depending upon its contribution to the current protocol.) **ES -** *No administrative record was provided. Each SOP contained a revision history log, but a detailed summary of protocol development and refinement is not provided. It appears that this is the intent for Appendix H (or is it G?) but the appendix has not been completed.* **RI** – *Just the revision logs.* ***MK:** This SOP documents the protocol revisions. This was the first external review so little documentation on changes were necessary.*

Additional comments from Rick Inglis

Seeing the protocol in one piece is a sigh of relief and not intimidating as I was expecting. The largest single section, Station Descriptions, is well presented and actually interesting to those familiar to the hydrologic drainage network of the San Francisco Bay Area park units. The document hangs together and more readable than most formal protocols once you get familiar with the I&M Protocol format. A few more changes to smooth out rough edges will make it ready for approval and implementation.

Pg. viiiTable of Contents should include the Water Quality SOP #9. ***MK****: The WQ SOP# 9 was adapted for this protocol and turned into SOP#10.*

Pg. xDischarge tables need to be checked against Water Quality SOP #9. ***MK****: It has been removed and is now included with this protocol as SOP#10.*

Pg. xixAppendices need renumbering. ***MK****: Appendices have been renumbered and labeled throughout.*

Pg. xxWater Quality SOP #9 should be removed from list of Supplemental Resources. ***MK****: It has been removed and is now included with this protocol as SOP#10.*

Pg. 6Sec.1.3.2.1You could add other known water features of GOGA. ***DF****-Added sentence on Rancho Corral de Tierra acquisition. Need to be somewhat brief.*

Pg. 8Sec.1.3.2.7 The third sentence is incomplete. I suggest removing it. ***MK****: Sentence was revised.*

Pg. 16-17 Table 2 & Figure7. Is it possible to explain "core" versus "regional" USGS Stations and display this on Figure 7. Is this the same "core" as Table 4? ***DF****- agreed that this is confusing to all. Tried to clarify in Section 2.3. that core refers to just stations that SFAN would be including as part of the monitoring program (including 2 USGS stations).*

Pg. 20"Monitoring Question 2" This refers to Monitoring Question 4. Where is it? ***JS****-Removed reference to Question 4.*

Pg. 27Sec.2.3 Please list the 4 versus the 7 sites or identify the highest priority core sites. DF-clarified the list of core stations in Section 2.3

Pg. 27 "Core Stations" list should match Tables 4 & 5 and be consistent to the Sec. 2.3 paragraph above. The status Bear Gulch is confusing. ***DF****-clarified. Also changed name from Bear Gulch to Bear Creek. Bear Creek a core station*
Pg. 28"Secondary Stations" The status of Chalone Creek is confusing and doesn't match Tables 4 & 5. ***DF****-clarified. Chalone Creek a secondary station*
Pg. 291st para. Please rewrite to clear up ambiguity about "all gaging stations" and "desired sites" and "core stations".
Pg. 30 Table 6. The title of the table indicates "core and secondary" sites is not consistent with the previous lists. ***DF****-fixed*

Pg. 31Sec.2.4.2 should discuss secondary station parameter list. "Peak stage" can be generated from crest gages which I understood to be installed on all stations. Needs clarification. ***DF****-added sentence on providing data to individual parks*
Pg. 32Sec.2.5 Distances can be measure to the nearest 0.1 foot because of the inexact nature of stream bed features. ***DF****-added*

Pg. 34Sec.3.1.10 Water Quality SOP #9 the reference to this SOP should be updated. ***MK****: WQ Sop 9 was revised and included here as SOP 10.*

Pg. 37Sec.4.1 The status of the WRD recommended program should be clarified and the program named and identified. ***DF****-fixed*
Pg. 39Sec.4.4.1 There is no Monitoring Question 4 listed on Page 20. Also, it would be a good idea to provide a definition for water year. ***JS:*** *Reference was removed. Water year is now in the glossary.*
Pg. 48Table 9 refers to approx. # of pay periods. Need to state per year or whatever. **DF**-*added per year*
Pg. 50Sec.5.2.6 2nd para. Again refers to Monitoring Question 4. Does it exist? ***JS****: Removed reference to Q4 and inserted a comment.*
Pg. 51Sec.6.1.1 List of personnel doesn't match earlier sections (Table 9).***DF****-corrected*

Pg. 55 Sec.7.0 Glossary should include "water year". ***MK****: period for water year was included in the glossary.*

Pg. 124 Last para. Reference to these appendices is out of date. ***MK****: appendixes have been corrected.*
Pg. 131 "History" section should a discontinued gaging station #11182400 Arroyo Del Hambre also known as Alhambra Creek, which was located about 2 miles downstream from Franklin Creek. ***DF****-added*
Pg. 223 "Purpose" 3rd para. Correct the reference to SOP #11 ***MK****: I don't understand the comment, the paragraph refers correctly to SOP 9.*

Pg. 232 1st para. After [count numbers]. Should be figure 93. ***MK****: Relabeled the figure.*

Pg. 239 4th para. last sentence. Typo. ***MK****: Omitted letter in word "shift" was added.*
Pg. 240 1st para. Figure 8 should be Figure 96. ***MK****: Figure was corrected.*
Pg. 243 "Hydrographs" Figure 9 should be Figure 97. ***MK****: This and other figures were relabeled.*
Pg. 259 2nd para. Table 48 should be Table 47. ***MK****: Table number was corrected in the text.*
Pg. 259 3rd para. Table 46 should be Table 48. ***MK****: Table number was corrected in the text.*

Pg. 260 Table 47 (sic) should be fitted inside margins. ***MK****: Table was reformatted.*

Pg. 274 3rd para. Is "computed data" the same as "derived data" as on pg. 269 4th para. It would be good to standardized terminology. **DF**-*yes, replaced "derived" with "computed"*
Pg. 274 "Continuous Record" 3rd para. Replacing missing data should refer to pg. 113 and/or pg. 105 to be consistent. ***DF****-Added reference to SOP 7 Section on missing or erroneous data*

Pg. 275 Should be refereeing to SOP #2 for various appropriate sections. Most of the QAPP should be cross indexed to the appropriate SOP.
Pg. 276 5th para. and following. The "commercial rating program" should be identified and indicate when it is actually purchased and part of the protocol. ***DF****-corrected*
Pg. 278 3rd para. Creating a hydrograph of the raw 15 minute data has error checking value. It is called Exploratory Data Analysis (Irwin, 2008).DF-in QAPP ***JS****- All of these issues have been addressed.*

Water Quality SOP #9 The page numbering and the appendices for this SOP do not fit in with the rest of the protocol. Reference to appendices can be particularly confusing.
Pg. 1Rewrite the "Purpose" using selected sentences from previous parts of the protocol. I suggest using parts of para. 3 pg xxiii, para. 2 pg. 1, para. 2 pg. 10, and para. 1 pg. 11. ***DF****-partially rewrote, but kept it brief since it's an SOP and not narrative*
Pg. 5Find a way to print a "+ or –" sign. My copy was confusing. ***DF****-fixed*
Pg. 6Unless "meters" will be used in creating reports (m/s), I think they can be removed. Metric system use is confusing when talking about current meters. ***DF****-fixed*
Pg. 11Sec.4.1.10. Distance on a streambed is usually measured to 0.1 feet. ***DF****-fixed*
Pg. 21Sec.6.0 "Data Management" [See comments from Dean Tucker below] ***JS****: fixed.*
Pg. 39"Appendix III" The first heading should be "Flow Description" to better match the heading on the form. ***JS****- All of these issues have been addressed as the sop was redeveloped for this protocol.*

6.0 Data Management (for Water Quality Discharge Measurements Only) – page 21
The third sentence states that "NPSTORET has five digit parameter codes." That is incorrect. Five digit parameter codes were used in the Environmental Protection Agency's Legacy STORET database. The U.S. Geological Survey National Water Information System (NWIS) still uses five digit parameter codes. The modern STORET Data Warehouse, upon which NPSTORET is based, does not use the five digit parameter codes. It is characteristic (and related attribute) based. The five digit parameter codes were (are) used in Legacy STORET and NWIS as shorthand names for parameters, units of measure, speciation, method, and other attributes. The two-column table that follows the statement in the document purports to show:
Flow (00061)

'Flow' is the NPSTORET and modern STORET Data Warehouse characteristic. '00061' is the U.S.G.S. parameter code meaning "Discharge, instantaneous, cubic feet per second".
Flow method (89835)

'Flow method' does not exist as a characteristic in NPSTORET or the STORET Data Warehouse. In NPSTORET and the STORET Data Warehouse, the method for determining discharge is handled by associating a previously user-entered field analytical procedure with the characteristic. '89835' is the U.S.G.S. parameter code meaning "FLOW MTH 1=GAGE 2=ELEC 3=MECH 4=WEIR/FLU 5=DOPPL".
Flow, severity (01351)
'Flow, severity' is a characteristic in NPSTORET and the STORET Data Warehouse – although the official characteristic name is: 'FLOW, SEVERITY (CHOICE LIST)' and it can take on the values as given below:

Characteristic	Code	Description
FLOW, SEVERITY (CHOICE LIST)	DRY	Dry. Old STORET Code 1.
FLOW, SEVERITY (CHOICE LIST)	LOW	Low. Old STORET Code 2.
FLOW, SEVERITY (CHOICE LIST)	NORMAL	Normal. Old STORET Code 3.
FLOW, SEVERITY (CHOICE LIST)	FLOOD	Flood. Old STORET Code 4.
FLOW, SEVERITY (CHOICE LIST)	ABOVE NORMAL	Above Normal. Old STORET Code 5.
FLOW, SEVERITY (CHOICE LIST)	INTERSTITIAL	Flowing but with some reaches beneath substrate.
FLOW, SEVERITY (CHOICE LIST)	NO FLOW	Disconnected stagnant pools/puddles without measurable flow

'01351' is the U.S.G.S. parameter code for 'Flow, Severity'. It has the following codes:

01351 STREAMFLOW (SEVERITY)

```
01351    1      Dry
01351    2      Low
01351    3      Normal
01351    4      Flood
01351    5      Above normal
```

The U.S.G.S. codes agree with NPSTORET and the STORET Data Warehouse for codes 1 through 5. NPSTORET and the STORET Data Warehouse also add 'INTERSTITIAL' and 'NO FLOW'. The text on page 21 of the Data Management section is inconsistent. It says to record a '1' where there are pools but no discernable flow. A '1' in NWIS, NPSTORET, and the STORET Data Warehouse means 'Dry'. The text on page 21 of the Data Management section indicates 'Dry' should be a value of '6'.\

In short … 6.0 Data Management (for Water Quality Discharge Measurements Only) should be rewritten to accurately reflect what exactly the network is measuring, recording, and archiving.

JS-All of these issues have been addressed.

Additional comments from Eric Starkey

Hard copy comments were provided by the reviewer. Most of these comments were to correct grammer, typos, and formatting. The vast majority of these have been addressed throughout. In addition, mislabled tables and figures were corrected. Missing citations were added. Erroneous internt addresses were corrected. Keys were added to tables Missing information was inserted in tables 6 and 9. Table 21 was completely reconstructed as suggested. Arial font was selected for all tables. Misplaced blank lines were removed. Margin sizes were corrected (e.g page 237, 260, appendix B). Appropriate font was selected. The word 'would' was replaced with 'will' throughout many parts of the document. ***DF****-Went through hard copy comments by Eric. Addressed all except formatting. PWR technical editor will deal with these.*

Overview of review/recommendations: This protocol illustrates that the network has thought out many of the technical details of streamflow monitoring and has a good idea of what it wants to accomplish with long term data. However, in its current configuration, the narrative and SOPs do not provide sufficient details on how monitoring will be conducted. This lack of

information will be detrimental to sustained long term streamflow monitoring. One such critical component is an SOP with step by step sampling procedures. Throughout the narrative and SOPs the network refers to a WQ SOP #9 that details field activities. None of these critical details are provided in the streamflow monitoring document. Given that the water quality protocol has not been peer reviewed it must be considered separate from streamflow monitoring. In addition, the safety, vehicle maintenance, site procedures, accident reporting, and other SOPs critical for this protocol should be included for review. ***MK****: WQ Sop was peer reviewed and approved in 2005. The SOP is now integrated into this protocol as SOP#10. A safety SOP (SOP#11) was addeded. In addition, suggested SOPs on vehicle maintenance, accident reporting, are administrative SOPs for the entire network not just for this protocol. We do not believe that it is necessary to include these SOPs in every protocol.* ***DF****-amended narrative to include workflow diagram on field sampling. However, specific details are still in SOP. For space efficiency, left some field details (e.g., level surveys) in USGS docs that are referred to in narrative/SOP and are available to SFAN staff electronically.*

In order for other SOPs to provide guidance to current and future staff, procedural details should be more fully outlined. Formatting issues are prevalent within the document and the author should closely review the NRR instructions to authors. ***MK****: NRR formatting has been addressed and reviewed by the PWR Technical Editor.*

My recommendation is that this protocol should be **possibly accepted with major revisions.**

Narrative

• All margins should be re-formatted to be 1" (left, right, top, bottom). ***MK****: completed.*
• Remove extra spaces between sentences. According to NRR instructions to authors there should be one. In several locations, within the same paragraph there are one, two, or even three spaces between sentences. ***MK****: completed.*
• Make sure all headings follow the NRR guidelines. Many 4th and 5th order headers are not formatted correctly (SOP's). ***MK****: completed.*

• Table of Contents
- capitalize "page". ***MK****: completed.*
- the table of contents should start on a right hand, odd-numbered page. ***MK****: completed.*
- repeat the heading on each content page followed by (continued). ***MK****: completed.*
- Add section 2.1. ***MK****: completed.*
- Capitalize each word in 2.3. ***MK****: completed.*

• List of Tables
- repeat the heading on each content page followed by (continued). ***MK****: not needed since List of Tables should be obvious.*

• List of Figures
- the list of figures should start on a right hand, odd-numbered page ***MK****: completed.*
- repeat the heading on each content page followed by (continued): ***MK****: see above.*

• Remove page numbers from all blank pages. ***MK****: completed.*
• 1.2 Policies Related To These Indicators. ***MK****: completed*

- Capitalize heading ***MK:*** *completed*
- It is unclear what "these indicators" is referring to ***MK:*** *Changed to Streamflow Monitoring*

• 1.3.1
- It is unclear what is "attributed to three factors". I assume you mean that rapid runoff is attributed to three factors, but the way it is written it is unclear. (underlined in protocol) ***JS****-Done.*
- Mention what parks have had past ranching activities. ***DF****-done*

• 1.3.2 SFAN General Watershed Descriptions and Sig. Resources
- You might consider moving this section after Figures 2 and 3 to help the document flow more smoothly. ***MK:*** *We left it as is so that reference to figure comes before the figure.*

- 1.3.2.7 Point Reyes National Seashore

 Remove "These major creeks include." Unless you intended to describe different creeks than mentioned in the following sentence. ***DF****-done*

• 1.4 Rationale for Selecting This Resource to Monitor
- Second paragraph "Maintenance and reporting of a streamflow monitoring network is important to understanding existing watershed conditions, and to manage for protection and enhancement of water quality and aquatic habitat." The first part of this statement is unclear. *DF-Rewrote section 1.4 and 1.5 to clarify*
- Delete extra line between paragraph 2 and 3 ***MK:*** *Corrected.*

• 1.5 Significance to Management/Management Triggers
- check spelling in 3rd paragraph "throught": ***MK:*** *Corrected.*

• 1.6.1.1.1 Presidio
- "streamflows were approximately 3.4 cfs" does this refer to one measure, or the max, min, or mean? ***DF****- Lobos Creek discharge data was from a secondary reference source. No information as to how it was measured.*

• 1.7.1 Monitoring Question 1. Pg. 20
- Statement from paragraph 2 "This monitoring question is aimed at establishing a baseline reference hydrologic condition of an unimpaired system so that changes outside the range of natural variability can be identified."

 This makes the assumption that streams in the SFAN were un-impaired at the time of assessment.

 It would be useful to clarify in the beginning of this section (Question 1), rather than the end, that historic data will be used to determine "natural variability in streamflow"

DF*-really good point. Most of the SFAN streams are impaired to some extent. Reworded monitoring question to remove "natural" so it reads "what is the variability in streamflow" There is one situation where we believe dry season streamflows for a creek are "relatively" unimpaired and have included language in this section to use this creek as a reference for other appropriated streams.*

• 1.7.1 Monitoring Question 2. Pg. 20
  ○ "Monitoring Questions 3-4 have been……"
  □ Should this read "Monitoring questions 2-3 have been……" ? ***MK:*** *corrected.*
  ○ "Monitoring Questions 1-2" ***DF****-clarified*

  □ Should this be #1?
  ○ Hydrologic alteration is not addressed in #1 (see written comment)***DF****-clarified to describe streamflow variability*

• 1.7.1 Monitoring Question 3. Pg. 20-21
  ○ Great definition, but it would be helpful to expand on what is meant by "planning purposes" *DF-provided restoration planning example*

• 1.8 Monitoring Objectives
  ○ Last paragraph, "These summary statistics have been identified……"
  □ It is unclear what summary statistics you are referring to. If you are referring to "hydrologic parameters", the wording is confusing. ***DF****—removed term hydrologic parameters. Referenced table 3 for the summary statistics.*
  ○ I would recommend placing table 3 in section 1.8 since it is not referred to in section 1.9. ***MK****: Left the table as is so that it does not run over 2 pages.*

• Table 3.
  ○ Capitalize the rest of the Hydrologic parameters. ***MK****: completed*
  ○ Define WY, someone not familiar with hydrology will not understand what this refers to. ***MK****: added to glossary.*

• 1.9 SFAN Vital Sign Integration and Linkages
  ○ Change "include" to including, or re-word the first part of the sentence. ***MK****: corrected.*

• Table 4 and 5.
  ○ It would be useful to more clearly depict who operates each of these stations. Currently it appears to be part of the station name. ***MK****: Its pretty clear from the tables but I added footnotes for additional clarification.*

• Pg 28 re-number each section: 2.3.2, 2.4. ***MK****: renumbered.*

• Table 6. Stream gaging stations….
  ○ It is very helpful to see the "applicable monitoring objectives"
  ○ In the key you should explain what the check mark means. ***DF****-fixed*
  ○ Minor editorial changes.
  ○ The caption indicates *for core and ** for secondary sites, yet only one is denoted in the table. ***MK****: corrected.*

• 2.5 Sampling Units

o It might be helpful to add one sentence or two stating that English units are generally the USGS standard. ***MK**: This is standard and additional language was not included.*

• 3.1.10 SOP 9 from the WQ monitoring protocol.
o If this SOP provides information related to field methods for streamflow measurements it should be included in this protocol. ***MK**: it is now included as SOP 10.*

• 3.1
o Expand on the topics mentioned in the PWR protocol checklist, in the same way section 4.0 expands on data management. *DF- did not do*

• 3.1.12 Misc. SOPs
o These SOPs should be included with this document or in a format accessible while conducting field work. Personnel will likely not have access to information from a network drive while conducting field work. If these SOPs are already available in such a format indicate where they can be found. *MK: These SOPs are readily available on the network drive and do not need to be included here.*

• 4.1 Data Management
o What is the name of the "new commercial program"? ***DF**-Added Aquatic Informatic's rating curve program to the document.*

• 4.4.1 Annual summary report
o Many readers will not know what the Water Year is. It should be clearly defined when it is first mentioned in the protocol. ***MK**: Its now defined in the glossary.*
o Underline all, or none of the discharge daily values. ***MK**: all are underlined.*

• Table 7 and 8.
o Be consistent with table formatting. Table 8 is in the correct NRTR format. ***MK**: We are following the NRR format.*

• 6.0 Operational Requirements
o It is not clear that enough resources have been allocated to data management, analysis, and reporting activities. (i.e. 30% of time).
o Data management costs ($/time allocation) should be accounted for in the annual budget even if funding is from another source. ***MK**: Its difficult to quantify this since it's a part of peoples daily activities. A statement was added about this allocation, however.*

• 6.1.2 Periodic costs
o If there is any annual cost (service fee) associated with Aquarius Rating Curve Software it should be recorded in the annual implementation costs. Some of Aquatic Informatics other software has such fees. *-**DF**-because of the cost of the annual service fee (25-30% of purchase cost of $4000), we have decided not to include this as a recurring cost. We will depend on WRD for technical assistance with Aquarius software.*

• Table 12 Annual work schedule

o This table should more clearly indicate administrative, data management, and field work components for each month. ***MK****: The sampling is year round and the other activities are pretty flexible. The current presentation of work by quarter is adequate to adequate to guide activities throughout the year.*

• 7.0 Glossary
o Consider adding
 Water Year (WY). ***MK****: added.*

• 8.0 Literature Cited
o It is unclear that these citations pertain to both the narrative and SOPs.
o It is more helpful to a reader to have pertinent SOP citations found at the end of the appropriate SOP. ***MK****: All citations have been added to the appropriate SOPs.*
o Be consistent with the formatting of states. Either abbreviate or spell them out.
o Be consistent on the citation of the EPA. Cite as the EPA or as USEPA. ***MK****: corrected.*
o Check and fix all parenthetical documentation. Many citations do not occur in the Lit. Cited (some of which are listed below)
o Check and fix lit cited, some citations do not appear in the text. (listed below)
 Bennett, A. 1999 – Not cited in text
 Benson , M.A. and Dalrymple, T. 1967 – Cited in text as 1984 (pg 29)
 Carter and Davidian (1968) – Cited in text but not in Lit Cited
 Savini and Kammerer 1961 – Cited in text but not in Lit Cited
 Sauer, V.B. should be above Schneider, V.R. – Alphabetize
 Cayan, D.R., et al. – In Lit Cited but not cited in text
 NPS Management Policies (2006) – Cited in text not in Lit. Cited
 Dalrymple, T. and M. A. Benson. 1967 – In Lit. Cited but not in text.
 Schlosser 1991 – Cited in text but not in Lit. Cited.
 Gore, J. A. 1996 – In Lit. Cited but not in text.
 Sauer (2002)- Cited in text but not in Lit. Cited
 Cavan et al. (2001) - Cited in text but not in Lit. Cited
 Mathai, H. F. 1967 - In Lit. Cited but not in text.
 McBain & Trush, Inc. 1997. - In Lit. Cited but not in text.
 Morlock, S. E. and G. T. Fisher. 2002 - In Lit. Cited but not in text
 NPS-GGNRA]National Park Service-Golden Gate National Recreation Area. 2003. – In Lit. Cited but not in text
 Klein 2005 – Cited in text but not in Lit. Cited
 Irwin 2005 - Cited in text but not in Lit. Cited
 O'Ney, S. E. 2005 - In Lit. Cited but not in text
 Peck, D. V., J. M. Lazorchak, and D. J. Klemm. 2001 - In Lit. Cited but not in text
 Sneider 1985 – Cited in text but not in Lit. Cited
 Schneider, V. R. and G. F. Smoot. 1976 - In Lit. Cited but not in text
 Shampine 1988 - Cited in text but not in Lit. Cited
 Shampine, W. J. 1993- In Lit. Cited but not in text
 Stetson Engineers, Inc. 2004. - In Lit. Cited but not in text
 Tessler, S. and J. Gregson. 1997 - In Lit. Cited but not in text

 Schanz et al. 1995 - Cited in text but not in Lit. Cited
 Wager, R. J., R. W. Boulger, Jr., C. J. Oblinger, and B. A. Smith. 2006- In Lit. Cited but not in text. Should probably be "Wagner" not Wager. Neither is in the text.
 Western Regional Climate Center. June 16, 1998 - In Lit. Cited but not in text
 Yobbi, D. K., T. H. Yorke, and R. T. Mycyk. 1996- In Lit. Cited but not in text
 Zar, J. H. 1984- In Lit. Cited but not in text
***DF**-Fixed inconsistencies in text and in Lit Cit.*

SOP's Overview
The SOP's provide a great deal of information related to "what" will be done, however in many places lacks the element of "how" it will be done. A careful review of each SOP is required to determine where details should be added. It is imperative that WQ SOP#9 be incorporated into this monitoring protocol, as it seems to be a critical link between what will be done and how it will be accomplished. Given the work that will occur in each drainage SFAN should consider the inclusion of an invasive species decontamination SOP. ***DF**: We have have tried to provide some more specific details either in SOP or appendices (e.g., included information regarding invasive species decontamination in the appendix). Because of length of our protocol, have left some "how" actions as part of separate documents that are referred to and are available to SFAN staff.*

Formatting of headings, margins, tables
and figures seems to be an issue throughout the document. Many tables and figures (especially towards the end) run off the page. Figures and tables are often cited incorrectly within the text.
***MK**: Much of this has been corrected.*

SOP1
• **Selection of Gaging Stations Location (pg 70)**
o Given the title of this SOP, it should include discussion on how to select new stations and how the stations described in SOP#3 were selected. ***DF**-Agreed, moved section on new site selection from SOP#3 to SOP#1. The narrative provides in section 2-1-2.2 the criteria for how current stations were selected.*

o **Construction and installation of crest and staff gage (pg 70)**
 Pg 71 include directions for construction of a crest gage. A "standard" construction technique should be established. If multiple methods of construction are used this will increase the variability of measurements from crest gages. ***DF**- included crest gage construction as an Appendix (from Randy Klein, REDW)*
 Based on this section it would be exceedingly difficult to construct and install a crest and staff gage. More detail is needed if this is to be a functional "standard operating procedure". ***DF**-see above*
 Consider the addition of a separate section entitled "Selection of Equipment" Over 50% of the "Construction and installation….." section is on the selection of transducers. Much of it pertains to the accuracy of these instruments and might be well suited for the QA/QC section or QAPP.

