National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Water Quality Monitoring Protocol for Wadeable Streams and Rivers in the Northern Great Plains Network

Standard Operating Procedures Version 1.0

Natural Resource Report NPS/NGPN/NRR—2014/868.1

ON THE COVER
Little Missouri River, Theodore Roosevelt National Park North Unit
Photograph by Mike Bynum, Northern Great Plains Network

Water Quality Monitoring Protocol for Wadeable Streams and Rivers in the Northern Great Plains Network

Standard Operating Procedures Version 1.0

Natural Resource Report NPS/NGPN/NRR—2014/868.1

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U.S. Department of the Interior
National Park Service
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Fort Collins, Colorado

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Executive Summary

The Water Quality Monitoring Protocol includes two parts: a Narrative and the Standard Operating Procedures (SOPs). The Water Quality Monitoring Protocol Narrative Version 1.0 describes a general overview of the status of water resources throughout the parks in the National Park Service's Northern Great Plains Network (NGPN), the objectives, the field methods, and the sampling design selected for this long-term monitoring program. This report includes the detailed SOPs for the NGPN's Water Quality Monitoring Protocol. All water quality monitoring is conducted by the United States Geological Survey (USGS) through Interagency Agreements. The USGS North Dakota Water Science Center (WSC) monitors water quality at Knife River Indian Villages National Historic Site and Theodore Roosevelt National Park. The USGS Wyoming WSC monitors water quality at Devils Tower National Monument, Fort Laramie National Historic Site, and Agate Fossil Beds National Monument. The USGS Nebraska WSC monitors water quality at Niobrara National Scenic River and Missouri National Recreational River. The basis for the field-oriented SOPs (#3 and #4) comes from the USGS National Field Manual for the Collection of Water-Quality Data (http://pubs.water.usgs.gov/twri9A) as well as other USGS reports. The remainder of the more administrative SOPs outline step by step procedures for NGPN staff to follow to accomplish the long-term monitoring program.

Acknowledgments

We wish to thank the National Park Service Water Resources Division staff, P. Penoyer and G. Rosenlieb, for their continued support of this monitoring program. Additionally, we thank R. Gitzen from Auburn University for his advice on the sampling design and B. Rowe from the USGS South Dakota Water Science Center for her draft streamflow document. Comments and reviews were provided by D. Tucker, P. Penoyer, M. Prowatzke, and A. Jarding of the National Park Service. Janice Faaborg provided technical editing of this document.

Glossary of Terms

Cell: a measured, equidistant portion of a stream channel cross section. The width, depth, and velocity of the cell are used to determine stream discharge. The cell is frequently referred to as a subsection.

Gaging station: facilities used to automatically monitor streams and other bodies of water. Instruments at these stations collect information such as water height, discharge, water chemistry, and water temperature.

Hydrographer: person who collects and processes water data.

Increment: a measured, equidistant portion of the stream channel cross section. This measurement is read from the cross-sectional tag line.

Range finder: a device that measures distance from the operator to a targeted point.

Stage: the height of the water surface at a streamflow measurement site, as determined by reading the stage at the gaging station or measuring from a permanent reference point to the water surface.

Stream discharge: the unit volume of water passing a given point on a stream or river over a given time. Stream discharge is expressed in cubic feet per second (ft^3/s).

Stream velocity: measure of the rate at which water flows past a given point. Stream velocity is expressed in feet per second (ft/s).

Streamflow: streamflow is synonymous with "stream discharge."

Vertical: the depth of the water measured at the midsection of an increment on the tag line. The readings on a wading rod are made when the wading rod is placed "vertically" on the stream bed.

Wading rod: a rod designed to secure a current meter in position to any desired depth while wading a stream. It allows the crew member to quickly set the meter to the correct depth without bringing the meter out of the water.

Acronyms

ADAPS	Automated Data Processing System
AGFO	Agate Fossil Beds National Monument
DETO	Devils Tower National Monument
FOLA	Fort Laramie National Historic Site
I&M	Inventory and Monitoring
KNRI	Knife River Indian Villages National Historic Site
MNRR	Missouri National Recreational River
MORU	Mount Rushmore National Memorial
NGPN	Northern Great Plains Network
NIOB	Niobrara National Scenic River
NPS	National Park Service
NWIS	National Water Information System
SOP	Standard Operating Procedure
THRO	Theodore Roosevelt National Park
USGS	U.S. Geological Survey
WSC	Water Science Center
WQM	Water Quality Monitoring

Water Quality Monitoring Protocol for Wadeable Streams and Rivers in the Northern Great Plains Network

Standard Operating Procedure (SOP)
SOP 1: Preseason Preparations

Version 1.0, October 2014

Revision History Log

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1.0 Draft	October 2014	NGPN	Revision following peer review		1.0
Add rows as needed for each change or set of changes tied to an updated version number					

Introduction

This SOP describes the step-by-step procedures for field work conducted by the U.S. Geological Service (USGS) Water Science Centers (WSCs; see the Water Quality Monitoring Protocol Narrative Version 1.0 for background information). Before each field season begins, detailed preparations must be completed to ensure sampling is undertaken according to schedule. Water quality data are collected during the ice-free season, generally from March through October. Coordination with USGS WSCs and park staff is critical, and all details for the season should be planned well in advance of the beginning of the water year. Administrative preparations should begin in late fall prior to spring sampling to allow enough time to complete the Interagency Agreements and to apply for research permits (Table 1).

Table 1. Checklist of activities to be conducted prior to collecting water quality data.

Pre-sampling Activities Checklist	Date
NGPN prepares multiyear Interagency Agreements with each USGS WSC	October prior to field work
NGPN and USGS review monitoring protocol	November prior to field work
NGPN confirms research permits with each park research coordinator	February prior to field work
USGS field staff review training and safety material	February prior to field work
USGS initiates data collection of continuous water quality data	March or April when streams and rivers are ice free

Preparation of Multiyear Interagency Agreements

The NGPN partners with the USGS WSCs through Interagency Agreements (Appendix A). The primary contacts for USGS are listed in Appendix B. The Interagency Agreements stipulate that each USGS WSC completes the following tasks each water year:

- Collect continuous water quality data as outlined in the USGS Standard Procedures for Continuous Water Quality Monitors (Wagner et al. 2006).
- Provide real-time water quality data for each park.
- Submit data deliverables such as corrected time series data as outlined in the Data Management SOP 5.

The Interagency Agreements must be renewed on a multiyear basis due to data collection and deliverables conducted over the course of two fiscal years (e.g., from March 2013 through December 2013). Steps to complete the agreements are outlined below.

1. Modify the following documents to reflect the cost and location of the stream and river monitoring to be conducted.
    a. Interagency Acquisition Agreement

i. Objectives

ii. Statement of Work

iii. Scope of Work

iv. Products

b. NPS Purchase Request Form

c. Determination of Best Procurement Approach

d. Determination and Findings

e. Department of Interior Inter/Intra-Agency Agreement Form (IAA)

f. NPS Individual Acquisition Plan and Rationale Document

2. The Interagency Acquisition Agreement, which includes the Scope of Work, is provided to each USGS WSC Program Lead for review prior to its submission to the Mount Rushmore National Memorial (MORU) Contract Specialist to ensure that all necessary modifications have been made and to expedite the contracting process.

3. When the Interagency Acquisition Agreement has been finalized, it and the other forms listed above are submitted to the MORU Contract Specialist. In general, the agreement should be in place no later than mid-January of each year.

Annual Review

The NGPN General/Aquatic Ecologist conducts an annual review of the Protocol's SOPs prior to field season. The annual review is a central element for the close-out procedures and should include examination of data management and analysis, reporting, and sampling design issues that may have occurred during the water year. Any changes to the SOPs should be completed with sufficient time to circulate revised material to the appropriate staff.

National Park Service Research Permits

Each fixed water quality monitoring site located within park boundaries requires a National Park Service (NPS) Scientific Research and Collecting Permit (see park contacts in Appendix B). In February of each year, the NGPN applies for a new permit or renewal of a permit online at the NPS Research Permit and Reporting System website: https://irma.nps.gov/rprs/Investigator/index. As part of this application process, the NGPN General/Aquatic Ecologist coordinates with the USGS staff and the appropriate park Research Coordinator to ensure that all the necessary forms are completed prior to actual field work. Any applications for additional permits (e.g., a permit from the Nebraska Department of Transportation for monitoring at the bridge in St. James, Nebraska) are initiated by the USGS WSCs.

Training for USGS Field Personnel

The NGPN does not train field crews; therefore, this SOP document is not meant to be a stand-alone training manual and does not replace training and/or documentation offered by the USGS WSCs. The WSCs have their field staff review the USGS National Field Manual for the Collection of Water-Quality Data (http://pubs.water.usgs.gov/twri9A) and the Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Station Operation, Record Computation, and Data Reporting (Wagner et al. 2006) every year prior to data collection.

The USGS National Field Manual lists chapters that provide guidelines referencing water sample preparation, equipment cleaning, water sample collection, and multiparameter instrument use for routine field measurements. Wagner et al. (2006) provides additional guidelines and standard procedures for continuous multiparameter sondes as well as station operation, record computation, and data reporting.

Safety for USGS Field Personnel

Safety considerations are paramount for both field and lab work and are emphasized in all Monitoring Protocols. Chapter A9 of the USGS National Field Manual for the Collection of Water-Quality Data (http://pubs.water.usgs.gov/twri9A) was designed to assist field personnel in the safe execution of water quality data collection. This chapter provides USGS personnel with information about hazards they may encounter during field work and describes procedures that help ensure the safety and health of the crew (see Figure 1 for example of USGS Job Hazard Analysis; Wagner et al. 2006). In addition, Chapter A9 promotes awareness of preventive measures and stresses a panic-free and common sense approach when personnel are confronted with hazards. The USGS also provides training, equipment, and medical programs that address a variety of safety situations.

The NGPN also provides each WSC with a copy of the Safety Plan for the Northern Great Plains Inventory & Monitoring Network (NGPN 2012) that outlines park and emergency contact information and provides directions/maps to the nearest hospitals/clinics. This safety plan also identifies the appropriate park point of contact (e.g., natural resource person or Visitor Center front desk) who coordinates with the USGS field lead to communicate park-specific safety procedures. The USGS field crew lead contacts park staff upon arrival and departure from the park.

JOB HAZARD ANALYSIS

Station: 09251000 Yampa River near Maybell, Colorado	**Date:** December 1, 2002

Prepared by: J.R. Dungan	**Approval by 1st line supervisor:** RW Boulger, Data Chief, signed copy on file	**Reviewed by 2nd line supervisor:**

Policy exemptions at this site: Use of a Personal Floatation Device (PFD) is exempted at this site when flow conditions permit the use of a pygmy meter. Use of the exemption must conform to conditions discussed in District Memorandum, *PFD Exemption Memorandum* dated January 22, 2002. If you have not read the memorandum or have not had in-water training you must wear a PFD.

Recommended Protective Clothing and Equipment: PFD, foul weather gear, cell phone, waders, wasp spray, winter cold weather gear, ice cramp-ons, multiple traffic cones, men working sign, ice bar, change of clothes, disinfectant supplies for Hanta-virus.

JOB/Job Steps	Potential hazards	Recommended Safe Job Practices
TRAVEL TO SITE Roads are both paved and dirt /gravel.	Poor driving conditions during winter due to ice/snow. Getting stuck, rolling your vehicle or running off the road. Getting lost.	Observe rules of the road, drive defensibly and according to road conditions.
GAGE INSPECTION Check flows (DCP) prior to leaving on field trip.	Rattlesnakes, drowning, insect bites and stings, encounters with cattle. Falls down steep bank.	Be observant for animals and snakes. Open gage with caution. Inspect the inside of the shelter for wasps or spiders and check for presence of rodent feces. Be aware of livestock in area. If wasps or spiders are present, use a long distance insect spray. If the presence of rodent feces is detected, follow the cleanup procedures as outlined in the USGS-WRD Hanta Virus Infection Prevention Plan. Be careful traversing steep bank.
WADING MEASUREMENTS Maximum wade is 1,510 cfs, ght 3.56; expect depths of 2.8 feet and velocities of 3.2 feet per second. Ice measurements are required in the winter.	Drowning, ankle or knee sprains, falling. Slippery cobbles on stream bed. Breaking through thin ice; getting hit by chunks of ice during spring ice break up; hypothermia; falling on ice. Afternoon thunder storms in the summer.	Know your wading limits. Typically a person can wade up to a factor of 9; 3 foot depths times 3 feet per second velocity. Consider the footing on the streambed. Continually test stream footing and probe the bottom with a wading rod. Use an ice bar to test ice conditions. Continually check for floating ice chunks when ice is breaking up. Do not enter the stream during an electrical storm.
BRIDGE MEASUREMENTS Bridge has significant traffic.	Getting struck by a vehicle or flying debris from the roadway. Falling over the bridge rail and drowning. Being struck by the bridge crane. Getting large debris caught on suspension cable.	Traffic control devices/signs are necessary. Wear highly visible reflective vests. Do not lean over bridge rail. Use sufficient counter weight for the bridge crane. The suspension reel must be equipped with a breakaway cable.

Figure 1. Example of USGS Job Hazard Analysis (Wagner et al. 2006).

Water Quality Monitoring Protocol for Wadeable Streams and Rivers in the Northern Great Plains Network

Standard Operating Procedure (SOP)
SOP 2: Selection of Water Quality Monitoring Sites

Version 1.0, October 2014

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Introduction

Site selection is an important aspect of the Water Quality Monitoring Protocol. Without proper placement of the stations, the data collected have limited value for assessment of status and trend of water quality. The best location for a water quality monitoring site is often also the best location for measuring surface-water discharge (Wagner et al. 2006).

Site Selection

The USGS samples at one monitoring site for each of the selected park units/ districts, and because of the importance of streamflow for interpretation of water quality data (Gilliom et al. 1995), the NGPN selected monitoring sites at existing gaging stations. With this criterion, five of the monitoring sites are co-located at currently operating gaging stations (Table 2; see Appendix A, pages A-1, A-4, A-8, A-10, and A-12 in the Water Quality Monitoring Protocol Narrative Version 1.0). Two of the stations (Belle Fourche River and Bow Creek) are at historically established USGS gaging stations but are not currently collecting real-time data (Table 2; see Appendix A, pages A-3 and A-8 in the Water Quality Monitoring Protocol Narrative Version 1.0).

The Knife River was ranked as a number 2 priority site, even though neither a current nor a historic gaging station have been located inside the Knife River Indian Villages National Historic Site (KNRI) park boundary (Wilson et al. 2014). The USGS North Dakota WSC balanced the need for a representative location within the Knife River with several factors such as stream stages, channel morphology, water velocity, potential for debris damage, and logistics to select an index site (Table 3). Subsequently, USGS located the monitoring site where Highway 37 crosses the Knife River, near where the Knife River enters KNRI (see Appendix A, page A-7 in the Water Quality Monitoring Protocol Narrative Version 1.0).

Table 2. Water quality sampling sites and USGS WSC collecting water quality data.

Park	Sampling Site	USGS WSC
Devils Tower National Monument (DETO)	Belle Fourche River at USGS Belle Fourche River at Devils Tower (Site #06427850)	Wyoming
Theodore Roosevelt National Park (THRO)	Little Missouri River at USGS Medora Gaging Station (Site #06336000)	North Dakota
Knife River Indian Villages National Historic Site (KNRI)	Knife River near Stanton, ND (Site #06340590)	North Dakota
Agate Fossil Beds National Monument (AGFO)	Niobrara River at Agate Daily Streamflow Station (Nebraska DNR Site #6454100)	Wyoming
Niobrara National Scenic River (NIOB)	Niobrara River at USGS Sparks Gaging Station (Site #06461500)	Nebraska
Missouri National Recreational River (MNRR)[1]	Niobrara River at USGS Verdel Gaging Station (Site #06465500)	Nebraska
Fort Laramie National Historic Site (FOLA)	Laramie River at USGS Fort Laramie Gaging Station (Site #06670500)	Wyoming
MNRR[2]	Bow Creek at USGS Bow Creek near St. James (Site #06478518)	Nebraska

[1]Niobrara River is a tributary located in the 39-mile District of MNRR.

[2]Bow Creek is a tributary located in the 59-mile District of MNRR.

Table 3. Factors to consider in placement and installation of continuous water quality monitoring sites (Wagner et al. 2006).

Site characteristics
Potential for water quality measurements at the site to be representative of the location being monitored.
Degree of cross-sectional variation and vertical stratification.
A channel configuration that may pose unique constraints.
Range of stream stage (from low flow to flood) that can be expected.
Water velocity.
Presence of turbulence that will affect water quality measurements.
Conditions that may enhance the rate of fouling, such as excessive fine sediments, algae, or invertebrates.
Range of values for water quality field parameters.
Need for protection from high-water debris damage.
Need for protection from vandalism.
Monitor installation
Type of state or local permits required before installation can begin.
Safety hazards relevant to monitor construction and installation.
Optimal type and design of installation.
Consideration of unique difficulties or costs of installation.
Logistics (maintenance requirements)
Accessibility of site, including parking access.
Safe and adequate space in which to perform maintenance.
Presence of conditions that increase the frequency of servicing intervals needed to meet data-quality objectives.
For stream sites, proximity to an adequate location for making cross-sectional measurements.
Accessibility and safety of the site during extreme events (for example, floods or high winds).
Availability of electrical power or telephone service.

Water Quality Monitoring Protocol for Wadeable Streams and Rivers in the Northern Great Plains Network

Standard Operating Procedure (SOP)
SOP 3: Measurement of Water Quality Parameters at Sites

Version 1.0, October 2014

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Introduction

The USGS WSC deploys the equipment and collects all water quality data at each of the eight sites (see Table 2 in SOP 2). Water quality multiparameter sondes log levels of the core parameters (pH, water temperature, dissolved oxygen, and specific conductance) at programmed intervals (e.g., every 15 minutes). These complex instruments require calibration and maintenance on a regular basis. Despite the need for frequent revisits to the sites, the exact timing of calibration and maintenance is difficult to predict because field conditions can change instantaneously with a rain event or as the warm season progresses. For example, if water temperatures are high and water levels are low, the multiparameter sonde may need to be checked at least biweekly for biological fouling (algal growth) on the sensors.

Deployment of Multiparameter Sondes

The USGS deploys Yellow Springs Instruments water quality multiparameter sondes during the ice-free seasons (approximately March through October), each calibrated in a USGS laboratory prior to installation at a field site. Large streams and rivers usually are monitored from the downstream side of bridge abutments, assuming that safety hazards and other difficulties can be reduced or overcome. All sondes are placed in an in situ monitoring system instead of a flow-through receptacle with a pumping sampler (Wagner et al. 2006).

In addition, all of the sondes, regardless of their co-location with an existing gaging station, have satellite telemetry to transmit the water quality data to each WSC office in near real-time (http://waterdata.usgs.gov/nwis/rt), allowing the USGS staff to monitor the systems remotely for problems and/or needed service. Initially, the provisional data are placed on the USGS National Water Information System (NWIS) website (http://waterdata.usgs.gov/nwis/). Each park can add the NWIS link to their individual park website. The NGPN receives the final corrected (approved) data at the end of the water year from the respective USGS WSC (see SOP 5 for more details).

Site Revisits

The USGS has developed specific procedures that staff must follow when revisiting a monitoring site (Table 4) to ensure a standardized examination for fouling and calibration drift. For each revisit, USGS Hydrographers fill out the USGS Continuous Water Quality Monitor Field Form (Figure 2).

Fouling Check

Wagner et al. (2006) define fouling error as the error in measurements caused by biological growth such as algae and/or accumulation of sediments such as sand on the sonde sensors. For example, both types of fouling are common along the sandy, braided systems of the Niobrara River. To calculate the error caused by fouling since the last site visit, USGS staff obtains sensor readings from the stream before and after the sensors are cleaned; the difference between the initial sensor readings and the cleaned-sensor readings is the result of fouling. The calculated fouling error is used for data corrections and to assess the quality of the water data (Wagner et al. 2006).

Calibration Drift Check

Calibration drift error is the error in measurements caused by changes in the sensors due to electronic drift over time (Starkey et al. 2008). Temperature affects the solubility of oxygen in the water, pH, specific conductance, and the rate of biological activity in water (Wilde 2006). The continuous multiparameter sondes measure water temperature with a thermistor, and although these thermistors are reliable, accurate, durable, and require little maintenance, the water temperature sensors in the sondes are checked during each site visit (Figure 2). Only non-mercury thermometers having current National Institute of Standards Technology certification or traceability are used to check the accuracy of field thermometers. If the temperature error is outside the calibration criteria limits (Table 5), then the whole sonde is replaced with a fully calibrated sonde, and the sonde with the malfunctioning temperature sensor is returned to the USGS Hydrologic Instrumentation Facility for repair or replacement.

The calibration drift error for each of the dissolved oxygen, pH, and specific conductance sensors is the difference between the cleaned-sensor readings and expected readings for each parameter while the sensors are in calibration standard solutions (solutions of a known value). Calibration of the sensors is performed during the revisits if the cleaned-sensor readings obtained during the calibration check differ by more than the calibration criteria (Table 5). If the calibration drift error is within the expected calibration criteria limits (Table 5), no calibration of the sonde sensor is necessary; if the sensor error is outside the expected criteria (listed in Table 5), the sensor is recalibrated using the standard solutions in the field (Table 4). The values of the calibration drift errors are used for data correction, assessment of data quality, and sensor troubleshooting (Starkey et al. 2008).

Table 4. SOP for the operation and maintenance of a continuous water quality monitor. When USGS staff arrive at a site, Sonde A is the live meter in the water and Sonde B is the recently calibrated independent field meter that USGS brings to the site (Wagner et al. 2006).

1. Conduct site inspection
   a. Record Sonde A readings, time, and monitor conditions while Sonde A is deployed in water (before cleaning Sonde A)
   b. With the independent field meter, Sonde B, record Sonde B readings and time near Sonde A

2. Remove Sonde A from the monitoring location (leave Sonde B in water)

3. Clean sensors of Sonde A

4. Return Sonde A to the monitoring location in the water
   a. Record the now cleaned Sonde A readings and time
   b. Using an independent field meter, Sonde B, record readings with Sonde B located near Sonde A

5. Remove Sonde A from water again, rinse thoroughly, and check calibration
   a. Record calibration-check values
   b. Recalibrate sensors of Sonde A if necessary

6. If all sensors are calibrated correctly, return Sonde A to monitoring location in the water
   a. Record Sonde A readings and time
   b. Using an independent field meter, Sonde B, record readings with Sonde B located near the Sonde A

7. Remove Sonde B from water

8. If Sonde A does not recalibrate or a sensor fails and it is not replaceable in the field, replace Sonde A with Sonde B

Table 5. USGS calibration criteria for sensors on the continuous water quality sondes (Wagner et al. 2006).

Measurement	**USGS Calibration Criteria** (variation outside the value shown requires recalibration)
Temperature	±0.2 °C
Specific conductivity	±5 µS/cm or ±3% of the measured value, whichever is greater
Dissolved oxygen	±0.3 mg/L
pH	±0.2 pH unit
Turbidity	±0.5 turbidity unit or ±5% of the measured value, whichever is greater

Attachment 1. USGS continuous water-quality monitor field form.

February 2006

Station No.________________

USGS science for a changing world

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

Station No. ______________________________ Station Name ______________________________

Monitor Inspected By ______________________ Date ___________ Watch Time _______ Time Datum ______

Gage Ht __________ (Rising, Falling, Steady, Peak) Channel Conditions ______________________________

Monitor Make/Model __________________________________ Monitor Serial No. ____________________

Field Meter Make/Model ______________________________ Field Meter Serial No. __________________

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

Comments:

MONITOR FOULING CHECKS

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

CALIBRATION DRIFT CHECKS

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

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

1–1 Monitor form ver. 3.0

Figure 2. USGS continuous water quality monitor field form with front page (1-1) and back page (1-2).

Station No. ________________________

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

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

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

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

Monitor form ver. 3.0

1–2

Figure 2 continued. USGS continuous water quality monitor field form with front page (1-1) and back page (1-2) (continued).

Maintenance

The frequency of maintenance is often governed by the fouling rate of the sonde's sensors. Fouling rate varies by sensor type, hydrologic and environmental conditions, and season (Wagner et al. 2006). The temperature and specific conductance sensors tend to be less affected by fouling than the dissolved oxygen and pH sensors. Fortunately, the availability of satellite telemetry can be used to verify proper equipment operation on a daily basis.

In the field, USGS staff must determine if the problem is with the sensor or the sonde and make the necessary corrections to ensure that the sonde is operational (Wagner et al. 2006). The USGS Hydrographers inspect the power supply. Batteries are usually low and should be replaced before the fouling and calibration checks. To ensure the sonde's battery compartment is air tight, all O-rings need to be lubricated before the battery compartment is closed.

The USGS Hydrographers then inspect and monitor the sensors and the calibration of each sensor. USGS field staff carries spare sensors and sondes so that troubleshooting is conducted during the revisits. For example, if the specific conductance sensor requires frequent calibration due to calibration drift, it may need to be replaced as well. The pH sensors tend toward sensitivity loss (Wagner et al. 2006). If USGS staff suspects sensitivity loss from sensor drift, the pH sensor can be easily replaced in the field. Troubleshooting in the field reduces record loss and the amount of time spent in processing records in the office.

Maintenance of the equipment is then recorded for each multiparameter sonde in the USGS Maintenance Record for Continuous Monitor form (Figure 3). These records provide the USGS staff with a history of maintenance for a specific sonde throughout the water year (Figure 3).

Station No. ______________________

MAINTENANCE RECORD FOR CONTINUOUS MONITOR

Correction factors applied to field meter readings? YES NO

Battery changed? YES NO Voltage __________volts

Sensors cleaned? YES NO Type of fouling ______________________________

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

Sensor changed? SC YES NO Sensor ID ____________________

pH YES NO Sensor ID ____________________

DO YES NO Sensor ID ____________________

Turbidity YES NO Sensor ID ____________________

Sonde Changed? YES NO New Sonde No. ____________ Old Sonde No. ______________

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

Comments ____

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

COMMENTS/OBSERVATIONS:

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

Monitor form ver. 3.0

1–4

Figure 3. General USGS maintenance record for continuous multiparameter sondes (Wagner et al. 2006).

Field Logs and Data Sheets

Legible, detailed, and in-depth field notes and instrument logs are essential for accurate record processing and verifiable computation of water quality monitoring records. The USGS designates one instrument logbook per multiparameter sonde and one per streamflow meter to serve as a complete record of all maintenance in the field, the laboratory, or by the manufacturer. This historical record of calibrations for each sensor in a multiparameter sonde must be kept in the instrument logbook that accompanies the instrument to the field and becomes the archival, chronological record of all calibrations, maintenance specific to the sensors, and general repairs. Interpretation of data analyses or data quality may depend on the documentation regarding instrument performance and the calibration solutions. Field measurement entries are checked by a second party and compared for accuracy and consistency with those entered into NWIS.

