



Sierra Nevada Network River Hydrology Monitoring Protocol

Standard Operating Procedures



ON THE COVER

Protection Ranger John Anderson performing a discharge measurement in Boundary Creek at Devils Postpile National Monument. Photograph by: Jennie Skancke.

Sierra Nevada Network River Hydrology Monitoring Protocol

Standard Operating Procedures Version 1.0

Jennie Skancke¹

Andrea Heard¹

Leslie Chow²

Alice Chung-MacCoubrey¹

¹National Park Service, Sierra Nevada Network Inventory & Monitoring Program
Sequoia and Kings Canyon National Parks
47050 Generals Hwy
Three Rivers, CA 93271

²National Park Service, Sierra Nevada Network Inventory & Monitoring Program
Yosemite Field Station
P.O. Box 700
El Portal, CA 95318

September 2017

U.S. Department of the Interior
National Park Service
Three Rivers, California

This report is available in digital format from the [Sierra Nevada Network website](#).

Please cite this document as:

Skancke, J. R., A. M. Heard, L. Chow, and A. L. Chung-MacCoubrey. 2017. Sierra Nevada Network River Hydrology Monitoring Protocol: Standard operating procedures version 1.0. National Park Service, Three Rivers, California.

These Standard Operating Procedures accompany the following protocol narrative:

Skancke, J. R., A. M. Heard, L. Chow, and A. L. Chung-MacCoubrey. 2017. Sierra Nevada Network river hydrology monitoring protocol: Narrative version 1.0. Natural Resource Report NPS/SIEN/NRR—2017/XXX. National Park Service, Fort Collins, Colorado.

(Will update this reference and link to it once the report is published.)

Contents

	Page
Figures.....	ix
Tables.....	xi
Appendices.....	xiii
Acronyms.....	xiv
SOP 1: Streamgage Station Overviews.....	1
1.1 Introduction.....	2
1.2 Preparing and Updating Station Descriptions.....	2
1.3 Station Overviews.....	4
1.3.1. Tuolumne River near Hetch Hetchy	4
1.3.2. Tuolumne River at Tioga Road Bridge.....	8
1.3.3. Lyell Fork of the Tuolumne River below Maclure Creek	10
1.3.4. Falls Creek	12
1.3.5. Merced River at Pohono Bridge	14
1.3.6. Merced River at Happy Isles.....	16
1.3.7. South Fork of the Merced River at Wawona	18
1.3.8. Middle Fork of the San Joaquin River in Devils Postpile	20
1.3.9. Kern near Kernville.....	22
1.3.10. Middle Fork of the Kaweah River near Potwisha.....	24
1.3.11. Marble Fork of the Kaweah River above Tokopah Falls.....	27
1.3.12. Marble Fork of the Kaweah River at Potwisha.....	29
1.3.13. East Fork Kaweah River near Three Rivers, CA.....	31
1.3.14. South Fork Kings River above Roaring River.....	33
SOP 2: Training and Annual Schedule of Tasks	37

2.1	Annual Schedule of Tasks	38
2.2	Training.....	39
2.2.1.	Required Training	39
2.2.2.	Recommended Training.....	40
SOP 3: Procedures and Equipment for Station Visits.....		43
3.1	Introduction.....	44
3.2	Equipment Maintenance and Repair for Streamgage Visits.....	44
3.3	Gaging Station Field Visits.....	46
3.3.1.	Preparation for Field Visits	46
3.3.2.	Equipment Checklist for Standard Station Visits	49
3.3.3.	Getting to SIEN-supported Stations.....	50
3.3.4.	Standard Station Visit Procedures	50
3.3.5.	Completing the Field Data Sheet	51
3.3.6.	Datalogger Download Procedures	55
3.4	Post Gaging Station Visit Activities	56
3.5	Station Improvements.....	57
3.6	Routine Station Maintenance.....	58
3.6.1.	Assessing Winter Ice Effects	58
3.7	Station Surveys and Datum Corrections.....	59
3.8	HOBOTemperature Logger Visits.....	61
SOP 4: Methods for Streamflow Discharge Measurements		69
4.1	Introduction.....	70
4.2	Overview of Quantitative Methods	70
4.2.1.	Six-tenths-depth Method.....	71
4.2.2.	Two-point Method	72

4.2.3.	Safe Conditions for Wading Measurements	73
4.2.4.	Selection of Methods and Equipment to Measure Discharge	73
4.3	Field Data Sheet.....	73
4.4	Preparing to Make a Wading Measurement	74
4.4.1.	Selection of Appropriate Cross-section	74
4.4.2.	General Performance Checks for Current Meters.....	74
4.5	Quantitative Discharge Measurements	75
4.5.1.	AquaCalc Method	75
4.5.2.	FlowTracker Method	78
4.5.3.	Salt Dilution Method.....	81
4.5.4.	Acoustic Doppler Current Profiler.....	82
4.6	Semi-quantitative Methods: Floats	88
SOP 5:	Safety Procedures	93
5.1	Introduction.....	94
5.2	Roles and Responsibilities.....	94
5.3	Backcountry Travel including Daily and Emergency Communications	99
5.4	Training Requirements	99
5.4.1.	Protocol and Park Leads	99
5.4.2.	Field Technicians	100
5.5	Wading Measurement Safety Procedures.....	101
5.5.1.	Knowledge of Rivers Protocol Narrative and SOPs	101
5.5.2.	Pre-trip Preparations	101
5.5.3.	Wading Guidelines.....	102
5.6	Before and After Action Reviews.....	104
5.7	Reporting Incidents and Accidents	105

SOP 6: Acquiring Streamflow and Temperature Data from Streamgauge Operators	115
6.1 Streamflow Data Sources	116
6.2 Acquiring Tabular Discharge Data from Operators	116
6.2.1. Historic Data	119
6.2.2. Procedures for Acquiring Data from non-USGS Operated Sites.....	119
6.2.3. Procedures for Acquiring Data from USGS-operated or USGS- reviewed Stations	120
SOP 7: Data Management.....	127
7.1 Introduction.....	128
7.2 Aquarius Informatics Software.....	129
7.3 Setting up SIEN locations and managing station metadata	131
7.4 Uploading and Saving Data to the Database	133
7.4.1. Entering Field Visit Data	134
7.4.2. Importing discharge Measurement Files.....	134
7.4.3. Importing Tabular Data.....	138
7.4.4. Managing Stage and Temperature Data.....	141
7.4.5. Examining the Time Series for Erroneous Data	141
7.4.6. Ice-affected Data.....	143
7.4.7. Data Corrections in Aquarius.....	143
7.4.8. Filling in Missing Stage Data	148
7.5 Rating Curves	148
7.5.1. Developing and Maintaining Rating Curves.....	149
7.5.2. Calculating Discharge	152
7.6 Validation, Verification, and Certification	153
SOP 8: Data Analysis.....	154
8.1 Hydrologic Summary Analyses	155

8.1.1.	Descriptive Statistics.....	155
8.2	Trend Analysis.....	158
8.3	Additional Hydrologic Analysis.....	160
8.4	Flood or Low-Flow Analyses.....	161
8.4.1.	Flow Duration Curve.....	161
SOP 9:	Reporting.....	163
9.1	Reporting Schedule.....	164
9.2	Hydrologic Status Reports.....	164
9.2.1.	Daily Values Table.....	166
9.3	Comprehensive Status and Trend Reports.....	168
SOP 10:	Quality Assurance Plan.....	169
10.1	Purpose.....	170
10.2	Project Management and Responsibilities.....	170
10.2.1.	Distribution List.....	171
10.2.2.	Responsibilities.....	171
10.3	Data Quality Objectives.....	172
10.4	Collection of Stage and Streamflow Data.....	174
10.4.1.	Gage Installation and Maintenance.....	174
10.4.2.	Measurement of Stage.....	175
10.4.3.	Levels.....	179
10.4.4.	Direct Measurements.....	179
10.4.5.	Indirect Measurements.....	182
10.4.6.	Low Flow Conditions.....	182
10.5	Processing and Analysis of Streamflow Data.....	182
10.5.1.	Measurements and Field Notes.....	183

10.5.2.	Continuous Record.....	183
10.5.3.	Records and Computation.....	184
10.6	Documentation and Records.....	188
10.6.1.	Gage Documents.....	189
10.6.2.	Site Documentation.....	189
10.6.3.	Field Notes.....	190
10.7	Water Temperature Data.....	190
10.7.1.	Measurement Sensitivity.....	190
10.7.2.	Bias	191
SOP 11:	Revising the Protocol	193
11.1	Procedures.....	194
11.2	Instructions	194
Literature Cited		197

Figures

	Page
Figure 1.1. The Tuolumne above Hetch Hetchy reservoir streamgage with staff plate shown on right bank.....	8
Figure 1.2. Tuolumne River at Tioga Road site. The view is facing downstream.	10
Figure 1.3. A technician performing a discharge measurement approximately 75 meters upstream of the Lyell Fork streamgage.....	12
Figure 1.4. Falls Creek gaging station.	14
Figure 1.5. Merced River and gaging station at Pohono Bridge.....	16
Figure 1.6. Merced River at Happy Isles with the historic gaging station on the right bank.....	18
Figure 1.7. Photo of South Fork Merced channel reach as taken from the streamgage.	20
Figure 1.8. The Middle Fork of the San Joaquin at the streamgage in DEPO.....	22
Figure 1.9. The Kern River near Kernville streamgage station.	24
Figure 1.10. SCE hydrographer collecting a low flow discharge measurement at the concrete gage control at the Middle Fork Kaweah streamgage.....	26
Figure 1.11. Schematic of the Middle and Marble Forks of the Kaweah and the SCE diversions.	27
Figure 1.12. The Marble Fork above Tokopah Falls streamgage station.	29
Figure 1.13. The Marble Fork at Potwisha diversion under low flow conditions.	31
Figure 1.14. The East Fork Kaweah streamgage at high flow conditions.	33
Figure 1.15. Kings River gaging station location, looking down river.....	35
Figure 3.1. Activities to be completed prior to, during, and after routine station visits.	48
Figure 3.2. This figure depicts how to measure the depth at the control: a) Locating the control relative to the gage and thalweg, and b) Reading the depth on the wading rod at the control point (Holmes et al. 2001).	54
Figure 3.3. HOBO logger. The large rounded end (right side of image) connects to the coupler for download.	61

Figure 3.4. HOBO shuttle and coupler. The coupler is the black portion on the right side of the photo.....	62
Figure 3.5. HOBOWare file download screen.....	62
Figure 4.1. Definition sketch of the current meter midsection method of computing cross-section area for discharge measurements (graphic from Turnipseed and Sauer (2010)).....	72
Figure 4B.1. Top-setting wading rod.....	91
Figure 4B.2. Angle Coefficient Protractor available from JBS Instruments.	92
Figure 6.1. Screen capture from NWIS showing how to generate a Water Year Summary.....	121
Figure 6.2. Aquarius Springboard Locations window showing streamgage locations being monitored by the Sierra Nevada Network Rivers Monitoring Protocol and a submenu listing actions/options for the location highlighted in blue.	122
Figure 6.3. Aquarius Springboard Location Manager window with the <i>Data Sets</i> tab selected and the <i>New</i> button pressed to display the options for creating a new data set.	123
Figure 6.4. Peak streamflow page used to obtain data from multiple sites using a file of site numbers and a specified output format.	126
Figure 7.1. A general workflow of SIEN River Hydrology data management activities and their corresponding SOPs.	128
Figure 7.2. The launch screen for the Aquarius Assistant.	131
Figure 7.3. The Aquarius Springboard home screen showing the SIEN stream gaging stations	132
Figure 7.4. Aquarius Springboard Location Manager dialog box for entering gaging station metadata	133
Figure 7.5. The “New Measurement Activity” screen in the “Field Visit Tool”.....	136
Figure 7.6. The “Discharge Measurement Details” screen in Aquarius is available after a discharge file has been uploaded. The screen allows the user to assign a grade to the measurement.	137
Figure 7.7. The Aquarius Springboard Append to Logger dialog box.	139
Figure 7.8. Step 2, choosing the target data set to append in the Append Logger File Box.....	141
Figure 7.9. Printout of recorded stage data and observed stage for error checking.....	142

Figure 7.10. Data Correction screen showing the highlighted data selected for correction.	144
Figure 7.11. Rating Curve Development toolbox. The numbered items are (1) Field Visit Table, (2) Rating Zoom 1 view, (3) Offset Manager tab, (4) Rating box, (5) Shift Diagram, (6) Time Series view, and (7) Rating Period Manager tab.	152
Figure 8.1. Example MATLAB script for calculating the mean annual flow, time to center of mass, and days to 98% of total annual runoff at the Merced River at Happy Isles station.....	157
Figure 8.2. A snapshot of the Hydrologic Statistics toolbox in Aquarius.	162

Tables

	Page
Table 1.1. The 14 gaging stations included in this protocol.	5
Table 2.1. Schedule of general activities to be completed annually.	38
Table 3.1. Spin test limits.....	45
Table 3.2. List of station improvement actions to be completed within the first two years of field implementation.	58
Table 3.3. Example Level Notes Worksheet (from NPS-WRD). Note: not all stations will have multiple staff plates or reference markers.....	60
Table 3.4. Station names and abbreviations to be used for file naming.....	63
Table 4.1. Spin test limits.....	75
Table 4.2. Suggested depths and velocity limits of current meters.....	75
Table 6.1. List of streamgages, operators, data acquisition processes, and station names used in the SIEN rivers database.	117
Table 6.2. Stations with data available through the USGS NWIS system.....	120
Table 7.1. Example measurement and site summary worksheet from Saguaro National Park.	147
Table 8.1. Hydrologic parameters that are measured or calculated for SIEN reports.....	156
Table 8.2. Hydrologic parameters that are analyzed in SIEN trend reports.....	158

Table 8.3. SIEN watersheds containing streamgages located along an elevational gradient. Both watersheds are in YOSE.	161
Table 9.1. The reporting schedule for the first six years of this protocol.	164
Table 9.2. An example of the summary statistics table that is included in the hydrologic status reports.	166
Table 9.3. Mean daily discharge (example data set from Easkoot Creek monitored by the San Francisco Bay Area Network).....	167
Table 9.4. Evaluation of trends in selected hydrologic characteristics representing the temporal distribution and magnitude of streamflows by the method of Kendall's tau. Positive trends are identified by (+) and shown in green. Negative trends are identified by (-) and shown in orange. The significance of trends is expressed by the p-value, for example, $p = 0.05$ indicates that a trend is significant at the 95 percent level. Table is from Andrews (2012).	168
Table 10.1. SIEN staff responsibilities and time contributions to the river monitoring protocol.	171
Table 10.2. Summary of data quality values for SIEN hydrology and temperature monitoring (table was adapted from Hughes et al. (In prep)).....	172
Table 10.3. Data protection standards for SIEN-supported stations (table was adapted from Hughes et al. (In prep)).	174
Table 10.4. Precision of measurements of surface water and related parameters (USGS values are from Sauer (2002)).	176
Table 10.5. Stream measurement device operating ranges, accuracy, field diagnostic checks, and corrective actions.....	177
Table 10.7. Temperature sensor range, accuracy, and resolution.	190

Appendices

	Page
Appendix SOP 3A. Field Form for Station Visits	65
Appendix SOP 3B. Current Meter Tracking Sheet.....	67
Appendix SOP 4A. Field Cheatsheet for Wading Discharge Measurements	90
Appendix SOP 4B. Procedures for Using a Top-setting Rod and Horizontal Angle Coefficient Protractor for Streamflow Measurements	91
Appendix SOP 5A. Local Contacts for Field Personnel.....	106
Appendix SOP 5B. Basic Safety Equipment Checklist.....	107
Appendix SOP 5C. Personal Protective Equipment Checklist	108
Appendix SOP 5D. Job Hazard Guideline: Wilderness Travel	109
Appendix SOP 5E. Job Hazard Guideline: Wading Rivers and Streams	112

Acronyms

AAR	After Action Review
ADCP	Acoustic Doppler Current Profiler
AMJJ	April, May, June, July
AMS	Alternative Measurement Sensitivity
API	Application Programming Interface
CDEC	California Data Exchange Center
CDWR	California Department of Water Resources
CFS	Cubic Feet per Second
CM	Center of Mass
CPR	Cardiopulmonary resuscitation
DEPO	Devils Postpile National Monument
EC	Electrical Conductivity
FGDC	Federal Geographic Data Committee
GAR	Green-Amber-Red
GOES	Geostationary Operational Environmental Satellite
HBN	Hydrologic Benchmark Network
HHWP	Hetch Hetchy Water and Power
HIF	Hydrologic Implementation Facility
HUC	Hydrologic Unit Code
HWM	High Water Marks
I & M	Inventory and Monitoring Division of the National Park Service
IRMA	Integrated Resources Management Applications (NPS)
IT	Information Technology
JHG	Job Hazard Guidelines
JSON	JavaScript Object Notation
KICA	Kings Canyon National Park
KRWA	Kings River Water Association
LEW	Left Edge of Water
MKT	Mann-Kendall Test
MQO	Measurement Quality Objective
NBII	National Biological Information Infrastructure
NIST	National Institute of Standards and Technology
NPS	National Park Service
NRDS	Natural Resource Data Series
NRR	Natural Resources Reports
NRSS	Natural Resource Stewardship and Science (NPS Directorate)
NWIS	National Water Information System
PDT	Pacific Daylight Time
PFD	Personal Flotation Device
PT	Pressure Transducer
PWR	Pacific West Region
PZF	Point of Zero Flow
QAP	Quality Assurance Plan

QA/QC	Quality Assurance/Quality Control
RC	Relative Concentration
RDB	Relational Database
REST	Representational State Transfer
REW	Right Edge of Water
RPD	Relative Percent Difference
RSD	Relative Standard Deviation
SCE	Southern California Edison Electric Company
SEKI	Sequoia and Kings Canyon National Parks
SEQU	Sequoia National Park
SIEN	Sierra Nevada Network
SMIS	Safety Management Information System
SNR	Signal to Noise Ratio
SOAP	Simple Object Access Protocol
SOP	Standard Operating Procedure
SPE	Severity-Probability-Exposure
SQL	Structured Query Language
SWE	Snow Water Equivalent
UC	University of California
UCSB	University of California, Santa Barbara
URL	Uniform Resource Locator (web address)
USGS	United States Geological Survey
WRD	Water Resources Division of the National Park Service
WY	Water Year
YOSE	Yosemite National Park

Sierra Nevada Network River Hydrology Monitoring Protocol

SOP 1: Streamgauge Station Overviews

Version 1.0

This standard operating procedure is part of the Sierra Nevada Network River Hydrology Monitoring Protocol, but is designed to be printed and viewed as a separate document.

Revision History Log

Previous version #	Revision date	Revised by	Changes	Justification	Page #'s affected	New version #

1.1 Introduction

The purpose of this standard operating procedure (SOP) is to provide an overview of the stations included in this protocol and guidance on the preparation, updating, and data management of streamgage station descriptions. We did not include the station descriptions in this SOP because station descriptions are dynamic documents (more so than the protocol) that will be updated on an annual basis and include specific locations and detailed descriptions of expensive equipment that should not be publicly available for security purposes. It is standard protocol for the USGS to maintain station descriptions as internal documents. Full station descriptions for SIEN-supported sites are available to Sierra Nevada Network (SIEN) staff on the SIEN network drive at: J:\sien\monitoring_projects\rivers\data\metadata.

SIEN has selected three stations for which we are providing some level of direct support, including funding, technical support, computation of rating curves and discharge measurements, and/or long-term management of the data. SIEN is the primary party responsible for maintaining the station descriptions for the Lyell Fork of the Tuolumne River below Maclure Creek and the Tuolumne River at Tioga Road stations. The USGS is the primary party responsible for maintaining the station description for the Middle Fork of the San Joaquin River in Devils Postpile National Monument. Station descriptions for the non-SIEN supported sites are maintained by the respective operators. The station overviews in this SOP provide contact information to acquire the descriptions and other information as needed. The Physical Scientist will acquire the most recent station description when analyzing and reporting on data.

1.2 Preparing and Updating Station Descriptions

Station descriptions are dynamic documents that become a history of the station and provide metadata for the site. For the two station descriptions to be maintained by SIEN, it is the SIEN Physical Scientist's responsibility to review them on an annual basis and update as needed. Station descriptions have a standard set of fields that are completed to the fullest extent possible when a station is installed and are then updated annually. Typically, they are greatly expanded after the first year of implementation as benchmark and cross-section surveys are completed and the first years of data are analyzed. SIEN station descriptions follow the format used by the National Park Service Water Resources Division and are based on the USGS guidance in Kennedy (1983).

The following is a list of the sections included in SIEN station descriptions and guidance on what should be included in each section. In addition, please refer to the National Park Service's Rincon Creek station description as a good example (available at: <https://irma.nps.gov/App/Reference/Profile/1047444>).

Location: Describes the location of the site including travel directions, a map, and latitude/longitude coordinates. The twelve digit Hydrologic Unit Codes (HUCs) should also be provided.

Establishment and History: Provides the data and original individual or agency that established the station. Provides a thorough history of the site including changes in operators, equipment upgrades and additions, and any other pertinent historic information.

Elevation: The elevation range starting from the streamgage site to the highest point in the watershed.

Hydrologic Conditions/Drainage Area: Provides the drainage area and a description of typical hydrologic conditions such as indicating a snowmelt dominant hydrograph, winter ice and snow conditions, or notable flooding potential.

Gage: A detailed description of all the equipment at the gaging station.

Benchmarks: Describes the original survey. Elevation control measurements are tracked in a table.

Channel and Control: Provides detailed descriptions of the channel, control(s), and point of zero flow.

Discharge Measurements: Describes the typical discharge measurement methods used at the site for all range of flows and where they are typically conducted relative to the gage.

Regulation and Diversions: Describes any regulations or diversions nearby that may affect the gage.

Cooperation: List of collaborators involved in operating the site and their roles.

Point of Contact(s): Identifies and provides email and phone for the primary contact(s).

Land Ownership: Identifies the land ownership where the gage is located.

Period of Record: Lists period of record, including any gaps.

Online Data: For sites that are accessible online, provides the url and any information needed to access the site information and data.

Photos: Includes photos as needed, especially those showing the gage, control, and channel conditions (typical or following a notable hydrologic event).

Stations descriptions are updated on an annual basis (or more frequently as needed). 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. An archive folder is kept under the metadata folders for the station folder (e.g., J:\sien\monitoring_projects\ivers\data\metadata\station_name\archive).

1.3 Station Overviews

The SIEN River Hydrology Protocol reports on 14 stations located throughout Devils Postpile (DEPO), Sequoia (SEQU), Kings Canyon (KICA), and Yosemite (YOSE) (**Table 1.1**). This section provides brief overviews of the 14 stations including general location, station establishment and history, elevation, drainage area, pertinent regulations and diversions, period of record, land ownership, cooperative arrangements, primary contact information, and links to online data.

The USGS program Streamstats (2011) was used to obtain an estimate of drainage area for some stations. The application is available at: <http://water.usgs.gov/osw/streamstats/california.html>.

1.3.1. Tuolumne River near Hetch Hetchy

Location

The monitoring site is on the Tuolumne River above Hetch Hetchy reservoir, approximately eight miles southeast of O'Shaughnessy Dam in Yosemite National Park, California (**Figure 1.1**). The site is located at latitude 37.9166 and longitude -119.658. The HUC is 180400090502:

Region: California

Subregion: San Joaquin

Basin: San Joaquin

Subbasin: Upper Tuolumne

Watershed: Falls Creek-Tuolumne River

Subwatershed: Register Creek-Tuolumne River

Establishment and History

The station was established in October 2006 by the USGS with primary funding from Hetch Hetchy Water and Power (HHWP). HHWP continues to fund USGS to operate the station.

Elevation

Elevation at the gage is 3,850 ft.

Drainage Area

Drainage area is 301 mi² (192,640 acres).

Regulation and Diversion

Hetch Hetchy reservoir and O'Shaughnessy dam are downstream.

Period of Record

October 2006 to present

Land Ownership

U.S. government (YOSE)

SOP 1: Streamgage Station Descriptions
SIEN Rivers Monitoring Protocol

Table 1.1. The 14 gaging stations included in this protocol.

Station Name	Park / Watershed	Start Date	Elevation (ft)	Current Operator	Long-term operator	Temperature Sensor	Notes
Tuolumne River above Hetch Hetchy	YOSE / Upper Tuolumne	2006	3,850	USGS	USGS	Yes	USGS operation is funded by HHWP
★ Tuolumne River at Tioga Road Bridge	YOSE / Upper Tuolumne	2002	8,583	YOSE, SIEN	YOSE, SIEN	Yes	Station also has turbidity. SIEN responsible for data mgt. Operation funded by HHWP.
★ Tuolumne River - Lyell Fork below Maclure Cr.	YOSE / Upper Tuolumne	2001	9,615	YOSE, SIEN, USGS	YOSE, SIEN	Yes	
Falls Creek	YOSE / Falls Creek (greater Tuolumne)	(1915-1983) 2010	5,350	HHWP	HHWP	Yes	
Merced River at Pohono Bridge	YOSE / Merced	1916	3,862	USGS	USGS	No	
Merced River at Happy Isles	YOSE / Merced	1915	4,017	USGS	USGS	Yes	HBN water quality station
South Fork Merced River at Wawona	YOSE / Merced	(1911-1921) 2007	3,960	Sierra Hydrographics	Sierra Hydrographics	Yes (SIEN HOBO**)	Funded and contracted by the Merced Irrigation District
★ Middle Fork of the San Joaquin in DEPO	DEPO / San Joaquin	2009	7,580	USGS	USGS, DEPO, SIEN	Yes (SIEN HOBO)	USGS operation is funded by DEPO and SIEN. DEPO and SIEN provide field support.
Kern River near Kernville	SEKI / Kern	1960	3,620	SCE	SCE	No	
Kaweah River Middle Fork near Potwisha	SEKI / Kaweah (Middle Fork)	1950	2,190	SCE	SCE	Yes (SIEN HOBO)	
Kaweah River Marble Fork above Tokopah Falls	SEKI / Kaweah (Marble Fork)	1992	8,616	USGS, UCSB	USGS, UCSB, SEKI	Yes	HBN water quality station. SIEN assist when needed
Kaweah River Marble Fork at Potwisha	SEKI / Kaweah (Marble Fork)	1951	2,210	SCE	SCE	No	Calculated values used for annual status reports only
Kaweah River – East Fork	SEKI / Kaweah (East Fork)	1952	2,700	SCE	SCE	No	

SOP 1: Streamgage Station Descriptions
SIEN Rivers Monitoring Protocol

Table 1.2. The 14 gaging stations included in this protocol (continued).

Station Name	Park / Watershed	Start Date	Elevation (ft)	Current Operator	Long-term operator	Temperature Sensor	Notes
SF Kings abv Roaring R	SEKI / Kings	2016	4,851	KRWA	KRWA	Yes	

*Stations where SIEN will provide long-term support via operations and/or funding.

**SIEN will install HOBO temperature loggers at some sites where temperature is currently not monitored.

HHWP= Hetch Hetchy Water and Power. SCE= Southern California Edison. KRWA = Kings River Water Association. UCSB= U. Calif. Santa Barbara, HBN – Hydrologic Benchmark Network

SOP 1: Streamgage Station Descriptions
SIEN River Monitoring Protocol

Land Ownership

U.S. government (YOSE)

Cooperation

The station is maintained and operated by USGS with funding from HHWP.

Primary Contacts

Armando R. Robledo
Supervisory Hydrologist
California Water Science Center Field Office
8550 23rd Avenue
Sacramento, CA 95826
Phone number: 916-381-0207 ex 310
email: arobledo@usgs.gov

Online Data

Data are available on the California Data Exchange Center (CDEC) as site ‘Tuolumne River Near Hetch Hetchy’ and NWIS as site ‘USGS 11274790 Tuolumne R a Grand Cyn Of Tuolumne ab Hetch Hetchy’. The url’s, respectively, are: http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=TRH and http://nwis.waterdata.usgs.gov/nwis/dv/?site_no=11274790&agency_cd=USGS&referred_module=qw.



Figure 1.1. The Tuolumne above Hetch Hetchy reservoir streamgage with staff plate shown on right bank.

1.3.2. Tuolumne River at Tioga Road Bridge

Location

The monitoring site is on the Tuolumne River just below the confluence of the Lyell and Dana Forks in Yosemite, California (**Figure 1.2**). The site is located at latitude 37.8763 and longitude -119.353. The HUC is 180400090102:

Region: California

Subregion: San Joaquin

Basin: San Joaquin

Subbasin: Upper Tuolumne

Watershed: Headwaters Tuolumne River

Subwatershed: Delaney Creek-Tuolumne River

Establishment and History

The station was established as a research site in the fall of 2001 by Dave Clow (USGS), Mike Dettinger (USGS), and Jessica Lundquist (University of Washington) as part of a hydroclimate monitoring network in YOSE. The site was initially referred to as the “Tuolumne at Hwy”.

SOP 1: Streamgage Station Descriptions
SIEN River Monitoring Protocol

Streamflow discharge measurements have been performed periodically from 2002 to present by field technicians employed by YOSE or Jessica Lundquist. In 2011, Jim Roche (YOSE) submitted a grant proposal to Hetch Hetchy Water and Power (HHWP) to upgrade the gaging equipment and for staff time to perform discharge measurements and maintenance. Starting in water year 2017, SIEN and YOSE will begin to collaboratively to manage the gage, with YOSE collecting and providing the data to SIEN for rating curve and data management.

Elevation

Elevation within this watershed ranges from 8,583 ft at the gage to 13,039 ft in the upper watershed (USGS 2011).

Drainage Area

The drainage area above the streamgage is 70.6 mi² (45,184 acres).

Regulation and Diversion

No upstream regulations or diversions.

Period of Record

October 2001 to present

Land Ownership

U.S. government (YOSE)

Cooperation

The station is maintained and operated by YOSE with funding from Hetch Hetchy Water and Power. The data are managed by SIEN.

Primary Contact(s)

Sierra Nevada Network Physical Scientist: Andi Heard, andi_heard@nps.gov, 559-565-3786
Yosemite Hydrologist: Jim Roche, jim_roche@nps.gov, 209-379-1446

Online Data

Real time stage are available on CDEC accessible from the 'Tuolumne Meadows' site. The url is: http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=TUM. Note that the online data is not the data set used for analysis in this protocol. SIEN will use the quality assurance and quality control (QA/QC) checked data set that is collected and uploaded to Aquarius by YOSE and SIEN.



Figure 1.2. Tuolumne River at Tioga Road site. The view is facing downstream.

1.3.3. Lyell Fork of the Tuolumne River below Maclure Creek

Location

The monitoring site on the Lyell Fork of the Tuolumne River is located in Yosemite National Park, California downstream of the Maclure Creek tributary (**Figure 1.3**). The latitude is 37.7778 and longitude -119.261. The HUC is 180400090107:

Region: California

Subregion: San Joaquin

Basin: San Joaquin

Subbasin: Upper Tuolumne

Watershed: Headwaters Tuolumne River

Subwatershed: Lyell Fork

Establishment and History

The station was established in 2001 by Dave Clow (USGS) as part of the hydroclimate monitoring network in YOSE. Streamflow discharge measurements have been performed periodically from 2001 to present by field technicians employed by the YOSE Physical Sciences branch or Dave Clow. Routine water chemistry samples have also been collected for Dave

SOP 1: Streamgage Station Descriptions
SIEN River Monitoring Protocol

Clow's research. In August 2013, YOSE and SIEN began to work collaboratively to convert the station from a temporary research site to a permanent long-term monitoring gaging station. Long-term funding is still uncertain for this site, however, YOSE and SIEN are working to secure funding.

Elevation

Elevation within this watershed ranges from 9,615 ft at the gage to 11,076 ft at the watershed boundary (USGS 2011).

Drainage Area

The Lyell Fork drainage area is 6.0 mi² (3,840 acres).

Regulation and Diversion

No upstream regulations or diversions.

Period of Record

October 2001 to present

Land Ownership

U.S. government (YOSE)

Cooperation

Presently, the station is cooperatively operated by USGS, YOSE, and SIEN. Full time long-term operation will transfer to SIEN and YOSE by 2017.

Primary Contact(s)

Sierra Nevada Network Physical Scientist: Andi Heard, andi_heard@nps.gov, 559-565-3786
Yosemite Hydrologist: Jim Roche, jim_roche@nps.gov, 209-379-1446

Online Data

Data are presently not available online.



Figure 1.3. A technician performing a discharge measurement approximately 75 meters upstream of the Lyell Fork streamgage.

1.3.4. Falls Creek

Location

The monitoring site is on Falls Creek in the greater Tuolumne River Watershed in Yosemite National Park, California (**Figure 1.4**). The site is located at latitude 37.9707 and longitude -119.764. The HUC is 180400090503:

Region: California

Subregion: San Joaquin

Basin: San Joaquin

Subbasin: Upper Tuolumne

Watershed: Falls Creek - Tuolumne River

Subwatershed: Falls Creek

Establishment and History

The USGS established the original station in 1915 and operated it until it was discontinued in 1983. The station was re-established in September 2010 by HHWP with less intrusive infrastructure. It is presently operated by HHWP.

Elevation

Elevation is 5,350 ft at the gage.

Drainage Area

Above the streamgage, Falls Creek has a drainage area of 46.0 mi² (29,440 acres).

Regulation and Diversion

No upstream regulations or diversions.

Period of Record

1915-1983 and September 2010 to present

Land Ownership

U.S. government (YOSE)

Cooperation

Operated exclusively by HHWP.

Primary Contacts

Adam B. Mazurkiewicz, Water Operations Analyst
Hetch Hetchy Regional Water System
Operated by San Francisco Water, Power and Sewer, Services of the San Francisco Public
Utilities Commission
PO Box 160, Moccasin CA 95347
phone: 209.989.2578
cell: 209.206.1130
fax: 209.989.2045
email: amazurkiewicz@sfgwater.org

Online Data

Data from 2010 through present are available from CDEC at site 'Falls CK NR Hetch Hetchy' :
http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=FHH. Data from the historic USGS gage
are available from NWIS at site 'USGS 11275000 Falls C NR Hetch Hetchy CA':
http://nwis.waterdata.usgs.gov/nwis/dv/?site_no=11275000&agency_cd=USGS&referred_module=sw.



Figure 1.4. Falls Creek gaging station.

1.3.5. Merced River at Pohono Bridge

Location

Located at Pohono Bridge in Yosemite Valley, 4.8 miles southwest of park headquarters in Yosemite National Park, California (**Figure 1.5**). The site is located at latitude 37.7165 and longitude -119.665. The HUC is 180400080304:

Region: California

Subregion: San Joaquin

Basin: San Joaquin

Subbasin: Upper Merced

Watershed: Yosemite Creek - Merced River

Subwatershed: Indian Canyon Creek - Merced River

Establishment and History

The station was established in October 1916 by the USGS and has been in operation by the USGS over the full period of record.

SOP 1: Streamgage Station Descriptions
SIEN River Monitoring Protocol

Elevation

Elevation at the gage is 3862 ft (USGS 2011).

Drainage Area

Above the streamgage, the Merced River has a drainage area of 321.0 mi² (205,440 acres).

Regulation and Diversion

There are no nearby regulations or diversions

Period of Record

October 1916 to present

Land Ownership

U.S. government (YOSE)

Cooperation

Operated exclusively by USGS.

Primary Contacts

Armando R. Robledo
Supervisory Hydrologist
California Water Science Center Field Office
8550 23rd Avenue
Sacramento, CA 95826
Phone number: 916-381-0207 ex 310
email: arobledo@usgs.gov

Online Data

The data are available from NWIS at site: 'USGS 11266500 Merced R A Pohono Bridge NR Yosemite CA':

http://waterdata.usgs.gov/nwis/nwisman/?site_no=11266500&agency_cd=USGS.



Figure 1.5. Merced River and gaging station at Pohono Bridge.

1.3.6. Merced River at Happy Isles

Location

The station is located downstream of Happy Isles Nature Center in Yosemite National Park, California (**Figure 1.6**). The site is located at latitude 37.7169 and longitude -119.558. The HUC is 180400080108:

Region: California

Subregion: San Joaquin

Basin: San Joaquin

Subbasin: Upper Merced

Watershed: Headwaters Merced River

Subwatershed: Sunrise Creek - Merced River

Establishment and History

The USGS established the station in 1915 and continues operation through present day. In September 2009 the gaging station was moved from the right bank to the left bank for the

SOP 1: Streamgage Station Descriptions
SIEN River Monitoring Protocol

following reasons: i) threatened stability of existing gage location due to a failing foundation and increased susceptibility to high flows following the removal of the old Happy Isles Bridge, ii) decreased power and communications reliability due to tree interference with solar panels and satellite antenna, iii) desired research activities at the site that could not be supported with existing infrastructure, and iv) desired increased interpretation for the river gage. The new gage is still located in the same pool as the historic gage.

Elevation

Elevation at the gage is 4,017 ft.

Drainage Area

The drainage area above the gage is 181.0 mi² (115,840 acres).

Regulation and Diversion

None nearby.

Period of Record

October 1915 to present

Land Ownership

U.S. government (YOSE)

Cooperation

The USGS is the primary operator. YOSE assists with collection of Hydrologic Benchmark Network (HBN) water quality samples.

Primary Contacts

Armando R. Robledo
Supervisory Hydrologist
California Water Science Center Field Office
8550 23rd Avenue
Sacramento, CA 95826
Phone number: 916-381-0207 ex 310
email: arobledo@usgs.gov

Online Data

The data are available from NWIS at site 'USGS 11264500 Merced R A Happy Isles Bridge NR Yosemite, CA':

http://waterdata.usgs.gov/nwis/nwisman/?site_no=11264500&agency_cd=USGS



Figure 1.6. Merced River at Happy Isles with the historic gaging station on the right bank.

1.3.7. South Fork of the Merced River at Wawona

Location

The monitoring site on the South Fork of the Merced River (**Figure 1.7**) is located near Wawona near the road bridge in Yosemite National Park, California. The latitude is 37.5417 and longitude is -119.672. The HUC is 180400080204:

Region: California

Subregion: San Joaquin

Basin: San Joaquin

Subbasin: Upper Merced

Watershed: South Fork Merced River

Subwatershed: Middle South Fork Merced River

Establishment and History

The USGS established the original station (11267500) on October 1, 1911 and operated it through September 30, 1921. Merced Irrigation District and YOSE reactivated the station on

SOP 1: Streamgage Station Descriptions
SIEN River Monitoring Protocol

October 4, 2007 to inform downstream agricultural water management and local public water supply management.

Elevation

Elevation at the streamgage is 3,960 ft.

Drainage Area

Above the streamgage, the South Fork Merced has a drainage area of 100 mi² (64,000 acres).

Regulation and Diversion

None nearby.

Period of Record

1911 – 1921 and October 2007 to present

Land Ownership

U.S. government (YOSE)

Cooperation

The station is operated by Sierra Hydrographics and supported financially by Merced Irrigation District. SIEN will install and manage a HOBO temperature logger at the station.

Primary Contacts

Dan Garrigue
Sierra Hydrographics
42163 Bald Mountain Road
Auberry, CA. 93602
Office: (559) 855-4420
Cell: (559) 285-0396

Email: dan@sierrahydrographics.com

Online data

Data are available on CDEC at site ‘South Fork Merced River at Wawona’:
http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=SMW



Figure 1.7. Photo of South Fork Merced channel reach as taken from the streamgage.

1.3.8. Middle Fork of the San Joaquin River in Devils Postpile

Location

The monitoring site on the Middle Fork of the San Joaquin River is located in Devils Postpile National Monument, California (**Figure 1.8**). The latitude is 37.6319 and longitude is -119.086. The HUC is 180400060402:

Region: California

Subregion: San Joaquin

Basin: San Joaquin

Subbasin: Upper San Joaquin

Watershed: Middle Fork San Joaquin River

Subwatershed: Middle Fork San Joaquin River

Establishment and History

The station was established by the USGS in 2009 with funding from DEPO. The site was managed year round by USGS and funded by DEPO through 2012. In October 2011 SIEN and DEPO began sharing the costs (50/50) to fund USGS to perform site visits four times a year (typically mid-February through mid-June), perform general maintenance and site upgrades, and manage the rating curve and data. DEPO is primarily responsible for conducting the site visits from approximately mid-June through mid-February and SIEN provides technical assistance.

Elevation

Elevation at the station is 7,580 ft.

Drainage Area

The drainage area above the gage is 43.8 mi² (28,032 acres).

Regulation and Diversion

No upstream regulations or diversions.

Period of Record

October 2009 to present

Land Ownership

U.S. government (DEPO)

Cooperation

DEPO, SIEN, and USGS collaboratively maintain the gage. USGS performs site visits four times a year (typically mid-February through mid-June), performs general maintenance and site upgrades, and manages the rating curve and data. DEPO is primarily responsible for conducting the site visits from approximately mid-June through mid-February and SIEN provides technical assistance. SIEN and DEPO both fund the USGS (50/50).

Primary Contacts

Devils Postpile National Monument Superintendent: Deanna Dulen, deanna_dulen@nps.gov, 760-924-5505

Sierra Nevada Network Physical Scientist: Andi Heard, andi_heard@nps.gov, 559-565-3786

US Geological Survey Hydrographer: Kevin Bazar, kwbazar@usgs.gov, 530-587-0910

Online Data

Data are available from NWIS. The station id is 'USGS 11224000 MF SAN JOAQUIN R NR MAMMOTH LAKES CA' and the url is:

http://nwis.waterdata.usgs.gov/nwis/nwisman/?site_no=11224000&agency_cd=USGS



Figure 1.8. The Middle Fork of the San Joaquin at the streamgage in DEPO.

1.3.9. Kern near Kernville

Location

The monitoring site on the Kern River is located in Sequoia National Forest, south of Sequoia National Park, California (**Figure 1.9**). The station is upstream of Lake Isabella near the town of Kernville. The latitude is 35.9453 and longitude is -118.476. The HUC is 180300010506:

Region: California

Subregion: Tulare-Buena Vista Lakes

Basin: Tulare-Buena Vista Lakes

Subbasin: Upper Kern

Watershed: Brush Creek – Kern River

Subwatershed: Brush Creek – Kern River

Establishment and History

Southern California Edison (SCE) established the site in October 1911 and continues to operate it through present. There is a river gage and a diversion gage. The diversion is 100 ft upstream of the river gage. The records have been published separately and as combined flows over the period of record.

Elevation

Elevation at the gage is 3,620 ft.

Drainage Area

Above the streamgage, the Kern River has a drainage area of 846.0 mi² (541,440 acres).

Regulation and Diversion

There is a river gage and a diversion gage. The diversion is 100 ft upstream of the river gage. The records have been published separately and as combined flows over the period of record.

Period of Record

October 1911 to present

Land Ownership

U.S. government (Sequoia National Forest)

Cooperation

The station is operated by SCE and records are reviewed by USGS.

Primary Contacts

SCE Hydrographer: Derrick Tito, Derrick.Tito@sce.com, 760-376-8350

Online Data

The data for the combined flow is available on NWIS at site 'USGS 11186001 Combined Flow of Kern R and Kern R No 3 CA':

http://waterdata.usgs.gov/nwis/nwisman/?site_no=11186001&agency_cd=USGS



Figure 1.9. The Kern River near Kernville streamgage station.