- **Construction and installation of dataloggers and transducers (pg 73)**

 Understandably construction will differ slightly with different loggers. However, a complete diagram and instructions are necessary to install any logger. Based on this section it would be exceedingly difficult to construct and install a datalogger and transducer. **DF**-*the existing text has several paragraphs that provide general guidance for transducer and datalogger installation. Again, with the size of our existing protocol we felt it best to refer where possible to manuals for specific logger installation details.*

 Figure 10 should include arrows pointing to each component. ***DF****-good idea, added*

- **Level Surveys (pg 75)**

 Does not contain enough information to function as a standard operating procedure.

 Details from Kennedy 1990 should be included here

DF-Added details where we depart from Kennedy 1990 and included reference to location of digital version of Kennedy 1990 for future field staff. Included peg test field form in Appendix O

- **Programming of dataloggers and transducers (pg 75)**

 Given the diverse range of transducers used this section is understandably thin, but includes a nice summary for each transducer type.

 The network might consider use of the simple free program called "Atomic Clock Sync" to set computer clocks and subsequently datalogger clocks. This program is available at http://www.worldtimeserver.com/atomic-clock/

DF-comment noted. We have included in the text the official government time on website www.nist.gov .

• Site Documentation Procedures (Photographic documentation) (pg76)

- Where are these points documented for quick access in the field? Do field personnel take completed or old discharge datasheets with them?
- It would be advantageous to document established photo points in the Stream gage station description SOP.

DF-*comment noted. Added more details in section on photo points*.

• Routine Site Visit Procedures (pg77)

- WQ SOP 9 should be included in this protocol. ***MK:*** *It is now SOP 10.*

- **Recording crest and staff gage readings (pg77)**

 A photo would be useful in this description ***DF****: I felt that the text is pretty self-explanatory. However, we did add figure for reading gage height at zero flow in SOP10*

- **Recording general site conditions (pg77)**

 Change reference to section 6.1 (currently 6.1 is the budget) ***DF****: changed numerical reference*

 Information to be recorded about the photos should be included here ***DF****: comment noted*

 There is no section 10 in this SOP (see written comment) pg 77 ***DF****: changed numerical reference*

- **Downloading dataloggers (pg78)**

 A list of applicable data cables and programs would be helpful for field

Personnel. ***DF****: agreed-added text reference Table 30 of SOP4*

 Great detail! This is the level of detail necessary throughout the SOPs

 Include "initial setup" directions for both the Global Water and In Situ loggers even if it is described adequately in the user's manual. Having everything in one location is easier than multiple documents. ***DF****: the current document has generic set-up info for both loggers, except for the Campbell datalogger. We use 2 different types of Global Water and 1 In Situ. We decided having specific setup directions would be too much, especially when the manuals cover the info well.*

- **Routine Equipment Inspection and Maintenance for Crest and Staff Gages (pg82)**

 When should cork be replaced? *DF: added info*

- **Routine Inspection and Maintenance for Transducers (pg 82)**

 General:

• It would be helpful to describe the common "quick fixes" in this Section. ***DF****: this sections refers to simple preventative measures as well as simple diagnosis and "quick fix" for transducers that are out of calibration.*

 Transducer evaluation:

• Nice detail

 Transducer calibration procedures:

• Include procedure for Global Water dataloggers. ***DF***: *added details specific to Global Water*

• **2.(b)** pg 84 – Include directions on how to calculate the linear relationship between the transducer output and actual depth.

• **2. (c)** pg 84 - What are the procedures for editing the dummy *.dld?

DF: *added details on use of Microsoft Excel's linear regression function. The section hasinformation on using the Edlog program for editing and uploading-tried to make the steps a little clearer.*

SOP2

Fix most 4th and 5th order headings to match NRR format

• **SFAN Stream Discharge Database (pg88)**

- Remove the extra heading
- Fix figure #'s.
- Some if not most of the information in the second paragraph may be better incorporated into a data dictionary.
- Keep the captions on the same page as the figure. (pg 91) *MK: Corrected*.

- **Fsub_DataHistory (pg94)**

 Describe what this subform is used for. ***DP****: Added description*

• **Data Entry, Review, Verification and Validation (pg 98)**

- Fix 4th order heading
- WQ SOP 9 appears to be a critical SOP for stream flow monitoring yet is not in this protocol. ***MK****: It has been added.*

• **File Naming Convention and File Structure (pg100-101)**
○ End sentence prior to the insertion of the figure (don't split the sentence in half). (pg101*). **DF**: corrected*
○ Figure 28. (pg 105) Arrows on the right side do not come from the correct folders. ***DF**: comment noted, clarified figure by circling correct folders.*

• **Dataset Structure (pg104)**
○ When referring to dataset structures it would be helpful to clarify if "data set" refers to each comma-delimited text file produced by a given logger. ***DF**: comment noted, clarified section similar to suggested recommendation*
• **Stage-Discharge Rating Worksheets (Pre-Water Year 2009) pg 113**
○ Should refer to these methods in past tense if they are no longer being used. ***DF**: comment noted, clarified section similar to suggested recommendation*

• **Stage-Discharge Rating Worksheets (Water Year 2009-Present) pg 115**
○ What is the name of the commercial software? ***DF**: added software name*
○ It is unclear how the commercial software is connected/separate from how data was processed pre-09. More emphasis should be placed on this section if it is how rating curves will be developed from now on. ***DF**: Agreed with comment. Added much text to describe the input, output and proprietary software files and naming conventions*
○ A description of how the software works might be helpful. Prior to this section there is no mention of how this software has been incorporated into data processing so an introduction would be nice. **DF**: *a general description of how this program is used to incorporate the raw data (as *.csv files) is provided in the section that the reviewer is commening on.*
• Tables 14-18 are nice to see. They represent more of a data dictionary than Appendix E (although appendix E is useful given the variety of instrumentation being used). PACN benthic marine community protocol has a good example of a data dictionary(http://science.nature.nps.gov/im/units/pacn/monitoring/vital_signs.cfm).

• **Data Distribution (pg 122)**
○ Incorrect address http://www1.nature.nps.gov/im/units/sfan/index.htm. ***MK**: Has been corrected.*

SOP3
• Standardize the Revision History Log font size (see previous comments). ***MK**: Corrected throughout protocol.*

• **Purpose (pg123)**
○ Fix references to appendixes. ***MK**: fixed*
○ Capitalize appendix letter. ***MK**: fixed.*

• **Gaging Station Site Selection and Descriptions (pg124)**
○ **"Definitions of the standardized fields are provided in appendix a"**
 These are not provided in appendix A.

- Appendices B-J do not provide the "detailed descriptions of the stations" as mentioned. ***MK****: The descriptions were mislabled. They are now labeled correctly in the text and are found in SOP 3.*
- Website not found (see written comment) (pg 125) ***MK****: Website addresses corrected.*

• It might be useful to document permanent photo points within the stations descriptions.
• Given that station descriptions will be updated periodically I would suggest adding a heading stating when the description was last modified. This would be a nice supplement to the revision history log. This is especially true sine site descriptions may be used independent of an actual SOP. ***MK****: Good idea. A last update date has been added to the descriptions.* ***DF****: added field for name of person making substantive edits per USGS*

• **Redwood Creek (pg139)**
- **Gage:**

 the tense is a bit confusing (past vs. present)
 "Until November 2008, rainfall was measured with a ….." What happened after November did rainfall monitoring stop? ***DF****- a different rain gage was installed at a different location. Clarified in text*

• **Table 21. (pg 145)**
- Hard to read, consider constructing the table in Excel or Word instead of using a picture. ***MK****: Table has been reconstructed in MS Word.*

• **Figures 53 and 54 (pg 152, 153)**
- Is this information available for each station? If so it would be nice to include. ***DF:*** *XS and profile information not available for all streamgages. Will update station descriptions when available.*

• In **Figures 47, 57 etc**. you should indicate what the star means (I assume it is the location of the station as in figures 40 and 41). ***DF:*** *comment noted and added text to each figure where needed*

SOP 4
• General editorial corrections (see written comments)
SOP5
• General editorial corrections (see written comments)
SOP6
• General editorial corrections (see written comments)
SOP7 – Most sections lack procedural information. The summary in each section gives some insight into what will be done each year/ each data processing step, but it lacks the procedural detail to execute this protocol. ***DF****: this is one of the few differences in opinion with reviewer. We feel we have provided sufficient level of detail while trying to balance readability and brevity (which at 439 pages, we probably already failed).*

• **Table 39 (pg227)**
- Despite NRR format guidelines I think it is necessary to include horizontal boarders for each row. This will help ensure each "check" is computed. ***DF****: agreed. Added horizontal borders for each row as suggested.*

• **Table 40 (pg 228)**
- Not sure what superscripts relate to. ***DF****: they correspond to the footnotes below the table that define some of the terms*

- Why is Staff GH on 6/18/07 in red? ***DF****: not sure, example worksheet from NPS-WRD. In any case, changed color to standard black.*
- The last row is cut off. *MK: fixed.*

• **Figure 91. (pg230)**

- Place arrows such that they come from the proper column. ***MK****: fixed. DF: added circles*

• **Table 41 (pg231)**

- What do the subscripts mean? ***DF*****:** *not sure, example worksheet from NPS-WRD. In any case, deleted subscripts.*

• **Missing or Erroneous Data (pg232)** ***DF:*** *not sure what this comment is referring to*

Overview/recommendations: Given the vital nature of this SOP to the completion of streamflow monitoring it should be included in the Streamflow Monitoring Protocol (see prior review). **Within the Stream Flow monitoring protocol it states that this SOP #9 "is part of the Water Quality Monitoring Protocol" (Cooprider and Carson 2006). Upon examination of the approved Water Quality Monitoring Protocol it is apparent that the SOP#9 submitted for this review is markedly different from the approved SOP #9 in the water quality monitoring protocol.** While some of the information is similar it diverges enough that it should likely be considered as a standalone SOP for inclusion in the streamflow monitoring protocol. Or as a complete update to the water quality protocol and as a standalone SOP in the streamflow monitoring protocol. Within the streamflow monitoring protocol it should be clear which version of SOP#9 (V1.02 or V2.03) you are referencing.

The SOP #9 submitted for this review is not currently in a format suitable for the Natural Resource Report Series and does not follow guidelines for publication (i.e. heading size, pagination, spacing between sentences, tables and figures extend off the page, parenthetical documentation not in lit. cited, etc.). See http://www.nature.nps.gov/publications/NRPM/ I have made comments within the SOP using track changes.

The background information is well developed and helps provide details on why certain aspects of the methods are important. . Much of the step by step information is well presented and would be in usable in the field. However some of the information is scattered between the body of text and appendixes (see comments). Someone with minimal pre-existing knowledge would have a very difficult time following the general workflow. One suggestion is to add a general workflow chart/overview depicting the major events during field sampling. Based upon the review of this SOP in conjunction with the review of the streamflow monitoring protocol I stand by my initial recommendation that this protocol should be **possibly accepted with major revisions, and that an approved version of SOP#9 (Field Methods for stream flow measurement) be included within the protocol.** ***MK****: As suggested, the WQ SOP 9 has been incorporated into the streamflow protocol as SOP. Formatting has been updated to meet the NRR standard. The reviewers comments in the previous draft were incorporated. We added correct literature citations, corrected margins, and corrected pagination. We kept the appendix about equipment maintenance instead of incorporating it into the text.* ***DF****-added general workflow chart for routine site visits and discharge measurements. In SOP7, we tried to provide as much detail for data analysis without making the SOP unreadable and cumbersome. Some of the details (e.g., specific software procedures for rating curve development) were not included because of the enormity of details, but the SFAN staff and others are referred to the digital reference manual (all 377 pages of it). In addition, personnel with sufficient training and background (see*

Review by Stephen Blanchard

Rick Inglis, Hydrologist
Water Operations Branch
National Park Service Water Resources Division
1201 Oak Ridge Drive, Suite 250
Fort Collins, CO 80525

Dear Rick:

My office has completed the peer review of the "San Francisco Bay Area Network Streamflow Monitoring Protocol" V 2.87 for the National Park Service's San Francisco Bay Area Network. The completed PWR Protocol Review Checklist is attached as is an electronic word document with the changes and comments shown using the track changes function.

The protocol is very well written. It is certainly scientifically credible, will be easily implemented, and the procedures are clear, concise, and understandable. The included station descriptions in SOP # 3 are outstanding. The watershed conditions, descriptions of structures and equipment, potential problems, and general setting of the data collection points are very detailed and informative. Individuals with no prior knowledge should be able to find, service, and understand the important aspects of each of the existing and proposed streamgages.

We noted throughout the report that the data collection sites are described by various terms including streamflow site, gaging station, gauge, etc. The preferred term used by the U.S. Geological Survey Water Resources Discipline is "streamgage." Consistent reference throughout the document would be valuable.

Minor points and comments, editorial suggestions, and request for clarification are included within the document itself. You should contact James Kolva, of my staff, if you have any questions or would like to further discuss any topics (jrkolva@usgs.gov: 703-648-5225).

Sincerely,

Stephen Blanchard
Chief, Office of Surface Water

RECEIVED
JUN 15 2009
BY:

MK: *Streamgage is now used throughout.*

Science Reviewer: James R. Kolva, USGS Admin. Reviewer

	Overall Organization and Presentation of Protocol Narrative
Yes	1. Is the overall monitoring protocol well-organized with sections clearly delineated?
Yes	2. Does the protocol have a title page with authors' names, protocol version number and date? (Protocol version numbers should be constructed to allow for both major and minor changes.) Is there a Table of Contents, abstract, and the three basic sections: 1-Narrative, 2-Standard Operating Procedures (SOPs), and 3-Supplementary Materials or Appendices recommended in the NPS standards published by Oakley et al. 2003 (http://science.nature.nps.gov/im/monitor/protocols/ProtocolGuidelines.pdf).
Yes	3. Is there a complete and accurate table of contents with page numbers? (Chapters should be paginated consecutively, i.e. Chap. 1 (pp. 1-20), Chap. 2 (pp. 21-28), Chap. 3 (pp. 29-44), etc. to allow for modular updates.)
Yes	4. Are the tables and figures clearly labeled and understandable?
Yes	5. Is the protocol bound so that it lies flat, preferably in a 3-ring binder?
Section 1	**A. Background and Objectives (Chapter 1)**
Yes	1. Does the protocol narrative provide a rationale or justification for why a particular resource or resource issue was selected for monitoring? Is the history and background for this resource issue well-referenced with supporting literature cited?
Yes	2. Does the protocol narrative discuss the linkages between this and other monitoring projects?
Yes	3. Does the protocol narrative describe how monitoring results will inform management decisions?

Yes	4. Does the protocol narrative contain careful documentation of the monitoring objectives or monitoring questions being asked?
Yes	5. Does the protocol narrative identify specific measurable objectives such as thresholds or trigger points for management actions?
Section 1	**B. Sampling Design (Chapter 2)**
Yes	1. Is there a clear and logical rationale for selecting the sampling design over others?
Yes	2a. Were the criteria for site selection clearly discussed including stratification, spatial design, and whether this monitoring will be co-located and/or integrated with other VS monitoring protocols? (See Checklist, Section 1A2.)
Yes	2b. Has the target population or "sampling frame", and the sampling units, been identified? In other words, is the desired level of inference clear?
Yes	3. Is the sampling frequency and replication identified?
Yes	4. Is the timing of sampling defined?
Yes	5. Are the location of sampling sites clearly identified?
Yes	6. Is the level of change that can be detected for the amount or type of sampling being instituted identified? (See Checklist, Section 1A5.)
Section 1	**C. Field Methods (Chapter 3)**
Yes	1. Are preparations for the field season and equipment setup included? Are requirements for permitting and compliance discussed?
Yes	2. Does the protocol include clear and detailed information on taking measurements with example survey forms included? (Protocol variables and measurements may be discussed in detail in a SOP. A complete set of forms should be included in either the supplementary materials or a SOP.)
Yes	3. Is the method of access for sampling sites provided?
Yes	4. Is there an overview of procedures for establishing, monumenting, and maintenance of plots discussed in one or more SOPs?
Yes	5. Does the protocol include details for the post-collection processing of samples or vouchers?
Yes	6. Does the protocol include procedures to be followed at the end of the field season?
Section 1	**D. Data Handling, Analysis and Reporting (Chapter 4)**
Yes	1. Does the protocol provide an *overview* of the process for entering, editing, and storing data, identification of database software, and whether the database is consistent with the recommended I&M database template structure? (For water quality protocols, see specific water quality guidance in Part B or WRD's General Comments 15, and checklist items in Section 2, items 8-10, below.)

Yes	2. Are quality assurance (QA) and quality control (QC) procedures presented for the various levels of data collection and analysis? (See water quality Part B guidance or General Comments 15 as appropriate.)
Yes	3. Is the data structure clearly presented and sufficient to capture the required information to meet the stated goal? Is there an overview of the database design?
Yes	4. Are there recommendations for routine data summaries and statistical analysis to detect change?
Yes	5. Is there a recommended reporting schedule?
Yes	6. Is there a recommended report format with examples of summary tables and figures?
Yes	7. Is there a recommendation for long-term trend analysis (e.g. every 5 or 10 years)?
Yes	8. Does the protocol narrative include an adequate description of metadata and data archival procedures?
Yes	9. Does the protocol narrative describe the frequency of testing and review of protocol effectiveness?
	E. Personnel Requirements and Training (Chapter 5)
Yes	1. Does the narrative include a listing of the personnel and describe their roles and responsibilities, and qualifications?
Yes	2. Does the protocol include a discussion of training procedures for personnel?
	F. Operational Requirements (Chapter 6)
Yes	1. Are facility, vehicle and equipment needs identified?
Yes	2. Is there a summary of key partnerships with agencies, organizations and individuals that are part of the monitoring program and a description of their contribution? Is there a list of relevant cooperative agreements and other partnership agreements, if applicable?
Yes	3. Is a schedule for the annual fieldwork and administrative needs required to implement this protocol included?
Yes	4. Is there an overall budget that summarizes the annual and periodic costs of implementation of the protocol? Does it seem reasonable?
Yes	5. Does the staffing plan and budget demonstrate that adequate resources have been allocated to data management, analysis, and reporting activities (ca. 30% are recommended)?
Section 1	**G. Literature Cited (Chapter 7)**
Yes	1. Are the literature citations relevant, sufficient and consistently formatted?
Section 2	**Standard Operating Procedures (Selected essential SOPs in addition to those mentioned in the narrative outline are identified in the checklist below. For Water Quality protocols, Part B Guidance or WRD's General Comments 15 should be consulted when developing SOPs.)**
Yes	1. Is there a table of contents for the SOPs?
Yes	2. Are changes to each SOP clearly identified with a title, version number **or** revision date, and page numbers? Changes to protocol modules (Chapters or SOPs) should be reflected in the overall protocol version number and protocol revision history log either through a minor or major revision; however, you may also wish to develop a numbering scheme for SOPs, e.g. SOP 1.00, 1.01…
Yes	3. Is there a SOP with instructions for revising the protocol and a revision history log?

Yes	4. Is there a SOP with instructions for preparation before the field season? Is there a SOP with instructions for procedures and equipment storage during and after the field season? (Also see numbers 10 and 11 below.)
Yes	5. Is there a SOP for training field personnel?
Yes	6. Is there a SOP that clearly defines protocol variables and how to measure them? (See Checklist, Section 1C2.)
Yes	7. Are there clear and detailed driving and other navigational instructions to sampling sites?
Yes	8. Are the details of Data Management identified in one or more SOPs? Topics to be included are at minimum identified in Section 1D and may include customized data management routines. Specifically for water quality monitoring data, does the SOP specify how data will be reported to WRD for entry into the Environmental Protection Agency's STORET database?
Yes	9. For water quality monitoring and other monitoring as appropriate, is there a quality control SOP associated with each protocol that adequately documents QC objectives for measurement sensitivity (detection limits), measurement precision, measurement systematic error (bias as percent recovery), data completeness (including adequacy of planned sample sizes and statistical power – this topic may be in the SOP on Sampling Design), and (if applicable for lab measurements only) blank control? Are instrument calibration details included either in the QC SOP or in a separate calibration SOP?
NA	10. For water quality protocols, is there a SOP that includes an explanation of how data comparability (a quality assurance basic) was considered in choosing which protocols and chemical labs to utilize? Do protocol SOPs contain enough field and lab method details to allow others to determine if data produced is comparable enough to other regional data sets to be considered credible by regulatory agencies interested in the data?
Yes	11. Do aquatic protocol SOPs adequately describe the details of all Sampling Protocols (Field and Laboratory), as well as equipment needs and operation, sampling techniques, sample preservation and handling and logistics?
Yes	12. Are all major procedures required for the protocol sufficiently explained? Are any SOPs missing?
Yes	13. Are the literature citations with the SOP relevant, sufficient and consistently formatted?
Section 3	**Supplementary Materials or Appendices**
No	1. Is there a table of contents with Section 3 – Supplementary Materials that clearly identifies the materials provided in this section of the protocol? ***MK****: Supplementary materials have now been integrated into the protocol. For example, WQ SOP 9 is now added to document as SOP 10.*
Yes	2. Are the supplementary materials relevant, sufficient and consistently presented? Consistent formatting is desirable, but not always possible.
Yes	3. Are data collection forms provided either in this section or in an SOP?
Yes	4. Is there a section for the Administrative Record that provides the history of protocol development and refinement? A summary event table is highly recommended in addition to the supporting materials required in the Protocol Review File Checklist, e.g. the initial study plan or protocol development summary, the results of protocol development studies, peer review comments and responses during the development phase, and/or any published

	protocol on which a major portion of the methodology included in this protocol is based. (The published protocol may be presented either in Section 2 or Section 3 depending upon its contribution to the current protocol.)

Literature Cited

Irwin, R. 2004. Vital signs long-term aquatic monitoring projects: Part B – Planning process steps: Issues to consider and then to document in a detailed study plan that includes a quality assurance project plan (QAPP) and monitoring "protocols" (standard operating procedures). National Park Service, Fort Collins, Colorado. Online. (http://www.nature.nps.gov/water/Vital_Signs_Guidance/Guidance_Documents/wqPartB.pdf). Accessed 24 March 2010.

Irwin, R. J. 2008. Draft Part B lite QA/QC review checklist for aquatic vital sign monitoring protocols and SOPs. National Park Service, Water Resources Division. Fort Collins, CO. (http://science.nature.nps.gov/im/monitor/TechnicalGuidance.cfm#TGWater). Accessed 24 March 2010.

Oakley, K. L., L. P. Thomas, and S. G. Fancy. 2003. Monitoring Protocol Guidelines. Wildl Soc Bulletin 31(4):1000–1003.

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

Standard Operating Procedure (SOP) 9. Quality Assurance Plan (QAP)

Version 1.12

Revision History Log

Prev. Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
	2/16/07	Darren Fong	Initiation of QAPP based on EPA (2002) and SFAN WQ QAPP	Consolidate QA/QC procedures into standardized EPA format	1.0
1.0	5/20/08	Darren Fong	Consolidation of QAPP materials from protocol narrative and WRD comments	Comments from WRD	1.1
1.1	8/6/08	Paul Johnson, Marcus Koenen	Proofreading		1.11
1.11	6/5/10	Darren Fong	Major revision	Comments from WRD to follow USGS QAP as much as possible	1.12

Figures

Page

Figure SOP 9.1. Relation between mean velocity and standard error of individual measurements for Marsh-McBirney Flo-Mate 2000 current meters (derived from Fulford 2001). ..... SOP 9.16

Tables

Page

Table SOP 9.1. Nominal precision of measurements of surface water and related parameters (from Sauer 2002). ..... SOP 9.5

Table SOP 9.2. Stream measurement device sensitivities, instrument calibration checks, and corrective actions..... SOP 9.8

Purpose

This SOP provides guidance to ensure high data standards are met associated with the SFAN streamflow monitoring program. The elements in this streamflow monitoring Quality Assurance Plan have undergone major revision; prior versions initially followed guidance established by the EPA (EPA 2002) as well as NPS Water Resources Division (Irwin 2008) for water quality programs. Currently, the format generally follows the standard water quality assurance plan format that is required by the U.S. Geological Survey for their district staff and focuses primarily on streamflow (Arvin 1995). It has been modified to include more recent guidance provided by Sauer (2002). However, because of our small program and the data quality limits already described in the protocol narrative, we have not used all the same standards adopted by the USGS. The situations where there is a difference from USGS standards will be noted in this SOP. Some of the sections in the USGS Quality Assurance Plan are duplicative of information provided in the Protocol Narrative and SOP's; however, these sections are still included in this document to ensure consistency with the USGS Quality Assurance Plan format. This QA Plan is reviewed and revised at least once every 5 years in conjunction with our programmatic review in order that responsibilities and methodologies are kept current and in order that the ongoing procedural improvements can be effectively documented.