A hard copy of each field form is placed in a second logbook for each site. The results of sensor calibrations are recorded on the field form at the time of calibration, along with lot numbers and expiration dates of calibration solutions (Figure 2), to document that the calibration was performed according to the required standard operating procedures. Calibration information and repairs or replacement of sondes, sensors, membranes, or modification to the sonde software can be recorded initially on field forms or in field notebooks but then must be copied into the instrument logbook. Permanent instrument logs documents instrument performance including:

- sensor repair or replacement;
- calibration dates, times, time datum, and temperatures;
- calibration standard values, expiration dates, and lot numbers;
- initial and final monitor calibration data; and
- field meter calibration values.

The goal is to have sufficient information for another individual to be able to independently compute the record with similar results. Clear notes simplify the record computation and final review processes.

Water Quality Monitoring Protocol for Wadeable Streams and Rivers in the Northern Great Plains Network

Standard Operating Procedure (SOP)
SOP 4: Measurement of Streamflow at Sites

Version 1.0, October 2014

Revision History Log

The following table lists all edits and amendments to this SOP since the original publication date. Users of this SOP must notify the NGPN General/Aquatic Ecologist regarding recommended and required changes. The General/Aquatic Ecologist reviews and incorporates all changes, completes the revision history log, and changes the date and version number on the title page and in the footer of the document file. For complete instructions, please refer to SOP 8 Protocol Revision.

Previous Version #	Revision Date	Revised By	Changes Made	Reasons for Change	New Version #
1.0 Draft	October 2014	NGPN	Revision following peer review		1.0
Add rows as needed for each change or set of changes tied to an updated version number					

Introduction

Streamflow information is essential for understanding water quality for the NGPN. Streamflow measurements are made regularly to determine the stage–discharge relation and to define the time and magnitude of streamflow events. Documentation of stream discharge can be used for interpretation of water quality data to determine trends over time.

Several terms are associated with the measurement of water in streams and rivers. For the purpose of this SOP, a flowing body of water is referred to as a "stream." The velocity of a stream is the measurement of rate at which water flows past a point in a given time, expressed in Imperial units, such as feet per second (ft/s). The USGS uses primarily mechanical current meters (e.g., Price AA meter and Price pygmy meters) and hydroacoustic meters (e.g., Acoustic Doppler Current Profilers and Acoustic Doppler Velocimeters) (Turnipseed and Sauer 2010). The velocity of water measurement is used with subsection or "cell" measurements to calculate the stream's volumetric discharge, or the unit volume of water passing a given point on a stream over a given time. Streamflow, commonly referred to as stream discharge, is measured in cubic feet per second (ft^3/s).

To be most useful, streamflow data collection must be standardized. The purposes of this SOP are to (1) provide guidance for selecting sites to determine streamflow measurements; (2) describe methods for the measurement of stream velocity at fixed points (verticals) within cells of a stream transect; and (3) provide the method for calculation of the stream discharge. Streamflow measurements accompany water quality sampling at each of the NGPN monitored stream sites.

Site Selection

Most USGS continuous-record streamflow-gaging stations transmit data by satellite to computers where the stage data are used to estimate streamflow using the developed stage-discharge rating, available in real-time (http://waterdata.usgs.gov/nwis/). Real-time USGS data are considered provisionary and subject to change until the USGS has completely processed and quality checked the data. Consequently, users consuming real-time USGS data must verify at a later date that the data they downloaded are unchanged, final, and approved (i.e., no longer provisionary). A few NGPN stream reaches of concern, however, are not located in proximity to currently operational USGS gaging stations (e.g., DETO and KNRI); therefore, selection of site locations for streamflow measurements warrants careful study of existing maps and information. Field reconnaissance is needed prior to site selection to assess flow patterns and uniformity, streambed stability, and site accessibility. Once the general area or reach of the stream is identified, site-specific considerations can be followed (Table 6). Few sites meet all of the criteria (Table 6); however, stream sites selected for measurement should meet as many beneficial characteristics as possible.

Table 6. General selection guidelines for streamflow measurement (Rantz et al. 1982).

General stream course is straight for about 300 feet upstream and downstream from the site.
Total flow is confined to one channel at all stages, and no flow bypasses the site as subsurface flow.
Total streambed is not subject to scour and fill and is free of aquatic plants.
Banks are permanent, high enough to contain floods, and are free of brush.
Unchanging natural controls are present in the form of a bedrock outcrop, other stable riffle for low flow, and a channel constriction for high flow.
Streamflow measurement site is far enough upstream from the confluence with another stream to avoid any variable influences that the other stream may have on the stage.
Flow lines are relatively parallel and uniform in velocity throughout the site selected for the cross section.
Reaches with obvious bed irregularities, such as large boulders or changes in depth, and inside or outside river bends, should be avoided.
Areas close to shore should be checked for debris or vegetation that may affect the flow meter, by lowering the flow meter and taking preliminary readings.

Methodology

Field personnel are required to follow USGS Protocol while conducting streamflow measurements. All safety precautions must be followed, including filing a plan with NPS dispatch to inform them of the location and intended plans. Streamflow measurements are made while wading the stream when the depth and the velocity of water permit crossing of the stream without danger or injury to personnel (see Job Hazard Analysis, Figure 1).

Streamflow measurement works best when conducted with a two-person crew to facilitate equipment set up and to measure the cross section cells. One person can serve as a data recorder while the other team member operates the equipment. Ideally the site location for a cross section is fairly uniform in depth and velocity throughout (Table 6). All USGS personnel collecting streamflow data are trained prior to streamflow measurement and supervision during their initial fieldwork. Quality control for determining the rate of flow in a stream is accomplished by using established procedures and trained personnel. Repeated streamflow measurements (passes) may be made for verification.

Securing the Tagline

USGS staff selects the best stream reach within the sample area on the basis of the channel geometry for measurement (Table 6). The tag line (or tape) is suspended across the channel perpendicular to the direction of streamflow. The tape is secured to stakes driven in on the wetted edge of each side of the stream so that the distance on the tag line increases from the left edge of the water to the right edge of the water when facing downstream.

If the channel width and flow conditions do not support use of a measuring tape, a range finder can be used to determine the channel width by sighting objects on the shore to determine distances. The distance of the object from the waterline is subtracted when calculating increments for the discharge (Figure 4) so that discharge values are not over estimated.

Midsection Measurements

The total stream width is measured to determine the width of each stream increment within the cross section (Figure 4). If the stream width is <5 feet, incremental spacing widths of 0.5 feet are used. If the stream width is >5 feet, 20 to 30 increments are used. The number of increments must be a whole number.

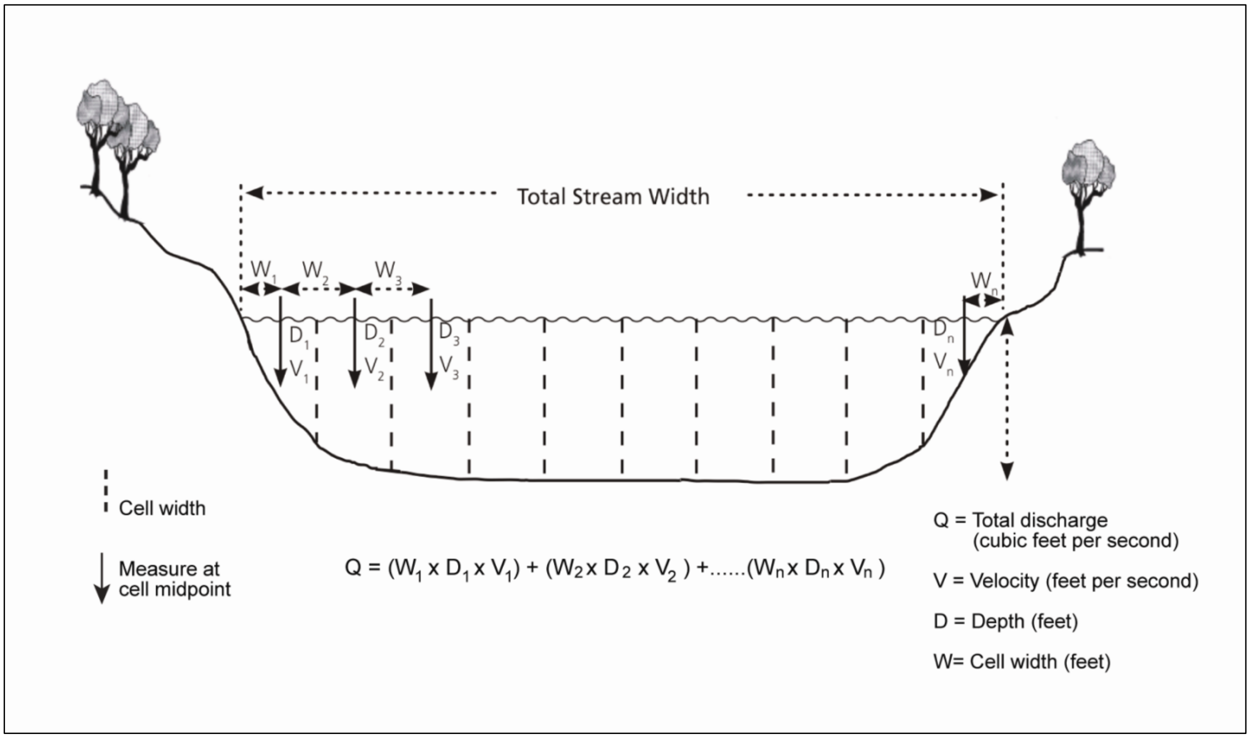

Figure 4. Velocity–area method for discharge calculations (courtesy of NPS, Southwest Alaska Network).

The center of each increment is referred to as the vertical. The first vertical measurement is located at a distance of one-half of the selected increment width from the edge of the water (Figure 4); all other verticals are located at the center of each remaining equal-width increment along the cross section. For example, if a 56-foot wide stream is divided into 23 increments of 2 feet each, the first sampling vertical would be 1 foot from the edge of the water, and subsequent verticals would be at 3, 5, and 7 feet, with continued verticals made on the tagline across the transect. Streams with divided flow, such as braided channels, may require a unique approach. The approach for increment measurements previously described can be used; however, only the portions of the stream with flowing water between each braided section of the stream would be measured.

Operation of a Wading Rod and Velocity Measurements

The streamflow measurement forms (USGS 9-275-F) can be partially completed before site visits to expedite field work (Figure 5). Once at the site, the remainder of the information/calculations are completed on hard-copy field forms or electronically entered into a computer. Measurements of stream velocity are made immediately downstream from the tag line to avoid disturbance of streambed sediment. Field notes and photographs accompany all field work.

The depth of flow is measured in each cell using a “top-setting” wading rod that has a main rod marked with 0.10-foot increments and a flow meter attached to a second sliding rod (Figure 6). The wading rod is placed vertically in the stream at the specified interval along the tape line so the base plate of the rod rests on the streambed. The person holding the wading rod stands about 3 inches downstream from the tag line and at least 1.5 feet from the wading rod, facing the bank so that the water flows against the side of the leg. The depth of water is read on the wading rod to the nearest 0.05 foot (Figure 6). During velocity measurements, the recorder follows behind and downstream of the operator, carries the calculator, makes necessary calculations, and calls out the distance values. It is difficult for one person to carry the flow meter, the connection wire, and the wading rod, even in calm channel conditions.

Depth velocity measurements can be determined by the six-tenths method, the two-point method, or a combination of these approaches.

9-275-x	07/08/2009	U.S. DEPARTMENT OF THE INTERIOR *U.S. Geological Survey*	Meas. No.	
Station Number			Comp. by	
		ADV Discharge Measurement Notes	Checked by	

Station Name					
Date	, 20____	Party			
Width	Area	Velocity	SNR	Gage Height	Discharge
Method		# Sections	Gage Height Change		
			in hrs.		
Manufacturer	Model		Serial No.	Firmware	Software
Data File	Std Velocity Profile		ADV Clock Sync'd		Diagnostic Test
	Y or N or Uncertain		Y at ______ or N		Y or N
Measured Water Temp	ADV Water Temp		Weather / Air Temp		Wind Speed / Dir.
°F / C at	°F / C at		°F / C		

Gage Readings							Rod Offset	
Time	Start End	Primary Reference					Pressure Sensor Calibrated?	
							Y or N	
							Rating number	
							Percent from rating	
							Indicated shift	
							Rain gage	
							Serviced / Calibrated	
							Salinity	
							ppt at	
Weighted MGH							Checkbar found	
GH corrections							Checkbar Changed to	
Correct MGH							at	

Wading, ice, upstr., downstr., side bridge			ft., mi. upstr., downstr. of gage			
Measurement rated	excellent (2%), good (5%), fair (8%), poor (>8%)		based on following conditions			
Flow						
Cross section						
Control						
Gage operating	Y or N	Record removed	Y or N	Filename		
Battery voltage	V	Intakes/Orifice cleaned/purged				
Bubble-gage psi	Tank		Line		Bubble rate	/ min
Extreme-GH indicators:	Max		Min		CSG Checked	Y or N
HWM on stick		Ref elev.		HWM elevation		
GH of zero flow = GH		- depth at control		=	ft, Uncertainty	±
Remarks						
	Sheet No.		of		sheets	

Figure 5. Example of the USGS form 9-275-F for discharge measurement notes.

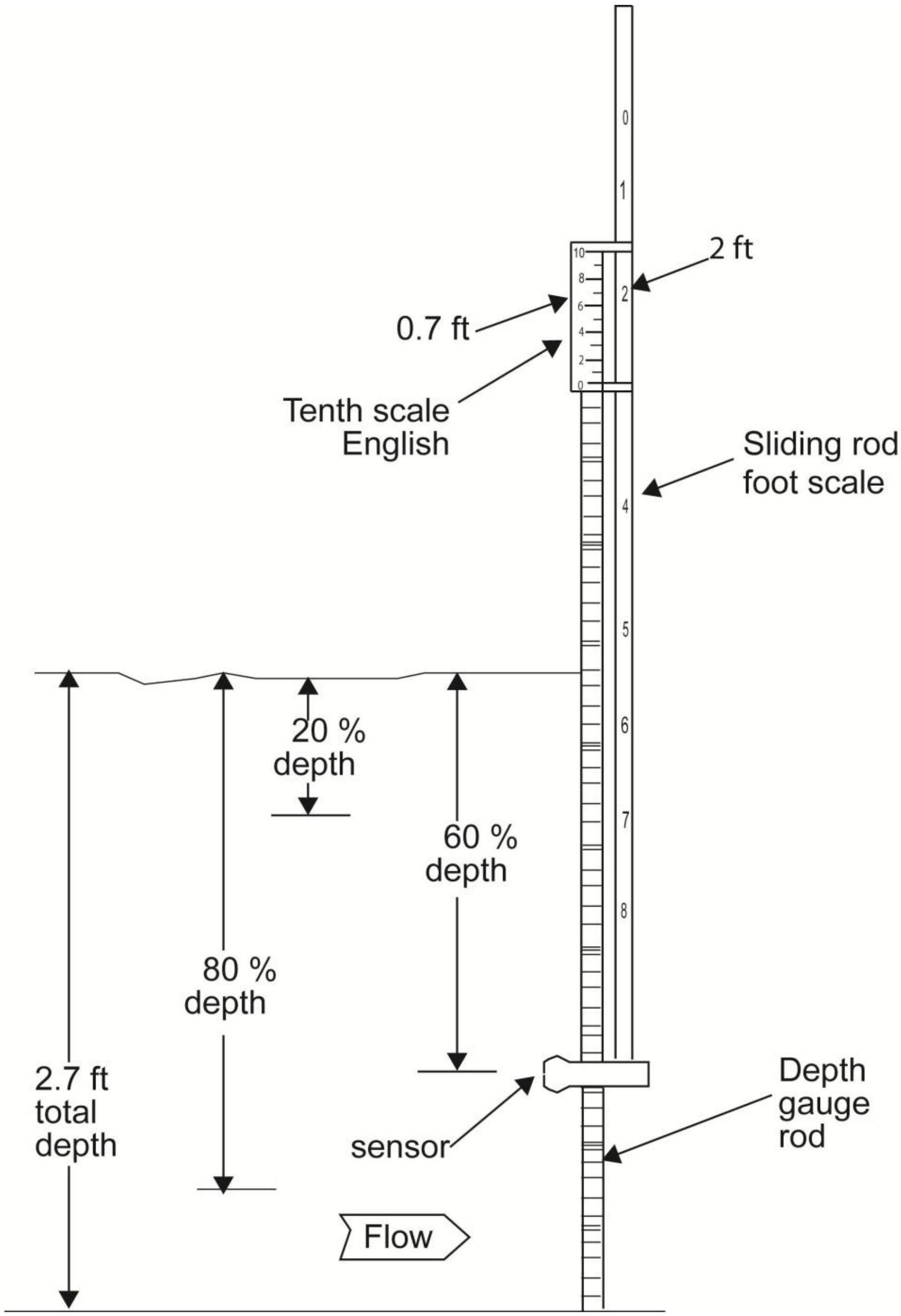

Figure 6. Top-setting wading rod with examples of flow at 20, 60, and 80% of depth.

Six-Tenths Depth Method

The six-tenths (0.6) depth method of measurement is used when the total depth is relatively shallow (<2.5 feet) (Rantz et al. 1982, Turnipseed and Sauer 2010) or the water depth is changing rapidly and there is not enough time to accurately measure velocity using the two-point method. The depth of the vertical and the 0.6-depth velocity measurement are required at the midpoint of the each cell of the transect (Figure 4). The sensor is set at 60% (0.6) of the depth from the stream surface; the top-setting rod is designed to place the sensor at this level when the foot scale on the sliding rod is lined up with the tenth scale on the top of the depth gage rod (Figure 6). For example, if the stream depth as observed on the depth gauge rod is 2.2 feet, the 2-foot mark on the sliding rod would be lined up with the two-tenths mark on the top of the depth rod, locating the sensor at the appropriate depth. The velocity value is then read by the operator and recorded on the USGS form 9-275-F (Figure 5).

Two-Point Depth Method

The two-point method is used when the total depth is >2.5 feet. This method uses the depth of the vertical and the velocity measurements at the 20% (0.2) and the 80% (0.8) depths from the stream surface as follows:

0.2 depth. The top-setting rod is designed to place the sensor at 20% of the depth from the stream surface when the foot scale on the sliding rod is lined up with the tenth scale on the top of the depth gauge rod, using a value of twice the depth of the cell (Figure 6). For example, if the cell depth as observed on the depth gauge rod is 2.7 feet, the operator would first multiply by two to obtain 5.4 feet. The operator would then line up the 5-foot mark on the sliding rod with the 0.4 mark on the top of the depth rod to place the sensor at the appropriate depth. The velocity value is then read by the operator and recorded on the data sheet.

0.8 depth. The top-setting rod is designed to place the sensor 80% of the depth from the stream surface when the foot scale on the sliding rod is lined up with the tenth scale on the top of the depth gage rod, using a value of half the depth of the cell. For example, if the cell depth as observed on the depth gauge rod is 2.7 feet, the operator would first divide by two to obtain 1.35 feet. The operator would then line up the 1-foot mark on the sliding rod with the 0.35 mark on the top of the depth rod to place the sensor at the appropriate depth. The velocity value is then read by the operator and recorded on the data sheet.

For the final calculation, the mean of the velocity measurements at the 0.2-depth velocity and the 0.8-depth velocity observations is used as the velocity of the vertical.

Three-Point Depth Method

The three-point depth method is used when the velocities in the vertical are abnormally distributed because of disruptive elements in the water or when water depth is extremely variable throughout the cross section. For the three-point method, velocities of cells are measured at depths of 20, 60, and 80%. The mean of the velocity measurements of the 0.2- and 0.8-depths are then averaged with the velocity measurement at the 0.6-depth when calculating mean velocity of the vertical.

Steps for Cross Sectional Measurements

Stream discharge is calculated from individual cell measurements of the cross section. The recorder and the operator use the following steps to complete cross-sectional measurements:

1. The recorder completes the information form (USGS 9-275-F) including the flow severity, weather conditions, and ancillary information (Figure 5).

2. The operator checks to see that the flow meter is ready to operate.

3. Exploratory depth measurements are taken while stringing the tagline to determine which method to use for the calculating the velocity, the 0.6-depth method and/or the two-point depth method. As previously mentioned, the 0.6-depth method is needed for all stream depths <2.5 feet.

4. Starting on the near shore, the operator determines the midpoint of the first cell (see section "Midsection Measurements").

5. The operator follows the tape out to the proper position.

6. The operator positions the wading rod to measure the depth of the vertical and calls out the total depth to the recorder. The operator stands downstream from and off to the side of the wading rod so that the flow is uninhibited as it passes by the sensor.

   - If the 0.6-depth method is used, no calculations are required, and the operator simply positions the sensor by moving the sliding rod (see section "Operation of a Wading Rod and Velocity Measurements"). The operator calls out the velocity measurements to the recorder.

   - If the two-point method is used, the recorder calculates the 0.8 depth using the method previously described in "Operation of a Wading Rod and Velocity Measurements." The operator adjusts the wading rod, takes a velocity reading at the 0.8 depth, and calls out the velocity for the recorder to enter on the form. The recorder then calls out the 0.2 depth, and the operator again adjusts the wading rod makes a second velocity reading, and calls out the new value.

7. Once the readings are made, the operator moves on to the midpoint of the next cell using the tape or tag line as a guide.

8. Steps 5 through 7 are repeated until the stream cross section is completed.

9. If the water is loud and/or the channel is wide, the recorder may need to follow the operator across the stream; however, the recorder should remain at least 3 feet away from the active flow area being measured.

10. The recorder can use the time between velocity readings to calculate the discharge for each cell so that an estimated total discharge can be determined (see section "Calculating

Wadeable Discharge” below). Total discharge for a stream is calculated by multiplying the width by depth by velocity for each cell measured in the cross section (Figure 4) and then summing the products.

11. Stream stage, the water level above a designated point in the stream at a given time, is recorded before and after each channel cross section is completed.

12. The operator or the recorder establishes a permanent point in the cross section and takes photographs upstream and downstream (Figure 7) from the center of the cross section. The channel should comprise about 80 to 90% of the photograph frame, with the horizon comprising about 10 to 20% of the frame. In addition, the USGS staff photographs the sonde in the stream (Figure 7). For more details, see the “Photographic Validation, and Management” section in SOP 5 below.

13. Equipment performance must be checked before and after each sampling event.

PHOTOGRAPHIC RECORD SHEET

PARK: ______________ **Site ID:** _______________________________

Date	**Photo Purpose**	**Photo #**	**Notes**

NPS Northern Great Plains Network Review:

Entered (initial and date): _______________100% Checked (initial and date): __________________ 10% Checked (initial and date): ______________________

Figure 7. Photographic record sheet for water quality monitoring used by USGS staff to record photos taken during each site visit. Photo purpose is to show upstream, downstream, or sonde.

Calculating Wadeable Discharge

The cross-sectional measurements taken by the operator and recorder are used to determine discharge for the entire stream. The USGS staff determines whether the six-tenths depth method, the two-point depth method (the mean velocity of measurements at 0.2 and 0.8 depths), or a combination is appropriate for velocity measurements and then enters the data accordingly on the USGS form 9-275-F (Figure 5). After the field work has been completed, the data entered at the field site are reviewed to confirm that information is complete and accurate. If data were recorded on a hard copy, they are entered into electronic files and saved in a designated electronic database. Values for total discharge (Q) are based on the following calculation:

$$Q = (W_1 \times D_1 \times V_1) + (W_2 \times D_2 \times V_2) + \ldots..(W_n \times D_n \times V_n)$$

where:

Q = discharge (ft^3/s)

W = width (feet)

D = depth (feet)

V = Velocity (ft/s)

n = total # of cells

Water Quality Monitoring Protocol for Wadeable Streams and Rivers in the Northern Great Plains Network

Standard Operating Procedure (SOP)
SOP 5: Data Management

Version 1.0, October 2014

Revision History Log

The following table lists all edits and amendments to this SOP since the original publication date. Users of this SOP must notify the NGPN General/Aquatic Ecologist regarding recommended and required changes. The General/Aquatic Ecologist reviews and incorporates all changes, completes the revision history log, and changes the date and version number on the title page and in the footer of the document file. For complete instructions, please refer to SOP 8 Protocol Revision.

Previous Version #	Revision Date	Revised By	Changes Made	Reasons for Change	New Version #
1.0 Draft	October 2014	NGPN	Revision following peer review		1.0
Add rows as needed for each change or set of changes tied to an updated version number					

Introduction

This SOP explains the procedures for managing data from the NGPN Water Quality Monitoring Protocol for Wadeable Streams and Rivers. AQUARIUS is the primary software environment for the water quality data. Procedures and guidelines in this document follow recommendations of the NGPN Data Management Plan (http://science.nature.nps.gov/im/units/ngpn/datamanagement.cfm).

Data Work Flow

For the time series data work flow for water quality and water quantity (at existing USGS gaging stations) monitoring (Figure 8), the USGS WSCs collect the water quality and streamflow data at the designated sites. Throughout the field season the WSCs periodically provide the NGPN with electronic copies of the raw 15-minute interval data recorded by the sondes and streamflow measurements collected during each visit. The USGS reviews and post-processes the provisional time series data either in their Automated Data Processing System (ADAPS) or AQUARIUS platform. At the end of the field season, each WSC provides the NGPN with electronic copies of the metadata files; the corrected/approved time series data; and the corrected, manually collected streamflow data, data sheets, and photographs. All USGS time series files are named consistent with the NGPN file naming system (see Management of Electronic Data Sheets below). The NGPN then puts the approved data on the Water Resource Division's AQUARIUS Server, analyzes these data, and distributes this information.

Data Verification and Validation

Data verification ensures the computerized data match the source data, and data validation is a review of data for range and logic errors. Collected water data are verified and validated by each respective USGS WSC for water quality and streamflow data. As part of this process the USGS calculates sensor-fouling error and instrument-calibration drift for each core parameter using the Inspection Summaries developed by USGS. Data are checked by the USGS Hydrographers, reviewed by other USGS staff (e.g., Chief, Hydrologic Data), and then listed as "approved" in the database. The USGS then sends the electronic files to the NGPN.