1.3.10. Middle Fork of the Kaweah River near Potwisha

Location

The monitoring site on the Middle Fork of the Kaweah River is located in Sequoia National Park, California approximately 40 meters upstream of the confluence with the Marble Fork Kaweah (**Figure 1.10**). The site is located at latitude 36.5122 and longitude -118.792. The HUC is 180300070103:

Region: California

Subregion: Tulare – Buena Vista Lakes

Basin: Tulare – Buena Vista Lakes

Subbasin: Upper Kaweah

Watershed: Middle Fork Kaweah River

Subwatershed: Lower Middle Fork Kaweah River

Establishment and History

In 1950, SCE established the stations on the main river and on the diversion 100 meters upstream. They have operated the sites through the entire period of record. Data are reported to the SEKI superintendent annually to ensure that minimum flows for aquatic life are being

SOP 1: Streamgage Station Descriptions
SIEN River Monitoring Protocol

achieved. Prior to 2002, the full record was reviewed by USGS and published on NWIS. After 2002, only flows below 36 cfs are reported and posted to NWIS. This agreement was reached because SCE does not have the resources to measure high flows with a high degree of precision.

Elevation

Elevation at the gage is 2,190 ft.

Drainage Area

Above the streamgage, Middle Fork of Kaweah River near Potwisha has a drainage area of 102.0 mi² (65,280 acres).

Regulation and Diversion

There are diversions upstream and downstream of the station (**Figure 1.11**). SIEN will acquire the discharge for the river gage and the diversion gage from SCE and combine the values to obtain the “combined flows” for trend analysis.

Period of Record

October 1950 to present

Land Ownership

U.S. government (YOSE)

Cooperation

The station is maintained and operated by SCE.

Primary Contacts

SCE Hydrographer: Derrick Tito, Derrick.Tito@sce.com, 760-376-8350

Online Data

Data for the river gage are available on NWIS at site ‘USGS 11206500 MF Kaweah R NR Potwisha Camp (River Only) CA:

http://waterdata.usgs.gov/nwis/nwisman/?site_no=11206500&agency_cd=USGS. The full range of flows are available up to 2002. After 2002 only flows below 36 cfs are posted. The data for the full range of flows are available by contacting SCE directly. Data for the diversion (SCE # 210) are also available directly from SCE.



Figure 1.10. SCE hydrographer collecting a low flow discharge measurement at the concrete gage control at the Middle Fork Kaweah streamgage.

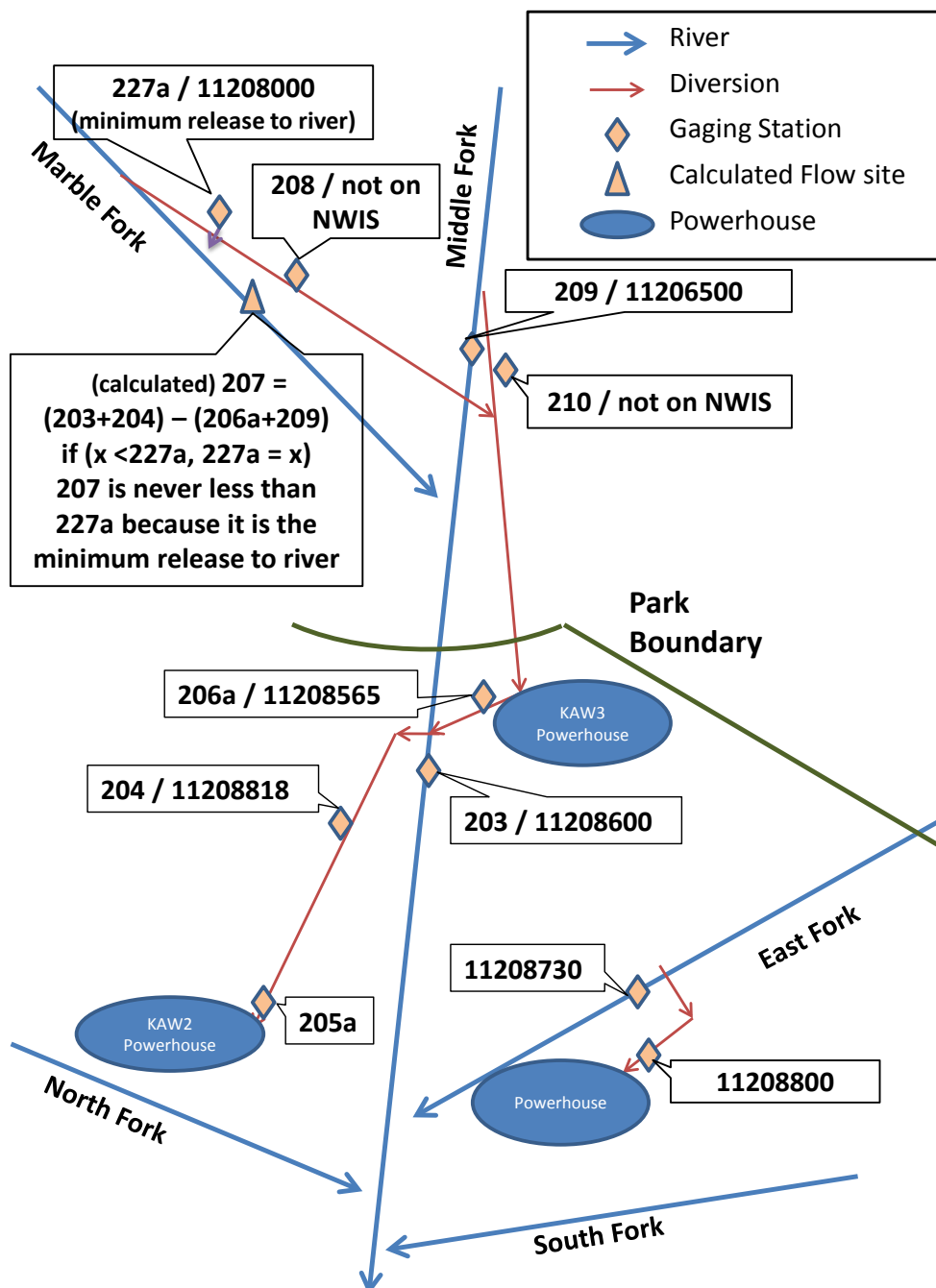


Figure 1.11. Schematic of the Middle and Marble Forks of the Kaweah and the SCE diversions. SCE uses an alternate numbering system from USGS. Gages are labeled: SCE# / USGS NWIS ID.

1.3.11. Marble Fork of the Kaweah River above Tokopah Falls

Location

The monitoring site is located in the upper portion of the Marble Fork Kaweah watershed upstream of Tokopah Falls in Sequoia National Park, California (**Figure 1.12**). The latitude is 36.6078 and longitude is -118.684. The HUC is 180300070401:

SOP 1: Streamgage Station Descriptions
SIEN River Monitoring Protocol

Region: California

Subregion: Tulare – Buena Vista Lakes

Basin: Tulare – Buena Vista Lakes

Subbasin: Upper Kaweah

Watershed: Marble Fork Kaweah River – Kaweah River

Subwatershed: Upper Marble Fork Kaweah River

Establishment and History

The station was established in 1992 and has been maintained by John Melack and Jim Sickman from the University of California (UC). In 2003 it was adopted as a USGS HBN station.

Elevation

Elevation at the gage is 8,616 ft.

Drainage Area and Slope

Above the streamgage, the Marble Fork has a drainage area of 7.35 mi² (4,704 acres).

Regulation and Diversion

There are no upstream diversions.

Period of Record

1992 to present

Land Ownership

U.S. government (SEQU)

Cooperation

The station is maintained and operated by UC. USGS provides some funding through the HBN program to UC for surface water data collection and to SEKI for water quality sample collection. UC staff collect discharge measurements and maintain the rating curve. UC also gages the outflow from Emerald and Topaz lakes which are further up in the watershed.

Primary Contacts

Professor at UC Santa Barbara: John Melack, melack@lifesci.ucsb.edu, 805-893-3879

Associate Professor at UC Riverside: Jim Sickman, james.sickman@ucr.edu

Online Data

Surface water data are not available online but may be obtained by contacting John Melack. Water quality data are available from NWIS at site 'USGS 11206800 Marble Fork Kaweah R AB Tokopah Falls NR Kaweah CA':

http://nwis.waterdata.usgs.gov/ca/nwis/nwisman/?site_no=11206800&agency_cd=USGS.



Figure 1.12. The Marble Fork above Tokopah Falls streamgage station. Cableway with auto sampler and staff plate on right bank.

1.3.12. Marble Fork of the Kaweah River at Potwisha

Location

The physical streamgage equipment for this station has been removed, but the calculated value relates to the discharge at the historic location. The historic station was located approximately 20 meters downstream of the diversion from the Marble Fork Kaweah adjacent to Potwisha Campground in Sequoia National Park. The latitude is 36.5199 and longitude is -118.800 (**Figure 1.13**). The HUC is 180300070402:

Region: California

Subregion: Tulare – Buena Vista Lakes

Basin: Tulare – Buena Vista Lakes

Subbasin: Upper Kaweah

Watershed: Marble Fork Kaweah River – Kaweah River

Subwatershed: Lower Marble Fork Kaweah River

Establishment and History

SCE established the original stations in March 1950. The gages included one established on the river (40 meters below the diversion) and on the diversion. The station had a cable way for high flow measurements and was located in an area frequented by visitors. The control would commonly be clogged by debris under low flow conditions and visitors would build rock dams

and play on the cable way. Thus, in October 2002, the infrastructure was removed and it was determined that a calculated value from the other existing gages is sufficient to ensure the minimum flow requirements are being met. There is an acoustic-velocity meter at the minimum flow release from the diversion to the river. Under low flow conditions no water makes it past the diversion so there is a large pipe which ensures that the required minimum flows are being sent back to the river (**Figure 1.13**).

Elevation

Elevation at the historic station location is 2,210 ft.

Drainage Area

Above the streamgage, the Marble Fork has a drainage area of 51.4 mi² (32,896).

Regulation and Diversion

There are both upstream and downstream diversions. See **Figure 1.11** for a schematic of the diversions.

Period of Record

1951 to present

Land Ownership

U.S. government (SEQU)

Cooperation

The station is operated exclusively by SCE.

Primary Contacts

SCE Hydrographer: Derrick Tito, Derrick.Tito@sce.com, 760-376-8350

Online Data:

The historic streamflow data (1951-2002) and the minimum flow data measured with the acoustic-velocity meter (2002-present) are available on NWIS at site 'USGS 11208000 Marble F Kaweah R (R only) A Potwisha Camp CA':
http://nwis.waterdata.usgs.gov/nwis/nwisman/?site_no=11208000&agency_cd=USGS.



Figure 1.13. The Marble Fork at Potwisha diversion under low flow conditions.

1.3.13. East Fork Kaweah River near Three Rivers, CA

Location

The monitoring site is on the East Fork of the Kaweah River, located 1.0 mi downstream of Grunigen Creek confluence, and 6.6 mi east of Three Rivers, California (**Figure 1.14**). The latitude is 36.4538 and longitude is -118.788. The HUC is 18030070203:

Region: California

Subregion: Tulare – Buena Vista Lakes

Basin: Tulare – Buena Vista Lakes

Subbasin: Upper Kaweah

Watershed: East Fork Kaweah River

Subwatershed: Lower East Fork Kaweah River

Establishment and History

The original station was established in 1952 by SCE as required by the Federal Energy Regulatory Commission. There are records for the following dates: May 1952 to September 1955, October 1957 to September 1978, October 1993 to current year. The records were

SOP 1: Streamgage Station Descriptions
SIEN River Monitoring Protocol

published as river only, and river and conduit combined from October 1962 to September 1978 and October 1993 to September 2002. Prior to October 1962 only the combined value is available. The record is reviewed annually by USGS.

Elevation

Elevation at the gage is 2,700 ft.

Drainage Area

Above the streamgage, the East Fork Kaweah River has a drainage area of 85.8 mi² (54,912 acres).

Regulation and Diversion

The conduit diverts water from the river slightly upstream from the river gage (**Figure 1.11**). The station is gaged on the main river as well as on the diversion near the SCE powerhouse with a water-stage recorder and acoustic-velocity meter. The diversion is gaged near the powerhouse, 3.3 miles downstream of the river gage. There could be some losses from the diversion between the river and the diversion gage, but for our purposes, we will sum the two values to get the combined value.

Period of Record

October 1952 to present (see Establishment and History for data gaps)

Land Ownership

Private

Cooperation

The station is operated by SCE. USGS reviews the records and posts them on NWIS.

Primary Contacts

SCE Hydrographer: Derrick Tito, Derrick.Tito@sce.com, 760-376-8350

Online Data

Data are available from NWIS for the river and conduit gaging stations. The river is available at site 'USGS 11208730 EF Kaweah R NR Three Rivers CA:

http://nwis.waterdata.usgs.gov/nwis/nwisman/?site_no=11208730&agency_cd=USGS (river only). The conduit is available at site 'USGS 11208800 EF Kaweah R Conduit 1 A PP NR Hammond CA:

http://nwis.waterdata.usgs.gov/nwis/nwisman/?site_no=11208800&agency_cd=USGS (conduit only).



Figure 1.14. The East Fork Kaweah streamgage at high flow conditions.

1.3.14. South Fork Kings River above Roaring River

Location

The station is on the South Fork of the Kings River in KICA at a bridge site near Cedar Grove (**Figure 1.15**). The latitude is 36.7869 and longitude is -118.617. The HUC is 180300100208:

Region: California

Subregion: Tulare – Buena Vista Lakes

Basin: Tulare – Buena Vista Lakes

Subbasin: Upper Kings

Watershed: Upper South Fork Kings River

Subwatershed: Granite Creek – South Fork Kings River

Establishment and History

The station was established in April 2016 by the Kings River Water Association (KRWA) through a grant from the California Department of Water Resources (CDWR).

Elevation

Elevation at the gage is 4,851 ft.

Drainage Area

Above the streamgage, the South Fork of the Kings River above Roaring River has a drainage area of 232.7 mi² (148,928 acres).

Regulation and Diversion

There are no upstream regulations or diversions.

Period of Record

April 2016 to present.

Land Ownership

U.S. government (KICA)

Cooperation

KRWA is the primary organization responsible for this station. They will utilize grant funding from the CDWR and will contract the services of Sierra Hydrographics for the establishment of the rating curve and operation of the station for the first 3-5 years.

Primary Contacts

Steven Haugen, P.E.

Watermaster

KRWA 4888 East Jensen Ave

Fresno, CA 93725

559-266-0767

shaugen@kingsriverwater.org

Online Data

Data are available from CDEC at site 'SF Kings R ABV Roaring R':

http://cdec.water.ca.gov/cgi-progs/stationInfo?station_id=KRR.



Figure 1.15. Kings River gaging station location, looking down river.

Sierra Nevada Network River Hydrology Monitoring Protocol

SOP 2: Training and Annual Schedule of Tasks

Version 1.0

This standard operating procedure is part of the Sierra Nevada Network River Hydrology Monitoring Protocol, but is designed to be printed and viewed as a separate document.

Revision History Log

Previous version #	Revision date	Revised by	Changes	Justification	Page #'s affected	New version #

2.1 Annual Schedule of Tasks

Included here is a simplified schedule of the annual field and office tasks that must be completed for this monitoring project (**Table 2.1**). Detailed instructions for specific tasks are included in the remaining SOPs. Training will occur at various times throughout the year. Field work at SIEN-supported sites occurs throughout the year and by a combination of year round and seasonal employees working for SIEN, YOSE, DEPO, and USGS. Therefore, training schedules will vary by site, the timing of new personnel, and local training requirements. It is important that parks and SIEN allow for adequate training time each year.

Table 2.1. Schedule of general activities to be completed annually.

Action	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
Prepare and submit research permits and MRA's (parks)												
NPS responsible for DEPO site visits (once every 4 to 8 weeks). USGS responsible Feb-Jun.												
Review and perform QA/QC on summer field data. Update rating curves.												
Obtain data & updated station descriptions from other station operators, format and upload to database (SOP 6).												
Provide refresher training for YOSE Hydrologist and field technicians												
Perform high flow measurements (parks and USGS)												
Perform wading measurements and SIEN-supported sites in Yosemite (YOSE)												
Perform data analysis and compile status and trend reports(could occur any time after all data has been acquired and uploaded to the database)												
Download water temperature loggers												
Repair or order equipment – send current meters for calibration												

2.2 Training

Training topics cover field methods, data management, equipment maintenance and repair, and safety. Individuals implementing this protocol should be familiar with the suite of SOPs. SIEN is responsible for training SIEN staff and the parks are responsible for training their staff, although the SIEN Physical Scientist is available to assist with training. Sections 2.2.1 and 2.2.2 list required and recommended training topics along with suggested reading and links to online trainings.

The recommended training approach for all field procedures is to first read through the SOPs, watch the USGS online trainings, and then perform the duties alongside someone with experience. There are several individuals with experience in these field methods including the USGS Hydrologic Technicians in charge of the DEPO streamgauge, the YOSE Hydrologist, several of the seasonal YOSE Physical Science Technicians, as well as others. Additionally, the USGS periodically offers more intensive courses in streamflow data collection techniques that the Physical Scientist may attend if he/she is not able to obtain the desired level of training by working with another individual in the parks or network. Training for data management activities can be acquired through online training videos that are available through the Aquarius support website and National Park Service (NPS) Water Resources Division (WRD) and by working closely with Aquarius customer support staff and the WRD Data Manager.

2.2.1. Required Training

The following trainings are required for all employees conducting field work at SIEN-supported sites:

- General orientation to the I&M program and this protocol (protocol narrative)
- Station visit methods (SOP 3)
- Quality assurance and quality control procedures (SOP 11)
- Data management – using the Aquarius software and database for rating curve development, formatting and uploading data to the database (SOPs 6, 7, 8)
- Safety and administrative trainings – these requirements vary for SIEN, DEPO, and YOSE. Staff and volunteers working at SIEN-supported sites will comply with their park/network's respective safety and administrative training requirements. Refer to SOP 5 for further details on safety requirements. SIEN safety and administration trainings are list below.

The following safety and administrative trainings are required for SIEN employees:

- SOP 5: Safety and the SIEN Safety Plan.
- Operational Leadership (required for year-round SIEN employees, recommended for field technicians)

SOP 2: Training and Schedule of Tasks
SIEN River Monitoring Protocol

- Backcountry travel and communications (SOP 5 and SIEN Safety Plan)
- Water safety (SOP 5)
- NPS required trainings—will vary by year (e.g., IT Security Training, Whistleblower)
- General NPS and administrative trainings (e.g., vehicle use, ethics, time sheets)

The following data focused trainings are required for the Physical Scientist and anyone working on data management, analysis, and reporting aspects of the protocol:

- Aquarius ‘Getting Started’ videos provided by the NPS Water Resources Division (WRD): <http://nrdata.nps.gov/programs/water/aquarius/aquariusvideos.mht>
- Aquatic Informatics training videos for using the Aquarius software. The videos are available at: <http://www.aquaticinformatics.com/support-login>. New users should contact Aquatic Informatics for a log-in and password. The following is a list of videos that should be watched prior to beginning work in Aquarius.
 - o Basic Hydrodynamics
 - o Introduction to Hydraulic Relations
 - o Importing Q Measurement Files
 - o Importing Logger Data Files
 - o Data Corrections 101: Environment Overview
 - o Field Visit Tool Overview
 - o Discrete Measurement & Gauge Height Entry

In addition the Physical Scientist is required per the Inventory and Monitoring Division to take the two-week USGS Field Water Quality for Surface Water training course. This is a new requirement and logistical hurdles with travel caps will need to be addressed before this can be accomplished.

2.2.2. Recommended Training

The following trainings are recommended for all employees conducting field work at SIEN-supported sites:

- Driver safety
- Cardiopulmonary resuscitation (CPR)
- Swift-water survival training
- USGS tutorial Measurement of Stream Discharge by Wading - provides details on the process and theory of streamflow measurements and proper methods and equipment. Refer to the USGS’s surface water training web page:
<https://pubs.usgs.gov/fs/2007/3099/>

SOP 2: Training and Schedule of Tasks
SIEN River Monitoring Protocol

- USGS trainings: USGS will allow non-USGS personnel in their training classes A list of courses is available at: <http://www.usgs.gov/humancapital/doilearn/>. The surface water records computation course is a highly recommended course for the Physical Scientist.

Sierra Nevada Network River Hydrology Monitoring Protocol

SOP 3: Procedures and Equipment for Station Visits

Version 1.0

This standard operating procedure is part of the Sierra Nevada Network River Hydrology Monitoring Protocol, but is designed to be printed and viewed as a separate document.

Revision History Log

Previous version #	Revision date	Revised by	Changes	Justification	Page #'s affected	New version #

Note:

This SOP also includes instructions for data management activities that take place upon returning from station visits.

3.1 Introduction

The SIEN-supported streamgages are each unique in their locations and history. In general, station visit procedures among sites are very similar and follow the same flow. However, there is some variation with the discharge measurement procedures and equipment used at each site. Here is a summary, by site, of the discharge measurement methods and equipment:

- San Joaquin in Devils Postpile – The primary method and equipment that DEPO and SIEN staff will use are wading measurements using current meters and the AquaCalc. These methods are consistent with the methods that USGS is using at this gage.
- Lyell Fork of the Tuolumne below Maclure – The primary method at lower flows is salt dilutions. Wading measurements with a FlowTracker are used for QA/QC comparisons. Dye tracer methods are used to capture higher flows.
- Tuolumne River at Tioga Road Bridge – The primary method, when it is safe to wade, is wading measurements with the FlowTracker. The acoustic Doppler current profiler (ADCP) boat is used for higher flows.

3.2 Equipment Maintenance and Repair for Streamgage Visits

Equipment for this protocol includes all items needed for SIEN-supported station visits such as safety gear, discharge measurement equipment, and the field laptop. This equipment will need to be routinely inspected and maintained so that it is in good condition and ready to be used for station visits.

Streamflow equipment includes those items needed to perform a direct flow measurement and salt dilution runs. Wading measurement methods require a FlowTracker or current meter (either pygmy or Price AA) with AquaCalc, wading rod, and a tag-line to measure the cross-section distance. The ADCP will require the boat and associated cable equipment. All wading equipment can be ordered from or sent for repair to Rickly Hydrological. Be sure to call to confirm that they can repair the equipment quickly enough that it is available prior to the next field visit. As described in the next section and Appendix SOP3B, current meters require routine care and periodically may need to be sent for calibration.

Rickly Hydrological Co. (1-800-561-9677)
Attn: Technical Services
1700 Joyce Ave.
Columbus, Ohio 43219

Salt dilutions require a conductivity meter, salt, pipettes, a plastic 1000 ml volumetric flask, and 2-liter capped container.

Bridgeboard and dye tracer methods may also be utilized during high flows, but those methods and thus equipment maintenance is beyond the scope of this protocol.

Current Meter Maintenance, Repair, Calibration, and Rating

The accuracy of discharge measurements depends on proper care and maintenance of the meters. Performance checks are needed to determine if meters meet acceptable criteria for use (**Table 3.1**). Current meters should be spin-tested prior to mobilization in the field and following a discharge measurement as well, because the meter could become bent during a measurement if it is hit by debris or knocked against a rock. The spin-test should be done in an area that is free of drafts. If a meter routinely fails to meet the spin-test minimum requirements, and does not improve after being disassembled, oiled and re-assembled, it should be sent to Rickly Hydrological for repair. SIEN and park staff should not attempt to repair meters beyond disassembling, oiling, and re-assembling the meter because the buckets and bearings can be easily bent and change the meter rating. SIEN, per USGS protocol, requires an office log that documents the results of performance checks (e.g., spin-tests for vertical axis meters) for each current meter. Field crews will maintain a spreadsheet for tracking meter performance checks and repairs. (see Appendix SOP3B for the template).

Table 3.1. Spin test limits.

Meters	Normal	Minimum
Pygmy	1.5	45 sec
Type-AA	4.0	2.0

Current meter maintenance is described in detail by USGS in TRWI, Book 8, Chapter 2, Calibration and Maintenance of Vertical-axis Type Current Meters (Smoot and Novak 1968). We have excerpted the instructions that are most pertinent for the field and stored them on the network at J:\sien\monitoring_projects\rivers\references\protocol_references. Instructions should be printed and laminated for crews to have in the field.

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. At a minimum, the following inspections should be completed upon return from each field visit to ensure that, in the case that the meter requires repair, there is sufficient time to accomplish the repair before the next field visit.

- Inspect the bucket and wheel hub assembly, yoke, cups, tailpiece, and the pivot point. The pivot point should be sharp and without burrs.
- Inspect the bearings and check the contact chamber for proper adjustment.
- 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.
- The surfaces and bearings should be clear of sediment and debris. Never store the meter in its carrying case when wet. Use the proper oil to lubricate the pivot and pivot bearing after approximately eight 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.

Meter Ratings

We will assume a standard USGS rating for all meters upon purchase. New meters will be purchased with a request that they have been calibrated at Hydrologic Instrumentation Facility (HIF) prior to purchase. The AquaCalc has the standard ratings for the AA and pygmy meter built in. Each SIEN meter should be entered into the AquaCalc with its serial number and the technician should be sure to select the appropriate meter prior to each discharge measurement. Because a meter's performance may change over time, meters will be sent to 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 HIF in Mississippi and Canada's National Calibration Service (Environment Canada). Each meter will be sent to be checked and calibrated within the first five years of routine use and at least every five years after that. If it is not possible to calibrate a meter to the standard rating, it will receive a specific rating. In a study of 253 meters, Hubbard et al.(1999) found that 36 percent of AA meters and 59 percent of pygmy meters failed to meet accuracy requirements for the standard rating, an indication that more meters should receive an individual rating. The documentation for the rating will be scanned and stored on the network drive and the serial number and rating will be entered into the AquaCalc under "non-standard meters" so the rating may be applied to each discharge measurement.

If a meter has a non-standard rating, it is important that all field personnel 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 be accomplished by storing the "non-rated," extra pivot pins in a small bag in the meter's container as an emergency back-up.

FlowTrackers and the ADCP, since they are not mechanical, are more difficult to troubleshoot and fix in the field. We recommend contacting the manufacturer when maintenance or repairs are necessary. These instruments will also be sent to the U.S. Geological Survey's HIF for calibration and repair.

3.3 Gaging Station Field Visits

The most common type of field visit for this protocol will involve downloading data from a streamgage, taking an instantaneous discharge measurement, and recording additional site visit data on a data sheet. Visits may also involve maintenance or improvement of the gage, a high flow measurement that would require non-standard equipment and additional personnel, or a survey of the gage. All visits begin in the office to prepare equipment and data sheets and end in the office (**Figure 3.1**). Following a field visit, files are downloaded, inspected and stored and equipment is visually inspected and stored for future use.

3.3.1. Preparation for Field Visits

First, it is necessary to determine the goal of the visit, i.e., a typical discharge measurement, station repairs, or survey. A standard SIEN station visit involves a discharge measurement and downloading data from the gage. Most visits will not involve surveying or high flow measurements. When surveying or high flow measurements are to be performed, one of the field

SOP 3: Procedures & Equipment for Station Visits
SIEN River Monitoring Protocol

staff must have experience with the methods. Resources for surveying and high flow methods are YOSE, USGS, or University of California staff. There is a standard set of safety gear that will be taken on all visits regardless of the purpose of the visit (See the safety equipment checklist in the section below). The following steps must be completed prior to departure:

1. Determine the purpose of the visit. If the purpose is to obtain a discharge measurement, check online SIEN gages to estimate if the river flows will be wadeable or suitable for salt dilutions. High flow conditions may dictate the use of safety equipment not normally used during low flow measurements.
2. Assemble appropriate field gear, site notebook(s), and data sheet(s). See the equipment checklist below. Printable versions of the field data sheet are at:
J:\sien\monitoring_projects\rivers\admin\forms\data_sheets.
3. Print and pack a copy of the most recent rating curve for the site(s) to be visited on Rite in the Rain paper. The rating curves are managed through Aquarius. To save time on the day of a station visit, the rating curve should already have been printed following updates from the last station visit. That is, after each station visit, data is uploaded, the rating curve is updated, and the printed rating curve is then stored with the equipment checklist and data sheets in preparation for the next trip.
4. Inspect equipment. Ensure that the field laptop is fully charged. Perform a spin test on current meters. Check batteries on the YSI meter and AquaCalc or FlowTracker.
5. Ensure that everyone is familiar with their respective safety and communication plans (Refer to the SIEN Safety Plan, SOP 5, or park safety plans).
6. Check the weather prior to departure. Be prepared with appropriate gear (i.e., rain gear, extra layers).

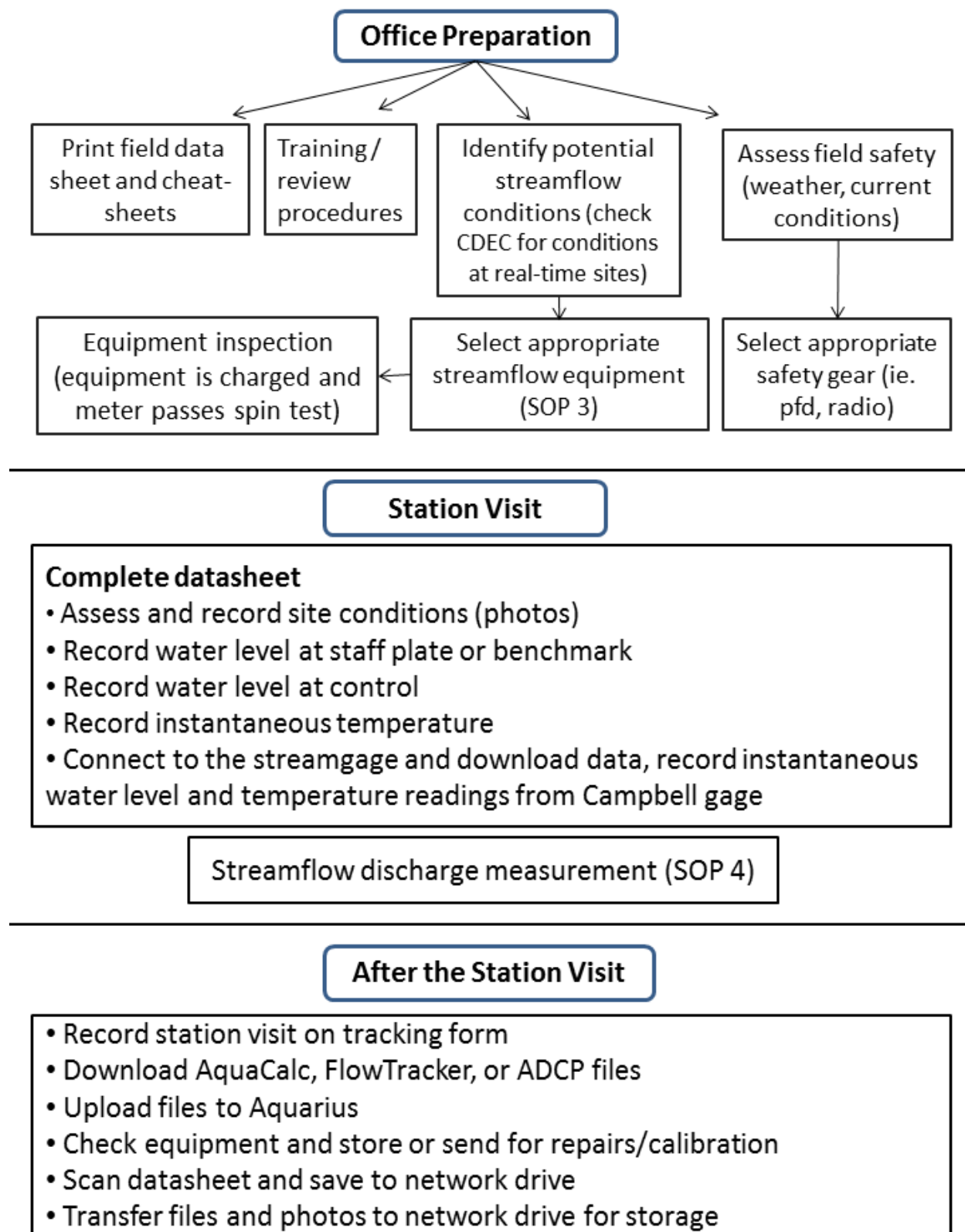


Figure 3.1. Activities to be completed prior to, during, and after routine station visits.

3.3.2. **Equipment Checklist for Standard Station Visits**

- ☐ Discharge measurement equipment (wading measurement)
 - o AquaCalc, FlowTracker, or ADCP
 - o Wading rod (for wading measurements)
 - o Current meter, if applicable
 - o Tagline or ADCP cables
- ☐ Data sheets (Appendix SOP 3A), field notebook and updated copy of rating curves
- ☐ Pencils
- ☐ Measuring tape, weighted section of steel tape and chalk, or foldable engineer ruler for tape down measurement
- ☐ Field computer with Loggernet software and cords
- ☐ Camera
- ☐ Waders
- ☐ PFDs
- ☐ YSI handheld water quality meter
- ☐ Extra batteries for the YSI and the AquaCalc or FlowTracker
- ☐ Zip ties and duct tape for possible equipment repair.
- ☐ Volt meter
- ☐ Laminated current meter maintenance instructions

Standard safety gear for all station visits:

- ☐ Radio (at a minimum, refer to respective park protocols to determine if a secondary communication device is required)
- ☐ Fluids (e.g., water, sports drinks) and food
- ☐ First Aid Kit
- ☐ Maps and Compass
- ☐ List of radio call numbers
- ☐ Flashlight or headlamp

- ☐ Vehicle safety items (toolbox, fire extinguisher, tire chains, shovel)
- ☐ Water purification for backcountry trips

3.3.3. Getting to SIEN-supported Stations

Station descriptions contain directions and a map to the sites. However, if technicians have not previously been to a station, they should always be accompanied by another person who has been to the site. All staff must carry a trail map of the area and a compass, even if they have experience finding these stations,

3.3.4. Standard Station Visit Procedures

1. Pull out the data sheet and complete (see following section for field descriptors).
2. Measure the water level at the staff plate or reference marker and record the water level and time. It is important to note the water level prior to completing other tasks to determine whether the stage is rising or falling during your visit.
3. Take a temperature measurement with the handheld meter as close as possible to the continuous water temperature sensor from the gage. Record the data on the data sheet.
4. Download the Campbell Scientific datalogger per instructions in section 3.3.6. After the download is complete, view the file in Loggernet to see if there are sections of missing data. If the file seems incomplete, try downloading again. Note start and end date for the data that has been downloaded.
5. Record the time, water level, and water temperature from the gage (from the Loggernet screen on the laptop) in the field notebook and on the datasheet. Do not disconnect the computer from the gage; the water level will be recorded again following the discharge measurement.

Note: If the water temperature varies from the gage sensor water temperature, we will apply a shift to the data within the Aquarius software in the office. It is not necessary to modify the temperature within the Campbell Scientific program.

6. Photo document the site including a downstream photo of control from gage pool, control conditions, upstream and downstream photos of discharge measurement cross-section (if wading), any indicators of high flow, and the channel cross section at the station.
7. Measure the depth at the control (**Figure 3.2**) and record with time stamp (only if the flow is low enough that it is safe to access).
8. Perform a spin-test on the current meter and record on the field form (if applicable).
9. Read the water depth at the staff plate and record with time stamp.
10. If conducting wading or ADCP measurements string the tagline or cable at an appropriate cross-section and perform a discharge measurement. If conducting salt dilutions or dye

tracer method, identify a reach of stream and starting and ending points (discharge measurement procedures are described in SOP 4).

11. Read the water depth at the staff plate and record with time stamp.
12. Return to the streamgage logger, record the time and water level that are displayed in Loggernet on the data sheet. Disconnect.

3.3.5. Completing the Field Data Sheet

The master copy of the SIEN field data sheet is located on the SIEN server (J:\sien\monitoring_projects\rivers\admin\forms\data_sheets), and an example copy is in Appendix SOP 3A. 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. Care should be exercised to ensure that others can interpret handwriting without ambiguity. 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.

Definitions of the fields on the field data sheet are as follows:

Date: Month, Day, Year

Time: Military, enter all times as Pacific Daylight Time (PDT).

Park: Standard four letter, NPS park code

Station: Location of discharge measurement, generally including name of creek and upstream or downstream from nearest landmark (e.g., Tuolumne at Tioga Rd Bridge)

Personnel: First initial and last name of person operating meter. Note if another individual is present.

Weather: Record current weather conditions by circling standard descriptors and days since last significant rain, if it is known.

Flow severity: A qualitative estimation of flow should be included with every station visit. 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 dependent on the stream and knowledge of monitoring personnel. 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.

SOP 3: Procedures & Equipment for Station Visits
SIEN River Monitoring Protocol

- 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.

Water level readings: A qualitative descriptor of the change in stage during your visit is circled; choices include rising, falling, steady, or peak. Record time in PDT (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. When stage is changing rapidly during your discharge measurement, record additional time and readings. If stage is surging at the staff plate, record the upper and lower ranges. Record the height of the streambed at the staff plate under “*Bed Level*’ field.

Gage-height change - Show actual change from start to finish.

High water mark: After spring high flows, 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.

Control Description: Note condition of control point (lowest point in thalweg below gage), including water height. If debris is present, note type of debris and clear it if it is possible to do so safely (**Figure 3.2**). The control is a feature in the stream downstream of the gaging station in subcritical flow that “controls” the relation between stage and discharge. For most streams, multiple controls usually occur and which one dominates depends on the stage of the stream. For example, at low flow a gravel riffle may be the control, at medium to high flow a culvert restriction may be the control.

Point of zero flow (PZF): 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 3.2** for illustration of how to measure water depth at the control.

Measurement type: Wading, salt dilution, dye tracer, or indicate another type if applicable.

Susp. Weight: Enter weight for 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). Mark ‘Float’ in this field if applicable.

S/N: Serial number of meter.

SPIN before/after: Duration of spin test in seconds before and after discharge measurement.

Width: Width field includes measurement of total wetted width (excludes dry sections).

SOP 3: Procedures & Equipment for Station Visits
SIEN River Monitoring Protocol

Method: Appropriate values include 0.6, 0.2/0.8, volumetric, estimated, ADCP, salt dilution.

Flow description: Record notes about flow conditions at cross-section in a standardized manner.

Cross section/substrate: Record notes about channel conditions at cross-section such as predominant substrate type, presence of vegetation in a standardized manner. If bridge measurements, note distances of bridge piers. If modifying cross-section for discharge measurements, record actions in the Observation/comments field.

Mean gage height and Discharge: These are recorded from the AquaCalc, FlowTracker, or ADCP following the measurement or from the salt dilution spreadsheet back in the office.

Observation/comments: Describe items that affect the interpretation of the record.

Water and air temperature measurements: Take one measurement with the handheld meter near the gage sensor and one in the air. Note location of measurement.

Photos taken: Take a photo of the control and one each facing upstream and downstream from the gage. Take a photo of the discharge measurement location if it is not visible from the gage.

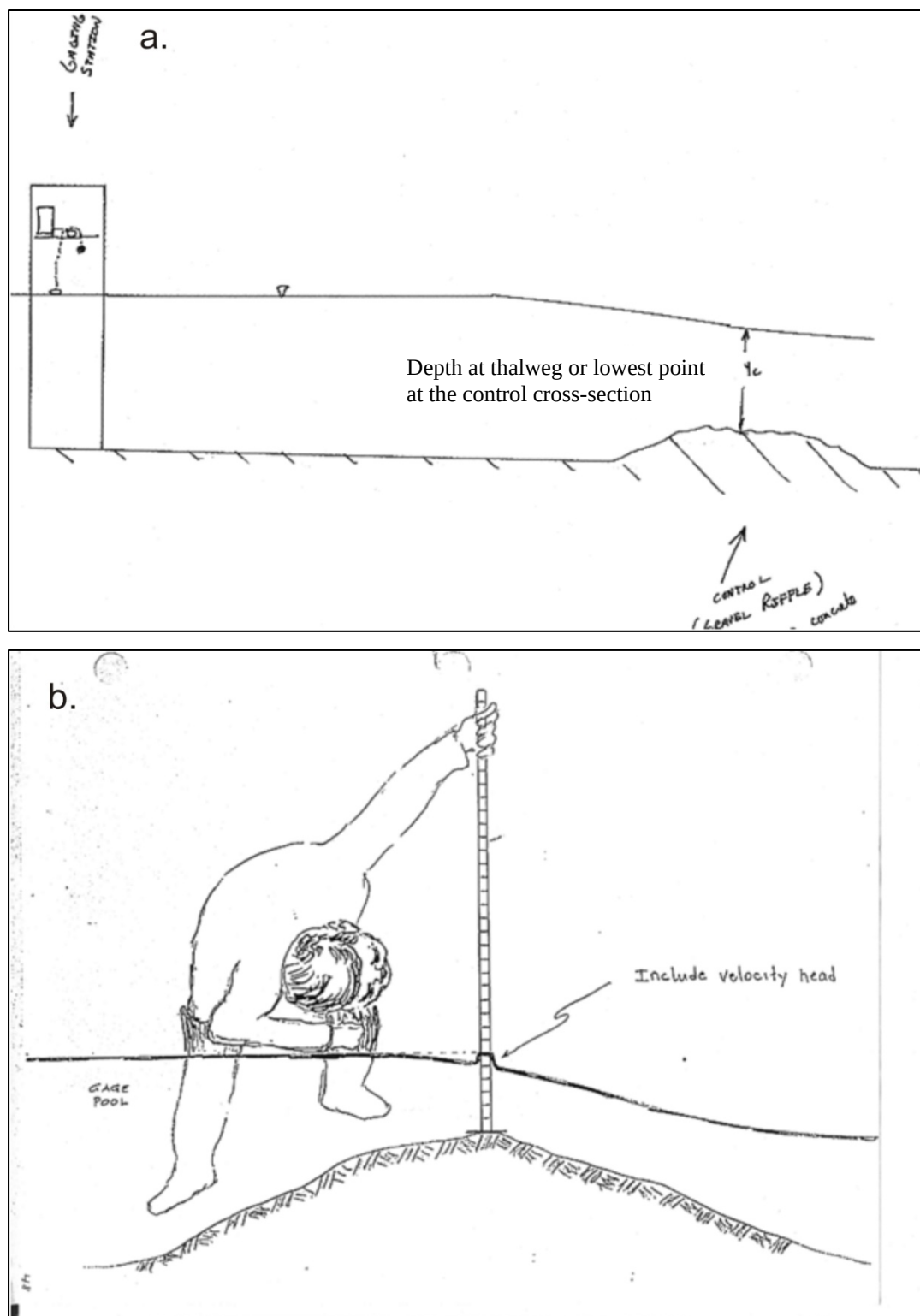


Figure 3.2. This figure depicts how to measure the depth at the control: a) Locating the control relative to the gage and thalweg, and b) Reading the depth on the wading rod at the control point (Holmes et al. 2001).

3.3.6. Datalogger Download Procedures

The following steps describe the download procedures for the Campbell Scientific CR1000 datalogger at the Tioga Bridge and Lyell Fork of the Tuolumne sites. The Devils Postpile datalogger is downloaded by USGS per their protocols. Programming code for the datalogger is stored on the SIEN network at J:\sien\monitoring_projects\rivers\operations.