Project Management and Responsibilities

This monitoring program is intended to provide a long-term, well-documented and systematic discharge record (greater than 30 years). 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. Programmatic reviews will involve SFAN Aquatic Professionals group and possibly Water Resources Division staff.

Title and Approval Sheet

This element identifies key project officials and documents their approval and commitment to the QAP. The proxy for this element will be signed individual Performance Appraisal Plans of individuals indicating commitments by SFAN network and Park-base funded staff to implementing the monitoring program and QAP.

Distribution List

Key personnel involved with the development, implementation, and review of this monitoring protocol will be on the electronic mailing list for receipt of this document and subsequent major revisions. These include:

- Vacant, Water Quality Specialist — San Francisco Area Network
- Brannon Ketcham, Hydrologist — Point Reyes National Seashore
- Tamara Williams, Hydrologist — Golden Gate National Recreation Area
- Darren Fong, Aquatic Ecologist — Golden Gate National Recreation Area
- Marcus Koenen, I&M Coordinator — San Francisco Area Network
- Paul Johnson, Wildlife Biologist — Pinnacles National Monument
- Gwen Gerber, Hydrologist — NPS-Water Resources Division
- Vacant, Hydrologist — NPS-Water Resources Division

Responsibilities

Quality assurance (QA) is an active process. Achieving and maintaining high-quality standards for surface-water data are accomplished by specific actions carried out by specific persons. Errors and deficiencies can result when individuals fail to carry out their responsibilities. Clear and specific statements of responsibilities promote an understanding of each person's duties in the overall process of assuring surface-water data quality.

Table 9 in the protocol narrative provides a list of responsibilities of personnel involved in the collection, processing, analysis, storage, or publication of surface-water data.

Collection of Stage and Streamflow Data

Reliable surface-water data are necessary for planning and resource management. The collection of stage and streamflow data is a primary component in the ongoing operation of the SFAN streamflow-streamgages (referred to in the remainder of this SOP as streamgages). The objective of operating a streamgage is to obtain a continuous record of stage and discharge at the site (Carter and Davidian 1968). A continuous record of stage is obtained by installing instruments that sense and record water-surface elevation in the stream. Discharge measurements are made at periodic intervals to define or verify the stage-discharge relation and to define the time and magnitude of variations in that relation. Personnel involved in the collection of stage and discharge data shall be properly trained, well informed, and follow the surface-water data collection policies and procedures established by this program.

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 measurements have been identified by USGS and nominal precision of surface water measurements for data analyses is described by Sauer (2002). Table SOP 9.1 lists the nominal precision for standard measurements by the USGS and by the SFAN streamflow program.

Current meters have different sensitivities at various discharge ranges, water depths and velocities. It would be inappropriate to use measurement devices outside of their recommended limits. The environmental tolerance limits by measurement device are provided in Table SOP 9.2. In some cases, the method detection limits have not been defined by a neutral party (e.g., USGS) and in these instances, the manufacturer’s method detection limit is noted.

Table SOP 9.1. Nominal precision of measurements of surface water and related parameters (from Sauer 2002).

Parameter	USGS Precision of Measurements	SFAN Precision of Measurements
Gage height or elevation of water surface	0.01 ft	Same for observed. Up to 0.02 ft for recorded.
Gage height of zero flow, natural channel	0.10 ft	Same
Gage height of zero flow, manmade control structure	0.01 ft	Same
Gage height of gage features	0.01	Same
Velocity (electromagnetic meter, ultrasonic meter, Price current meter)	0.01 ft/s	Same for Price-style meters
Depth (uneven streambed, deep streams)	0.10 ft	Same
Depth (smooth streambed, shallow streams)	0.01 ft	Same
Width (wading measurements, narrow cross sections)	0.10	Same
Width (bridge, cable, boat, wide cross sections)	1.0 ft	Same
Ground elevation (cross section)	0.1 ft	Same
Reference and benchmarks	0.001 ft	0.005

Gage installation and maintenance

Proper installation and maintenance of streamgages are critical activities for ensuring quality in streamflow data collection and analysis. Effective site selection, correct design and construction, and regular maintenance of a gage can make the difference between efficient and accurate determination of drainage-basin discharge or time-consuming, poor estimations of flow.

Sites for installation of streamgages are selected with the intent to meet the purpose of each specific gage. Additionally, sites are selected with the intent of achieving, to the greatest extent possible, ideal hydraulic conditions. Criteria that describe the ideal gaging-station site are listed in Rantz et al. (1982a). These criteria include unchanging natural controls that promote a stable stage-discharge relation, a satisfactory reach for measuring discharge throughout the range of stage, and the means for efficient access to the gage and measuring location. Other aspects of controls considered by personnel when planning gage-house installations include those discussed in Kennedy (1984).

The individual responsible for selecting sites for new streamgages is the Technical Program Lead, assisted by the Field Lead (Network Water Quality Specialist) and NPS-WRD Hydrologist. The responsibility for ensuring proper documentation of agreements with property owners for streamgages not on NPS lands is held by representatives for the individual Parks. Approval of site design is the responsibility of Technical Program Lead with assistance from NPS-WRD Hydrologist. Responsibility for construction of streamgages is held by the field staff and Technical Program Lead. Inspection and approval of the completed installation is the responsibility of Technical Program Lead.

A program of careful inspection and maintenance of streamgages and gage houses promotes the collection of reliable and accurate data. Allowing the equipment and structures to fall into

disrepair can result in unreliable data and safety problems. Visual inspection of streamgage and control is performed at sites by field staff of streamgage and control to document changes since prior visits. These inspections and maintenance include checks of desiccant, battery voltage, visible damage to equipment, etc. To prevent the buildup of mud or the clogging of intakes, stilling wells are flushed annually. Any inspection and maintenance information are recorded on the standard site visit and discharge measurement datasheet (Appendix SOP 10B). Any problems are also reported by field staff to the Technical Program Lead.

Measurement of Stage

Many types of instruments are available for measuring the water level, or stage, at streamgages. There are non-recording streamgages (Rantz et al. 1982a) and recording streamgages (Rantz et al. 1982a). Because the uses to which stage data may be put cannot be predicted, surface-water stage records at stream sites should be collected with instruments and procedures that provide sufficient accuracy to support computation of discharge from a stage-discharge relation, unless greater accuracy is required (Office of Surface Water memorandum 93.07).

USGS has described a criterion for acceptable instruments capable of sensing and recording stage with a sensitivity of either 0.01 ft or 0.2 percent of the effective stage being measured, whichever is less restrictive (USGS 1992). In general, operation of SFAN streamgages for the purpose of determining daily discharge includes the goal of collecting stage data at the accuracy of +/- 0.02 feet.

The types of instrumentation installed at any specific gage station operated by SFAN is dependent on a balance between cost-efficiency and performance, no requirement for power from the grid or telephone communication, and effective under high sediment loads. Types of water-level recorders operated by personnel in SFAN include dataloggers that record output from pressure transducers and ultrasonic meters. The responsibility for determining what type of water-level recorder is operated at each streamgage is held by the Technical Program Lead, under consultation with individual parks and NPS-WRD hydrologists. Ensuring that new equipment has been installed correctly is the responsibility of Lead Field Staff and Technical Program Lead. Proper maintenance of gage instrumentation or replacement, if appropriate, of equipment is the responsibility of Lead Field Staff.

Accurate stage measurement requires not only accurate instrumentation but also proper installation and continual monitoring of all system components to ensure that accuracy does not deteriorate with time (Boning 1992). To ensure that instruments, located within the gage house, record water levels that accurately represent the water levels of the body of water being investigated, "inside" and "outside" water-level readings are obtained by independent means. At stations equipped with a stilling well, USGS guidance refers to the base or reference gage as the instrument installed inside the gage house, and other streamgages are installed outside the gage house to indicate whether or not the intakes are operating properly (Rantz et al. 1982a). However, all of our current streamgages have narrow diameter stilling wells that do not allow for “inside” water-level readings. Therefore, the outside staff gage serves as the reference gage (Meyer 1996).

The environmental tolerance limits for measurement devices used by the SFAN are listed in Table SOP 9.2. Use of devices outside their recommended limits could compromise data quality.

Ensuring that instrumentation installed at streamgages is properly serviced and calibrated is the responsibility of field staff. This responsibility is accomplished by inspection of the gage height record, and comparison to past and current outside gage heights during station visits. When deficiencies are identified, field staff are expected to repair or correct the problem. Typical problems in the past have included differences between staff gage and datalogger reported water heights. A list of typical problems and possible corrective actions is provided in Table SOP 9.2.

Gage Documents

It is required that certain documents are placed in each gage station enclosure for the purpose of keeping an on-site record of observations, equipment maintenance, structural maintenance, and other information helpful to field personnel. Documents maintained at each gage house include (1) the most recent digital stage-discharge relation (rating); (2) a graph of the rating upon which each new measurement is plotted; (3) the most recent station description listing all streamgages and reference marks at the site and associated elevations, locations of measurement cross sections, information related to extreme events including the potential for channel storage between the gage and measuring section during flood conditions, and other information (see the section "Site Documentation, Station Description" in this SOP); (4) a log updated by field personnel upon each site visit describing control conditions and listing gage readings, measurement values, gage-house maintenance, and equipment maintenance; (5) a calendar; (6) information regarding the particulars of individual dataloggers including wiring diagram and programming instructions; and (7) important telephone numbers.

Table SOP 9.2. Stream measurement device sensitivities, instrument calibration checks, and corrective actions.

Measurement	Instrument	Recommended Ranges	Sensitivity	Method detection limits	Bias Reduction Actions/Frequency	Corrective Action
Discharge	Modified Parshall flume (3 inch)	0.001>Q<0.488 cfs[13]	2–3%[1]	0.001 cfs[1]	Check estimate with volumetric method	Errors may be associated with seepage, inadequate equilibrium period before reading.
	H Flume (1.5 foot)[2]	0.001>Q<4.6 cfs	N.A.	0.001 cfs[4]	Check estimate with volumetric method	Errors may be associated with inaccurate gage height measurements, damage to v–notch, flume floor not level, and submergence conditions (>50%)[3].
	Volumetric	N.A.	N.A.	N.A.	N.A.	Increase sample time or volume.
	Float	N.A.	N.A.	N.A.		
Velocity	Gurley pygmy [4]	0.3 to 1.5 feet depths[1] and for SFAN when >0.25 ft/s	2%[4], Variable, 1.5–6% from 3 to 0.25 ft/s, resp[14]	0.05 ft/s[4]	Spin test greater than 45 secs.[7] /Each use	If spin test fails, follow maintenance procedures (SOP 10). Ensure accuracy by regular certified tow tank calibrations.
	Price AA	>1.5 foot depth, 0.10–12 ft/s[5]	Variable, Variable, 1–6% from 8 to 0.25 ft/s, resp[14]	0.10 ft/s[5]	Spin test greater than 2 minutes.[7] /Each use	If spin test fails, follow maintenance. procedures (SOP 10). Ensure accuracy by regular certified tow tank calibrations.
	Swoffer 2100 (rated meter only)	For SFAN., for depths >.0.17 feet and when velocity >0.25 ft/s[11]	1%[4], Variable, approx 1% from 0.5 to 8 ft/s[11] and approx 6% @ 0.25 ft/s	0.01 ft/s *	Calibration value of 186 & spin test > 300.	If calibration <186, follow maintenance procedures (SOP 10). Ensure accuracy by regular certified tow tank calibrations.
	Marsh-McBirney Flo-Mate 2000	For SFAN., for depths >.0.17 feet and use >0.75 ft/s and for cable suspension	2%[4], Variable 4.5%@1.1ft/s [11]	0.01 ft/s *	Zero check/Before each field day	Ensure accuracy by regular certified tow tank calibrations.
Stage Height	Crest gage			0.01 ft		Eye exam
	Staff gage			0.01 ft		Eye exam. If low light, use flashlight
	Pressure transducer (Druck, INW and Global Water)	0–12 feet (INW&Druck, 5psig), 0–15 feet (Global Water)	Generally 0.1% (full scale range)	0.01 ft (INW&Druck). 0.02 for Global Water	Zero, mid, and full span calibration check at known water depths/min. yearly	Check data sheets for transcription errors or explainable field conditions. Check transducer to see if diaphragm is damaged or plugged with fine sediments. Check calibration of transducer. See if relationship linear and slope and intercept similar to programmed values. If all else fails, send transducer to manufacturer for service and repair.

Table SOP 9.2. Stream measurement device sensitivities, instrument calibration checks, and corrective actions (continued).

Measurement	Instrument	Recommended Ranges	Sensitivity	Method detection limits	Bias Reduction Actions/Frequency	Corrective Action
Rainfall	Tipping bucket (Davis Instruments II, Onset)	Max rate undefined	4% (<2 in/hr) 5% (2–4 in/hr)	0.01 inch	Known volume of water /min. yearly	Adjustments to tipping bucket (leveling, alter sensitivity).
Topographic	Topcon Autolevel AT-G2 or Laser Beacon	N.A.	<0.01 ft	0.01 ft	Routine survey closures and periodic peg tests	Resurvey if closure fails. If fails peg test, check and adjust instruments.

[1]Rantz and others 1982
[2]Plasti-fab, H-flume manufacturer
[3]Kilpatrick and Schneider 1983
[4]Detection limits based on manufacturer specifications
[5]Sneider 1985, Office of Surface Water (OSW) Branch Memo 85.07 (USGS)
[6]Sauer and Meyer 1992
[7]Hubbard 1989, OSW Technical Memorandum No. 89.07
[8]Blanchard (2005)
[9]Campbell Scientific (2004)
[10]Marsh-McBirney Inc. 1990
[11]Fulford 2001
[12]Davis Instruments 2004
[13]USGS-HIF
[14]Hubbard 1999
*Resolution of meter readout

It is the responsibility of field staff to exchange outdated material with updated gage documents as needed. When field personnel visit a gage house and identify a need to update one or more of the documents, that person is responsible for making sure an updated version is obtained and placed in the gage. Individuals having questions related to what documents should be kept in a gage house, when the documents should be replaced with newer documents, or appropriate methods of appending logs or plotting measurements should contact the Technical Program Lead.

Levels

The various streamgages are set to register the altitude of a water surface above a selected level reference surface called the gage datum. The gage's supporting structures--stilling wells, backings, shelters, bridges, and other structures--tend to settle or rise as a result of earth movement, static or dynamic loads, vibration, or battering by floodwaters and flood-borne ice or debris. Vertical movement of a structure makes the attached streamgages read too high or too low and, if the errors go undetected, may lead to increased uncertainties in streamflow records. Leveling, a procedure by which surveying instruments are used to determine the differences in altitude between points is used to set the streamgages and to check them from time to time for vertical movement (Kennedy 1990). Levels are run periodically to all bench marks, reference marks, reference points, and streamgages at each station for the purpose of determining if any datum changes have occurred (Rantz et al. 1982a). In addition, level surveys will also record water surface and point of zero flow (Meyer 1996). All level rods will be read by this program to the nearest 0.005 ft.

Levels are run at newly installed streamgages during the first water year that the gage is constructed. Levels are run to established streamgages at least once every three years. When running a level circuit from a single instrument set-up location, the instrument must be moved and point re-surveyed.

If the gage or the reference marks are found to be unstable, then annual or more frequent circuits will be run. Streamgages are reset to agree with levels when there are vertical changes of 0.02 feet or greater. When streamgages are reset, field personnel document the reset by noting changes on the level notes datasheet (See SOP 1).

Levels are run by use of field methods and documentation methods described in Kennedy (1990) and Harrelson et al 1994. Although fiberglass rods are not recommended by USGS for level use, that is the standard equipment that is available to this program. Level rods are checked prior to use along the full length of the rod. Foot graduations on the rod are compared with a steel tape or ruler. The rod is considered satisfactory if graduations are within 0.005 feet. This information is recorded on the level notes datasheet (See SOP 1). The level instruments are checked using the two-peg test (Harrelson et al 1994) prior to level field work for the year, and as necessary, whenever there is reason to doubt instrument performance (Meyer 1996). If the level instrument fails the peg test, the manufacturer’s instructions should be followed to adjust the instrument.

It is the responsibility of the field staff to ensure that field level notes are checked. The level information is entered in the level-summary form by field staff. Ensuring that levels are run correctly and that all level notes are completed correctly is the responsibility of field staff.

Ensuring that levels are run at the appropriate frequency is the responsibility of Technical Program Lead.

Site Documentation

Thorough documentation of qualitative and quantitative information describing each streamgage is required. This documentation, in the form of a station description and photographs, provides a permanent record of site characteristics, structures, equipment, instrumentation, altitudes, location, and changes in conditions at each site. Printed records of station descriptions will be kept with the site visit and discharge measurement datasheet (Appendix SOP 10B) for each station. All photographs for existing stations are in digital format and are stored on the Marin Headlands, Golden Gate National Recreation Area server (See SOP 2 Data Management).

Station Descriptions: A station description is prepared for each streamgage and becomes part of the permanent record for each station. Station descriptions will be written within the first 3 months after establishment. The responsibility for ensuring that station descriptions are prepared correctly and in a timely manner is held by the Technical Program Lead. Station descriptions are updated when channel or equipment changes necessitate.

Station descriptions are written to include specific types of information in a consistent format (Kennedy 1983). The standard fields for station descriptions follow Kennedy (1983) and our current station descriptions are provided in SOP 3 as examples.

Photographs: Photographs such as newly installed gage houses, station controls, reference marks, damaged structures, and high water marks are made by field personnel for the purpose of documenting gage-house construction, changes in control conditions, or to supplement various forms of written descriptions. All field personnel will bring digital cameras in the field for photographic documentation. Each photograph that becomes part of the station record is identified by a unique filename provided by the camera. Information regarding the photos (e.g., direction and object photographed) is recorded on the site visit and discharge measurement datasheet (Appendix SOP 10B) and stored in the SFAN discharge database. Details regarding storage, location, and photo documentation are provided in SOP 2 Data Management.

Direct Measurements

Direct measurements of discharge are made with any one of a number of methods described in Rantz et al. (1982a). For our program, this includes current meters, flumes, volumetric, and weirs. The most common is the current-meter method. A current-meter measurement is the summation of the products of the subsection areas of the stream cross section and their respective average velocities (Rantz et al. 1982a). Procedures used for current-meter measurements are described in Rantz et al. (1982a), Carter and Davidian (1968), and Buchanan and Somers (1969).

When personnel make measurements of stream discharge, attempts are made to minimize errors. Sources of errors are identified in Sauer and Meyer (1992). These include random errors such as depth errors associated with soft, uneven, or mobile streambeds, or uncertainties in mean velocity associated with vertical-velocity distribution errors and pulsation errors. These errors also include systematic errors, or bias, associated with improperly calibrated equipment or the improper use of such equipment. Bias describes the systematic or persistent distortion of a measurement process that causes errors in one direction from the true value (EPA 2002). In

almost all instances, equipment bias can be determined through routine equipment calibration against reference or true values.

Equipment measurement bias will be identified and minimized to the extent practicable in our program. Equipment measurement bias for our program will be determined by routinely rating velocity meters under controlled settings (e.g., tow tanks). Given the expense of these calibrations, SFAN meters will be calibrated once every 3 years or sooner if repairs are made to the meters. All calibration checks are recorded. Equipment measurement bias can be minimized by assessing the departure of reported velocities from rating curve (residuals) and only using the meters under those velocity conditions where residuals are smallest. Past ratings of network velocity meters indicate larger departures from rating curves near the lower velocity ranges for pygmy and Swoffer meters (Thibodeaux 2000). When possible, more accurate direct measurement measures such as flumes or weirs will be employed under low velocity conditions.

Measurement bias associated with personnel will be assessed by an independent measurement of discharge by standard field crew and an independent party. It is assumed that all equipment are in equivalent and good condition and that discharge measurement differences represent differences in sampling technique. Bias will be calculated as the percent difference between the independent measurement and the blind measurement conducted by standard field crew. Should bias exceed 10%, discussions between the surface water measurement expert and network staff will be initiated to determine cause (e.g., equipment error, sampling technique). This bias estimate should be conducted each WY or when field personnel change.

The streams in this network are characterized by streamflows that are flashy and during summer and fall periods, have discharges that are difficult to measure accurately with current meters (e.g., shallow depths with low velocity). Unfortunately, in many of these situations, it is also difficult to use alternate procedures (e.g., weirs and flume) because of the nature of the channels (coarse bottoms with significant underflow). Because of such situations, we feel that it is acceptable to use meters to below their generally acceptable limits, but when doing so, we will acknowledge the increased uncertainties in the discharge estimate.

To reduce error, the SFAN program will follow the following: Depth criteria for meter selection.--Field staff select the type of current meter to be used for each discharge measurement based on criteria provided by USGS (Schneider 1985). Meters are used with caution when a measurement must be made in conditions outside of the ranges of the method provided by USGS. Any deviations from those criteria are noted and the measurement accuracy is downgraded accordingly.

It is recommended that a change of meters is not made during a measurement in response to the occurrence of two or more subsections in a single measurement cross section that exceed the stated ranges of depth and velocity.

Number of measurement subsections.--The spacing of observation verticals in the measurement section can affect the accuracy of the measurement (Rantz et al. 1982a). Under ideal conditions, observations of depth and velocity will be made at a minimum of 25-30 verticals, which are normally necessary so that no more than 5 percent of the total flow is measured in any one

vertical. Even under the worst conditions the discharge computed for each vertical should not exceed 10 percent of the total discharge and ideally not exceed more than 5 percent (Rantz et al. 1982a). Exceptions to this policy are allowed in circumstances where accuracy will be sacrificed if this number of verticals were maintained, such as for measurements during rapidly changing stage (Rantz et al. 1982a). Fewer verticals than are ideal are sometimes used for very narrow streams (about 12-feet wide when an AA meter is used and about 5 feet wide when a pygmy meter is used). In these situations, SFAN staff will space verticals no closer than 0.3 feet. Measurement of discharge is essentially a sampling process, and the accuracy of sampling results typically decreases markedly when the number of samples is less than about 25.

Other direct methods of measuring discharge.--This program may use other direct methods of measuring discharge including float or volumetric techniques, and methods involving portable weirs and flumes. Standard procedures described by Rantz et al. (1982a) and Buchanan and Somers (1969) will be followed and have been incorporated in SOP 10. These procedures are preferred over current meter measurements when meter limits are exceeded and when channel conditions are suitable for use of these alternate methods.

Computation of mean gage height: SFAN will use the procedures for the computation of mean gage height during a discharge measurement presented in Rantz et al. (1982a). These procedures have been incorporated into our discharge database. Mean gage height is one of the two variables used in describing the stage-discharge relation at a streamflow-gaging site.

Check measurements: Verification of measurements that deviate from an established rating, particularly the high and low portions of the rating, is important. An outlying measurement that is not verified by following measurements creates doubts that are not easily resolved, particularly if the person that made the measurement is relatively inexperienced. A good measurement could be disregarded or a poor measurement given full weight, if a check measurement is not available.

The USGS generally requires a check or second measurement whenever the discharge measurement plots more than 5 percent from the established rating, or about 5 percent from a newly established shift curve (Meyer 1996). This is a reasonable policy, provided the station has a fairly stable control, and measuring conditions are good. Summer-fall streamflows in SFAN are often around 1 cfs or less. Such conditions are not conducive to good discharge measurements by current meters and often stream conditions prevent use of alternate direct measurements that are generally more accurate for low flows. Under these situations, we will accept deviation from an established rating of up to 10 percent before a check measurement is required. In any case, a complete description of the control conditions during the measurement(s) is an absolute requirement. An obvious control change may make a check measurement much less desirable than a follow-up measurement a day or more later at a different stage (Meyer 1996).

In making a check measurement, the possibility of systematic error is eliminated by changing the measurement conditions as much as possible (Rantz et al. 1982b). The equipment, such as the meter, is changed. If the measurements are being made from a bridge, the measurement verticals are changed by measuring at verticals between those originally used; if wading measurements

are being made, a new measurement section is sought, or the measurement verticals in the original section are changed.

Field Notes

Thorough documentation of field observations and data-collection activities performed by field personnel is a necessary component of surface-water data collection and analysis. To ensure that clear, thorough, and systematic notations are made during field observations, discharge measurements are recorded by field personnel on discharge field forms for SFAN. This form is provided in Appendix SOP 10B.

Original observations, once written on the discharge field form, are not erased. Original data are corrected by crossing the value out then writing the correct value. Some examples of original data on a discharge-measurement note sheet include gage readings and depth. Examples of information on a discharge-measurement note sheet that is derived from original data, but not in itself original data, such as the total discharge and mean gage height. Computed data can be erased for the purpose of correction.

All computed data from discharge measurements should be calculated in their entirety before field personnel leave the field site. All applicable fields in the data form should be checked before leaving the field site for accuracy, legibility and completeness. The definitions for these fields are provided in SOP 10 in the section *Completing the Discharge and Water Quality Measurement Note Form*.