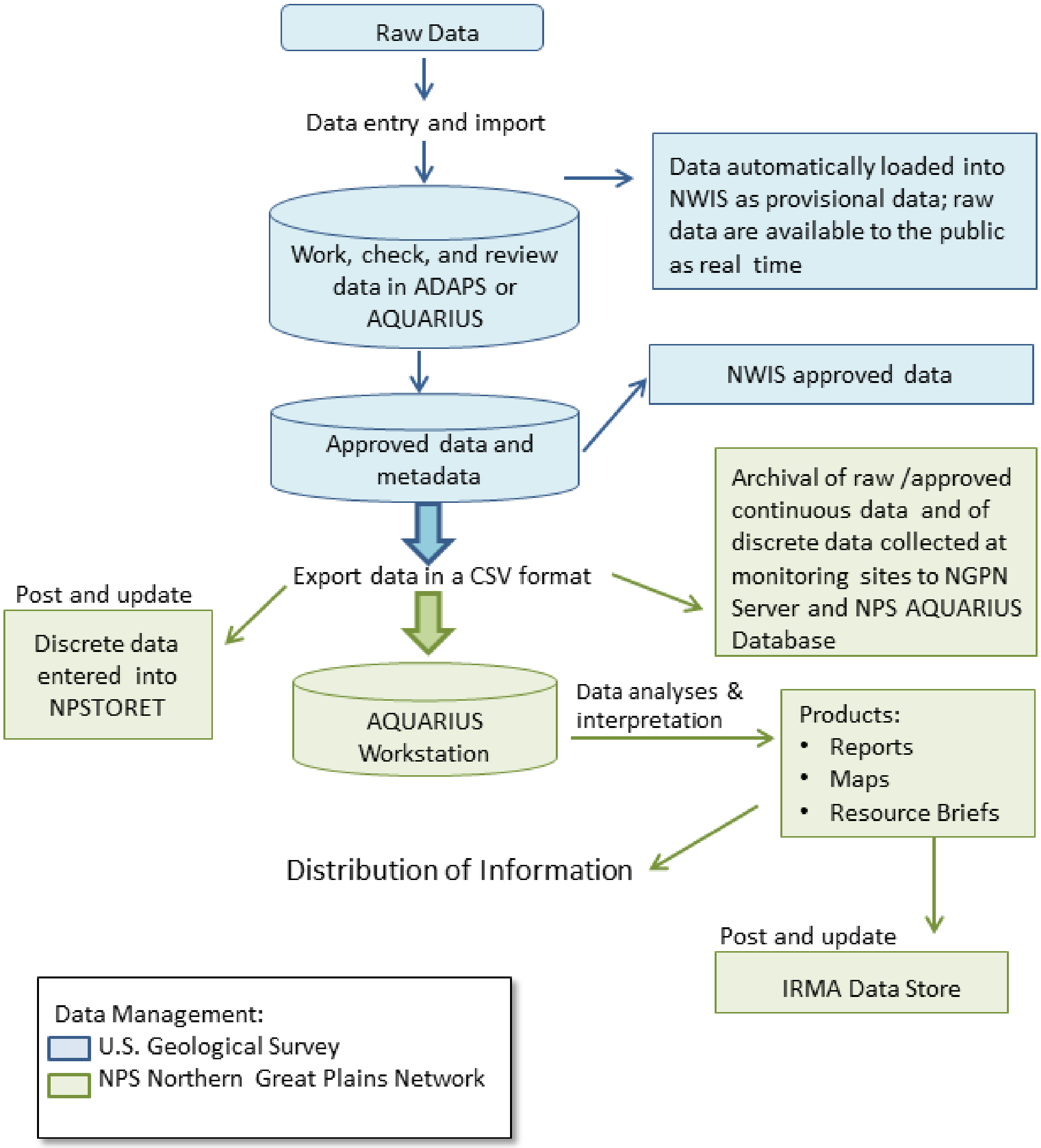

Figure 8. Diagram of data work flow for water quality and streamflow data collected at selected waterbodies in NGPN park units. The USGS is in the process of transitioning from the old Automated Data Processing System (ADAPS) to an AQUARIUS platform. This transition should be completed in the next several years.

Metadata

Metadata can be defined as the detailed information about this water quality program including monitoring station locations, measured parameters, equipment collection methods, program contacts, data format, time and physical conditions (weather) of collection, access/use constraints, and distribution. These data are derived from the USGS documentation the NGPN receives as deliverables.

Steps for Metadata Creation

1. Metadata Interview Form (Attachment A) and Information Gathering:
   The General/Aquatic Ecologist provides the Data Manager with a copy of any additional information, such as the USGS Station Report, valuable for the development of metadata.

2. Sensitivity Review:
   The data are not considered sensitive and are made available to the public through NWIS.

3. Metadata Review:
   The General/Aquatic Ecologist reviews the metadata for quality control before posting them to the NPS Integrated Resource Management Applications (IRMA) portal (https://irma.nps.gov/App/Portal/Home).

Management of Electronic Data Sheets

During each site revisit the USGS Hydrographers record the metadata related to the visit as well as fouling and calibration drift checks onto the USGS Continuous Water-Quality Monitor Field Form (Figure 2; SOP 3). In addition, USGS Hydrographers fill out the Cross Section Survey and the USGS Discharge Measurement Notes (Figure 5; SOP 4). Processing these data sheets involves the following steps:

- Original paper data sheets remain with the respective USGS WSCs.

- The USGS provides NGPN electronic copies of all field data sheets after they have been verified and validated by USGS staff.

- The General/Aquatic Ecologist reviews and ensures that all information on the electronic copies is legible.

- Electronic copies of the data sheets are stored on the NGPN server under the respective Park's 'DATA' subfolder (e.g., N:\Groups\Monitoring\Water_Quality\DETO\DATA\WaterQuality\DataSheet\ or N:\Groups\Monitoring\Water_Quality\DETO\DATA\Streamflow\DataSheet\)

All data sheets are saved in Adobe PDF format and stored in their respective subfolder (refer to SOP 5 Data Storage section below) using the standard file naming convention, PARK_WQM_XXXXXXXX_Content_YYYYMMDD, where all file name components are separated by an underscore.

- PARK is the four-letter park code.
- WQM is used to indicate water quality monitoring.
- XXXXXXXX is the Site ID or USGS Streamflow Station number.
- 'Content' indicates a description of the file. Options for the file contents include:
  - 'StnAnalysis_Rpt' for the USGS Station Analysis Report files;
  - 'ContWQMon' for the USGS Continuous Water-Quality Monitor Field form files;
  - 'FieldMeter_Cal' for the USGS Meter Calibrations and Lot Numbers files;
  - 'Photolog' for the Photographic Record Sheet files;
  - 'DischargeMeas' for the USGS Discharge Measurement Notes files;
  - 'InspectSum' for the USGS Inspection Summaries for each parameter;
  - 'RawData' for the raw sonde files; and
  - 'ApprovedData' for the approved sonde data files.
- Date (YYYYMMDD) is in the format: year (4 digits) month (2 digits) day (2 digits). The exception to this date format is in the approved data files where only the year (YYYY) is listed before the file extension.

The General/Aquatic Ecologist checks to ensure that the file names correctly reflect the file content.

Photographic Validation and Management

The General/Aquatic Ecologist validates all photographs during the photo file naming process by comparing photo content with the file's name/date and by comparing photo content among all photos taken at the same site.

There are two types of photographs: data or general (see NGPN Image Management SOP, unpublished internal document). Data photographs are taken by the USGS Hydrographers and recorded on the Photographic Record Sheet (Figure 7; SOP 4).

- Data photographs include the original digital photographs taken by USGS during each site revisit. The USGS lists the "Photo Purpose" part of the Photographic Record Sheet (Figure 7; SOP 4) as upstream, downstream, or sonde placed in the water. The data photos are copied to the NGPN server (N:\Groups\Monitoring\Water_Quality\PARK\IMAGES\Original\, where "PARK" is the four-letter park code).
- For each data photograph, a copy is made of each image and stored in the 'DataPhoto' folder (N:\Groups\Monitoring\Water_Quality\PARK\IMAGES\Edited\DataPhoto). The

General/Aquatic Ecologist assigns the data photo a new file name that includes the original photo number stamped onto the image (see below). This duplication is needed to cross-check photos with the Photographic Record Sheet until the photo files are ready for archiving. Only the edited files are archived.

- Photographic Record Sheets are stored in the 'PhotoLog' folder (N:\Groups\Monitoring\Water_Quality\PARK\IMAGES\PhotoLog) until the end of the water monitoring season. After the water season the 'PhotoLog' folder is archived.

General photographs include all other photographs taken primarily by NPS staff during site revisits such as images of staff, calibration activities, deployment activities, cross sectional surveys, landscapes, equipment, etc.

- General photographs are also copied to the NGPN server (N:\Groups\Monitoring\Water_Quality\PARK\IMAGES\Original\, where "PARK" is the four-letter park code).

- General photographs are then saved into the 'General' folder (N:\Groups\Monitoring\Water_Quality\PARK\IMAGES\Edited\General). Only high quality general photographs useful for presentations, reports, or other communications should be renamed and saved to this folder.

For edited data photographs, the standard file naming convention (i.e., the names given to copies) is PARK_WQM_XXXXXXXX_Content_OriginalPhotoNumber_YYYYMMDD.jpg, where all file name components are separated by an underscore. For edited general photographs the standard file naming convention is PARK_WQM_XXXXXXXX_Content_YYYYMMDD_SequentialNumber.jpg.

- PARK is the four-letter park code.

- WQM is used to indicate water quality monitoring. If the photo is a general photo not related to the water monitoring Vital Sign, the WQM can be eliminated from the image file name. For example, if you take a general photo of just Devils Tower while conducting water quality monitoring, the file name becomes DETO_Landscape_20130321.jpg.

- XXXXXXXX is the Site ID or USGS Streamflow Station Number. For general photos not related to the actual water quality Vital Sign, the Site ID can be eliminated from the general image file name (see above).

- 'Content' indicates a generic description of the photo. The 'Content' portion of a data photograph is listed on the Photographic Record Sheet (i.e., upstream, downstream, or sonde). For general photographs, the most frequently used categories are people, hydrography, or landscape (NGPN Image Management SOP unpublished internal document).

- OriginalPhotoNumber is the number given to the photo by the camera and recorded in the 'Photo #' column of the Photographic Record Sheet for the data photographs only.

- Date (YYYYMMDD) is the date the photo was taken in the format: year (4 digits), month (2 digits), and day (2 digits).

- If there is more than one general photograph taken on the same date with the same content category, sequential numbers are used after the date the photos were taken.

Example file names for data and general photographs:

- DETO_WQM_06427850_Upstream_0076_20130321.jpg
- DETO_WQM_06427850_People_20130419_1.jpg
- DETO_WQM_06427850_People_20130419_2.jpg

Data Entry

After the NGPN receives the approved data from USGS, the General/Aquatic Ecologist adds the respective state regulatory thresholds for the four core parameters into the USGS approved, comma separated value (CSV) files (see Table 4 in the Water Quality Monitoring Protocol for Wadeable Streams and Rivers in the Northern Great Plains Network: Narrative Version 1.0 for current threshold levels and state contact information). For example, for the State of Nebraska Department of Environmental Quality regulatory thresholds, a column of 5.0 is added for the dissolved oxygen threshold, a column of 2000 for the specific conductivity threshold, 22 for the water temperature threshold, and two columns for pH (6.5 for the low threshold and 9.0 for the high threshold levels) (Table 7). Including this data entry step allows NGPN to plot the status of each core parameter in relationship to the respective regulatory thresholds using the 'Charting' toolbox in AQUARIUS software (see SOP 6).

Table 7. An example of the addition of state regulatory threshold levels (shaded columns) for the core parameters into the approved CSV files received from the USGS WSCs.

Date	Time	Water Temperature	Maximum Water Temperature Threshold	Specific Conductance	Specific Conductance Threshold	Dissolved Oxygen	DO Threshold	pH	Lower pH Threshold	Upper pH Threshold
5/1/2011	0:15:00	22.33	22	406.65	≤2,000	7.47	≥5.0	8.44	6.5	9.0
5/1/2011	0:30:00	22.36	22	406.06	≤2,000	7.40	≥5.0	8.46	6.5	9.0
5/1/2011	0:45:00	22.35	22	405.51	≤2,000	7.25	≥5.0	8.47	6.5	9.0
5/1/2011	1:00:00	22.30	22	404.95	≤2,000	7.16	≥5.0	8.48	6.5	9.0
5/1/2011	1:15:00	22.26	22	404.48	≤2,000	7.13	≥5.0	8.50	6.5	9.0
5/1/2011	1:30:00	22.20	22	403.92	≤2,000	7.18	≥5.0	8.51	6.5	9.0
5/1/2011	1:45:00	21.91	22	403.63	≤2,000	7.13	≥5.0	8.51	6.5	9.0
5/1/2011	2:00:00	21.77	22	403.22	≤2,000	7.07	≥5.0	8.51	6.5	9.0
5/1/2011	2:15:00	21.91	22	402.74	≤2,000	6.99	≥5.0	8.52	6.5	9.0

AQUARIUS Data Management Using Springboard

The NGPN has access to the NPS AQUARIUS license that includes the AQUARIUS Springboard and Workstation/Whiteboard interfaces as well as the AQUARIUS Database. The NPS Water Resources Division (WRD) has developed overview documents and videos (http://nrdata.nps.gov/programs/water/aquarius/AQUARIUSVideos.htm) to help NPS users begin to use AQUARIUS. Many of the AQUARIUS instructions in this SOP are found in the WRD overview documents and videos. Additional software training videos and the AQUARIUS user manual are found by clicking the 'Help' menu within AQUARIUS or by going to http://aquaticinformatics.com/support.

To access the AQUARIUS system, users must be validated by (1) contacting WRD staff to be included in the AQUARIUS Active Directory group; (2) being added by WRD staff as an authenticated user of the AQUARIUS system; and (3) receiving a 'Remote App' desktop icon ( ) and access instructions from WRD staff to connect to the hardware server in Denver, Colorado, that hosts the AQUARIUS system.

To start the AQUARIUS software, the 'Remote App' desktop icon ( ) is used to first access the hardware server (inp2300fcvgett1.nps.doi.net or just localhost) that hosts the AQUARIUS system. The user is prompted to enter an Active Directory user name and password, and once logged in, the AQUARIUS Assistant adds an icon ( ) to the Task Bar at the bottom of the screen. The user right-clicks on the 'AQUARIUS Assistant' icon and selects 'Launch Springboard,' and is then asked to enter an Active Directory user name and password for the Springboard login. Further AQUARIUS directions and information are provided in the Water Resource Division's overview documents or videos (http://nrdata.nps.gov/programs/water/aquarius/AquariusVideos.htm).

When using Springboard, users work directly with the AQUARIUS Database, and data are automatically saved. Springboard has a "location" centric view of time series data management (http://nrdata.nps.gov/programs/water/aquarius/AquariusVideos.htm), and time series data sets are stored in the AQUARIUS Database under a specific location. The 'Northern Great Plains Network' location folder is in the left column of Springboard. To open, click the ► icon to the left of the 'Northern Great Plains Network' folder to show the park (or Program) folders, then select the park of interest under the "Northern Great Plains Network' folder. The location(s) on the right are associated with the selected parks.

Location Manger Tool

The 'Location Manager' tool allows the user to create and manage locations, data sets, user access, and notifications. The NGPN index water quality site locations selected for long-term monitoring have already been added to the AQUARIUS Database (e.g., for DETO the location name is Belle Fourche River at Devils Tower WYO). If you need to add a new location, click the 'Location Manager' icon ( ) in the top toolbar (without selecting an existing location) and follow the prompts in the 'Location Manager' window. Once a location has been created in the AQUARIUS Database, time series data sets for the location are stored in parameter "containers" (see Append Logger Files Tool section below).

Field Visit Tool

Throughout the field season, the NGPN receives the raw data and copies of field data sheets from the respective USGS WSC for entry into AQUARIUS. The 'Field Visit' tool allows users to enter or import discrete measurements, data files, observations, data sheets, and photos collected during each site revisit. The NGPN uses the 'Field Visit' tool to provide a backup for data and notes collected while in the field.

To see all site revisits previously entered for a particular location, select the location's park folder from the 'Northern Great Plains Network' folder on the left and click the 'Location Identifier' (e.g., DETO_06427850) under 'Locations.' A list of site revisits for the specific location should appear under the 'Visits' tab (Figure 9) below 'Locations.'

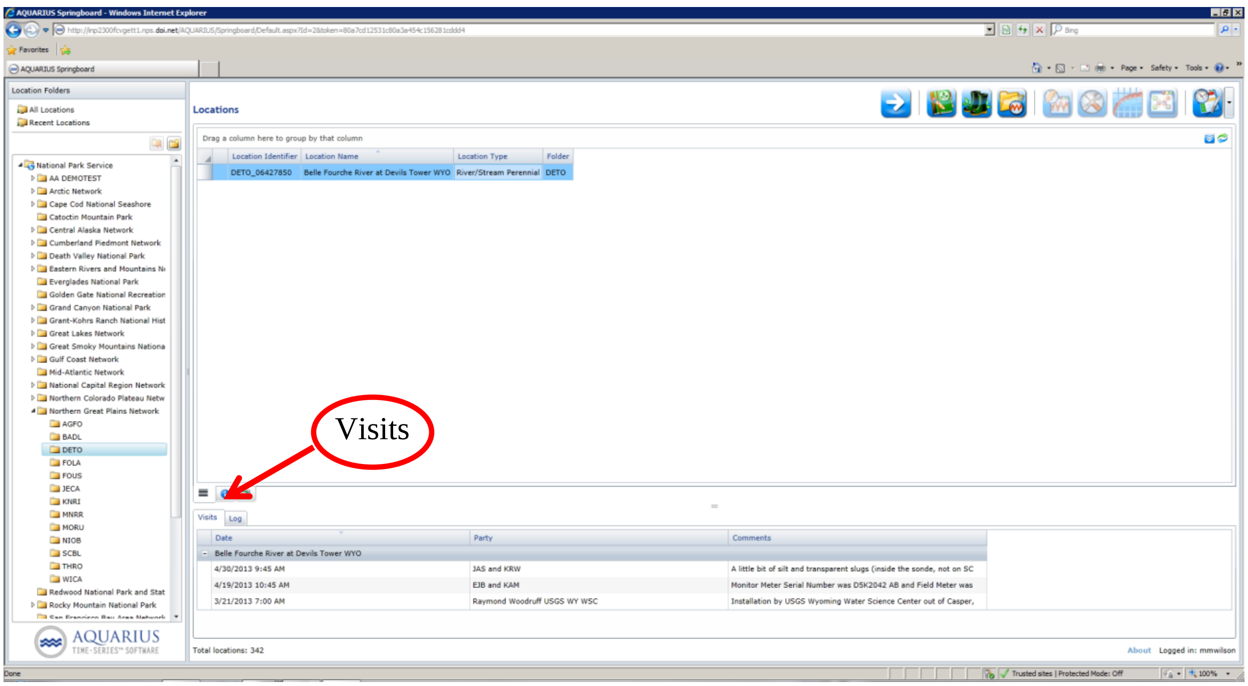

Figure 9. Previously loaded site revisits listed for a specific location under the 'Visits' Tab at the bottom of the screen in AQUARIUS Springboard.

To add a new site revisit for a park from Springboard, select the visited location (so it is highlighted in cyan) and then either right-click the visited location and choose 'Field Visit' or left-click the 'Field Visit' icon ( ) at the top of the screen. Click the 'New' icon (New) at the top (Figure 10) and select 'Field Visit' from the dropdown. Enter the date and time for the site revisit from the USGS field data sheets, click 'OK,' then click the 'Save & Exit' icon ( ).

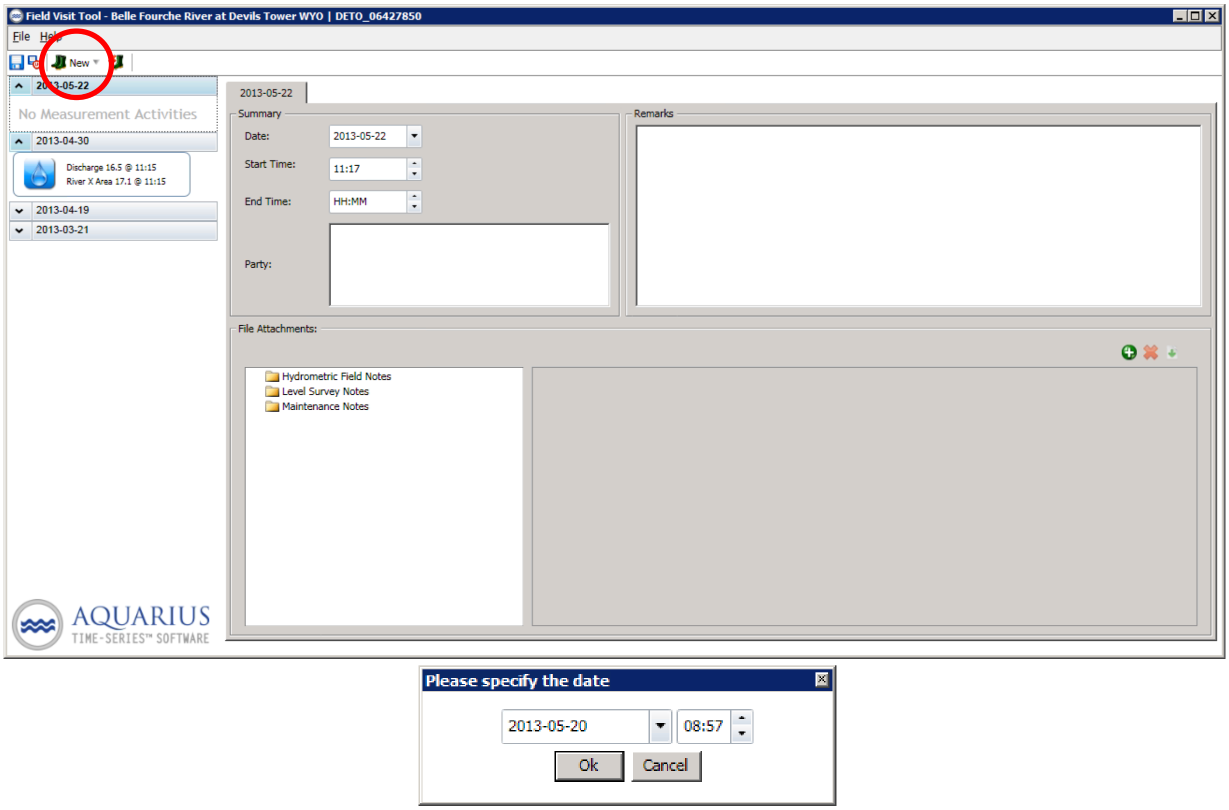

Figure 10. Establish a new site revisit for a location.

To be consistent with the folder naming conventions for the NGPN, three new folder names (Images, Streamflow, and WaterQuality) are added for each site revisit. Highlight the location, click on the 'Location Manager' icon ( ), then under the 'General' tab, highlight the folder PARK_sitenumber (e.g., DETO_06427850). AQUARIUS links the file attachments between the 'Location Manager' and 'Field Visit' tools based on folders sharing the same date name (e.g., 2013-03-21). If the year of the new site revisit already exists in Location Manager, highlight this year folder, click the 'New Folder' icon ( ) located below the image on the far left side, then double click 'New Folder' until the black rectangle with white font appears. Rename this folder with the new site revisit using YYYY-MM-DD (e.g., 2013-03-21).

If the year of the new site revisit is not in the 'Location Manager,' highlight the folder PARK_sitenumber (e.g., DETO_06427850) and click the 'New Folder' icon ( ) located below the image on the far left side. Scroll to bottom of the folder list, double click 'New Folder,' and a black rectangle with white font appears. Rename this folder with the year of the site revisit (e.g., 2014). Highlight this new folder and again double click the 'New Folder' until the black rectangle with white font appears. Rename this folder with the new site revisit using YYYY-MM-DD (e.g., 2013-03-21). To add the three new folders (Images, Streamflow, and WaterQuality), highlight the date folder (YYYY_MM_DD) (Figure 11), click the 'New Folder' icon, then double click and rename it to 'Images.' Create two more folders under the date folder and name them 'StreamFlow' and

‘WaterQuality.’ Click the ‘Save & Exit’ icon ( ) in top left-hand corner of ‘Location Manager’ window.

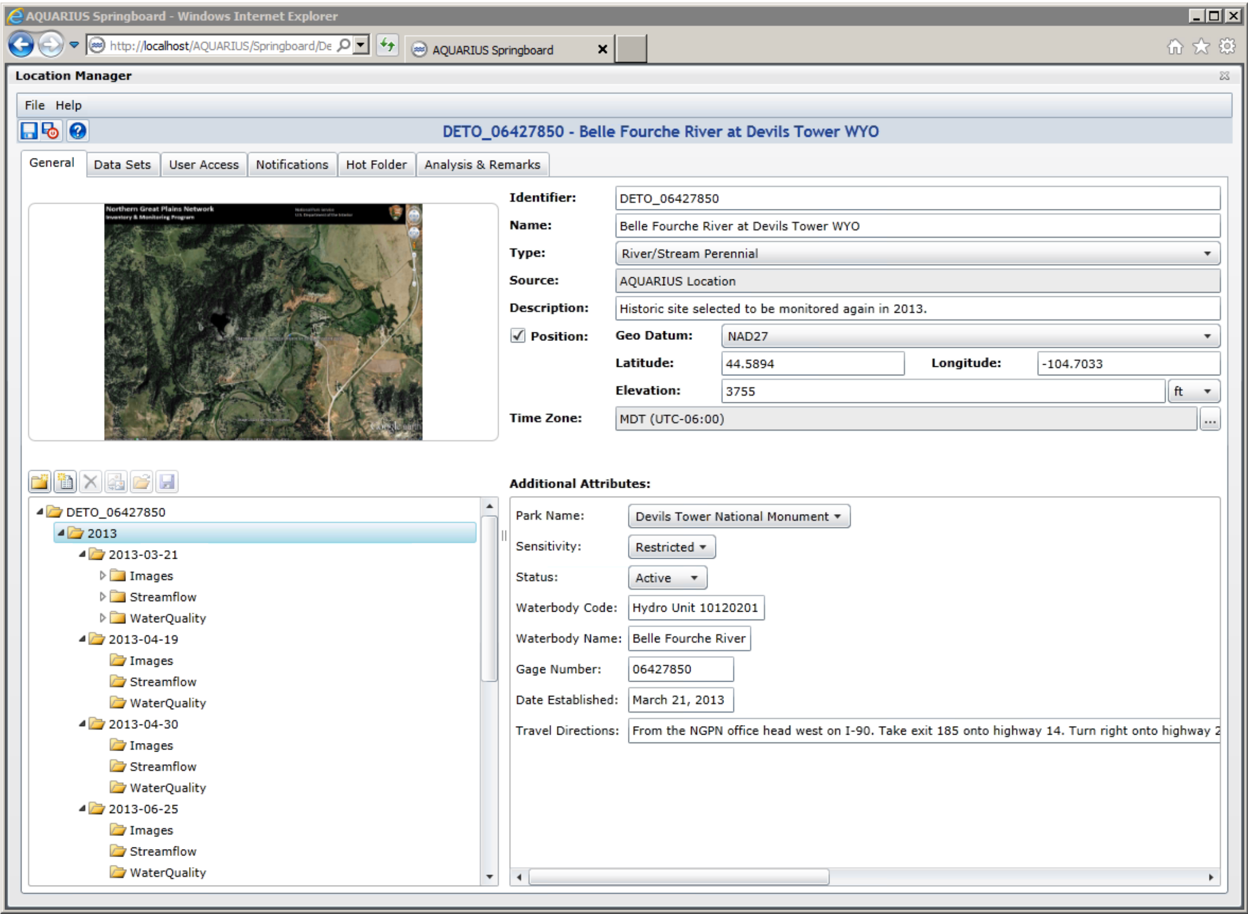

Figure 11. Use the ‘Location Manager’ tool to add new ‘Field Visit’ folders.