1. Open Loggernet software on the field computer.
2. Connect the USB - CS/IO cable from the field computer into the CS/IO port on the datalogger.
3. Select Main>>>Connect.
4. In the station list column select the appropriate station ID. Click the “Connect” icon button.
5. Click the Table Monitor: Passive Monitoring scroll bar>>>Public. This will display real time values for all public variables collected by the program running on the datalogger.
6. In the field notebook, record real time values for each hydrologic parameter collected by the datalogger: Stage, Water Temp, Specific Conductivity, Turbidity, Battery Voltage, Station Date/Time.
7. Click the “Collect Now” icon button. This will download all data tables being stored by the program running on the datalogger. These files will be stored in the default storage folder: C Drive>Campbellsci>Loggernet. Each data table is stored with the naming convention: SiteID_TableName.dat.
8. Loggernet “.dat” files can be read by the ViewPro application in Loggernet, to view files immediately after download, with the file download screen still open, select the desired data table and click “View”. Alternatively, any .dat file can be viewed at any time by opening the ViewPro application from the Loggernet starting window Data>View Pro>File>Open
9. In ViewPro, inspect the downloaded file of interest, scroll to bottom of file fields to confirm that the last data entry occurred immediately before download.
10. Plot Stage data field in ViewPro: Click on the Stage column header, this will automatically highlight the entire field, Click the New Line Graph icon button, in the prompted Graph window select the number of Records to view in the graph, click apply. To inspect an entire record select a large value, to inspect a specific event of interest select a small value.
11. Confirm that no obvious data errors exist in the stage record, i.e. spikes, zero values etc.
12. Close out of Graph, ViewPro and Data Collection windows. In the connection screen click the “Set” button to synchronize the Station Date/Time with the Adjusted Server Date/Time.

13. Click the “Disconnect” icon button. Close Loggernet.
14. It is important that the drift of the CS450 Pressure Transducer (PT) is measured and accounted for. To do this, the manual staff plate reading or tape-down measurement must be compared to the PT real time stage value. *The manual measurement is taken twice to assure accuracy, if possible compare and confirm measurements with field partner(s). The PT has an offset applied to it, in order for it to match the manual reading of the staff plate or tape down. If the PT shows a difference from the staff plate of greater than 0.02 ft, the offset needs to be changed.
15. In the Logger Net starting window click Program>CRBasic Editor
16. Open the CR1000 program titled YOSE_WWQ_LYELLBLWMACLURE.CR1, this is located in the folder: Desktop\DataloggerPrograms
17. Scroll down through the program to the line: 'Pressure Transducer measurements SDI12Recorder (Level(),3,0,"M!";2.31,0) 'stage is in ft, Water T is C (C3).
18. The bold and underlined value in step 17, which is the last value in the PT command line, is the offset. To change it, highlight the value and adjust the offset to match the staff plate.
19. Click the Compile scroll down menu>Compile, Save and Send.
20. Click OK in the prompted dialogue box. **If you have not downloaded data from the datalogger, all data values will be erased.**
21. Check that the offset change was correct by viewing the real time Stage value. After the new program is uploaded to the datalogger, real time values will take 1 minute to update. The Stage value should now be within 0.01ft. of the staff plate reading.
22. Click the “Disconnect” icon button. Close Loggernet.

3.4 Post Gaging Station Visit Activities

Post field visit activities should occur immediately upon returning to the office. The activities are as follows:

Equipment

Equipment should be fully dried, current meters oiled, and electronic equipment charged. Once completed all equipment is stored and ready for the next visit.

Data

Data are uploaded to Aquarius immediately following a field visit. The tasks include:

1. Scan datasheets, upload to Aquarius, and enter field data into Aquarius (SOP 7).
2. Transfer Campbell Scientific streamgage files from the field laptop to Aquarius (SOP 7).

3. Transfer discharge measurement files to Aquarius and store originals on the network (SOP 7)
 - a. AquaCalc: Transfer data from the AquaCalc to the computer using DataLink, the software that comes with the AquaCalc and available from: www.jbsenergy.com. Refer to the detailed directions in the AquaCalc user's manual for basic instructions and the DataLink user's manual for more detailed instructions to transfer and view these files.
 - b. FlowTracker: Files are downloaded using the FlowTracker software package and instructions are available with the FlowTracker manuals. The .dis and .wad files are both be saved and uploaded to Aquarius. The .wad file is attached to the specific field visit. All files are immediately uploaded to Aquarius.
4. Transfer photos from the camera to the network and name per SIEN file naming standards. The naming convention is to concatenate the following information: station name abbreviation, a descriptor (e.g., control or high water), date the photo was taken, first initial and last name of the photographer. For example:
SIEN_YOSE_TUOLLYFK_Control_20120222_JSkanke.
Photos are organized in the SIEN network structures by station, then year and are stored at: J:\sien\monitoring_projects\rivers\data\photos_videos\Originals. Technicians that do not have access to the network should send the photos to the SIEN Physical Scientist. The photos are then uploaded to Aquarius.

3.5 Station Improvements

The SIEN-supported stations are in need of improvements in order to make them suitable for long-term operation. Benchmarks will be added so each site has three for use during routine surveys. Surveys are performed to assess changes in the channel over time or shifts in any of the gage equipment relative to the benchmark (Kenney 2010). Included here are suggested improvements for the initial years of protocol implementation (**Table 3.2**). Detailed recommendations for these improvements can be found in the trip report from WRD's technical assistance visit (Appendix F in the protocol narrative). SIEN will also add a webcam at the Lyell Fork if the budget and environmental compliance allows. There is already one installed at DEPO. Webcams aid in understanding the winter record by providing a view of the actual conditions at the site on a daily basis.

Table 3.2. List of station improvement actions to be completed within the first two years of field implementation.

Action	Person(s) Completing
Work with Yosemite Wilderness to determine feasibility of installing a staff plate and benchmarks at Lyell Fork of the Tuolumne	YOSE Hydrologist
Install staff plate at Lyell Fork of the Tuolumne	YOSE and SIEN staff
Survey in three benchmarks at the Lyell Fork of the Tuolumne and two additional at Tuolumne River at Tioga Road	YOSE Hydrologist and physical science techs
Install second pressure transducer and house transducers in a stilling well at Lyell Fork Tuolumne	YOSE and SIEN staff
Complete compliance for DEPO upgrades	DEPO with assistance from SIEN
Install staff plate and survey in with three benchmarks at Devils Postpile site	USGS

3.6 Routine Station Maintenance

Streamgages have multiple components that could fail or be damaged and need to be replaced or repaired. Most components can be ordered from Campbell Scientific. These are:

1. The Campbell Scientific logger which is located in the gage house
2. The pressure transducer
3. The battery
4. The solar panel
5. Wiring

Further, some components, such as the pressure transducer, need annual maintenance or assessment as described in the following sections.

3.6.1. Assessing Winter Ice Effects

Stations should be monitored for ice effect during the winter season to the best of the operator's ability. The USGS monitors the Devils Postpile gage for ice effect by monitoring the real-time stage data for any sudden atypical changes, monitoring the webcam, and making site visits throughout the winter. The two Tuolumne River sites are more challenging as winter access is not available and we presently have limited real-time data or webcams. Winter effects, presently, will have to be determined after the winter season is over and the sites can be reached, observed, and data downloaded. SIEN and YOSE will attempt to upgrade the site stage data to real-time. However, even if ice effect is suspected, we have limited ability to conduct follow-up activities (e.g., we will not be able to access the site to confirm or take a discharge measurement) due to restricted winter access.

3.7 Station Surveys and Datum Corrections

Surveys of the SIEN-supported stations will be completed in the first two years of protocol implementation in accordance with Kenney (2010). We have consulted with a NPS WRD hydrologist on locations and methods for staff plate installations and benchmarks at the Lyell Fork and Tioga Bridge Tuolumne River sites. The SIEN Physical Scientist and YOSE Hydrologist will work with the YOSE wilderness office to obtain approval to install a staff plate and three benchmarks at the Lyell Fork site, which is located in designated wilderness. Pending approval, the YOSE Hydrologist will install and survey in the staff plate. The Tioga Bridge site presently has a staff plate that is surveyed into one benchmark. The SIEN Physical Scientist and YOSE Hydrologist will work with the YOSE compliance office to obtain approval to survey in two additional benchmarks. The Tioga Bridge site is not in wilderness so the approval process is more straightforward, and it is likely that nearby, previously-established benchmarks may be used. The USGS will install a staff plate and survey in two additional benchmarks at the Devils Postpile gage. The site has already been surveyed to two benchmarks, but the benchmarks are located on trees that may not be stable over the long-term. Information on station surveys prior to SIEN's involvement is available from Yosemite staff for the Tuolumne Bridge site and from the station description for the Devils Postpile site.

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. The template used by NPS-WRD for maintaining level notes will also be adopted by this program (**Table 3.3**). These datum corrections are stored as metadata in Aquarius through the field visit manager and applied to rating curves. Hardcopies are filed in the Physical Scientist's office.

SOP 3: Procedures & Equipment for Station Visits
SIEN River Monitoring Protocol

Table 3.3. Example Level Notes Worksheet (adapted from NPS-WRD). Note: not all stations will have multiple staff plates or reference markers.

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 coarse 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				

3.8 HOBO Temperature Logger Visits

SIEN will install and maintain HOBO temperature loggers (**Figure 3.3**) at three sites (**Table 1.1**):

- South Fork Merced at Wawona
- Middle Fork San Joaquin at DEPO
- Middle Fork Kaweah near Potwisha

To setup a new logger prior to deployment, first install HOBOWare. Next, connect the logger to the shuttle and the shuttle to the computer. Follow the user manual to set up the new logger with the site name, time, date and logging interval. We will use a 15-minute logging interval. If possible, place the HOBO logger in a PVC housing with small holes. Note that the sensor on the HOBO is at the top, rather than on the portion that connects to the coupler so it is important that the entire logger is secured in an area where it will stay submerged.

The logger does not need to be removed from the site until the battery dies, because the data is downloaded using the shuttle and coupler. For all visits that involve downloading loggers with the shuttle, check the battery life on the shuttle by connecting to HOBOWare. The shuttle takes two AA batteries. The loggers are easy to download using the shuttle. Align the arrow on the shuttle with the arrow on the logger, and then press the coupler lever down until it touches the side of the shuttle (**Figure 3.4**). The LED light on the shuttle will blink yellow during the download and then switch to green when the download is complete. Refer to the HOBO user manual for detailed instructions and troubleshooting.



Figure 3.3. HOBO logger. The large rounded end (right side of image) connects to the coupler for download.

SOP 3: Procedures & Equipment for Station Visits
SIEN River Monitoring Protocol



Figure 3.4. HOBOWare shuttle and coupler. The coupler is the black portion on the right side of the photo.

Upon returning to the office, attach the waterproof shuttle to the computer with the remote cable. Open HOBOWare Pro and select “**Device \ Manage Shuttle.**” When the shuttle is connected, the files that were downloaded in the field will be displayed in the window. The status will read “**Not Offloaded**” and the boxes will be checked (**Figure 3.5**).

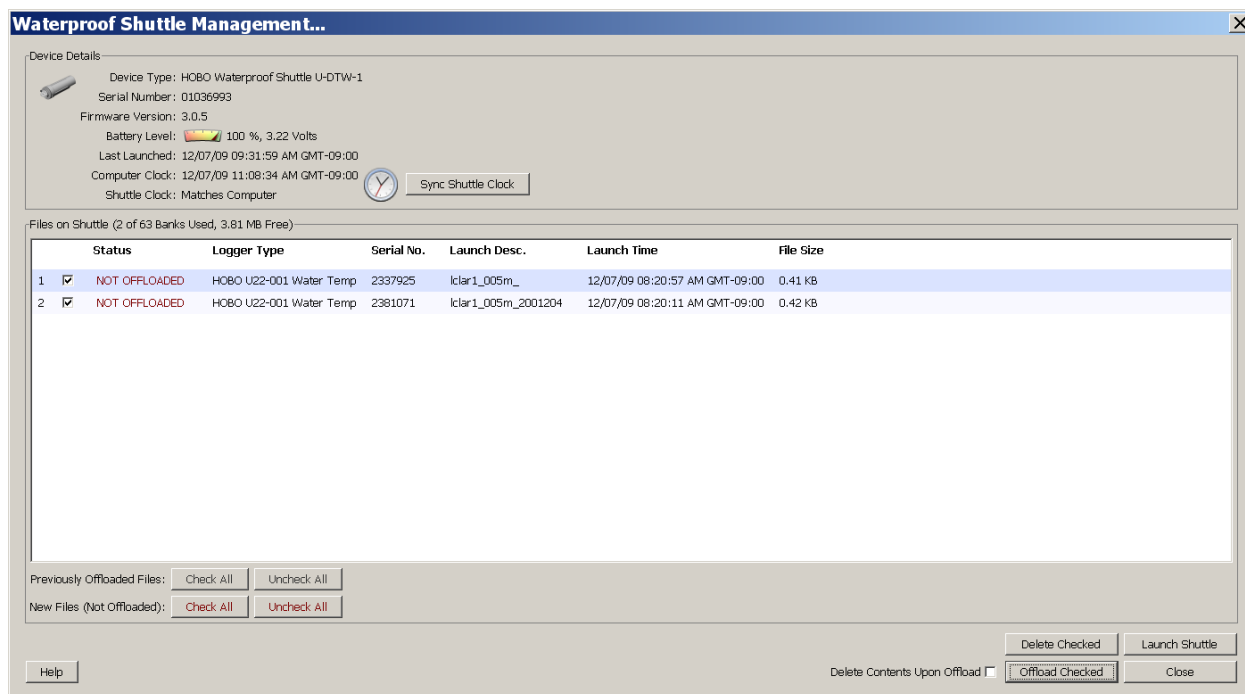


Figure 3.5. HOBOWare file download screen.

Click **Offload Checked** in the lower right. Do not check the **delete contents after offloaded** box in case there are problems. There is another option to delete the files once the data have been viewed.

The offloaded files will appear in a new screen and you will now have an option to save these files. The directory will default to the last folder in which data were saved. Ensure that you are in the correct folder, for example, files from the South Fork Merced will be stored at:

J:\sien\monitoring_projects\rivers\data\Tabular\Original_Data\SouthForkMerced\WY2012\HOBOTempFiles

Close the shuttle window and open the files that were downloaded to check for valid data. Select **File \ Open DataFile** and navigate to the folder where the data files were saved. Once the data files have been reviewed, close the files and return to the shuttle manager.

If the data in the files are missing or otherwise irregular, re-download the files from the shuttle. Select **Device \ Shuttle Manager**. When the window comes up the status will show up as “offloaded.” Check the box(es) of the files to be re-downloaded. A new default shuttle folder with the data and current time will be created. If the data still appear irregular, replace that logger and send it in to Onset for data retrieval.

To delete the files on the shuttle, select **Device \ Shuttle Manager**. Check the boxes by each offloaded file and then select **Delete Checked** in the lower right. Select yes to delete the files from the shuttle. Once the files have been deleted, the files previously listed will be cleared.

Open Windows Explorer and navigate to each file. Rename HOB0 logger files using the station names in **Table 3.4**. Use the following naming convention: “station name”_ “date the data was downloaded from the logger”, i.e., SIEN_YOSE_MERCSOFK_20120212. Upload the tabular data to the database following the instructions in SOP 7.

Table 3.4. Station names and abbreviations to be used for file naming.

Station Name	Station Name for File Naming
South Fork Merced River at Wawona	SIEN_YOSE_MERCSOFK
Middle Fork Kaweah - River	SIEN_SEQU_KAWEMIFK_R
San Joaquin Middle Fork in DEPO	SIEN_DEPO_SAJOMIFK

Next, it is necessary to save the HOB0 logger files in a format that is easily uploaded to the database. If the software has been newly installed or has been recently upgraded, open HOB0ware Pro and verify that your export settings are set like those shown below. Select **File / Preference**. Select **General** from the left side, then expand **Export Settings** and set the following:

Column separator – comma

Check the following boxes:

- separate date and time into two columns;
- include logger serial number.

SOP 3: Procedures & Equipment for Station Visits
SIEN River Monitoring Protocol

Date format – M D Y

Date separator – slash

Time format – 24 hr

Leave the remaining defaults as set. Click **OK** at the bottom right and close the **Export Settings**, close the **Preferences** window.

Open raw data file and select **File / Export Points as Excel Text / Export** to a single file. Select **Export to a single file**, then click the **Export** button. Name the .csv file as you did the raw data file.

Appendix SOP 3A. Field Form for Station Visits

For correct formatting, print this form from the master file at:
J:\sien\monitoring_projects\rivers\admin\forms\data_sheets

National Park Service - Sierra Nevada Network

FIELD VISIT FORM

DATE _____ PDT TIME _____ PDT LOCAL TIME _____ PDT OR PST?

WQ Msmt _____ PDT Flow Msmt _____ PDT

PARK _____ YOSE _____ STATION _____ PERSONNEL _____

WEATHER: (circle one descriptor from each category) Days since last significant rainfall if known: _____

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

Water Level (Stage) Readings: At a minimum, record the start and stop readings (PDT 24 Hr)

Circle one: Rising / Falling / Steady / Peak G.H. CHANGES _____ ft. in _____ minutes.

Time	Benchmark or staff plate (note if tape-down)	Bed level at staff-plate	Time	Benchmark or staff plate (note if tape-down)

HIGH WATER MARK: _____

CONTROL DESCRIPTION: Control type (natural riffle, channel, channel constriction, weir); Conditions (clear, affected by moss, leaves, etc)

Control location: _____ ft d/s of gage; Depth @ control pt: _____ ft

Point of zero flow (= water level at staff plate - depth @ control pt.): _____ ft. **GAGE POOL**

DESCRIPTION: Flow / Pool / Dry

Campbell logger stage reading prior to and following the discharge msmt _____ / _____ ft.

Downloaded Campbell logger? Yes / No (name file with download date)

MEASUREMENT TYPE (circle one) Wading Salt Dilution Other _____

Susp. Weight (for bridge msmts): _____

LOCATION: _____ ft. Upstr / Dnstr. (of gage)

SOP 3: Procedures & Equipment for Station Visits
SIEN River Monitoring Protocol

METER TYPE _____ S/N _____ SPIN/CALIB Before Meas. _____
After _____

Width _____ ft # of Sections _____ Method (0.6 or 0.2 / 0.8, estimated)

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) _____

MEAN GAGE HEIGHT _____ (mean of the heights from the start through the end of the discharge msmt)

DISCHARGE _____

QA/QC: Is measurement part of precision assessment: Y or N

OBSERVATIONS/COMMENTS/NOTES: _____

Parameter	Measurement	Units	Method	Equip S/N	Notes
Air Temperature		°C	YSI-meter		
H ₂ O Temperature		°C	YSI-meter		

PHOTOS TAKEN? Yes / No HOW MANY? _____

ID	Location (UTM or pt. #)	Description (include orientation)

Appendix SOP 3B. Current Meter Tracking Sheet

66

1

Sierra Nevada Network River Hydrology Monitoring Protocol

SOP 4: Methods for Streamflow Discharge Measurements

Version 1.0

This standard operating procedure is part of the Sierra Nevada Network River Hydrology Monitoring Protocol, but is designed to be printed and viewed as a separate document.

Revision History Log

Previous version #	Revision date	Revised by	Changes	Justification	Page #'s affected	New version #

Reference and Training Materials

Except where noted, most of the procedures described here have been obtained from standard USGS field protocols (Buchanan and Somers 1969, Rantz and others 1982a, Turnipseed and Sauer 2010). The reader is referred to those documents, which are available electronically on the internet and locally on the SIEN network, for a more specific description of methods. Field personnel are encouraged to review the USGS tutorial CD *Measurement of Stream Discharge by Wading* (<https://pubs.usgs.gov/fs/2007/3099/>). It provides details on the process and theory of streamflow measurements and proper methods and equipment.

Field personnel should review the appropriate field operation manuals prior to going into the field (e.g. AquaCalc, FlowTracker, or ADCP). The manuals include instructions for using the instruments while performing discharge measurements, helpful tips, and instructions for saving and downloading measurement files. The manuals are located on the SIEN network drive at: J:\sien\monitoring_projects\rivers\Equipment.

4.1 Introduction

This standard operating procedure describes the field methods for discharge measurements.

Except where noted, the procedures have been obtained from standard USGS field protocols. The most comprehensive instructional document for performing discharge measurements is Turnipseed and Sauer (2010). All staff that will perform discharge measurements must familiarize themselves with this document. Field personnel should watch the USGS tutorial *Measurement of Stream Discharge by Wading* (Nolan et al. 2000) which provides details on the process and theory of streamflow measurements and proper methods and equipment. These trainings are available from: <http://pubs.usgs.gov/fs/2007/3099/>.

There are multiple methods for determining instantaneous discharge. Here we include detailed procedures for the primary methods SIEN will use, which are wading measurements using a current meter and Flowtracker, salt dilutions, ADCP, and semi-quantitative float methods. There are several additional methods (Rhodamine dye, bridge board, survey methods) that SIEN may elect to use to capture high flows in specific situations. These are beyond the scope of this protocol and will require assistance from trained hydrologists (e.g. USGS). We just include the primary references for these more complex methods:

- Bridge board measurements - Turnipseed and Sauer (2010)
- Bridge measurements - <http://wwwrcamnl.wr.usgs.gov/sws/SWTraining/FlashFandR/QMeas2/QMeas2.html>.
- Dye tracer method – Wilson et al. (1986).
- Indirect measurements by survey method - Following USGS methodology (Chapters A1-A5 from <http://pubs.usgs.gov/twri/>). Specialized software will also be needed. Options include WinXSPRO A Channel Cross Section Analyzer (Hardy et al. 2005) or HEC-RAS (http://www.wsi.nrcs.usda.gov/products/w2q/H&H/Tools_Models/Ras.html).

4.2 Overview of Quantitative Methods

Stream discharge will be measured quantitatively using established procedures (Moore 2004a, b, 2005, Turnipseed and Sauer 2010). We will primarily use vertical axis meters (pygmy and Price AA), FlowTrackers, or salt dilutions for quantitative methods. The ADCP will be used to capture high flows at the Tioga Bridge site. Qualitative descriptions of the discharge measurement site such as cross-section and control conditions will be included.

For salt dilutions, we will use the slug method (Moore 2004a, 2005). A reach of stream is selected where the length is determined based on the estimated discharge (higher flows require a longer reach). A salt solution, of known conductivity, is released into the river at the upstream location and the time is recorded. At the downstream location, a technician records the electrical conductivity of the river at periodic time intervals (e.g. 5 seconds) for the period of time required to capture the increase and subsequent decline in conductivity from the injected salt. The salt

concentration, electrical conductivity measurements and mass balance principles are used to calculate the discharge (Moore 2005).

Wading 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 (**Figure 4.1**). 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 (ft³/s or cfs).

Current meters and FlowTrackers measure velocity at a single point. Discharge measurements are based on the mean vertical velocity obtained from each measured cell, which is derived from depth-integrated measurements within the vertical profile. The mean velocity can be estimated using a few velocity measurements in conjunction with a known relationship between the velocity measurements and the mean vertical velocity. The velocity may be measured at one depth (the six tenths depth method) or two depths (two-point method) in each cross-section.

All wading discharge methods share several similar steps. They include:

1. Assessment of conditions for safety
2. Selection of appropriate device to measure discharge
3. Use of properly maintained and calibrated discharge equipment
4. Selection of appropriate site for streamflow measurement
5. Division of the channel into 25-30 cross-sections (with no more than 5% of the total flow in one cross-section)
6. Allowing enough time for the meter to stabilize in each cross-section (typically 40 seconds)
7. Determining the mean velocity at each vertical
8. Tabulating the data in field notes and/or electronically recording data on the AquaCalc or FlowTracker (recording both manual and electronic data is recommended when enough personnel are available)
9. Plotting the tabulated discharge on the current rating curve

4.2.1. Six-tenths-depth Method

The six tenths method is used when the water depth in a section is less than 1.5 ft. All velocity measurements are based on the total depth within each cell. The 0.6 depth velocity reading is taken as an average vertical velocity at 0.6 from the surface, once the total depth is known. This method could be used when depths are greater than 1.5 ft when the water depth is changing rapidly and there isn't enough time to accurately measure velocity using the two-point method.

4.2.2. Two-point Method

All velocity measurements are based on the total depth within each cell. Therefore, the depth must be measured and recorded at each cell. The two-point method requires three depth measurements: the total depth in the cell, and the 0.2 and 0.8 depth from the surface. The velocity is recorded at 0.2 and 0.8 of the total depth. These values are averaged to estimate the mean vertical velocity. This method provides the most consistent and accurate results (Buchanan and Somers 1969), but takes more time. This method is not used in waters less than 1.5 feet because the current meter is too close to the surface and the bottom to provide accurate readings.

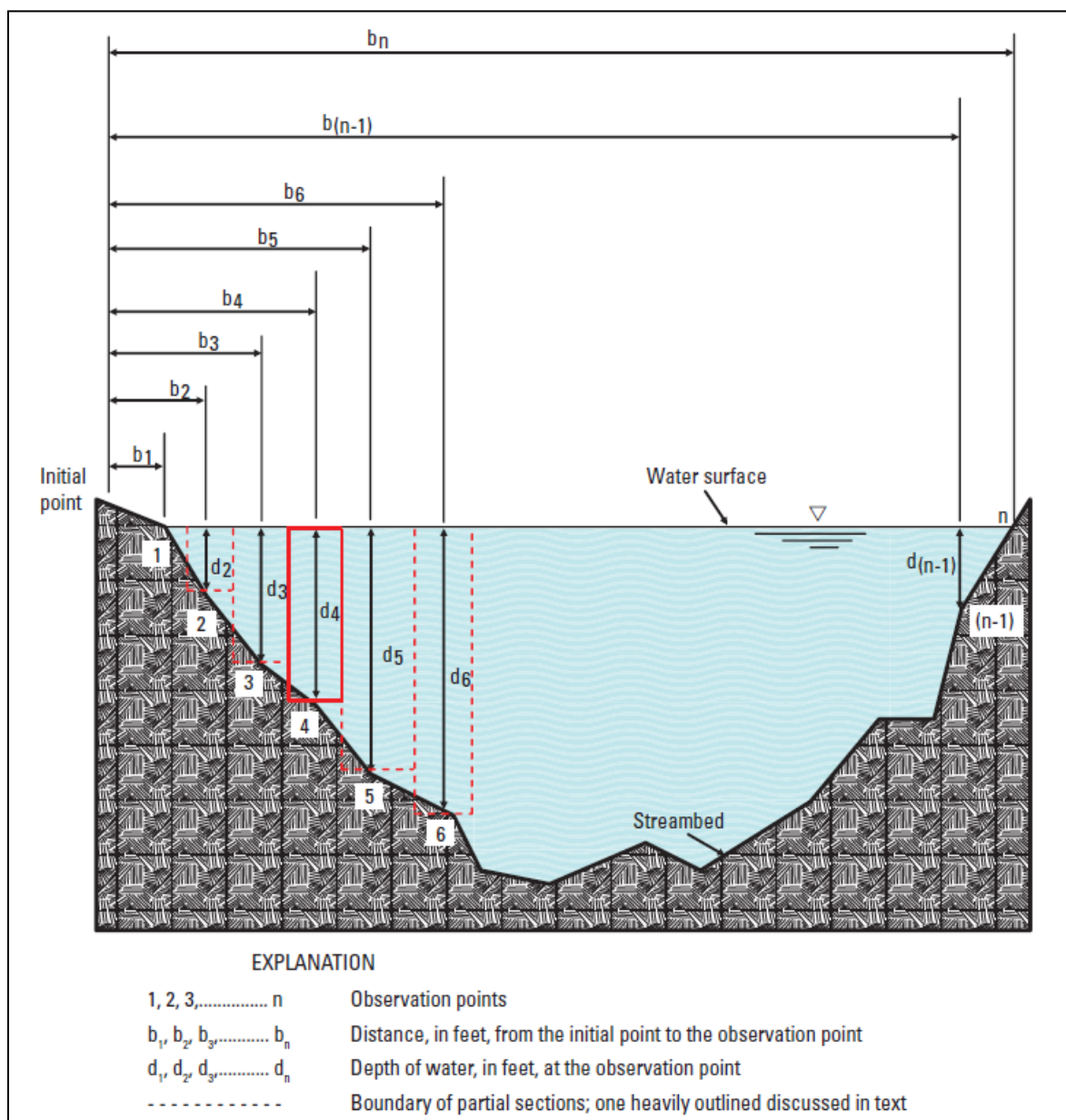


Figure 4.1. Definition sketch of the current meter midsection method of computing cross-section area for discharge measurements (graphic from Turnipseed and Sauer (2010)).

4.2.3. Safe Conditions for Wading Measurements

The Sierra Nevada Network considers wading measurements to be typically unsafe when the depth exceeds four feet at any velocity or when the product of velocity (ft/s) and depth (ft) exceeds eight (note that ten is often used, but SIEN has decided to go with a more conservative protocol due to the remote nature of our sites). When it is determined not safe to use wading methods, you may use salt dilution, tracer dye methods, the ADCP, or timed float methods. Refer to Safety SOP 5 for wading safety guidance.

4.2.4. Selection of Methods and Equipment to Measure Discharge

Existing stream conditions dictate the best tool for the job. Under extreme low flow conditions, most current meters and Flowtrackers 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 with an error around 5 percent due to boundary effects (Meyer 1996, Turnipseed and Sauer 2010). For extreme low flows, salt dilutions or the float method should be used.

Wading measurements are less accurate and more challenging in steep mountain channels with many boulders, such as the Lyell Fork of the Tuolumne below Maclure site. Under these circumstances salt dilutions or dye tracer methods may be most appropriate. Salt dilutions are often preferred in low to moderate flows because it is a less expensive method and the equipment is easier to deal with. Dye tracer methods are best at higher flows when salt solutions will be too dilute to effectively raise the stream conductivity.

Wading measurements will be conducted with either a current meter or FlowTracker. Both methods are acceptable at SIEN sites. The FlowTracker has the advantage of automatically correcting for angles, which is advantageous in rocky stream reaches. The disadvantage is the signal to noise ratio (SNR) is often low due to the dilute nature of the streams. The criteria for equipment selection and environmental tolerance limits for our current meters are provided in Appendix SOP 4A (Field Cheatsheet for Wading Discharge Measurements). Standard ratings will be used for all Price meters. For all other meters, individually rated meters will be used for measurements.

The ADCP will be used at the Tioga Bridge site when flows are too high for wading. The wide, even channel and low slope make this site a good candidate for the ADCP.

4.3 Field Data Sheet

We have a standardized data form to record discharge and water temperature measurements, as well as information about the streamgage (Appendix SOP 3A). Many of the fields in the SIEN form 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. Care should be exercised to ensure that others can interpret handwriting without ambiguity. 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. The AquaCalc, FlowTracker, and ADCP store each cross-sectional distance and associated velocity. If limited personnel are available these data will

not be duplicated on the data sheet. However, whenever possible we recommend duplicating paper and electronic notes as a quality assurance procedure. The AquaCalc or FlowTracker will display the final discharge value which will be recorded on the data sheet. Field descriptors are included in SOP 3 – Field Visit Procedures.

4.4 Preparing to Make a Wading Measurement

(adapted from Norris et al. (2011))

4.4.1. Selection of Appropriate Cross-section

The first step when preparing to make a discharge measurement is to select an appropriate reach of river. Rantz (1982a) list criteria for 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 (the current meters will work outside these conditions). See **Figure 4.1**.
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.

4.4.2. General Performance Checks for Current Meters

(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 criterion 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 (USGS 1989). Methods for inspecting meters are described in most of the USGS procedural documents - Smoot and Novak (1968), Rantz et al. (1982a) and Buchanan and Somers (1969). For this monitoring program, records of performance checks and any repairs are stored in an Excel spreadsheet that is stored on the network drive. When conducting performance checks on current meters:

- 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 two minutes or longer and pygmy meters should spin for 45 seconds or more (**Table 4.1**). 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.

Table 4.1. Spin test limits

Meters	Normal	Minimum
Pygmy	1.5	45 sec
Type-AA	4.0	2.0

Select the current meter and suspension to be used for the discharge measurement. Either pygmy or Price AA meters will be used depending upon conditions. The criteria for equipment selection are provided in **Table 4.2**. 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.

There may be instances when two or more subsections in a single measurement cross section exceed the stated ranges of depth and velocity. However, meters should not be changed during a measurement in response to such an occurrence. If there are many cross sections that exceed the specifications for the pygmy meter, the best option is to switch to the Price AA meter and begin the entire discharge measurement again. 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.

Table 4.2. Suggested depths and velocity limits of current meters.

Meter	Velocity (ft/sec)	Water Depth (feet)	Method
pygmy	0.25 – 3.00	0.30 -1.5	0.6
		1.5 or deeper	0.2 & 0.8
AA	0.25 – 8.00	1.5 – 2.5	0.6
		2.5 or deeper	0.2 & 0.8

4.5 Quantitative Discharge Measurements

4.5.1. AquaCalc Method

(adapted from Norris et al. (2011))

After the equipment has been readied and initial sections of the data sheet completed, begin the measurement.

1. String the tag line across the cross section and determine the width of the stream at the measurement cross section as follows:
 - a. String a tag line or measuring tape for measurements (generally ‘0’ of tape or tag line starts at the left bank [looking downstream]).

- b. String the line at right angles to the direction of flow to avoid horizontal angles in the cross section.
 - c. 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. The USGS criteria are that observations of depth and velocity ideally be made at a minimum of 25 verticals, which are necessary so that no more than 5% of the total flow is measured in any one vertical. 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 (Turnipseed and Sauer 2010). Fewer verticals are sometimes used for very narrow streams (less than 12 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 25.
2. Record the stream stage at the beginning of the measurement and start time.
3. Turn on the AquaCalc. Select “Measure” from the main menu, then “Setup” then “Section Setup”. The AquaCalc refers to an entire discharge measurement as a “section”.
4. In the AquaCalc, enter the gage ID, the user ID, current meter, and “TopSet Rod”.
5. Leave the measure time at the default – 40 seconds, unless the stage is rapidly rising or falling, in which case a shorter interval (e.g. 20) can be used.
6. Set the “Percent Q Limit” to 5%. Enter the estimated Q from the established rating curve, turn on the “Percent Q” mode.
7. Enter whether you are starting on the right or left bank when you are facing downstream.
8. Press Esc to return to the Measure screen.
9. Enter the distance on the tag line at the water edge (see **Figure 4.1**). Press the New Vertical Key.
10. If creek stage is changing, record the time and gage height periodically, during the course of the measurement.
11. For each vertical:
 - a. Enter the distance on the tagline, press “Stream Depth”, enter the depth to the nearest 0.1 ft and press Enter.
 - 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. Use the top-setting mechanism 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. For more detailed descriptions on how to use a top-setting rod for streamflow measurements, see Appendix SOP 4B.
 - d. Enter the “observation depth” (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 the flow line is not perpendicular to the tape/tag line, record the horizontal angle coefficient. The horizontal angle coefficient is determined by using the protractor (See Appendix SOP 4B).
 - e. Ensure that the meter is spinning. Press “Measure”. Press the Esc or abort key to cancel the measurement if needed. If you press “Halt”, the measurement will be recorded before the interval is complete.
 - f. If using the 2- point method at 0.2 and 0.8 depths, select a new observation depth in the existing vertical. If using the 1-point method, select “New Vertical”.
 - g. Move to each of the verticals and repeat this procedure until the entire cross section has been traversed.
 - h. Mark the last vertical as the edge of water by pressing the Edge/0 Key.
12. Record the stream stage at the staff plate at the end of the measurement.
 13. Press “Display Total” to view a summary of the entire measurement. Record the total discharge on the data sheet.
 14. Plot the total discharge on the rating curve (copy brought into the field). If the discharge measurement total is not within 5% of the rating curve, a check measurement should be performed. Use the same equipment and cross section for the check measurement.

The AquaCalc’s Percent Flow mode is a very powerful tool in increasing the accuracy of discharge measurements. Using this mode a technician can produce more accurate measurements with fewer measurements and in a shorter time. Using this automated method, you enter an estimated discharge based on the current stage and a previously created rating curve or rating table or based on a very recent measurement under very similar conditions. The AquaCalc monitors the sub-section discharge and recommends the location of the next vertical, keeping each sub-section discharge below the limits you set.

Alternately, use the Calculate Distance mode, which calculates the next distance based on the difference between the previous two distances. In this case, you must estimate the number of

subsections in advance, based on the total width of the stream, and then manually enter the first two distances. General guidance when manually 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.
- Space verticals no closer than 0.3 ft apart.

If necessary, the channel cross section can be modified to increase measurement accuracy. Temporarily, dikes can be constructed to cut off dead water and shallow flows. Rocks, vegetation, and debris can be temporarily removed within 3 to 6 feet of the measurement cross section. Take care not to modify the control section of the river. 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.

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. Therefore, when velocities are less than 0.2 ft/sec and depths <0.3 ft for more than 25% of verticals and velocities, it is important to note the conditions and it may be possible to direct the flow by building natural walls which create a narrow channel with deeper water. It would be rare to encounter such conditions at SIEN stations, but because these low flows are rare and may cause stress to aquatic life, they are especially important to document.

4.5.2. FlowTracker Method

FlowTracker instrument operation adapted from SonTek's FlowTracker – Quick Start Guide that is available as part of the FlowTracker documentation.

After the equipment has been readied and initial sections of the data sheet completed, begin the measurement:

1. String the tag line across the cross section and determine the width of the stream at the measurement cross section as follows:
 - a. String a tag line or measuring tape for measurements (generally '0' of tape or tag line starts at the left bank [looking downstream]).
 - b. String the line at right angles to the direction of flow to avoid horizontal angles in the cross section.

- c. Determine the locations of the measurement verticals using the following guidelines:
 - d. The spacing of observation verticals in the measurement section can affect the accuracy of the measurement. The USGS criteria are that observations of depth and velocity ideally be made at a minimum of 25 verticals, which are necessary so that no more than 5 percent of the total flow is measured in any one vertical. 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 (Turnipseed and Sauer 2010). Fewer verticals are sometimes used for very narrow. 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 25.
2. In the field data sheet record the stream stage at the beginning of the measurement and start time.
3. Get yourself and the FlowTracker settled, facing upstream, at the starting point on one of the stream edges.
4. Turn the FlowTracker on and press “Enter” to display the Main Menu.
5. Press **1** to enter the Setup Parameters Menu. Review the current settings and edit as needed. When finished press **0** to return to the main menu. The settings should be:
 - a. Units: English
 - b. Mode: Discharge
 - c. Discharge Equation: Mid-section
 - d. Averaging Time: 40 seconds (unless stage is rapidly changing and then you may reduce the time)
 - e. Salinity: 0.0 ppt
6. Press **2** to enter the Systems Functions Menu where you will field test the FlowTracker prior to conducting the measurement.
 - a. Press **4** to collect and verify temperature data.
 - b. Press **5** to check battery voltage.
 - c. Press **6** to collect and verify raw data. Ideally, SNR values should be > 4 dB (although this may be challenging in SIEN’s dilute waters).
 - d. Press **9** to verify the internal clock time.

- e. Press **0** to return to the Main Menu.
7. Press **3** to Start Data Run and display the Data File Name Menu. Press **1** and enter a file name.
8. Select the **Starting Edge** screen. Use the marked buttons on the keypad to enter the location on the tagline, depth, correction factor (if applicable), and starting edge (left edge of water (LEW) or right edge of water (REW)).
9. Move to the next vertical and press **Next Station**. Enter the location on the tagline, depth, and method of measuring velocity.
10. Position the probe at the correct depth and orientation. The probe's x-axis must be maintained perpendicular to the tagline and held away from underwater obstacles as best as possible. Keep the probe as steady as possible throughout the measurement.
11. Press **Measure**. The display will show the real-time measured velocity and SNR values. Once the averaging time is complete (40 sec) a summary is displayed. Press **1** to accept or **2** to repeat the measurement.
12. Repeat steps 9-11 for all the vertical sections.
13. When you reach the opposite edge of water select **End Section** and the ending-edge information is displayed. Enter the information for this edge as you did with the starting edge.
14. To review verticals use the **Previous Station** and **Next Station** buttons to toggle through your data.
15. Press **Calc Discharge** to compute the total cross-sectional discharge.
16. Press **0** to return to the Main Menu. **Returning to the Main Menu is very important to ensure all your data are saved.**
17. If creek stage is changing, record the time and gage height periodically, during the course of the measurement.
18. Record the stream stage at the staff plate at the end of the measurement.
19. Plot the total discharge on the rating curve (copy brought into the field). If the discharge measurement total is not within 5% of the rating curve, a check measurement should be performed. Use the same equipment and cross section for the check measurement.

General guidance when manually 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.
- Space verticals no closer than 0.3 ft apart.

If necessary, the channel cross section can be modified to increase measurement accuracy. Temporarily, dikes can be constructed to cut off dead water and shallow flows. Rocks, vegetation, and debris can be temporarily removed within 3 to 6 feet of the measurement cross section. Take care not to modify the control section of the river. 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.

4.5.3. Salt Dilution Method

The salt dilution procedure follows methods described by Moore (2004a, b, 2005). Refer to these documents for background on the method. A minimum of two salt dilutions will be performed each visit.

1. Select a stream reach with an upstream injection point and downstream measurement point. The reach of stream should not contain any pools or backwater areas. Typically, the length should be 25 stream widths. However, you may find that a shorter or longer length is required to achieve complete mixing.
2. Make the slug by dissolving salt (non-iodized table salt) in enough water to make a 1.00 liter salt solution. The quantity of salt depends on the streamflow and channel conditions. You should make a slug that will raise the background stream conductivity by 100-200%. Prior to going into the field refer to previous salt dilution data sheets to get an idea of the volume of salt you will likely need.
3. Pipette 15 ml of the slug into 1000 ml flask with streamwater. This is the secondary salt solution. Store this solution in the stream to maintain the streamwater temperature until you do the field calibration (step 6).
4. Release the slug at the upstream injection point. If it is safe to wade, it is ideal to release the slug from the middle of the stream. The footbridge is another option.
5. At the downstream site place a hand held conductivity meter in the stream where there is adequate flow and record electrical conductivity (EC) readings at 5 second intervals. Start recording measurements as soon as the slug is released. You will see the conductivity increase from the background value and reach a high steady state value when the salt is completely mixed (EC_{ss} is the electrical conductivity at steady state). Then the EC will decrease as the salt solution passes. You may stop recording once the conductivity has returned to background levels. The total time will vary, but will be on the order of 15 minutes.

6. Compute a field calibration where you estimate the slope of the relation between the relative concentration (RC) at steady state and the EC. Note that when you return to the office you will re-calculate the slope in Excel to get a more accurate measurement. Calculate the slope, k:

- a. Compute the relative concentration of the secondary salt solution RC_{sec} created in step 3:

$$RC_{sec} = \frac{X}{V_o + X}$$

where X is the volume of the injection solution added to the stream water (typically 15 ml) and V_o is the volume of streamwater (typically 1000 ml).

- b. Measure and record the electrical conductivity of the stream water (EC_0).
- c. Fill a calibration tank (~ 2 liter plastic container) with 1000 ml of streamwater (V_c). Pipette 15 ml of the secondary salt solution into the flask. This is the calibration solution. Mix thoroughly and record the EC.
- d. Repeat step 6c a minimum of three times. If the EC of the calibration solution exceeds the EC_{ss} after the third time you are done. If it does not then continue until you exceed the EC_{ss} . At each step compute the relative concentration (RC):

$$RC = \frac{RC_{sec} \sum y}{(V_c + \sum y)}$$

where $\sum y$ is the cumulative amount of secondary solution added to the calibration solution and V_c is the volume of streamwater in the calibration tank.

- e. Estimate k in the field using the following equation:

$$k = \frac{RC_f}{EC_f - EC_0}$$

where RC_f is the relative concentration from the final calibration mixture and EC_f is the corresponding electrical conductivity.

7. Upon returning to the office, enter field data into the salt dilution Excel spreadsheet. The spreadsheet is set-up to compute k and the discharge.

4.5.4. Acoustic Doppler Current Profiler

The ADCP is used to measure high flows at the Tuolumne River Tioga Bridge site.