A quarterly review of field note sheets completed by different field staff is required by the Technical Program Lead for new staff and annually thereafter. Deficiencies found in the content, accuracy, clarity, or thoroughness of field notes are identified and communicated to field staff by written or oral means. The deficiencies are remedied by providing specific instructions to appropriate field staff.

Acceptable Equipment

Some of the equipment used by the SFAN for the measurement of surface-water discharge is commonly used by USGS (Rantz et al. 1982a). Our most commonly used meter is the Price-style pygmy current meter. Other meters include Swoffer 2100 (horizontal axis) and Marsh-McBirney Flo-Mate (electromagnetic). Methods followed by SFAN personnel for inspecting, repairing, and cleaning these meters are summarized in SOP 10 and summarized information is described in Smoot and Novak (1968), Rantz et al. (1982a), and Buchanan and Somers (1969).

The ultimate responsibility for the good condition and accuracy of a current meter rests with field personnel who use it (Office of Surface Water memorandum 89.07). A timed spin test made a few minutes before a measurement does not ensure that the meter will not become damaged or fouled during the measurement. Field personnel must assess apparent changes in velocity or visually inspect the meter periodically during the measurement to ensure that the meter continues to remain in proper operating condition.

Spin Tests: For pygmy meters, spin tests are required prior to each field trip. For Swoffer 2100 and Marsh-McBirney Flo-Mate meters, manufacturer instructions for calibration tests will also be done prior to each trip. Test results are documented in an electronic log that is part of the

SFAN discharge database. The log records date, personnel, spin test or calibration test, identified problems, and any corrective actions. Repairs are made to meters when deficiencies are identified through tests or inspection. Review of this log by the Technical Program Lead is required annually. If deficiencies are observed during this review of the log, appropriate field staff are informed and the problem is corrected immediately.

In addition to the timed spin tests performed prior to field trips, field personnel are required to inspect the meter before and after each measurement to see that the meter is in good condition, that the cups spin freely, and the cups do not come to an abrupt stop. Descriptive notations are made at the appropriate location on the field-note sheet concerning the meter condition, such as "OK" or "free" or other such comments.

Alternate Equipment

Pygmy meters are only recommended for use between 0.5 and 12 ft/sec (Schneider 1985) due to higher errors at lower velocities. We have set tentative tolerance limit for use of pygmy and Swoffer meters at 0.25 ft/sec and accept the higher potential errors of about 6 percent (Thibodeaux 2000; Environment Canada 2006).

Some of the current meters used by the SFAN network are not generally used by USGS. These include Swoffer 2100 and Marsh-McBirney Flo-Mate. These meters represent equipment provided by SFAN parks for use by this program at no-cost. Current meters not in general use by USGS will require meter ratings at specialized facilities (e.g., USGS Hydrologic Instrumentation Facility) to document performance with respect to test velocities. The SFAN program will use these meter ratings to adjust observed values. These meter ratings will be stored as scanned documents and the ratings themselves and applicable dates entered into the SFAN discharge database. The meter ratings will be used to correct observed velocities.

Error Estimation for Discharge Measurements

Information regarding the quality of discharge measurements will be calculated using the procedures described by Sauer and Meyer (1992). They assign estimates of standard error based on the components described above to descriptors of measurement quality which range from “poor” (>8 percent error) to “excellent” (less than or equal to 2 percent error).

For individual stream discharge measurements under good conditions (e.g., good stream conditions, field equipment in good working condition), measurements are typically within 2–4% of the mean (Sauer and Meyer 1992, Rantz et al. 1982a). Sauer and Meyer (1992) note that while standard measurement errors can range around 2% under ideal conditions, measurements may vary to about 20 percent when shortcuts and non-ideal conditions are present. Many of these shortcuts (such as 1 point velocity measurements per vertical) are done during flood conditions to speed collection of data before the stream stage changes.

Sauer and Meyer (1992) developed procedures that are being used by USGS to describe the accumulated errors associated with individual discharge measurements. These errors are associated with instrument performance, flow pulsation, flow turbulence, horizontal angles, vertical velocity distribution, and sample depth. The formulas for estimating these errors based on field conditions and standard USGS meter configurations are provided in Sauer and Meyer (1992). Our program uses their formulas in our MS Access discharge measurement database for

estimates of discharge measurement error for USGS standard equipment (see SOP 2). Generated information will be used to determine whether adjustments to existing rating curves are needed to changes in the relationship between stage and discharge.

Because Sauer and Meyer (1992) only assessed error associated with USGS standard equipment (Price AA and Price pygmy meters), we have used similar analyses to estimate measurement error associated with non-standard equipment (Marsh-McBirney electromagnetic meter and Swoffer horizontal axis meter). Data for this assessment was derived from Fulford (2001) which assessed the performance of Swoffer 2100 and Marsh-McBirney Flo-mate 2000- both models that SFAN uses depending upon conditions. For Swoffer 2100, the distribution of standard errors for individually rated meters followed the distribution of Price AA meters (Fulford 2001) except at velocities of 0.25 ft/sec. where errors exceeded those observed for Price AA. For velocities at or below 0.25 ft/sec, a fixed standard error of 1.74 was derived from individually-rated Swoffer meters in Fulford (2001). A power function regression, similar to approach by Sauer and Meyer (1992), was used to fit the Marsh-McBirney Flo-mate 2000 data (Figure SOP 9.1). These formulas are used to estimate measurement error associated with Marsh-McBirney Flo-Mate meters.

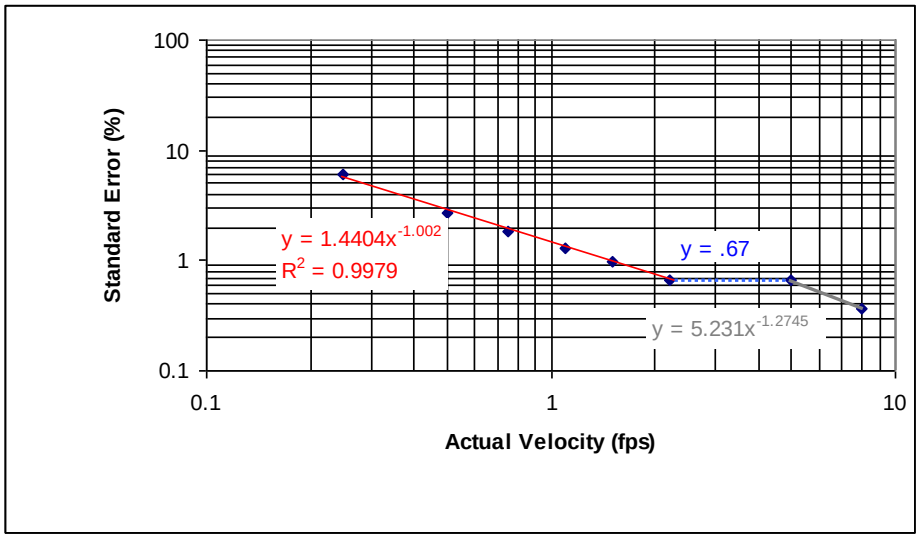


Figure SOP 9.1. Relation between mean velocity and standard error of individual measurements for Marsh-McBirney Flo-Mate 2000 current meters (derived from Fulford 2001).

Indirect Measurements

In many situations, especially during floods, it is impossible or impractical to measure peak discharges by means of a current meter. There may not be sufficient warning for personnel to reach the site to make a direct measurement, or physical access to the site during the event may not be feasible.

A peak discharge determined by indirect methods is in many situations the best available means of defining the upper portions of the stage-discharge relation at a site. Because extrapolation of a stage-discharge relation, or rating, beyond twice the measured discharge at a streamgage is

undesirable and may be unreliable, discharge measurements made by indirect methods during periods of high flows are important forms of data (Rantz et al. 1982b).

Because of the staffing and technical limitations of the SFAN program, there will be no attempt to use indirect methods to estimate peak discharge. The upper limits of discharge estimation will be twice the measured discharge at a streamgage. Field staff will strive to collect information after peak events including on high water marks, crest-gage stages, and photographs that may help in determining channel roughness and extent of floodplain inundation. Should individual Park units require peak discharge data, this information will be provided to them for their own purposes.

Crest-stage Gages

Crest-stage gages are used as tools for determining peak stages at otherwise ungaged sites, confirming peak stages at selected sites where recording gages are located, confirming peak stages where manometers or pressure transducers are used, and determining peak stages along selected stream reaches or other locations, such as upstream and downstream from bridges and culverts.

The operation of crest-stage gages is part of the SFAN monitoring program. Procedures in the operation of crest-stage gages are presented in Rantz et al. (1982a). One or more gages are maintained at each selected site where peak water-surface elevations are required on a stream.

Crest-stage gages are used only to confirm or determine peak stages. When extremely high peaks occur, an outside high-water mark to confirm the gage reading is found when possible, is described on the note sheet, and is flagged by a durable indicator so that the elevation of the high-water mark can be determined the next time levels are run. Crest-stage gage data are recorded on the site visit and discharge measurement datasheet (Appendix SOP 10B).

Artificial Controls

Artificial controls, including broad-crested weirs, thin-plate weirs, and flumes, are built in stream channels for the purpose of simplifying the procedure of obtaining accurate records of discharge (Rantz et al. 1982a). Such structures serve to stabilize and constrict the channel at a section, reducing the variability of the stage-discharge relation.

Artificial controls are used at one of the streamgages maintained by this program (Lobos Creek). In situations where artificial controls are installed as permanent structures, stage-discharge relations are based on the manufacturer's design rating.

When field inspections of artificial controls are performed, specific information pertaining to control conditions and any corrective measures are written on the field sheets for the purpose of assisting in analysis of the surface-water data. These notes include inspection of whether the flume is level, the presence of algae or debris in the flume that may affect rating, and whether freefall conditions are present. When problems pertaining to artificial controls are encountered by field personnel, the Technical Program Lead is contacted.

Low-flow Conditions

Streamflow conditions encountered by personnel during periods of low flow are typically quite different from those encountered during periods of medium and high flow. For this program, low-flow discharge measurements are made to define or confirm the lower portions of stage-discharge relations for streamgages and to help in the interpretation of other associated data. Additionally, low-flow measurements can be used to define the relation between low-flow characteristics in one basin and those of a nearby basin for which more data are available (Schneider 1985b).

In many situations, low flows are associated with factors that reduce the accuracy of discharge measurements. These factors include accumulation of small debris that impedes the free movement of current-meter buckets and larger percentages of the flow moving in the narrow spaces between cobbles that are not sampled. When natural conditions are in the range considered by the field personnel to be undependable, the cross section is physically improved for measurement by removal of debris or large cobbles, construction of dikes to reduce the amount of nonflowing water, or other such efforts (Buchanan and Somers 1969). After modification of the cross section, the flow is allowed to stabilize before the discharge measurement is initiated. Modifications to the channel should be made at locations that will not affect the gage height. If modification changes the gage height, notes are made on the field datasheet to identify the time of change, new gage height, and any changes to the control height. Even after channel modifications and as stated in prior section, stream channel conditions may still result in use of current meters under situations that exceed the standard limits of the equipment. Such condition will be reflected in the standard error estimate for the measurement.

For low-flow conditions, it is important to get the point of zero flow or the gage height at the lowest point in the downstream control. In addition, field staff should provide a semi-quantitative accuracy rating of the point of zero flow (Meyer 1996).

Processing and Analysis of Streamflow Data

The computation of streamflow records involves the analysis of field observations and field measurements, the determination of stage-discharge relations, adjustment and application of those relations, and systematic documentation of the methods and decisions that were applied. Streamflow records are computed and published for each streamgage annually (Rantz et al. 1982a).

This section of the QA Plan includes descriptions of procedures and policies pertaining to the processing and analysis of data associated with the computation of streamflow records. The procedures coincide with those described by Rantz et al. (1982a) and by Kennedy (1983).

Measurements and Field Notes

The gage-height information, discharge information, control conditions, and other field observations written by personnel onto the datasheets form the basis for records computation for each streamgage. Measurements and field notes that contain original data are required to be stored indefinitely (Hubbard 1992). Measurements and other field notes for the water year that is currently being computed are filed in the current record folder. Measurements and notes for previous water years are filed in the back files for the gage. Measurement data are entered into computer files as described in SOP 2 Data Management.

Original data obtained by direct observation in the field is called "observed data" here; subsequent values derived from the observed data are called "computed data." The distinction between observed data and computed data is that observed data cannot be recovered if lost; computed data can always be recovered from the observed data. Therefore, observed data should never be altered or destroyed.

A measurement and site summary list for each Water Year will be kept both as a hand-listed form similar to the USGS Standard Form 9-207 as well as an electronic version (spreadsheet). This form includes key site visit information, summary of discharge measurements and corresponding gage heights, and any gage-height corrections. Most of the fields will be derived as output from the SFAN stream discharge database and imported into our measurement and site summary spreadsheet.

Continuous Record

Surface-water gage-height data are collected as continuous record (hourly, 15-minute, or 5-minute values, for example) in the form of electronic storage such as data loggers, electronic transmissions by satellite, and cellular phone/modem. Streamflow records are computed by converting gage-height record to discharge record through application of stage-discharge relations. Ensuring the accuracy of gage-height record is, therefore, a necessary component of ensuring the accuracy of computed discharges.

Gage-height record is assembled for the period of analysis as completely as possible. Periods of inaccurate gage-height data are identified, then corrected (see the section "Datum corrections, gage-height corrections, and shifts") or deleted as appropriate. Items included in the assembly of gage-height record and procedures for processing the data are discussed by Kennedy (1983) and Rantz et al. (1982b).

Data are entered at the field or project office. Periods of missing record or "bad" record are identified and resolved as described earlier in SOP 7 (Section- *Preparation of recording streamgage data for analysis-missing or erroneous data*).

Records and Computation

Records computed for each station are often worked as a whole each year by a single individual. Records for each station are thoroughly checked either manually or through computational measures. Approximately 10 percent of all records are reviewed in detail by the Technical Program Lead.

Procedures for Working and Checking Records: The process for checking records is similar for all types of data. Sauer (2002) notes that the accuracy of unit values of gage height and other parameters can be verified using threshold comparisons, rating comparisons, direct reading comparisons, and graphical methods. Once erroneous data are flagged, parameter value corrections such as datum corrections are applied.

Threshold comparisons will be utilized to flag values that may exceed an expected minimum or maximum value. For instance, recorded gage height data for a SFAN stream may to range from 0 to about 10 feet over the course of a wet water year. Threshold flags at 0 and 10 feet can be set to

identify gage height periods that cross these thresholds for further examination. These threshold comparisons will be done in our *Recording Streamgage Spreadsheet*.

Rating comparisons will be done to identify periods where gage height values exceed the limits of our rating. Direct reading comparisons involve the use of observed readings from the field for comparison and verification of recorded unit values. The most common example involves comparison of recorded stage data with presumably more accurate gage-height observations. Graphical comparisons will include plots of time on the independent axis (x-axis) and recorded values with observed values on the dependent axis (y-axis).

More detailed procedures for ensuring the thoroughness, consistency, and accuracy of streamflow records are described below:

Gage Height: The accuracy of surface-water discharge records depends on the accuracy of discharge measurement, the accuracy of rating definition, and the completeness and accuracy of the gage-height record (Boning 1992). Computation of streamflow records includes ensuring the accuracy of gage-height record by comparisons of gage-height readings made by use of independent reference gages, comparison of inside and outside gages, examination of high-water marks, comparisons of the redundant recordings of peaks and troughs by use of maximum and minimum indicators, examination of data obtained at crest-stage gages, and confirmation or updating of gage datums by levels.

Records computation includes examination of gage-height record to determine if the record accurately represents the water level of the body of water being monitored. Additionally, it includes identifying periods of time during which inaccuracies have occurred and determining the cause for those inaccuracies. When possible and appropriate, inaccurate gage-height record is corrected. When corrections are not possible, the erroneous gage-height data are removed from the set of data used for streamflow records computation.

Time and Date: All electronic dataloggers will be set to Pacific Standard Time. Review of field notes with datalogger and watch date and time will be done to identify periods when the datalogger clock had erroneous date and time. These records will be corrected in the *Recording Streamgage Spreadsheet* (See SOP 7).

Levels: Errors in gage-height data caused by vertical changes in the gage or gage-supporting structure can be measured by running levels. Gages can be reset or gage readings can be adjusted by applying corrections based on levels (Kennedy 1983).

Procedures for computing records for each station include ensuring that the front sheet has been completed for each set of levels, checking levels, ensuring that the level information was listed in the historical levels summary, and ensuring that information was applied appropriately as datum corrections. The individual computing the record is required to check field notes for indications that the gages were reset correctly by field personnel. If it is determined that the gage(s) should have been reset, a correction for the difference is applied to the gage-height record. The individual computing the records makes appropriate adjustments to the gage-height record by applying datum corrections.

Ratings: The development of the stage-discharge relation, also called the rating, is one of the principal tasks in computing discharge record. The rating is usually the relation between gage height and discharge (simple rating). Ratings for some special sites involve additional factors such as rate of change in stage or fall in slope reach (complex ratings) (Kennedy 1983). We follow the procedures for the development, modification, and application of ratings described by Kennedy (1984). District personnel also follow guidelines pertaining to rating and records computation that are presented by Kennedy (1983) and by Rantz et al. (1982a).

To improve consistency in the development, drafting, and analysis of stage-discharge relations the following instructions are provided. For the purpose of this instruction, a stage-discharge relation (rating) is defined as a graph, an equation, or a table.

A permanent rating curve master sheet (family of curves) will be established and maintained for each streamgage that has an unstable control. The initial master sheet should contain the fewer of all curves used for the last ten years or the last five curves. The plot should include the curve used for the peak of record. This curve compilation will provide a ready reference for shape and slope when developing new curves. Any new curves that cross or diverge (in mid-to high-flow ranges) require an explanation in the analysis. When these curve families are plotted, each family will be reviewed. Crossed curves, diverging curves, and mis-plotted points, should all be assessed for percent error and necessary revision.

At sites where flow approaches zero, rectilinear plotting of the rating is required. The method for developing low flow ratings in unstable channels is described by Kennedy (1984). This method utilizes the point of zero flow (PZF) obtained during streamflow measurements. The PZF should be obtained for every measurement if it is safe to do so. Exceptions are bedrock or concrete controls and lined channels. The accuracy of each determination of PZF should be rated. For example: PZF = 3.07 +/- .02 ft.

Ratings plotted on log-log paper have an intercept, curvature, and slope that are directly related to physical channel characteristics. Certain parts of a log-log rating and, occasionally, the entire curve can be linearized by adjusting the gage-height scale offset (e). The recommended procedure to determine a value for "e" is in Rantz et al. (1982a). A commercial rating (Aquarius rating curve software) program will be used for adjustment of scale offset. Once the curve or parts of it (not including overbank flow or extreme low flow) are linearized, the slope of the rating curve can be determined. Determining the slope of the curve in several places (straight-line segments only) is a good check on whether or not measurements were connected that should not have been, due to an intervening peak. A slope of 2.0 or less generally indicates channel control is effective.

A definition of smoothness of a rating is that first and second differences progress uniformly. The first differences should progress with each value (in most cases) larger than the one before, and with no uneven jumps. If the progression is not uniform, and the percentage between the computed versus expected discharge is more than 2 percent, it is necessary to adjust the input points. If there is a physical feature that causes a change in slope of the curve, it must be thoroughly described in the rating portion of the station analysis. The differences will only

decrease with increasing stage when there is an actual reversal in the shape of the curve. Such reversals can only occur where some impeding effect on discharge occurs, such as backwater (Rantz et al. 1982b). First differences should be reviewed by the hydrographer developing the rating.

In the absence of peak-discharge measurements, the existing high-end rating curve may be extrapolated to values at less than twice the greatest measured discharge (Rantz et al. 1982b). In situations where extrapolated values are needed, additional guidance will be sought on appropriate computational methods (e.g., slope-conveyance) that would assist in the general shape and slope of the rating curve.

The Technical Program Lead is ultimately responsible for ensuring that ratings are correctly developed, entered into the computer, checked, and stored. The NPS-WRD hydrologists may be contacted for assistance with rating development. New ratings are checked before copies of the ratings are sent outside the office.

Datum Corrections, Gage-height Corrections, and Shifts: A correction applied to gage-height readings to compensate for the effect of settlement or uplift of the gage is usually measured by levels and is called a "datum correction" (Kennedy 1983). Datum corrections are applied to gage-height record in terms of magnitude (in feet) and in terms of when the datum change occurred. In the absence of any evidence indicating exactly when the change occurred, the change is assumed to have occurred gradually from the time the previous levels were run, and the correction is prorated with time (Rantz et al. 1982b). For our program, datum corrections are applied when the magnitude of the vertical change is equal to or greater than 0.02 foot.

A correction applied to gage-height readings to compensate for differences between the recording gage and the reference gage is called a "gage-height correction" (Rantz et al. 1982). These corrections are applied in the same manner as datum corrections. Gage-height corrections are applied so the recorded data are made to agree with base-gage data. These corrections are applied when the difference between the recording gage and the base gage is equal to or greater than 0.02 foot. The correction should be applied only if there was little surge or little change in stage.

A correction applied to the stage-discharge relation, or rating, to compensate for variations in the rating is called a shift. Shifts reflect the fact that stage-discharge relations are not permanent but vary from time to time, either gradually or abruptly, because of changes in the physical features that form the control at the streamgage (Rantz et al. 1982b). Shifts can be applied to vary in magnitude with time and with stage (Kennedy 1983). This program will not have a fixed guideline for applying shifts based on a percent departure of discharge measurements from an existing rating. Shifts will be determined based on consideration of the relative accuracy of the measurements, the number of measurements consistently different from the rating, as well as the percent departure from the rating.

Datum corrections, gage-height corrections, and shifts are documented in the station analysis. Paper copies of calculations, notes and diagrams are maintained in the current folder. Checking

transitions from one water year to the next is expected. Datum corrections and shifts (or rating application) on September 30 should be compatible with those used on October 1.

Hydrographs: A discharge hydrograph is a plot of daily mean discharges versus time. The date is aligned with the horizontal axis and the discharge is aligned with the logarithmic vertical axis. In the process of computing station records, this hydrograph is a useful tool in identifying periods of erroneous information, such as incorrect shifts or datum corrections. Comparison of hydrographs of the same period will be made with other similar, nearby stations to identify any serious errors in data computation (Rantz et al. 1982b).

Information placed on the hydrograph for each station includes station name, station number, water year, date the hydrograph was plotted, drainage area, plot of daily mean discharge data, plots of measurements, streamflow stations with which the hydrograph was compared, and any other information that may be of importance. Estimates may be made in red.

Station Analysis: A complete analysis of data collected, procedures used in processing the data, and the logic upon which the computations were based is documented for each year of record for each station to provide a basis for review and to serve as a reference in case questions arise about the records at some future date (Rantz et al. 1982b). Topics discussed in detail in the station analysis include equipment, hydrologic conditions, gage-height record, datum corrections, shifts, rating, discharge, special computations, remarks, and recommendations, (Rantz et al. 1982b, Kennedy 1983). The station analysis is written by the Technical Program Lead. Individuals who work portions of the computations for the year should write sections of the station analysis pertaining to the work they completed.

Furnished Records: The SFAN periodically receives surface-water data collected under the supervision of other agencies, organizations, or institutions. Most frequently, these data are individual discharge measurements obtained at streamgages by consultants. When received, these data are used in the data analyses and annual data report publication and may be used in comparison of computed streamflow data for specific stations.

If the SFAN receives furnished data by other organizations, agencies, or institutions, the data are checked and compared with other station data, if possible. All metadata regarding the furnished data would be obtained. The Technical Program Lead is responsible for checking the data and determining whether the data can be useable. If errors in the data are suspected, the furnishing agency is contacted to determine if an error has been made. The Technical Program Lead is responsible for contacting the data donor.

Daily Values Table: With few exceptions, for each streamgage operated by the SFAN a discharge value is determined and stored for each day. The daily values table generated by use of computer software represents what discharge values are stored for each day of the water year.

Daily mean discharge is one of the major products of the records-computation process. The person who works the records is responsible for determining that the calculated daily mean discharges accurately represent the actual streamflow conditions. That person is responsible for ensuring that the daily-values table, which includes those values stored in the daily-values

computer file, contains the correct data. In addition, it is that individual's responsibility to ensure that the correct values stored in the daily values table also are contained in the hydrograph, working primaries, and the publication-ready manuscript. In turn, the checker confirms the accuracy of this information. A hard copy of the daily values table is included in the station primary folder. The finalized daily values are stored in the SFAN network by Water Year and station, for future retrieval and analyses. The person who works the records updates the progress board upon completion of the station records. The checker then updates the progress board accordingly when the checking process has been completed.

Manuscript and Annual Report: When records computation for the water year has been completed and the data collected and analyzed by SFAN personnel have been determined to be correct and finalized, the surface-water data for that water year are published along with other data in the SFAN's annual streamflow data report. Information presented in the annual data report includes daily discharge values during the year, extremes for the year and period of record, and various statistics. Additionally, station descriptions are presented in the annual data report. Information contained in the manuscript includes physical descriptions of the gage and basin, history of the station and data, and statements of cooperation.