To add the new site revisit information, refresh Springboard by clicking the ‘Refresh’ icon ( ) in the upper right corner of the ‘Locations’ tab and then click the Location Identifier (e.g., DETO_06427850) under ‘Locations.’ A list of site revisits for the specific location should appear under the ‘Visits’ tab (Figure 9) below ‘Locations.’ Select the date of the new site revisit from under the ‘Date’ tab and double click. The new site revisit information opens in the ‘Field Visit’ tool. Enter the staff who participated in the site revisit in the ‘Party’ field and any relevant comments or remarks in the ‘Remarks’ field (Figure 12). Note that as of September 29, 2014, the canned ‘Field Visit’ folders (i.e., Hydrometric Field Notes, Level Survey Notes, and Maintenance Notes) cannot be renamed or deleted from the ‘Field Visit’ tool.

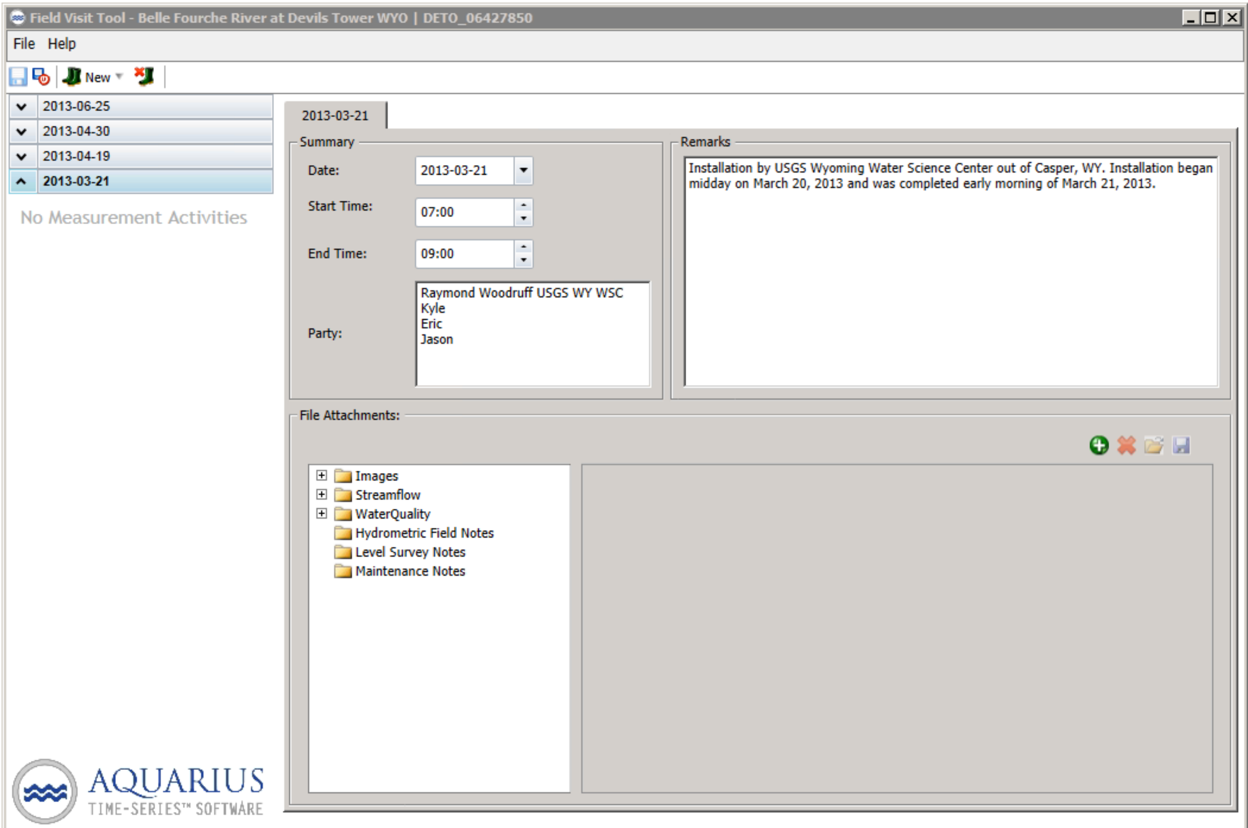

Figure 12. Fill in appropriate 'Party' and 'Remarks' fields for a new site revisit using the 'Field Visit' tool.

The 'Images' folder contains the edited photos and the photolog for the corresponding site revisit. The 'StreamFlow' folder in the 'Field Visit' tool includes the Discharge Measurement Form. The 'WaterQuality' folder in the 'Field Visit' tool contains the data sheets related to water quality (e.g., Continuous Water-Quality Monitor Field Form, Field Meter Calibrations and Lot Number AQUARIUS Database Form, and Cross Section Survey file) and the raw logger data for each visit to the location.

To attach files to each of the three folders, click the corresponding folder (e.g., Images) in the lower left-hand corner of the 'File Attachments,' then click the 'Plus' icon ( ) to attach files (Figure 13). Click the N Drive (N on INPNGPN), navigate to N:\Monitoring\Water_Quality\PARK\IMAGES\Edited\DataPhoto, and double click the image (e.g., DETO_WQM_06527850_Downstream_0094_20130625.jpg) (Figure 14). Follow the above procedures to add Streamflow and Water Quality data. These folders are found at: N\Monitoring\Water_Quality\DETO\DATA.

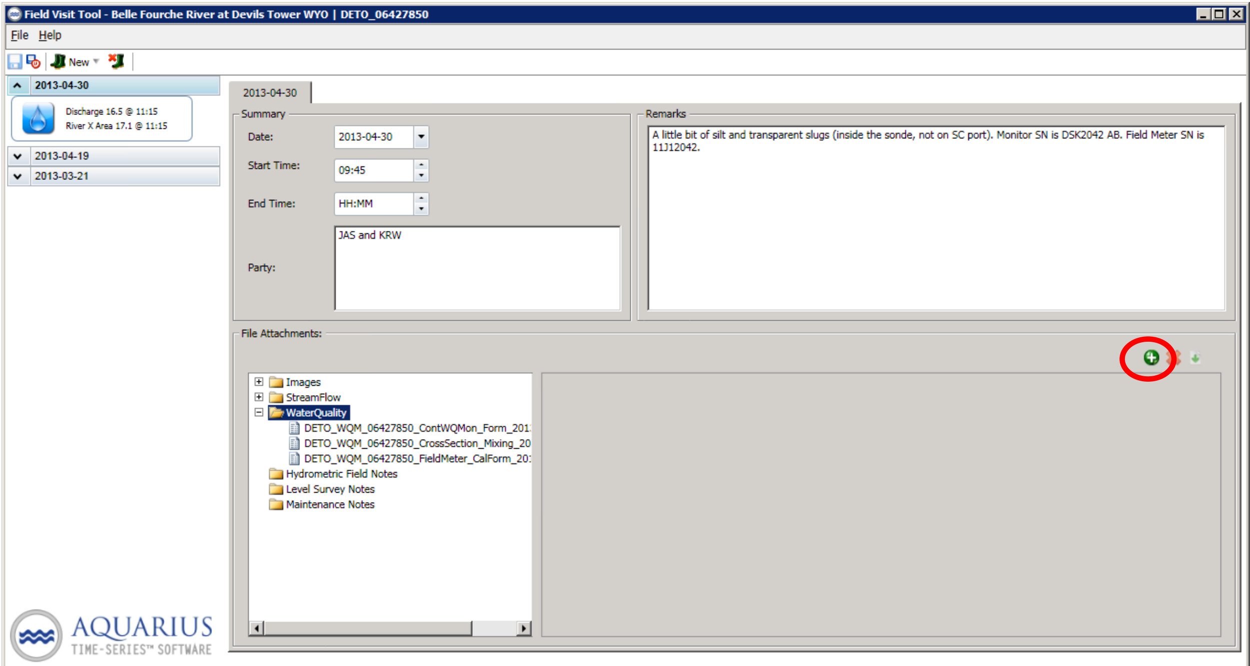

Figure 13. Attachment of files to 'Field Visit' folders using the 'Field Visit' tool.

The 'Field Visit' tool also allows users to enter or import discrete measurements and observations made during site revisits. For example, 'Flow Tracker' files (extension .dis) can be attached to each site revisit entry. Click the 'New' icon (New) again, and this time select 'Measurement Activity From File.' Select 'Flow Tracker DIS' from the 'Measurement Activity From File' dropdown and navigate to N\Monitoring\Water_Quality\DETO\DATA\Streamflow. Open the 'Flow Tracker' folder and the .dis file for the correct date. After attaching all of the desired files, click the 'Save' () or 'Save & Exit' () icon. When you return to Springboard, refresh by clicking the 'Refresh' icon () in the right corner of the 'Locations' tab.

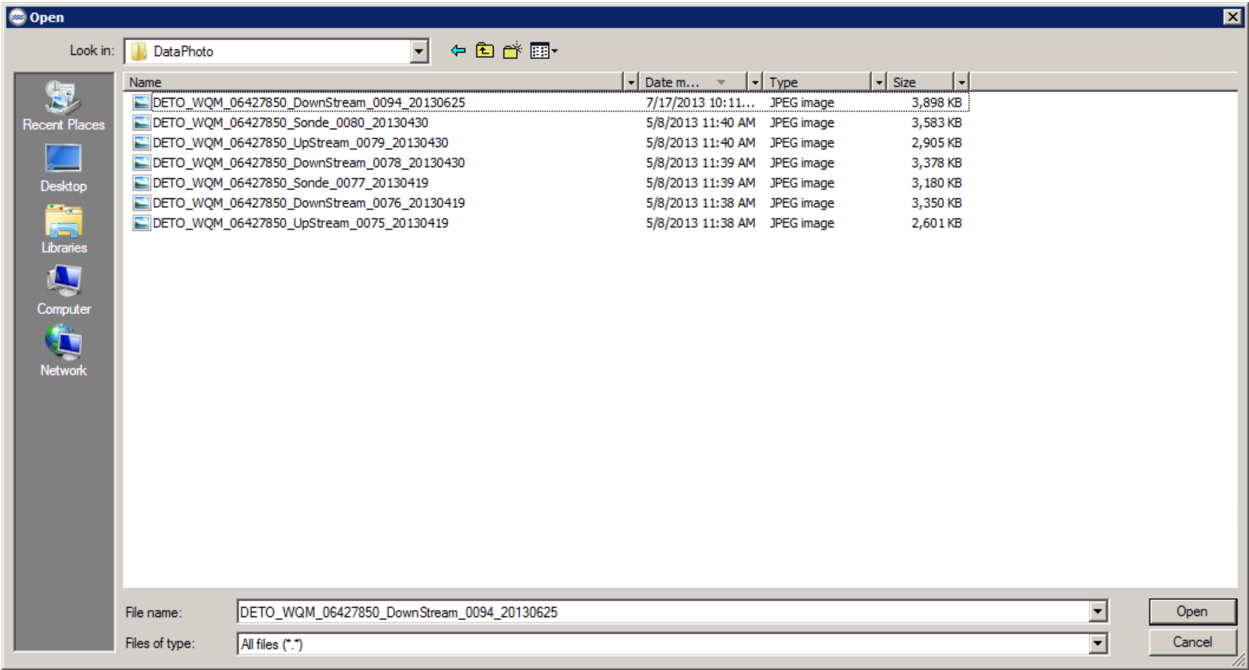

Figure 14. Select the edited image located on the NGPN Server.

Append Logger Files Tool

By February of the year following each field season, the NGPN receives the approved time series water quality data from the respective USGS WSCs as CSV files. These approved data are processed/post-provisional by the respective USGS WSC staff. The state regulatory threshold levels are added to the USGS approved files so the collected parameter values can be charted against the state regulatory thresholds (see Data Entry section and Table 7 above). An example of this file is located at N\Monitoring\Water_Quality\DETO\ANALYSIS\Status\DETO_WQM_06427850_Thresholds.

AQUARIUS stores time series data in parameter containers. For example, for each location, all approved water temperature time series data recorded are stored in one container; a second container holds all approved pH time series data collected, etc. To examine the status of each parameter, additional containers are created to house each parameter's regulatory threshold levels to chart the parameter against the respective state regulatory threshold levels.

New parameter containers are created using the 'Append Logger File' tool. In Springboard, highlight the location (e.g., DETO_06472850_Belle Fourche River at Devils Tower WYO) and click the 'Append Logger File' icon ( ) at the top of the screen; alternatively, right-click the location and select 'Append Logger File' (if the tool does not open, look for it in the Windows Task Bar and click it.)

The first step of the 'Append Logger File' tool is to select a file and the configuration settings (see the '**Step 1: Select a logger file and load it**' box in the 'Append Logger File' window) (Figure 15). Click the icon to the right of the 'Logger File' box to browse to the location of the CSV file on the NGPN 'N Drive.' Select 'N on INPNGPN.' Click the 'Monitoring' and then 'Water_Quality' folders. Browse under the park alpha code\DATA\WaterQuality\Logger\Approved folder and locate the .csv file. Click 'Open.'

Based on the current structure of the approved USGS files, the NGPN has already created a 'Config file' that works for these files. You can click the ... icon to the right of the 'Config File' box to browse for the file on the NGPN N drive under the park alpha code\DATA\WaterQuality folder and select/open the previously saved 'Config File' (e.g., NGPN_WQM_20130521.cfg) and then click the 'Load File' button in the lower right-hand bottom corner of 'Step 1: Select a logger file and load it' window to complete the first step of the 'Append Logger File' tool (Figure 15). Skip the 'Import From File Wizard' and go to '**Step 2: Choose the target data sets and append**' box of the 'Append Logger File' tool section below (Figure 21). Note: If the USGS changes the structure of its processed/post-provisional data files, a **new** configuration is defined for these files so that AQUARIUS understands the new file structure and knows which data to import into AQUARIUS. For this **new** configuration, click the 'Config Settings' option button. AQUARIUS initiates the four-step 'Import from File Wizard.'

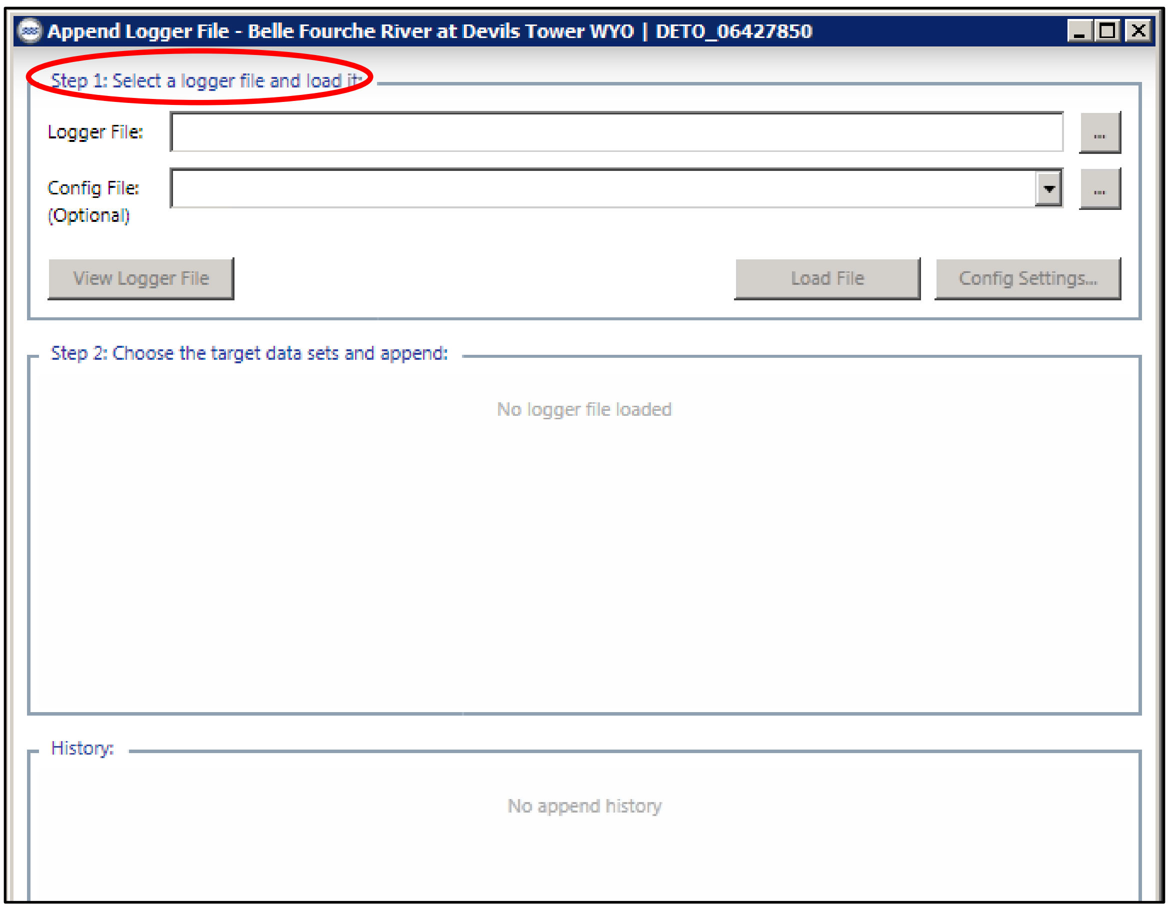

Figure 15. First step of the 'Append Logger File' tool. Select a logger file and load it.

Import from File Wizard

Step 1 of the four-step 'Import from File Wizard' is to click the 'Time Series' radio button and select 'Text File (CSV, etc.)' from the dropdown box (Figure 16), then click 'Next' at the bottom of the screen.

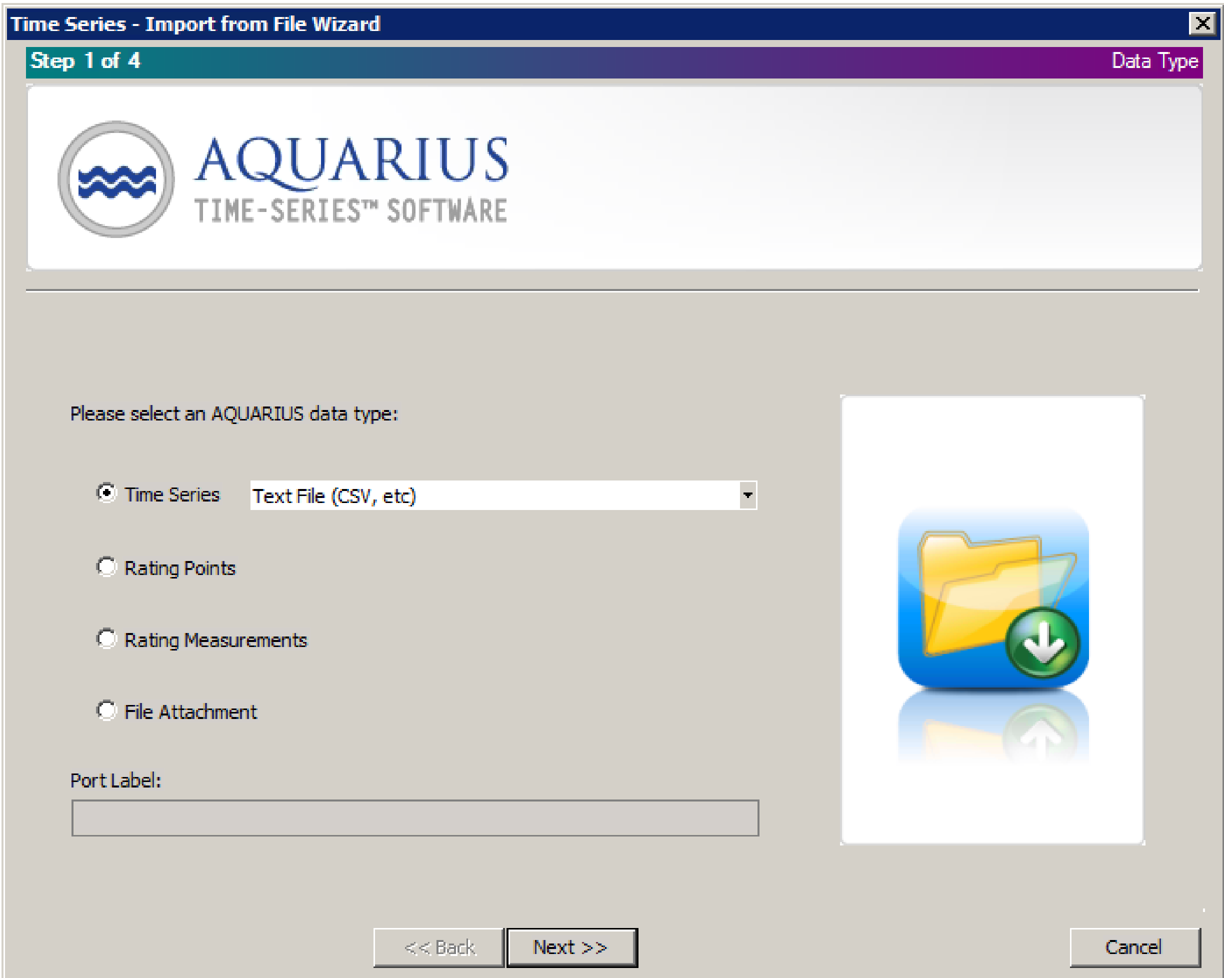

Figure 16. Import from File Wizard step 1. Select the appropriate data type.

Step 2 of the 'Import from File Wizard' is to locate the data within the file and specify the column delimiter. The default specification for AQUARIUS is to 'Start import at row' #1 and 'Delimiters' as 'Comma.' Change the 'Start import at row' to 2 and the 'Number of headers:' to 1 (Figure 17). All of the CSV-approved parameter files from USGS are formatted identically with one header. Click 'Next.'

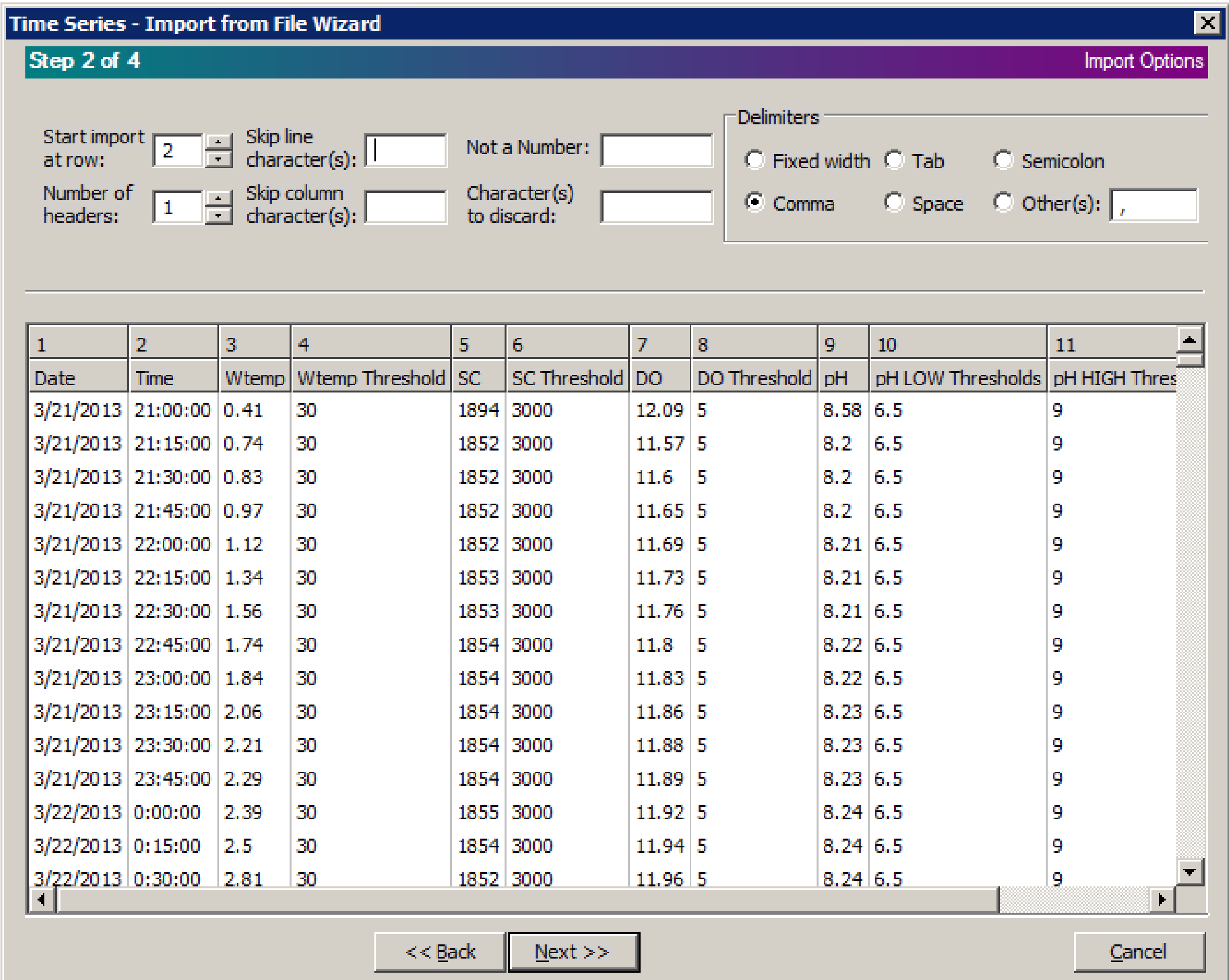

Figure 17. Import from File Wizard step 2. Specify what data AQUARIUS should import.

Step 3 of the Wizard is to define the contents of each column and skip columns not being imported. Select column 1 (Date). To switch between columns, in the upper right corner click the left or right blue arrows to move among the columns. Click the radio button next to 'Date/Time.' Select mm/dd/yyyy from the 'Date/Time Format' dropdown, then use the ... icon to select MDT (UTC-06:00). Because several NGPN parks are located in the Central Time Zone, select the correct Time Zone for the respective park. For column 2, click the right blue arrow in the upper left corner of the 'Import from File Wizard' window, indicate that it is a Date/Time column, and select 'HH:MM:SS' from the dropdown.