Equipment needed:

- 2 thin cords to run across a cross-section of the stream (a yellow and a green line)

SOP 4: Streamflow Discharge Measurements
SIEN River Monitoring Protocol

- 2 2-4 ft pieces of rebar
- Weight to toss the cord across the stream (e.g., a loop of washers)
- 2 tape measures
- 2 carabiners
- ADCP boat stored in black pelican case
- Field computer (HP iPAQ palm pilot or Microsoft Surface tablet) with the StreamPro software and Bluetooth Manager installed
- Plastic pen used for iPAQ or stylus
- Mallet
- Field notebook and pencil
- Watch
- Possibly waders and wader boots

Note: There must be at least two people to do this type of flow measurement at high flows (i.e. when the stream is not crossable)

Instructions for taking a discharge measurement with the ADCP:

1. Record the staff plate level at the reference point for the cross section.
2. Select an appropriate site for the cross-section (see section 4.4.1).
3. Have one person head to the opposite side of the stream with a rebar, mallet, and a tape measure.
4. Connect the green thin cord to the weight and toss it across the stream to a partner on the other side. The partner will anchor it along the stream edge by pounding the rebar in and attaching the green cord to it.
5. Attach the yellow cord to the green cord and have your partner pull it across to their side so that both the green and yellow cords span the entire stream.
6. Make sure both cords are tight and in a position perpendicular to flow (to establish a cross-section). Anchor both cords in on your side. Clove hitches work well for a tight anchor that can be easily adjusted.
7. Get the boat out of its pelican case, flip it over, and take off the cap on the underside that protects the instrument.
8. Turn the Bluetooth receiver on by pressing the black button on top of boat.
9. Place the boat in the stream so that the front end is facing upstream and connect it to the two cords. One line will be the pull line and will attach to the boat via an overhand knot on a carabiner. The other line will act as a guide to keep the boat traveling in a path perpendicular to the stream and as a back-up safety line to keep the boat from floating

away if it comes free from the primary line. The boat will attach to this line using a clipped carabiner that runs smoothly along the line.

10. Turn the field computer on and first make sure the Bluetooth feature is working. Go to the Start menu -> Settings -> Tab for connections -> Bluetooth. Click to make sure the Bluetooth status indicates that Bluetooth is on. Once Bluetooth is on, click ok in the top right corner to return to the main screen.
11. Make a folder in the field computer that is labeled by site and date.
 - a. Click on Start -> Programs -> File Explorer.
 - b. Click on the picture of the storage card on the bottom panel (looks like a silver rectangle with a red downward-pointing arrow in it).
 - c. Click on Edit (in lower left corner) -> New Folder.
 - d. Enter name for folder, consisting of location ("TuolTiogaBridge", and underscore, and date "20160622").
 - e. Close folder (click on x in upper right hand corner).
12. In the start menu, open the StreamPro program
13. In the Setup tab, make sure the configuration file is sensible for the stream of interest (i.e. max depth may be set at 3 feet, so ensure that your cross-section is not deeper than that depth).
14. Set up configuration file.
 - a. Click on **Setup** tab along the top panel.
 - b. Click on **Configuration File** -> **Factory Default** (This will load the factory default settings).
 - c. If your rulers/tape measures are in 10ths of feet, click on **Units – English** at the bottom of the screen.
 - d. Click on **Configuration File** -> **Change Settings**.
 - e. Measure the transducer's depth below the water's surface, enter under Transducer Depth.
 - f. Make sure that you have an accurate estimate for the maximum depth of the river channel. Enter this under Max Stream Depth. The number of cells and cell size will update automatically. However, if the number of cells times the cell size is less than the max stream depth, the instrument will not record velocity all the way to the bottom in the deepest part of the river. If this is the case, you should

uncheck the **read only** box and increase the number of cells and cell size such that their multiple equals the max depth. (Note that further experimentation is needed to determine the best combinations of cells).

- g. Click on **Configuration File** → **Save As**
- h. Name the file with location and date as described above.
- i. Click on **Folder** and scroll down to the folder you created earlier for this site.
- j. Click on **Location** and scroll down to **Storage Card**. This step is very important because if the battery dies, the main memory will be lost, but the storage card memory will remain.

15. Determine edge distances.

- a. Click on **Test** tab.
- b. Click on **Instrument** → **Start Pinging**.
- c. If you get an “Error in communication” message, click on **Tools** → **Re-Connect!** in the lower left-hand panel.
- d. Gradually pull the boat away from the shore until the **Number of Good Bins** is two or more. The number will turn from red to black when you’ve reached a good spot. Mark the rope here with a knot or a piece of tape and measure how far the boat is from the shore.
- e. Tow the boat across the river to the opposite side and stop away from the bank at the closest spot where you have at least two good bins. Again, mark the rope and measure how far you are from shore.

16. You may now begin a transect:

- a. Click on **Data Collection** tab.
- b. Click on **Transect Start**.
- c. Note whether the boat is on the left or right edge (this is river left or river right, which is what you see when standing in the middle of the river facing downstream).
- d. Enter the distance from the boat to the edge. Be careful of units. This should be what you measured in the prior step.
- e. Follow instructions on screen: Click **Transect Start** to begin and have the partner on the opposite end of the stream slowly pull the boat across the stream

under the thin line while you hold the line parallel and let it feed on your end.
Tips for pulling the boat:

- i. It is easier to pull the line at a steady rate with some resistance at the other end.
 - ii. Note that the boat should only be pulled as far across the transect as a good cross sectional flow allows (i.e. each edge is determined by the point at which there is still enough flow across the path to allow for a good cross sectional measurement).
 - iii. The StreamPro software may tell you to move the boat slightly to get a better cross sectional measurement for the left or right edge.
 - iv. It is most important to pull the boat at a steady speed than at a very slow pace. Try to get each transect to take approximately the same amount of time.
- f. During the measurement note any white squares or problem areas and try to adjust your measurement accordingly.
 - g. When you get to the other bank, click **Transect Stop**.
 - h. After clicking **Transect Stop**, you will be prompted to enter the edge distance for the other side.
 - i. Repeat these steps until you have at least four good transects within 5% of the average that are evenly distributed between left and right starts. You should do an even number of transects so that your mean isn't weighted from pulling the boat a greater number of times from one side of the stream.
 - j. The USGS sets a standard of at least 720 seconds of total measurement time for their discharge measurements. The rule to get a certain measurement duration overrides other USGS suggestions to pull the boat at the same speed that the water is moving (i.e. you do not need to pull the boat at a certain speed. Pull it steady and evenly and generally slowly).
17. Check errors in measurements.
- a. For each transect note how much of the profile was estimated (the ADCP will estimate the top surface of the water, the bottom of the river or creek bed, and edges that it is unable to capture). If the total amount of the profile that was estimated is around 20-30%, the measurement is likely good. If less than 30% of the profile was estimated, the measurement may be fair.
 - b. Click on **History** tab.

- c. Look at the list of transects and the mean values. Any transect that deviates more than 5% from the mean should be highlighted.
- d. If there is a wide range of values, try making some more measurements.

18. Record results.

- a. This is done electronically under the **History** tab.
- b. In the field notebook, write down the mean discharge, mean velocity, mean distance. Include notes regarding the spread of discharge measurements. Were many outside of the 5% error bounds?

19. When done, it is CRUCIAL that you do the following:

- a. Click **File** → **Exit StreamPro** in the lower left-hand corner. Do NOT click the “X” in the upper-right-hand corner to close.
- b. Close **Programs** – this time it’s okay to click the X
- c. Turn Bluetooth off. Click on symbol on lower-right-hand corner of main screen and click **Turn Bluetooth OFF**.
- d. Turn iPAQ off and return it to its charging cradle upon returning to the office.
- e. Turn the boat off.

20. Troubleshooting:

- a. Soft, or Normal, Reset: If the iPAQ PC is acting strange and/or you want to stop all running programs, press the stylus into the small hole on the bottom right-hand side. This is also necessary if the iPAQ drains its battery completely – in this case, charge it in its cradle for about 15 minutes, and then press the reset hole and put it back on its cradle to continue charging. This will not erase programs or saved data but will erase any unsaved data.
- b. You can perform a Hard, “Full,” reset by deactivating the battery. (This also occurs if the battery is completely drained. This is not typical protocol, but if you need to do it, press and hold the two bottom applications buttons (**Calendar** and **itask**) and then use the stylus to press the reset button. This WILL erase all the programs and saved data. Reactivate the battery by connecting the pocket PC to AC power and/or by pressing the reset button again with the stylus.

4.6 Semi-quantitative Methods: Floats

A quantitative flow measurement cannot always be obtained using the USGS established methods. 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 semi-quantitative 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 (Turnipseed and Sauer 2010).

Rantz and others (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. SIEN will aim to select a channel reach of 30 feet or longer near the streamage.

To measure discharge using the float method(adapted from Leopold (1997):

- Using stakes or flags, mark the upstream starting line on each bank. Mark the finish line in a similar manner. We recommend using the streamgage as either the start or finish line. 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 at the 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 thus not accurately reflect stream velocity. Leopold (1997) recommends orange peels because they are cheap, float nicely at the surface, are 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, three replicates will be used. For each measurement, floats are tossed upstream of starting line and the travel time is 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 field notebook and comments field of the data form.

SOP 4: Streamflow Discharge Measurements
SIEN River Monitoring Protocol

- 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).

Appendix SOP 4A. Field Cheatsheet for Wading Discharge Measurements

Table 4A.1. Suggested depths and velocity limits of current meters

Meter	Velocity (ft/sec)	Water Depth (feet)	Method
Pygmy	0.25 – 3.00	0.30 -1.5	0.6
		1.5 or deeper	0.2 & 0.8
AA	0.25 – 8.00	1.5 – 2.5	0.6
		2.5 or deeper	0.2 & 0.8

Table 4A.2. Spin test limits.

Meters	Normal	Minimum
Pygmy	1.5	45 sec
Type-AA	4.0	2.0

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 and obstructions.
- Have an estimate of what the discharge will be before the 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 at least 25 measurement verticals.
- No more than 5% of the total flow should be in a single measurement cell.
- Read staff gage before, during, and after measurement.
- Check the meter during measurement for fouling or interference.
- 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 (0.2 and 0.8 depths) 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.
- For flow not perpendicular to tag line, orient meter parallel to flow and record angle coefficient.

Appendix SOP 4B. Procedures for Using a Top-setting Rod and Horizontal Angle Coefficient Protractor 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 (Figure 4B.1). To set the sensor at 60 (most common), 20 and 80 percent depths from the surface, follow the following instructions:

1. 60 Percent of Depth (0.6)

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.

2. 20 percent of Depth (0.2)

Multiply the total depth by 2. If the total depth is 3.1 feet, the rod would be set at 6.2 feet (3.1×2). Line up the **6** on the sliding rod with the **2** on the tenth scale.

3. 80 percent of Depth (0.8)

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.

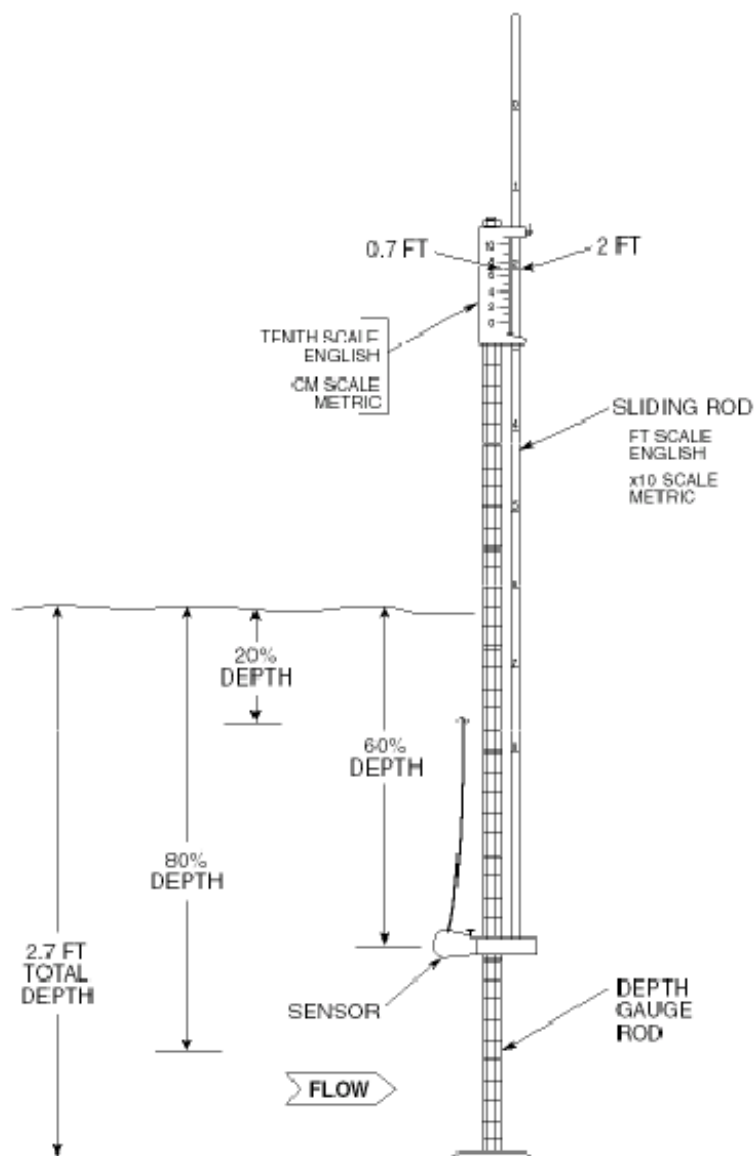


Figure 4B.1. Top-setting wading rod.

SOP 4: Streamflow Discharge Measurements
SIEN River Monitoring Protocol

Figure 4B.2 shows a protractor designed to measure the velocity vector if the direction of flow is not at right angles to the cross section. The protractor measures the cosine or the horizontal angle of the current meter to tagline or bridge rail. The measured velocity is multiplied by the protractor angle coefficient to determine velocity normal to the measuring section.

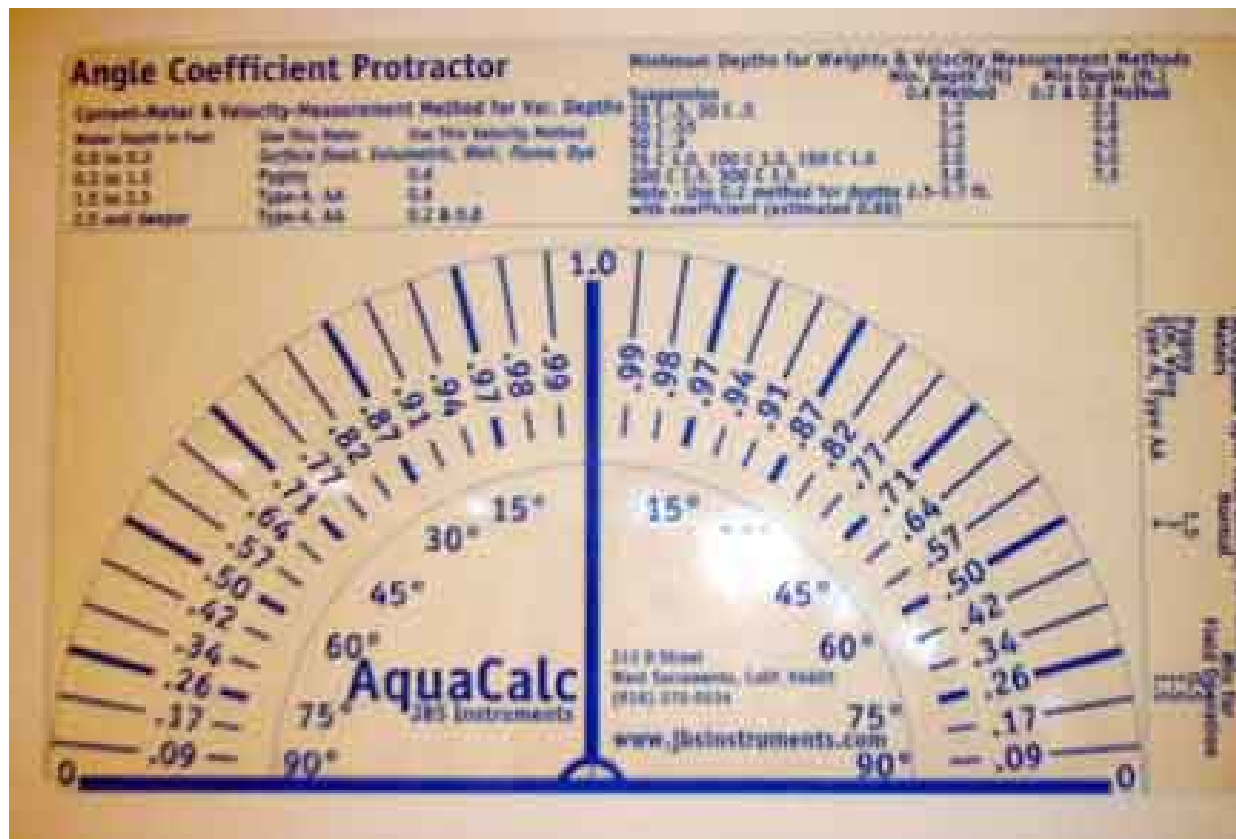


Figure 4B.2. Angle Coefficient Protractor available from JBS Instruments.

Sierra Nevada Network River Hydrology Monitoring Protocol

SOP 5: Safety Procedures

Version 1.0

This standard operating procedure is part of the Sierra Nevada Network River Hydrology Monitoring Protocol, but is designed to be printed and viewed as a separate document.

Revision History Log

Previous version #	Revision date	Revised by	Changes	Justification	Page #'s affected	New version #

5.1 Introduction

This SOP provides safety information, checklists, and forms for network and park staff who are involved with field activities at the three SIEN-supported sites – the Lyell Fork of the Tuolumne below Maclure, Tuolumne at Tioga Road Bridge, and the San Joaquin at Devils Postpile. Safety at the other sites reported on in this protocol is the responsibility of the individual station operators/agencies. This SOP should be used in conjunction with other important documents, including the network safety plan, relevant Job Hazard Guidelines, DEPO winter travel and field work SOPs, park management guidance and regulations, and other references and manuals, such as Chapter A9 of the USGS National Field Manual (Lane and Fay 1997). This SOP summarizes basic safety information and procedures, but does not comprehensively cover every safety issue. This SOP is intended to engage all personnel and to provide a foundation for an on-going open and dynamic process for addressing field safety. The SIEN Physical Scientist is responsible for updating this SOP.

Safety of personnel is always the first concern in a field-oriented monitoring program. Field work requires an awareness of potential hazards and knowledge of basic safety procedures. Station visits may require one or more nights in the backcountry. Hazards may include hiking on steep trails over rough terrain, adverse weather conditions, hazardous plants and animals, waterborne pathogens, and a variety of other environmental and physical hazards. At the streamgage site, staff will periodically wade into rivers, exposing themselves to the risk of losing footing, exposure, hypothermia, and being swept downstream. Travel may also involve long driving trips between parks and network offices, particularly at the end of field days. Advanced planning can mitigate or eliminate many of the above safety hazards and better prepare staff for dealing with these issues.

In this SOP, we define roles and responsibilities of key personnel in implementing the safety program, outline training requirements, and describe safety guidelines for conducting stream discharge wading measurements. Individual parks are responsible for their own safety protocols. They may opt to adopt the SIEN protocol guidelines described in this SOP, adopt a revised version of this SOP, or write their own. SIEN staff will follow procedures in this SOP unless otherwise noted.

5.2 Roles and Responsibilities

Clearly defined roles and responsibilities are critical for a safe monitoring program, especially when it is a collaborative effort among multiple programs. Here we define the roles and responsibilities for the key individuals that are directly involved in implementing rivers monitoring: SIEN Program Manager, SIEN Physical Scientist (protocol lead), DEPO Superintendent, DEPO Ecologist (DEPO lead), Yosemite Hydrologist (YOSE lead), and supporting SIEN staff. We did not define roles and responsibilities for YOSE and DEPO field technicians as safety is the responsibility of DEPO and YOSE leads in accordance with their respective park and program policies and SIEN Rivers Monitoring policies where applicable.

Network Program Manager

The SIEN program manager will participate and ensure completion of protocol readiness reviews, supervise the SIEN physical scientist, promote and oversee safety of the network staff, and stay apprised of activities, progress, and issues. Specific responsibilities include:

- Communicate safety vision clearly and continually to SIEN employees.
- Communicate park and network river monitoring responsibilities to Steering Committee.
- Monitor Physical Scientists performance, recognize successes, and take corrective actions when needed.
- Incorporate safety as a critical result in the Physical Scientists performance plans.
- Review and sign field readiness certifications.
- Incorporate safety into all decision-making processes.
- Ensure requests are submitted for adequate funding of SIEN and River Monitoring safety programs and training that are sponsored by SIEN.
- Incorporate principles from operational leadership to help all SIEN employees take responsibility for safety, understand human error and accident causation, manage stress, evaluate risk, maximize situational awareness, make appropriate decisions, communicate effectively, and be assertive regarding safety in the workplace.
- Ensure all SIEN employees understand their roles and responsibilities in implementing a safety program.
- Investigate all accidents and near misses involving SIEN employees, and implement corrective actions for identified hazards. Participate in accidents and near miss reviews involving park employees as appropriate.

DEPO Lead/Ecologist

The DEPO lead is responsible for coordinating, overseeing, and, often, conducting the rivers sampling field work. Primary responsibility for onsite field safety falls to the DEPO lead, including winter backcountry travel, summer frontcountry field work, and river sampling. Specific responsibilities include:

- Develop and update Winter Backcountry Travel and Emergency and Daily Communications SOPs.
- Conduct pre-season GARs prior to the summer and winter field seasons.
- Provide required trainings for all individuals conducting rivers sampling (refer to section 5.4.2).
- Provide adequate safety equipment (SOP 5B and C)

SOP 5: Safety Procedures
SIEN River Monitoring Protocol

- Read and have a strong understanding of the protocol.
- Follow the river sampling safety guidelines outlined in this SOP (section 5.5).
- Monitor employee's performance, recognize successes, and take corrective actions when needed.
- Review Job Hazard Guidelines (JHGs) and appropriate protocol SOPs with all individuals that participate in rivers sampling. Provide feedback and suggested changes to Protocol Lead.
- Devise river sampling schedule and share with SIEN Physical Scientist. Notify Physical Scientist of schedule changes and report the outcome of each field outing.
- Ensure field technicians are properly trained on emergency response procedures prior to conducting field work.

Protocol Lead/Physical Scientist

The SIEN Physical Scientist does not supervise the individuals carrying out field work. Therefore, the primary role of the Physical Scientist is to identify and communicate annual objectives, facilitate communication among parties, take the lead in scheduling and coordinating field readiness reviews, maintain close contact with park personnel (park leads and appropriate field staff), ensure safety related roles are clearly defined and understood, and provide safety guidance specific to river field methods for parks to adopt as they see appropriate (this does not include backcountry travel for non-SIEN field staff). The protocol lead will be available for consultation, review and comment on trip plans, and will be apprised of the outcome of each field trip.

- Provide technical support and guidance as needed for field work at the SIEN-supported sites.
- Write and update the Safety SOP. Include park leads in SOP development and updates.
- Develop and recommend JHGs for river sampling tasks. Communicate JHGs to park leads overseeing sampling at SIEN-supported sites.
- Review JHGs with SIEN employees that participate in river fieldwork.
- Lead the effort to complete field readiness certifications.
- Participate in pre-season Green-Amber-Red (GAR) analyses with park leads.
- Investigate all accidents and near misses involving SIEN employees, and implement corrective actions for identified hazards. Participate in accidents and near miss reviews involving park employees as appropriate.

SOP 5: Safety Procedures
SIEN River Monitoring Protocol

- Conduct and/or participate in regular de-briefings or after action reviews with other field personnel to ensure safety remains a central focus for all participants
- Incorporate safety into all decision-making processes.
- Incorporate principles from operational leadership to help all SIEN employees take responsibility for safety, understand human error and accident causation, manage stress, evaluate risk, maximize situational awareness, make appropriate decisions, communicate effectively, and be assertive regarding safety in the workplace.

DEPO Superintendent

The DEPO Superintendent's primary roles are to promote and oversee safety at DEPO and supervise and work closely with the DEPO Ecologist on river sampling operations, participate in and certify field readiness reviews, review and approve individual trip plans, ensure that field team members adhere to park safety policies (e.g., emergency communications, check-in, backcountry travel,), and stay apprised of activities, progress, and issues related to river field work at DEPO. Specific responsibilities include:

- Communicate safety vision clearly and continually to DEPO employees and volunteers.
- Monitor DEPO Ecologist's performance, recognize successes, and take corrective actions when needed.
- Incorporate safety as a critical result in the DEPO Ecologist's performance plans.
- Review and sign field readiness certifications for DEPO streamgauge work
- Incorporate safety into all decision-making processes.
- Participate in pre-season GAR analyses.
- Review and mitigate workload issues to allow adequate time for crew supervision and interaction.
- Work with DEPO lead to plan adequate time for field staff training and orientation.
- Adequately fund river monitoring safety programs and training.
- Ensure emergency response procedures are in place and DEPO lead is properly trained on these procedures prior to supervising employees and conducting field work.
- Approve trip plans.
- Approve USGS sampling visits and track staff during winter visits to the monument per check-in/check-out procedures described in DEPO's Winter Backcountry Travel SOP. Note: USGS is responsible for safety of their staff, whom are expected to follow USGS safety protocols and check weather and environmental conditions for their trips (e.g., weather predictions, snow conditions, avalanche hazard predictions).

YOSE Lead/Hydrologist

The YOSE lead is responsible for supervising Yosemite field technicians. Primary responsibility for onsite field safety falls to the YOSE lead, including training and oversight for safe backcountry travel and river sampling. Specific responsibilities include:

- Communicate safety vision clearly and continually to YOSE employees and volunteers.
- Takes the lead on and conducts a pre-season GAR with SIEN and YOSE staff.
- Ensure that required trainings (refer to section 5.4.2) are provided for all individuals conducting river sampling.
- Ensure crews have adequate safety equipment (SOP5B and C)
- Read and have a strong understanding of the protocol.
- Follow the river sampling safety guidelines outlined in this SOP (section 5.5).
- Monitor employees' performance, recognize successes, and take corrective actions when needed.
- Ensure that JHGs and sampling protocol are covered with all YOSE individuals that participate in rivers sampling.
- Ensure field technicians are properly trained on YOSE backcountry travel and emergency response procedures prior to conducting field work.

Supporting SIEN Staff

SIEN staff will periodically assist with rivers sampling field work under the guidance of the Physical Scientist. Specific responsibilities include:

- Collaborate with protocol lead to review and contribute to JHGs, and review, implement, and use employee safety and health orientation checklists.
- Incorporate safety into all decision-making processes and job tasks.
- Understand their roles and responsibilities in implementing a safety program.
- Identify and report hazards to protocol lead, program manager, or park management.
- Apply principles from operational leadership to understand human error and accident causation, manage stress, evaluate risk, maximize situational awareness, make appropriate decisions, communicate effectively and be assertive regarding safety in the workplace.
- Conduct and/or participate in de-briefings or after action reviews with other field personnel to identify risks, near misses, weak signals, and any other concerns that may compromise field safety.

5.3 Backcountry Travel including Daily and Emergency Communications

The Lyell Fork of the Tuolumne is ~ 9 miles from the trailhead; therefore, a site visit typically requires an overnight trip departing from Tuolumne Meadows. The Middle Fork of the San Joaquin at Devils Postpile site is easily accessible in the summer (i.e. a short walk from the ranger station), but requires backcountry winter travel from approximately November – June (snowpack dependent). Backcountry travel and communications procedures are specific to each park and outlined in DEPO and YOSE SOPs. The following outlines which protocols are followed when:

- Yosemite field staff conducting field work at the Lyell Fork will follow YOSE wilderness travel plan protocols. The Yosemite Hydrologist is responsible for training and oversight.
- DEPO staff conducting field work on the San Joaquin will follow DEPO backcountry winter travel and front country fieldwork JHGs and emergency communications protocols. The DEPO Superintendent and Ecologist are responsible for training and oversight.
- SIEN staff, when accompanying park staff, will follow the respective park travel and communications protocols.
- SIEN staff, traveling without park staff, will follow SIEN backcountry travel and communications protocols as described in the Safety Plan for the Sierra Nevada Inventory and Monitoring Network.
- If other situations arise, SIEN and park staff will communicate to ensure safety procedures are clearly defined.

5.4 Training Requirements

5.4.1. Protocol and Park Leads

The following is a list of required and recommended trainings for the rivers project and park leads. Leads new to their positions are expected to complete the required trainings within their first year. Prior to entering the river and performing discharge measurements leads must have completed the required trainings for field technicians (section 5.4.2). Supervisors will provide additional oversight and work closely with leads until fully trained.

Required Trainings:

- Operational Leadership
- Water safety (review wading measurement safety. See section 5.5 for SIEN wading safety or specific park water wading safety SOP as appropriate).
- Protocol training – have read through protocol and completed methods trainings described in section 5.4.2.

SOP 5: Safety Procedures
SIEN River Monitoring Protocol

- Backcountry travel and communications protocols (park specific)
- Facilitating an After Action Review (AAR)
- Park specific required trainings
- Required training for SIEN field staff per SIEN safety plan (SIEN Protocol Lead only)

Recommended trainings:

- CPR
- Basic First Aid to Wilderness First Responder courses
- Driver safety
- Throw-rope training
- Swift water rescue

5.4.2. Field Technicians

The following is a list of required and recommended trainings for anyone conducting rivers field work. The exception is staff from other organizations, divisions or projects that are cross-training. They are exempt from these trainings if accompanied by a lead. Required trainings must be completed prior to participating in field work.

Required Trainings:

- Backcountry travel and communications protocols (park specific)
- Water safety (includes: wading measurement safety (section 5.5 or park specific SOPs) and throw-rope)
- Familiarity with the River Protocol, especially field and safety SOPs.
- Operational leadership concepts: technicians will receive a minimum of two hrs training including the GAR model, Severity-Probability-Exposure (SPE) model, and other concepts protocol and park leads determine are pertinent to sampling in DEPO or YOSE
- Winter skills as described in the DEPO Backcountry Winter Travel SOP (DEPO field crews only).
- Park specific required trainings

Recommended trainings:

- CPR
- Basic First Aid to Wilderness Responder
- Driver safety
- Swift water rescue

5.5 Wading Measurement Safety Procedures

5.5.1. Knowledge of Rivers Protocol Narrative and SOPs

Reading and understanding the protocol, and in particular, the SOPs, are crucial prior to initiating field work. This basic understanding of the protocol and the ability to recognize bad data in the field can improve safety by enabling field teams to address errors before leaving the site, eliminating unnecessary trips, and reducing unnecessary exposure to risk. Recognition of data errors on site allows for immediate adjustment in the field. The physical scientist and park leads at Yosemite and Devils Postpile will allow adequate time for accompanying field staff to become familiar with SOPs. Field-related SOPs will also be covered as part of the hands-on training.

Hands-on training and practice prior to the first sampling period will help ensure high quality data collection. Familiarity with the use and maintenance of equipment, procedures for collecting and processing data, techniques for cleaning and maintaining field equipment, and stream safety are essential to the success of the river monitoring project.

Field work requires an awareness of potential hazards and knowledge of basic safety procedures. Advanced planning can reduce or eliminate many safety hazards. An integral part of informed awareness and successful mitigation of potential hazards is a process that helps to reveal hazards. SIEN is using JHGs to critically examine tasks, identify specific hazards, and reduce or eliminate these risks. A JHG is created for specific activities or a particular protocol and evolves with the input of subsequent employees to remain a current and effective safety tool. All employees are expected to know, understand, and contribute to JHGs. All JHGs are stored on the network drive and are referenced within the SIEN Safety Plan.

5.5.2. Pre-trip Preparations

Before leaving for the field site, the field crew will ensure all required safety and work equipment (including vehicles) are available, maintained, and in good working condition. The park lead will ensure that emergency contact forms have been completed and filed and that field staff have basic safety equipment (Appendix SOP 5D) and personal protective gear (Appendix SOP 5C). The field crew will also notify appropriate park staff of relevant details about the sampling trip, including following SIEN and DEPO's respective backcountry travel plans for remote site visits.

All field-going staff are required to discuss and review relevant job hazard guidelines, including those in Appendix SOP 5D (JHG for Wilderness Travel) and Appendix SOP 5E (JHG for Wading Rivers and Streams). Potential safety and health concerns include dehydration, heat stress, hypothermia, lightning, falls, sunburn, animal encounters, stream crossings, and drowning. JHGs should be used as a catalyst for discussion and understanding of all safety concerns for this protocol. Discussions should address safety concerns including all aspects of safe wilderness travel to and from the site (such as traveling over rough terrain, high water crossings with and without a backpack, trip planning and notification, lightning and other weather events, heat and cold exposure, high elevation, snow travel, map and compass, GPS) with emphasis on the specific area being accessed and current local conditions. The parks are

responsible for documenting improvements for JHGs, and the physical scientist is responsible for incorporating changes into the JHG and protocol (as needed).

Principal steps in the implementation of the rivers monitoring protocol include travel to and from the sites, site monitoring from the bank of the river, and site monitoring by wading across the river. Station visits involving wading (i.e., water entry) will always be conducted with a minimum of two people. While working in pairs is also recommended for work conducted from the bank (i.e., no water entry), working alone may be acceptable in some lower risk situations (e.g., downloading dataloggers).

DEPO will be conducting winter field visits to the DEPO gage. The DEPO Ecologist, in close communication with the DEPO Superintendent, will be the lead on coordinating these trips. DEPO winter travel safety guidelines are established by DEPO and described in their Winter Backcountry Travel SOP.

5.5.3. Wading Guidelines

Wading in stationary or flowing water is hazardous, particularly when either the depth and/or flows are excessive. This section provides general guidance on wading safety.

Assessing Whether to Wade

Water depths are often deceptive and the force of flowing water must not be underestimated. Before entering the water, a person must assess factors affecting the safety of wading at a particular site. These factors can include but are not restricted to:

- stream depth
- stream velocity
- rate of change of level
- a person's height, weight, confidence, and ability
- prior knowledge of the stream
- stream bed characteristics

Wading is an inherently risky activity, and the added complexity of simultaneously making discharge measurements only increases risk. Thus the wading method of discharge measurement should always be undertaken with a minimum of two people – at least one person needs to be on the bank spotting individual(s) in the river. If onsite inspection indicates that wading cannot be completed safely, than alternative non-wading methods will be used, another site will be chosen, or measurements skipped for that visit.

Guidelines for an upper wading limit include:

1. When the depth of water (ft) multiplied by the flow velocity (ft/sec) exceeds a value of 10, the river should be assumed to be unsafe for wading. More conservative guidance suggests this value should not exceed 8.

Water depth (ft) * flow velocity (ft/sec) > 8 $\equiv$ Unsafe to cross

2. Depths over 4 feet should not be waded. At lesser depths and slower velocities, the river may still be unsafe to wade due to site conditions, individual capabilities, and other factors. Return to the shore immediately if you have a sense that the current is too strong to stay upright. Do not question your judgment if a situation feels unsafe.

We consider hydrology field work a “fair weather” program. The team should not schedule field work for periods when adverse conditions are forecast, especially during winter sampling. Crews in the field should recognize that conditions can change rapidly and must be assessed immediately before making the final decision to enter the water. The field crew may find that the snow along the banks is so deep that accessing the river is dangerous or impossible. Weather conditions may suddenly deteriorate, becoming windy, cold and stormy. The water may be running too deep and fast to allow safe entry. A downed tree immediately downstream could be a hazard if there is any potential of being swept away by the current.

If You Decide to Wade

A tagline or rope fixed to the bank may be carried as a safety line, but it must not be tied to the person. Once fixed securely to both banks, this line can serve as a useful support, providing it is only used whilst standing downstream of the anchor point.

Time is well spent looking for the safest place. Locate a suitable stream reach, such as:

- Where the river widens or divides; the water flows quietly; water is shallow and clear.
- At a shingle bar above shallow rapids.
- Between river bends (deeper water and stronger currents occur on the outside bank of a curve)
- Where the river bed has a smooth bottom. Avoid boulders, logs and smooth rock slabs if possible.

Additionally, while wading, be aware of surrounding conditions. The spotter on the bank should also be watching for and communicating changes in conditions.

- Watch for debris floating with the current, such as logs, aquatic vegetation, or “rafts” of animals seeking higher ground.
- Watch for sand channels that can shift under foot and become quicksand.
- Watch the stream stage, especially when it could rise rapidly from rain events including upstream thunderstorms.

Wading Apparel and Personal Protective Equipment

Due to SIEN’s cold climate, chest waders are usually worn for wading activities. The waist of the waders should be “sealed” around the wearer’s body by securing the drawstring (if fitted) in a quick release bow and by fastening a quick release divers webbing belt securely around the waist. When wearing a rain coat over the waders, fasten the webbing belt around the waist over the coat. When wearing a personal flotation device (PFD) over rain gear, the webbing belt should

be secured around the rain gear, but underneath the PFD. In the case of accidental immersion, these procedures will restrict the loss of air and ingress of water, resulting in increased buoyancy.

Waders are to be accompanied by proper footwear. Rubber waders and sandals with neoprene booties may be appropriate when working in shallow water. However, during higher flows, boots with non-felt sticky bottoms should be worn.

PFDs should be worn during ALL wading activities. The appropriate PFD must be worn for the given conditions and may include a Level 50 (similar to PFD Type 2), Level 100 (similar to PFD type 1), or level 150 (similar to inflatable PFD Type 1) PFD. PFDs should be routinely inspected after returning to the office.

Dress appropriately for weather conditions. Weather can change quickly in the Sierra Nevada. Be prepared for sunny and hot conditions by drinking plenty of water and protecting yourself from exposure to sun with the use of sunscreen, a hat, and sunglasses. Anticipate bad weather by bringing raingear, extra layers, and extra food. Be alert to changing weather by watching for developing clouds, wind shifts, and the sound of thunder. If the weather begins to change, get to shore. Lightning can strike even when there are no clouds overhead. If there is lightning in the area, get inside a building or car. If this is not possible, go to lower areas such as valleys and canyons. Do not remain near large solitary trees or in the middle of open areas.

5.6 Before and After Action Reviews

At a minimum, AARs are conducted after each field visit, field season, close call, or other serious incidents as an important part of cultivating mindfulness towards safety, establishing safety routines, and the continuous learning cycle. Protocol and park leads will acquire training in AARs so they can facilitate discussions and train field crews in conducting AARs.

Why conduct AARs? They provide the opportunity to review project activities, identify weak signals and discuss future corrections, learn from the group's collective experience, and identify areas to change/improve at the personal, project, and/or organizational level. Conducting AARs following each field tour helps establish safety review and contemplation as part of the routine.

For AARs to be effective, participants must feel 'safe' from embarrassment, humiliation, or retribution. Park leads must receive proper training on how to facilitate AARs. Park leads may designate crew or team leads to facilitate AARs where appropriate. AARs are NOT to be used as opportunities to provide safety training.

The AAR centers around these four questions:

1. What did we set out to do?
2. What actually happened?
3. Why did it happen?
4. What are we going to do next time?
 - What will we sustain?
 - What will we improve?

5.7 Reporting Incidents and Accidents

In the event of an accident or incident, follow park or SIEN emergency communication protocols to get needed assistance such as medical attention.

Once the immediate emergency has been handled, the supervisor should be notified as soon as possible. The supervisor then reports the incident/accident to appropriate personnel and completes any park-specific reporting forms (e.g., SEKI-134B the Sequoia and Kings Canyon NP Incident/Accident Report, or the Yosemite National Park Supervisor Incident/Accident or Close-Call Reporting Form (2-1a)). When work related injuries or diseases require medical treatment, supervisors and employees must complete a Department of Labor Form CA-1 (Federal Employee's Notice of Traumatic Injury and Claim for Continuation of Pay/Compensation) or CA-2 (Notice of Occupational Disease and Claim for Compensation). The Safety Management Information System (SMIS) is the automated system for reporting submitted CA-1s or CA-2s for the Department of the Interior (<https://www.smis.doi.gov>). Employees should complete a CA-1 or CA-2 electronically at <https://www.smis.doi.gov> before the end of the next work shift after an accident. After the employee completes the CA-1 or CA-2, the supervisor logs onto SMIS and completes the supervisor portion. The supervisor takes any corrective action necessary to prevent similar incidents.

For SIEN staff, more detailed information on reporting incidents and accidents can be found in the SIEN Safety Plan.

Appendix SOP 5A. Local Contacts for Field Personnel

Duty station		Name	Telephone
YOSE	YOSE Hydrologist	Jim Roche	209-379-1446
	YOSE Resources Division Chief	Vacant	209-379-1219
	YOSE Emergency	Dispatch	911
SEKI	SIEN Program Manager	Sylvia Haultain	559-565-3788
	SIEN Physical Scientist	Andi Heard	559-565-3786
	SIEN Data Manager	Alex Eddy	559-565-3709
	SIEN Ecologist	Jonny Nesmith	559-565-3765
	SEKI Safety Officer	Todd Payne	559-565-3108
	Emergency	Dispatch	559-565-3195 or 911
DEPO	Ecologist	Monica Buhler	760-924-5505
	Administrative Assistant	Isaac Vaughan	760-924-5505
	Superintendent	Deanna Dulen	760-924-5505

Appendix SOP 5B. Basic Safety Equipment Checklist

Safety items needed for the Rivers Monitoring Protocol are listed below. This list is specific to conducting work at the stream flow site and does not include backcountry travel equipment.

Basic Safety Equipment Checklist	
	List of emergency phone numbers and office contacts (SOP5A)
	List of radio call numbers, dead zones, and relevant repeaters
	First aid kit
	Park radio
	Secondary communication device (e.g., GeoPro satellite messaging device)
	Personal cellular phone (optional)
	Throw rope
	Signaling device (e.g., whistle)
	Fluids (e.g., water, sports drinks)
	Job Hazard Guidelines (JHGs)

Appendix SOP 5C. Personal Protective Equipment Checklist

Personal Protective Equipment (PPE) must be selected based on the hazards likely to be encountered. Items needed for Rivers Monitoring sampling are listed below.

PPE Checklist	
	Hiking boots
	Chest waders, hip boots, and/or rubber knee boots, plus warm socks
	Personal Flotation Device (PFD)
	Hat with a brim
	Insect repellent
	Rain gear
	Sunglasses
	Sunscreen
	Work gloves (optional)
	Lightweight long-sleeve shirt and pants for sun protection
	Wool or polypropylene long underwear
	Lightweight warm hat and gloves
	Complete change of clothes
	Headlamp and spare batteries
	Fluids (e.g., water, sports drinks)

Appendix SOP 5D. Job Hazard Guideline: Wilderness Travel

This job hazard guideline is a starting point for discussions rather than a comprehensive treatment of all safety issues that may be encountered. When reviewing JHGs, everyone should be involved in creatively enhancing and bringing personal additions to the process.

SIEN Job Hazard Guideline

Job Description:

Date of last update:

Wilderness Travel

January 2012

Division with primary responsibility for this JHG:

Last updated by:

Reviewed by:

Approved by:

Sierra Nevada Network

Linda Mutch

Required standards & general notes

Employees are traveling in groups of two or more, or they report daily by radio if traveling alone. Supervisor knows destination and route and return date.

Required personal protective equipment

Radio, first-aid kit, cold and wet-weather gear, appropriate foot wear, solar protection (hat, bandana, and/or sun block), appropriate water purification equipment (usually a filter), flashlight, and minimal pack weight (1/3 of body weight).