A variety of reviews will be required before an annual report is finalized. Someone other than the person who computed and wrote the station analysis checks each station. NPS WRD surface water hydrologist will be asked to review each station analyses. The SFAN I&M coordinator does the final review of the data and publication.

Computational Check List: A process flow-chart and digital computational check list will be used by the SFAN. The flow chart provides a general overview of the computational process that may be useful for new staff (See SOP 7). This digital check list is a means of tracking the status of records computation for each station and ensuring that errors do not occur by omitting the necessary procedural steps.

Collection of Precipitation Data

Regular maintenance of the rain gage equipment is essential to obtain accurate data. The field personnel responsible for the streamgage will also be responsible for ensuring that rain gage equipment is in good working condition. Field inspection of equipment will occur concurrently with routine stream gage visits, at roughly one-month intervals. Typical inspection items include presence of vegetation or obstructions within a 45-degree cone above the gage, clogged orifices, and gages not level.

Bias may exist for tipping buckets that either consistently under- or over-report rainfall amounts. Bias can be determined through measurement of a known quantity of water by tipping buckets. Details of calibration procedures are provided in SOP 6-Procedures for Tipping Bucket Rain Gage Stations. For our program, rain gages will be calibrated annually (Blanchard 2005).

Should the percent difference (between actual and reported rainfall amounts) exceed 5 percent, procedures will be initiated to adjust the tipping bucket to reduce measurement bias (See SOP 6 Procedures for Tipping Bucket Rain Gages). When data are known to be biased, data qualifiers will be placed in the output (e.g., rainfall daily values table) indicating the measured magnitude

of the bias and expected periods of biased data. The end user can then decide whether to adjust the computed data to remove the bias. Any adjustments will be duly noted in the data files and in the annual report.

Documentation and Records

Standardized datasheets will be used to record field data for this protocol. In the past, details about routine station visits including a log of maintenance and measurement activities and level notes have been recorded in water-resistant field notebooks. Because streamgages and water quality sampling sites are co-located and may be visited on the same dates, we decided to have a single standardized datasheet. The datasheet is based on the USGS 'Discharge Measurement Notes' Form 9-275-F. All datasheets will be stored chronologically in binders by station. In addition, computer printouts of discharge record summary from the database will also accompany the field records. All field binders are located at the offices of the field staff. For PINN stations, current water year binders will be located at the Natural Resource Management Office while the remaining binders will be located at the PORE Natural Resources Office. Original datasheets for older water years will be stored at the SFAN I&M Office, Building 1063, Fort Cronkhite, Sausalito CA 94965. Instructions on filling out site visit and discharge measurement datasheets are provided in SOPs 1 and 10, respectively.

Electronic data for this project are stored in MS Excel spreadsheets and a MS Access database. Details about the types of data stored including backup procedures are included in SOP 2 Data Management.

Both long-term and annual reports will be produced from this protocol. Electronic and paper copies will be located at the SFAN I&M Office and available through the I&M coordinator.

Literature Cited

Arvin, D. V. 1995. A workbook for preparing surface water quality-assurance plans for districts of the U.S. Geological Survey, Water Resources Division. Open File Report 94-382. U.S. Geological Survey, Water Resources Division, Denver, Colorado. Online. (http://water.usgs.gov/osw/pubs/swqaplan.pdf). Accessed 24 March 2010.

Buchanan, T. J., and W. P. Somers. 1969. Techniques of water-resources investigations of the United States Geological Survey. Chapter A8, Discharge measurements at gaging stations. U.S. Government Printing Office, Washington, DC.

Carter, R. W., and J. Davidian. 1968. General procedure for gaging streams. Chapter A6 *in* Techniques of water-resources investigations of the United States Geological Survey. Book 3. U.S. Geological Survey, Washington. D.C. Online. (http://www.ecy.wa.gov/programs/eap/models/usgs_twri.html). Accessed 30 March 2010.

[EPA] Environmental Protection Agency. 2002. Guidance for quality assurance project plans. EPA QA/G-5. 2002 December. Office of Environmental Information, Washington, D.C.

Harrelson, C. C., C. L. Rawlins, and J. P. Potyondy. 1994. Stream channel reference site: an illustrated guide to field technique. USDA Forest Service General Technical Report RM-245. USDA Forest Service, Fort Collins, Colorado.

Irwin, R. J. 2008. Draft Part B lite QA/QC review checklist for aquatic vital sign monitoring protocols and SOPs. National Park Service, Water Resources Division. Fort Collins, CO. (http://science.nature.nps.gov/im/monitor/TechnicalGuidance.cfm#TGWater). Accessed 24 March 2010.

Kennedy, E. J. 1983. Computation of continuous records of streamflow. Chapter A13 *in* Techniques of water-resources investigations of the United States Geological Survey. Book 3. U.S. Geological Survey, Washington. D.C. Online. (http://www.ecy.wa.gov/programs/eap/models/usgs_twri.html). Accessed 30 March 2010.

Kennedy, E. J. 1984. Discharge ratings at gaging stations. Chapter A10 *in* Techniques of water-resources investigations of the United States Geological Survey. Book 3. U.S. Geological Survey, Washington. D.C. Online. (http://www.ecy.wa.gov/programs/eap/models/usgs_twri.html). Accessed 30 March 2010.

Kennedy, E. J. 1990. Levels at streamflow gaging stations. Chapter A19 *in* Techniques of water-resources investigations of the United States Geological Survey. Book 3. U.S. Geological Survey, Washington, D.C. Online. (http://www.ecy.wa.gov/programs/eap/models/usgs_twri.html). Accessed 30 March 2010.

Meyer, R. W. 1996. Surface-water quality-assurance plan for the California district of the U.S. Geological Survey. Open-File Report 96-618. U.S. Geological Survey, Sacramento, California.

Rantz, S. E., et al. 1982a. Measurement of stage and discharge. Volume 1 *in* Measurement and computation of streamflow. U.S. Geological Survey Water-Supply Paper 2175. U.S. Government Printing Office, Washington, D.C.

Rantz, S. E., et al. 1982b. Computation of discharge. Volume 2 *in* Measurement and computation of streamflow. U.S. Geological Survey Water-Supply Paper 2175. U.S. Government Printing Office, Washington, D.C.

Sauer, V. B. 2002. Standards for the analysis and processing of surface-water data and information suing electronic methods. U.S. Geological Survey Water-Resources Investigations Report 01-4044.

Sauer, V. B., and R. W. Meyer. 1992. Determination of errors in individual discharge measurements. U.S. Geological Survey Open-File Report 92-144, Reston, Virginia.

Smoot, G. F., and C. E. Novak. 1968. Calibration and maintenance of vertical-axis type current meters. Chapter B2 *in* Techniques of water-resources investigations of the United States Geological Survey. Book 8. U.S. Geological Survey, Washington, D.C. Online. (http://www.ecy.wa.gov/programs/eap/models/usgs_twri.html). Accessed 30 March 2010.

Thibodeaux, K.G. 2000. Letter and rating report for two Gurley pygmy current meters and Swoffer model 2100 current meter dated June 24, 2000 sent to Darren Fong, Golden Gate National Recreation Area from K.G. Thibodeaux, Chief, Hydraulic Laboratory Facility, USGS.

Schneider, V. R. 1985. Equipment and supplies-current meters. USGS Office of Surface Water Branch Technical Memorandum No. 85.07. 1985 May 13. USGS, Washington, D.C.

[USGS]United States Geological Survey. 1992. Office of Surface Water Technical Memorandum No. 93.07.

Standard Operating Procedure (SOP) 10. Field Methods for Streamflow Measurements

Version 2.05

Revision History Log

Prev. Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.0	8/3/05	Mary Cooprider	Minor changes	Finalizing for formal peer review	1.01
1.01	3/9/06	Rob Carson	Minor updates to text and tables	Addressing peer reviewer comments	1.02
1.02	1/07	Darren Fong	Major changes to methods and dataforms	To include all discharge measurement methods and to standardize with USGS procedures	2.0
2.0	5/10/07	David Press	Proofreading and major edit to Section 5.0		2.01
2.01	1/30/09	Darren Fong	General edits	Reviewer comments	2.02
2.02	2/18/09	Jennie Skancke	Updated tables and minor edits	Needed updated equipment info	2.03
2.03	9/16/09	Jennie Skancke	Incorporated peer review comments. Update data management section	Incorporate SOP into Streamflow protocol.	2.04
2.04	6/8/10	Darren Fong	General edits	Responding to comments	2.05

Figures

Page

Figure SOP 10.1. Reading crest depth on wading rod at control point below streamgage (from Holmes et al. 2001). ..... SOP 10.13

Tables

Page

Table SOP 10.1. SFAN meters and rating equations. ..... SOP 10.6

Appendixes

Page

Appendix SOP 10 A. Field Cheat-Sheet for Wading Discharge Measurements ..... SOP 10.25

Appendix SOP 10 B. Field Form for Recording Discharge and Water Quality ..... SOP 10.27

Appendix SOP 10 C. Descriptions for Measurement Note Sheets (from NPS-WRD) ..... SOP 10.31

Appendix SOP 10 D. Procedures for Using a Top-setting Rod for Streamflow Measurements ..... SOP 10.32

Appendix SOP 10 E. Modified Parshall Flume Procedures ..... SOP 10.33

Purpose

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, for example, include state and federally endangered coho salmon (see also SFAN Salmonid Monitoring Protocol, Reichmuth et al. 2010), federally threatened California red-legged frog and steelhead trout. A number of SFAN monitoring protocols including water quality and coho salmon monitoring are dependent and responsive to streamflow conditions.

Streamflow measurements are required by both SFAN water quality and streamflow monitoring programs. Flow measurements collected in conjunction with water sample collection and stream chemistry measurements are critical to the SFAN Water Quality Monitoring Program. First, flow measurements are necessary to determine where to collect field measurements and samples. Flow measurements also provide useful information about seasonal variability in water quality parameters and pollutant load estimates. Therefore, quantitative streamflow will be assessed at all water quality monitoring sites where practical. Where time or stream conditions do not permit flow measurements then a qualitative estimate will be provided. Discharge measurements will be used by the streamflow monitoring program for establishing stage-discharge rating curves for individual recording streamgages. Once a rating curve is established for a stream gage then water levels can be used to estimate stream discharge.

This standard operating procedure describes in greater detail, the field methods for discharge measurements. Where possible, most of the procedures follow standardized protocols for streamflow monitoring that have been adopted by the United States Geological Survey.

Scope and Applicability

The procedures described below cover routine discharge measurements conducted in the field by both SFAN streamflow and water quality monitoring programs. All methods require the collection of field parameters including width, depth, and/or water column velocity. Use of discharge measurements to develop rating curves will be discussed separately in the Data Analyses SOP.

Reference Materials

Except where noted, most of the described procedures have been obtained from standard USGS field protocols (Buchanan and Somers 1969, Rantz et al 1982a, b). Both of these documents are available electronically on the internet and the reader is referred to those documents for a more specific description of methods. Field personnel are encouraged to review the USGS tutorial CD *Measurement of Stream Discharge by Wading* (Nolan et al 2000). It provides details on the process and theory of streamflow measurements and proper methods and equipment.

Discharge Measurement Procedures

The SFAN monitoring objectives for streamflow are quite ambitious. They include the stated desire to monitor the frequency, magnitude and duration of peak flow and extreme low flow events. These objectives encompass a wide range of conditions. During the late summer the

wetted channel in some areas may be no wider than a foot and less than an inch in depth, whereas bankfull flows at the same location may approach 1,000 cfs with water depths greater than 10 feet during the winter. To accurately measure discharge under these conditions, different measurement techniques and equipment are needed.

The first step is to identify the streamflow condition at the time a measurement is desired. Prior to leaving for the field, the lead field staff needs to identify the streamflow conditions at the sample site in order to have the appropriate equipment to measure discharge. High flow conditions may dictate the use of safety equipment (e.g., personal flotation devices) not normally used during low flow measurements. Currently, two SFAN streams (Lagunitas and Redwood Creek) have gages maintained by other agencies that provide real-time gage height data on the Internet. For Redwood Creek, the Internet link is http://173.11.87.141/Redwood_Cr_Hour/panel.htm. For Lagunitas Creek, the Internet link from the USGS National Water Information System is http://waterdata.usgs.gov/nwis/dv/?site_no=11460600&PARAmeter_cd=00060,00065. Alternately, local weather data can be used to predict conditions. The National Weather Service website (http://www.nws.noaa.gov/) has local forecast models that predict the amount of daily rainfall for a three-day window.

In general, stream discharge will be measured quantitatively using established USGS procedures (Rantz et al. 1982a). Depending on flow conditions, flow measurements will be obtained using existing SFAN equipment including electromagnetic meters (Marsh-McBirney Flo-Mate), horizontal axis meters (Swoffer 2100), vertical axis meters (Gurley pygmy), flumes (3-inch modified Parshall and H-flume), or volumetric measurements. Semi-quantitative discharge estimates may also be made using floats under extreme high flow conditions. Qualitative descriptions of the discharge measurement site such as cross-section and control conditions will be included. No estimate of subsurface flows will be done under this monitoring protocol.

Current meter discharge estimates, regardless of meter type, follow the same basic procedures. A cross-section of the stream is chosen and the stream is divided into panels or sections. The width, depth, and velocity of each section are then recorded and individual discharge measurements per section are computed. Total stream discharge is the sum of individual discharge measurements in each panel and is recorded in cubic feet per second (ft^3/s or cfs). Flume estimates of discharge are much simpler. Once installed in the proper location, the height of water in the flume is used to estimate discharge based on manufacturer's rating.

Quantitative Methods

Overview

Several methods exist for measuring discharge but most methods share several similar steps. They include:

1. Selection of appropriate device to measure discharge
2. Use of properly maintained and calibrate discharge equipment
3. Selection of appropriate site for streamflow measurement
4. For current meters, dividing the channel into 25–30 cross-sections

5. Making the current measurements by meter at several points in the vertical while allowing enough time for the device to stabilize (40 seconds for most current meters)
6. Determining the mean velocity at each vertical
7. Tabulating the data in field notes
8. Making field computations using the tabulated data

Selection of Appropriate Device to Measure Discharge

Existing stream conditions dictate the best tool for the job. Under extreme low flow conditions, most current meters would not provide accurate discharge estimates. These conditions occur when 25 percent of the verticals are equal to or less than 0.3 ft and water velocities are less than 0.2 ft/sec (Meyer 1996). Pygmy meters under-register velocities at depths shallower than 0.3 ft; typically, the error is around 5 percent due to boundary effects (Meyer 1996, Rantz et al. 1982a). Electromagnetic (Marsh-McBirney Flo-mate 2000) and horizontal axis (Swoffer Model 2100) meters also perform poorly at low velocities (<0.5 ft/sec) (Fulford 2001). Options for measuring extreme low flow conditions include: volumetric, Parshall flume, and portable weir plates (Rantz et al. 1982a).

Wading measurements using meters are typically unsafe when the depth exceeds four feet at any velocity or when the product of velocity (ft/s) and depth (ft) exceeds eight. Under these conditions, measurements from bridges must be done. When conditions such as excessive floating debris prevent use of meters from a bridge, qualitative estimates of discharge may be done using timed floats.

For the SFAN monitoring program, wading current meter measurements will be conducted with either Gurley pygmy, Marsh-McBirney, Swoffer 2100, or Price AA meters depending upon their availability and conditions. The SFAN field technician and program lead will determine appropriate equipment for wading measurements using criteria provided by the USGS (1992). The criteria for equipment selection is provided in Appendix SOP 10A (Field Cheatsheet for Wading Discharge). For bridge measurements, sounding weights and Marsh-McBirney (preferable) or Price AA meters will be used. For extreme low flow measurements, individually rated flumes, weirs, volumetric or float method will be used. Standard ratings will be used for all Price meters. For all other meters, individually rated meters will be used for measurements. The environmental tolerance limits for our meters are provided in Table SOP 9.2 in SOP 9 (Quality Assurance Plan ([QAP]).

Equipment Rating

Equipment used to measure discharge or flow (e.g. current meters) should be tested/calibrated prior to mobilization in the field. Consult the manufacturer's manual for specific calibration methods and appropriate applications for selected current meter and other devices used in the flow/discharge determinations.

Because a meter's performance may change over time, all meters should be individually rated by a facility that specializes in flow meter calibration. At this time, two non-commercial facilities that perform this service include U.S. Geological Survey's Hydrologic Instrumentation Facility (HIF) in Mississippi and Canada's National Calibration Service (Environment Canada). The

SFAN parks have used both facilities. Currently, our meters are rated once every five years or when an alteration or repair is made to a meter, although it is preferable to rate the meters more frequently.

Use of individually and frequently rated meters can reduce the amount of error associated with the equipment. Schneider and Smoot (1976) noted the standard error of reported meter velocities were higher for those that used standard ratings rather than individual ratings.

To preserve the integrity of the rated meters, all field personnel must ensure that all individual parts that were used in the rated meter are also used in the field. For example, this includes correctly identifying and using the same pivot pins for the pygmy and Price AA meters. This can accomplished by storing the "non-rated," extra pivot pins in a small bag in the meter's container as an emergency back-up. To protect the integrity of the Swoffer current meter's rating, personnel should not adjust the existing calibration setting by turning the adjustment screws on the meter. Any changes to current meters (e.g., replacement of bucket wheel or props) should be documented in the meter maintenance log that is part of the SFAN stream discharge database and be sent out for a new rating.

The list of SFAN meters and flumes and their respective ratings is provided in Table SOP 10.1. This table is also part of SFAN's Microsoft Access discharge database. Any new ratings should result in modifications to this table.

Table SOP 10.1. SFAN meters and rating equations.

Meter Model Type	Serial No.	Rating Date	Rating Performed by	Rating Equation	Standard Error	Notes
Modified Parshall Flume	PF97001	N.A.	USGS	Q=1.120*H^1.628 H=water height in flume (ft)	N.A.	Individually rated flume
Price AA				NA		
Gurley pygmy	Gurley 93	22-Jun-00	USGS-HIF	V= 0.976 R (rev/s) + 0.036	0.005	
Gurley pygmy	NN3961	15-Jul-08	USGS-HIF	V= 0.994 R + 0.02	0.012	Has magnetic head
Swoffer 2100	1797	23-Jun-00	USGS-HIF	V=0.939 R (ft/s) + 0.064	0.012	Use WY00 to March 2005
Swoffer 2100	1797	21-Sep-06	Env. Canada	V = 0.9651R (ft/s) + 0.0602	0.010	Use from April 2005 to June 2008
Swoffer 2100	1797	12-Aug-08	Env. Canada	V=0.990R + 0.066		Use from Nov 2008 to Present
Marsh-McBirney Flo-Mate	2004242	22-Apr-09	Marsh-McBirney	V = R (Vel. Reading ft/s)	N.A.	Two point calib (0, 4.52 ft/s)
Marsh-McBirney Flo-Mate	2002549	03-Jan-07	Marsh-McBirney	V = R (Vel. Reading ft/s)	N.A.	Two point calib (0, 4.52 ft/s)

Care of Discharge Measurement Devices

All equipment used to conduct flow measurements are expensive and require care to ensure high performance. Details on proper care of vertical axis current meters can be found in Smoot and Novak (1968).

Equipment should be transported in appropriate cases to avoid damage. Rinse the current meters with moving parts in clear water as soon as possible after use and dry using a soft cloth. The surfaces and bearings should be clear of sediment and debris. Never store the meter in its carrying case when wet. For vertical axis meters, use the proper oil to lubricate the pivot and pivot bearing after approximately 8 hours of use, or at least once a week during periods of frequent use. To avoid damage to the pivot and pivot bearing on the Pygmy meter, be sure to replace the pivot with the brass shipping pivot when the meter is not in use. For the Price AA meter, a nut below the bucket wheel is tightened so that the pivot is secured.

General guidelines regarding performance checks and inspection of current meters that SFAN network uses are presented below. Detailed instructions are provided in the Appendices.

General Performance Checks for Meters and Flumes

(modified from Peck et al. 2001)

The accuracy of discharge estimates depends on proper care and maintenance of a meter. Performance checks are needed to determine if discharge measurement devices meet acceptable criteria for use. USGS procedures require an office log that documents the results of performance checks (e.g., spin-tests for vertical axis meters) for each current meter (Hubbard 1989). Methods for inspecting meters are described in most of the USGS procedural documents- Smoot and Novak (1968), Rantz and others (1982a) and Buchanan and Somers (1969). For this monitoring program, records of performance checks and any repairs are stored in the SFAN streamflow discharge database.

Horizontal-Axis Meters (Swoffer):

- Check that the calibration adjustment cover screws are tightly fitted on the display case.
- Periodically check the condition of the connector fitting between the display unit and the sensor.
- Connect the sensor to the display unit and check the calibration value stored in memory. If this value is less than the correct value for the display unit-sensor rotor combination, replace the batteries.
- Prior to use, perform a spin test of the rotor assembly. Turn the knob to ‘Count.’ Place the propeller vertically and blow on it. Immediately press ‘Reset’ button. A displayed count value of 300 or greater is indicative of satisfactory performance at low current velocities.
- Check the displayed calibration value prior to use. It should display a value near 186.
- If a buzzing sound occurs when the rotor assembly is spun, or if the shaft shows visible wear, replace the rotor assembly.

- Periodically examine the thrust-bearing nut on the rotor assembly. If a "cup" begins to form on the bottom surface of the nut, it should be replaced.
- **NOTE**: any repairs to the meter or modification of the 'Calibration Adjust' set screws will alter the rating of the meter such that the displayed velocity may be inaccurate. Therefore, after any repairs or modifications, the meter should be sent to an appropriate facility for calibration.

Vertical-axis Meters (from Smoot and Novak 1968):

- Inspect the bucket and wheel hub assembly, yoke, cups, tailpiece, and the pivot point prior to each use. The pivot point should be sharp and without burrs.
- Inspect the bearings and check the contact chamber for proper adjustment.
- Always conduct a spin test of the meter prior to each use, under still air conditions. To avoid damage to the unit, blow on rather than flick the bucket wheels to get them to spin. Acceptable Price AA meters should spin 2 minutes or longer (Hubbard 1989). Acceptable pygmy meters should for 45 seconds or more (Hubbard 1989).
- The vertical axis meters should not wobble or stop abruptly during the spin tests. Wobbles may indicate a bent wheel bucket or shaft. These defects can be spotted with a visual inspection. Spin test performance for individual meters are recorded on field datasheets and stored in the discharge database.

Electromagnetic Meters (Marsh-McBirney 1990)

- Once per week, check the zero value using a bucket of quiescent water. Place the probe in the bucket at least three inches away from bucket sides and allow it to sit for 10–15 minutes with no disturbance. The velocity value obtained should be ±0.05 ft/sec. Adjust the meter zero if the value is outside this range.
- An annual calibration by the manufacturer or by the USGS Hydrologic Instrumentation Facility is recommended.

Flumes (H-flume, 3-inch modified Parshall): Temporary flumes should be inspected to ensure they are free from dents that may change the hydraulics in the flume. Permanent flumes (e.g., H-flume) should be periodically inspected to ensure that there are no features within the flume that may change the rating (e.g., sediment and debris, aquatic plant/algae growth). Unless damaged, no adjustment to the original flume's rating equation should be necessary. Field calibration checks can be performed by conducting volumetric measurements (e.g., the timed bucket technique) at the outlet of the flume.

Selection of Appropriate Site for Streamflow Measurement

Rantz and others (1982a) lists the ideal cross-section for obtaining a discharge measurement:

1. Cross section lies within a straight reach, and flow lines are parallel to each other.
2. Velocities are greater than 0.5 ft/s and depths are greater than 0.5 ft.
3. Streambed is relatively uniform and free of numerous boulders and heavy aquatic growth.
4. Flow is relatively uniform and free of eddies, slack water, and excessive turbulence.

5. Measurement section is relatively close to the gaging-station control.

Preparing to Make a Wading Discharge Measurement
(adapted from Norris and Fisher 2006)

Measure and record flow after recording visual observations of channel conditions (See Section 4.1.8. *Completing Discharge Measurement Form*). Do not collect water samples in the area disturbed during a flow measurement. At sites with a staff plate, observe and record the time (Local Standard) and gage height to the nearest hundredth of a foot in the field logbook.

If necessary, the channel cross section can be modified to increase measurement accuracy. Temporary dikes can be constructed to cut off dead water and shallow flows. Rocks, vegetation, and debris can be temporary removed within 3 to 6 feet of the measurement cross section. After modifying a streambed, allow the flow to stabilize before starting the flow measurement. All moved materials should be replaced upon completion of field measurements.

Select the current meter and suspension to be used for the discharge measurement:
Either Gurley pygmy, Marsh-McBirney, Swoffer 2100, or Price AA meters will be used depending upon their availability and conditions. The criteria for equipment selection are provided in Appendix SOP 10A (Field Cheatsheet for Wading Discharge). For bridge measurements, sounding weights and Marsh-McBirney (preferable) or Price AA meters will be used. Meters are used with caution when a measurement must be made in conditions outside of the ranges of the method provided by the USGS Office of Surface Water. Any deviations from those criteria are noted and the measurement accuracy is downgraded accordingly.