The remainder of Step 3 of the Wizard defines the columns of data and selects columns with missing data or data that will not be imported. Advance to column 3, click the radio button for ‘Data,’ and set these data to ‘Raw.’ After selecting a column, define the parameter using the ... icon next to ‘Parameter.’ Select ‘Water Temp’ as the parameter, ‘Units’ of °C, ‘Gap Tolerance’ of 15 minutes, ‘Int. Type’ of 1-Inst. Values, and type in Water Temperature for the ‘Label’ (Figure 18). Because these data are already approved by USGS, you can set Approvals here. For the approved USGS data under ‘Approval,’ select 3 (Approved) (Figure 18). After you choose a parameter, the ‘Units’ are automatically selected based on the default settings. If the default is not correct, manually select the correct unit from the ‘Units’ dropdown box. For ‘Gap Tolerance,’ any gap longer than 15 minutes is treated as missing data, which are not plotted in the ‘Charting’ tool.

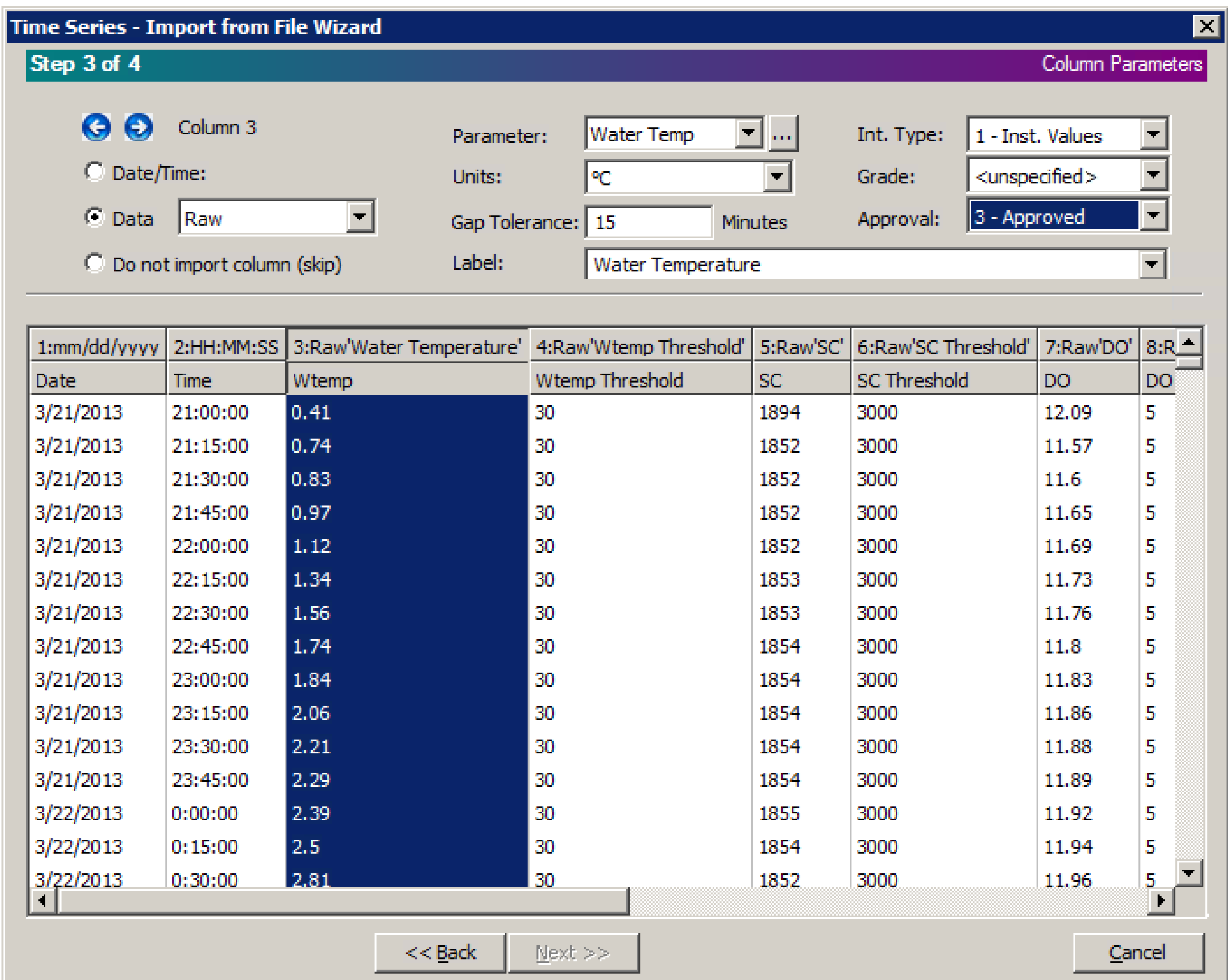

Figure 18. Import from File Wizard step 3. Specify the date and time formats as well as the formats for the data.

Repeat this process for columns 4 (Water Temperature Threshold) through 11 (pH High Threshold). After selecting a column you do not wish to import (e.g., Stage and Rating), select the ‘Do not import column (skip)’ radio button (Figure 19) and click ‘Next.’ Note that all of the columns must be defined before the ‘Next’ button is activated (Figure 19).

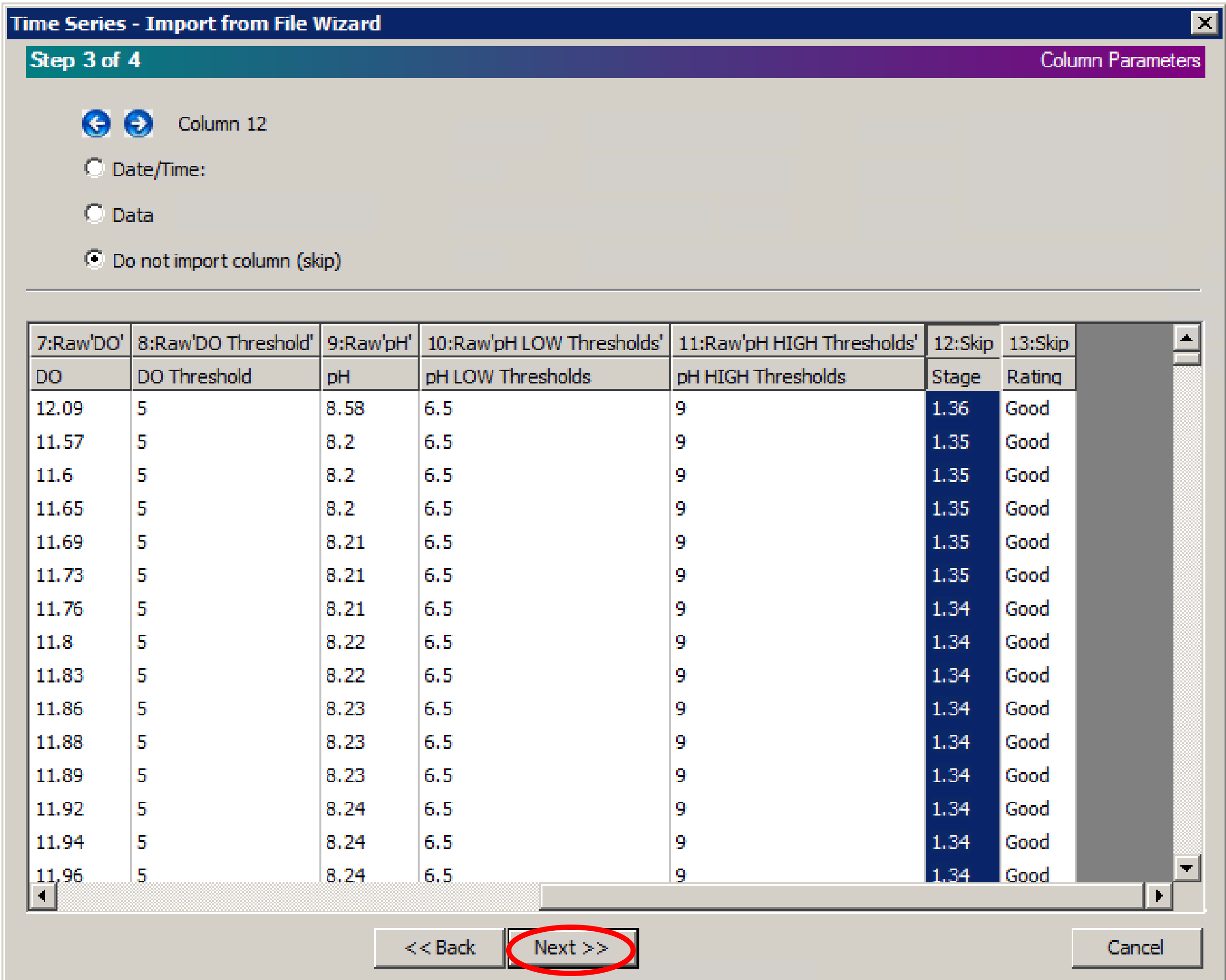

Figure 19. Step 3 of File Wizard. Example of skipped data.

Step 4 of the Wizard provides the option to select gap processing. Choose the default 'Gap Processing' option, which means AQUARIUS identifies any gaps longer than 15 minutes in the import file. Check the box next to 'Save Configuration' to save the newly created import file definition/specification so it can be reused with similarly structured/formatted files in the future (Figure 20). Name the configuration file using NGPN file naming (e.g., NGPN_WQM_20130521.cfg). When done, click 'Finish.'

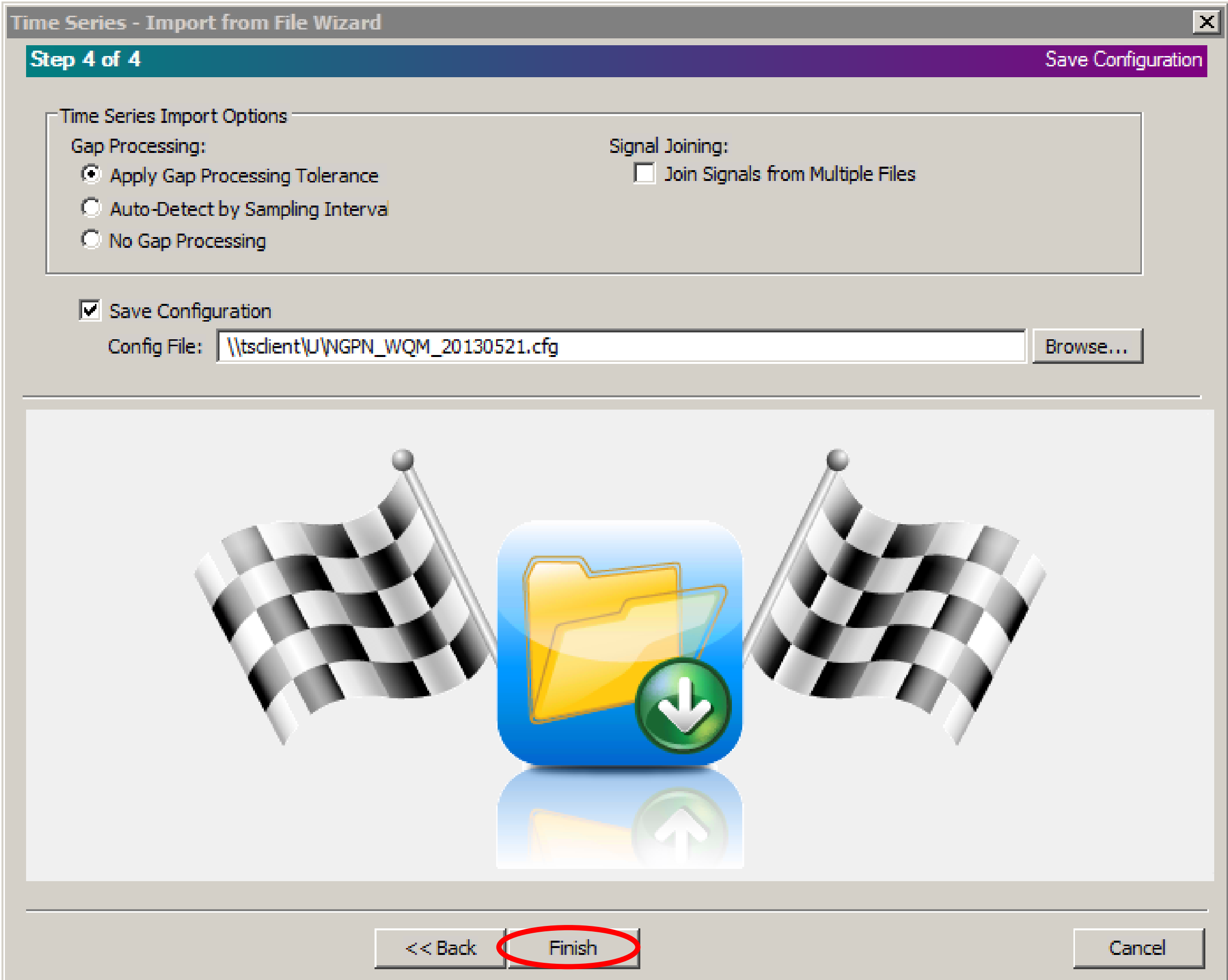

Figure 20. Import from File Wizard step 4. Check the box to save the configuration file.

After an existing configuration file has been selected, or if a new configuration file has been created, move down to '**Step 2: Choose the target data sets and append**' box of the 'Append Logger File' tool section (Figure 21). In Step 2, tell AQUARIUS either to create a new time series container or to append the data files to an existing time series container. Initially, use the 'Append Logger File' tool to create a new time series container for each parameter and its corresponding threshold level(s) at each location. Once these times series containers are created, append future data files to the already existing containers using the 'Append Logger File' tool.

For this example, new time series containers are created with one data set container for each parameter and one data set container for each of the state regulatory threshold levels associated with a parameter (Fig. 21). The options under 'Append to' are 'Do not append' (which means it will be skipped) or 'Create New Time Series.' Note: If data set containers already exist for the location, they also appear as selections under 'Append to.' If data files are being appended to existing containers, select the appropriate container under the 'Append to' list of containers. After indicating how each time series should be handled with the 'Append to' dropdown boxes, click the enabled 'Append' button (Figure 21).

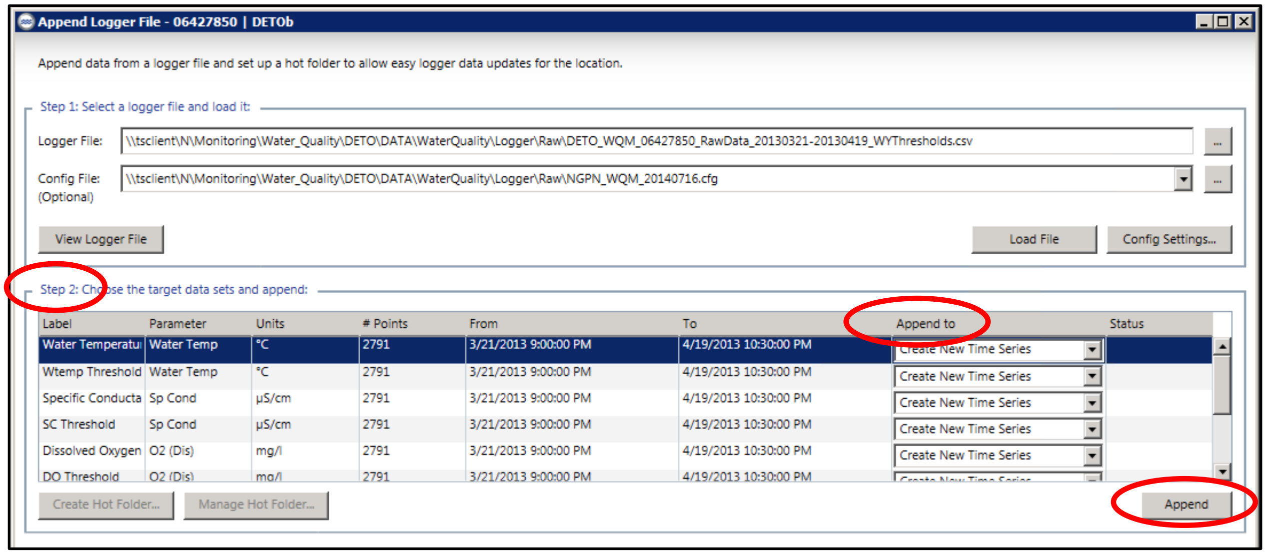

Figure 21. Create new time series containers for each parameter and its corresponding threshold level(s) using the 'Append Logger File' tool.

The 'Append Logger File' tool uses the information in the 'Import from File Wizard' (parameter name, unit, etc.) to create the containers and load them with the import data. AQUARIUS fills in the created container names in the 'Append to' boxes (Figure 22).

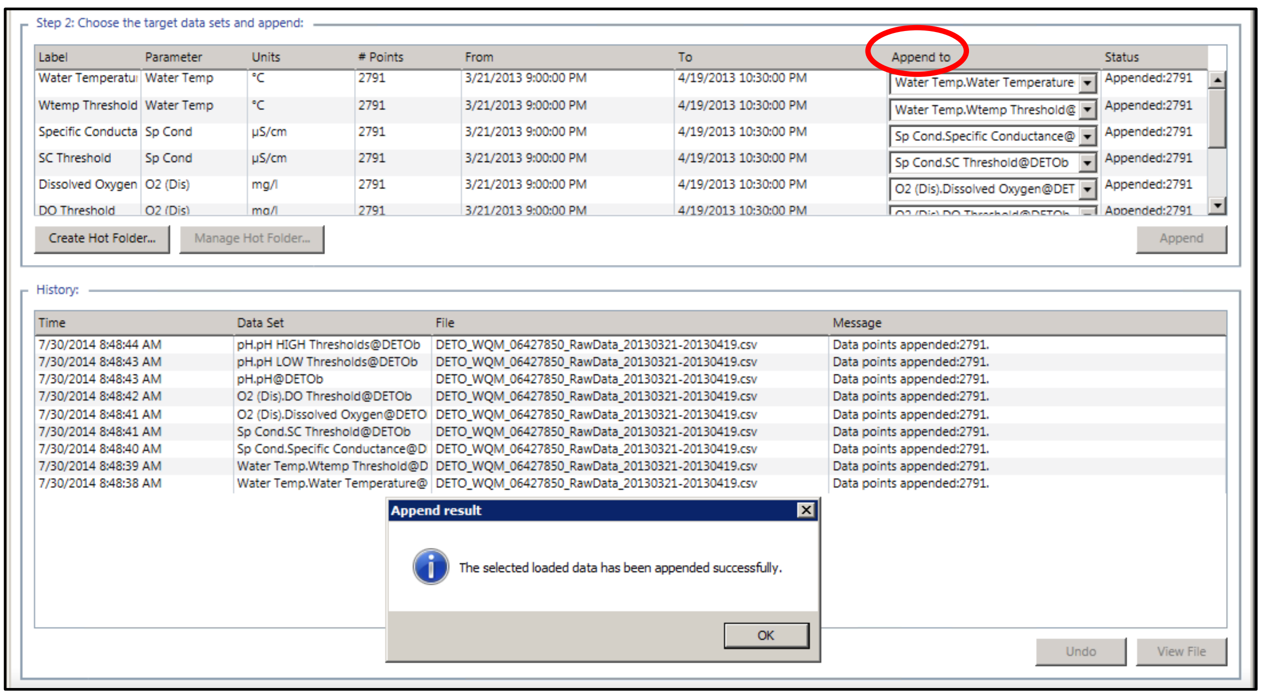

Figure 22. 'Append Logger File' tool creates new data set containers for each parameter and its corresponding threshold level(s).

To examine the time series data set containers that were created, return to Springboard by clicking the 'X' in the upper right corner of the window of the 'Location Manager' tool. With the location selected, click the ‘Go To Data Sets’ icon ( ) in the toolbar (Figure 23), select a data set container, and left-click the ‘Quick View’ icon ( ) in the toolbar. A graphical depiction of the data appears (Figure 24). ‘Quick View’ allows the user to check if the data in the data set containers are correct.

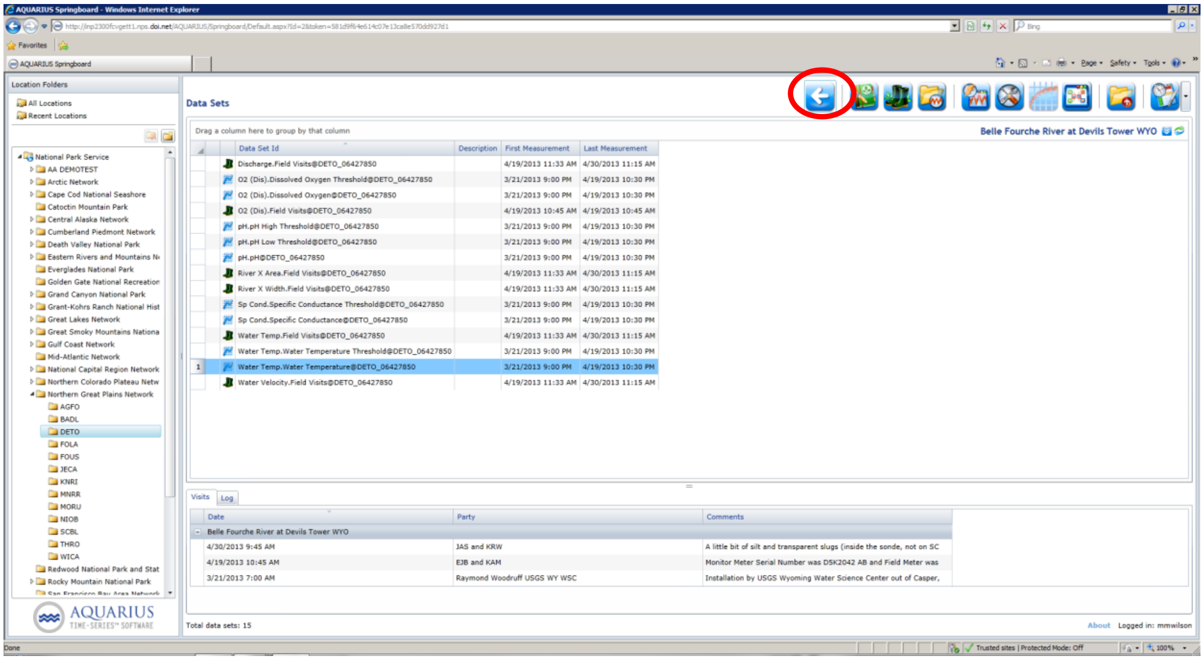

Figure 23. Examine the data set containers by selecting the ‘Go To Data Sets’ button.

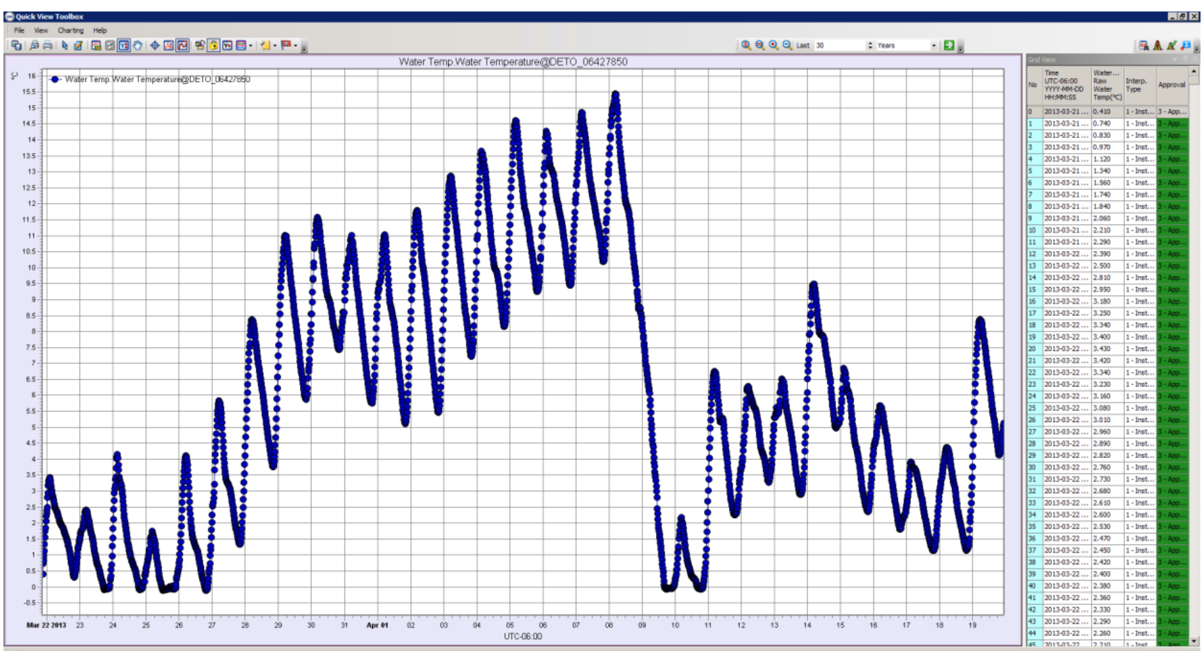

Figure 24. View data set container in ‘Quick View.’

Data Storage

Electronic files for water quality monitoring are stored following a file structure developed for the NGPN (Figure 25). These files are considered the working files. After data validation, the files are moved to the Archived Data directory on the NGPN server. This directory is read-only to all users except the Data Manager. Descriptions of the types of files stored within each park's folder within the 'Water_Quality' folder follow:

- ANALYSIS: USGS Water Quality Station Analysis Reports, other derived data, and files for and from statistical analysis for this park.
- DATA: water quality data, streamflow data, metadata, scanned data sheets, AQUARIUS data, and the original files sent to NGPN by USGS (backup).
- DOCUMENTS: maps, reports, and research permits associated with the Water Quality Vital Sign specific to the park.
- GIS: shapefiles, coverages, layer files, geodatabases, GPS files, GIS/GPS-associated metadata, and spatial imagery specific to the park and the Water Quality Vital Sign.
- IMAGES: data and general photographs from the park related to the program and the electronic photolog files.

Other folders within the 'Water_Quality' folder contain the following types of files:

- MISCELLANEOUS: files/documents that do not logically go into other folders (e.g., presentations).
- PROTOCOL: correspondence, development documents, Protocol Narrative, SOPs, blank data sheets, field season and Protocol review forms, training documents, and instructions for data analysis.