Typical tools & equipment

Backpack (or rucksack if traveling by stock), bear-proof food storage canister or pannier (if necessary), cold and wet-weather gear, appropriate foot wear (boots for rugged areas, footwear for wading streams, etc.), tent (optional), adequate sleeping bag, solar protection (hat, bandana, and/or sun block), water purification equipment (usually a filter), food and food preparation equipment, first aid kit (including snake bite kit), park radio, mosquito repellent (optional), compass and map, flashlight, work gear

Activity	Potential Hazards	Safe Action or Procedure
Backpacking with heavy loads	Heavy loads	Try to carry no more than 1/3 of your body weight while traveling in the backcountry.
	Load instability	When carrying heavy loads, pack the gear so that heavy equipment is carried low on your back to increase stability. Consider using hiking poles.
	Excessive loads	Assess equipment needs to ensure only required equipment is being carried.
	Muscular pain & soreness	Start slowly to ensure muscle groups are given adequate time to warm up. Use stretching exercises before starting.
	Fatigue	Take frequent breaks for food & water. Stop hiking for the day after reasonable distance is achieved.
	Back strain	Lift loads with your legs to avoid back injuries.
Hiking on steep or rough terrain off trail	Steep slopes & poor footing (falls)	Move slowly & deliberately across steep areas. Use trees & solid rocks for handholds when they are available. Check footholds before using them. Fall into the slope if you slip or slide. Have a companion spot you from a more secure location.
	Footing	Plan to cross snow late in the day for better footing; cross streams early before flow increases due to increased run-off & unbuckle waist belt on pack—use hiking poles.
	People above you or below you	Never be above or below someone on a loose or unstable slope. Be aware of the ground surface in front of you - watch for slick, sloped & unstable areas surfaced by loose rock, leaves or sticks. Members of a party should move up such slopes one at a time, together at the same elevation at all times, or parallel to each other & out of rock fall danger.
Route finding	Hazardous obstacles	Plan routes to avoid or limit exposure to known hazards such as steep slopes, river crossings, poisonous vegetation, etc.
	Crossing streams	Bring extra shoes for water crossings. Take extra time to scout for the safest place to cross. Avoid making crossings without a partner present. Cross with a hiking pole or large stick to provide additional stability. Unbuckle your pack's hip strap to facilitate ejection of your pack if you slip. Avoid areas with deep water or swift currents. Abort crossing if water levels or environmental conditions are too dangerous.
	Disorientation	Ensure all personnel are knowledgeable with map & compass as well as GPS usage. Keep track of current position & location of prominent landmarks with frequent map updates. Whenever possible, stick to established trails.

SOP 5: Safety Procedures
SIEN River Monitoring Protocol

Activity	Potential Hazards	Safe Action or Procedure
<i>Inclement weather</i>	Unfamiliarity with current & forecasted weather	Obtain weather forecasts prior to beginning back country travel & monitor weather broadcasts via radio during trip.
	Inappropriate gear for the conditions	Assess anticipated routes, elevations, & weather conditions when planning what gear to carry. Always carry rain gear, a warm hat, gloves, & a warm jacket when traveling in the backcountry.
	Thunderstorms	Avoid exposed ridge tops and being on or near lakes, meadows or other exposed areas if thunderstorms are approaching or developing nearby. Move to lower elevations away from tall trees as storms approach. If hair begins to stand up, immediately minimize exposure by moving to lower elevations away from isolated trees & crouch down on the balls of your feet to reduce ground contact.
	White outs	In the event of white out conditions, immediately seek shelter & wait for conditions to improve. Do not attempt to "feel your way" over the pass.
	Hypothermia	Layer your clothing such that it will be easy to regulate your body temperature by adding or subtracting layers. DO NOT wear cotton as a layer.
	Heat stress	Drink plenty of liquids, keep hydrated, & take frequent breaks for snacks & water.
<i>Camp cleanliness & health</i>	Contamination of shared food	Wash hands thoroughly with dirt, silt, duff, sand, or if available hand sanitizer before handling food, dishes, utensils, etc.
	Contamination of shared water	Wash hands before gathering and/or filtering water; avoid contaminating filtered water with unfiltered water at source.
	Contamination of anything common (i.e., tools, dishes, paperwork, etc)	Wash hands (especially after bathrooming) before handling anything common to the crew. Crew health and morale depends on it; project success the same.
	Bathroom habits in the backcountry	Before touching anything common, WASH!
	Bears & other wildlife	Properly store food, thoroughly wash dishes and keep a clean camp area.

Appendix SOP 5E. Job Hazard Guideline: Wading Rivers and Streams

This job hazard guideline is a starting point for discussions rather than a comprehensive treatment of all safety issues that may be encountered. When reviewing JHGs, everyone should be involved in creatively enhancing and bringing personal additions to the process.

SIEN Job Hazard Guideline

Job Description:		Date of last update:	
Wading Rivers and Streams		March 13, 2012	
Division with primary responsibility for this JHG:	Last updated by:	Reviewed by:	Approved by:
Sierra Nevada Network	Alice Chung-MacCoubrey		
Required standards & general notes	Field work is performed in pairs, and teams report twice daily by radio and/or satellite messaging device, depending on park. Supervisor knows destination, route, and return date.		
Required personal protective equipment	Personal flotation device (PFD); chest waders, hip boots, and/or rubber knee boots; rain gear; second set of warm clothing; park radio; satellite messaging device; first-aid kit; cold and wet-weather gear; appropriate foot wear; solar protection (hat, bandana, and/or sun block)		
Typical tools & equipment	Backpack, wading rod; walking stick/pole; rope & throw bag.		
Activity	Potential Hazards	Safe Action or Procedure	
<i>Crossing rivers and streams during travel</i>	Swept away by force of water	Carefully select the crossing location. Look for areas where the river widens or divides or a wide, calm, and slow moving section of water where water flows quietly. Look for a shingle bar above shallow rapids or between river bends. Seek areas where the river bed has a smooth bottom devoid of boulders, logs, and smooth rock slabs. Assess hazards prior to crossing: Avoid areas upstream from strainers (log jams), water falls, or rapids. If unsure of your ability to cross safely, find a new location or don't cross. Be aware of rapidly changing weather. Heavy rainfall may also swell rivers and creeks and make them impassable. Unbuckle your pack prior to crossing so you can get it off easily if you fall in. Have someone posted downstream with a rope or throw bag.	

SOP 5: Safety Procedures
SIEN Rivers Monitoring Protocol

Activity	Potential Hazards	Safe Action or Procedure
<i>Crossing rivers and streams during travel</i>	Losing footing	Be aware of slick surfaces on logs and rocks when crossing. Be aware of unstable footing and have good water crossing shoes or sandals. Recognize that water levels can change rapidly; an area that was easily crossed in the morning may be impassable in late day. Water levels tend to peak in the middle of night.
	Being swept downstream	Use following formula to determine upper limit for wading: Water depth (ft) * flow velocity (ft/sec) > 10 $\equiv$ Unsafe to cross Assume the float position if swept downstream (head up, face-up, feet pointed downstream). Look for calm areas of water or eddy's, a place to safely get out of the current. Avoid logs strung across the river as the water may pin you against it.
	Being knocked unconscious	Avoid crossing alone, and make sure everyone is safely across before leaving
	Same as above for crossings	Same as above for river crossings
	Conducting measurements requires a longer period in the water (prolonged exposure to risk)	Wear a personal flotation device appropriate to conditions. Be well prepared before entering the water to avoid having to return to shore to retrieve forgotten items. Attach a tagline or rope to fixed objects upstream on each bank, and use it as a safety line.
	Full attention is not on wading conditions while conducting measurements	Ask your partner on shore to watch for floating debris, pay attention to conditions, and alert you to dangers. Your partner should have emergency equipment on hand or easy to access, including a throw bag, the park radio, and emergency contact numbers.
<i>Wading across rivers and streams while taking measurements</i>	Prolonged exposure to cold temperatures	Use appropriate personal protective equipment, including chest waders, hip waders, rain gear, and/or warm clothing to stay warm and dry.
	Waders filling with water	'Seal' waders against the body at the waist by securing the drawstring with a quick release bow know and fastening a quick release divers belt.

Sierra Nevada Network River Hydrology Monitoring Protocol

SOP 6: Acquiring Streamflow and Temperature Data from Streamgage Operators

Version 1.0

This standard operating procedure is part of the Sierra Nevada Network River Hydrology Monitoring Protocol, but is designed to be printed and viewed as a separate document.

Revision History Log

Previous version #	Revision date	Revised by	Changes	Justification	Page #'s affected	New version #

Note: This SOP includes instructions to acquire summarized streamflow data from streamgage operators and store it locally. SOP 7 includes instructions for uploading this data to the database.

6.1 Streamflow Data Sources

SIEN will acquire mean daily discharge data from other agencies for 12 of the 14 stations; the two remaining stations' data are managed by SIEN. The discharge data for the 12 stations will be obtained by either i) downloading it from the USGS NWIS server or ii) submitting an annual request to the other agency, contractor, or researcher. We download data from NWIS for seven stations: four are operated by the USGS, two are operated by Southern California Edison whose records are reviewed and published by USGS to NWIS, and one station is operated by researchers from the University of California, Santa Barbara. We will obtain discharge data from five stations by submitting annual requests to SCE (2), Sierra Hydrographics (1), Hetch Hetchy Water and Power (1), and KRW (1). Data acquisition processes for the 14 stations are shown in Table 6.1.

6.2 Acquiring Tabular Discharge Data from Operators

Most streamgage operators review and process their data during the winter and make it available for the previous water year (Oct 1-Sept 30) in March or April. For the four stations not available on the USGS NWIS website, we will submit requests in May for mean daily discharge, instantaneous peak discharge, and water temperature (for stations collecting water temperature data). The operators will send the data either as an Excel spreadsheet or a delimited text file. These raw data files will be uploaded to the Aquarius database and archived locally in folders organized by station and water year. For example, the following is the location for data from the South Fork Merced station for water year (WY) 2010:

[\\Inpsekihqgis1\sekigis\sien\monitoring_projects\rivers\data\Tabular\Original_Data\SouthForkMerced\WY2010](\\Inpsekihqgis1\sekigis\sien\monitoring_projects\rivers\data\Tabular\Original_Data\SouthForkMerced\WY2010).

The file names follow the station names used in the Aquarius database along with the water year. The station names are included in **Table 6.1**. For example, the data file for the South Fork Merced WY2010 would be saved as SIEN_YOSE_MERCSOFK_WY2010 with the appropriate file extension.

Data acquisition procedures for stations operated or reviewed by USGS are slightly different, although the file naming and storage convention is the same as above. See section 6.2.1 for detailed instructions.

The following sections identify organizations or individuals to whom a request will be sent and the stations for which data will be requested. A list of the most up to date contact information for each request is stored on the SIEN shared drive at: J:\sien\monitoring_projects\rivers\admin.

SOP 6: Acquiring Data from Streamgage Operators
SIEN Rivers Monitoring Protocol

Table 6.1. List of streamgages, operators, data acquisition processes, and station names used in the SIEN rivers database.

Station	Operator(s)	Current Data Acquisition Process	Source for Historic Data	Aquarius station name
Tuolumne River above Hetch Hetchy	USGS (funded by HHWP)	Download from NWIS	NWIS	SIEN_YOSE_TUOLHEHE
Tuolumne River at the Tioga Road Bridge	YOSE / SIEN collaboration (with funding from HHWP)	YOSE will download the streamgage and upload 15-min data to Aquarius	2001 to 2011 from Jessica Lundquist (U Washington)	SIEN_YOSE_TUOLTIRO
Lyell Fork of the Tuolumne River below Maclure Creek	YOSE / SIEN collaboration	YOSE will download the streamgage and upload 15-min data to Aquarius	2001 to 2011 from Dave Clow	SIEN_YOSE_TUOLLYFK
Falls Creek	HHWP	Annually acquire data from HHWP	1915 to 1983 from NWIS. 2010 to present from HHWP. 1983 to 2010 gage was out of operation	SIEN_YOSE_TUOLFACK
Merced River at Pohono Bridge	USGS	Download from NWIS	NWIS	SIEN_YOSE_MERCPOBR
Merced River at Happy Isles	USGS	Download from NWIS	NWIS	SIEN_YOSE_MERCHAIS
South Fork Merced River at Wawona	Sierra Hydrographics (funded by Merced Irrigation District)	Annually acquire data from Sierra Hydrographics	1958 to 1968 from NWIS. 2007 to present from Sierra Hydrographics	SIEN_YOSE_MERCISOFK
Middle Fork of the San Joaquin in DEPO	USGS (funded by DEPO and SIEN)	Download from NWIS	NWIS	SIEN_DEPO_SAJOMIFK
Kern River near Kernville	SCE	Download from NWIS	NWIS	SIEN_SEQU_KERNKERN (combined flows = river + diversion)

Table 6.1. List of streamgages, operators, data acquisition processes, and station names used in the SIEN rivers database (continued).

Station	Operator(s)	Current Data Acquisition Process	Source for Historic Data	Aquarius station name
Kaweah River Middle Fork near Potwisha	SCE	Annually acquire data from SCE Hydrographer	1951 to 2002 from NWIS. 2002 to present from SCE	SIEN_SEQU_KAWEMIFK_R SIEN_SEQU_KAWEMIFK_D
Kaweah Marble Fork above Tokopah Falls	USGS and Melack/Sickman	Download from NWIS	1992-2012 data from Melack and Sickman	SIEN_SEQU_KAWEMATO
Kaweah River Marble Fork at Potwisha	SCE	Annually acquire data from SCE Hydrographer	1951 to 2002 from NWIS. 2002 to present from SCE	SIEN_SEQU_KAWEMAPO_R SIEN_SEQU_KAWEMAPO_D
Kaweah River – East Fork	SCE	Download from NWIS	NWIS	SIEN_SEQU_KAWEEAFK_R (river) SIEN_SEQU_KAWEEAFK_D (diversion)
South Fork Kings River abv Roaring River	KRWA	Annually acquire data from KRWA	KRWA	SIEN_KICA_KINGSSFK

6.2.1. Historic Data

In our initial request for data, we will ask for records covering the entire period of record. These files will be labeled with the corresponding water years (e.g., WY1999_2000) and stored in a folder labeled with the water years of record (e.g., WY1999_2010). The historic data will be imported into the Aquarius database. New records for subsequent years will be appended to this dataset.

6.2.2. Procedures for Acquiring Data from non-USGS Operated Sites

Southern California Edison

SCE diverts water from the Middle, Marble and East Forks of the Kaweah River and the Kern River. The East Fork and Kern River diversions are outside the park boundary. **Figure 1.11** in SOP 1 provides a schematic of the gaging locations and diversions operated by SCE. The East Fork and Kern River data are reviewed by the USGS and posted on the NWIS website. The annual data request to SCE for station data not posted on NWIS includes the values for the Middle and Marble Fork of the Kaweah and for the diversions from each. We will obtain separate spreadsheets for the river gages and the diversion gages, store and upload them separately to the Aquarius database, combine the values within Aquarius, and then store the combined values as a separate parameter linked to the river gaging stations. The italicized text immediately below is a template for submitting the data request.

“I am requesting mean daily discharge and approved unit values for the Middle and Marble Fork Kaweah River and the Middle and Marble Fork diversions - SCE gage numbers 207, 208, 209, and 210. I would also like the instantaneous peak and low flow discharges for the water year XXXX-XXXX.”

University of California – The Marble Fork Kaweah above Tokopah Falls

John Melack and Jim Sickman, researchers at UCSB and the University of California, Riverside (UCR) respectively, have managed this station in cooperation with USGS researcher Dave Clow as part of the USGS HBN. Although the stage data is telemetered to the USGS through a GOES satellite, the streamflow data is unavailable through NWIS. Stage data is acquired directly from John Melack or his field technician, Kevin Skeen, and uploaded to the Aquarius database.

Sierra Hydrographics – The South Fork of the Merced River

Sierra Hydrographics operates one station in the SIEN, the South Fork Merced at Wawona. They are contracted by the Merced Irrigation District to operate this station and manage the data. We will obtain the mean daily values, peak and low flow discharge data directly from the operator. Although the river stage is sent hourly to CDEC and the 15-minute discharge is available to be downloaded at: http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=SMW, we will wait until the data are finalized and acquire it directly from Sierra Hydrographics.

Hetch Hetchy Water and Power – Falls Creek, Tuolumne River

The final quality controlled data will be obtained by request from Hetch Hetchy Water and Power((HHWP) using the information on the rivers contacts sheet. Although the data are available for viewing in real time from CDEC, we will wait for the finalized data from HHWP.

6.2.3. Procedures for Acquiring Data from USGS-operated or USGS-reviewed Stations

There are four stations operated by the USGS in YOSE (3) and DEPO (1) that post data on NWIS. Additionally, data from two stations operated by Southern California Edison are posted on NWIS after the data have been reviewed and reported by the USGS (**Table 6.**). The Physical Scientist should acquire both the data and a Water Year Summary via NWIS.

Table 6.2. Stations with data available through the USGS NWIS system.

Station	NWIS ID	Direct link to the station
Middle Fork San Joaquin at DEPO	11224000	http://nwis.waterdata.usgs.gov/nwis/nwisman/?site_no=11224000&agency_cd=USGS
Tuolumne Above Hetch Hetchy	11274790	http://waterdata.usgs.gov/nwis/nwisman/?site_no=11274790&agency_cd=USGS
Merced River at Pohono Bridge	11266500	http://waterdata.usgs.gov/nwis/nwisman/?site_no=11266500&agency_cd=USGS
Merced River at Happy Isles	11264500	http://waterdata.usgs.gov/nwis/nwisman/?site_no=11264500&agency_cd=USGS
East Fork Kaweah River (Operated by SCE)	11208730 & 11208800	http://nwis.waterdata.usgs.gov/nwis/nwisman/?site_no=11208730&agency_cd=USGS and http://nwis.waterdata.usgs.gov/nwis/nwisman/?site_no=11208800&agency_cd=USGS
Kern River at Kernville (Operated by SCE)	11186001	Combined flows available through NWIS - http://waterdata.usgs.gov/nwis/nwisman/?site_no=11186001&agency_cd=USGS

The Water Year Summary has replaced the Annual Data Reports that USGS use to publish and is now generated by the user via the NWIS interface (**Figure 6.1**). To generate a summary:

1. Navigate to the station of interest (URLs are provided in SOP 1).
2. Select ‘Water Year Summary’ from the ‘Available data for this site’ drop down menu and click ‘Go’.
3. Select the parameter(s) and water year of interest. Click ‘Go’.

- The summary will be generated. Select 'Print this report' and save it as a pdf. The report should be saved in the original data folder for the appropriate station (J:\sien\monitoring_projects\rivers\data\tabular\original_data\<station name>).

Water-Year Summary for Site USGS 09370600

Click to hide state-specific text

Available data for this site: Water-Year Summary GO

Click to hide Water-Year Summary instructions and information

- Water-Year Summary reports summarize a year of hydrologic data in a printer-friendly format.
- For water years 2014 onward, choose a water year and parameter and an on-demand Water-Year Summary report will be generated.
- For water years 2006 through 2013, choose a water year and an Annual Water Data Report will be provided.
- For water years 2005 and earlier, Annual Water Data Reports may be [available in digital format](#).
- Not all sites have reports available for every water year.

Available Parameters

☐ 00060 Discharge(Mean)

Select a water year

2014 GO

Water year 2014:
2013-10-01 to 2014-09-30

USGS 09370600

Figure 6.1. Screen capture from NWIS showing how to generate a Water Year Summary.

In Version 3.2 release 5, Aquarius can retrieve gaging station data directly from the NWIS website using the USGS Daily Values Site Web Service. Once the dataset has been created in Springboard it can be viewed, corrected, and analyzed like any dataset managed by Aquarius Springboard. We will use the USGS Daily Values Site Web Service to acquire data for the seven SIEN gaging stations that post data to NWIS. SIEN will use the RESTful web services to create separate datasets for historical and current year mean daily discharge and the instantaneous peak discharge for each water year (Oct-Sept) for each station.

Note: For the East Fork Kaweah, acquire the data for both stations listed in Table 6.. The diversion and river values will be stored separately in the database and the combined values calculated by the Physical Scientist. The combined flows will then be stored as a separate parameter under the river station.

Procedures for Acquiring NWIS Data:

Background: We will use the representational state transfer (REST) service provided by the USGS Daily Values Site Web Service to acquire data from NWIS. The REST service accepts a query in the form of a URL and returns a dataset based on conditions and filters specified in the URL. The conditions and filters in the URL specify the path to the data, the station of interest, the desired statistic, and the start and end dates of the data you are seeking. The data are returned in WaterML1.1 (an XML schema) by default so it can be displayed in Aquarius Springboard. However, the legacy format, which is a variant of an ASCII tab-delimited file structure referred

SOP 6: Acquiring Data from Streamgage Operators

SIEN River Monitoring Protocol

to as 'rdb', and JavaScript Object Notation (JSON) formats are also available. A description of the REST service, tools to generate and test the REST URL, and an explanation of the output are provided here: <http://waterservices.usgs.gov/rest/DV-Service.html#How>.

To create a dataset, log in to the Aquarius server and open the Springboard module. By default, Springboard will open in the folder containing the list of gaging stations being monitored by SIEN (**Figure 6.2**). (Note: SOP 7 includes an introduction to Aquarius and instructions for setting up stations).

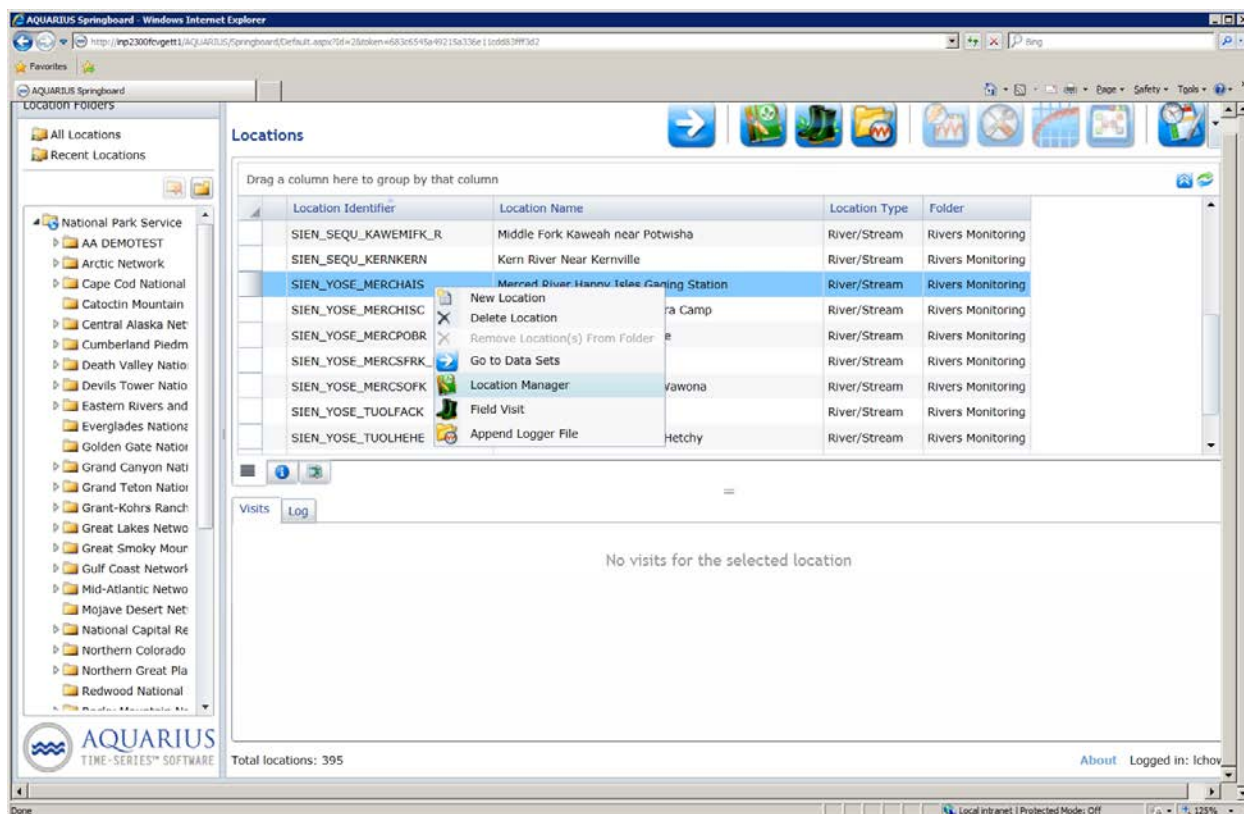


Figure 6.2. Aquarius Springboard Locations window showing streamgage locations being monitored by the Sierra Nevada Network Rivers Monitoring Protocol and a submenu listing actions/options for the location highlighted in blue.

1. Highlight the station you want to create a dataset for and right-click on the station to open the action/option submenu.
2. On the sub-menu, select **Location Manager**. This will open the **Location Manager** window (**Figure 6.3**).
3. Select the **Data Sets** tab. Click on the **New** button.
4. Select **Time Series – External** near the bottom of the sub-menu. This will open a blank **Data Set Details** form for entering information about the new data set.

SOP 6: Acquiring Data from Streamgage Operators SIEN River Monitoring Protocol

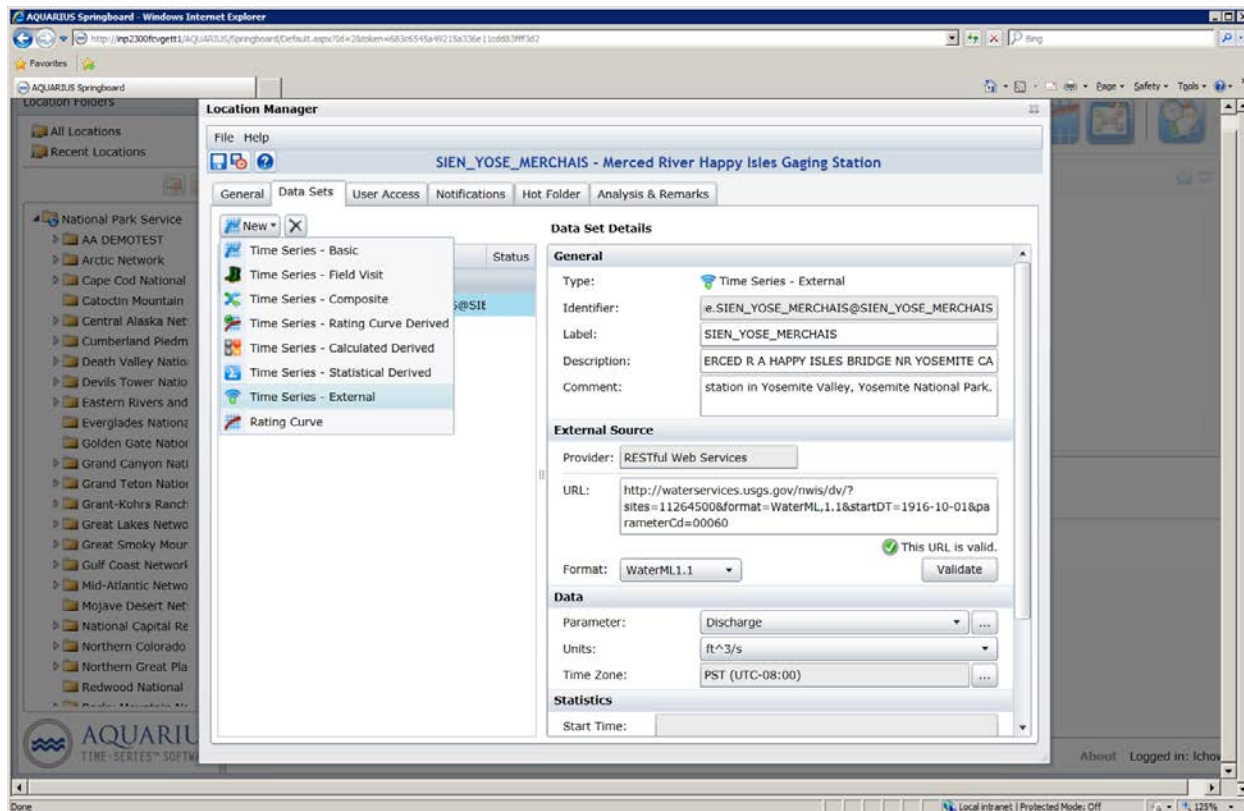


Figure 6.3. Aquarius Springboard Location Manager window with the *Data Sets* tab selected and the *New* button pressed to display the options for creating a new data set.

5. Populate the **General** section of the form with the requested information. Required information is indicated by a red asterisk.
 - a. Enter data in the **Label** field first. This information will be used in conjunction with the **Parameter** field from the **Data** section of the form to automatically populate the **Identifier** field. The format for the **Label** field is unit of measure, underscore, sensor id.
 - b. Provide a brief description of the dataset and any relevant comments such as the period of record
6. In the **External Source** section of the **Data Set Details** form, click on the down arrow on the right end of the box labeled **Provider** and select **RESTful Web Services**.
7. In the URL field, enter the URL that will be used by REST to query and fetch the data set. The URL must always be in this format:
<http://waterservices.usgs.gov/nwis/dv/?<arguments>>

You specify the arguments that go in <arguments>.

- Each URL argument name is followed by an equal sign followed by one or more values for that argument. Where multiple values are allowed for the same argument, you can separate values with commas.
 - URL arguments are separated by ampersands (&)
 - The order of the URL arguments does not matter
 - An argument must be on the list of allowable arguments otherwise a HTTP 400 error code is returned. The list of arguments can be found here:
<http://waterservices.usgs.gov/rest/DV-Service.html#URL>
8. The example URL shown below retrieves mean daily discharge data from the Merced River Happy Isles gaging station in WaterML1.1 format starting with data from August 23, 1916. (Note: although it is divided into individual components for readability, the URL is normally written as a single line.)
- <http://waterservices.usgs.gov/nwis/dv/> – this section identifies the server and path to the data. The “dv” specifies the subdirectory containing “daily values; “iv” specifies the subdirectory containing “instantaneous values”. The “?” initiates the query and precedes the list of arguments.
 - [sites=11264500](http://waterdata.usgs.gov/ca/nwis/sw) – “sites=xxxxxxx” identifies the gaging station of interest where xxxxxxxx is the eight digit NWIS ID/Site Number for that site. In this example 11264500 is the Merced River Happy Isles gaging station. A list of surface water monitoring sites in California is here: . <http://waterdata.usgs.gov/ca/nwis/sw>
 - [format=](http://waterdata.usgs.gov/codes-and-parameters/parameters) - Specifies the format of the output. The default is WaterML,1.1 which is an XML schema that can be read and displayed in a chart or table by Aquarius Springboard. Specifying “rdb” returns a tab-separated text file. Specifying “json” returns Javascript Object Notation suitable for web pages running Java scripts.
 - [parameterCd=00060](http://help.waterdata.usgs.gov/codes-and-parameters/parameters) - The parameter code representing the statistic or parameter of interest. It is a five-digit code which can be found here: <http://help.waterdata.usgs.gov/codes-and-parameters/parameters>. In this example, 00060 is the code for mean daily discharge in cubic feet per second.
 - [startDT=1916-08-23](http://waterservices.usgs.gov/nwis/dv/?sites=11264500&format=waterml,1.1&startDT=1916-08-23&parameterCd=00060). – This argument specifies the date range of the data you are seeking. If you omit [endDT=](http://waterservices.usgs.gov/nwis/dv/?sites=11264500&format=waterml,1.1&startDT=1916-08-23&parameterCd=00060) the query will return everything up to the most recent date available. StartDT and EndDT are separate arguments, meaning that each must be preceded by an ampersand. The required date format is yyyy-mm-dd.

The URL you enter in the box next to the URL label on the *External Data* section of the *Data Set Detail* form should look like the URL:

<http://waterservices.usgs.gov/nwis/dv/?sites=11264500&format=waterml,1.1&startDT=1916-08-23&parameterCd=00060>

9. After entering the URL, click the *Validate* button in the lower right of the *External Source* panel. If the URL has been entered correctly, the text immediately above the *Validate* button should say “*This URL is valid*”.
10. In the *Data* panel, click on the down arrow in the box next to the *Parameter* label and select the parameter you specified in the URL. If the parameter you want is not on the list click the button with three dots at the right edge of the box and search for the parameter you want. The Units field below the Parameter box should populate automatically. If not, select or search for the correct units as described for the Parameter field.
11. Once you have finished entering the Data Set details information, click the Save or Save and Exit button near the upper left corner of the Location Manager window to save your work.

To acquire peak instantaneous discharge from NWIS:

Note: Each year we will replace the previous year’s file.

1. Open the NWIS web interface page, **USGS Surface-Water Data for the Nation** (<http://nwis.waterdata.usgs.gov/nwis/sw>), in an internet browser.
2. Scroll down the page and click on **Peak-Flow Data**.
3. On the returned page, **Choose Site Selection Criteria**, check the box next to **File of Site Numbers** in the column –**Site Identifier**--, do not check any of the other boxes on the page, then press *Submit*.
4. **Select sites which meet all of the following criteria:** On this page, click in the box below *File of Site Numbers* and browse to the file:
SIEN_StreamGages_NWIS_SiteNumbers.txt in
J:\sien\monitoring_projects\rivers\data\Tabular\Original_Data.
5. On the resulting page (**Figure 6.4**), scroll down to the section **Retrieve Published peak streamflow data for Selected Sites**. Define the date range for the data you want by clicking in the boxes next to *Retrieve data from:* and using the pop-up calendar. Right below, select the radio-button next to **Tab-separated data** and choose the desired date format from among the choices in the drop down pick list. Choose *Save to file* in the adjacent box then click *Submit*.
6. When prompted, save the file to:
J:\sien\monitoring_projects\rivers\data\tabular\original_data\peak_streamflow\xxxx
where *xxxx* represents the year that you specified in Step 4. The resulting data file is a tab delimited text file. Rename it *peak_streamflow_xxxx.txt* where *xxxx* represents the water year the data are from.

This file is a tab delimited file that can be opened in MS Excel or any text editor.

SOP 6: Acquiring Data from Streamgage Operators
SIEN River Monitoring Protocol

The screenshot shows a web browser window titled "USGS Surface Water for USA: Peak Streamflow - Windows Internet Explo...". The address bar shows the URL: http://nwis.waterdata.usgs.gov/nwis/peak?search_criteria=site_no_file_atta. The page header includes the USGS logo and navigation links. The main content area is titled "Peak Streamflow for the Nation" and contains the following sections:

- Select sites which meet all of the following criteria:**
Define one or more values for each of the following site-selection criteria: --- or select [new criteria](#)
 - ☒ **File of Site Numbers** -- enter the full pathname of a file containing site numbers
 - * Selecting this search criteria disables the Show sites on a map option which is currently incompatible with file attachments.
 -
- Choose Output Format**
Display **Summary of Selected Sites**
Choose one of the following options for displaying descriptions of the sites meeting the criteria above:
 - ☒ Show sites on a map new
 - ☐ Table of sites grouped by
 - ☐ Scroll list of sites -- allows selection of data for multiple sites
 - ☐ Brief descriptions -- allows selection of data for multiple sites
 - ☒ Site-description information displayed in
 - (Select fields to include in site-description output)
 -
 - ☒ Site identification number
 - ☐ Site name
 - ☐ Site type
 - ☐ Save file of selected sites to local disk for future upload
- Retrieve Published peak streamflow data for Selected Sites**
Choose one of the following options for displaying data for the sites meeting the criteria above
 - ☒ Retrieve data from: to: (YYYY-MM-DD -- Blank = all data)
 - ☐ Graphs of data
 - ☐ Table of data
 - ☒ Tab-separated data *
 - * Save compressed files with a .gz file extension.
 - ☐ peakfq (watstore) format *
 - * Save compressed files with a .gz file extension.

Figure 6.4. Peak streamflow page used to obtain data from multiple sites using a file of site numbers and a specified output format.

Sierra Nevada Network River Hydrology Monitoring Protocol

SOP 7: Data Management

Version 1.0

This standard operating procedure is part of the Sierra Nevada Network River Hydrology Monitoring Protocol, but is designed to be printed and viewed as a separate document.

Revision History Log

Previous version #	Revision date	Revised by	Changes	Justification	Page #'s affected	New version #

This SOP introduces the user to the Aquarius software and provides instructions for managing data and rating curves in Aquarius. Portions of the text and figures in this SOP were borrowed or adapted from the National Park Service – Water Resources Division’s (NPS-WRD) Aquarius guidance documents (Unpublished documents, available at: <http://nrdata.nps.gov/programs/water/aquarius/aquariusvideos.mht>).

7.1 Introduction

Data take on different forms during various phases of a project and are maintained in different places as they are acquired, processed, documented, analyzed, reported, and distributed. **Figure 7.1** outlines these data management activities and lists the SOPs for specific procedures.

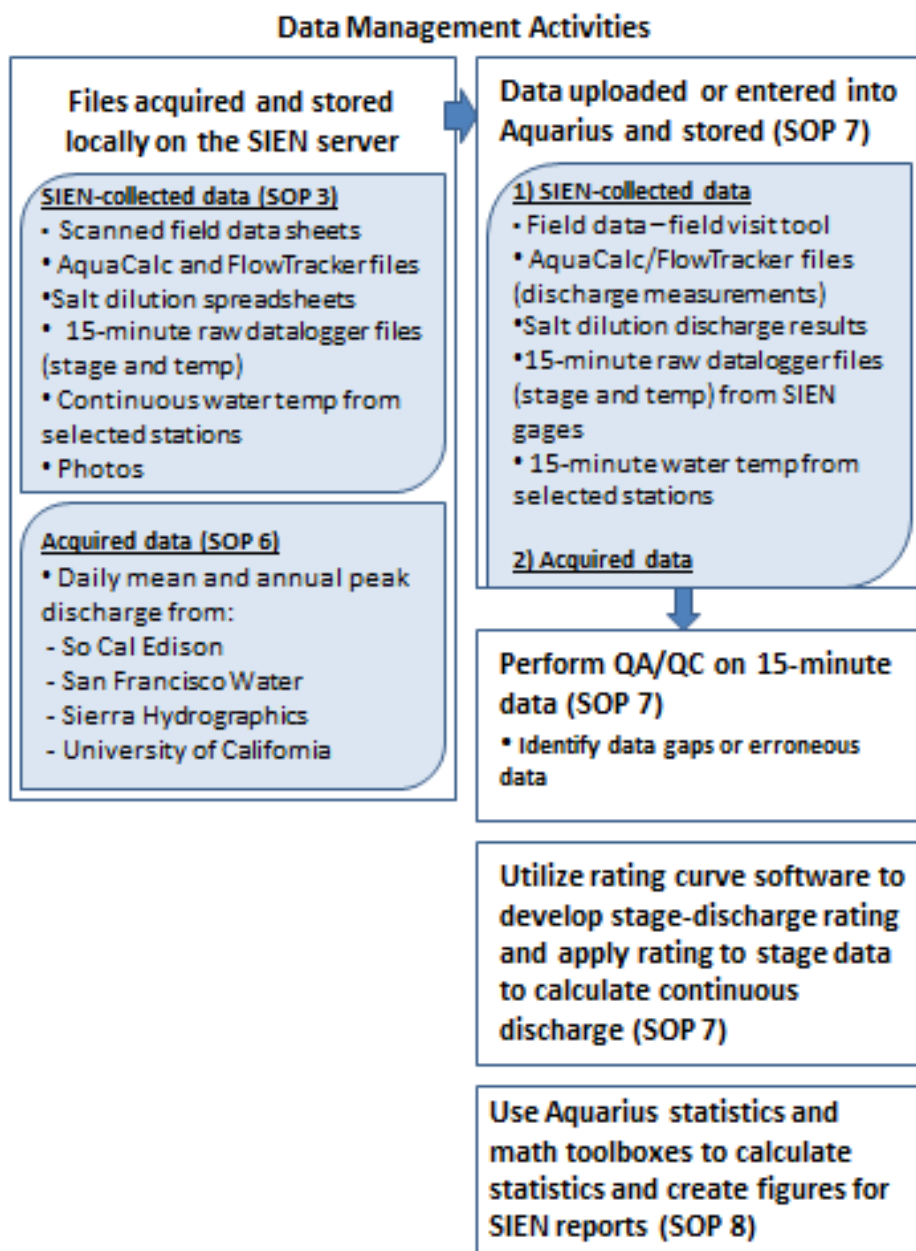


Figure 7.1. A general workflow of SIEN River Hydrology data management activities and their corresponding SOPs.

This SOP introduces the Aquarius software and describes how to set up SIEN gaging station locations, enter field visit data, upload time series data (i.e., 15 minute stage data, mean daily

discharge data, and continuous temperature data), identify and apply corrections to the time series, and manage the rating curves. It also describes the data validation, verification, and certification processes.

The basic procedures for stream discharge analyses have been obtained from Kennedy (1983), Kennedy (1984) and Sauer (2002). It is advisable to read these documents to gain a thorough understanding of the concepts and methods that are used to manage discharge records and rating curves. These and other background documents are located on the SIEN server at:

J:\sien\monitoring_projects\rivers\Resources\ProtocolResourcesAndTraining.

7.2 Aquarius Informatics Software

Aquarius (<http://aquaticinformatics.com>) is a software platform designed to simplify the management and analysis of time-series data. Implemented within Microsoft Structured Query Language (SQL) Server, the Aquarius database is based on Aquatic Informatics' proprietary schema that is optimized to handle continuously collected data. The schema is available from WRD and Aquarius and also stored locally on the SIEN network (J:\sien\monitoring_projects\rivers\data\tabular\Aquarius\schema). In the event that Aquarius software is no longer available to us (e.g., they go out of business) the database can be accessed via an application programming interface (API). Aquarius has published API protocols using standard simple object access protocol (SOAP) and REST web services (Aquatic Informatics Inc 2016b, a). The NPS Aquarius system is managed by WRD's Data Manager (currently Dean Tucker - Dean_Tucker@nps.gov). He and NRSS IT staff are responsible for archiving and backup procedures.

Aquarius has devised two interfaces for working with the database. Springboard, the Aquarius Server user interface, provides tools to import and store gaging station metadata, record and annotate field sampling events, and manage associated time series datasets. Whiteboard, the graphical user interface for Aquarius Workstation provides an additional innovative set of quality assurance and data analysis tools. We are primarily using the Springboard interface. Whiteboard is used for calculating hydrologic statistics and conducting flood frequency analysis using tools that are not available in Springboard.

Aquarius Informatics software is an extremely rich and powerful program. That power entails a high degree of complexity. A new user can significantly improve their productivity and avoid frustration by reading the instructions for getting started with Aquarius, including how to log on to the shared license, creating stations, and uploading and working with data. New versions of the Aquarius software are issued several times a year. The most recent version of program instructions is available on the NPS Water Resources Division (WRD) web page at: <http://nrdata.nps.gov/programs/water/aquarius/aquariusvideos.mht>.

Aquatic Informatics has also developed numerous helpful training videos for using the Aquarius software. The videos are available at: <http://www.aquaticinformatics.com/support-login>. New users should contact Aquatic Informatics for a log-in and password. Aquatic Informatics continually adds and updates videos. The following list of videos should be watched prior to beginning work in Aquarius.

- Basic Hydrodynamics
- Introduction to Hydraulic Relations
- Importing Q Measurement Files
- Importing Logger Data Files
- Data Corrections 101: Environment Overview
- Field Visit Tool Overview
- Discrete Measurement & Gauge Height Entry

After watching the videos and reviewing WRD's Aquarius documentation, contact Dean Tucker to be added to the NPS' Aquarius Users Group and obtain the AQAssistant.rdp file so you can connect to Aquarius through Remote Desktop. A copy of the AquariusAssistant.rdp file is located in: J:\sien\monitoring_projects\rivers\resources\aquarius.