It is recommended that a change of meters is not made during a measurement in response to the occurrence of two or more subsections in a single measurement cross section that exceed the stated ranges of depth and velocity. However, there may be situations when a change of meters is recommended or allowed during a measurement, for example when a very shallow overflow or secondary channel is to be measured along with a larger, deeper main channel. The program lead should be consulted for specific situations.

Determine the width of the stream at the measurement cross section as follows:

- String a tag line or measuring tape for measurements (generally ‘0’ of tape or tag line starts at the left bank [looking downstream]).
- String the line at right angles to the direction of flow to avoid horizontal angles in the cross section.
- Determine the locations of the measurement verticals using the following guidelines:

The spacing of observation verticals in the measurement section can affect the accuracy of the measurement (Rantz et al. 1982a). The USGS criteria are that observations of depth and velocity ideally be made at a minimum of 20 verticals, which are necessary so that no more than 5 percent of the total flow is measured in any one vertical. Even under the worst conditions the discharge computed for each vertical should not exceed 10 percent of the total discharge and ideally not exceed more than 5 percent (Rantz et al. 1982a). Exceptions to this policy are allowed in circumstances where accuracy would be sacrificed if this number of

verticals were maintained, such as for measurements during rapidly changing stage (Rantz et al. 1982a). Fewer verticals are sometimes used for very narrow streams (less than12-feet wide when an AA meter is used and less than 5 feet wide when a pygmy meter is used). Measurement of discharge is essentially a sampling process, and the accuracy of sampling results typically decreases markedly when the number of samples is less than 20. However, SFAN streams are commonly small and narrow and modifications to the ideal will often need to be made.

Here are some rules-of-thumb when spacing measurement points along the cross-section:

- Select verticals to best represent the distribution of discharge in the cross-section.
- Equal widths of partial sections across the entire cross section are not recommended unless the discharge is well distributed.
- Concentrate measurements at locations along the cross-section where the flows are the greatest. Make the width of the subsections less as depths and velocities become greater.
- For wading measurements with pygmy, Swoffer, and Marsh-McBirney meters space verticals no closer than 0.3 ft apart.

Completing the Discharge and Water Quality Measurement Field Data Form

A data form to record water quality and discharge measurements, as well as information about the streamgage has been created (Appendix SOP 10B). Many of the fields are the same as those found on USGS Form 9-275-F and NPS Water Resources Division discharge form. All forms will be printed on water-resistant paper and the four pages of the data form are formatted to fit on one double-sided page. Care should be exercised to ensure that others can interpret handwriting without ambiguity. Recommendations include crossing '7' along the axis to distinguish them from '1' and using '0' before decimal fractions to ensure that the decimal point is not missed. Corrections to original observations on the data forms shall be made by a single strike-through line over the incorrect value then writing the correct value adjacent.

Once the field staff are ready to take discharge measurements, the sampling event data fields should be filled out. Definitions of these fields are as follows:

Meas. No.: Number the measurements consecutively in chronological order including all field estimates and indirect measurements (Sauer 2002). Alphabetic characters can be used in sequence to insert records in an already established sequence (Sauer 2002). Record observations of no flow, but do not number these as measurements.

Entered by: First initial and last name of person entering the data into the streamflow database

Checked by: First initial and last name of person checking data entry

Date: Month, Day, Year

Time: Military, local standard time at start

Park: Standard four letter, NPS Park code (e.g., GOGA-Golden Gate National Recreation Area)

Station: Location of discharge measurement, generally including name of creek and upstream or downstream from nearest landmark (e.g., Redwood Creek at Hwy 1 bridge)

Personnel:meter: First initial and last name of person operating meter

Personnel:notes: First initial and last name of person recording field notes

Measurement type: Wading or bridge measurement.

Location: Fill in distance of discharge measurement from gage and whether measurement is upstream or downstream of gage.

Meter type: Brand name of meter (e.g., pygmy Gurley). Mark 'Float' or flume type in this field if applicable

S/N: Serial number of meter or flume

SPIN before/after: For vertical axis and Swoffer meters, duration of spin test in seconds before and after discharge measurement.

Weather: Record current weather conditions by circling standard descriptors and days since last significant rain (Wager et al. 2006).

Gage readings: A qualitative descriptor of the change in stage during your visit is circled; choices include rising, falling, steady, or peak. Record local standard time (military) under '*Time*' and corresponding gage height (nearest 0.01 ft) under '*Staff Plate'* header. At minimum, record this data just prior to and after a discharge measurement. Where stage is changing rapidly during your discharge measurement, record additional time and staff readings. If stage is surging at the staff plate, record the upper and lower ranges. Only the mean value, however, is entered into the database. Place water height measurements from flume or weir readings in the '*Other*' field. Record the height of the streambed at the staff plate under "Bed Level' field. This section should also be used to record stage heights before and after control point is cleaned of debris (and actions described in the *Observation/Comments* field).

High water mark: During the winter-spring, this field should record any temporary signs of high water marks in the vicinity of the gage with the height of these marks estimated on the staff plate to the nearest 0.1 feet..

Gage height at zero flow: Indicates water stage on staff plate where surface flows cease. To estimate, measure water depth at lowest point on the control and subtract it from the staff plate reading. See Figure SOP 10.1 for illustration of how to measure water depth at the control.

Crest stage: Circle whether crest stage was checked and add minor notes adjacent (e.g., cork line broad). Record the crest stage relative to the staff plate markings (especially if crest gage extends beyond height of staff plate). Also, give an approximate age of the crest stage reading.

Logger Readings: A variety of fields are recorded to document downloaded logger data.

Logger Date:Time (PST) : record local standard time (military) of logger.

Device date and/or time reset?: circle yes or no if logger date:time is reset and record the new values.

Logger Stage: Record the instantaneous stage values.

Ave. Logger Stage: Record arithmetic average of the 3 stage values in decimal feet.

Logger Pressure (PSI): Record raw logger pressure data (PSI) when available.

Battery: Record battery voltage (see manufacturer specifications for battery replacement)

New Data Correction: Record any data corrections to recorded stage data (in feet) in order to match observed stage at gage.

New Logger Stage: Record new stage level (hopefully the same as observed stage height).

Misc. Logger Fields: A user-defined list to record real-time parameters that might be recorded on individual dataloggers (e.g., water temperature, rainfall)

Downloaded filename: Record filename of data in standardized manner. Filename includes station identifier and download date. First two letters correspond to station, then YYMMDD. Used default filename extensions (either *.dat or *.csv). Ex: RW081218.dat is the Redwood station downloaded on December 18, 2008.

Dessicant replaced: Record whether dessicant was replaced.

Flow severity: EPA's qualitative descriptor regarding flow conditions (see definitions later in section)

Width: Width field includes measurement of total wetted width (excludes dry sections).

Area: Includes wetted cross-section area (excludes dry section),

Ave. velocity: Includes computed, mean water velocity measurements for cross-section

Gage height: Mean gage height for period of discharge measurement

Method: Appropriate values include 0.6, 0.2/0.8, volumetric, estimated, flume.

Method coefficient: Usually 1.0. Refer to WSP 2175 (Rantz et al. 1982a)

Hor. angle coeff.: If all flow is normal to the cross section, enter 1.0. If direction of flow varies, enter "varies" or "as noted". If flow angle is constant, enter coefficient used.

Susp. Type: Enter weight for suspension measurements or rod if used.

Susp. coeff. : Enter vertical angle coefficient if not 1.0 for suspended meter measurements

Meter___ft above bottom - For suspended meter measurements using a weight, record height above bottom of weight to the center-line of the meter cups or probe

No. of sections: Count number of sections where velocity was measured but not zero.

Gage-height change - Show actual change from start to finish. Indicate whether net change was upward (+) or down (-).

Flow description: Record notes about flow conditions at cross-section in a standardized manner. (See Appendix SOP 10C).

Cross section/substrate: Record notes about channel conditions at cross-section such as predominant substrate type, presence of vegetation in a standardized manner (See Appendix SOP 10C). If bridge measurements, note distances of bridge piers. If modifying cross-section for discharge measurements, record actions in the Observation/comments field.

Control: Note condition of control point (highest point in thalweg below gage), including water height. If debris is present, note type of debris and clear it (also record pre- and post- gage height and time). (See Appendix SOP 10C).

Observation/comments: Describe items that affect the interpretation of the record.

Water Quality measurements: See SFAN water quality monitoring protocol for field descriptions.

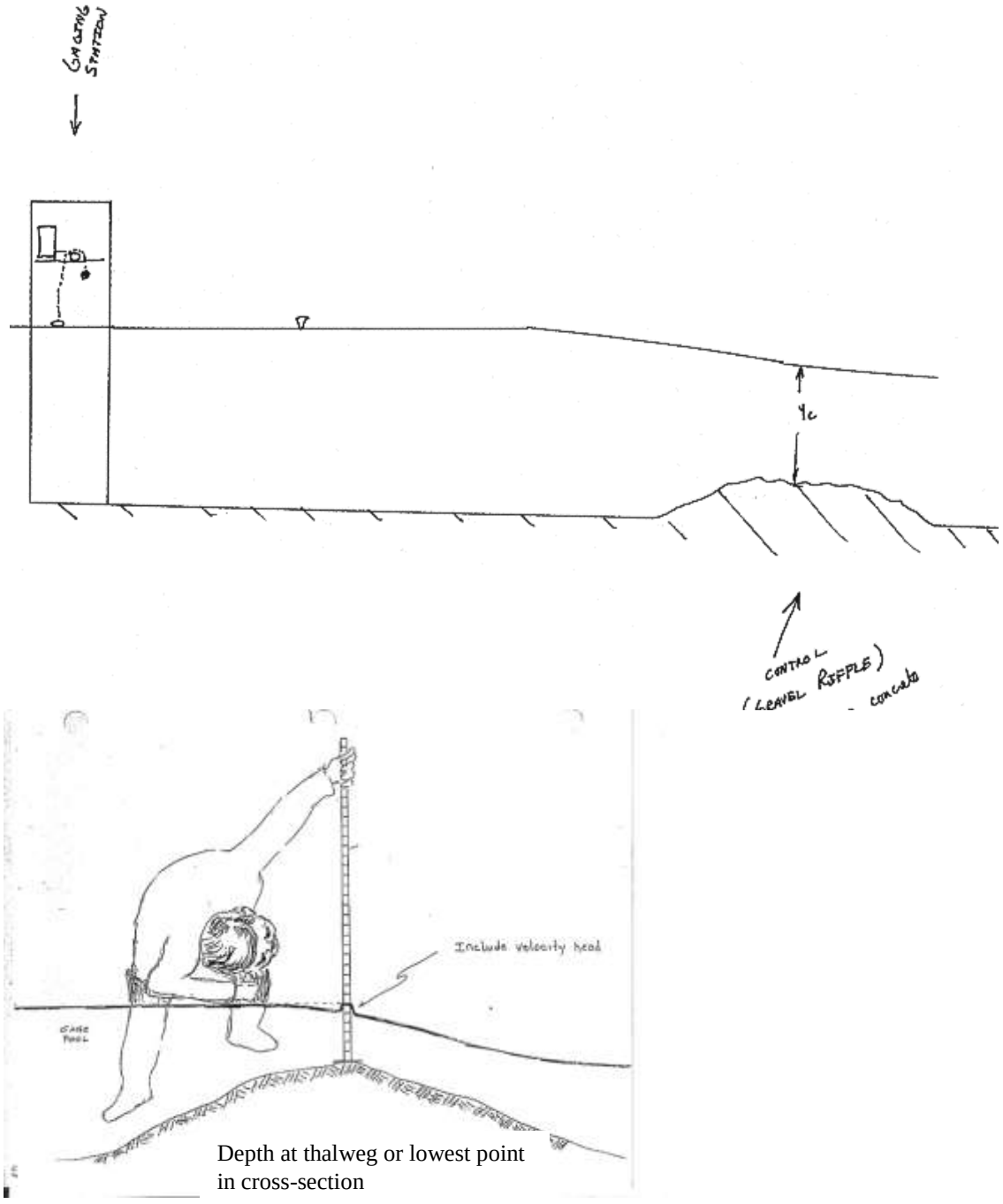


Figure SOP 10.1. Reading crest depth on wading rod at control point below streamgage (from Holmes et al. 2001).

Making the Discharge Measurement (adapted from Norris and Fisher 2006)

1) After the equipment and the data sheet have been readied, begin the measurement.
2) Record the stream stage at the beginning of the measurement and start time.
3) Indicate on the note sheet the distance from the initial point to the edge of the water.
4) Measure the distance to edge of water and record the depth as 0.
5) If creek stage is changing, record the time and gage height periodically, during the course of the measurement.
6) For each vertical, measure the mean velocity:
    a. Record the distance from initial point and the depth at the vertical to the nearest 0.1 ft.
    b. Determine the method of velocity measurement. For water depths up to 1.5 feet, a single measurement of velocity is made at 0.6 times the depth and is taken as the average velocity in the subsection. For water depths between 1.5 and 2.5 feet, measurements of velocity are made at 0.2 and 0.8 times the depth and averaged to determine the average velocity in the subsection.
    c. Measure the water depth in the vertical using the 0.1 ft graduations on the wading rod. Use the top-setting mechanism to set the meter at the desired 0.2, 0.6, or 0.8 position. The 0.6 position is set directly. The 0.2 position is set by doubling the depth and setting that value; the 0.8 position is set by halving the depth and setting that value. For more detailed descriptions on how to use a top-setting rod for streamflow measurements, see Appendix SOP 10D.
    d. Record the meter position (as 0.8, 0.6, 0.2). After the meter is placed at the proper depth, orient the meter parallel to the flow line (except for electromagnetic meters). Rest the rod base at the height of first contact with the stream bed directly under the tape measure. Do not work the base of the rod between cobbles or into the mud of a soft bottom channel. If this flow line is not perpendicular to the tape/tag line, record the horizontal angle coefficient (See Appendix SOP 10E).
    e. For pygmy and Price AA meters, count the number of complete revolutions made by the rotor within a period of 40-70 seconds. Start the stopwatch simultaneously with the first signal or click; counting "zero," not "one." As you approach 40 seconds, get ready to stop the stopwatch when the meter makes a complete revolution and read the time to the nearest second, or to the nearest even second if the hand is on a half-second mark.
    f. Record the number of revolutions and the time interval.
    g. If the velocity is to be observed at more than one point in the vertical, determine the meter setting for the additional observation, time the revolutions, and record the data. Calculate the velocity and record in “Velocity at point” on data form. For multiple measurements in the vertical, place the mean values in the field “Velocity, mean in vertical”
    h. Move to each of the verticals and repeat this procedure until the entire cross section has been traversed.
    i. For Swoffer 2100 and Marsh-McBirney Flo-mate, set the proper averaging time. For Marsh-McBirney, set it to 40 seconds. For Swoffer, set meter to ‘Display Averaging.’

Record the averaging interval on the dataform under the field "Time, in seconds." Record velocity as "Velocity at point" on data form.

7) When all verticals have been measured, record the distance from the initial point to the ending edge of the water, the depth at the edge of water, and the ending time of the measurement.
8) Record the stream stage at the staff plate at the end of the measurement.

Recording Flow Data

As noted previously, event data for water quality and discharge measurements are recorded on the first and second pages of our standardized form (see Appendix SOP 10B for blank form). The third and fourth pages include the actual point measurements. The definition of each field is as follows:

- *LEW/REW:* Although not listed, the field staff should note which record corresponds to the left and right edges of water looking downstream.
- *Angle coefficient:* Place horizontal angle adjustment ratio. If blank, assume flow is perpendicular.
- *Distance from initial pt:* Note location on tape (to nearest 0. 1 feet)
- *Width:* Width of section (computed field, nearest 0.01 feet)
- *Depth:* Water surface height (nearest 0.01 feet)
- *Obs. Depth:* Location of velocity reading as a ratio from surface (generally 0.2, 0.6, or 0.8)
- *Revolutions:* Number of complete revolutions of vertical axis meters
- *Time in seconds:* Elapsed time for reported number of revolutions
- *Velocity, at point:* Velocity at a single point in the water column (nearest 0.01 ft/sec). **Note:** recorder should note if velocity is uncorrected or based on recent rating equation.
- *Velocity, mean in vertical:* Mean velocity in water column (computed). **Note:** recorder should note if velocity is uncorrected or based on recent rating equation.
- *Adjusted for hor. angle:* Velocity corrected for horizontal angle adjustment
- *Area:* Area of section (computed, sq. feet)
- *Discharge:* Partial discharge of section (computed, cubic feet per second)

Low-flow Discharge Measurements

Under low flow conditions, use of pygmy flow meters may result in substantial measurement errors. Schneider and Smoot (1976) found that standard error of measurements increased substantially as actual velocities fell below 0.5 ft/s. Price pygmy meters could have velocity measurement errors around 15% at actual velocities of 0.1 ft/s. Therefore, when velocities are less than 0.2 ft/sec and depths <0.3 ft for more than 25% of verticals and velocities, alternative discharge measurements should be conducted using flumes, volumetric measurements, or thin-plate weirs (Rantz et al. 1982a, Meyer 1996). The typical low flow measurement methods for our monitoring program are Parshall flumes, thin-plate weirs, and volumetric measurements. The

installation and use of thin-plate weirs are well-described in Rantz et al. (1982a) and therefore, not discussed below. The procedures for Parshall flumes and volumetric measurements are described below:

Modified Parshall Flume: For our small streams, a modified 3-inch Parshall flume can be used to measure extreme low flow conditions. The modified Parshall flume can measure flows from 0.0008 cfs to 0.497 cfs with 2-3 percent accuracy (Rantz et al. 1982a). Procedures for measurement of flows using this flume can be found in Rantz et al. (1982a). Some additional details for installation and use of the flume are provided below:

1. Select a flume installation site that will not alter water surface elevation at the recording streamgage.
2. Select an installation site that will allow for free-fall of water at the flume outlet (generally the steepest site in the area) or a submergence ratio of less than 0.6.
    a. Submergence ratio is calculated as the difference in head between the upstream and downstream ends of throat (Appendix SOP 10E). To determine submergence ratio, use a ruler to measure down from the flat top of the level flume at the throat entrance (Appendix SOP 10E, Point 'A') and exit (Appendix SOP 10E, Point 'B'). Record values in ft. Divide distance 'A' by 'B.'
3. Near free-fall conditions may be created by raising the bed using sand bags or by adding fine streambed materials.
4. Direct flows into flume by using wing walls of various materials (preferable) or by raising water levels using a sand bag dam (however, use of small dams in SFAN streams with coarse bottoms has resulted in underestimates of discharge due to seepage through the stream bottom).
5. Pack fine sediments around and underneath flume to prevent leakage and level flume. A level flume is critical for accuracy.
6. Do not take gage height measurement in flume until upstream water surface elevation stabilizes.
7. Take height measurements every 30 seconds for 3 minutes (water depth above flume floor at stilling well hole) and record values in ft on datasheet. Estimate percentage of flows that may be bypassing the flume and record in comments field.

Volumetric Estimates: These estimates may provide the most accurate measurement of discharge. However, situations where this measurement can be used are limited. Measurement procedures are:

1. Identify a location where free-fall water conditions occur (e.g., outlet of culvert, natural cascade).
2. Use a bucket or other container to capture water for measured period of time.
3. Measure volume in container ($V=\pi*radius^2*$height of water in a perfectly cylindrical container). The measuring container should be calibrated in a lab and marked with an indelible marker.

   a. **Note:** when measuring height of water, make sure container is resting on level ground. Several depth measurements along side of container can be done to check level conditions.

4. Repeat measurement (3 replicate samples).

High-flow Discharge Measurements from Bridges

When stream conditions are unsafe for wading measurements, the recorder can measure velocity, depth, and distance from a bridge using a weight to hold the current meter in place at each location. Although Price AA meters have been used by USGS and others for bridge measurements, our primary meter will be the Marsh-McBirney Flo-Mate. Unlike mechanical meters such as the Price AA, this electromagnetic meter has no moving parts that can be damaged by floating debris. However, before leaving the office for bridge measurements, field staff need to determine whether conditions are safe for measurement. Safety procedures are detailed in Section 9 below. Once safe working conditions are established, the technician can measure velocity using the following technique:

1. Attach the current meter to a weighted cable. The meter and weight are raised or lowered using a sounding reel connected to a counter and supported by a bridge board or portable bridge crane. The specific configuration used is dependent on the size of the weights. If the weight is greater than 50 lbs, a crane must be used while a bridge board can be used for weights less than 50 lbs.
2. For bridge measurements, it is useful to mark graduations on the bridge rail with paint, permanent marker, or tape prior to a runoff event. Features of the bridge or bridge railing such as supports can also be measured in advance to serve as locations for measurement verticals. Repeated measurements at the same location are helpful for analyzing bed changes over time (See #7)
3. Record water stage at the staff plate and start time. If water is surging on the staff plate, record the range of the trough and peak. Make periodic water stage and time measurements throughout the measurement period.
4. If pre-marked locations are not present on the bridge, stretch a measuring tape across the stream channel. Divide the distance between the right and left water surface edges into a minimum of 25 sections. Use closer intervals for the deeper portions of the channel. In general, each measurement should not represent more than 10% of the total flow across the section. It is recommended that 20-25 measurements per transect be performed. Exceptions to this minimum number of measurements are described below.
5. Starting at the LEW, for each measurement location, read and note the distance from the initial starting point (LEW).
6. For water depths up to 1.5 feet, a single measurement of velocity is made at 0.6 times the depth and is taken as the average velocity in the subsection. When stream depth is 1.5 feet or greater, perform velocity measurements at both 0.2 and 0.8 of the depth. In deeper sections where there is any doubt about the velocity distribution, it is advisable to make measurements at 0.2, 0.6, and 0.8 times the depth. Such situations include measurements near obstructions such as debris or bridge piers.

7. Lower the weight into water until the center of current meter bucket wheel is at the water surface. Set the outer dial on the reel to read zero. Lower the weight until the weight touches the streambed. Read the outer dial on the reel and add the distance from the meter to the bottom of the weight to obtain total depth. If the weight is not hanging vertical, record any vertical angle corrections to the total depth. The bucket wheel or sensor tip is the point of measurement and should be located at the calculated point of the 0.2, 0.6, and 0.8 times the depth.
8. These values will be used to determine the average velocity in the section of the stream. Use the dial to set the meter at the desired 0.2, 0.6, or 0.8 positions. The 0.6 position is set directly. The 0.2 position is set by doubling the depth and setting that value; the 0.8 position is set by halving the depth and setting that value.
9. For the Marsh-McBirney, set the velocity averaging period to 40 seconds.
10. If flow is not perpendicular to the measurement point, horizontal angle adjustment factors should be estimated using the markings on the discharge measurement data form (Appendix SOP 10A).
11. Measure bed changes relative to fixed points from the bridge at the same locations where velocity measurements are obtained.
12. Lower the weight into water until the bottom of the weight reaches the bottom of the bridge. Set the outer dial on the reel to read zero. Lower the weight until the weight touches the streambed. Record any vertical angle corrections. Record the vertical distance to streambed from bottom of the bridge.
13. Continue across the width of the channel until reaching the water's edge on the right bank.
14. When the flow is changing rapidly (more than 10% in three minutes or less), Rantz et al. (1982a) suggest changing standard measurement procedures to ensure discharge measurements are conducted quickly. These include the following:
    a) Reduce the number of observation verticals in the measurement cross-section.
    b) Make a single velocity observation for each vertical.
    c) Reduce velocity observation time to 20–30 seconds.
    d) Record staff gage and observation time every third measurement.

At Redwood Creek, bridge measurements would be made upstream of the existing streamgage at Highway One on a safe pedestrian bridge. To synch staff gage measurements, field staff should first read the staff gage and time at the Highway One Bridge and then immediately read the staff gage at the pedestrian bridge upon arrival.

Semi-quantitative Methods: Floats

A quantitative flow measurement cannot always be obtained using the USGS established method. Equipment limitations and safety considerations may preclude taking flow measurements. Since flow measurements can be very important in determining pollutant loads or explaining measured parameters it is often useful to obtain an estimate. This usually occurs during storm events when stream flow is too high to safely obtain a traditional flow measurement. One method that can be used to estimate flow is the float method. Discharge

estimates using floats apply similar sampling logic as measurements using current meters. Velocity measurements are obtained across the cross-section. However, error of estimates may range from 10% under good conditions to as much as 25% under poor conditions (Rantz et al. 1982a)

Rantz et al. (1982a) and Leopold (1997) suggest establishing a site for flow measurements where the reach is straight and where a travel time of at least 20 seconds can be measured, but a shorter time may be used for streams with such high velocities that it is not possible to find a straight reach of channel having adequate length. Leopold (1997) recommends that a channel reach of 30 feet be used.

For our purposes, a channel reach of 30 feet or longer will be used nearest the streamgage.