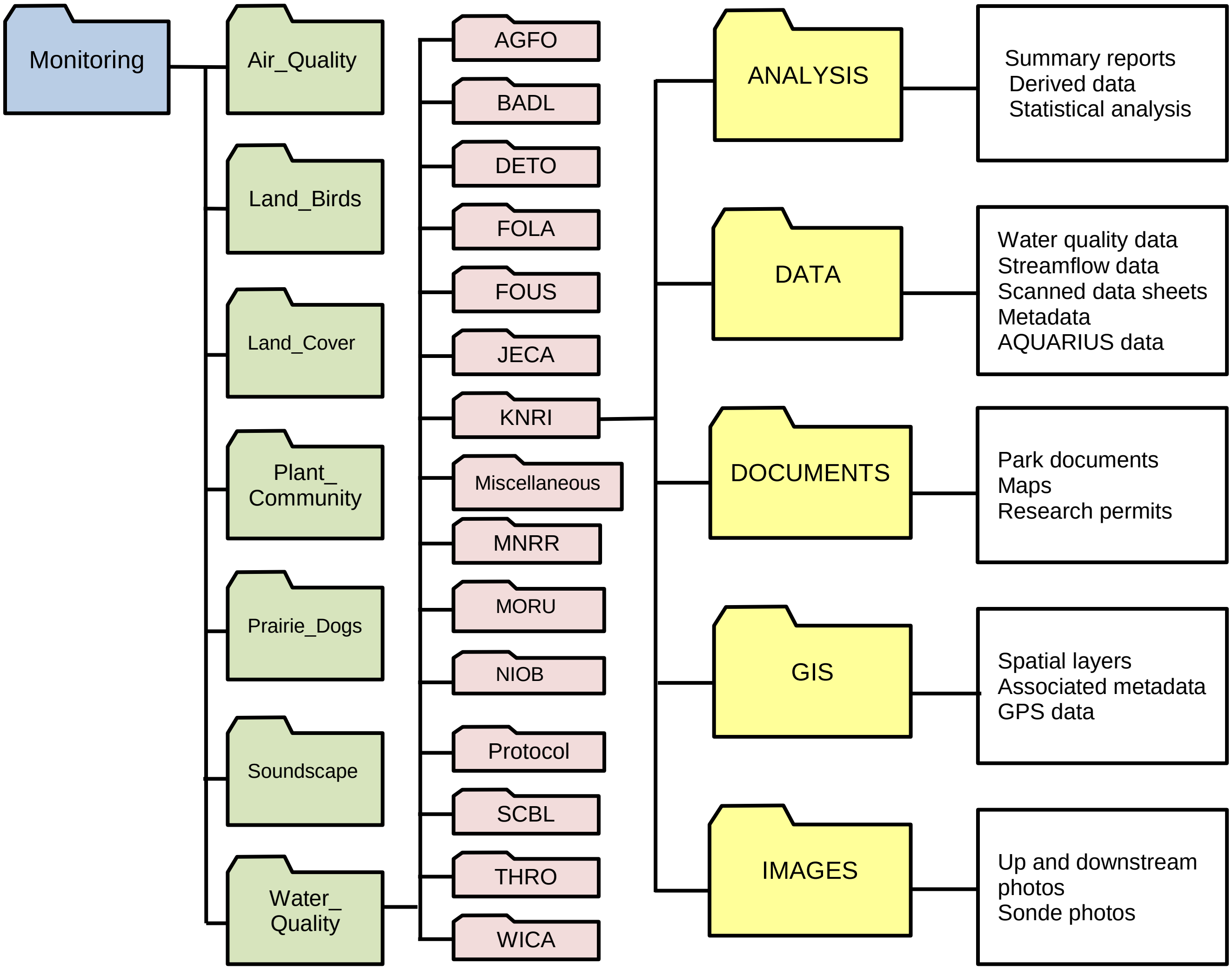

Figure 25. An example of the file structure used to store NGPN Water Quality monitoring data and information at KNRI.

Data Archiving and Editing of Archived Data

During the validation phases, the General/Aquatic Ecologist is responsible for the data. Once validation of the data (AQUARIUS Databases, scanned data sheets, images, etc.) is complete, the General/Aquatic Ecologist notifies the Data Manager that the electronic database files, images, and completed Metadata Interview form are ready for archiving and storage. The Data Manager creates a new metadata record and archives the data.

Archiving consists of storing read-only, electronic versions of the data sheets and images (edited data photographs) on the NGPN server. Backup copies of the data are maintained at the NGPN office. Tape backups of all NGPN server files occur daily. Weekly and monthly server backups are transferred for offsite storage at MORU.

The Data Manager maintains a data management log for each Vital Sign, including a data edit log that records changes made to data sets after they have been archived. Such changes are inevitable and necessary but are made only under the following conditions: (1) data integrity must be maintained; (2) once archived, all changes to the data set must be documented; and (3) mistakes made during editing must be recoverable. Any editing of archived data is accomplished jointly by the General/Aquatic Ecologist and Data Manager. Every change must be documented in the data edit log and accompanied by an explanation that includes pre- and post-edit data descriptions.

Prior to any changes in an archived data set, a copy is stored with the appropriate date in the file name, which allows changes to be tracked over time. Versioning of archived data sets is handled by changing the date included in the file name to ensure that the most current version is used in analysis. Frequent users of the data are notified of the updates and provided with a copy of the most recent archived version.

Schedule

A schedule for the different phases of data management ensures that all steps are completed in a timely manner (Table 8), including the deliverable data management products, the responsible individual, and the target completion date for data products from the Water Quality Protocol. A schedule for reports derived from these data is presented in SOP 6 Data Analysis and Reporting.

Table 8. Deliverable data management products, responsible individual, and target completion date for data products from the NGPN Water Quality Monitoring Protocol.

Deliverable Data Management Product	Primary Responsibility	Target Completion Date
Initial Metadata Interview Form	General/Aquatic Ecologist	3 weeks prior to start of first field season
Raw/provisional data files sent to NGPN	USGS WSC	November
Process raw/provisional data	USGS WSC	December
Verification/validation of data	USGS WSC	January (year following field season)
Approval of (processed/post-provisional) data and metadata files	USGS WSC	February (year following field season)
Archival of USGS electronic files (approved data, data sheets, and photographs) to NGPN server	General/Aquatic Ecologist	May (year following field season)
AQUARIUS Database with approved data from index sites	General/Aquatic Ecologist	June (year following field season)
Updated Metadata Interview Form	General/Aquatic Ecologist	September (year following field season)

Attachment A. WQM Electronic Metadata Interview Form – Version 1.00.

Your name:
Today's date:

1. Have you already prepared metadata for this data set?
    a. If yes, please send a copy of the document or reference to where it can be found and skip to item **16**.
2. What is the title of the data set?
3. Who is the originator(s) owner of the data set? (Include address and telephone number)?
    a. If someone else should answer question about the data, please list the name, address, and telephone number.
    b. Are there other organizations or individuals who should get credit for support, funding, or data collection and analysis?
4. Does the data set contain any sensitive information that should not be released to the public? NPS?
    a. Explain why the data should not be released to the public.
    b. Explain why the data should not be released to the non-park NPS staff.
5. Is the data set published or part of a larger publication?
    a. If so, what is the reference?
6. Include a brief (no more than a few sentences) description of the data set.
7. Why were the data collected in the first place?
8. What is the time period represented by the data set?
9. Were the data developed primarily through:
    a. Site revisits?
    b. Remote instrumentation (e.g., multiparameter sondes, etc.)?
    c. Existing data sources?
10. What is the status of the data you are documenting? – *complete, in progress, planned*
    a. Will the data set be updated? If so, how frequently?
11. Where were the data collected? Include description and coordinates, if known.
12. List some keywords to help search for this data set.
    a. If a controlled vocabulary was used, what is the reference?
13. List any related data sets that could be documented for cross-reference.
14. Is your data set archived in a databank or data catalog? If yes, please include a reference to the documentation and skip to item 16. If No:
    a. What measures did you take to make certain that your data set was as nearly correct as possible?
    b. Were there any things that you excluded from your data collection (e.g., streams without surface flow)?
    c. What is the form of your data set? – *spreadsheet, ASCII file, CSV file, GIS layer, database, other*.
    d. What is the filename for your data set?
        i. For each file or table, list the fields in the data set and for each field list:
        * The definition of the field.
        * If the data are coded (Enumerated Domain), list the codes and the definitions.

* If the codes come from a published code set (Codeset Domain), list the reference.
* If the data are measured (Range Domain), list the units and the minimum and maximum allowable values ("no limit" is acceptable).

ii. Otherwise, the domain is unrepresentable. Include a brief description of what is in the field.

15. Is the data set available for distribution: If no, go to 16.
    a. Are there legal restrictions on who may use the data?
    b. Do you have any advice for potential users of the data set?
    c. What are your distribution instructions?
16. You are done. Send this completed document with the relevant responses to this interview to your metadata coordinator (Stephen Wilson, Northern Great Plains Network Data Manager Stephen_K_Wilson@nps.gov, 605.341.2804).

Water Quality Monitoring Protocol for Wadeable Streams and Rivers in the Northern Great Plains Network

Standard Operating Procedure (SOP)
SOP 6: Data Analysis and Reporting

Version 1.0, October 2014

Revision History Log

The following table lists all edits and amendments to this SOP since the original publication date. Users of this SOP must notify the NGPN General/Aquatic Ecologist regarding recommended and required changes. The General/Aquatic Ecologist reviews and incorporates all changes, completes the revision history log, and changes the date and version number on the title page and in the footer of the document file. For complete instructions, please refer to SOP 8 Protocol Revision.

Previous Version #	Revision Date	Revised By	Changes Made	Reasons for Change	New Version #
1.0 Draft	October 2014	NGPN	Revision following peer review		1.0
Add rows as needed for each change or set of changes tied to an updated version number					

Data Analysis

Only data graded as “good” or “fair” by the USGS are used in analyses. Data analyses include calculation of summary statistics to examine the status of the core parameters, long-term trends, and a recalculation of power analyses. The status of water quality at each park compares the time series water quality data with the respective state regulatory thresholds for each core parameter. Trend analysis is analyzed with the ‘Advanced Descriptive Statistics’ tool box of AQUARIUS or using a script within R. The recalculation of the power analyses are conducted to re-examine our ability to detect long-term trends a (±20% linear change in the means of core parameters over a 10-year period). More specific scripts used to calculate the trend and power analyses are included in a revision to this SOP following consultation with the USGS WSCs data analysts and a quantitative ecologist.

Status of Core Water Quality Parameters and Streamflow Data

The status of water resources is addressed by looking at the seasonal and annual patterns in the mean and variability of the core water quality parameters as well as exceedances of the park core water quality parameters in relation to the state regulatory thresholds (see Table 4 in the Water Quality Monitoring Protocol Narrative Version 1.0 l for a listing of the respective state regulatory thresholds). Note that the states do not have regulatory thresholds for streamflow. The exceedances or proportion of core water quality parameter samples above (or below) the respective state regulatory thresholds and the summary statistics are generated using the AQUARIUS ‘Descriptive Statistics’ tool. These report tables will be similar to the format in Table 9.

Plots of the time series data and the exceedance conditions for each water quality parameter also quickly convey status. Because streamflow influences the water quality measurements, graphical plots of streamflow and each water quality parameter are generated to compare against time using the AQUARIUS ‘Charting’ tool. All calculations and graphical plots use the USGS approved data to aid in the interpretation and discussion of the park water quality.

Table 9. Summary of descriptive statistics and percent exceedances for core water quality parameters for a sampling period at AGFO on the Niobrara River from 7-14 May 2009.

Descriptive Statistic	**Water Temperature (°C)**	**pH**	**Specific Conductance (µS/cm)**	**Dissolved Oxygen (mg/L)**
Mean	13.65	7.90	456.86	6.05
Standard Deviation	1.80	0.13	4.87	1.88
Median	13.73	7.89	456	5.83
Minimum	10.13	7.67	446.27	2.75
Maximum	18.06	8.17	468.93	9.44
Number of Points	697	697	697	697
Nebraska Department of Environmental Quality Standards	Max. limit is 22°C	6.5–9.0	≤2000	≥5.0
Number of Points below or above threshold	0 (above)	0 (above) 0 (below)	0 (above)	257 (below)
% exceedance[a]	0%	0%	0%	37%

[a] Proportion of samples above or below the respective state regulatory threshold.

0–5% exceedance	(green)
5–25% exceedance	(yellow)
>25% exceedance	(red)

Descriptive Statistics Tool in the AQUARIUS Whiteboard

The AQUARIUS Springboard interface has fewer tools for analyzing and processing data than the Whiteboard interface. Fortunately, Springboard includes a ‘Whiteboard’ tool that allows time series data sets to open on the AQUARIUS Whiteboard. AQUARIUS Whiteboard relies on a series of toolboxes that can be dragged onto the Whiteboard and ‘wired’ together. To access the ‘Whiteboard’ tool from Springboard, highlight the location and click the ‘Go to Data Sets’ icon ( ). With the locations data sets displayed, hold the ‘Ctrl’ key and select the data set containers to be analyzed in the order they should appear on the ‘Read from Server’ tool (Figure 26). For example, in Figure 26 dissolved oxygen was selected as #1 and its corresponding threshold container was selected as #2. The pH can then be selected as #3 with low and high threshold levels as #4 and #5. As a result, the ‘Read from Server’ tool should have the four core parameter data sets and the five data set containers for the State regulatory thresholds (Figure 27).

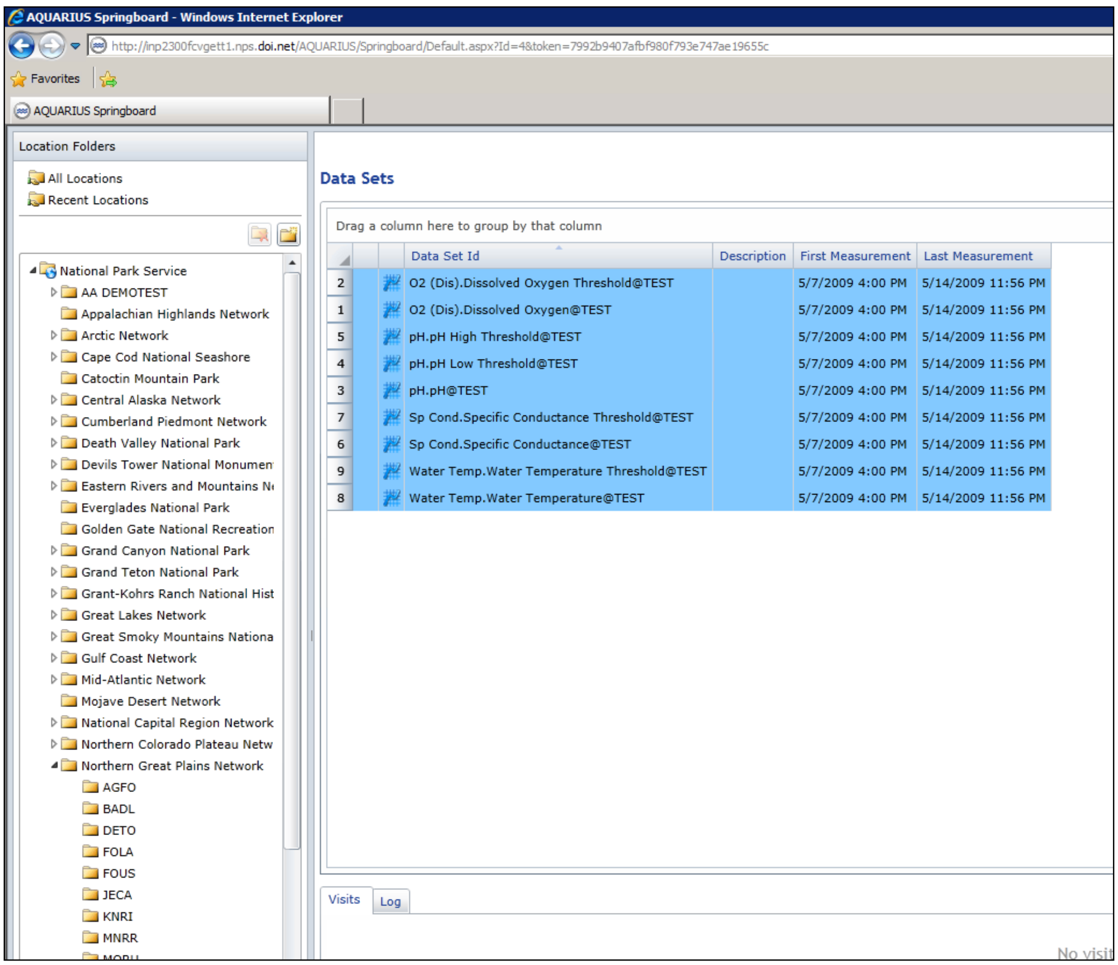

Figure 26. Highlighted data set containers identified from #1 to #9 to use on the AQUARIUS Whiteboard.

Note that while this is a quick way to move data from Springboard into the Whiteboard, any changes you make to the data in Whiteboard are not automatically saved in the AQUARIUS Database, and the ‘Write to Server’ tool in Whiteboard must be used to save database changes. Because these are approved data from the USGS, however, any data modification in Whiteboard is unlikely, and the 'Write to Server' tool will likely not be needed.

To launch the Whiteboard, left-click the toolbar's 'Whiteboard' icon (). Springboard launches the AQUARIUS Whiteboard and populates it with the 'Read from Server' tool that has nine output ports (one for each of the data set containers). The #1 data set container you selected in Springboard is the top output port on the 'Read from Server' tool with the #9 data set at the bottom of the tool. To more easily determine which output port responds to which data set container, click the 'Read from Server' icon and then grab and drag the icon to enlarge it (Figure 27). Hover the cursor on top of any output port on the 'Read from Server' tool to obtain a summary of the parameter time series (Figure 27).

On the left hand column of the AQUARIUS Whiteboard, open the 'Math and Statistics' toolbox. Double click the 'Descriptive Statistics' tool four times or drag the icon four times to the Whiteboard. Move each 'Descriptive Statistics' icon to the right of the 'Read from Server' icon (Figure 27). 'Wire' each of the four core parameter output triangles to separate 'Descriptive Statistics' icons (Figure 27).

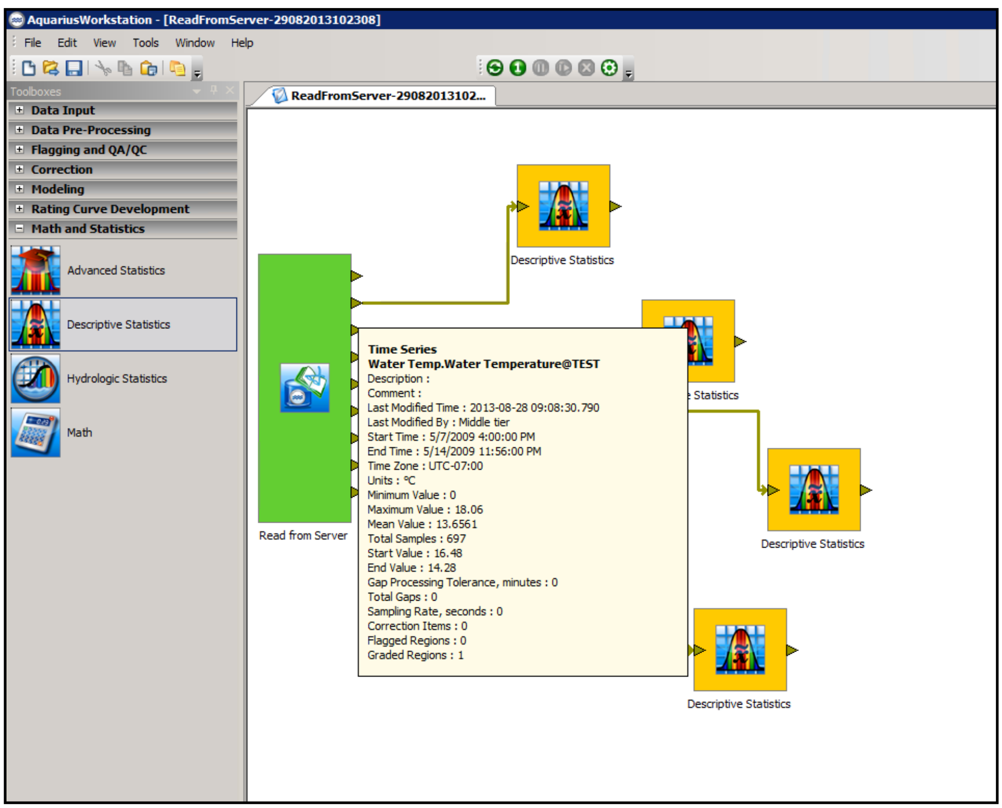

Figure 27. AQUARIUS Whiteboard with the 'Read from Server' tool expanded; the information box identified for one of the data set containers; and each of the core parameters 'wired' to one 'Descriptive Statistics' icon.

On the Whiteboard, double click one of the 'Descriptive Statistics' icons. In the 'Descriptive Stats Control' window place an 'x' next to the following items: Data Points, Minimum, Maximum, Mean, Median, and Standard Deviation in both the 'Generate an Ouput Port' and the 'Compute This Value' boxes (Figure 28).

Use the 'Upper Threshold' and 'Lower Threshold' boxes to provide the number of records that are above or below the State regulatory thresholds. For example, to find the number of dissolved oxygen records <5.0 mg/L (Nebraska Department of Environmental Quality Threshold), type in '5' in the 'Threshold Value' under the 'Lower Threshold' box and place two check marks to the left of 'Number of Measurements Below' (Figure 28). For the Nebraska pH thresholds, use '9' for the upper threshold value and '6.5' for the lower threshold value because the pH level lies in between these upper and lower values. Below the threshold boxes click the 'Compute' button.

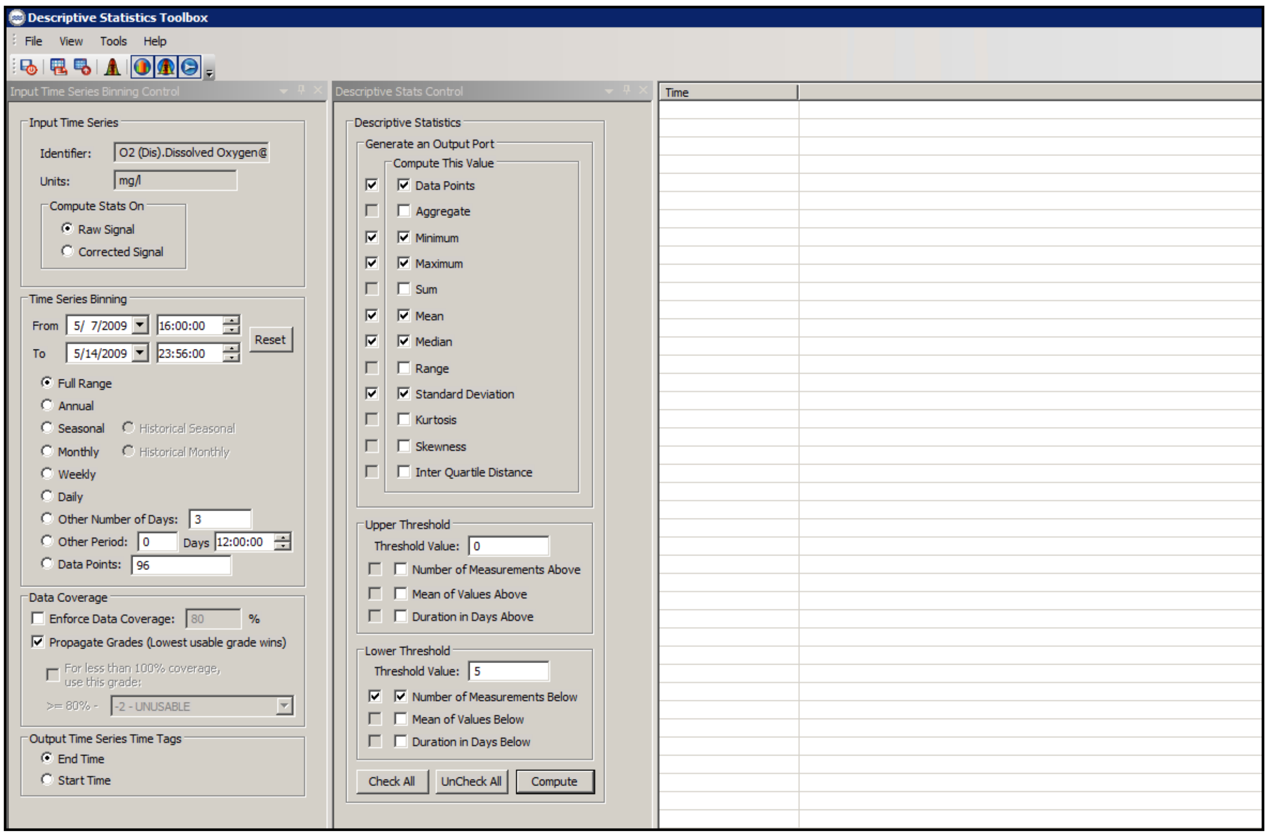

Figure 28. Whiteboard screen shot of the 'Descriptive Statistics' tool for a dissolved oxygen parameter.

To export these results, go to 'File' in the upper left hand corner of the 'Descriptive Statistics' tool and click 'Export' (Figure 29). Name the CSV file using the NGPN's file naming convention (e.g., DETO_WQM_0642785_DescriptiveStats_DO) and save it on the N drive (N\Monitoring\Water_Quality\PARK\ANALYSIS\Status). Repeat this process for each 'Descriptive Statistics' icon to generate the statistics for the other core parameters.

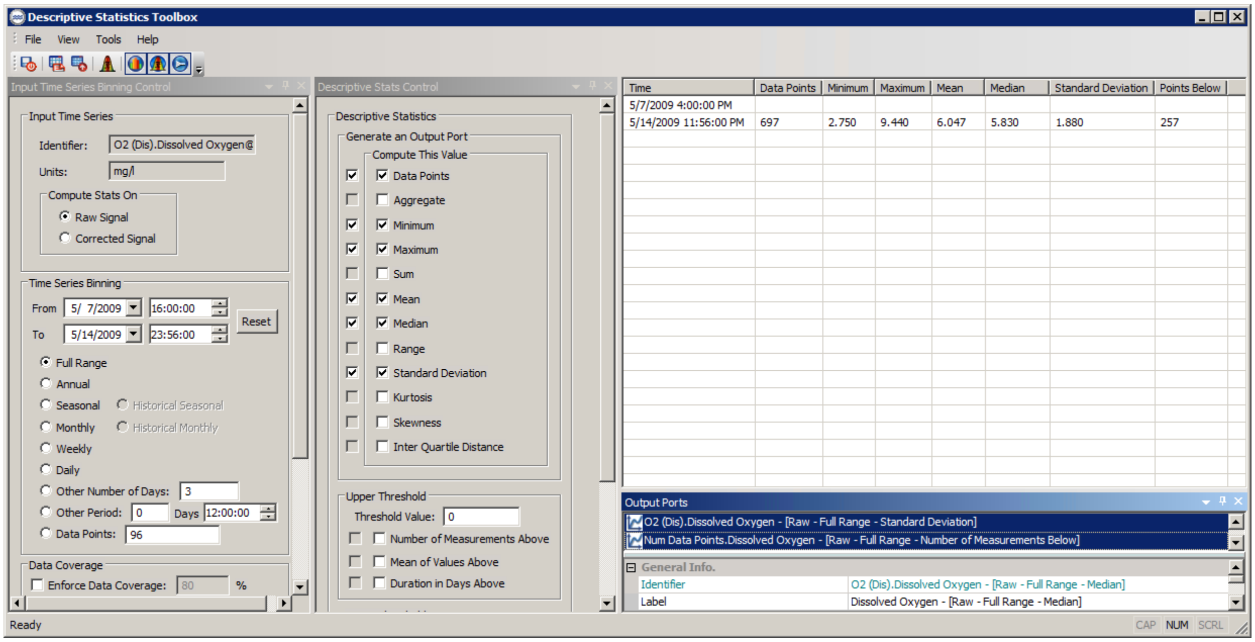

Figure 29. Results for the dissolved oxygen parameter collected 7–14 May 2009 at AGFO.