NPS-WRD hosts Aquarius on their servers and has five licenses available for park and network users. Users log in remotely using the Windows remote desktop connection (i.e. the AQAssistant.rdp). The AquariusAssistant.rdp file can be copied to your desktop or in any location that fits your workflow. Double-clicking on the AquariusAssistant.rdp icon will open a remote desktop session that prompts you for a password. Type in your NPS network login password and press enter to launch Aquarius Assistant. Click Okay on the warning screen. Upon starting, Aquarius Assistant will minimize itself to an icon that can be found among the active-task icons on the right end of the Windows taskbar at the bottom of your screen (Figure 7.2). Right-clicking on the Aquarius Assistant icon will open a menu for accessing the Aquarius Springboard and Whiteboard modules. If you need more information, read the procedures described in Connecting to Aquarius v3.0 on GETT1.pdf located at: J:\sien\monitoring_projects\rivers\resources\aquarius or refer to the videos described previously. Your log-in information for Aquarius Springboard or Aquarius Workstation/Whiteboard is the same as your NPS network access.

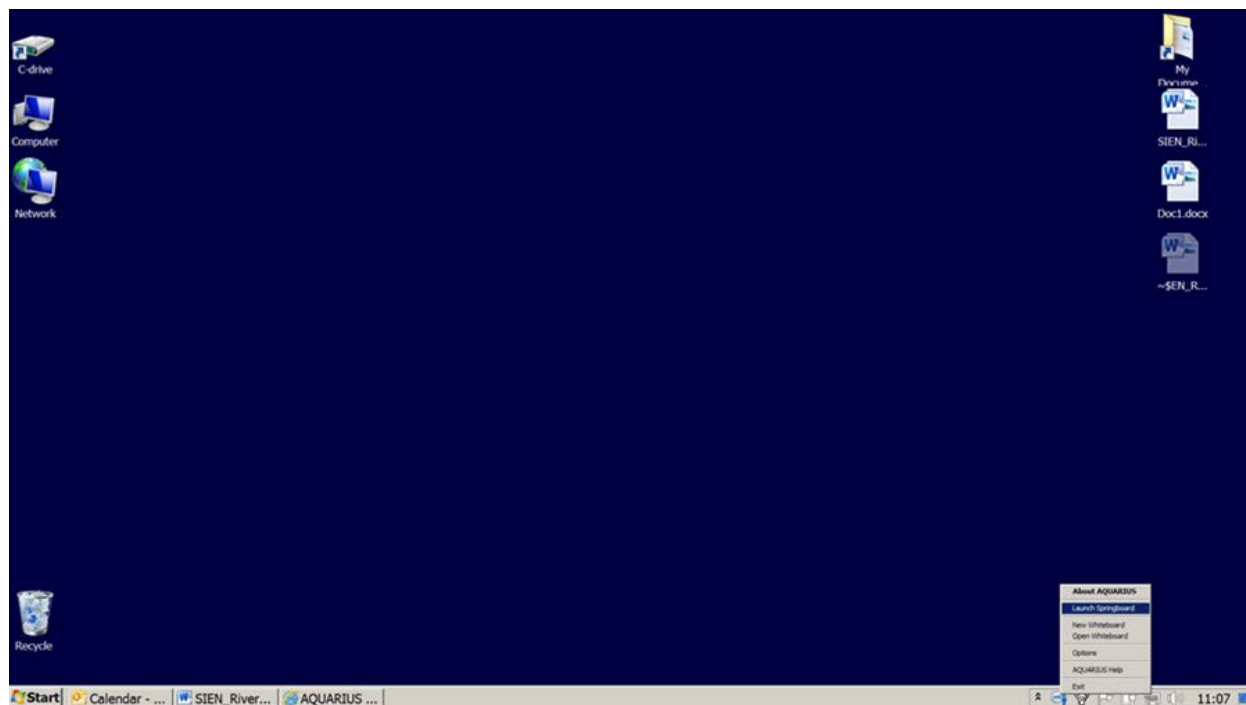


Figure 7.2. The launch screen for the Aquarius Assistant.

7.3 Setting up SIEN locations and managing station metadata

Start Aquarius Springboard by selecting Springboard from the Aquarius Assistant menu described in section 7.2. You will be presented with the Aquarius Springboard launch screen. Enter localhost for the server name (this should be filled in automatically). Click **OK**. The Aquarius Springboard Welcome screen will open. Enter a *Username* and *Password*, make sure **English** is selected as the *Language* then press **Login**. Provided you have already been added as a registered Aquarius user, your username and password are your NPS active directory credentials. If you have questions about the steps just described, consult *Connecting to Aquarius v3.0 on GETT1.pdf* on the NRSS server at <http://nrdata.nps.gov/programs/water/aquarius/aquariusvideos.mht> or posted on the local SIEN server in *J:\sien\monitoring_projects\ivers\resources\aquarius*.

When Springboard opens select *Sierra Nevada Network\River Monitoring* from the navigation pane on the left side of the window (**Figure 7.3**). The list of stream gaging stations currently being monitored by SIEN is shown in the main window.

SOP 7: Data Management

SIEN River Monitoring Protocol

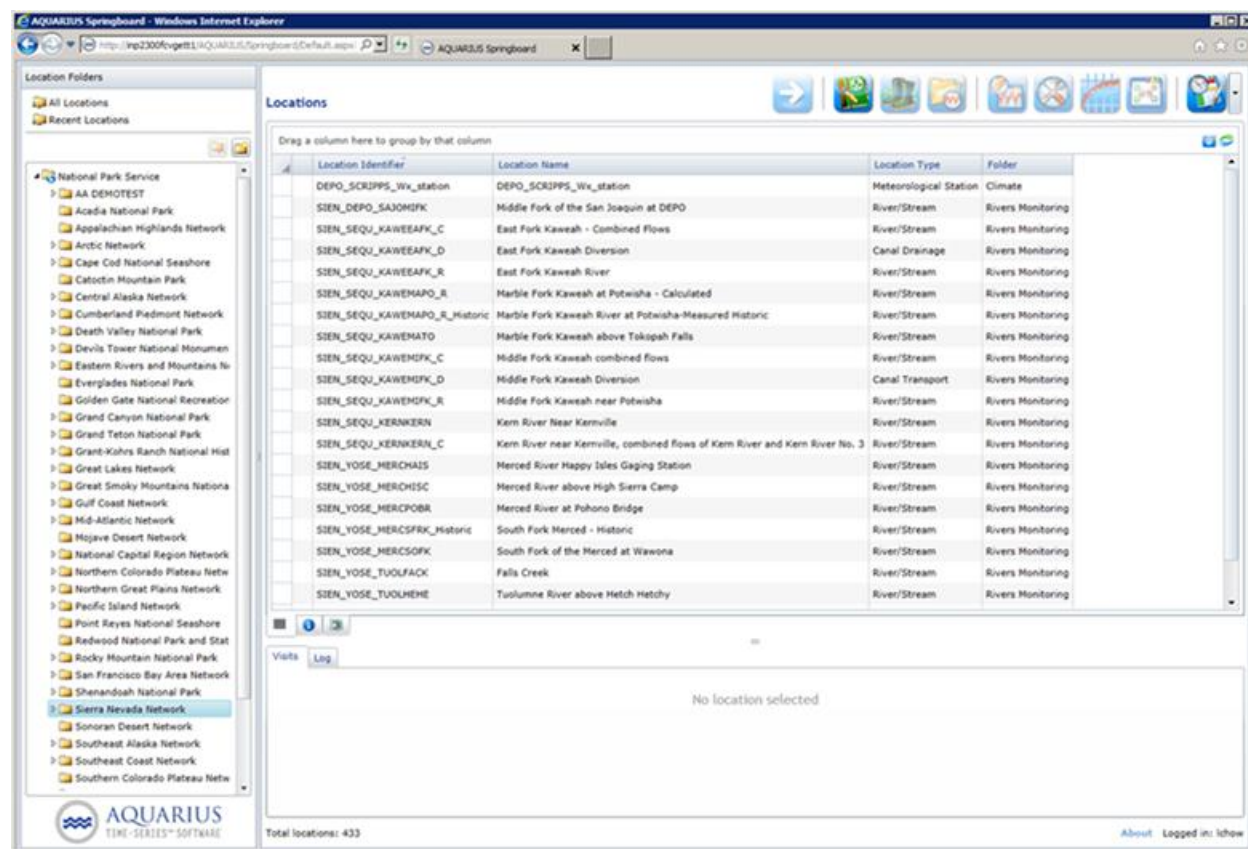


Figure 7.3. The Aquarius Springboard home screen showing the SIEN stream gaging stations

The Aquarius Server's central organizing concept is the monitoring location (i.e., stream gaging station). Each monitoring location is attributed with metadata such as station type, geospatial references, information about benchmarks at the gage, and installed equipment. All time series, rating curves, and field visit information must be associated with a monitoring location. This is done using the Aquarius Springboard Location Manager which provides a comprehensive set of tools for importing, managing, and documenting the data and analyses associated with a gaging station. Although the Aquarius Workstation/Whiteboard can also import time series data, Springboard is the preferred option for performing data management tasks because it has more data management capabilities. Another reason Springboard is the preferred platform for supported data management tasks is that any changes made to data in Springboard are automatically written to the Aquarius database while any changes made in Whiteboard require dragging out the 'Write to Server' tool and specifically writing the data back to the Aquarius database. Once a time series has been appended or stored in a station dataset it can be corrected using Aquarius Springboard.

You create a new monitoring location by right-clicking on an open area within the main **Location Manager** window and selecting **New Location** from the pop-up menu. Alternatively, you can select **Sierra Nevada Network\Rivers Monitoring** from the left navigation pane and click on the Location Manager icon (the notebook and pencil) near the top right corner of the main Springboard window. This will open a dialog box where you enter metadata about the gaging station (**Figure 7.4**). Right-clicking on an existing station in the main Springboard

window and selecting **Location Manager** from the menu allows you to edit the metadata for that station.

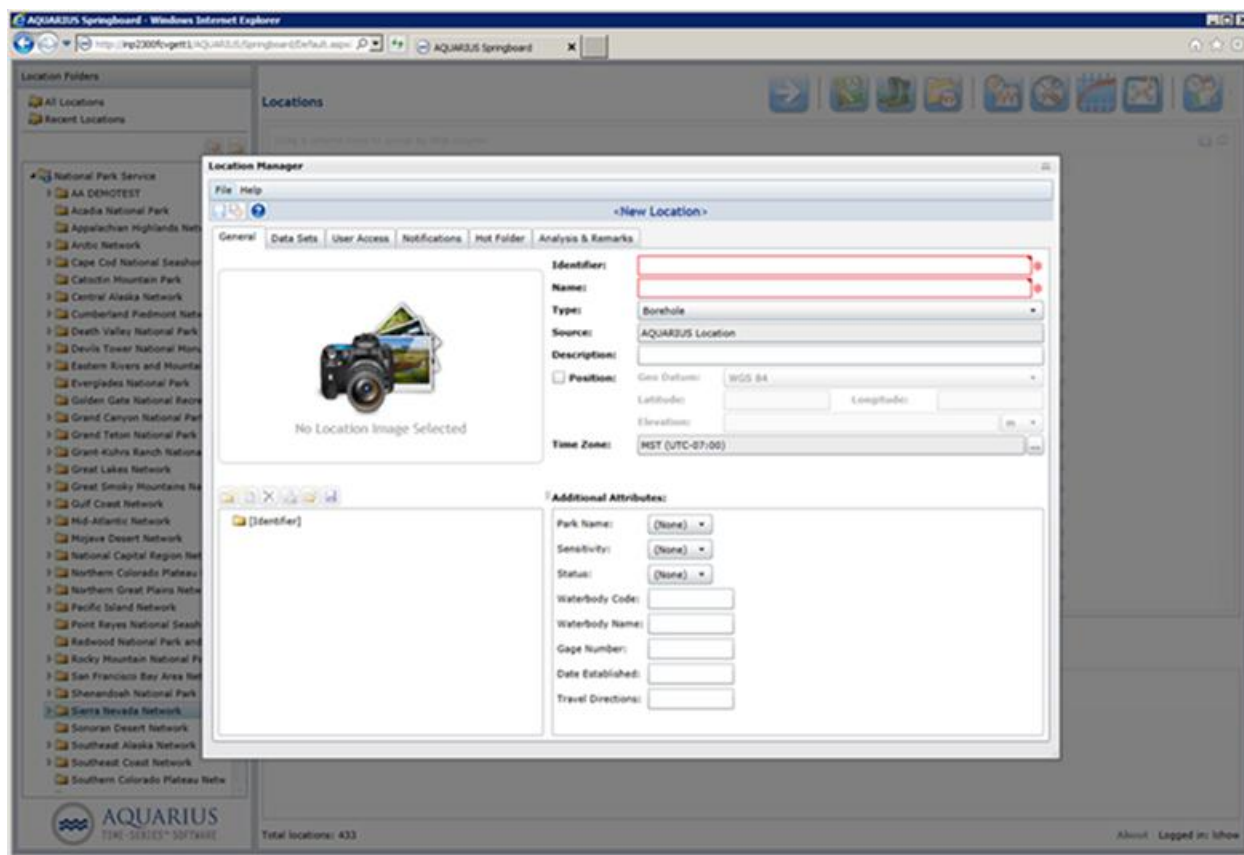


Figure 7.4. Aquarius Springboard Location Manager dialog box for entering gaging station metadata

Although some station metadata is stored in the Aquarius Springboard Location Manager, current requirements for posting data to the NPS Integrated Resources Management Applications (IRMA) require the creation of metadata compliant with the Federal Geographic Data Committee (FGDC) Metadata Standard and the National Biological Information Infrastructure (NBII) Biological Data Profile. The USGS is currently working with Aquarius Informatics to incorporate the required metadata into the Aquarius software. However, this functionality will not be available for one to two years. In the interim, SIEN will develop an ArcMap geodatabase for this project that incorporates the required metadata information.

7.4 Uploading and Saving Data to the Database

There are three types of data that will be stored in the Aquarius Server database:

1. Station visit data that has been recorded on the field datasheet including instantaneous temperature and water level measurements (entered manually).
2. Discharge measurement files (from the AquaCalc, FlowTracker, or ADCP) and salt dilution discharge results.

3. Tabular data

- a. Mean daily discharge values from streamgaging operators (from archived, read-only raw data on the SIEN server as Excel and csv files).
- b. 15-minute stage data from SIEN-supported stations (Campbell Scientific logger files) and HOBO temperature logger files (csv files).
- c. Daily flow data for stream gaging stations listed on the USGS NWIS web site. Technically, although these data are not “stored” on the Aquarius server (they are downloaded in real-time using the REST services discussed in SOP 6), they appear as tabular data that can be manipulated like other data stored on Aquarius Server.

The steps for uploading and saving the three types of data described above all follow the same general pattern.

1. Log in to Aquarius Springboard.
2. Select an existing station from the main Springboard window or create a new station following the procedure described previously.
3. Depending on the type of data you are entering or uploading, click on either the **Field Visit** or **Logger File Upload** icon near the top of the main Springboard window.

7.4.1. Entering Field Visit Data

After each station visit, save electronic files as read-only files and scan field data sheets in preparation for upload to Aquarius (*Refer to SOP 3: Post gagingstation visit activities*). Launch Aquarius Springboard (**Figure 7.3**), select a station from the main Springboard window and choose the **Field Visit Tool** (the icon with the boots). Create a station visit entry in Aquarius which includes a list of field personnel, temperature measurements, links to photos that were taken, and any other data that were recorded on the field datasheet.

Choose **New Field Visit** to add a new field visit (**Figure 7.5**). Input all relevant data from the field data sheet. Be sure to include notes about the visit such as the weather or obvious changes to the river channel upstream and downstream of the gage. Choose **New / Measurement Activity** to add discrete measurements to the selected visit.

7.4.2. Importing discharge Measurement Files

Following each field visit, the AquaCalc, FlowTracker, or ADCP files are downloaded (see SOP 3). These files must be linked to a station visit following the same instructions for entering field visit data. Launch the **Field Visit Tool** from Springboard. Create a new field visit as per section 7.4.1 above or select an existing field visit and then select **New / Measurement Activity From File**. Set the ‘Files of type’ to be AquaCalc Pro or FlowTracker files (*.csv) and select the appropriate file for the station visit.

SOP 7: Data Management
SIEN River Monitoring Protocol

The **Discharge Measurement Details** button is available after a measurement file has been uploaded. The screen allows the user to view the measurement and assign a grade based on the number of sections and conditions (**Figure 7.6**).

SOP 7: Data Management

SIEN River Monitoring Protocol

New ▾ A New Measurement Activity can be created using the drop down menu.

- Field Visit
- Field Visit From File
- Measurement Activity
- Measurement Activity From File

If the Field Visit is already created, selecting **New Measurement Activity** will allow you to manually enter observations, choosing **New Measurement Activity From File** will allow you to create a measurement activity by importing a supported measurement file. Selecting **New Field Visit From File** will create a new field visit and measurement activity using information within the file for the date and time.

The **Measurement Activity** section is a table view of selected results from the selected activity. The **Measurement Activity Label** may be customized and an **Approval Level** assigned to the activity.

Field Visit Tool - Dalwhinnie | Dalwhi

File Help

2011-05-12

Stage 3.273 @ 17:28
Discharge 3.35 @ 17:01

Activity Name: Measurement Activity Conditions: Approval Level: Undefined

Observations:

Source	Time	Parameter	Qualifier	Value	Units	Corr.	C.Value	Grade
Manually Entered	17:18	Stage		3.26	m	0	3.26	4 - PARTIAL
Manually Entered	17:33	Stage		3.28	m	0	3.28	5 - EST NO
Flow Tracker v2.20.dis	17:18	Discharge		3.35	m ³ /s	0	3.35	40 - EST VERY
Flow Tracker v2.20.dis	17:18	River X Area		11.175	m ²	0	11.175	40 - EST VERY
Flow Tracker v2.20.dis	17:18	River X Width		29.75	m	0	29.75	40 - EST VERY
Flow Tracker v2.20.dis	17:18	Water Temp		15.44	°C	0	15.44	40 - EST VERY
Flow Tracker v2.20.dis	17:18	Water Vel		0.3	m/s	0	0.3	40 - EST VERY

Aggregated Results:

Source	Time	Parameter	Value	Units	Grade	Remark
Manually Entered	17:28	Stage	3.273333333	m	4 - PARTIAL	
Manually Input Discharge	17:01	Discharge	3.35	m ³ /s	40 - EST VERY Gi	
Manually Input Discharge	17:01	River X Area	11.175	m ²	40 - EST VERY Gi	
Manually Input Discharge	17:01	Water Vel	0.3	m/s	40 - EST VERY Gi	

Figure 7.5. The “New Measurement Activity” screen in the “Field Visit Tool”.

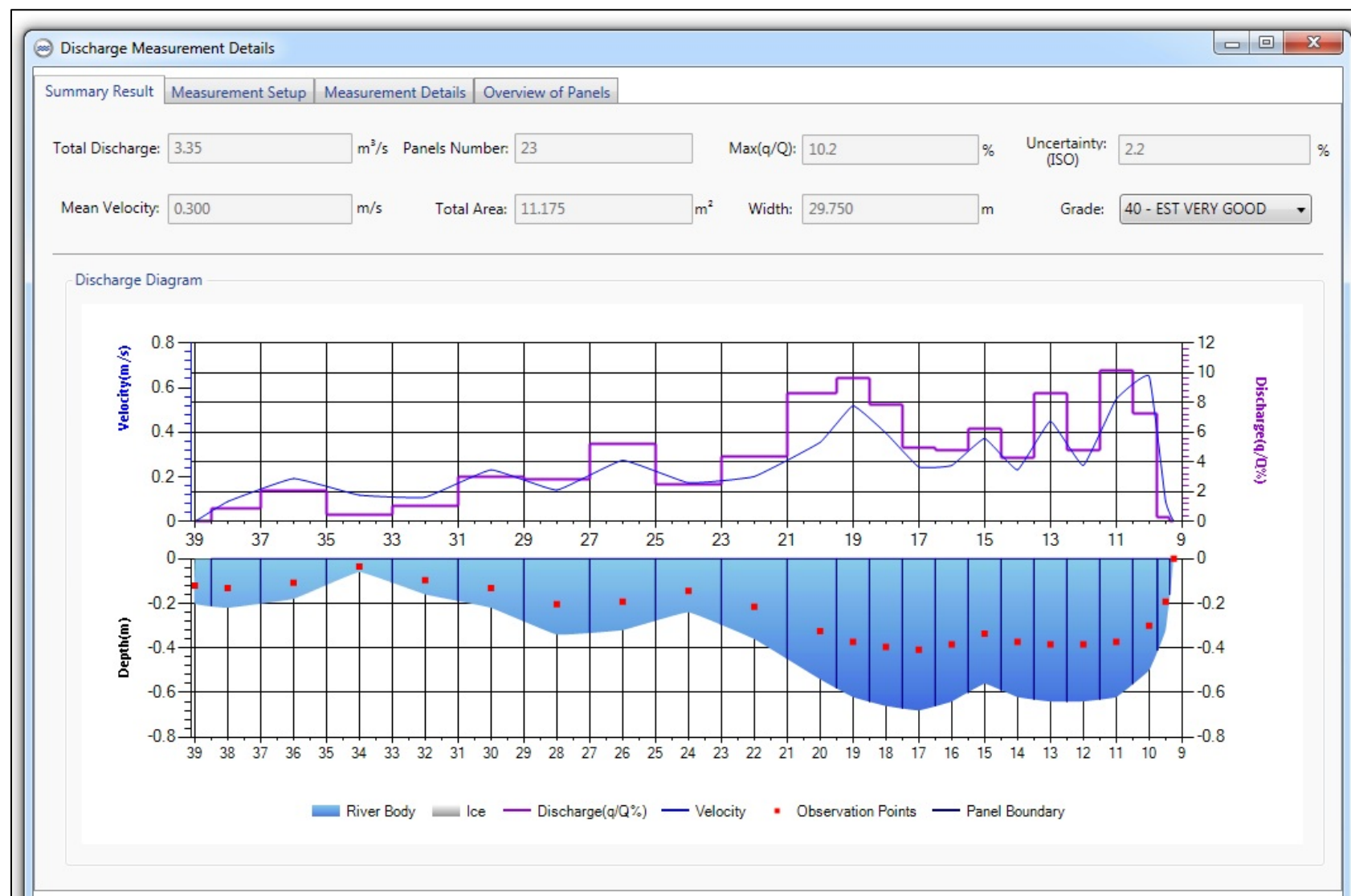


Figure 7.6. The “Discharge Measurement Details” screen in Aquarius is available after a discharge file has been uploaded. The screen allows the user to assign a grade to the measurement.

7.4.3. Importing Tabular Data

SIEN works with three types of time-series data: i) mean daily discharge data that have been acquired from other operators, ii) HOBO temperature logger data, and iii) instantaneous data from the Campbell Scientific dataloggers. Although the tabular data originate from three different sources, they are all imported into Aquarius Springboard using the same basic procedures. This involves identifying the file to be imported then identifying an existing configuration file or creating a new configuration file that describes the structure of the data in the logger file.

Datasets are uploaded to the Aquarius database and assigned to their station of origin using the Aquarius Springboard 'Append Logger File' tool. Each dataset represents a collection of data for a specific parameter (i.e. mean daily discharge, 15- minute discharge, or water temperature). After a parameter dataset has been created, you can add additional data to it by using the 'Append Logger File' tool in Springboard. Once the file has been added as a dataset, the data can be edited and corrected, as necessary, using Springboard's 'Data Correction' toolbox.

Follow this step-by-step process to import time-series data into Aquarius:

1. Launch Aquarius Assistant and open Springboard. Select a station location from the list in the main window.
2. Either right-click on the station and select "Append to Logger" from the drop down menu or find Append to Logger in the row of icons near the upper right of the Springboard window (hovering over an icon will display a description of the icon) and click on it.
3. The Append to Logger dialog box will open (**Figure 7.7**). Enter the name of a logger file (including the directory path to the file) or browse to the logger file by clicking on the button to the right of the Logger File text entry box.
4. Next, either enter the name of a configuration file in the "Config File : (optional) text box, browse to a configuration file by clicking the button to the right of the text box, or click the 'Config Settings...' button in the lower right of the dialog box to select or define a configuration file. The configuration file describes the structure of the data in the logger file. Clicking on the "Config Settings" button opens the **Import from File Wizard**. (Note that once you have defined a configuration file for a logger file, you can save it to use again.)
5. Next, the user will set the **Start Import At** feature. This feature sets the pointer on the first row of data to import. In the **Start import At** box, click the up arrow to include the header columns. Click **Next**.

SOP 7: Data Management
SIEN River Monitoring Protocol

Append data from a logger file and set up a hot folder to allow easy logger data updates for the location.

Step 1: Select a logger file and load it:

Logger File:

Config File:

(Optional)

Step 2: Choose the target data sets and append:

No logger file loaded

History:

Time	Data Set	File	Message
10/7/2015 7:28:16 A	Water Temp.WaterT	lyellblwmaclure_519_T15min20150921.dat	Data points appended:8461.
10/7/2015 7:28:12 A	Sp Cond.Specific Co	lyellblwmaclure_519_T15min20150921.dat	Data points appended:8461.
10/7/2015 7:28:07 A	Stage.Primary@SIEN	lyellblwmaclure_519_T15min20150921.dat	Data points appended:8461.
10/7/2015 7:28:06 A	Water Temp.WaterT	lyellblwmaclure_519_T15min20150921.dat	Data points appended:8461.
10/7/2015 7:28:05 A	Stage.CS450_Raw@S	lyellblwmaclure_519_T15min20150921.dat	Data points appended:8522.
10/7/2015 7:28:02 A	Battery Voltage Und	lyellblwmaclure_519_T15min20150921.dat	Data points appended:8461.
7/27/2015 12:31:17	Stage.Primary@SIEN	2002-2012_JL_stage_discharge_watertemp	Data points appended:122644.
7/27/2015 11:44:39	Water Temp.Solinst	2002-2015_JL_stage_discharge_watertemp	Data points appended:173073.
7/27/2015 11:44:21	Discharge.JL- Rating	2002-2015_JL_stage_discharge_watertemp	Data points appended:173073.
7/27/2015 11:44:06	Stage.JL-Solinst@SIE	2002-2015_JL_stage_discharge_watertemp	Data points appended:173073.

Figure 7.7. The Aquarius Springboard Append to Logger dialog box.

6. Now, the user determines which columns to import and set the format for the date and time. Be sure to process all the columns before pressing the Next button.
 - a. Date and time column(s): click the **Format Date / Time** type in the date format (e.g., **mm/dd/yyyy**). Select the time column and click the **Format Date / Time** radio button and type in the time format (e.g.,**HH:MM:SS**).
 - b. Data columns: Select the **Data** radio button on the left to and select **Raw** in the associated drop down menu. Select the parameter (e.g. water temperature, water level) and units. Set the **Gap Tolerance** to 30 minutes and the **Int. Type** to 1 – Inst. Values. **Grade** and **Approval** should be set to the appropriate options; they

can also be changed later when working in Aquarius.

Note: **Gap Tolerance** defines how much time can elapse between consecutive measurements after which Aquarius would identify a 'gap' in the time series. For important information on the complexities of Gap Tolerance, check out the Aquarius Frequently Asked Questions document from NPS-WRD (<http://nrdata.nps.gov/programs/water/aquarius/AquariusVideos.htm>). In brief, a previously defined time series Gap Tolerance entered for a data set container on the **Location Manager's Data Set** tab that is greater than 0 takes precedence over the Gap Tolerance setting entered in Step 3 of the **Import Wizard** when appending into that existing dataset container. Int. Type defines the interpolation type and is used for graphical and reporting purposes. Here '1 – Inst. Values' identifies these time series measurements as instantaneous values.

- c. Columns that do not need to be imported (e.g. battery): Select the column and click the **Do not Import** button. Notice that the format and description sections become grayed out. Select any additional columns that you don't want to import and click **Do not Import**. Notice that the columns selected for import have headers, while those that were not selected say **Skip**. Click **Next**.
7. Next, choose to save the configuration (.cfg) file. This is a small script that can be used to import additional .csv files with the **exact same layout**. If the .csv files differ at all, either an error message will be displayed when additional files are imported or an incorrect data column will be imported. Click the **Save Configuration** box.
8. By default, the .cfg file will be saved in the current working folder. Select browse and rename the configuration file to a file name that is useful and intuitive (e.g., YOSE_MERCSOFO_2012_HOBO_import). Click **Save**. The final screen of the import wizard will show the path of the saved configuration file. (You can specify a location on the local SEKI server in J:\sien\monitoring_projects\ivers\data\tabular\aquarius so it is readily available for reuse). Click **Finish** to complete the import process.
9. Next move to box 'Step 2: Choose the target data set and append'. In this step. The user tells Aquarius to which dataset container they wish to append each parameter using the **Append** to drop down boxes (**Figure 7.8**). If it is a new time series for this station (i.e., the first time this parameter was uploaded for the station) then select **Create New Time Series**. To append to an existing time series, select the existing time series file name. To skip a time series, select **Do not append**. Then select **Append** when ready to upload the files. If all went well, the status indicates it has been appended and it will be logged in the **History** box located in the bottom of **Append Logger** file box. Note: if something goes awry you can undo the append by selecting the time series and clicking **Undo**.
10. You should now see a new time series listed in the **Data Sets** page for that station.

Step 2: Choose the target data sets and append:

Label	Paramet	Units	# Points	From	To	Append to	Status
Temp	Temperatu	°C	6095	8/6/2008 9:00:00 PM	9/20/2008 3:00:00 PM	Create New Time ▼	
Stage	Water Lew	ft	6095	8/6/2008 9:00:00 PM	9/20/2008 3:00:00 PM	Create New Time ▼	

Create Hot Folder... Manage Hot Folder... Append

Figure 7.8. Step 2, choosing the target data set to append in the Append Logger File Box.

7.4.4. Managing Stage and Temperature Data

Time series data from the SIEN-supported gages and HOBO temperature loggers must go through multiple steps before it is ready for use in analyses. The process starts with uploading the 15-minute data files from the Campbell Scientific streamgage loggers and HOBO temperature loggers and ends with a corrected data set that is ready for analysis. Once the datalogger files have been imported into Aquarius (per procedures in section 7.4.3) they are ready to be examined and corrected if any erroneous data points or sensor drift is identified.

7.4.5. Examining the Time Series for Erroneous Data

The time series data sets are reviewed to identify any missing or erroneous records. It is likely that a portion of the data record each year will be missing or erroneous due to ice effect or equipment failure. Viewing the data in a graphical format can assist in identifying potential data errors including suspect data or gaps. The Quick View tool can be used to examine the data.

It is especially important to ensure that electronic stage data are as accurate as possible. Small errors in stage result in large errors in estimated discharge, because of the exponential relationship between stage and discharge. USGS's Office of Surface Water memorandum 93.07 (Boning 1992) notes that a one percent error in the effective stage input to the rating would translate into a three percent error in the computed discharge. Examining the hydrograph is an effective way to evaluate the validity of datum or gage-height corrections, identify periods of faulty gage-height data, and estimate discharges for periods of missing record or periods of no stage-discharge relation (Rantz and others 1982a). Figure 7.9 shows a time-series of stage data from Redwood Creek in Marin County, California and some of the potential data gaps and errors. Temperature data should also be viewed visually as a time series to help identify any gaps or suspect data points.

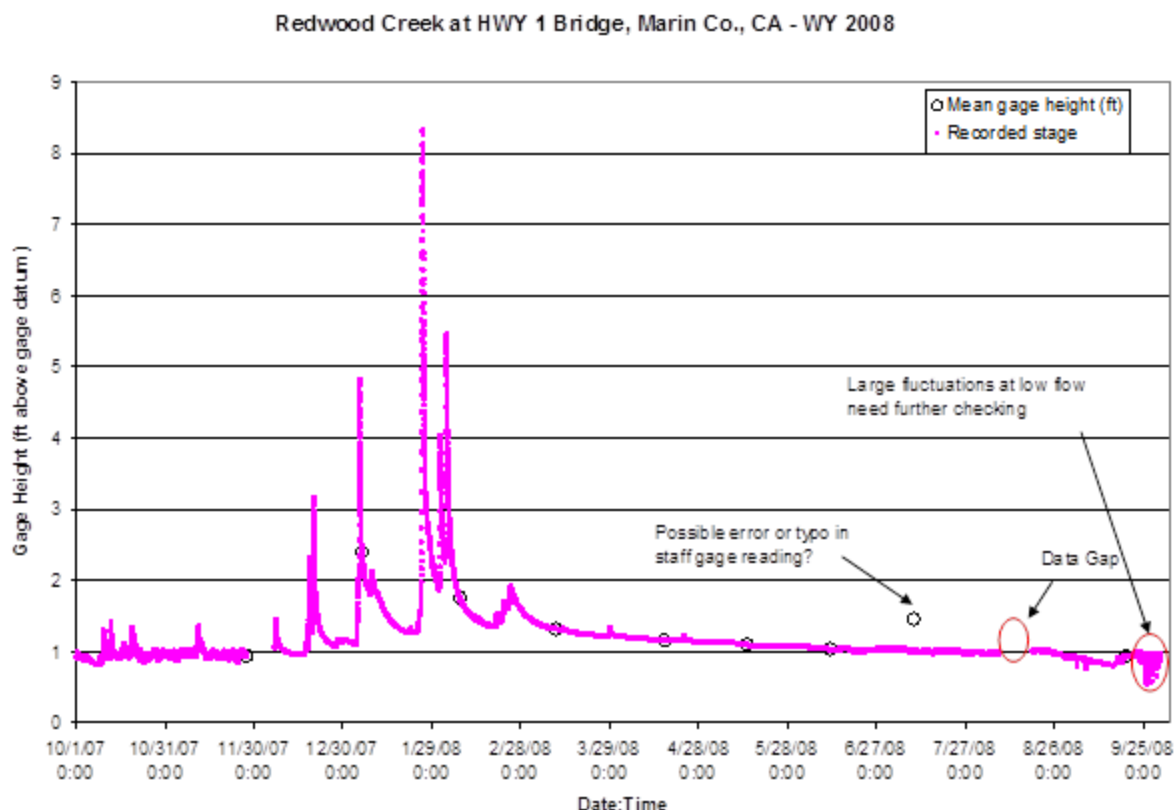


Figure 7.9. Printout of recorded stage data and observed stage for error checking.

When examining data we suggest first looking for erroneous data at the ends of the time series. There is often a time period at the beginning and end when the logger was out of water prior to being installed or downloaded. These data should be trimmed from the original data set.

Secondly, the data should be examined for sensor drift. When the pressure transducer or thermistor values deviate from the staff plate or the manual field temperature measurements the series will need to be corrected for drift. Drift effects can be minimized by conducting frequent visits to manually record water level and temperature.

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 and others 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, it is necessary to determine whether data corrections are warranted. Gage-height corrections will be applied when the gage-height difference between the recording gage and the staff plate is less than 0.01 ft; there is no need for correction because the accuracy of staff plate reading is 0.01 ft. 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. The amount of drift is then distributed over the applicable time period using linear interpolation. The linear interpolation is calculated for each 15-minute data record and used to correct the raw stage height (Rantz and others 1982b).

Drift corrections for temperature will be applied when the difference between the manual temperature reading and the logger thermistor differ by greater than 0.5 C°. Linear interpolation will be used to correct for temperature drift, as described above for stage data.

After drift corrections have been applied to the dataset, the preliminary corrected data should be further checked to identify erroneous data. For stage data, the minimum values in the electronic data should be closely reviewed for accuracy because, occasionally, negative stage values may occur due to equipment or user error (e.g., pulling transducer from stilling well for cleaning and forgetting to accurately document time of actions).

If, after initial review, the suspect data are determined to be erroneous, these records should be deleted and action noted in Aquarius comments, recorded data files, and summary reports. If the data for this period are essential (e.g., occurring during peak storm event), there are approaches for estimating and filling in missing data (refer to section 7.4.8). 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, data sources used to assist corrections, who did the corrections, and date corrections were made).

For additional guidance on data correction approaches refer to Kennedy (1983) and Sauer (2002).

7.4.6. Ice-affected Data

SIEN-supported gages are highly susceptible to ice effects since they are at high elevations. Thus managing these data will involve identifying and correcting for ice effects. Ice effects on hydraulic parameters result in channel storage and release events and, as a result, can alter the stage-discharge relationship. The sign of the stage-discharge relation is positive if these events occur upstream of the gage. The sign of the stage-discharge relation is negative if these events occur in the same channel reach. Ice-affected stage data may appear as a spike in the data. Therefore, it will be important to identify whether the data indicates a true winter precipitation event or ice effect. It is possible to confirm winter precipitation events by examining the precipitation data from nearby weather stations or by referencing lower elevation stations.

Correcting for ice-affected data can be tricky. We have arranged for technical assistance from the Water Resources Division on analyzing our data and in particular correcting ice-affected data. The Aquarius Informatics support staff is an additional resource as they are knowledgeable about options for correcting ice-affected data within the Aquarius rating curve software.

7.4.7. Data Corrections in Aquarius

Once the data are imported, visually examined, and erroneous data identified, data corrections may be made, as appropriate, using the Data Correction toolbox in Springboard. Procedures to correct raw data in Aquarius are described below. Aquarius maintains both the original uncorrected data set and a corrected data set so the original data are never lost. Individual corrections can be toggled on or off by selecting them in the correction log.

The two most common types of data correction we will encounter are i) trimming erroneous data from the beginning and end of a water-level record (the erroneous data is from the time period

when the sensor may have been out of water for installation, inspection, or download) and ii) adjusting the data for sensor drift. Steps for using the Data Correction Tool in Springboard for these two common data corrections are as follows:

1. Select a station and then the data set of interest from the list of data sets. Click on the Data Correction icon at the top of the Springboard menu bar (it can also be accessed by right clicking on the data set). This displays a screen with four sections: i) graph of the data ii) Correct Control box, iii) Time Series Grid (shows the data in tabular form), and iv) Change List (a log of the corrections). Note that the sections may be hidden or reorganized per the user's preference.
2. The first step is to select the data that you want to apply a correction to. Click on the **Mark Region** tool (green highlighter) above the graph. Then, to select the data, scroll down in the Time Series Grid and select the first record. You can then scroll to the last record, hold down the shift key, and select it. The desired block of records will be highlighted in blue while the selected measurement region is also highlighted in cyan on the graph (**Figure 7.10**). You can also use the **Mark Region** tool to visually select a region on the graph. You can use the zoom tools to enlarge an area of the graph so you can see it more clearly. If you want to just quickly select all the time series parameter's measurements, click the **Mark All Region** tool. To deselect all the currently selected measurements, use the **Delete Mark/Pivot Points** tool.

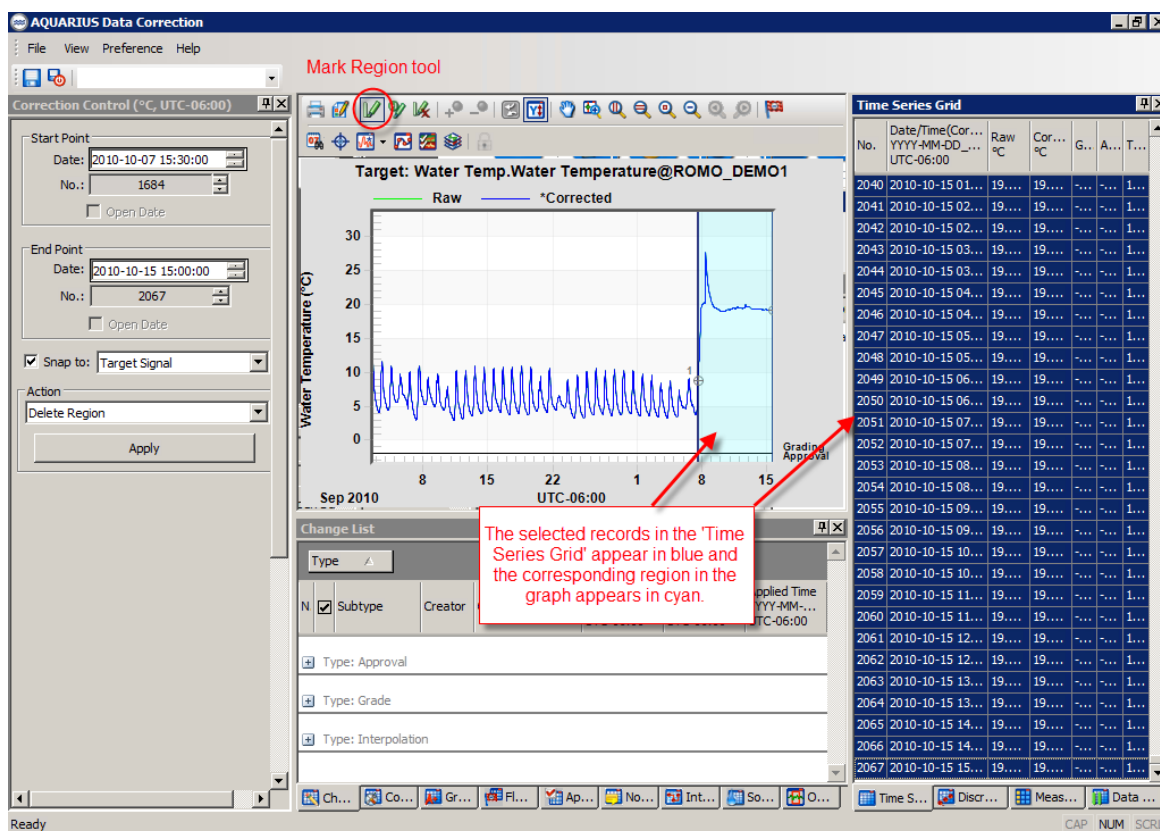


Figure 7.10. Data Correction screen showing the highlighted data selected for correction.

3. Once you have the desired area selected/highlighted, use the Action combo box in the Correction Control to select the desired action (i.e. Delete Region or Drift Correction).

To delete data:

- a. In the Action combo box select **Delete Region** from the drop down menu and then click the **Apply** button to apply the action.

4. To correct for drift:

- a. In the **Action** combo box select **Multi-Point Drift Correction** from the drop down menu.
 - b. Set the Adjustment to **Linear**.
 - c. Set the Adjustment Step to **0**.
 - d. Complete the Pivot Points table: The table automatically populates the **Date/Time** with the first and last points of the selected region. To add additional points to the table (e.g., you have a staff plate reading from a point in the middle of the selected series) click the **Add Pivot Point** button and then click the point on the graph or in the table. It will add this point to the table. You can then edit the Date/Time so it reflects the exact time the measurement was made. Next populate the **Difference** fields. This is determined by taking the difference between the reference measurement and the logger measurement at each pivot point (e.g., if the staff plate reading is 0.80 and the logger reading is 1.00 then the difference is -0.20).
 - e. Click the **Apply** button to apply the action.
5. The Apply Correction window will pop up showing the information that is related to the correction task. Select a standard comment or type in a new comment stating the cause of the erroneous data. Keep these statements brief. Use the **Add to List** feature, which allows the user to add the comment to a pick list. Add the comment to the pick list to keep comments standard and reduce typing. This comment will be available for future corrections related to data download periods.
 6. Notice in the graph, the portion of the time series that was corrected appears as a green line as it is still part of the 'Raw' (original) data. Aquarius doesn't change the original data. The corrected time series is the blue line. In the Time Series Grid notice that the raw data values are still all there and are in green-shaded cells. The adjoining corrected column now shows the word 'Empty' next to raw data that has been deleted. There is now information in the Correction History Manager documenting the correction. If the data points need to be restored, click undo in the Correction History Manager.
 7. Select the **Save and Exit** icon.