To measure discharge (adapted from Leopold 1997):

- Using stakes or flags, mark the upstream-most "starting line" on each bank. Do similar at the "finish line." The streamgage can be used as either the start or finish points. Measure distance between the starting and ending lines to the nearest foot.
- The cross-sectional areas are needed at both the start and finish points. If a recent cross-section survey has been done at the streamgage, record the gage height at the start and end of discharge measurement. Mark the existing water surface extent and height with stakes on the left and right banks at both start and finish points. Surveys would be needed once conditions are safe of cross-sectional area at either start or finish points.
- Select a float that is neutrally buoyant, visible and biodegradable. Floats that ride on the water may be influenced by wind and also do not reflect stream velocity. Leopold (1997) recommends orange peels because they are cheap, float nicely at the surface, easy to see, and give acceptable results.
- The channel cross-section should be divided into three equidistant lanes. Replicate float measurements are recorded for each lane. For our purposes, 3 replicates will be used. For each measurement, floats are tossed upstream of starting line and the travel time recorded between the "starting line" and "finish line." If the float is caught at the bank or held up by debris, discard that measurement.
- Because use of float method is expected to be infrequent, standardized data fields have not been prepared. Such data should be recorded in the Comments field of the data form.
- Discharge estimates using the float method are the product of the mean cross-sectional area for the channel reach and mean velocity for the stream. Surface velocities are converted to mean in vertical by multiplying velocity estimates by 0.8 (Leopold 1997).

Qualitative Methods

Flow severity, a qualitative estimation of flow is commonly used in water quality monitoring and is included as a field in NPSTORET. It is also used by the San Francisco Bay Regional Water Quality Control Board's Surface Water Ambient Monitoring Program (SWAMP). Flow severity should be recorded for each visit to a freshwater stream. It should be recorded regardless of whether or not it was possible to measure flow. There are no numerical flow guidelines associated with flow severity. This is an observational measurement that is highly dependent on

the stream and knowledge of monitoring personnel. It is a simple but useful piece of information when assessing water quality data. The seven flow severity values are; No Flow, Low Flow, Normal, Flood, Above Normal, Interstitial, and Dry.

These flow severity values are defined as follows:

- No Flow: There is no flow throughout the reach. There may be disconnected pools.
- Low Flow: Typical streamflow condition in the summer months when the streamflow drops below winter/spring baseflow.
- Normal: Winter/spring baseflow. In spring-fed streams, this is year-round.
- Flood: Water level is above bankfull.
- Above Normal: Water level is above the normal baseflow, usually during or following storm events but not at bankfull stage.
- Interstitial: Some surface but mostly subsurface flow between pools
- Dry: No pools are present; the entire reach is dry.

Discharge Measurement Data Entry

A Microsoft Access database, entitled *SFAN Stream Discharge Database*, has been designed to facilitate data entry and management of individual discharge measurements and used to maintain records of data verification, field personnel, photo points, and current meter and flume metadata. The Data Management SOP (SOP 2) provides great detail regarding the structure and format of this database. This database is intended to replace the use of Excel spreadsheets for entry, storage, and computation of individual discharge measurements and event data. Past spreadsheets have been plagued with data entry problems mainly due to "cut and paste" type errors that have resulted in incorrect discharge calculations and mean gage heights.

Equipment Repairs, Replacements and Upgrades

Current meters will be repaired when routine inspections and calibration checks show that the meters are not performing within specified ranges. Typical problems that we have experienced with Gurley pygmy meters include damage to wheel bucket (causing failure of spin test) and excessive wear of pivot pins (also causing failure of spin test). Both Marsh-McBirney meters within SFAN have had problems associated with the failure of the zero test. The Swoffer meter which GOGA has had for over 20 years has been repaired once (LCD display) and individual rating equations have indicated that the meter is performing well over the manufacturer's stated velocity range.

When more than minor repairs are required for current meters, the program lead will evaluate whether state-of-the-art current meters should be purchased to replace damaged ones. Hydroacoustic meters are becoming more commonly used by USGS and other agencies for accurate measurement of water column velocity. Hydroacoustic meters have advantages over standard current meters because they lack moving parts to get damaged and have simple maintenance, stable instrument calibration, low-velocity thresholds of less than 0.1ft/s, high sample and data output rates and quality-assurance data, which are not available from mechanical meters (Morlock and Fisher 2002). However, their costs may be up to $8,000 per unit.

If additional funds become available (approx $3,000), the program will consider equipment upgrades that will allow for use of equipment to automate calculation of stream discharge and reduce the chance of math and transcription errors. Currently, Aquacalc Pro™ is a handheld computer that can be attached to existing meters and provides this worthwhile function.

Preparation for the Field Season

Discharge measurement activities will occur year-round. However, because the type of field equipment is dependent upon seasonal flow conditions there are some activities that can be done on a seasonal basis. Prior to the winter, all equipment used for bridge deployment should be checked to see if they are in good condition. Any equipment calibration/rating for the Marsh-McBirney electromagnetic meters should be done during this time. Similarly, because wading gear is less frequently used in the winter, any equipment calibration/rating for pygmy meters should be done during this period.

San Francisco Bay Area Network (SFAN) Streamflow Monitoring Protocol: SOPs

Literature Cited

Buchanan, T. J., and W. P. Somers. 1969. Techniques of water-resources investigations of the United States Geological Survey. Chapter A8, Discharge measurements at gaging stations. US Government Printing Office, Washington, DC.

Holmes, R. R., Jr., Terrio, P. J., Harris, M. A., and Mills, P. C., 2001, Introduction to field methods for hydrologic and environmental studies, US Geological Survey Open-File Report 01-50, Reston, Virginia.

Leopold, L. B. 1997. Rainfall and stage data needed: Napa River Basin instructions for construction of a wire weight gage, for recording data, for measuring stream velocity with floats, and for analysis of these data. Unpublished Report.

Marsh-McBirney, Inc. 1990. Model 2000 installation and operations manual, Rev. D. 2000 November. Manuals available online. (http://www.marsh-mcbirney.com/). Accessed 30 March 2010.

Meyer, R. W. 1996. Surface-water quality-assurance plan for the California district of the US Geological Survey. Open-File Report 96-618. US Geological Survey, Sacramento, California.

Morlock, S. E. and G. T. Fisher. 2002. Hydroacoustic current meters for the measurement of discharge in shallow rivers and streams. Pages 33–43 *in* T. L. Wahl, C. A. Pugh, K. A. Oberg, and T. B. Vermeyen, editors. Hydraulic Measurements and Experimental Methods: Proceedings of the Specialty Conference. 2002 July 28–August 1. Estes Park, Colorado.

Nolan, K. M., R. R. Shields, and M. S. Rehmel. 2000. Measurement of stream discharge by wading. US Geological Survey Water Resources Investigation Report 00-4036. Version 1.1. CD version.

Norris, M. and G. Fisher 2006. National Capital Region Network: surface water dynamics protocol. National Park Service, National Capital Region. Online: http://science.nature.nps.gov/im/monitor/protocols/NCRN_Streamflow_Data-Protocol&SOPs_Ver_1.pdf. Accessed 10 June 2010.

Peck, D. V., J. M. Lazorchak, and D. J. Klemm. 2001. Environmental monitoring and assessment program-surface waters: Western pilot study field operations manual for wadeable streams. US Environmental Protection Agency.

Rantz, S. E., et al. 1982a. Measurement of stage and discharge. Volume 1 *in* Measurement and computation of streamflow. US Geological Survey Water-Supply Paper 2175. US Government Printing Office, Washington, D.C.

Rantz, S. E., et al. 1982b. Computation of discharge. Volume 2 *in* Measurement and computation of streamflow. US Geological Survey Water-Supply Paper 2175. US Government Printing Office, Washington, D.C.

Reichmuth, M., B.J. Ketcham, D. Fong, S. Carlisle, E. Brown, and M. Koenen. 2010. Salmonid monitoring protocol for the San Francisco Area Network: standard operating procedures - version Natural Resource Report NPS/SFAN/NRR—2010/203. National Park Service, Fort Collins, Colorado.

Sauer, V. B. 2002. Standards for the analysis and processing of surface-water data and information suing electronic methods. US Geological Survey Water-Resources Investigations Report 01-4044.

Schneider, V. R. 1985b. Programs and plans: Policy on providing low-flow information. USGS Office of Surface Water Branch Technical Memorandum No. 85.17. 1985 September 20. USGS, Washington, D.C.

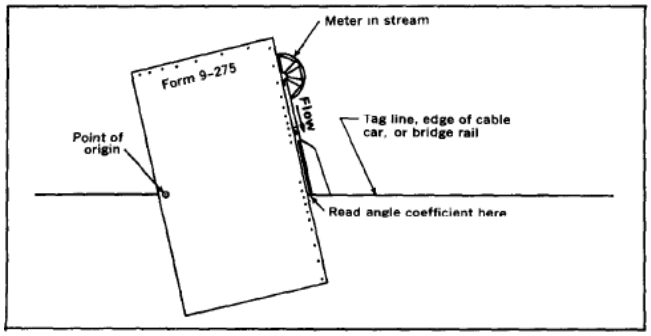
Schneider, V. R., and G. F. Smoot. 1976. Development of a standard rating for the Price Pygmy current meter. US Geological Survey Journal of Research 4(3):293–297.

Smoot, G. F., and C. E. Novak. 1968. Calibration and maintenance of vertical-axis type current meters. Chapter B2 *in* Techniques of water-resources investigations of the United States Geological Survey. Book 8. US Geological Survey, Washington, D.C. Online. (http://www.ecy.wa.gov/programs/eap/models/usgs_twri.html). Accessed 30 March 2010.

Appendix SOP 10 A. Field Cheat-Sheet for Wading Discharge Measurements

Velocity limits of current meters.

Meters	Velocity (ft./sec.)
Swoffer 2100	0.25–8.00
Marsh-McBirney	0.75–8.00
Pygmy	0.25–3.00
AA	0.25–8.00



Meter operation.

Water Depth (feet)	Meter use	Method
2.5 or deeper	Type-AA	0.2 & 0.8
1.5–2.5	Type-AA	0.6
1.5 or deeper	Pygmy, Swoffer 2100, Marsh-Mc Birney	0.2 & 0.8
0.30–1.5	Pygmy	0.6
0.2–1.5	Swoffer 2100, Marsh-McBirney	0.6

Spin test limits.

Meters	Normal	Minimum
Pygmy	1.5	45 sec
Ice, vane	4.0	2.0
Type-AA	4.0	2.0
Swoffer 2100		300 counts

Summary of Current Meter Use

- Locate measurement close to the streamgage to avoid any significant loss or gain in flow.
- Reach should be straight and uniform.
- Streambed should be free of large rocks, obstructions.
- Have an idea what the discharge will be before measurement.

- Parts of the stream with greater depth and velocity should have closer verticals.
- Keep the first sub-section as small as possible (depth will often be zero and assume no flow).
- A measurement cross section should have 25–30 measurement verticals.
- No more than 10% of the total flow should be in a single measurement cell.
- Read staff gage below, during, and after measurement
- Each measurement should be at least 40 seconds duration, and end on a complete revolution of the meter bucket wheel.
- Check the meter during measurement for fouling or interference.
- Because of accuracy limitations, Marsh-McBirney will be restricted to bridge deployments.
- The AA meter should be used in depths 1.5 feet or greater. It should not be used less than 0.5 feet from any boundary such as the bed or bank of a channel.
- A two point, two and eight tenths, velocity method should be used with an AA in depths over 2.5 feet.
- Use pygmy meter at depths between 0.3 and 1.5 feet. Do not use at <0.3 feet from any boundary.
- Minimum acceptable spin tests are 45 seconds for a pygmy and 2.0 minutes for an AA meter. Ensure zero check on Marsh-McBirney and calibration check value of around 186 for Swoffer 2100 and minimum of 300 counts for spin test when propeller is pointed up.
- Complete discharge calculations on the appropriate form before leaving a site.
- For flow not perpendicular to tag line, orient meter parallel to flow and record angle coefficient as in figure above.

Appendix SOP 10 B. Field Form for Recording Discharge and Water Quality

National Park Service
San Francisco Bay Area Network

DISCHARGE AND WATER QUALITY MEASUREMENT FORM

DATE _____ **TIME WQ Visit** _____ PST / PDT **TIME Flow Msmt** _____ **PST**

PARK _____ **STATION** _____ **PERSONNEL** _____

WEATHER: (circle one descriptor from each category) **Days since last significant rainfall**: _____

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

FLOW SEVERITY (circle one): Dry / Low / Normal / Above Normal / Flood / No Flow / Interstitial

---

GAGE READINGS: Start and Stop readings at minimum (PST 24 Hr & Staff Plate & Bed Level) **DOWNLOAD GAGE?** _____
Circle one: Rising / Falling / Steady / Peak (see notebook for details)

Time	Staff Plate	Other*	Bed Level	Time	Staff Plate	Other*	Bed Level

*Other: sensor depth reading, or flume depth

PZF (GH @ zero flow): _____ft. (= GH - water depth @ control pt.) **GAGE POOL DESCRIPTION:** Flow / Pool / Wet / Dry

CREST STAGE READING: _____ft. (measured off of staff plate) **HIGH WATER MARK:** _____

FLOW MSMT PERSONNEL: Meter_____Notes_____

MEASUREMENT TYPE (circle one) Wading / Bridge **LOCATION**: _____ ft. Upstr / Dnstr. (of gage)

METER TYPE_____**S/N**_____

SPIN/CALIB Before Meas._____ After_____

Width_____ Area_____ Avg. Vel._____ **MEAN GAGE HEIGHT**_____ **DISCHARGE**_____

SUSP. TYPE (circle) Rod / Cable # of Sections_____ **G.H. CHANGES**_____ ft. in _____minutes.

FLOW DESCRIPTION: Steady or varied; uniform or non-uniform; laminar or turbulent; suspended material? (leaves or algae in water)

_____

CROSS SECTION / SUBSTRATE: Uniform/non-uniform; smooth/moderately rough/rough/very rough;

Channel bed material (mud/sand/cobbles/pebbles/boulders) _____

CONTROL DESCRIPTION: Control type (natural riffle, channel, channel constriction, wier); Conditions (clear, affected by moss, leaves, etc)

Control location: _____ ft upstr / dnstr. (of gage); Depth @ control pt: _____ft

---

OBSERVATIONS/COMMENTS/NOTES:_____

STATION ID:_____ STATION LOCATION:_____ Meas. # _____

Entered into NPSTORET □ Entered by _____ Verified by _____

Entered into Streamflow DB □ Entered by _____ Verified by _____

WATER QUALITY: Yes/No Time:_____ Grab Samples Collected?__Yes/No__(circle parameters below)

BIOLOGICAL SAMPLES: Yes/No Time:_____ _ total coliform / *E. coli* / fecal coliform _

NUTRIENT SAMPLES: Yes/No Time:_____ __TKN / NO_3 / NH_3_____

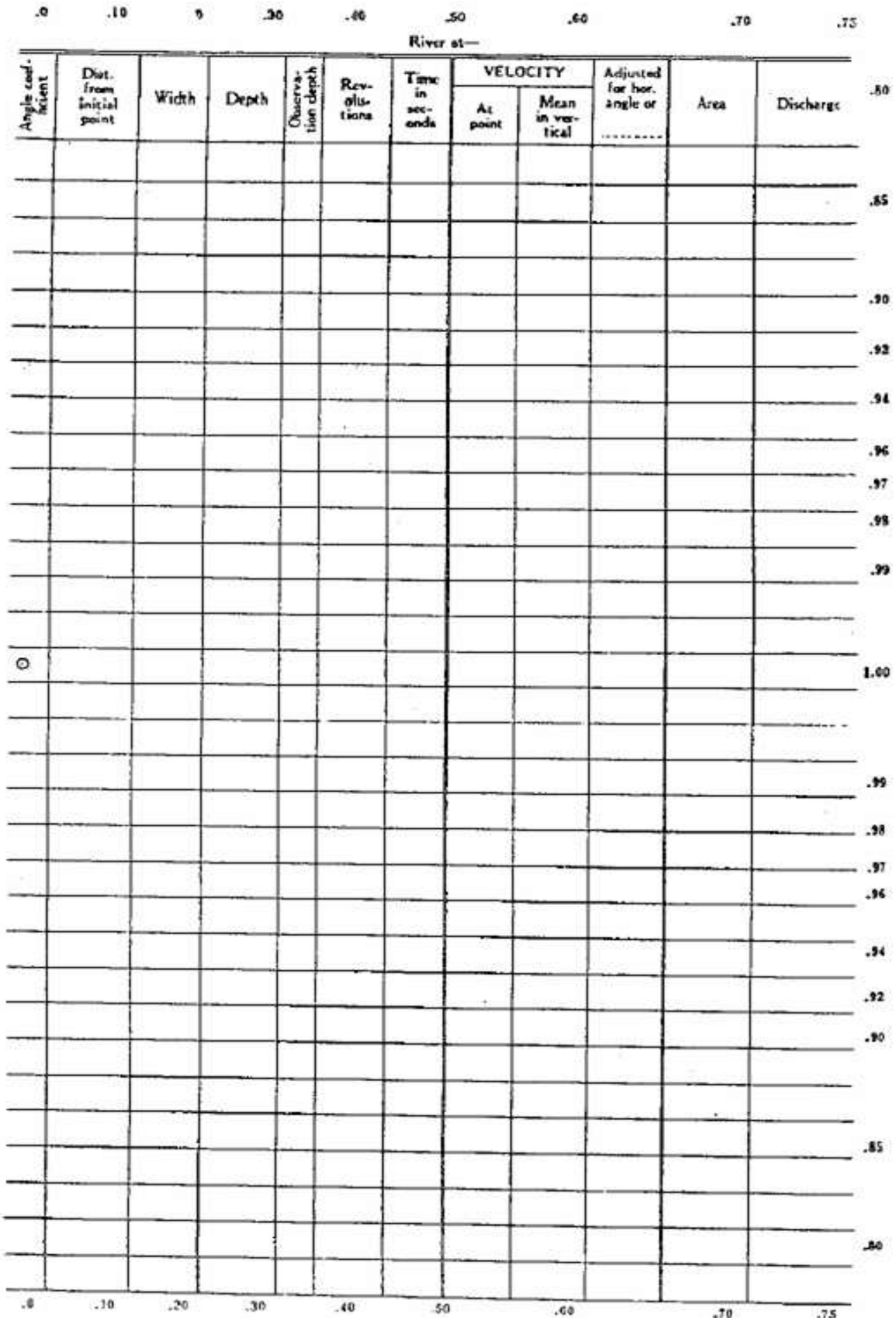
OTHER PARAMETERS: Yes/No Time:_____ __turbidity / TSS / SSC_____

Parameter	Measurement	Units	Method	Equip S/N	Notes
Air Temperature		ºC			
H_20 Temperature		ºC	YSI Pro Plus		
Conductivity		µS/cm	YSI Pro Plus		
Specific Conductance		µS/cm	YSI Pro Plus		
Salinity		ppt	YSI Pro Plus		
Dissolved Oxygen		% Sat.	YSI Pro Plus		
Dissolved Oxygen		mg/L	YSI Pro Plus		
pH		pH units	YSI Pro Plus		
Turbidity		NTU	Hach 2100		Bottle #: _____

PHOTOS TAKEN? Yes / No **HOW MANY?** _____

ID	Location (UTM or pt. #)	Description (include orientation)

Bacteria Results: @ _____**x dilution**	
Total Coliform	**E. Coli**


.0
.10
.20
.30
.40
.50
.60
.70
.75
River st—
Angle coef-ficient
Dist. from initial point
Width
Depth
Observation depth
Revolutions
Time in seconds
VELOCITY
At point
Mean in vertical
Adjusted for hor. angle or .....
Area
Discharge
.80
.85
.90
.92
.94
.96
.97
.98
.99
0
1.00
.99
.98
.97
.96
.94
.92
.90
.85
.80
.0
.10
.20
.30
.40
.50
.60
.70
.75

Appendix SOP 10 C. Descriptions for Measurement Note Sheets (from NPS-WRD)

Flow

Steady or Varied
Change in GH during measurement (Uniform or Non-Uniform)
Flow distribution in the cross section (Laminar or Turbulent)
Flow pulsattion Vertical component
Presence of Suspended Material
Meter performance affected by leaves or algae in water

Cross-Section

Uniform or Non-Uniform
Fross-section profile (Even or Uneven)
Smooth, moderately rough, rough, very roughIrregularity of bed
Channel bed material
Mud, sand, pebbles, cobbles, boulders?
Upstream bed material that may create turbulent flow

Control

Describe control type:

Natural riffle

- Length
- Bed material
- Stable or subject to change
- Channel
- Flow contained in channel, in the bank vegetation, or over bank flow
- Channel constriction
- Banks stability
- Bank composition

Weir

- Type and condition
- Location
- Feet downstream of gage?
- Conditions (options include: clear and unobstructed, affected by moss or algae, affected by leaves or other debris)
- Any noticeable changes in condition

Appendix SOP 10 D. Procedures for Using a Top-setting Rod for Streamflow Measurements

Top-setting rods are designed to allow the user to quickly adjust the position of the sensor at 20, 60, and 80 percent of the total depth. The typical top-setting wading rod is illustrated below. To set the sensor at 60 (most common), 20 and 80 percent depths from the surface, follow the following instructions:

60 Percent of Depth

To set the sensor at 60 percent of the depth, line up the foot scale on the *sliding rod* with the *tenth scale*, located on top of the depth gage rod. If, for example, the total depth is 1.1 feet, then line up the **1** on the foot scale with the **1** on the tenth scale (Marsh McBirney 1990).

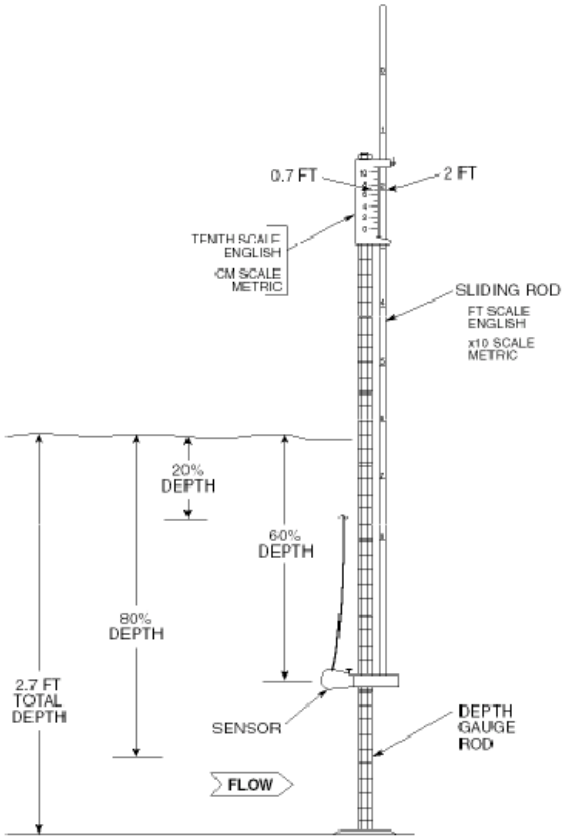
20 percent of Depth

Multiply the total depth by 2. If the total depth is 3.1 feet, the rod would be set at 6.2 feet (3.1 x 2). Line up the **6** on the sliding rod with the **2** on the tenth scale.

80 percent of Depth

To set the sensor at 80 percent of the depth, divide the total depth by two. For example, the total depth is 3.1 feet and the rod would be set at 1.55 feet (3.1/2). Line up the **1** on the sliding rod between the **5** and **6** on the tenth scale.

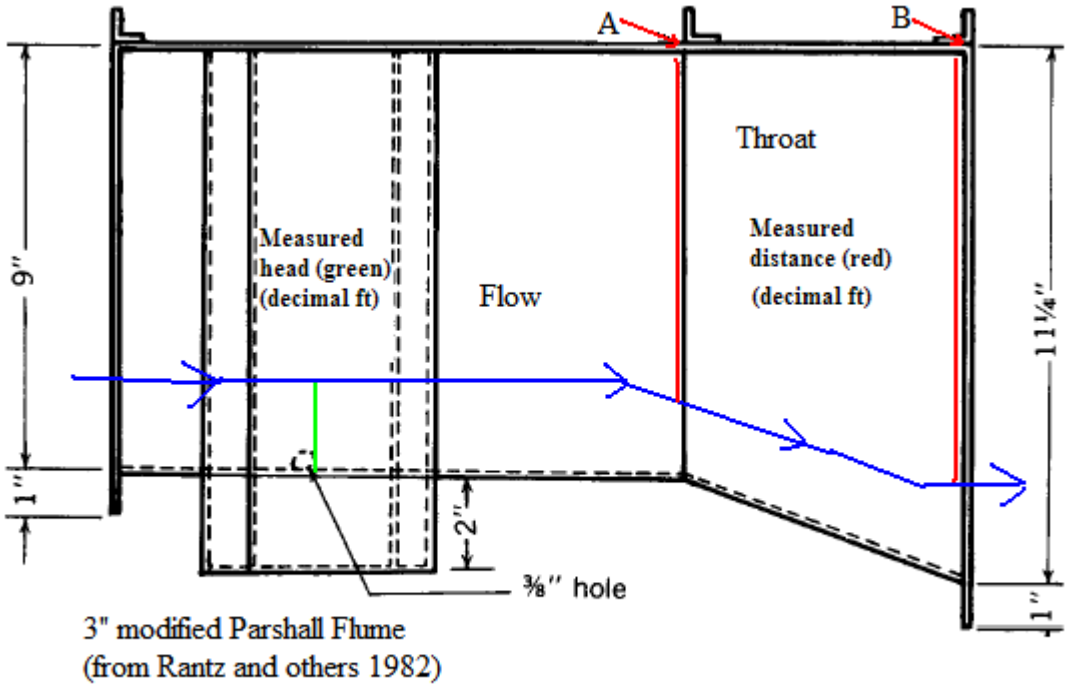
Top setting wading rod



Appendix SOP 10 E. Modified Parshall Flume Procedures

Record measured head of water above flume floor.