Insert the results for the four core parameters into the table format used in Table 9 (see ‘Status of Core Parameters’ section above). Calculate the % exceedance for each parameter using the number of points above/below the state regulatory threshold(s) and the total number of data points collected as output to the CSV file (Figure 30).

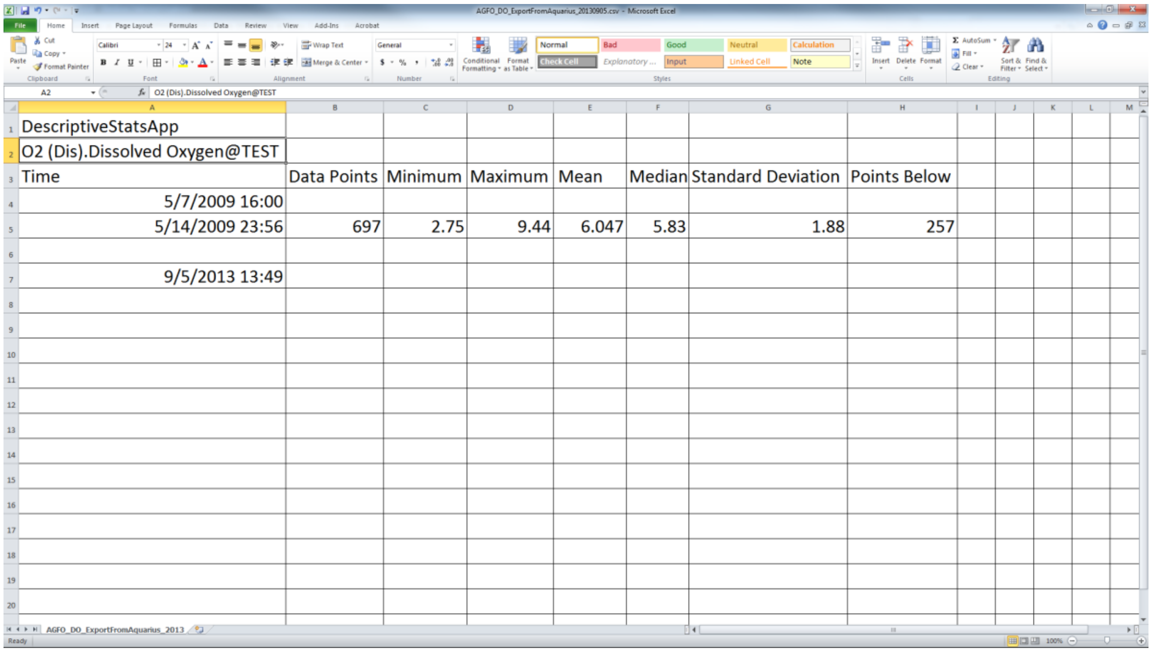

Figure 30. Example of dissolved oxygen summary statistics exported from AQUARIUS Whiteboard to a CSV file.

Charting Tool in the AQUARIUS Whiteboard

Plots of time series data and exceedance conditions for each parameter are also generated to convey the status of water quality for each of the selected parks. An example of time series plots is dissolved oxygen measured at AGFO for a 7-day period in 2009 (Figure 31).

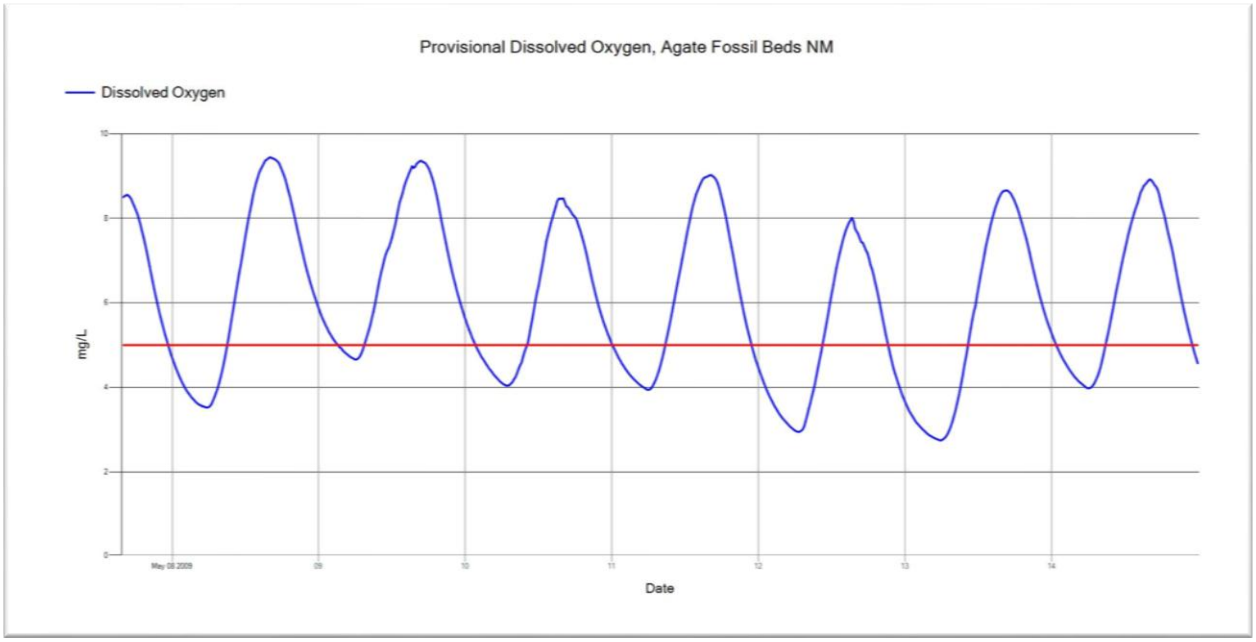

Figure 31. Summary plot of provisional dissolved oxygen data collected at AGFO for 7 days in 2009. The red line indicates the regulatory threshold set by the Nebraska Department of Environmental Quality (5.0 mg/L).

Summary plots are produced using the ‘Charting’ tool in the Whiteboard interface. Click the ‘Visualization and Reporting’ toolbox on the left side of the Whiteboard. Click the ‘Charting’ tool four times or drag the icon to the Whiteboard four times to produce one ‘Charting’ icon for each core parameter. Right-click the ‘Charting’ icon and select the ‘Properties’ pane. Under ‘Input Ports’ (Time Series), highlight the ‘1’ and type in ‘2,’ and two input ports will appear on the left side of the ‘Charting’ icon. Connect the dissolved oxygen and dissolved oxygen threshold output from the ‘Read from Server’ icon to the ‘Charting’ icon. Continue to wire each parameter and their corresponding threshold level(s) to a ‘Charting’ icon (Figure 32). Save this Whiteboard for subsequent reuse as an *.aqw file.

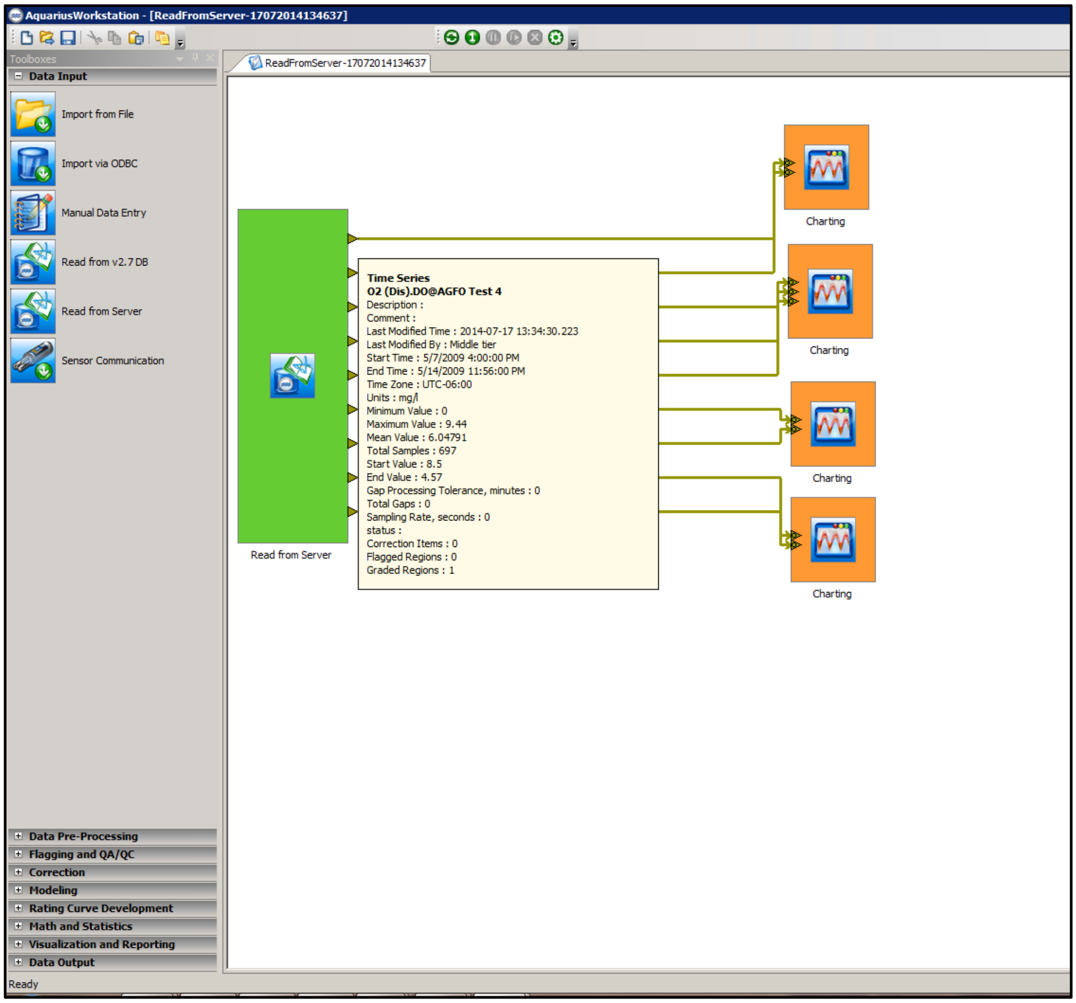

Figure 32. Screen shot showing how each of the parameters and their corresponding threshold level(s) are connected to the four 'Charting' tools and the start/end time of the data set container.

To reuse the Whiteboard, right click the 'AQUARIUS Assistant' icon () on the Task Bar and choose 'Open Whiteboard.' Locate the saved Whiteboard (*.aqw) on the NGPN Server, highlight the Whiteboard, and click 'Open.' When the 'Connect to AQUARIUS Server' window pops up, enter your password, click 'Login,' and close the 'Welcome to AQUARIUS Window.' The old Whiteboard should be open (Figure 32). Hover the cursor over the wires to see the start/end time of the data set container to determine whether all of the data you want to chart are present in the *.aqw file's 'Read from Server' tool.

If, while hovering on the wire, some of the data are missing, either open Springboard and append the missing data, or double-click the 'Read from Server' tool to open it and refresh the data set. The 'Read from Server' window opens, then double click the 'Save & Exit' icon (). This process ensures that the entire period of record is available (otherwise the Whiteboard only contains the data used in the previous period of record). The 'Read from Server' window then closes. Hover the cursor over the wires again to ensure the entire period of record is included.

Double click one of the ‘Charting’ icons and select the ‘Chart Options’ icon () from the toolbar. The ‘Charting’ tool plots the entire period of record. If only a graph of the

current year of data is needed, adjust the X-Axis. Click the ‘X Axis’ tab on the left-hand side under ‘Chart Options,’ then under ‘Auto’ adjust the Minimum and Maximum date and times to display the graphical time frame of interested.

Font and color are modified under the ‘General’ tab. Ensure the ‘Show Chart Title’ is checked and then rename the chart (e.g., Provisional Dissolved Oxygen, Agate Fossil Beds NM) by replacing the default title (Figure 33). Select the font, color, chart background color, plot background color, and whether or not a chart frame is preferred.

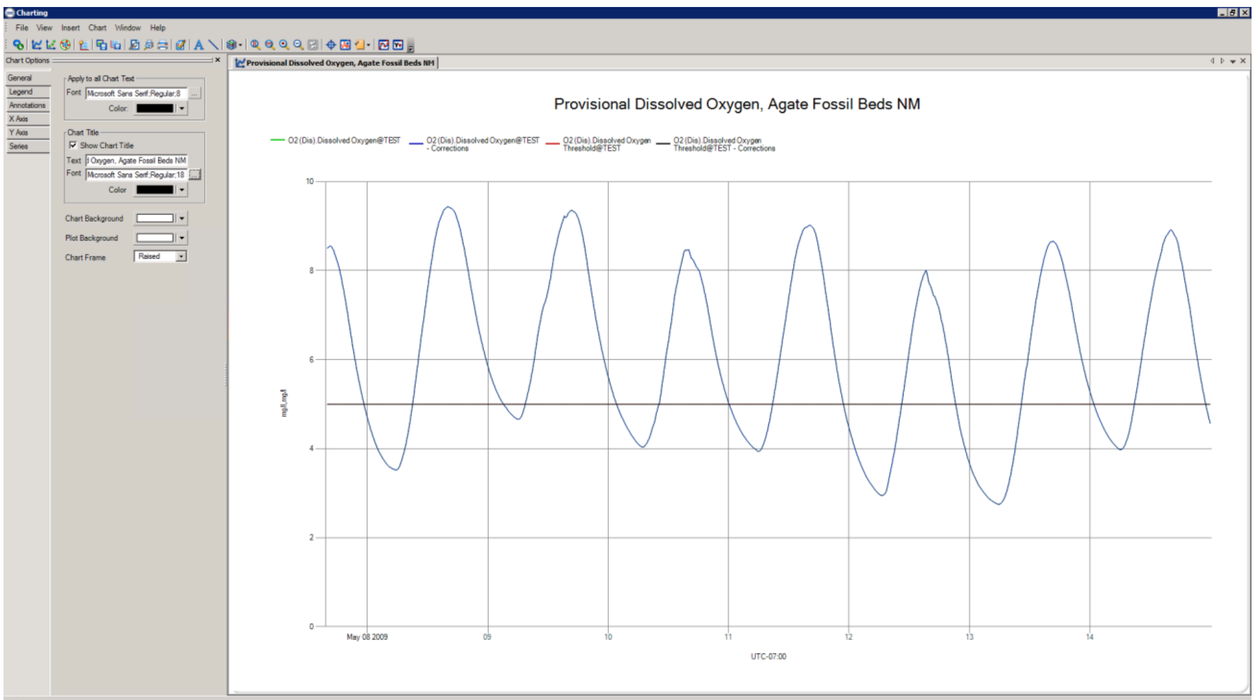

Figure 33. Modifying chart features using the ‘General’ tab in the ‘Charting’ tool.

Click the ‘Legend’ tab. Leave the ‘Text’ box blank unless setting up a separate legend on the chart. Increase the font size of the ‘Legend Items’ to a size that looks appropriate for the chart (Figure 34); actual legends are modified under the ‘Series’ tab.

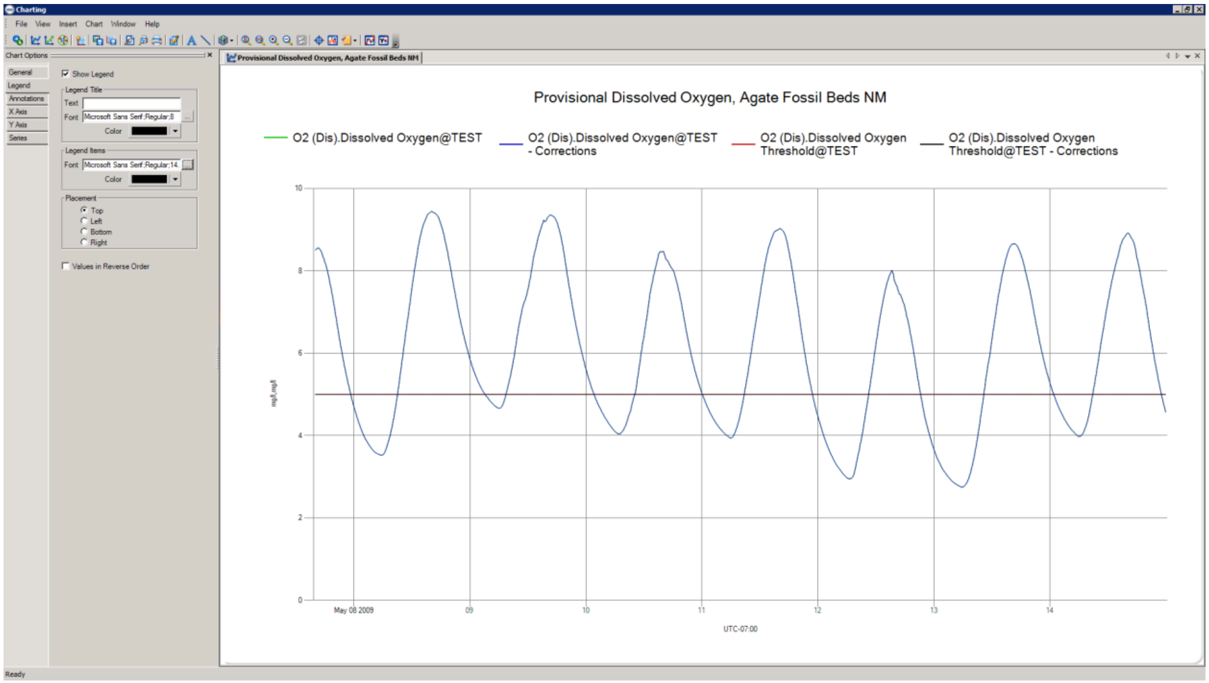

Figure 34. Modifying chart using the 'Legend' tab in the 'Charting' tool.

Select the 'X Axis' tab on the left side of the 'Chart Options,' type in a new title such as 'Date,' and select the font and color for the 'X Axis Title' (Figure 35). Likewise, adjust the 'X Axis Labels' and the line/grid colors to preference. Go into the 'Y Axis' tab and modify as needed.

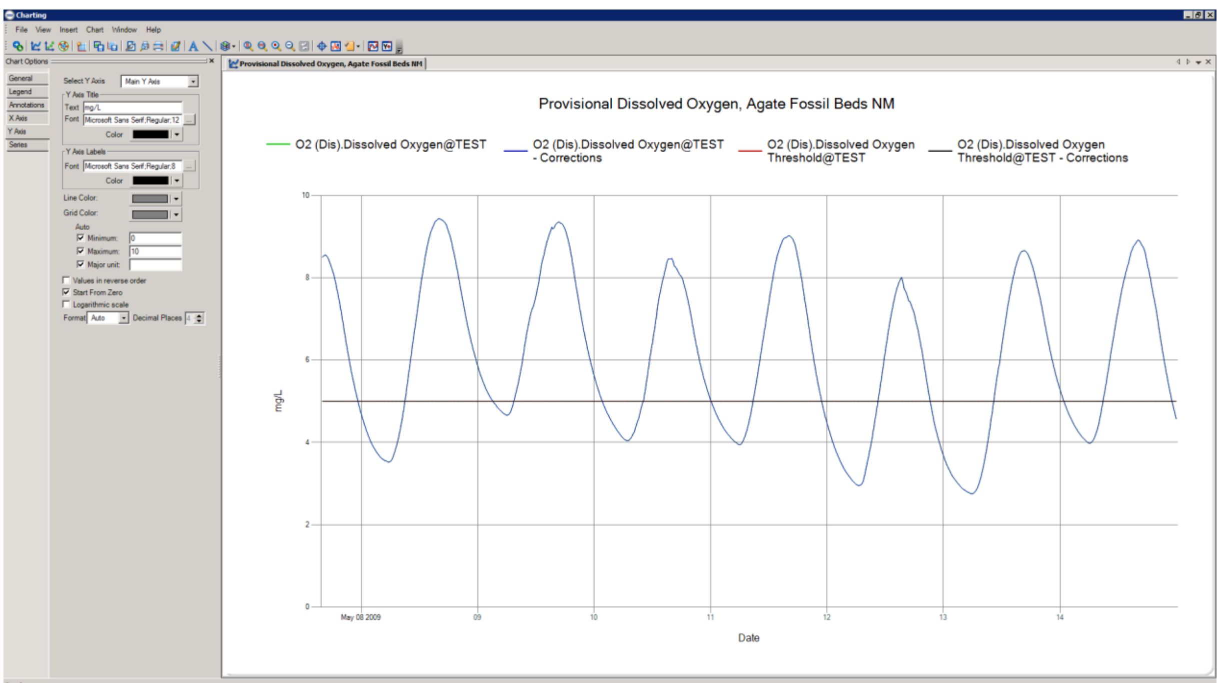

Figure 35. Modifying the X- and Y-axes using the 'X Axis' and 'Y Axis' tabs in the 'Charting' tool.

Under the ‘Series’ tab, select the parameter with corrections (e.g., ‘O2 (Dis).Dissolved Oxygen@TEST – Corrections) using the dropdown arrow; ensure the ‘Show in Chart’ and ‘Show in Legend’ boxes are checked. In the ‘Legend Text’ box, type in the parameter name (e.g., Dissolved Oxygen). Select the color and thickness of the line under ‘Line Options.’

Go back up to ‘Series’ and select the parameter threshold with corrections (e.g., O2 (Dis).Dissolved Oxygen Threshold@TEST – Corrections). To show the threshold line(s) in the chart but not the title in the legend, check ‘Show in Chart’ and leave the ‘Show in Legend’ box unchecked. Select the color and thickness of the line. To include the threshold in the legend, type in the ‘Legend Text’ box a title such as Dissolved Oxygen Regulatory Threshold; ensure the ‘Show in Chart’ and ‘Show in Legend’ boxes are checked (Figure 36).

Go back up to the ‘Series’ box and select the other series (without ‘correction in the title’) and uncheck both the ‘Show in Chart’ and ‘Show in Legend’ boxes. Repeat for the fourth series. Click the ‘Save as Image’ icon () in the toolbar to save the active chart as an image file (e.g., AGFO_WQM_06454100_StatusChart_DO_2014.jpg). Place the chart image file in the N\Monitoring\Water_Quality\PARK\ANALYSIS\Status folder.

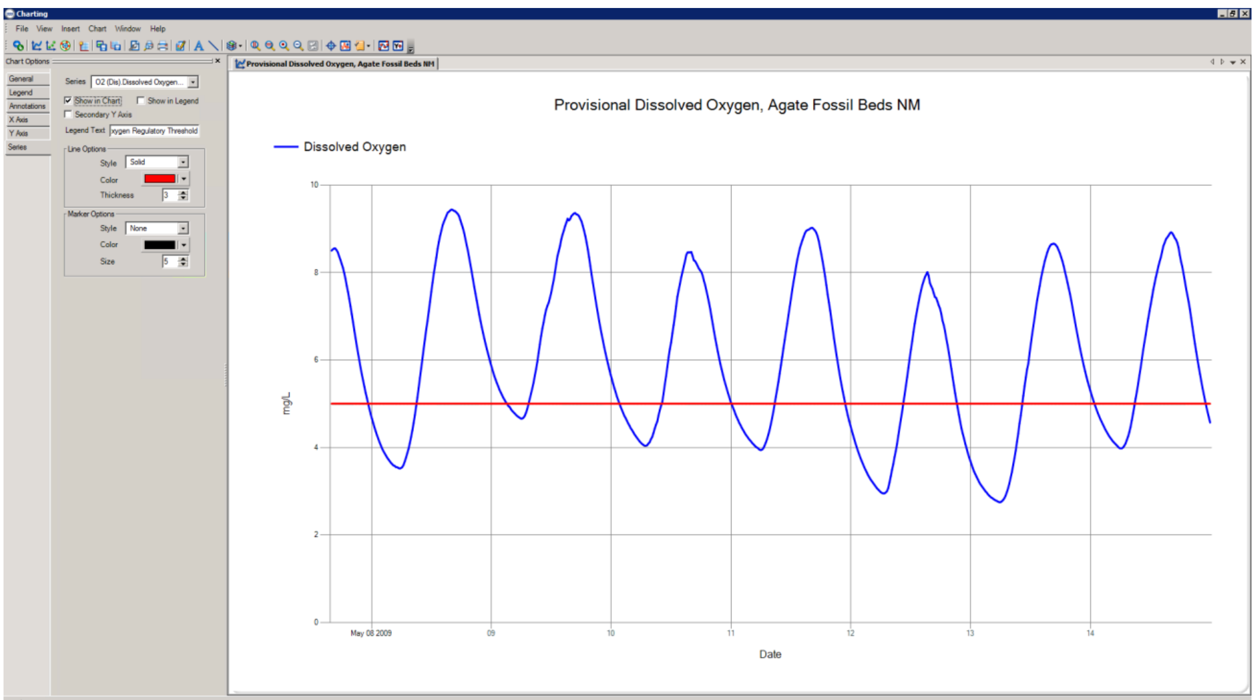

Figure 36. Final chart using features in the ‘Series’ tab. The red line is the state regulatory threshold.

AQUARIUS also allows templates to be set up for the summary plots so that all plots have a similar look and feel. Click the 'Save as Template' icon ( ) to save the active chart as a chart template. Template files (e.g. AGFO_WQM_06454100_ChartTemplate.xml) are located in the N\Monitoring\Water_Quality\PARK\ANALYSIS\Status folder.

To use an existing chart template, first 'wire' the core parameter and its threshold outputs to the 'Charting' icon (remember to increase the number of input ports), then double click the icon. Go to 'File' on the toolbar, click the 'Create Chart from Template' icon ( ), and navigate to the template .xml file. Highlight and open the template .xml file, and the chart opens in the template's format (Figure 37).

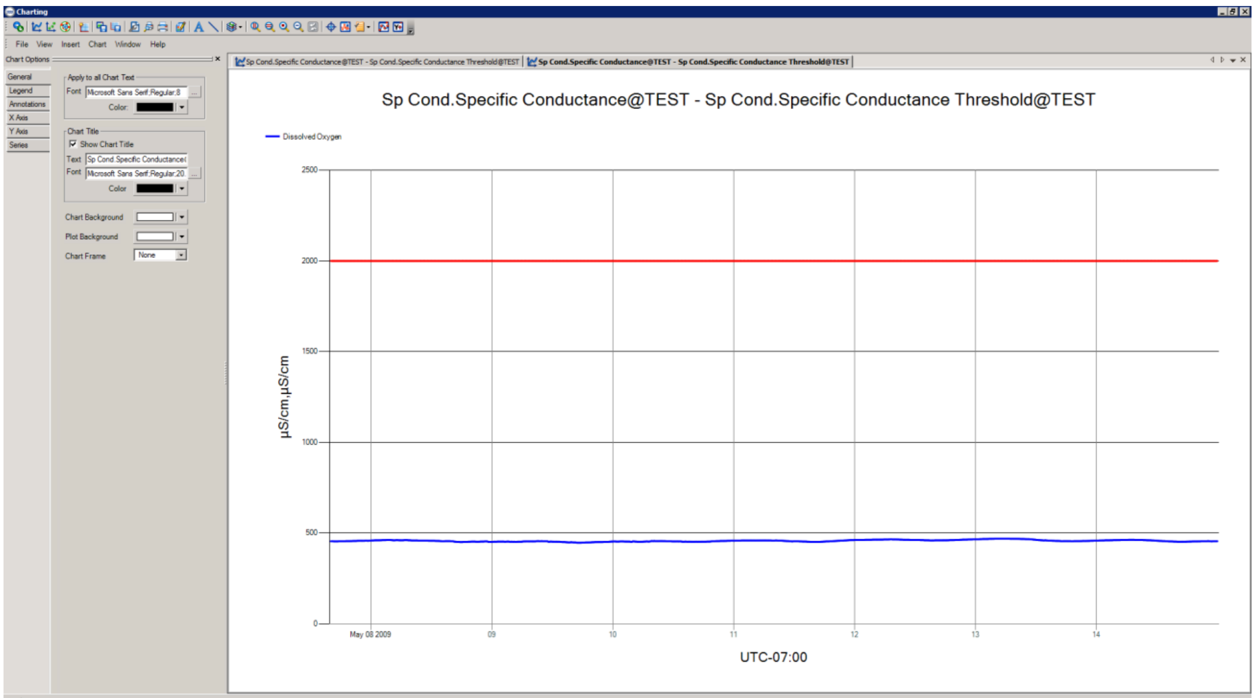

Figure 37. Example of an exceedance chart created from 'Create Chart from Template' tool for specific conductivity (blue line) and the corresponding state regulatory threshold (red line).

This chart requires some modification of the label titles and font size for the legend. Click the 'General' tab and type in the new chart title (e.g., Provisional Specific Conductivity, Agate Fossil Beds NM), then click the 'Legend' title to ensure the legend font is correct. Redo the 'X Axis Title' (e.g., Date) and the 'Y Axis Title' (e.g., µS/cm). Click the 'Series' tab and type in the 'Legend Text' (e.g., Specific Conductivity) for the parameter correction series. Click the 'Save as Image' icon to save the active chart as an image file (Figure 38).

Important Note:
When you complete an AQUARIUS session by exiting Whiteboard or closing the Springboard web page, also right-click the 'AQUARIUS Assistant' icon ( ) on the Task Bar and choose 'Exit' to free up the license for other would-be users.

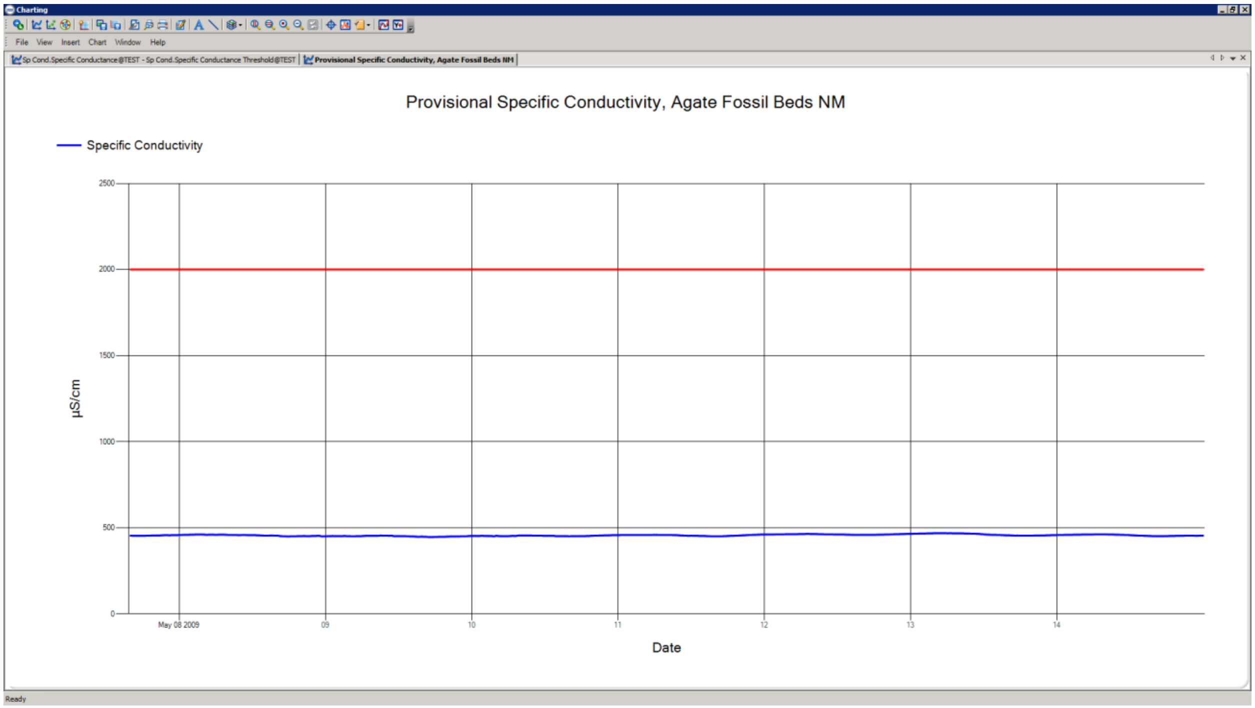

Figure 38. Final chart created from a template for specific conductivity collected at AGFO (blue line). The red line is the state regulatory threshold.

Long-term Trend Analysis of Core Water Quality Parameters and Streamflow Data

The NGPN, in collaboration with a USGS Analyst and/or a Quantitative Ecologist, examines trend analyses for the water quality and the streamflow time series data after the first two cycles of data collection. The objective of these trend analyses is to detect any gradual or rapid changes over time at each of the monitoring sites. Due to the rapid development and advancement of techniques for analysis, the approaches listed in this SOP will likely be modified and expanded with Protocol revisions over the next several years.

Because seasonality is a major source of variation for water quality parameters and for streamflow, the feasibility of using the Seasonal Mann-Kendall Test will be examined for trend analyses (Helsel and Hirsch 2002). This test accounts for seasonality by computing the Mann-Kendall Test on each of the seasons (i.e., months) separately and then combining the results. For example, June data at a monitoring site is compared to June data collected at the same site during the second cycle of data collection. The Kendall S statistics for each month is summed for each month to form an overall statistic (Helsel and Hirsch 2002). To analyze these data, the NGPN may use the AQUARIUS Workstation 'Advanced Statistics' toolbox or one of the statistical freeware R packages for the Seasonal Mann-Kendall Test. The R freeware is a statistics and programming language used for computations and graphics that can be downloaded at no charge from http://www.r-project.org/. Documentation for the R package 'rkt' (for Seasonal and Regional Kendall Tests) can be found at http://cran.r-project.org/web/packages/rkt/rkt.pdf.

For long-term trends in streamflow at existing USGS gaging stations (Table 2; SOP 2) with a sufficient period of record, we will examine the feasibility of using EGRET (Exploration and

Graphics for RivEr Trends). EGRET software (https://github.com/USGS-R/EGRET/wiki) is written in the open-source R language and is designed for the analysis of long-term trends in streamflow. It obtains data from USGS NWIS and places it directly into R, where it uses “flow-normalization” to remove the effect of the random year-to-year variation in streamflow. EGRET currently works best for daily streamflow data sets of about 200 or more samples over a time period of about 20 years. Some testing with smaller data sets has been conducted with no significant problems, but further testing is still needed.

Power Analyses of Core Water Quality Parameters

The initial power analyses reported in Appendix B of the Water Quality Monitoring Protocol Narrative Version 1.0 were tied to specific analytical methods, such as a simple linear regression for monthly means of the parameters, a linear mixed-effects model, a meta-analysis approach, and a Kendall-Mann test. Unfortunately, these early analyses were based on insufficient data to refine the within-season and yearly variance estimates needed to provide more precise estimates of expected power for the various sampling designs. After the completion of several cycles of data collection, however, patterns of within-season variability across numerous years will be available, improving previous estimates of variability. These improved estimates are an important part of assessing whether the sampling design used in this Protocol should be modified to better meet quantitative objectives of the NGPN. To provide information useful to park managers, this Protocol must have adequate power to detect changes in water quality characteristics and provide suitably precise estimates of the magnitude of these changes.

For the trend reports, NGPN will probably use a variety of alternative methods (e.g., seasonal Kendall tests) rather than separate analyses for each month, as originally used (see Appendix B in the Water Quality Monitoring Protocol Narrative Version 1.0). As stated in Appendix B of the Water Quality Monitoring Protocol Narrative Version 1.0, assessing power under other alternative methods will require more extensive computer simulations. The NGPN will consult with the USGS Analysts and/or a Quantitative Ecologist to determine the best approach(es) to evaluate the power to detect trends. Similar to the initial analyses, all simulations and analyses will be conducted in program R (R Development Core Team 2010).

Reporting

An important goal of the NPS Inventory and Monitoring (I&M) Program is to share the results and knowledge gained from monitoring vital natural resources. The primary audience and users of these water monitoring reports are park managers, planners, natural resource specialists, interpreters, the general public, and the scientific community (Fancy et al. 2009). This SOP details the reporting components of the NGPN Water Quality Monitoring Protocol for Wadeable Streams and Rivers. The reporting portion of this SOP involves preparation of annual and trend reports. Annual reports include summary statistics, while trend reports include analyses of trends and recalculation of power analyses after data are available. Reports are written by the General/Aquatic Ecologist. Annual reports follow the NPS template for the Natural Resource Data Series, and trend reports are peer-reviewed and developed following the NPS standards for the Natural Resource Technical Report series (http://www.nature.nps.gov/publications/NRPM/index.cfm). All final documents are sent to the park staff and uploaded to the NGPN website at http://science.nature.nps.gov/im/units/ngpn/.

Annual Reports

Annual reports generated for each park summarize the water quality and streamflow data collected during the previous water year. Each report includes an introduction, background, the objectives of the long-term monitoring as well as a description of the study area and the methods used to monitor the water data. The results section of each report includes summaries of the descriptive statistics such as the mean, median, minimum, and maximum values for each of the core water quality parameters as well as the streamflow data on a monthly basis throughout the ice-free season. The annual data summary also reports the standard deviation of each of these attributes for each month of sampling and the season as a whole. The level of exceedances of the respective state regulatory thresholds for each of the core water quality parameters are also calculated and included in summary tables (see Table 9). In addition, graphs with the parameter data plotted against the threshold level(s) (see Figure 31) as well as graphs of each core parameter and streamflow data over time are included in the summary reports. In the discussion section, local weather conditions and storm events are also examined, and the possible effect of these external factors on the water quality records are addressed. This final section also discusses the important results along with possible recommendations for future monitoring efforts. An appendix for each Annual Report includes the site-specific USGS Station Analysis Report, which includes a description of the equipment the USGS deployed, the status of the stage and core parameters, and any parameter corrections. The remarks section provides an overall quality rating of the record (excellent, good, fair, or poor) for each parameter. Format for these reports follows the NPS Natural Resource Publications Management for the Natural Resource Data Series.

Resource Briefs

In addition to Annual Reports, a one- or two-page Resource Brief is prepared for each park's interpretive staff and the general public. Like the annual reports, the proportion of observations above or below the state regulatory threshold is reported annually in the resource brief along with any unusual observations (e.g., high flow events).

Trend Reports

After two complete cycles of the sampling design are conducted at each of the selected park sites, long-term trends since the initiation of data collection are estimated and summarized in the Trend Reports. A Trend Report is published for each park. The primary objective of these reports is to provide an in-depth analysis and synthesis of several years of the time series data. Similar to the NGPN plant community comprehensive syntheses, the water quality trend reports likewise provide greater detail than the Annual Reports (Symstad et al. 2012) by (1) evaluating trends with respect to normal range of variability and/or thresholds; (2) relating environmental attributes to the collected water quality data; (3) using different analytical techniques; (4) incorporating data from other Vital Signs; and (5) focusing on specific management issues. In addition, the trend reports include a power analysis of the current sampling design implemented at the selected parks and make any recommendations for changes to the design. The format for these reports follows the NPS Natural Resource Publications Management for the Natural Resource Technical Report Series.

Schedule

Annual reports are produced each year by April 30 of the year following data collection at a park (Table 10). Because of the 3-year rotation of water quality monitoring sites, two or three annual reports are produced in any one year (Table 10). Similarly, the park resource briefs are completed by June 1 following the collection year (Table 10).

The more in-depth trend reports are produced by October 30 after the second cycle of sampling is complete. For example, trend reports for the first three parks monitored (DETO, THRO, KNRI) are produced by October 30, 2017 (Tables 10 and 11). The three sites along the Niobrara River (AGFO, NIOB, and the 39-mile District for MNRR) trend reports are produced the following year, and trend reports for the last two sites (FOLA and the 59-mile District for MNRR) will be completed in 2019 (Tables 10 and 11).

Table 10. Publication schedule for the NGPN Water Quality Monitoring Protocol for Wadeable Streams and Rivers.

Report	Primary Responsibility	Target Date	Destination(s)
Annual Report	General/Aquatic Ecologist	April 30 of following year	NPS Data Store[1] NGPN Website Park Staff
Resource Brief	General/Aquatic Ecologist	June 1 of following year	NGPN Website Park Staff
Trend Report	USGS General/Aquatic Ecologist	October 30 following completion of two water years of data collection	NPS Data Store[1] NGPN Website Park Staff
Other Publications	General/Aquatic Ecologist Data Manager Network Coordinator	As completed	NPS Data Store[1] NGPN Website Park Staff

[1] NPS Data Store is one of the Integrated Resource Management Applications (IRMA) (https://irma.nps.gov/App/Portal). This application is the NPS-wide repository for documents, publications, and data sets that are related to NPS natural and cultural resources.

Table 11. Revisit design for parks in the NGPN water quality monitoring program. A water year runs from about March through October of a calendar year.

	Year					
Park	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
DETO	x			x		
THRO	x			x		
KNRI	x			x		
AGFO		x			x	
NIOB		x			x	
MNRR[1]		x			x	
FOLA			x			x
MNRR[2]			x			x

[1]Niobrara River tributary to the 39-mile District of MNRR.

[2]Bow Creek tributary to the 59-mile District of MNRR.

Standard Operating Procedure (SOP)
SOP 7: Postseason Procedures

Version 1.0, October 2014

Revision History Log

The following table lists all edits and amendments to this SOP since the original publication date. Users of this SOP must notify the NGPN General/Aquatic Ecologist regarding recommended and required changes. The General/Aquatic Ecologist reviews and incorporates all changes, completes the revision history log, and changes the date and version number on the title page and in the footer of the document file. For complete instructions, please refer to SOP 8 Protocol Revision.

Previous Version #	Revision Date	Revised By	Changes Made	Reasons for Change	New Version #
1.0 Draft	October 2014	NGPN	Revision following peer review		1.0
Add rows as needed for each change or set of changes tied to an updated version number					

Introduction

This SOP explains procedures to be completed after the water quality equipment is removed from the sites, including a review of the field season with cooperators and closing out the Interagency Agreements. As part of this process, the General/Aquatic Ecologist ensures that the NGPN receives the corrected data from the USGS WSC in a timely manner (usually in February following the water year).

Review the Field Season and Interagency Agreements

The General/Aquatic Ecologist and/or NGPN Coordinator meet with the USGS WSC staff to discuss the field season at each park. The review includes the following steps:

1. Complete a final, thorough check of all data sets and clarify any ambiguities. Record decisions made regarding these ambiguities and the reasons behind those decisions.

2. Review what was accomplished and what was not completed. Record all instances of missing data and explain why they are missing.

3. Discuss any and all information that would impact the quality of data collected, such as misunderstandings of data collection procedures, inclement weather, etc.

4. Determine whether the park staff has any safety or communication concerns that should be addressed prior to the next field season.

5. Determine whether the USGS Hydrographers have concerns that should be addressed before the next field season. Include a discussion of how issues in item 3 above could be remedied.

6. Determine how the field season went overall.

In addition, the General/Aquatic Ecologist contacts each park to discuss the field season and determine if the park staff had any concerns or areas for improvement.

Data Management

Complete and accurate record keeping of data derived from the field is crucial. The General/Aquatic Ecologist and USGS staff share the responsibility for verifying and documenting data according to the guidelines in this Monitoring Protocol and all applicable SOPs. Refer to the NGPN Data Management Plan for overall guidance (Brumm 2009).

Standard Operating Procedure (SOP)
SOP 8: Protocol Revision

Version 1.0, October 2014

Revision History Log

The following table lists all edits and amendments to this SOP since the original publication date. Users of this SOP must notify the NGPN General/Aquatic Ecologist regarding recommended and required changes. The General/Aquatic Ecologist reviews and incorporates all changes, completes the revision history log, and changes the date and version number on the title page and in the footer of the document file.

Previous Version #	Revision Date	Revised By	Changes Made	Reasons for Change	New Version #
1.0 Draft	October 2014	NGPN	Revision following peer review		1.0
Add rows as needed for each change or set of changes tied to an updated version number					

Introduction

Long-term monitoring programs need flexibility to adapt to changes in resources, technology, methodology, and priorities over time. Monitoring efforts must often assess the trade-offs of making major Protocol modifications as new technologies emerge. The purpose of this SOP is to discuss strategies for adapting to these changes and to outline how to make and track changes to the NGPN Water Quality Monitoring Protocol and its accompanying SOPs.

Adapting to Decreased/Increased Funding

Changes in future funding to accomplish the sampling described in this Protocol are likely, usually driven by increased or decreased NGPN budgets and/or changes in priorities. In these circumstances, staff must carefully consider the impact of modifying the sampling design on the long-term monitoring of water quality parameters. Once the baseline data have been collected over several 3-year cycles, the NGPN may want to re-evaluate the current sampling design by means of a power analysis to determine any changes to the current sampling scheme.

If funding is decreased, a less expensive technology may reduce the need for intensive sampling using multiparameter sondes. In addition, a less intensive sampling schedule may be feasible, especially if a power analysis based on at least two rotations of data indicates that an increase in the length of the sampling cycle to, for example, every 5 years instead of every 3 years may provide similar trends over time. A third option is to sample only the top five priority sites (labeled as number 1 in Table 7 of the Water Quality Monitoring Protocol Narrative Version 1.0) and remove or delay sampling at the number 2 sites (i.e., DETO, KNRI, and MNRR 39-Mile District).

If funding is increased, NGPN and park staff may want to expand the sampling to additional fixed sites at a park or to include relevant analytes of concern, such as atrazine. Decisions to expand sampling will be based on close examination of the baseline data as well as close communication with the park staff and the USGS WSCs involved in the sampling process.

Steps for Revising the Protocol

The following procedures were taken from Symstad et al. (2012) and ensure that both minor and major revisions to this document align with the NGPN Monitoring Plan (Gitzen et al. 2010).

1. Consult the Protocol Review Forms stored with the current version of the Protocol for suggestions made by previous NGPN, park staff, or cooperators such as the USGS.

2. Discuss proposed changes with USGS staff prior to making modifications, especially with the Data Manager because certain types of changes may jeopardize data set integrity unless they are planned and executed to avoid problems. In addition, because certain changes may require altering the database structure or functionality, advance notice of changes will minimize disruptions to program operations. Consensus should be reached on who makes the changes and in what timeframe.

3. Make the agreed-upon changes in the appropriate Protocol document. A change in one document may necessitate 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, program activity timing or responsibilities for various program tasks may change in several SOPs.

4. Document all edits in the Revision History Logs embedded in the Protocol Narrative and each SOP. Log changes only in the document being edited (i.e., if a change is applied to an SOP, log those changes only in that document). Record the date of the changes (i.e., the date when all changes were finalized), author of the revision, the change and the paragraph(s) and page(s) where changes are made, brief reason for making the changes, and the new version number. Version numbers increase incrementally by hundredths (e.g., version 1.01, 1.02) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.00, 3.00). Record the previous version number, date of revision, and author of revision; identify paragraphs and pages where changes are made, rationale for revisions, and the new version number.

5. Circulate the modified document for internal review among NGPN staff and cooperators. Minor changes and clarifications are reviewed in-house. When significant changes in methodology are suggested, revisions first undergo internal review by NGPN staff. Additional external review including, but not limited to, NPS staff with appropriate expertise is required.

6. Upon ratification and finalizing changes:

    a. Ensure that the version date (last saved date field code in the document header) and file name (field code in the document footer) are updated properly throughout the document.

    b. Put a copy of each changed file in the archive folder found inside the ‘PROTOCOL’ folder.

    c. Rename the copied files by appending the revision date in YYYYMMDD format so that the revision date becomes the version number, and this copy becomes the ‘versioned’ copy to be archived and distributed. For example, the second minor revision of this document would be named ‘NGPN_WQM_SOPs_1.02_20130423.docx’ in the archive subfolder.

    d. Inform the Data Manager so the new version number(s) can be incorporated into the project metadata.

7. Create PDF files of the versioned documents to post to the Internet and share with others. These PDF files should have the same name and be made from the versioned copy of the file.

8. The Data Manager ensures that revised document files are in the proper folder on the NGPN shared drive and have the correct access protections.

9. The Data Manager posts the revised version and updates the associated records in the proper I&M databases, including but not limited to the NGPN Intranet and Internet web sites and the national I&M program's Protocol database.

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Appendix A. Generic Interagency Agreement with USGS Water Science Centers using the 2013 Wyoming Water Science Center as an example.

INTERAGENCY ACQUISITION AGREEMENT

Agreement Number: FXXXXXXXX

Page 1 of 3

OBJECTIVES AND STATEMENT OF WORK

OBJECTIVES

The objectives of this Interagency Agreement between the National Park Service (NPS) Northern Great Plains Network (NGPN) and the U.S. Geological Survey (USGS) Wyoming Water Science Center (WSC) are to rent necessary multiparameter sonde(s) from USGS Hydrologic Instrumentation Facility; to collect water quality and streamflow data during the ice-free season at designated sampling site(s); and to provide raw and approved data in a CSV format to the NPS.

STATEMENT OF WORK

A. The USGS agrees to:

1. Complete the work outlined in the attached Scope of Work, Appendix 1, by February 7, 2014.
2. Maintain frequent contact with the NPS Agreements Technical Representative throughout FY2013 and FY2014.
3. Notify the NPS Agreements Technical Representative within 15 working days of foreseeable problems regarding deliverable due dates or delays in meeting deadlines.

B. The NPS agrees to:

1. Provide $XX,XXX in payment for completion of work outlined in the attached Scope of Work, Appendix 1.
2. Consult with the USGS Wyoming WSC principal investigator on work progress and provide information support as needed.
3. Facilitate the NPS Scientific Research Permit process at DETO.
4. Provide timely reviews of the draft final products and other deliverables.

APPENDIX 1

SCOPE OF WORK

To accomplish the work identified in this Scope of Work, USGS staff follows approved USGS Standard Operating Protocols and the approved “Water Quality Monitoring Protocol for Wadeable Streams and Rivers in the Northern Great Plains Network: Narrative Version 1.0.” The NGPN’s Protocol can be found on the NGPN’s web site at http://science.nature.nps.gov/im/units/ngpn/.

A. The USGS Wyoming WSC requests multiparameter sondes (e.g., YSI 6920) from the USGS Hydrologic Instrumentation Facility on the first of the calendar year to ensure availability of advanced continuous monitoring sondes.

B. The USGS Wyoming WSC collects water quality and streamflow data during the ice-free season (roughly March through November) at the USGS Gaging Station #06427850 (historic site) located on the Belle Fourche River inside DETO, WY.

C. USGS provides the field/lab work labor, travel, streamflow measuring equipment, and supplies, such as standards for calibrations. In addition, USGS requests any necessary permission(s) from the State to work from the Wyoming Highway 110 bridge.

D. Standard USGS forms and spreadsheets are used for site revisits and data recording.

E. Water quality measurements consist of water temperature, dissolved oxygen, pH, and specific conductivity and are recorded by the multiparameter sondes every 15 minutes.

F. Sondes are serviced every 3 weeks (or as needed) to download data, calibrate units using a second field meter following USGS Protocol, and change nonfunctioning units/sensors as needed.

G. During each site revisit, water quality field parameters are measured at multiple points in a single cross section using standard USGS methods. Stream discharge is also measured in accordance with USGS Protocols.

H. The USGS staff take digital photographs upstream and downstream of the gaging station during each site revisit (see attached NGPN Photographic Record Sheet).

PRODUCTS:

The USGS Wyoming Water Science Center delivers the following products and services:

1) Upload the provisional data as real-time water quality data on the National Water Information System (NWIS) website at http://nwis.waterdata.usgs.gov/nwis.

2) Provide NPS the raw 15-minute interval data downloaded from the continuous monitoring sondes as CSV files as well as copies of the raw streamflow data in an electronic format every 6-8 weeks throughout the field season.

3) Deliver the corrected and approved 15-minute interval water quality and streamflow data to the NGPN by February 7, 2014 as CSV files.

4) Provide NPS electronic copies of all field data sheets and photographs (including the NGPN Photographic Records Sheets) taken at the site by February 7, 2014.

5) Send NPS electronic copies of the Inspection Summaries for each water quality parameter (workbook) by February 7, 2014.

6) Send NPS a Station Analysis Report by February 7, 2014. This report encompasses site information from initial deployment in the spring to retrieval of equipment in the fall (see attached example).

Appendix B. USGS Water Science Center and NPS park contacts listed by state.

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NPS 960/127008, October 2014

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