SOP 7: Data Management
SIEN River Monitoring Protocol

It is important to document any corrections for both program staff and others that may be using the data. We will use a measurement and site summary worksheet developed by NPS-WRD staff and based on USGS Standard Form 9-207 (Table 7.1) and in the future a water year discharge computation checklist specific to Aquarius (to be developed by NPS-WRD). These forms track changes including key site visit information, summary of discharge measurements and corresponding heights, and any data corrections by station and water year. This information is essential for managing rating curves.

SOP 7: Data Management
SIEN River Monitoring Protocol

Table 7.1. Example measurement and site summary worksheet from Saguaro National Park.

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. Datalogger 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.
08/08/07			8:55	Chuck Perger	3.14	FLOW	3.05	0.09	0.09				Staff plate viewed from opposite bank, with turbulence staff reading may be at ±0.02. 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.

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 GH¹ - 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 Descriptor² - **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

7.4.8. Filling in Missing Stage Data

In some cases, it may be necessary to fill in missing data. However, filling in missing data should only be attempted if there are reasonably accurate means to do so. In some situations, a backup recording streamgauge 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 a 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) 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 to 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. Unfortunately, finding appropriate data for this approach is unlikely in the SIEN.

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 (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. SIEN will employ the assistance of an expert for any work of this sort and synthetic or generated data will be clearly documented.

7.5 Rating Curves

Once the instantaneous (15-minute) water stage data have been corrected, additional steps are needed to convert water stage data to discharge. These steps include the establishment and maintenance of the stage-discharge relationship (rating curve) followed by computation of a 15-minute discharge record. The development of the rating curve 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). SIEN will be using simple ratings. 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 (1982b).

A rating curve is developed from numerous stage and discharge measurements and computations made at the site over a range of flows. The rating curve is produced using the Rating Development toolbox in Springboard to plot stage versus discharge (typically gage height in feet versus discharge in cubic feet per second). Increasing the number of points used to develop the curve increases its precision. A minimum of 10 points per year is recommended initially. The

rating curve will likely shift over time thereby requiring periodic measurements to either confirm the permanence of the rating or to apply changes/shifts in the rating. To attain the highest level of accuracy, it is important to include measurements taken at high and low flow extremes.

Otherwise, extrapolating values for discharge outside of the range of actual stage/discharge measurements can introduce error.

SIEN will manage the rating curves for the two sites in the upper Tuolumne watershed. Both of these sites have historic data and rating curves are being developed by the historic operators. We will obtain the rating curves from the previous operators and continue to maintain them.

There are two toolboxes available in Springboard that we will use to maintain and apply the rating curves. The Aquarius Rating Development toolbox is used to develop and manage rating curves. The Rating Curve Player toolbox is used to apply the rating curve to the corrected stage data and calculate 15-minute discharge.

7.5.1. Developing and Maintaining Rating Curves

The development and maintenance of rating curves requires training in hydrologic principles and cannot be fully described in a linear SOP. Thus, the purpose of this portion of the SOP is to orient the user to Aquarius and the basic procedures to develop and maintain rating curves in the Aquarius environment. We recommend watching the online Aquarius training videos featuring rating curve development as a compliment to these instructions. The Physical Scientist should also reference the rating curve sections SOP 10 for quality assurance and control considerations.

To create a rating curve in Aquarius:

1. In the Sierra Nevada Network/Rivers Monitoring folder double click on the station of interest to open that station.
2. Open the **Location Manager** (notebook icon at the top).
3. Select the **Data Sets** tab and then under the New drop down menu select **Rating Curve**.
4. Complete the Data Set Details:
 - a. Give it a unique label name
 - b. Add a description and comments as appropriate
 - c. For the Inputs select Stage and ft
 - d. For the Outputs select Discharge, ft^3/s , and PDT.
 - e. Click on the **Save** icon (disk on top left) and exit the Location Manager.
5. On the Data Sets page highlight the rating curve you want to edit and click on the **Rating Development** tool (graph icon). This will open a new window that has multiple customizable windows within it. The key windows are noted in the screen capture (**Figure 7.11**).

6. Identify the points to include in the rating curve. View the field data in the Field Visit Table Box (**Figure 7.11, 1**) and click/unclick the Status box to select/unselect the points to include in the rating curve.
7. View the selected points graphed on a log-log plot by selecting the **Rating Zoom 1** view (**Figure 7.11, 2**). Note that you can also select and deselect points on the graph using the Select and Unselect Measurement Points icons.
8. Set the offset in the Offset Manager box (**Figure 7.11, 3**).
 - a. Check the **Offset 1** box and enter the offset value in the adjacent box.
 - b. To determine the offset value start with the estimated point of zero flow.
 - c. In the Rating Zoom 1 (**Figure 7.11, 2**) box add rating points just below the lowest point and above the highest point. Aquarius will automatically create a line connecting these two points. This line is your rating curve. Adjust the offset number to achieve the best match between the line and data points.
 - d. You can extrapolate a conservative distance beyond the end points of the curve. When selecting the low and high end points of the curve consider that the end point should never exceed twice the measured discharge and it should not go beyond a stage level where the geometry of the channel changes.
9. View the rating equation in the Rating table (**Figure 7.11, 4**) and view the residuals in the Shift Diagram box (**Figure 7.11, 5**) to see how well the data fit the curve.
10. Define the period of applicability.
 - a. View the data and rating curve in the Time Series View (**Figure 7.11, 6**) to determine the time period that the rating curve covers.
 - b. Open the **Rating Period Manager** box (**Figure 7.11, 7**).
 - c. Check the **Rating Period Box**.
 - d. Enter the Start Date/Time and the End Date/Time.
 - e. Click Apply.
 - f. You can also adjust the date range visually on the time series graph. Select the **Adjust Date** icon and manually move the Rating bar located below the time series graph.
11. Breaking points: If there breaking points in the curve (e.g. between the section and channel controls) you can break the data into sections and create rating curve equations for each section. This is accomplished through the Offset Manager box.

- a. Open **Offset Manager** box (**Figure 7.11, 3**).
- b. Select **Offset 2** to create a second curve.
- c. Identify the transition point. This is the data point that transitions between the two offsets – it will be included in the data for the offset above and below it.
- d. Enter the break point. The break point is determined by the stage of the transition point on the curve.
- e. Create the second rating curve equation using the same steps as the first equation.

Once a rating curve is developed it will be routinely updated following site visits. Once a field visit is entered into Aquarius, the Physical Scientist can update the rating curve with the new discharge measurement(s).

1. Open the **Rating Curve Development** toolbox.
2. You should see the newly entered point on the graph. It will initially be inactive so will appear greyed out.
3. In the **Field Visit Table** (**Figure 7.11, 1**) activate the new point by checking the box in the status field.
4. If the new point is outside the date range, update the rating period in the **Rating Period Manager** (**Figure 7.11, 7**). If it is outside the range, the data point symbol will be smaller than those within the range.
5. Assess how well the new point fits to the existing curve by viewing the error results and residuals on the shift diagram. If you are comfortable with the new point, you can adjust the offset as/if needed and update the curve.

SOP 7: Data Management

SIEN River Monitoring Protocol

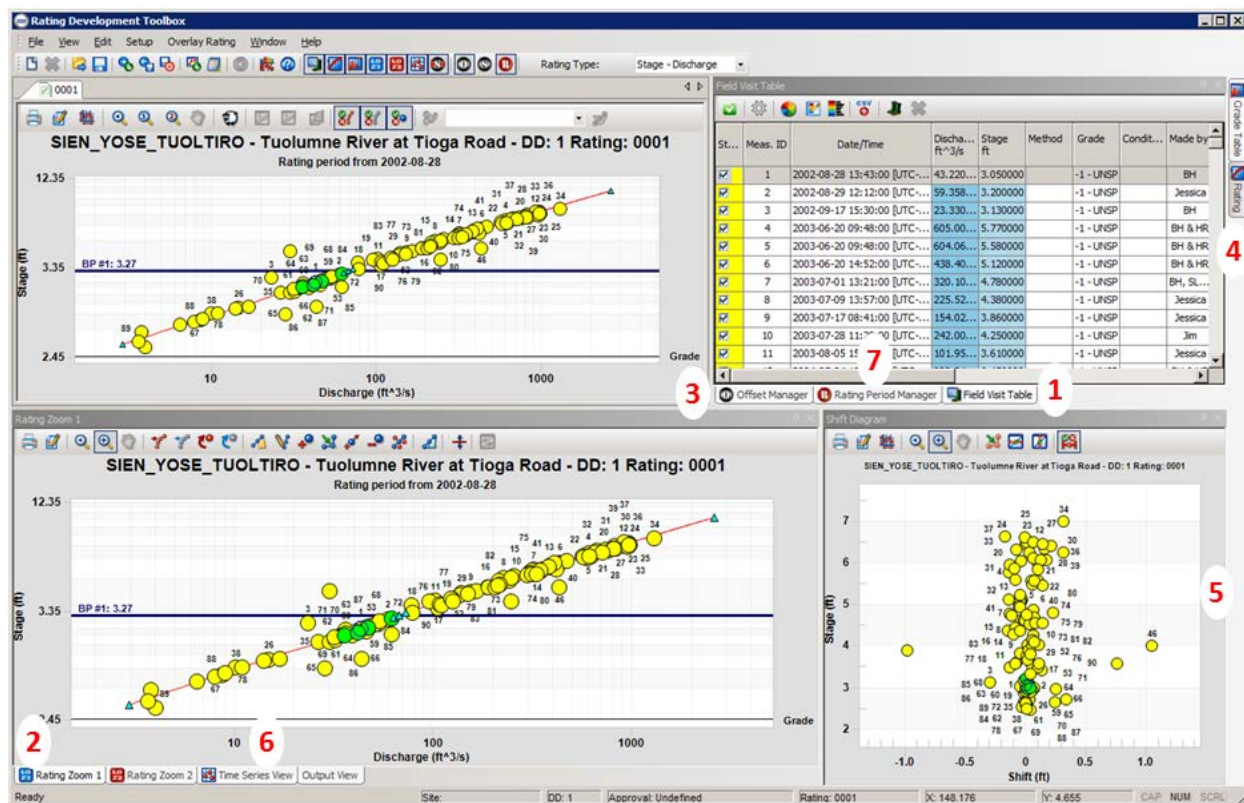


Figure 7.11. Rating Curve Development toolbox. The numbered items are (1) Field Visit Table, (2) Rating Zoom 1 view, (3) Offset Manager tab, (4) Rating box, (5) Shift Diagram, (6) Time Series view, and (7) Rating Period Manager tab.

7.5.2. Calculating Discharge

To calculate discharge:

1. In the Sierra Nevada Network/Rivers Monitoring folder double click on the station of interest to open that station.
2. Open the **Location Manager** (notebook icon at the top).
3. Select the Data Sets tab and then under the **New** drop down menu select **Time Series – Rating Curve Derived**.
4. Complete the data set details section.
 - a. Complete the label (name), description, and comments as appropriate.
 - b. Rating curve: from the drop down menu select the rating curve that you want to use.

- c. Inputs: from the drop down menu select the stage data set that you want to apply the curve to.
- d. Output: the parameter will default to discharge. Select the units and time zone.
- e. Gaps: The recommended setting for the gap tolerance is one minute longer than the time interval of the data (e.g. set a 15 minute data set to 16 minutes).
- f. **Save and Exit the Location Manager.**
- g. The new discharge data set will show up on the list of station data sets.
- h. Double click on the discharge data set to enter the **Rating Curve Quick View Toolbox.**
- i. In the **Rating Curve Quick View Toolbox** you can view and edit the resulting hydrograph.

7.6 Validation, Verification, and Certification

Data are validated by the field technician collecting the field and uploading it to Aquarius. After entering and uploading data, the field technician will compare all typed database entries to the data sheet. They will then scroll through uploaded data files and note any noticeable data quality concerns. Concerns will be reported to the Physical Scientist.

Data verification is completed by the Physical Scientist on an annual basis, following the end of each water year. The Physical Scientist will check 10% of the field data sheet entries for transcription errors. Individual stage and discharge data points will be compared with the rating curve to identify additional potential errors. All rating curves and associated equations will be checked in this fashion.

Once the Physical Scientist has completed the verification of the field data, examined the continuous data in Aquarius, applied appropriate corrections, and is comfortable that the data are of high quality they will complete the data certification form. Data are certified annually.

Sierra Nevada Network River Hydrology Monitoring Protocol

SOP 8: Data Analysis

Version 1.0

This standard operating procedure is part of the Sierra Nevada Network River Hydrology Monitoring Protocol, but is designed to be printed and viewed as a separate document.

Revision History Log

Previous version #	Revision date	Revised by	Changes	Justification	Page #'s affected	New version #

Training:

Watch the Aquatic Informatics video “Introduction to the Descriptive Statistics Toolbox”. <http://aquaticinformatics.com/support-login>. Usernames and passwords are supplied by Aquatic Informatics. Choose the ‘Aquarius 360 Customer Support’ portal and click ‘Login’. Click on ‘AI Training Videos’, found in the tabs along the top of the screen. In the ‘View:’ drop-down, select ‘Chapter 11 – Aquarius Whiteboard Toolbox’ and then click on ‘Introduction to Descriptive Statistics Toolbox’.

8.1 Hydrologic Summary Analyses

This SOP describes the procedures for calculating hydrologic and water temperature summary statistics, developing flood frequency curves, and creating figures for reports.

8.1.1. Descriptive Statistics

The summary descriptive statistics that are calculated for each report are listed in **Table 8.1**. We will use a couple of programs to calculate these statistics with Aquarius software being the primary (Aquatic Informatics). The Aquarius software has built-in toolboxes which allow for the easy output of summary statistics. Some of the statistics selected for this protocol are not currently built into the Aquarius toolboxes, and these are noted in **Table 8.1**. However, we will work with Aquatic Informatics to build the necessary formulas and tools. If Aquarius developers cannot build tools for specific statistics, we will calculate the statistics using MatLab scripts developed by Ned Andrews (2012). The example script shown in **Figure 8.1** has been written to calculate three statistics. We recommend working with Ned Andrews to modify the scripts for each station. While the MatLab scripts are a good backup, the advantage of using Aquarius tools is that the inputs from all stations can be routed through the statistics toolbox such that the statistics for all stations are calculated at once.

The procedures associated with calculation of snowmelt timing statistics are not as well established. A variety of techniques have been used in the hydrologic literature. For example, a number of methods have been developed to calculate the onset of snowmelt using streamflow records (Cayan et al. 2001, Lundquist et al. 2004). We will utilize the method established in Lundquist et al. (2004) unless the current literature suggests that an improved method is available.

Table 8.1. Hydrologic parameters that are measured or calculated for SIEN reports.

Parameter	Measured or Calculated	Currently built into Aquarius toolboxes	Procedure
Water level	Measured	n/a	Collected by logger at 15-minute intervals (reported for SIEN-supported sites)
Instantaneous discharge	Measured	n/a	Direct measurement, salt solution, or indirect measurement by survey of the cross section (reported for SIEN-supported sites)
Mean daily and mean annual discharge	Calculated	Yes	Calculated using 15-minute discharge. (Calculated by SIEN for SIEN-supported sites; requested for cooperator sites)
Instantaneous peak discharge	Measured and calculated	Yes	Projected from rating curve to match the peak water level or measured using discharge measurement methods. (Calculated by SIEN for SIEN-supported sites; requested for cooperator sites)
April, May, June, July percent of annual flow (AMJJ/Annual)	Calculated	No	Total discharge measured during April – July / Total discharge for the water year. Calculated from mean daily values.
Days to runoff center of mass (CM) – also referred to as center timing	Calculated	No	The number of days from the beginning of the water year (Oct 1) to the date when half the total annual water year discharge has occurred. Calculated using mean daily values. $CM = \frac{\sum_i (T_i Q_i)}{\sum_i Q_i}$
Days to onset of snowmelt	Calculated	No	The number of days from January 1 to when the cumulative departure from the mean flow is most negative. See Lundquist et al. (2004). Calculated using mean daily values.
3, 7, 10, and 14 day high flow	Calculated	Yes	The highest mean daily flows over 3, 7, 10 or 14 consecutive days.
3, 7, 10, and 14 day winter and summer low flow	Calculated	Yes	The lowest mean daily flows over 3, 7, 10 or 14 consecutive days. Winter = December through February Summer = July through September
No. of days from Oct 1 to the winter and summer 7-day low flow	Calculated	No	Count of days to the summer 7-day low flow. Calculated using mean daily values.
No. of days from Oct 1 to 3-day and 14-day high flow	Calculated	No	Count of days to the 3 and 14 day high flows. Calculated using mean daily values.
Water temperature	Measured	n/a	Collected by logger at 15-minute intervals
Mean daily and mean annual water temperature	Calculated	Yes	Calculated using 15-minute temperature data
Daily and annual minimum and maximum water temperature	Calculated	Yes	Calculated using 15-minute temperature data

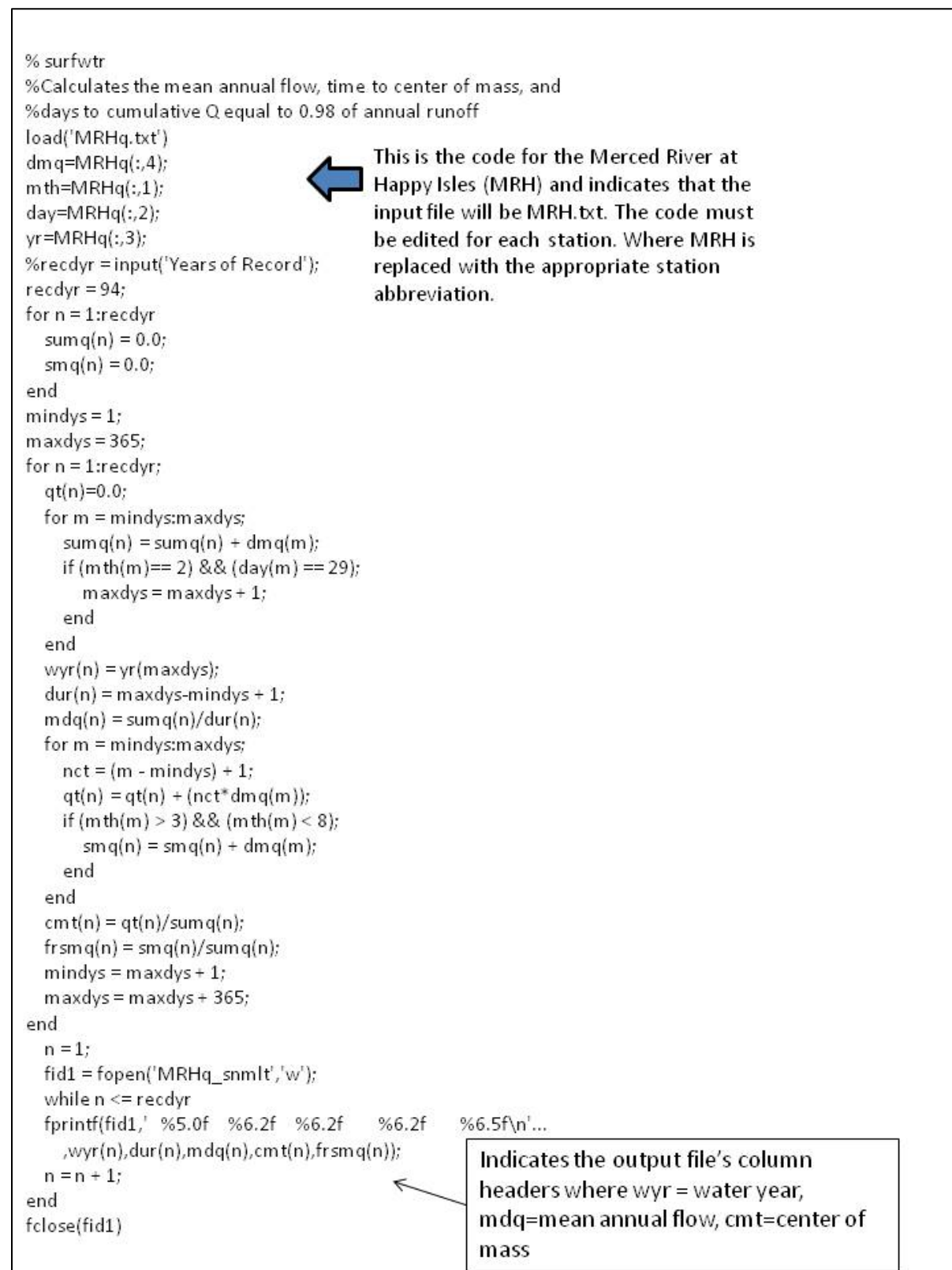


Figure 8.1. Example MATLAB script for calculating the mean annual flow, time to center of mass, and days to 98% of total annual runoff at the Merced River at Happy Isles station.

8.2 Trend Analysis

SIEN is testing for trends in a suite of temperature and hydrologic statistics. Neither broad regional studies nor a specific analysis of Sierra Nevada data could identify widespread significant trends in mean annual streamflow (Pagano and Garen 2005, Luce and Holden 2009, Andrews 2012). However, stationarity, or lack of trend, in mean annual flow does not indicate stationarity in the rest of the distribution (Luce and Holden 2009). For example, even if no trend is observed for mean annual flow, trends may be observed in the winter or summer mean flows. For this reason, it is important to examine trends in mean annual discharge as well as a number of additional hydrologic statistics that are more descriptive of streamflow timing (**Table 8.2**).

Table 8.2. Hydrologic parameters that are analyzed in SIEN trend reports.

Parameter
Mean annual discharge
Instantaneous peak discharge
April, May, June, July percent of annual flow (AMJJ/Annual)
Days to runoff center of mass
Days to onset of snowmelt
3, 7, 10, and 14 day high flow
3, 7, 10, and 14 day winter and summer low flow
Number of days from Oct 1 to the winter and summer 7-day low flow
Number of days from Oct 1 to 3-day and 14-day high flow
Mean daily and mean annual water temperature
Daily minimum and maximum water temperature

Trend analyses should not only focus on the entire period of record, but alternate time scales as well (i.e. a subset of the period of record). USGS hydro-climatology researcher Mike Dettinger, in his review of Andrews (2012), suggested:

“All of the trend tests reported spanned the entire period of (reasonably complete) record of each time series. This is a standard statistical approach, but may be questionable here. Considering that the anthropogenic greenhouse forcings that are suspected to underlie at least some of the trends being tested for have mostly been imposed during the past 40 years, the inclusion of many decades prior to the 1960s or 1970s in the trend analyses may be doing more to water down, or mask, important trends than to make them more

detectable or reliably identified. To be specific, as shown in Figure 2 in Dettinger (2005), about 80 to 90% of the anthropogenic greenhouse forcing increases of the 20th Century occurred after about 1970.”

Similarly, Dettinger suggested examining streamflow with respect to known past Pacific Decadal Oscillation and El Nino-Southern Oscillation time periods.

The first step in identifying alternate time periods is to plot the data that will be analyzed and visually examine them for apparent trends. While trends observed in the visual assessment step may not be statistically significant, they can provide an overview of how a parameter has changed over time. For example, if the smoothed trend lines hint that a trend has been up for 10 years and then down for 10 years, a typical monotonic trend test might conclude “no trend” (Manly 2001). This conclusion might be less helpful to a resource manager than a conclusion that might result from looking at a simple plot of values vs. time.

The first step in trend analysis is to calculate an annual value for each of the descriptive statistics for the period of record for each station and the second is to select a trend analysis method(s). There are several parametric, non-parametric, and mixed methods for hydrologic trend analysis. In preparation for this protocol, Starcevich and Kane (2017) performed trend analyses for multiple statistics from two SIEN rivers and found that a parametric test may be significant at the 0.10 level when the nonparametric test is not significant and vice versa. For this reason and to add weight to any significant results, we will use more than one test when performing our trend analysis. Trend analyses will be performed for single stations and aggregated groups of stations (e.g., aggregated by park and network).

We will first conduct trend analyses with parametric tests if assumptions of normality are met as parametric tests typically provide higher power (Starcevich and Kane 2017). We will use linear regression as described in Andrews (2012) and Starcevich and Kane (2017) for single station trend analyses. Linear regression is considered a fundamental tool in the analysis of water-resources data (Helsel and Hirsch 2002) and can be a powerful method for detecting trend if the assumptions of the models are met (Starcevich and Kane 2017). Linear regression is the process of fitting a straight line to a data set that consists of an explanatory (independent, predictor, or *X*) variable and a response (dependent, predicted, or *Y*) variable. We will use a linear mixed model, as described in the trend and power analysis, to examine trends for multiple stations and as a secondary parametric analysis for single stations (Starcevich and Kane 2017). A mixed model allows some effects to be considered fixed and some to be considered random. Fixed effects contribute to the mean of the outcome and random effects contribute to the variance. Random effects are used to estimate variation of linear trends among subjects (e.g., streams) and over time.

If assumptions for parametric trend tests are not met, nonparametric tests will provide a more powerful and robust approach (Starcevich and Kane 2017). We will use the Kendall tau-b test as our primary nonparametric test for single stations per Andrews (2012) and Starcevich and Kane (2017). The Kendall tau-b uses the ordinal nature of the year covariate and the ranks of outcomes of interest to find trends in the data. The Kendall tau-b is a rank test that uses the qualities of the ranks in the presence of no trend to assess trend as opposed to distributional assumptions. This method has been used by the US EPA (Kelly and Jett 2006) and by state natural resource

agencies to detect hydrologic trends. The Regional Kendall Test (Helsel and Frans 2006) is nonparametric approach that can be used to assess the trends across multiple stations (e.g. park and network groupings). We will use this method when the assumptions for the mixed linear model are not met and as a secondary test for the linear mixed model when assumptions are met.

In addition to the primary and secondary trend tests discussed above, we will mention two other tests that may be of interest to the data analyst. These tests are commonly used by the USGS, other agencies, and researchers and are likely to be considered when comparing SIEN data to other analyses that use these methods. Helsel and Hirsch (2002) recommend the Kendall-Theil robust line as a nonparametric alternative to linear regression for statistical analysis of water-resources data. One example of its application is by Stahl et al. (2010) who used this approach to assess discharge trends in watersheds throughout Europe. This robust nonparametric method is resistant to the effects of outliers and non-normality in residuals that commonly characterize hydrologic data sets. The USGS has created a Visual Basic program for using the Kendall-Theil robust line (Granato 2006). The Mann-Kendall Test (MKT) is another nonparametric statistical method used to assess trends in data sets that has been used by the USGS to assess trends at their streamgages (Lins and Slack 1999). The advantages of this test are that it is widely-used and applicable to any type of monotonic trend (i.e., not just linear changes). Burn and Elnur (2002) also used the MKT non-parametric test to detect trends in hydrologic variables.

Finally, our data analysis will involve exploration of covariates as appropriate. We will use a step-wise linear regression of log transformed values of stream discharge (i.e., total annual) in a regression with the annual precipitation volume, or the percent of precipitation arriving in a given season within a watershed (i.e., AMJJ precipitation as a percent of the total annual precipitation). Other potential covariates may include, but are not limited to, snow water content at snow courses within each watershed and water temperature (from those streamgages where temperature is recorded continuously). Burn and Elnur (2002) are a good reference as they investigated trends in hydrologic variables as they relate to meteorological variables and response to climate change. Precipitation and snow water content for nearby climate and snow course monitoring stations may be obtained from CDEC (<http://cdec.water.ca.gov/>).

8.3 Additional Hydrologic Analysis

Several of the streamgages selected for this protocol occur along an elevational gradient within watersheds (**Table 8.3**). These stations were installed along the elevational gradient and were selected by SIEN in part because the magnitude of observed and predicted hydrologic changes varies with elevation, as described in the protocol narrative. Our exploratory data analysis will involve calculating the ratio of the contributing area to the mean annual, mean monthly or seasonal mean discharge at each gage. We will examine the variability of this ratio between years and between stations.

Table 8.3. SIEN watersheds containing streamgages located along an elevational gradient. Both watersheds are in YOSE.

Watershed	Station name	Elevation	Contributing Area
Merced River	Merced River at Happy Isles	4,017 ft	181 mi ²
	Merced River at Pohono Bridge	3,862 ft	321 mi ²
Tuolumne River	Lyell Fork of the Tuolumne below Maclure Creek	9,615 ft	6.0 mi ²
	Tuolumne River at Tioga Road Bridge	8,583 ft	70.6 mi ²
	Tuolumne River above Hetch Hetchy	3,830 ft	301 mi ²

8.4 Flood or Low-Flow Analyses

The flood (or high-flow) 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 (1972) 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 recurrence interval (or return period) 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 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 one. For low-flow analyses, the smallest event is assigned a rank of one (Riggs 1972). Once the data are 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 (Riggs 1972, Linsley et al. 1982). Specific procedures for fitting a frequency curve are also found in Linsley et al. (1982) and Riggs (1972). In the examples used by Riggs (1972), 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.

We will use the flood frequency analysis function in Aquarius Hydrologic Statistics toolbox, from which the user may select from several methods including the log-Pearson Type III distribution, to perform these analyses and create figures for our reports (**Figure 8.2**).

8.4.1. Flow Duration Curve

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. 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). If segments of missing or unreliable data exist, these data 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 completed in Aquarius or Microsoft Excel.

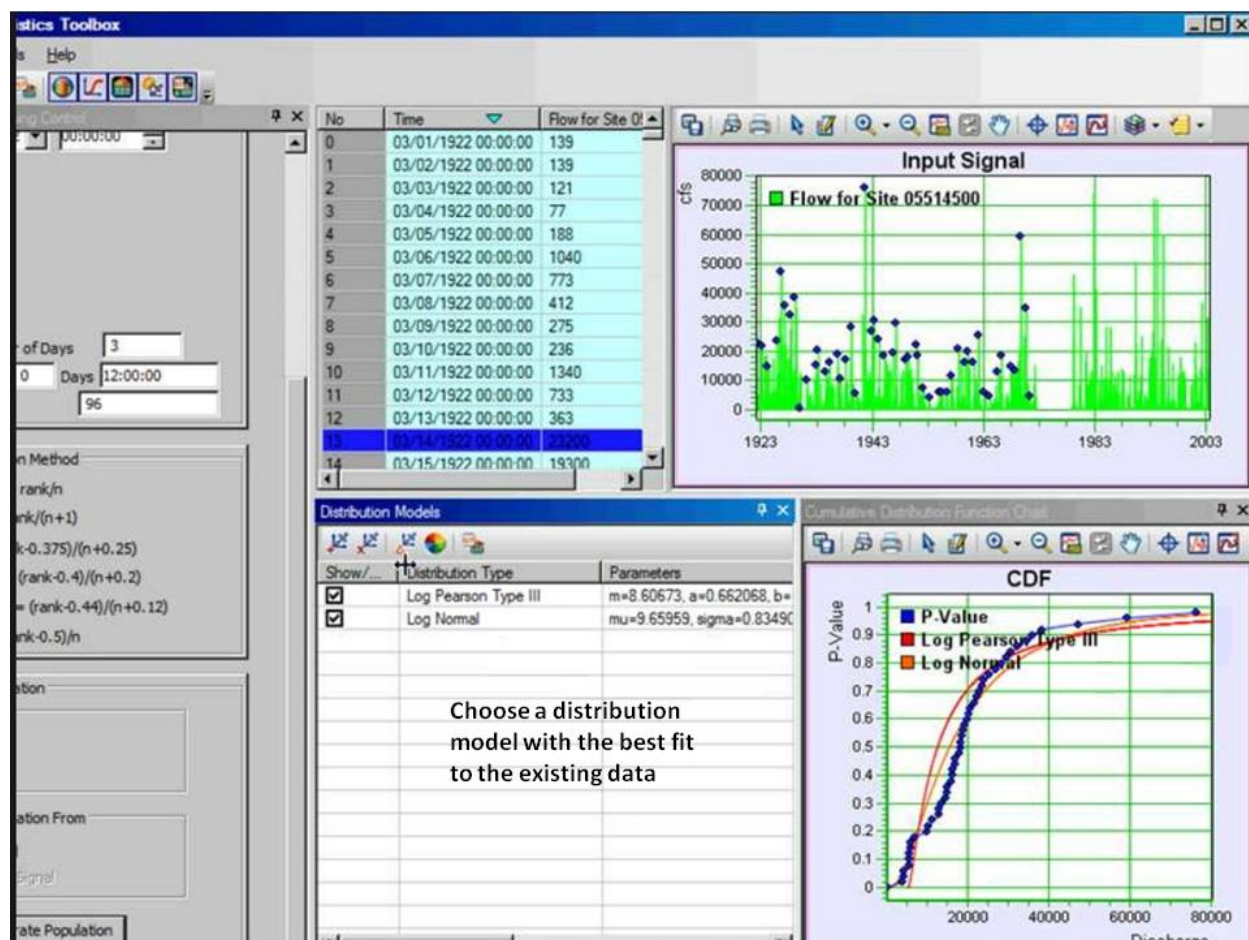


Figure 8.2. A snapshot of the Hydrologic Statistics toolbox in Aquarius.

Sierra Nevada Network River Hydrology Monitoring Protocol

SOP 9: Reporting

Version 1.0

This standard operating procedure is part of the Sierra Nevada Network River Hydrology Monitoring Protocol, but is designed to be printed and viewed as a separate document.

Revision History Log

Previous version #	Revision date	Revised by	Changes	Justification	Page #'s affected	New version #

9.1 Reporting Schedule

Hydrologic data will be analyzed and reported every two years in a hydrologic status report, as well as every four years in comprehensive status and trend reports (**Table 9.1**). Resource briefs summarizing highlights from the aforementioned reports will be published following the completion of each report. All reports will be published through the National Park Service's Natural Resources Reports (NRR) or Natural Resources Data Series (NRDS). The format for these reports and more detailed descriptions of the suggested content are included in this SOP. Prior to publication, reports will be sent to those organizations whose data is included in the reports so they may have an opportunity to comment.

Table 9.1. The reporting schedule for the first six years of this protocol. Schedule repeats with a trend report each four years and status report each two years.

	FY 2018	FY 2019	FY 2020	FY 2021	FY 2022	FY2023
Hydrologic status report	For WYs 2016 & 2017		For WYs 2018 & 2019		For WYs 2020 & 2021	
Comprehensive hydrologic status and trend report		Through WY 2017				Through WY 2021

9.2 Hydrologic Status Reports

The hydrologic status report will loosely follow the format of USGS' Annual Water Summary Reports (formerly the Annual Water Data Reports), but will be produced every two years. The suggested content for status reports is included here, and the Physical Scientist will periodically consult with park staff to determine whether the content is still appropriate for their needs. The Physical Scientist may elect to expand on these analyses, time permitting.

Required and suggested content:

1. Yearly hydrographs for each station (required): A discharge hydrograph is a plot of daily mean discharges (vertical axis) versus time (horizontal axis). 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, the median daily discharge for the period of record, instantaneous discharge measurements, and any other information that may be of importance. Any estimated discharges will be indicated in red.
2. Temperature time series for each station (required): The time series is a scatter plot of daily mean, minimum, and maximum temperature (vertical axis) versus time (horizontal axis). All time series 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 plot for each station includes station name, water year, date the plot was created,

drainage area, manual temperature measurements, and any other information that may be of importance.

3. Summary statistics for each station (required): Report on the summary statistics listed in **Table 9.2**. Note any peak events (i.e., highest flow in 50 years – equal to the 50 year flood). Be sure to note if peak events occurred outside the runoff period and identify whether they were associated with some atmospheric phenomenon such as a large rain event. Discuss the number of extreme events that have occurred in the recent years compared to the period of record. See the SIEN Climate Reporting Protocol (Skancke et al. 2012) for climate data and reports.
4. Mean annual and peak discharge in relation to watershed snow water equivalent (SWE) (suggested): Reference the CDWR snow course watershed summaries.
5. Any failures by SCE to meet minimum in-stream flow requirements in SEKI (required): Although this report will be published every other year, the Physical Scientist will compare minimum flows with flow requirements on an annual basis and verbally communicate to park staff any failures by SCE to comply. Flow requirements are:
 - a. Site 227a (Marble Fork at Potwisha): Sept - Dec 1.5 cfs; Jan - Feb 6.0 cfs; March - June 9.0 cfs; Jul - Aug 6.0 cfs
 - b. Site 209 (Middle Fork nr Potwisha): Sept - Dec 9.5 cfs; Jan - Feb 14 cfs; March - June 30 cfs; Jul - Aug 14 cfs

The following statistics will be calculated for every station, but may be placed in an appendix:

1. The 3, 7, 10 and 14-day winter and summer low flows and the dates on which they occurred.
2. The 3, 7, 10, and 14-day high flows and the date on which they occurred.
3. The number of days from October 1 to the 7-day winter and summer low flows.

Note: For multi-day low or high flow statistics (i.e., winter 3-day low flow) the date reported is the first day of the multi-day high or low flow.

USGS annual water summary reports will be included in an appendix for stations where the data are managed and served by USGS.

Table 9.2. An example of the summary statistics table that is included in the hydrologic status reports.

<Station Name>			
Summary Statistics	Water Year 2009	Water Year 2010	Water Years 1917-2010 (Period of Record)
Annual total discharge (cfs)	247,079	266,961	179,566.1
Annual mean discharge (cfs)	677	731	627
Highest annual mean (cfs)			1,466 in 1983
Lowest annual mean (cfs)			127 in 1977
Highest daily mean (cfs)	4,380 on May 2	6,230 on June 7	21,000 on Jan 2, 1997
Lowest daily mean (cfs)	18 on Oct 1	18 on Oct 1	5.4 on Oct 26, 1977
Maximum peak flow (cfs)	6,900 on June 4	7,010 on June 7	24,600 on Jan 3, 1997
Annual seven-day minimum (cfs)	19 on Sept 27	19 on Oct 1	5.6 on Oct 20, 1977
Annual seven-day maximum (cfs)	1,200 on June 3	1,575 on June 2	14,100 on June 1, 1997
Number of days to snowmelt Onset	161	155	166
April, May, June, July discharge as a percent of the total annual discharge (AMJJ/Annual)	65 percent	62 percent	71 percent
Number of Days from Oct 1 to the runoff center of mass	125	137	145
Annual mean water temperature (C°)	12.5	12.0	
Annual min and max water temperature (C°)	1.0	20.0	

9.2.1. Daily Values Table

Daily values tables that display daily mean discharge, daily mean temperature, daily minimum temperature, and daily maximum temperature are created for each water year. The format for these tables will follow the example daily mean discharge value table presented in **Table 9.3**. These tables are included in the report appendices. 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, daily, monthly and instantaneous peak discharge values, and annual mean, minimum, and maximum water temperature.

SOP 9: Reporting
SIEN River Monitoring Protocol

Table 9.3. Mean daily discharge (example data set from Easkoot Creek monitored by the San Francisco Bay Area Network).

UNITED STATES DEPARTMENT OF THE INTERIOR - NATIONAL PARK SERVICE - WATER RESOURCES DIVISION
STATION NUMBER 375353122381901 EASKOOT CREEK AT STINSON BEACH, CA STREAM SOURCE
LATITUDE 37 53 53 LONGITUDE 122 38 19 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									

9.3 Comprehensive Status and Trend Reports

The comprehensive status and trend reports contain similar summary information to the summary reports along with additional analyses including trend tests on hydrologic and temperature statistics for the longer data sets and flow duration curves. Trend analyses are conducted by single station, network, and park. To facilitate comparisons to broader analyses done by others, we have selected many of the same metrics that current peer-reviewed articles have used to analyze trends in hydrologic time series data (e.g., Andrews (2012) and Burns and Elnur (2002)). **Table 9.4**, from Andrews (2012), allows the reader to compare observed trends among stations and statistics. Similar tables will be created for the comprehensive status and trend reports. SIEN comprehensive status and trend reports will include an addition table, of the same format as **Table 9.4**, displaying temperature trend results.

Table 9.4. Evaluation of trends in selected hydrologic characteristics representing the temporal distribution and magnitude of streamflows by the method of Kendall's tau. Positive trends are identified by (+) and shown in green. Negative trends are identified by (-) and shown in orange. The significance of trends is expressed by the p-value, for example, p = 0.05 indicates that a trend is significant at the 95 percent level. Table is from Andrews (2012).

		7-Day	14-Day	Calendar Days to 7-Day	Calendar Days to 14-Day	Calendar Days to 7-Day	Calendar Days to 14-Day	Calendar Days to 3-Day	Calendar Days to 14-Day	Annual Mean Discharge
Merced River at Happy Isles Bridge near Yosemite	11264500	+	+	None	None	None	None	-	-	None
		.015	.014					.038	.035	
Merced River at Pohono Bridge near Yosemite	11266500	+	+	None	None	None	None	None	-	None
		.036	.047						.214	
Bear Creek near Lake Thomas A. Edison	11230500	+	+	+	+	None	+	-	-	+
		.043	.032	.009	.106		.143	.138	.085	.207
Pitman Creek below Tamarack Creek	11237500	+	+	+	+	+	None	None	-	+
		.0148	.0041	.0072	0.567	.0037			0.183	.234
Kern river near Kernville	11186000	+	+	None	-	-	None	-	-	None
		.181	.149		.256	.153		.0128	.033	
West Walker River below Little Walker River near Coleville	10296000	None	None	None	-	-	+	-	-	None
					.168	.236	.091	.002	.024	
Middle Fork Tuolumne River near Oakland Recreation Camp	11282000	+	+	+	+	None	None	-	None	None
		.110	.114	.073	.055			.235		
South Fork Tuolumne River near Oakland Recreation Camp	11281000	+	+	+	None	-	None	None	None	None
		.131	.118	.134		.047				
Middle Fork Kaweah river near Potwisha Camp	11206500	None	None	+	None	+	None	+	None	None
				.285		.049		.262		
Marble Fork Kaweah River at Potwisha Camp	11208000	None	None	None	None	None	None	+	None	None
								.264		
South Fork Kaweah River at Three Rivers	11210100	+	+	+	None	None	None	-	None	None
		.223	.176	.269				.28		
San Joaquin River Miller Crossing	11226500	+	+	+	None	None	None	None	None	None
		.190	.164	.087						
Clavey River near Buck Meadows	11283500	+	+	-	+	-	+	+	+	+
		.110	.088	.199	.076	.251	.084	.028	.056	.026
North Fork Tuolumne River Long Barn	11284700	+	+	+	None	-	+	None	None	+
		.109	.130	.286		.050	.084			.101

Sierra Nevada Network River Hydrology Monitoring Protocol

SOP 10: Quality Assurance Plan

Version 1.0

This standard operating procedure is part of the Sierra Nevada Network River Hydrology Monitoring Protocol, but is designed to be printed and viewed as a separate document. The majority of the content for this SOP has been adopted from the San Francisco Network Streamflow Protocol (Fong et al. 2011) and USGS quality assurance plan guidance.

Revision History Log

Previous version #	Revision date	Revised by	Changes	Justification	Page #'s affected	New version #

10.1 Purpose

This SOP defines procedures for quality assurance and quality control (QA/QC) to be used with the SIEN River Hydrology Monitoring Protocol and provides guidance to ensure high data standards are met. Quality assurance is the planned and systematic pattern of all actions necessary to provide adequate assurance that a project outcome optimally fulfills expectations. Quality control is the systematic evaluation of the various aspects of a project to ensure that the standards of quality are being met. Quality control includes quantifiable performance characteristics for data quality indicators like measurement precision, measurement bias, and measurement sensitivity; whereas, most quality assurance measures are qualitative aspects such as staff training and qualifications. Together, QA/QC is a substantial part of any monitoring program. The objective of QA/QC is to ensure that the data generated by a project are meaningful, representative, complete, precise, comparable, scientifically defensible, and reasonably free from bias (Irwin 2008).

The format generally follows the standard water quality assurance plan (QAP) format that is required by the U.S. Geological Survey for their district staff and focuses on river hydrology (Arvin 1995). It has been modified to include more recent guidance provided by Sauer (2002) and Kennedy (1983). 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. This QAP is reviewed and revised at least once every five years in conjunction with our programmatic review so that responsibilities and methodologies are kept current and the ongoing procedural improvements can be effectively documented.

The overall goal of SIEN's river monitoring program is to provide park managers with information needed to make management decisions that will maintain the ecosystem integrity of the Sierra Nevada park units. The specific monitoring objectives are:

1. Detect long-term trends in timing and volume of streamflow using fixed, continuous, water stage recording stations at existing streamgages in selected major watersheds of the SIEN.
2. Detect long-term trends in stream water temperature using continuous temperature loggers at a subset (10) of the streamgages selected for hydrologic monitoring.

10.2 Project Management and Responsibilities

This monitoring program is intended to provide analysis of long-term, well-documented and systematic discharge records (greater than 30 years). The proposed staffing plan involves permanent SIEN staff that are base-funded, specialists, and park staff, including field work performed by technicians supervised by park staff. Programmatic reviews will involve the SIEN water work group and possibly NPS-WRD staff.

10.2.1. 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:

- SIEN Physical Scientist
- SIEN Data Manager
- SIEN Program Manager
- YOSE Hydrologist
- SEKI Hydrologist
- NPS-WRD Hydrologist

10.2.2. Responsibilities

Quality assurance is an active process. Achieving and maintaining high-quality standards for surface-water data are accomplished by well documented 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 10.1** provides a list of the responsibilities of personnel involved in the collection, processing, analysis, storage, or publication of surface water data.

Table 10.1. SIEN staff responsibilities and time contributions to the river monitoring protocol.

Assigned staff and time requirement	Responsibilities
SIEN Physical Scientist 8 pay periods	• Project oversight and administration • Protocol updates and revisions • Install and download water temperature loggers • Provide technical support for SIEN-supported gages, includes periodic site visits • Ensure compliance with safety procedures for SIEN staff conducting field work • Communicate with and solicit data from non-SIEN station operators • Manage continuous stage data and including rating curves for SIEN-supported sites in YOSE • Maintain and archive project records • Perform data summaries and analyses • Complete reports, metadata, and other products • Assist with agreements • Every 4 yrs: Additional 2 PP for comprehensive status and trends report
SIEN Data Manager 1 pay period	• Consultant on data management activities • Facilitate review and posting of data, metadata, reports, and other products to national databases and clearinghouses
SIEN Program Manager 2 pay periods	• Project Lead oversight • Ensure Physical Scientist has received safety training, understands principles, & implements safety procedures • Budget and agreement administration • Consultant on all phases of protocol review and implementation • Review reports and other products

10.3 Data Quality Objectives

Data quality objectives are a series of standards that collectively ensure SIEN is collecting data of known and well-documented quality that meet the protocol objectives. The data quality objectives comprise data quality values, measurement quality objectives (MQOs), and data protection standards. We present a summary of data quality values for the river protocol in **Table 10.2** with additional detail described in the appropriate sections of the QAP. MQOs are quantitative values for QA/QC measures such as accuracy, precision, and bias and are presented within the stage, streamflow, and temperature sections. Data protection standards address data security and identify appropriate audiences for data and metadata (**Table 10.3**). These objectives were informed by existing standards, especially from USGS, and considered when selecting field measurements and gaging station methods and equipment.

Table 10.2. Summary of data quality values for SIEN hydrology and temperature monitoring (table was adapted from Hughes et al. (In prep)).

Data Quality Value	Definition	Protocol Considerations
Precision	Random error that is the measure of the reproducibility of a measurement when an analysis is repeated. It is typically calculated using relative percent difference (RPD) or relative standard deviation (RSD) for two or more measurements.	Instruments are periodically sent to the USGS for calibration and precision assessment. Precision in the field is typically tested by conducting repeated measurements. Precision standards for appropriate measurements and instruments are identified in this QAP
Bias	Systematic error that is the systematic or persistent distortion of a measurement process that causes errors in only one direction (EPA 2002). For historical comparisons, results for bias are usually expressed as a percent recovery with the correct or expected answer being considered 100%.	Instruments are periodically sent to the USGS for calibration. Bias can be difficult to estimate for some hydrologic parameters in the field. For example, we will never know what true discharge is in the field when assessing field discharge measurements. Temperature measurements are assessed by comparison to standardized thermometers.
Accuracy	The overall agreement of a measurement to a known value. An assessment of accuracy includes a combination of random error (precision) and systematic error (bias) components that are due to sampling operations. Accuracy, typically reported as uncertainty (its opposite), is measured directly or calculated as the sum of the square root of the sum of squares of the standard deviation of random errors plus the sum of squares of estimated systematic errors (Sauer 2002).	Instruments are periodically sent to the USGS for calibration and accuracy. Accuracy for discharge measurements is challenging to assess in the field because we cannot know the true discharge under field conditions (see protocol s considerations for bias). Accuracy standards are identified in this QAP for appropriate measurements and instruments.

Table 10.2. Summary of data quality values for SIEN hydrology and temperature monitoring (table was adapted from Hughes et al. (In prep)) (continued).

Data Quality Value	Definition	Protocol Considerations
Alternative measurement sensitivity plus (AMS+)	Provides an estimate of instrument noise and natural heterogeneity in an in situ environment. It is calculated as the range of measurement precision uncertainty based on a sample size of seven samples and 99% confidence.	In situ temperature measurements are assessed using AMS+ per methods described in this QAP.
Representativeness	Measurements represent conditions at the time of sampling. Combined with accuracy, leads to repeatable data collection.	Representativeness of monitor deployment location evaluated by comparison of field data with cross-section profile to assure that station location is at well mixed section of water. Sensor fouling and calibration drift evaluated as part of monthly continuous monitoring site visits. Data adjusted as necessary in accordance with accepted operating procedures.
Comparability	Data are collected using compatible field monitoring equipment. All stations are operated and maintained on a consistent schedule using standardized procedures. Data are assessed and analyzed in accordance with consistent procedures described in this protocol.	The 14 stations SIEN reports on are managed by multiple agencies and organizations. Many operators follow USGS protocols, but differences must always be considered when analyzing interpreting these data across stations. Note that the primary analyses are for single station so comparability is less of a concern.
Timeliness/Currency	Ability to provide data in a consistent and timely manner in order that managers, researchers, and the public have access to the data when they need it.	For SIEN-supported stations, we provide data in near-real time via NWIS and CDEC. QA/QC'ed data sets are available on an annual basis via request to SIEN and eventually will be made publicly available via Aquarius.
Completeness	All data/ measures required to evaluate accuracy representativeness are present; incomplete data sets (either at a location, across sampling locations, or over time) lose utility or relevance. Data records contain values as planned across the period of record.	Methods, sampling plans, and analyses are designed and implemented such that they result in a complete dataset across space and the planned period of record. The hydrologic measurements require a complete annual record and, thus, the protocol includes standardized approaches for estimating discharge when there are gaps in the data set.
Consistent Representation	Use of standard definitions when describing data quality or resource quality based on data	Standard definitions of data quality are described in this protocol and indicated on field forms and in Aquarius.

Table 10.2. Summary of data quality values for SIEN hydrology and temperature monitoring (table was adapted from Hughes et al. (In prep)) (continued).

Data Quality Value	Definition	Protocol Considerations
Security	Access to data, products, and systems limited to appropriate audiences.	The streamflow and temperature data and resulting products do not have any restrictions. Station location information is available upon request, but not made publicly available (Table 10.3).

Table 10.3. Data protection standards for SIEN-supported stations (table was adapted from Hughes et al. (In prep)).

Type of Data	Level of Protection	Rules for Dissemination
Discharge and temperature data (near real-time)	Unprotected	Data available on-line in near real-time
Discharge and temperature data (QA/QC'ed)	Unprotected	Data available upon request and eventually publicly available via Aquarius
Monitoring station locations and full metadata	Operationally protected	Provided upon request to those that have a need to access the station(s)

10.4 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 streamgages associated with this protocol. The objective of operating a streamgage is to obtain a continuous record of stage and discharge at the site. 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 for SIEN-supported sites shall be properly trained, well informed, and follow the data collection procedures established in this protocol.

10.4.1. 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, design and construction, and regular maintenance of a gage can make the difference between efficient and accurate determination of discharge and time-consuming, poor estimations of flow.

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. (1982b). 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 are discussed in Kennedy (1984).

The SIEN Physical Scientist is responsible for i) selecting sites for new streamgages, ii) approval of site design, iii) construction of streamgages and approval of the completed installation, and iv) improving existing streamgages. The Physical Scientist may request technical assistance from a WRD Hydrologist, the YOSE Hydrologist, the SEKI Hydrologist, and/or a USGS Hydrologist.

A program of careful inspection and maintenance of streamgages 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 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 regularly. Any inspection and maintenance information are recorded in the site's field notebook.

10.4.2. Measurement of Stage

SIEN collects manual stage measurements by reading a staff plate or tape down and collects automated 15-minute stage measurements using vented pressure transducers. Instrumentation at a gage is dependent on a balance between cost-efficiency and performance. The responsibility for determining the manual measurement equipment and specific type and model of water-level recorders is held by the Physical Scientist and the primary operator. The equipment should meet SIEN precision and accuracy requirements. The precision should be 0.01 ft (Sauer 2002) for manual data collection and 0.02 ft for pressure transducers (**Table 10.4**). The accuracy should be within +/- 0.02 feet (**Table 10.5**). The SIEN accuracy requirement is slightly higher than the recommended USGS accuracy requirements due to the challenges of monitoring stage in steep mountainous rivers using wilderness friendly equipment. The USGS recommends striving for an accuracy of either 0.01 ft or 0.2 percent of the effective stage being measured, whichever is less restrictive (Boning 1992).

Accurate and precise stage measurement requires not only selecting instrumentation that meets SIEN specifications but also proper installation and continual monitoring of all system components to ensure that accuracy and precision do not deteriorate with time (Boning 1992). At SIEN-supported gages, ensuring that new equipment has been installed correctly and proper maintenance or replacement of instrumentation is the responsibility of the Physical Scientist. This responsibility is accomplished by inspection of the gage height record and comparison to past and current gage heights during station visits. When deficiencies are identified, such as significant drift between visits, staff will repair or correct the problem. Typical problems in the past have included differences between staff gage and datalogger reported water heights.

Table 10.4. Precision of measurements of surface water and related parameters (USGS values are from Sauer (2002)).

Parameter	USGS Precision of Measurements	SIEN 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 ft

Table 10.5. Stream measurement device operating ranges, accuracy, field diagnostic checks, and corrective actions.

Measurement	Instrument	Recommended Water Level Ranges	Accuracy	Field Diagnostic Tests	Corrective Actions
Velocity	Volumetric	N.A.	N.A.	N.A.	Increase sample time or volume.
	Float	N.A.	N.A.		
	Pygmy	0.3 to 1.5 feet depths ¹	1.5–6% from 3 to 0.25 ft/s ²	Spin test greater than 45 secs prior to each use.	If spin test fails, follow maintenance procedures (SOP 3). Assess accuracy by regular certified tow tank calibrations.
	Price AA	>1.5 foot depth	1–6% from 8 to 0.25 ft/s ²	Spin test greater than 2 minutes ⁴ prior to each use	If spin test fails, follow maintenance procedures (SOP 3). Assess accuracy by regular certified tow tank calibrations.
	Flow Tracker	>0.79 inches	±1% of measured velocity, 0.25 cm/s ³	Beam check	If beam check fails follow maintenance procedures in the FlowTracker manual. Assess accuracy by regular certified tow tank calibrations.
	ADCP	0.1-6 m ³	±1% of water measured velocity; ±2mm/s ³	Beam check	If beam check fails, follow corrective actions in manual and ADCP USGS guidance. Assess accuracy by regular certified tow tank calibrations.
Stage Height	Staff gage				Eye exam. If low light, use flashlight
	Pressure transducer (Druck)	0–12 feet (Druck, 5psi)	+/- 0.02 ft	Zero, mid, and full span calibration check at known water depths/min. Frequency is 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 10.5. Stream measurement device operating ranges, accuracy, field diagnostic checks, and corrective actions (continued).

Measurement	Instrument	Recommended Water Level Ranges	Accuracy	Field Diagnostic Tests	Corrective Actions
Topographic	Topcon Autolevel AT-G2 or Laser Beacon	N.A.	<0.01 ft	Routine survey closures and periodic peg tests	Resurvey if closure fails. If fails peg test, check and adjust instruments.

¹Rantz and others (1982a)

²Hubbard et al. (1999)

³Detection limits based on manufacturer specifications

10.4.3. Levels

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 periodically for vertical movement (Kenney 2010). 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 and others 1982b). In addition, level surveys will also record water surface and point of zero flow (Meyer 1996). The precision objective for levels is 0.005 ft (Table 10.4).

Levels should be run at newly installed streamgages during the first water year that the gage is constructed and at established streamgages at least once every three to five years. However, several of the SIEN-supported gages were not intended for long-term operation when they were installed. We intend to stabilize these gages, install benchmarks, and perform surveys shortly after we begin implementing this protocol and every three to five years over the course of their operation. 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.

Levels are run by use of field methods and documentation methods described in Kenney (2010) and Harrelson et al. (1994). Although they are not recommended by USGS for level use, fiberglass rods are the standard equipment 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. 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 Physical Scientist.

10.4.4. Direct Measurements

Direct measurements of discharge are made using the methods described in SOP 4 and based on USGS protocols. For our program, these methods primarily include wading (using current meters and FlowTrackers), volumetric, and the ADCP. SIEN has protocols in place to minimize errors

during streamflow measurements. 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. Errors also include systematic errors, or bias, associated with improperly calibrated equipment or the improper use of such equipment. In almost all instances, equipment bias can be determined through routine equipment calibration against reference or true values.

There are multiple measurements collected when making a direct discharge measurement, including width of the cross-section, water depth associated with each velocity measurement, ground elevation for the cross-section, and the velocity measurement. The SIEN precision objectives for these variables are presented in **Table 10.4**. Instrument environmental tolerance limits and accuracy objectives are presented in **Table 10.5**. These objectives are derived from USGS standards and from USGS recommended instrument capabilities.

Equipment measurement accuracy (bias and precision) for our program will be assessed and maintained by routinely sending in velocity meters for calibration and having them rated under controlled settings (e.g., tow tanks). Given the expense of these calibrations, SIEN meters will be calibrated once every three to four years or sooner if repairs are made to the meters. All calibration checks are recorded. Between calibrations, equipment measurement uncertainties can be minimized by i) performing spin tests (current meters) and beam tests (FlowTrackers) prior to going into the field, ii) post-field assessing the departure of reported velocities from rating curves (i.e., the residuals), iii) and only using the meters under those velocity conditions where residuals are smallest.

Measurement accuracy associated with personnel is more challenging to measure. Precision will be assessed by having two field crew members measure discharge one after the other, at a time when the stage is stable. This should be conducted in a stable channel (e.g. we recommend the Tioga Bridge site) and conducted once per year. Precision will be calculated as the percent difference between the two measurements and should be within 5%. Should precision exceed 5%, discussions between the surface water measurement expert and network staff will be initiated to determine cause (e.g., equipment error, sampling technique). Since it is not possible to know the ‘true’ discharge in the field, evaluating bias for field personnel working in field conditions is not possible and thus we will only be measuring field precision.

There are several quality assurance and control practices that field technicians will follow to improve discharge measurement data quality:

Selecting the proper number of measurement subsections

The spacing of observation verticals in the measurement section can affect the accuracy of the measurement (Turnipseed and Sauer 2010). 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 five 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 five percent (Turnipseed and Sauer 2010).

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 (Turnipseed and Sauer 2010). Fewer verticals than are ideal are sometimes used for very narrow

streams (e.g. about 12-feet wide when an AA meter is used and about five feet wide when a pygmy meter is used). In these situations, verticals should be spaced at least 0.3 feet apart. Measurement of discharge is a sampling process, and the accuracy of sampling results typically decreases markedly when the number of samples is less than about 25.

Perform 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 five percent from the established rating, or about five percent from a newly established shift curve (Meyer 1996). SOP 4 includes instructions for examining results to determine whether a check measurement is needed. This is a reasonable policy provided the station has a fairly stable control and measuring conditions are good. 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, systematic error can be minimized by changing the measurement conditions as much as possible (Rantz and others 1982b). For example, periodically changing the equipment (e.g. use different current meters), changing the cross-section, or changing the vertical sections within a cross-section.

Equipment field tests

The equipment used by the SIEN for the measurement of surface-water discharge is commonly used by USGS (Turnipseed and Sauer 2010). Our most commonly used meters are the Price AA and pygmy current meters and the FlowTracker. Methods followed by SIEN personnel for inspecting, repairing, and cleaning these meters are summarized in SOP 3 and summarized information is also described in Smoot and Novak (1968) and Buchanan and Somers (1969).

For pygmy and AA meters, spin tests are required prior to each field trip and discharge measurement. Test results are documented on the field data sheet and spreadsheet on the SIEN server. 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. 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.

For FlowTrackers, beam tests are required prior to going into the field. Beam tests are diagnostic tests conducted with the FlowTracker submerged in a bucket of water. The testing protocol is described in the FlowTracker manual.

10.4.5. Indirect Measurements

Indirect measurement methods are described in SOP 4 and include salt dilutions and dye tracer methods. Salt dilutions are the primary discharge measurement method at the Lyell Fork of the Tuolumne site. Precision will be measured by repeating salt dilutions during a time period when the stage is stable and calculating the RPD. It is protocol to conduct at least two salt dilution runs per visit (when salt dilutions are the primary discharge method) so there will be a precision measurement associated with each discharge value. Precision measurements for salt dilutions should be within 5% (Day 1976, Moore 2005). Bias is, again, challenging to measure since it's not possible to know the true discharge. However, actions can be taken to improve the accuracy (bias and precision) of the measurements. These include completely dissolving the salt in the injection slug, minimizing errors in measuring stream-water volumes and injection solutions by properly using high quality pipettes and flasks and carefully preparing the solutions, protecting solutions from dilution when it's raining, and only conducting salt dilutions during appropriate conditions (e.g. the channel is free of ice and snow) (Moore 2005).

SIEN may use dye tracer methods for high flow measurements or a step-backwater survey following a high flow event. These methods are beyond the scope of the protocol and if/when implemented will be done in conjunction with a hydrologist trained in these techniques.

10.4.6. 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. 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 of the cross section 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.

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).

10.5 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. For USGS managed gages, streamflow records are computed and published annually (Rantz and others 1982b). SIEN will compute streamflow records on an annual basis and publish biennially.

The accuracy of surface water discharge records depends on the cumulative accuracy of discharge measurements, rating definition, and the completeness and accuracy of the gage-height record (U.S. Geological Survey 1992). Estimated accuracies of discharge records for individual days commonly are about five to 10 percent (U.S. Geological Survey 1992). Sauer and Meyer (1992) found that “standard error estimates for individual discharge measurements range from two percent under ideal conditions to 20 percent under poor conditions and when shortcut methods are used”.

This section of the QAP 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. (1982b) and by Kennedy (1983).

10.5.1. 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. 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.

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 as outlined in SOP 3.

10.5.2. Continuous Record

Surface water gage height data are recorded electronically (i.e., on dataloggers) as a continuous record of 15-minute values (or other desirable recording rates). 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.

The 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 SOP 7) 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 and others (1982b). Periods of missing or "bad" records are identified and resolved as described in SOP 7.

10.5.3. 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.

Procedures for Working with 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. All procedures take place in the Aquarius software, which contains special tools for these tasks.

The following are tools and approaches for ensuring the thoroughness, consistency, and accuracy of streamflow records:

Threshold comparisons: These will be utilized to flag values that may exceed an expected minimum or maximum value. For instance, recorded gage height data at a SIEN streamgage may range from zero to five feet over the course of a wet water year. Threshold flags at zero and 10 feet can be set to identify gage height periods that cross these thresholds for further examination.

Rating comparisons: 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).

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, 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 PDT. Review of field notes with datalogger and watch date and time will be done to identify periods when the datalogger clock recorded an erroneous date and time.

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 a discharge record. The rating is usually the relation between gage height and discharge (Kennedy 1983). We follow the procedures for the development, modification, and application of ratings described by Kennedy (1984). We also follow guidelines pertaining to rating and records computation that are presented by Kennedy (1983) and by Rantz et al. (1982b).

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.

All rating curves for each streamgage are permanently stored in the Aquarius SQL Server database. The rating 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 misplotted 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 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 +/- 0.02 ft.

Ratings plotted on a log-log graph 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, defined as e . The recommended procedure to determine a value for e is in Rantz and others (1982b). The Aquarius rating curve software program will be used for adjustment of scale offset (SOP 7). 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 two 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 and others 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 and others 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 SIEN Physical Scientist is ultimately responsible for ensuring that ratings are correctly developed, checked, and stored for the sites where SIEN is responsible for data management. 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 and others 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 and others 1982b). 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 and others 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 the rating curve, calculations, notes and diagrams are printed from Aquarius and maintained in a station 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, the 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 and others 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 and others 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.

Daily Values Table: With few exceptions, for each streamgage operated by the SIEN 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. 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 rivers database for future retrieval and analyses.

Reports: When records computation for the water year has been completed and the data collected and analyzed by SIEN personnel have been determined to be correct and finalized, the surface-water data for that water year are published along with other data in SIEN's hydrologic status report (published every two years) or comprehensive status and trends report (published every four years). Information presented in the status 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 a report is finalized. Someone other than the person who computed and wrote the station analysis checks each station. During the first few years of protocol implementation, an NPS WRD surface water hydrologist will be asked to review the station analyses. Reports are reviewed in compliance with the IMD and NRR report series peer-review process.

Identifying Estimated Daily Discharge

Estimated daily-discharge values published in the water-discharge tables of annual reports are identified. This identification is shown either by flagging individual daily values with the letter "e" and noting in a table footnote, "e- Estimated," or by listing the dates of the estimated record in the REMARKS paragraph of the station description.

Accuracy of Field Data and Computed Results

The accuracy of streamflow data depends primarily on i) the stability of the stage-discharge relation or, if the control is unstable, the frequency of discharge measurements, and ii) the accuracy of observations of stage, measurements of discharge, and interpretations of records.

The degree of accuracy of the records is stated in the REMARKS in the station description and in Aquarius. "Excellent" indicates that about 95 percent of the daily discharges are within five percent of the true value; "good" within 10 percent; and "fair," within 15 percent. "Poor" indicates that daily discharges have less than "fair" accuracy. Different accuracies may be attributed to different parts of a given record.

Values of daily mean discharge in this report are shown to the nearest hundredth of a cubic foot per second for discharges of less than 1 ft³/s; to the nearest tenths between 1.0 and 10 ft³/s; to whole numbers between 10 and 1,000 ft³/s; and to three significant figures above 1,000 ft³/s. The number of significant figures used is based solely on the magnitude of the discharge value. The same rounding rules apply to discharge values listed for partial-record stations.

Discharge at many stations, as indicated by the monthly mean, may not reflect natural runoff due to the effects of diversion, consumption, regulation by storage, increase or decrease in evaporation due to artificial causes, or to other factors. For such stations, values of cubic feet per second per square mile and of runoff in inches are not published unless satisfactory adjustments can be made for diversions, for changes in contents of reservoirs, or for other changes incident to use and control. Evaporation from a reservoir is not included in the adjustments for changes in reservoir contents, unless it is so stated. Even at those stations where adjustments are made, large errors in computed runoff may occur if adjustments or losses are large in comparison with the observed discharge.

10.6 Documentation and Records

Standardized datasheets will be used to record field data for this protocol. Details about routine station visits including a log of maintenance and measurement activities and level notes are

recorded in water-resistant field notebooks and on the field datasheet. The datasheet is based on the USGS 'Discharge Measurement Notes' Form 9-275-F. All datasheets are scanned and stored on the SIEN server, then stored in binders by station (located in the SEKI office). Instructions on filling out the datasheets are provided in SOP 3.

10.6.1. 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 i) the most recent digital stage-discharge relation (rating), ii) a graph of the rating upon which each new measurement is plotted, iii) 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, iv) 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 and, v) information regarding the particulars of individual dataloggers including wiring diagram and programming instructions.

It is the responsibility of field staff to exchange outdated material with updated gage documents as needed. A new graph and copy of the stage-discharge relation will be placed in the gage house during each station visit.

10.6.2. 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. Station descriptions are stored in Aquarius.

Station Descriptions: A station description is prepared for each streamgage and becomes part of the permanent record for each station (see SOP 1). For new stations, descriptions will be written within the first three months after establishment. Station descriptions are updated annually and note information such as channel or equipment changes.

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. Crews will bring a digital camera on each trip for photographic documentation. Each photograph that becomes part of the station record is identified by a unique filename. Instructions for naming and storing photos are provided in SOP 3 in the section devoted to post-field visit procedures. Information regarding the photos (e.g., direction and object photographed) is recorded on the site visit and discharge measurement datasheet and stored in the database along with links to the photos, which are stored on the SIEN server.

10.6.3. 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 field data sheets as detailed in SOP 3.

Original observations, once written on the field data sheet, are not erased. Original data are corrected by crossing the value out and 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, are 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 3.

10.7 Water Temperature Data

The SIEN-supported gages at Yosemite have a Campbell Scientific CS547A temperature probe. Additionally, HOBO temperature loggers are installed at stations selected for this monitoring program that are operated by other individuals or organizations. The temperature range, accuracy, and resolution of the sensors used by SIEN are listed in **Table 10.7**.

Table 10.7. Temperature sensor range, accuracy, and resolution.

Sensor Type	Sensor Model	Temp Range	Accuracy	Resolution
Integrated with datalogger	Campbell Scientific CS547A	0 to 50°C	±0.4 °C	Unknown
HOBO temp logger	Pro V2	-40 to 70°C	0.2°C over 0 to 50°C	0.02°C at 25°C

10.7.1. Measurement Sensitivity

Portions modified from the NCPN Quality Assurance Project Plan (Sharrow et al. 2007)

Instrument sensitivity will be evaluated using alternative measurement sensitivity and alternative measurement sensitivity plus (AMS+) as described by Irwin (2008) and Thoma et al. (unpublished report), respectively. In the range of quantitative values where low-level detection limits are not an issue, measurement sensitivity is determined by evaluating the variability of repeated measurements on an environmental sample. AMS uses seven measurements collected in quick succession in a laboratory setting and provides an estimate of instrument noise. Field-measured sensitivity for temperature will be evaluated using AMS+. AMS+ is based on seven measurements conducted in-situ and provides an estimate of instrument noise and natural heterogeneity.

Over time, AMS+ can be used to bound measurement uncertainty on each single data point (when seven measurements are made on the same environmental sample). It includes instrument

noise and natural heterogeneity (Sharrow et al. 2007). We will determine AMS+ based on seven measurements of nearby, but not identical, in-situ samples recorded with the temperature sensors in the field (Irwin 2008). With the sensor that is attached to the streamgage recorder, these measurements are recorded in rapid succession while viewing the real-time data on the field laptop with the Loggernet software. With the HOBO loggers, it is not possible to view real-time measurements in the field. The seven AMS measurements are recorded at the start of a station visit and should be done at least once yearly. The target AMS is 0.1 °C.

AMS+ is calculated as: $t * sd$, where;

sd = sample standard deviation of measurement values obtained in-situ

t = 3.708, the 99% confidence middle (two-sided) t-value for sample size seven

10.7.2. Bias

Modified from the UCBN Quality Assurance / Quality Control SOP (Starkey et al. 2008)

During each site visit, SIEN will quantify the bias error caused by calibration drift by taking repeated cross measurements with a handheld temperature meter and comparing them to the Campbell or HOBO temperature sensor value. Bias will be expressed as a percent recovery with the correct or expected answer being considered 100% and an acceptable range between 90-110% (Sharrow et al. 2007, Irwin 2008). It is not possible to routinely clean the sensors because they are secured to the bottom of the streambank, therefore we will not check for fouling during regular site visits. When data are processed for analysis and prior to uploading into the database they will be corrected to account for drift error (SOP 7).

The handheld field meter will be checked against a National Institute of Standards and Technology (NIST) certified thermometer in the lab twice a year. The acceptable range is between 90-110%.

Sierra Nevada Network Rivers Hydrology Monitoring Protocol

SOP 11: Revising the Protocol

Version 1.0

This standard operating procedure is part of the Sierra Nevada Network River Hydrology Monitoring Protocol, but is designed to be printed and viewed as a separate document.

Revision History Log

Previous version #	Revision date	Revised by	Changes	Justification	Page #'s affected	New version #

11.1 Procedures

This monitoring protocol is an actively evaluated and updated document that reflects the latest procedures of the monitoring program. Revisions are expected, and can involve only minor changes with little overall impact or occasional major revisions and course corrections. The protocol is evaluated each year in association with annual data summaries with more thorough evaluations every other year in conjunction with the hydrologic summary reports.

Recommendations for revision are made by the Protocol Lead to the Program Manager. The narrative as well as each SOP has a Revision History Log whereby changes can be recorded. Older versions of the narrative and SOPs should be archived to ensure proper legacy of past work is maintained. Each revision will require an updated version number. Minor changes are recorded as decimal numbers (e.g., 1.0, 1.1, 1.2, etc...). Major changes are recorded as a change in the primary number of the protocol version (e.g., 1.0, 2.0, 3.0, etc...). In some cases, major revisions to the protocol may require additional peer-review. If this is the case, the Protocol Lead and Program Manager will coordinate with the Pacific West Region (PWR) I&M Program Manager.

11.2 Instructions

The following procedures will ensure that both minor and major revisions to this document will align with the monitoring protocol and data management.

1. Discuss proposed changes with other project staff prior to making modifications. It is important to consult with the Data Manager prior to making changes because certain types of changes may jeopardize dataset integrity unless they are planned and executed properly. Also, because certain changes may require altering the database structure or functionality, advance notice of changes is important to minimize disruptions to project operations. Consensus should be reached on who will be making the changes and in what timeframe.
2. Make the agreed-upon changes in the appropriate protocol document. Note that the protocol is split into separate documents for each appendix and SOP. Also note that a change in one document may necessitate other changes elsewhere in the protocol. For example, a change in the narrative may require changes to several SOPs; similarly, renumbering an SOP may mean changing document references in several other documents. Also, the project task list and other appendices may need to be updated to reflect changes in timing or responsibilities for the various project tasks.
3. Document all edits in the Revision History Log embedded at the beginning of the protocol narrative and each SOP. Record changes only in the document being edited (i.e., if there is a change to an SOP, log those changes only in that document and not in the narrative). In the appropriate columns, record the previous version number (Previous Version #), revision date (Revision Date), individual who revised the document (Revised by), a change description (Change), a brief reason for making the changes (Justification), page(s) where changes are made (Page #s Affected), and the new version number (New Version #). Version numbers increase incrementally by tenths (e.g., version 1.1, 1.2) for minor changes. To ensure that minor errors noted or recommendations are not lost,

changes should be made to the protocol within 30 days of when they are noted, once the network team has reviewed and approved the recommended changes. Major revisions will be designated with the next whole number (e.g., version 2.0, 3.0).

4. Circulate the changed document for internal review among project staff and cooperators. Minor changes and clarifications will be reviewed in-house. When significant changes in methodology are suggested, revisions will first undergo internal review by the project staff. Additional external review, including, but not limited to, National Park Service staff with appropriate research and statistical expertise, will be required. Significant changes requiring external review may include changes to the sample design or trend detection methodologies.
5. Upon ratification and finalizing changes:
 - a. Ensure that the version date (last saved date field code in the document header) and file name are updated properly throughout the document.
 - b. Place a copy of each changed file to the protocol archive folder (i.e., a subfolder under the protocol folder in the project workspace).
 - c. The copied files will be renamed by appending the revision date in YYYYMMDD format. In this manner, the revision date becomes the version number and this copy becomes the “versioned” copy to be archived and distributed.
 - d. The current, primary version of the document (i.e., not the versioned document just copied and renamed) does not have a date stamp associated with it.
 - e. To avoid unplanned edits to the document, reset the document to read-only by right-clicking on the document in Windows Explorer and checking the appropriate box in the Properties popup.
 - f. Inform the Data Manager so the new version number(s) can be incorporated into the project metadata.
6. As appropriate, create PDF files of the versioned documents to post to the internet and share with others. These PDF files will have the same name and be made from the versioned copy of the file.
7. Send a digital copy of the revised monitoring protocol to all individuals who had been using a previous version of the affected document. Ensure that field staff has a hardcopy of the new version.
8. The Physical Scientist will place a copy of the revised protocol in the proper folder on network shared drives and archive the previous version in the archive drives.

SOP 11: Revising the Protocol
SIEN River Monitoring Protocol

The SIEN Data Manager will post the revised version and update the associated records in the proper I&M databases, including but not limited to IRMA, SIEN websites, and the protocol database.

Literature Cited

- Andrews, E. D. 2012. Hydrology of the Sierra Nevada Network national parks: Status and trends. Natural Resources Report NPS/SIEN/NRR--2012/500, National Park Service, Fort Collins, CO. <https://irma.nps.gov/App/Reference/Profile/2184307>.
- Aquatic Informatics Inc. 2016a. Aquarius 3.10 acquisition service API. Vancouver, B.C., Canada.
- Aquatic Informatics Inc. 2016b. Aquarius 3.10 publish web service API. Vancouver, B.C., Canada.
- 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, Denver, Colorado.
- Boning, C. W. 1992. Policy on statement on stage accuracy. USGS Office of Surface Water Branch Technical Memorandum No.93.07, Washington, D.C. <http://water.usgs.gov/admin/memo/SW/sw93.07.html>
- Buchanan, T. J., and W. P. Somers. 1969. Discharge measurements at gauging stations. Techniques of water-resources investigations of the United States Geological Survey. Chapter A8. Washington, D.C.
- Burn, D. H., and M. A. Elnur. 2002. Detection of hydrologic trends and variability. *Journal of Hydrology*. **255**(1–4):107-122.
- Cayan, D. R., S. A. Kammerdiener, M. D. Dettinger, J. M. Caprio, and D. H. Peterson. 2001. Changes in the onset of spring in the western United States. *Bulletin of the American Meteorological Society*. **82**:399-415.
- Day, T. J. 1976. On the precision of salt dilution gaging. *Journal of Hydrology*. **31**:293-306.
- Dettinger, M. D. 2005. From climate change spaghetti to climate-change distributions for 21st Century California. Article 4. *San Francisco Estuary and Watershed Science*. **3**(1).
- Dunne, T., and L. B. Leopold. 1978. *Water in environmental planning*. WH Freeman and Company, San Francisco, California.
- EPA. 2002. Guidance for quality assurance project plans. EPA QA/G-5, Washington, D.C. <https://www.epa.gov/quality/guidance-quality-assurance-project-plans-epa-qag-5>.
- Fong, D., D. Press, M. Koenan, and M. DeBlasi. 2011. San Francisco Bay Area Network (SFAN) streamflow monitoring protocol: Volume 1: Narrative and appendixes - version 2.92. Natural Resource Report NPS/SFAN/NRR—2011/343, National Park Service, Fort Collins, CO.
- Granato, G. E. 2006. Kendall-Theil Robust Line (KTRLLine-version 1.0): A visual basic program for calculating and graphing robust nonparametric estimates of linear-regression coefficients between two continuous variables. *Techniques and Methods of the U.S. Geological Survey*. Book 4, Chapter A7. U.S. Geological Survey.

- Hardy, T., P. Palavi, and D. Mathias. 2005. WinXSPRO a channel cross section analyzer, user's manual. Version 3.0. USDA Forest Service, Rocky Mountain Research Station, Washington, D.C.
- Harrelson, C. L. C.C.Rawlins, and J. P. Potyondy. 1994. Steam channel reference site: An illustrated guide to field technique. USDA Forest Service General Technical Report RM-245, Fort Collins, Colorado.
- Helsel, D. R., and L. M. Frans. 2006. Regional Kendall test for trend. *Environmental Science & Technology*. **40**(13):4066-4073.
- Helsel, D. R., and R. M. Hirsch. 2002. Statistical methods in water resources. Techniques of water resources investigations. Book 4, Chapter A3. U.S. Geological Survey, Washington D.C.
- Holmes, R. R. J., P. J. Terrio, M. A. Harris, and P. C. Mills. 2001. Introduction to field methods for hydrologic and environmental studies. US Geological Survey Open-File Report 01-50, Reston, Virginia.
- Hubbard, E. F., K. G. Thibodeaux, and M. N. Duong. 1999. Quality assurance of U.S. Geological Survey stream current meters: The meter-exchange program 1998-98. Open-file report US Geological Society, Reston, Virginia.
- Hughes, J., B. Witcher, and J. C. DeVivo. In prep. Data quality standards for continuous water quality monitoring in the Appalachian Highlands Network. Natural Resource Report NPS/APHN/NRR---20XX/XXX, National Park Service, Fort Collins, CO.
- Irwin, R. J. 2008. Part B lite - QA/QC review checklist for aquatic monitoring protocols and SOPs. Unpublished report. National Park Service, Water Resources Division, Fort Collins, CO. <https://irma.nps.gov/DataStore/Reference/Profile/2225069>
- Kelly, V. J., and M. Jett. 2006. Ecologically-relevant quantification of streamflow regimes in western streams. EPA/620/R-06/056, U.S. Environmental Protection Agency, Washington, D.C.
- Kennedy, E. J. 1983. Computation of continuous records of streamflow. Techniques of water-resources investigations. Book 3, Chapter A13. U.S. Geological Survey, Washington D.C.
- Kennedy, E. J. 1984. Discharge ratings at gaging stations. Techniques of water resources investigations of the United States Geological Survey. Book 3, Chapter A10 Washington, D.C.
- Kenney, T. A. 2010. Levels at gaging stations. U.S. Geological Survey techniques and methods. 3-A19. U.S. Geological Survey.
- Lane, S. L., and R. G. Fay. 1997. Safety in field activities. Techniques of water-resources investigations. Book 9, Chapter A9. U.S. Geological Survey, 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. <http://eps.berkeley.edu/people/lunaleopold/>
- Lins, H. F., and J. R. Slack. 1999. Streamflow trends in the United States. *Geophysical Research Letters*. **26**(2):227-230.

- Linsley, R. K., M. A. Kohler, and J. L. Paulhus. 1982. Hydrology for engineers. Third edition edition. McGraw-Hill, New York.
- Luce, C. H., and Z. A. Holden. 2009. Declining annual streamflow distributions in the Pacific Northwest United States, 1948–2006. *Geophysical Research Letters*. **36**(16):L16401.
- Lundquist, J. D., D. R. Cayan, and M. D. Dettinger. 2004. Spring onset in the Sierra Nevada: When is snowmelt independent of elevation? *Journal of Hydrometeorology*. **5**(2):327-342.
- Manly, B. F. 2001. Statistics for environmental science and management. Chapman and Hall / CRC, Boca Raton, USA.
- 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.
- Moore, R. D. 2004a. Introduction to salt dilution gauging for streamflow measurement part 1. streamline Watershed Management Bulletin. **7**(4):20-23.
- Moore, R. D. 2004b. Introduction to salt dilution gauging for streamflow measurement part 2: Constant rate injection. Streamline Watershed Management Bulletin. **8**(1):11-15.
- Moore, R. D. 2005. Slug injection using salt in solution. Streamline Watershed Management Bulletin. **8**(2):1-6.
- 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, U.S. Geological Survey.
- Norris, M. E., Pieper J.M., T. M. Watts, and A. Cattani. 2011. National Capital Region Network Inventory and Monitoring Program water chemistry and quality monitoring protocol version 2.0: Water chemistry, nutrient dynamics, and surface water dynamics vital signs. Natural Resource Report NPS/NCRN/NRR--2011/423 National Park Service. Fort Collins, Colorado.
- Pagano, T., and D. Garen. 2005. A recent increase in western U.S. streamflow variability and persistence. *Journal of Hydrometeorology*. **6**(2):173-179.
- Peck, D. V., J. M. Lazorchak, and D. J. Klemm. 2001. Environmental monitoring and assessment program-surface waters: Western pilot study field operations for wadeable streams. US Environmental Protection Agency.
- Rantz, S. E., and others. 1982a. Measurement and computation of streamflow: Volume 1. Measurement of stage and discharge. Geological Survey Water-Supply Paper 2175, US Geological Survey, Washington, D.C. <http://pubs.usgs.gov/wsp/wsp2175/#pdf>.
- Rantz, S. E., and others. 1982b. Measurement and computation of streamflow: Volume 2. Computation of discharge. Geological Survey Water-Supply Paper 2175, US Geological Survey, Washington, D.C. <http://pubs.usgs.gov/wsp/wsp2175/#pdf>.
- Riggs, H. C. 1972. Low-flow investigations. Techniques of water-resources investigations. Book 4, Chapter B1. U.S Geological Survey, Washington, D.C.

- Sauer, V. B. 2002. Standards for the analysis and processing of surface-water data and information using electronic methods. US 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.
- Schneider, V. R., and G. F. Smoot. 1976. Development of a standard rating for the Price Pygmy current meter. U. S. Geological Survey Journal of Research. 4(3):293-297.
- Sharrow, D., K. W. Thoma, and M. Beer. 2007. Water quality vital signs monitoring protocol for park units in the Northern Colorado Plateau Network (NCPN) Moab, Utah.
- Skancke, J. R., A. L. Chung-MacCoubrey, L. S. Chow, and J. D. Balmat. 2012. Sierra Nevada Network climate reporting protocol: Version 1.0. Natural Resources Report NPS/SIEN/NRR--2012/543. Fort Collins, Colorado.
- Smoot, G. F., and C. E. Novak. 1968. Calibration and maintenance of vertical-axis type current meters. Techniques of water-resources investigations. Book 8, Chapter B2. U.S. Geological Survey, Washington, D.C.
- Stahl, K., H. Hisdal, J. Hannaford, L. Tallaksen, H. v. Lanen, E. Sauquet, S. Demuth, M. Fendekova, and J. Jódar. 2010. Streamflow trends in Europe: Evidence from a dataset of near-natural catchments. Hydrology and Earth System Sciences Discussions. 7(4):5769-5804.
- Starcevich, L. A. H., and S. L. Kane. 2017. Power analysis of trends in streamflow parameters for the Sierra Nevada Network - Appendix C. in J. R. Skancke, A. M. Heard, L. Chow, and A. L. Chung-MacCoubrey, editors. Sierra Nevada Network river hydrology monitoring protocol National Park Service, Fort Collins, Colorado.
- Starkey, E. N., L. K. Garrett, T. J. Rodhouse, G. H. Dicus, and R. K. Steinhorst. 2008. Upper Columbia Basin Network integrated water quality monitoring protocol: Narrative version 1.0. Natural Resource Report NPS/UCBN/NRR--2008/026. Fort Collins, Colorado.
- Turnipseed, D. P., and V. B. Sauer. 2010. Discharge measurements at gaging stations U.S. Geological Survey Techniques and Methods Book 3, Chapter A8, U.S Geological Survey.
- U.S. Geological Survey. 1992. Policy statement on stage accuracy. Office of Surface Water Technical Memorandum No. 93.07, <http://water.usgs.gov/admin/memo/SW/sw93.07.html>.
- USGS. 1989. Policy to ensure the accurate performance of current meters. Office of surface water technical memorandum No. 89.07, <http://pubs.usgs.gov/tm/tm3-a8/>.
- USGS. 2011. Streamstats. Available at: <http://streamstats.usgs.gov/>. Accessed: 22 November, 2011.
- Wilson, J. F., E. D. Cobb, and F. A. Kilpatrick. 1986. Fluorometric procedures for dye tracing. Techniques of Water-Resources Investigations. Book 3, Chapter A12. U.S. Geological Survey, Washington D.C.