Determine submergence ratio by dividing A/B.



3" modified Parshall Flume
(from Rantz and others 1982)

Standard Operating Procedure (SOP) 11. Safety Procedures

Version 1.0

Revision History Log

Previous Version #	Revision Date	Author	Changes Made	Reasons for Change	New Version #
	6/8/10	Marcus Koenen	Created	To address review comments	1.0

Tables

Page

Table SOP 11.1. Site visit checklist. ..... SOP 11.4

Table SOP 11.2. Job hazard analysis. ..... SOP 11.8

Purpose

This SOP provides guidelines for field safety procedures to be followed by stream monitoring staff at GOGA, JOMU, PINN, PORE, and PRES.

Scope and Applicability

The USGS National Field Manual (NFM) provides background information on safety policies from the Department of Interior (DOI), the Occupational Safety and Hazard Act (OSHA), the Environmental Protection Agency (EPA), and the Department of Transportation (DOT). The USGS National Field Manual extensively covers all of the topics below:

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

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

Also see SFAN Field Safety SOP maintained on the GOGA Marin Headlands server (Inpgogamahe\Divisions\Network I&M\Shared\Standard Operating Procedures\SFAN Field SOPs\Standard Operating Procedures) for information on:

- Emergency Procedures
- Emergency Contacts for PORE and GOGA
- Vehicle Safety
- Air Quality Guidelines
- Slippery Substrates
- Mandatory Safety Equipment
- Recommended Personal Gear

Procedures and General Requirements

Site Visit Notification

Prior to conducting site visits, field staff should review the Site Visit Checklist (Table SOP 11.1). For individual safety, it is critical to inform park staff about the field itinerary. Park staff may need to contact you while you are in the field and may need to provide assistance in case of emergency. Informing park staff can also provide interpretive opportunities to park visitors. In addition, other staff including seasonal employees or volunteers may want to accompany field surveys whenever possible.

Table SOP 11.1. Site visit checklist.

Required Action
Inform supervisor regarding your field activities including: • sampling locations (with map) • mode of transportation • names of field technicians • expected sampling times • vehicle information (make/model)
Your cell phone or radio is fully charged.
Check weather and be aware of potential changes (e.g., storms, floods, etc.
All field technicians have reviewed SOP Field Safety and know how to contact emergency personnel or park staff if needed

Environmental Precautions

Sudden Oak Death

When sampling in areas known to carry *Phytophthora ramorum*, the organism responsible for causing Sudden Oak Death, you must disinfect yourself, your vehicle, and your gear to avoid spreading the infection.

The Crew Leader should familiarize herself with known infection sites, and sites where infection is possible due to presence of potential host plants. To minimize the risk of spread, the following measures should be incorporated into field surveys:

- Avoid parking in mud.
- Do not transport water, soil or plant material.
- Carry cleaning materials in your vehicle; use an old screwdriver, stiff brush, and towel for removing mud and other debris, then rinse with water and spray with a disinfectant, such as Lysol or a 10% bleach solution.
- Consider having separate sets of footwear for infected and non-infected sites.

- If you suspect you have found a new infestation site, record the location and symptomatic hosts and report to Vegetation Management for the site's park.

Safety Precautions

Field work occurs year round and may include sampling during storm events. It is always recommended for two field staff to be present under normal sampling procedures. In the event of storms, it is mandatory for two staff to be present for sampling. All field staff should obtain First Aid and CPR training before working in the field. Wilderness First Aid or higher is recommended because many sampling stations may be remote.

Weather and Field Attire

Summer conditions are often hot (between 90 - 100°F). Because of the possibility of encountering poison oak and general uneven terrain found off-trail, field personnel should wear long pants and high-topped hiking boots. Leg gaiters are also recommended to reduce the exposure to poison oak and the risk of tick bites during surveys. If rubber boots are worn, they should fit well to reduce risk of slipping.

Field Hazards

Insects

Biting or stinging invertebrates (wasps, spiders, ticks, mosquitoes, scorpions) may be encountered. The bites or stings from these animals can be painful, but usually not fatal. If bitten or stung and painful swelling or an allergic reaction occurs, seek medical attention immediately. Check your clothing and exposed skin frequently when in the field for ticks and upon returning from the field, do a more thorough body search for ticks. Ticks are common and may transmit Lyme's disease. Ticks embedded in the skin should be carefully removed immediately. They can be tested for the presence of Lyme's disease and the bite should be monitored for symptoms. West Nile Virus is also present and is transmitted by mosquitoes. Only a few species of mosquitoes carry the virus and fewer are infected. Another issue to be aware of is Hantavirus which is spread through rodent feces and normally a concern indoors, or garages, or other areas where equipment may be stored. As with all hazards, consult the USGS National Field Manual for details.

Poisonous/Toxic Plants

Poison oak is found throughout the study area. Before doing any fieldwork personnel should become familiar with the dangers associated with exposure to this native plant. If exposure occurs wash thoroughly with soap and rinse with plenty of water upon returning from the field and then apply Tecnu® ointment (provided at headquarters). If a strong reaction occurs, seek medical attention and alert your supervisor as soon as possible.

Hazardous Wildlife

Mountain lions occur in the study are but are rare. Rattlesnakes may also occur but rarely near riparian areas where sampling will occur.

Inclement Weather and Surface Water Activities

Sampling during storm events is of particular concern in Mediterranean climates. Most, if not all, of the streams in the SFAN are "flashy", meaning that water level rises rapidly during a storm

event. For example, individuals taking flow measurements in Chalone Creek (PINN) have had to end flow measurements since the stage rose to an unsafe level during the short time that the velocity measurements were being taken. Do not attempt to wade in a stream for which water depths are greater than 4 feet or for when the product of velocity and depth exceeds 8. During high flows use of a wading belt is recommended to avoid the waders filling with water. Any time chest waders are worn, a life jacket is required.

Other potential hazards to be considered at all parks include flowing logs and other debris, quicksand (particularly at PINN), falling trees, drowning, falling, back injuries from lifting/bending/falling. A thorough list of hazards is particularly useful for staff that may not be familiar with the local weather and climate, topography, flora, or fauna. A good summary of these hazards is provided in the Job Hazard Analysis (JHA) (Table SOP 11.2).

Contaminated Water

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

Transportation

Most of us drive a vehicle regularly and may not always think about the hazards associated with it. It is very important to inspect the vehicle before leaving. Ensure that safety equipment is in the vehicle. During driving to and from sampling areas it is particularly important to consider issues such as nighttime driving and fatigue, storms, road flooding, driving in (initially) unfamiliar areas and remote areas where large animals may be crossing the road.

Environmental Hazards and General Emergency Information

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

Mandatory Safety Equipment

Each field crew is required to carry the following equipment:

- park radio and a cell phone.
- first-aid kit

Each vehicle must have:

- a flashlight

- safety triangles
- spare tire and tools

Recommended Personal Gear

Each field crew member is strongly encouraged to carry the following equipment:

- water bottles
- snacks
- hat
- pocket knife
- long-sleeved shirt and light-colored, long pants
- sunscreen
- insect repellent
- leather work gloves (if needed)
- solid footwear
- rubber boots or waders
- wading belt
- compass and map
- backpack
- rain poncho
- special medications if necessary (e.g., Benadryl, EpiStick)

Job Hazard Analysis (JHA) for Streamflow Monitoring Activities

Table 52 is a Job Hazard Analysis (JHA) developed to analyze the duties, tasks, and potential hazards associated with the program, and addresses the hazards through safe work behaviors and procedures.

Table SOP 11.2. Job hazard analysis.

Work activities	Hazards	Controls and Safe Behaviors
Office Work- Computer use for email and data entry	Muscle and eye strain, repetitive stress injury	Proper posture and use of ergonomic furniture
		Take breaks every hour.
Travel to Field Locations in Vehicle	Driving hazards such as accident	Use defensive driving techniques.
		Expect oncoming traffic on one-lane roads in park.
		Be alert for foggy conditions.
		Watch for deer and other wildlife, and adjust speeds to safely operate around areas of high use.
`		Obey traffic laws and wear seatbelt at all times.
		Do not drive when fatigued, be familiar with route or prepare for unknown route.
		Do not talk on radio or cell phone while driving.
		Do not put hot drinks on your lap.
		Be familiar with the vehicle and its operation.
		Check gauges, tires, wipers, fluids and replace when necessary.
		Check vehicle has spare tires, jumper cable and jack with all parts.
Hiking to work areas on trails, routes or off trail navigation	Getting lost or confused as a group	Have map, compass, GPS and other navigational aids and know how to use them.
	Losing a crew member	Travel together when off-trail.
		Make sure both members of the team are aware of location, and can find route out if they are separated.
		When trail hiking, plan stops at trail junctions to regroup.
		Arrange meeting places and times; all crewmembers must wear a watch.
		Have a travel plan for each day and make sure it is understood by all crewmembers.
		Stay in communication via radio or stay in sight.

Table SOP 11.2. Job hazard analysis (continued).

Work activities	Hazards	Controls and Safe Behaviors
		Carry cell phone and/or radio and spare batteries.
		If lost or disorientated, stay calm, assess location by consulting map and landmarks, and proceed to nearest road or trail.
		Do not panic; have a mental plan for what to do if lost
		If injured, stay put and radio dispatch.
	Loose footing	When traveling in areas with steep or unstable terrain, stagger your positions so that you are not immediately below someone, yell "rock" if you dislodge one.
	Exposure to cold, wet conditions	Wear proper equipment- and bring extra layers.
		Recognize the signs of hypothermia in yourself and others.
		Carry and eat high-calorie foods, stay well-hydrated.
	Exposure to heat and sun	Have hat, sunscreen and sunglasses.
	Overexertion and dehydration	Recognize the signs of dehydration.
		Take frequent rest stops (15 min per every 2 hours) and stay hydrated
	Injuries due to hiking (aches, sprains and blisters)	Pay attention to footing- plan ahead for the route to avoid steep, unstable terrain
		Use appropriate footwear, boots and socks.
		Prevent blisters and have blister treatments (moleskin, tape etc) accessible.
	Injuries due to falling (lacerations, broken bones, head injuries)	Pay particular attention to traveling on steep slopes, unstable terrain, through dense vegetation, and in foggy conditions. Practice fall- arrest techniques (roll on to stomach, dig elbow, feet and knees in).
		Have first aid kit, stabilize injured person, treat for shock and know how to initiate rescue via radio.
	Injuries due to carrying a heavy pack	Reduce pack weights when possible.
		Pay attention to how you put your pack on (avoid twisting motions- get help or place pack on surface or against tree).
		Make sure your pack is properly fitted and balanced.

Table SOP 11.2. Job hazard analysis (continued).

Work activities	Hazards	Controls and Safe Behaviors
Sampling during storm events.	Rain storm	At least two people should sample during any storm events because of increased risk factors (slippery surfaces, current).
	Lightning storms	In the event of a lightning storm, turn your radio off, if near a vehicle, get entirely inside. If in the out of doors try to do the following: separate the group, get off ridge tops and away from trees, get as low as possible and if possible lie on non-conductive material.
	Wind storms	If it is windy enough to blow small twigs and branches out of the trees, try to get out of the woods or find an area away from hazard trees.
Hiking to/around work areas-stream and river crossings, ponds	Exposure, sprains, broken bones,	Avoid swift or deep water crossings by using foot or automobile bridges.
		Be careful on slippery logs and watch footing on either side of stream crossing.
	Falling into water, drowning	When sampling with waders always wear a life jacket and properly fitted wading belt.
		If carried by the stream, float with current keeping feet close to the surface to avoid entrapment in rocks. Swim to shore to get out of current.
	Hypothermia	Recognize early symptoms for hypothermia and treat as necessary (e.g. change into warm/dry clothing). Notify dispatch and evacuate sampling site.
Working in the outdoors	Exposure to allergy-causing plants and insects	Alert crew members to possible problems with allergens. Be alert for toxic plants and alert to common bee and wasp nesting habitat and activity-especially the person in front.
		Carry Benadryl, epi-pen or other antihistamine
	Exposure to toxic plants	Avoid poison oak and stinging nettle when possible. Wear long-sleeved shirts, long pants, and hiking boots. Wash skin exposed to poison oak with Tecnu or other appropriate cleaner and change clothes if necessary at end of day/survey.
		Do not eat any fungus or plant unless you are 100% sure it is edible.
	Exposure to ticks	Wear proper attire (long-sleeved shirts and long pants) and do frequent tick checks. If bitten by black legged tick, properly remove tick and monitor general health condition.

Table SOP 11.2. Job hazard analysis (continued).

Work activities	Hazards	Controls and Safe Behaviors
	Exposure to *giardia*, *E. coli* and other pathogens	Do not drink any water unless it has been filtered, boiled or treated in some fashion.
		Do not create more contaminated areas- urinate away from streams and water, dig a cathole for solid waste and bury toilet paper.
		Wash hands when possible and carry hand cleaner.
	Improper nutrition due to inappropriate food choices	Bring a variety of healthy, nutritious food that will give you good energy during travel and work. Do not rely on sugar snacks.
	Loss of food to ravens, raccoons, small animals	Prevent animals from getting into your food by not leaving you backpack open or accessible to animals.
	Cougar attack	If approached by cougar make yourself large and noisy, wave arms, yell, grab a stick. Back away from cougars but do not turn and run, ever. If attacked, fight back.
	Strange or aggressive human interactions	Terminate contact with visitor and leave the area, contact dispatch or emergency numbers (911).

Standard Operating Procedure (SOP) 12. Decontamination During and After Field Activities

Version 1.0

Revision History Log

Previous Version #	Revision Date	Author	Changes Made	Reasons for Change	New Version #
	6/8/10	Darren Fong Jennie Skancke	Created	To address review comments	1.0

The following procedures for preventing the spread of invasive or problematic aquatic species are based on excerpts from the California Center for Amphibian Disease Control (2007) and recommendations from Gary Fellers, USGS BRD scientist. A brief background of known local threats is provided along with an overview of useful decontamination procedures. The intent of this SOP is to help reduce or prevent the spread of aquatic diseases and invasive species between watersheds while conducting routine field procedures.

Specific threats by invasive plants, animals, or diseases are of course dependant on location, however section 2 is meant as a blanket decontamination procedure. Additional considerations may be necessary as new threats are realized.

Threats

Chytrid Fungi

The greatest aquatic invasive concern in the SFAN network is Chytrid fungi.

Background: Chytrid fungi are widespread in the environment where they act as decomposers of keratin, chitin, cellulose, and other plant material. Chytrids are also known parasites of fungi, algae, higher plants, protozoa, and invertebrates, but none were known to infect vertebrates until recently. Since amphibian chytrid (*Batrachochytrium dendrobatidis* = Bd) was described in 1999, it has been found in many amphibian populations around the word, including many that are declining. While Bd is probably moved naturally from one water body to another on dispersing amphibians, or on waterbirds and flying insects, it is important to assure that researchers are not spreading Bd between sites as part of research or monitoring programs.

Whirling Disease

While whirling disease has not documented in the SFAN streams, it has been documented in California (Modin 1998).

Background: While the transmission stage of Whirling Disease is a microscopic spore so the only way to identify the disease is from infected fish. Young fish may be exhibiting the "Whirling" behavior that gave the disease its name, in which the fish swims in circles. The tail of an infected fish often turns black. Because the parasite attacks the cartilage tissue of a fish's head and spine if the fish survives to be 1.5 months the spinal development of the fish is often altered giving the fish a crocked or spiral shape and/or deformed head.

Environmental Impact: Native to Eurasia, whirling disease is having devastating impacts on coldwater fisheries in North America. All species of trout and salmon may be susceptible to whirling disease. Other members of the trout and salmon family, such as mountain whitefish are also at risk. Rainbow trout and cutthroat trout appear to be more susceptible than other trout species. Brown trout become infected with the parasite, but they appear to have immunity to the infection and have not been as greatly impacted as rainbow trout. Scientific studies have demonstrated that grayling and bull trout are very resistant to infection. However, regardless of species, when each infected fish dies, many thousands to millions of the parasite spores are released to the water. These parasitic spores are virtually indestructible -- they can withstand freezing and desiccation, and can survive in a stream for 20 to 30 years. The parasite is sure to

continue to spread to drainages now clean, since it is so easily and unknowingly transported by animals, birds and humans (USFWS 2008).

New Zealand Mud Snail *(from BAMBI 2008)*

Background: The New Zealand mud snail (NZMS, *Potamopyrgus antipodarum*) is a small hydrobiid snail that is spreading rapidly in fresh and brackish waterbodies in many western states. Several Bay Area locations have reported NZMS, most recently in 2007 from eastern Contra Costa County and in Niles Canyon and lower Alameda Creek. NZMS can survive on damp wading gear or equipment and hitchhike to new locations. There is no effective way to remove established populations so preventing the spread is important for anglers, researchers and others who regularly enter creeks.

Environmental Impact: Just one snail can colonize a stream; within a few years they can reach high densities and displace much of the native macroinvertebrate community, seriously impacting aquatic food webs and habitat.

Decontamination Procedures

Compliance with the most recent version of the US Forest Service "**2008** Fire Ops Guidance for Aquatic Invasive Species" may be used.

Prevention

Avoid dumping water directly from one stream or lake into another. Avoid obtaining water from multiple sources during a single operational period unless drafting/dipping equipment is sanitized between sources. Minimize driving equipment through water bodies.
Obtain maps of invasive presence in or around your sample area, be aware and respond accordingly at each site. You can never be certain that invasives are NOT present, but at least you will know ahead of time where they ARE present.

Sanitation

All equipment particularly the boots of waders should be brushed clean. All equipment should be scrubbed and sanitized with Quat128 or bleach following field work. Procedures for preparing Quat128 or a bleach solution from powdered bleach are included below.

Quat128: The following outlines the use of Quat128 and Sparquat256, preferred alternatives to bleach which may harm stainless steal water quality equipment as well as personal gear. Refer to the US Forest Service "**2008** Fire Ops Guidance for Aquatic Invasive Species" (p. 4-6,), for complete tables of aquatic invasives of concern and other methods of control.

Set up a portable disinfection tank using a 5% cleaning solution of quaternary ammonium compound – common cleaning agents used in homes, swimming pools, and hospitals that are safe for gear and equipment when used at the recommended concentration. Two brands are readily available from GSA or local suppliers: *Quat128*® (by Waxie) or *Sparquat 256*® (by Spartan). Costs and effectiveness are comparable; use either (Table 1).

Table 1. Recipe for 5% cleaning solution using either *Quat128*® *or Sparquat 256*®

Volume of tap water	Volume of *Quat128*®	Volume of Sparquat 256®
100 mL water	4.63 mL	3.00 mL
1 gallon water	6.35 liquid oz.	4.12 liquid oz.
1 gallon water	12.7 tbsp	8.2 tbsp
1 gallon water	0.79 cups	0.51 cups
100 gallons water	4.96 gallons	3.22 gallons

Where feasible dip gear or equipment into the cleaning solution. Alternatively, put the 5% cleaning solution in backpack spray pumps to clean portable equipment. The solution must be in contact with the surface being sanitized for at least 10 minutes and then rinsed with water. Ideally, test the cleaning solution daily according to the directions below. The cleaning solution can be used repeatedly for up to a week unless heavily muddied or diluted. If the concentration is too weak, dispose of the used solution properly and make a new solution.
Consult the product label and Material Safety Data Sheet for additional information.

Testing Solution: To determine if the solution is below the 5% strength use "Quat Chek 1000" Test Papers (purchase these from the supplier of the cleaning compound). The used cleaning solution needs to be diluted to about 600 ppm of ammonium compounds before it can be tested with these papers.

Take **one** cup of used *Sparquat 256*® cleaning solution, pour into a bucket. Add **5** cups of water. Mix. OR
Take **one** cup of used *Quat128*® cleaning solution, pour into a bucket. Add **4** cups of water. Mix. Test the diluted solution with "Quat Chek" Test Paper. Match up the color of the paper with the ppm's on the color chart. For optimal disinfection, the diluted solution should have a concentration between 600 and 800 ppm. If it is too dilute, dispose of properly and make a new cleaning solution.

Disposal: Do not dump cleaning solution into any stream or lake, or on areas where it can migrate into any stormdrain, waterbody, or sensitive habitat. It may be possible to dispose of used cleaning solution over open land. Consult Resource Advisor before using this method. Depending on volume, used cleaning solution may be disposed of by trucking off-site for disposal in a wastewater treatment facility. Used cleaning solution may or may not be suitable for disposal in on-site septic systems. Consult the local agency's Utilities Supervisor or Facilities Manager prior to disposal.

Sparquat 256® by Spartan Chemical Company; GSA (NSN No. 1025-04) = $54/case (4 gal); Additional info can be found at http://www.spartanchemical.com
Remember to buy "Quat Chek 1000" test papers when you purchase the chemicals ("Operational Guidelines", 2008).

Storage: *Sparquat 256*® and *Quat128*® can be stored up to two years in an unopened container without losing its effectiveness. Both should be stored in a cool, dry place, out of direct sunlight. Temperatures can range from 32º to 110º F.

Purchase: Both products are available from GSA (**https://www.gsaadvantage.gov**) and are commonly available through local janitorial and swimming pool chemical suppliers.
Quat 128® by Waxie's Enterprises Inc.; GSA (NSN No. 170304) =$36/case (4 gal);
Additional info can be found at http://www.waxie.com

Sparquat 256® by Spartan Chemical Company; GSA (NSN No. 1025-04) = $54/case (4 gal);
Additional info can be found at http://www.spartanchemical.com
Remember to buy "Quat Chek 1000" test papers when you purchase the chemicals ("Operational Guidelines", 2008).

Bleach: Granulated swimming pool chlorine bleach can be purchased at any swimming pool supply store in a variety of quantities, up to and including 40 pounds. Recent pricing (April 2004) for this chemical is approximately $90.00 for 40 pounds and $68.00 for 25 pounds. Granulated chlorine bleach has the distinct advantage of being in dry form and is therefore much more portable than the gallons of liquid bleach currently being carted around by some folks. Besides being heavy and cumbersome, liquid bleach loses most of its effectiveness within 2 weeks of the container being opened. The abbreviated active life of opened liquid bleach solutions can mean that although folks are following the decontamination procedure they are not accomplishing the task of killing pathogens if they are using bleach which has lost its effectiveness. Old liquid bleach is not disinfecting anything.

Procedure

1. Always start your fieldwork with sterilized equipment. Prior to going in the field, decontaminate ("decon") all equipment (dip nets, two-pole seines, hip boots, chest waders etc.) using the recommended disinfectants at the recommended concentrations. To minimize the spread of New Zealand mud snails, gear should be be frozen (at least 6 hours) or completely dried out between use (BAMBI 2008).

2. Check and clean field gear, particularly waders or hipboots, between sites. The soles of waders and hipboots may pick up small organisms such as snails that can be transported between watersheds. A spray bottle of either Quat128 and Sparquat256 will be brought into the field when multiple watersheds are visited. Field gear would be sprayed onto the gear upon leaving a site. At arrival at the new site, a bucket of water would be used to rinse gear prior entering the water.

3. Do not use felt soled waders for streamflow field work. Felt soled waders can transport small animals that adhere easily to the felt. They are also difficult to clean free of mud that may also be vectors of aquatic invasives.

Literature Cited

[BAMBI] Bay Area Macroinvertebrate Bioassessment Information Network. 2008. New Zealand mud snail Bay Area alert. (http://www.bayareabugs.org). Accessed 30 March 2010.

California Center for Amphibian Disease Control. 2007. Decontamination Protocol to Reduce the Risk of Spreading Infectious Amphibian Diseases in Freshwater Systems. Online: http://www.ccadc.us/docs/DeconForProfessionals.pdf. Accessed 10 June 2010.

Modin, J. 1998. Whirling disease in California: a review of its history, distribution, and impacts, 1965–1997. Journal of Aquatic Animal Health 10:132–142.

[USFWS] United States Fish and Wildlife Service. 2008. Harmful aquatic hitchhikers. Protect your waters [web site]. US Fish and Wildlife Service and the U.S. Coast Guard. Online. (http://www.protectyourwaters.net/hitchhikers). Accessed 23 March 2010.

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.

NPS 963/107253, April 2011

National Park Service
U.S. Department of the Interior

Natural Resource Program Center
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov