Northeast Temperate Network
Lakes and Streams Monitoring Protocol
Revision 2.01, March 2007

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1.00	12/15/06	NA	NA
2.00	3/23/07	Most	See Appendix 4, Revision Details
2.01	3/31/07	1.1.7.7	Added mg/L to ueq/L conversion factor.

CONTENTS

TABLES

FIGURES

LIST OF ACRONYMS

ACAD	Acadia National Park
ADCP	Acoustic doppler current profiler
ANC	Acid Neutralizing Capacity
ASR	Analytical Service Request

ASTM	American Society for Testing and Materials
BOHA	Boston Harbor Islands National Recreation Area
Chl	Chlorophyll
DI	Deionized Water
DO	Dissolved Oxygen
ELRO	Eleanor Roosevelt National Historic Site
EWI	Equal Width Increments
GIS	Geographic Information System
GPS	Global Positioning System
HDPE	High Density Polyethylene
HOFR	Home of Franklin D. Roosevelt National Historic Site
LDC	Legacy Data Center
MABI	Marsh-Billings-Rockefeller National Historical Park
MDEP	Maine Department of Environmental Protection
MDI	Mount Desert Island
MQO	Measurement Quality Objective
MIMA	Minute Man National Historical Park
MORR	Morristown National Historical Park
MDS	multiparameter Display System
NAWQA	National Water-Quality Assessment Program
NHP	National Historical Park
NHS	National Historic Site
NP	National Park
NPS	National Park Service
NRA	National Recreation Area
NETN	The Northeast Temperate Network
NGVD	National Geodetic Vertical Datum
NOAA	National Oceanic and Atmospheric Administration
NWIS	National Water Information System
NWQL	National Water-Quality Lab
ONRW	Outstanding National Resource Waters

ORW	Outstanding Resource Waters
OSHA	Occupational Safety and Health Administration
PDA	Personal Data Assistant
PFD	Personal Flotation Device
PPFD	Photosynthetic Photon Flux Density
PRIMENet	Park Research and Intensive Monitoring of Ecosystems Network
QA/QC	Quality Assurance/Quality Control
RSD	Relative Standard Deviation
ROVA	Roosevelt-Vanderbilt National Historic Site
SAGA	Saint-Gaudens National Historic Site
SAIR	Saugus Iron Works National Historic Site
SARA	Saratoga National Historical Park
SD	Secchi Disk Depth
SOPs	Standard Operating Procedures
SPU	Standard Platinum Units
STORET	U.S. Environmental Protection Agency's storage and retrieval database
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
TSI	Trophic State Index
USCG	U.S. Coast Guard
USDOI	U.S. Department of the Interior
USFWS	U.S. Fish and Wildlife Service
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
VAMA	Vanderbilt mansion national Historic Site
VLMP	Volunteer Lake Monitoring Program
WEFA	Weir Farm National Historic Site
YSI	Yellow springs Instrumentation

Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
Length		
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
Area		
square foot (ft^2)	0.09290	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
acre	4,047	square meter (m^2)
acre	0.4047	hectare (ha)
Volume		
ounce, fluid (fl. oz)	0.02957	liter (L)
Flow rate		
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

°F=(1.8×°C)+32

Temperature in degrees Fahrenheit (°F) can be converted to degrees Celsius (°C) as follows:

°C=(°F-32)/1.8

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Vertical coordinate information is referenced to the insert datum name (and abbreviation) here for instance, “North American Vertical Datum of 1988 (NAVD 88).”

Horizontal coordinate information is referenced to the insert datum name (and abbreviation) here for instance, "North American Datum of 1983 (NAD 83)."

Altitude, as used in this report, refers to distance above the vertical datum.

Freshwater Vital Signs Monitoring Plan for National Parks in the Northeast Temperate Network (NETN)

PHASE III: Water-quality Monitoring Protocols in Lakes, Ponds and Streams

By Pamela J. Lombard, William G. Gawley, and James M. Caldwell

Abstract

Water-quality-monitoring protocols for lakes, ponds, and streams in parks in the National Park Service Inventory and Monitoring Program's Northeast Temperate Network (NETN) are presented. Protocols consist of a narrative in part I and Standard Operating Procedures (SOPs) in part II. The narrative in part I includes monitoring objectives, sampling design, proposed sampling sites for each park in NETN and applicable state water-quality standards. SOPs in part II include step-by-step instructions for field methods and data management, including quality assurance and quality control. Part II is intended for use as a manual and reflects SOPs currently in use by other agencies collecting water-quality data in NETN parks. If SOPs are updated to reflect new methods, all older versions of the protocols must be archived.

Part I. Monitoring Protocols

1. Monitoring Protocol Narrative

1.1 Introduction

The Northeast Temperate Network (NETN) is made up of the following 11 National Parks (NP), National Historical Parks (NHP), National Recreation Areas (NRA), National Historic Sites (NHS), and National Scenic Trails (NST):

- Acadia NP, Maine (ACAD)
- Appalachian NST, Maine to Georgia (APPA)
- Boston Harbor Islands NRA, Massachusetts (BOHA)
- Marsh-Billings-Rockefeller NHP, Vermont (MABI)
- Minute Man NHP, Massachusetts (MIMA)
- Morristown NHP, New Jersey (MORR)
- Roosevelt-Vanderbilt NHS, New York (ROVA)
- Saint-Gaudens NHS, New Hampshire (SAGA)
- Saugus Iron Works NHS, Massachusetts (SAIR)
- Saratoga NHP, New York (SARA)
- Weir Farm NHS, Connecticut (WEFA)

The Appalachian NST is beyond the scope of this monitoring program, and will not be considered further in this document. In the remainder of NETN parks, freshwater resources are subjected to natural and anthropogenic impacts and alterations, which have imposed stress on these resources for many years. Current and historic threats to aquatic ecosystems in National Park Service (NPS) units throughout the northeastern U.S. have led to specific physical, biological, or chemical stressors to the freshwater ecosystems. The documentation of baseline water-quality and water-quantity conditions is essential to the long-term maintenance of freshwater resources. Documenting the changes in baseline conditions will assist natural resource managers to identify and manage stressors in park freshwater ecosystems.

The NPS has conducted a three-phase project to design a freshwater-resources monitoring plan. The NPS will monitor indicators (vital signs) that represent the overall health or condition of park resources and track the effects of stressors. The U.S. Geological Survey (USGS) has worked in cooperation with the NPS on each phase of this project to develop water-quality-monitoring protocols. These phases can be described as follows:

PHASE I: Development of a scoping report for long-term monitoring in NETN parks. This report includes an inventory of freshwater resources in the parks, a description of monitoring programs in each park, descriptions of current and emerging threats to NETN ecosystems, and a list of stressors and candidate monitoring variables (vital signs) that could be used to assess the status of park ecosystems over the long term.

PHASE II: Design of prototype guidance for monitoring freshwater resources in NETN parks and development of a list of priority monitoring variables (vital signs) that will be measured in all NETN parks.

PHASE III: Development of monitoring protocols for selected high-priority vital signs in NETN lakes, ponds and streams. Conduct feasibility (pilot) testing of recommended freshwater-quality/aquatic-resource vital signs at select NETN parks to finalize the freshwater-resource monitoring design for NETN.

Phase I showed that although baseline freshwater-quality data are collected in some NETN parks, NETN as a whole does not have a comprehensive freshwater long-term (greater than 10 years) data-collection program that includes systematic quality control and data management. Environmental threats common to all NETN parks include climate change, atmospheric deposition, visitor overuse and invasive species (Shriver et al, 2004). Phase I was initiated in 2003 and the report was completed in 2004 (Lombard, 2004). The Phase II report includes a summary of a workshop at ACAD in May 2004 in which freshwater-quality professionals discussed the potential list of vital signs and made recommendations as to their ecological relevance, management significance and utility, feasibility, and response variability. The potential vital signs developed in Phase I were reviewed and ranked, and specific measures for high-priority vital signs were proposed. The Phase II report also included a comparison of the recommended list of high-priority vital signs with the water-quality monitoring that is currently (2004) taking place in each park. Phase II was initiated in 2004 and the report was completed in that same year (Lombard and Goldstein, 2004).

This report describes Phase III, the results of the study to design water-quality-monitoring protocols for lakes, ponds, and streams. These protocols consist of a narrative in part I and Standard Operating Procedures (SOPs) for field methods, data management, quality assurance and quality control in part II.

1.1.1 Freshwater Resources- lakes, ponds, and streams

In this Phase III report, lakes are defined as freshwater bodies with surface areas greater than 15 acres. ACAD is the only park in NETN that has lakes. There are nine lakes entirely within its boundaries on Mount Desert Island (MDI) and five lakes that are partially within its boundaries. The lakes on MDI at ACAD range in surface area from 16 acres to 897 acres, and from 1 to 46 m deep. Many have small impoundment structures at their outlets (Kahl et al, 2000).

Many NETN parks have ponds, including man-made impoundments, between 1 and 15 acres. ACAD has 10 ponds; MABI, WEFA, SAGA, BOHA and MORR have 1 pond each; and ROVA has 3 ponds. Ponds less than 1 acre are not addressed in this report.

Streams and rivers within NETN parks vary from headwater streams to tidal rivers. There are approximately 50 miles of perennial rivers and streams flowing through or adjacent to NETN parks. Thirty-five miles of stream are in ACAD, 8 miles in SARA, and less than 2.5 miles in each remaining park. The Concord River flows through MIMA and the Saugus River flows through SAIR. SARA and ROVA border the Hudson River and are occasionally flooded by it during times of high water.

1.1.2 Justification for Selected Vital Signs

The vital signs for fresh waterbodies included in the Phase III protocol are water chemistry, nutrient enrichment, water quantity, and the detection of invasive plant species. Measures of water chemistry, nutrient enrichment, water quantity and the detection of invasive plant species directly address the NPS Inventory and Monitoring objective to detect change in the status of physical, chemical, or biological attributes of the ecosystem. Measures of water chemistry including specific conductance, pH, water temperature, and DO and are fundamental to any long-term water-quality-monitoring program, are critical for interpreting the biotic condition and ecological processes of a resource, and are mandatory as directed by the Inventory and Monitoring Program at the national level (National Park Service, 2002). Measures of water quantity are necessary for monitoring the physical status of the freshwater ecosystems, and are fundamental to the interpretation of water-chemistry measures. Although only a qualitative estimate of water quantity is mandatory as a part of the Inventory and Monitoring Program, hydrologists at the workshop in Phase II identified quantitative measurements of water quantity, such as discharge and lake levels, as top priority.

In addition, acid-neutralizing capacity (ANC), color, and water clarity in lakes will be measured at all NETN parks. A long-term record of these basic water-chemistry parameters in the lakes and streams of NETN parks will enable resource-management professionals to detect trends that could be related to global and regional climate change and site-specific anthropogenic change. Moreover, a long-term data set of the selected parameters is essential to interpreting any trends noted from long-term biological and process-oriented data sets.

Recommended nutrient-enrichment measures include algal biomass, total and dissolved phosphorus and nitrogen, and water clarity. These will also be measured in all NETN parks to give managers guidance regarding the trophic status and productivity of freshwaters in parks. Nutrient enrichment and the acceleration of eutrophication have been identified in most NETN parks as one of the stressors of greatest concern (Lombard and Goldstein, 2004).

Invasive species are the stressors of greatest concern across all systems in the parks including freshwater aquatic, wetlands, marine, and terrestrial systems (Shriver et al., 2004). Protocols for the early detection of invasive plant species in lakes and ponds are included in these Phase III protocols. The detection of invasive animal species was identified as high priority, but the development of a protocols for detection depends on future funding and (or) collaboration with other agencies.

Other vital signs identified as high priority for protocol development include macroinvertebrates in streams, zooplankton community composition in lakes, and fish community composition in lakes and streams. Because of funding constraints, however, protocol development for these vital signs would depend on collaboration with other agencies. Protocols for freshwater wetlands will be established independently (H. Neckles, USGS, oral comm., 2006).

The water quality of ground water, springs, and seeps were considered during the vital-sign prioritization process, but were determined to be beyond the scope of the vital-signs program. NETN would, however, benefit greatly from information regarding the ground-water resources, especially in parks such as MORR where many of the streams are ground-water fed. Ground-water data and data on springs and seeps can be integrated into a vital-signs program if available.

Fecal bacteria in water were also considered in the prioritization process because this parameter is included in state water-quality standards. Although it is necessary in most states to meet standards for bacteria, fecal bacteria were not necessarily considered to be an indicator of overall freshwater ecosystem health, and thus they are not included in these Phase III protocols.

For additional justification and prioritization of vital signs and measures see the Phase II water-quality report (Lombard and Goldstein, 2004).

1.1.3 Protocol Development and Background

Protocols for NETN monitoring adapt existing protocols that meet the objectives and standards of this vital signs program to maintain consistency of data wherever possible. Measures of lake water chemistry, nutrient enrichment in lakes, and lake water levels have been monitored in ACAD since 1997 (Breen et al., 2002) and ACAD has developed protocols for these measures (Gawley, 1996). These protocols are consistent with lake-monitoring protocols used by the Maine Department of Environmental Protection (MDEP) Lake Assessment Program Standard Operating Procedures (Maine Department of Environmental Protection, 2004) and with Maine Volunteer Lake Monitoring Program protocols (VLMP) (Williams, 2004). Protocols for the detection of exotic invasive species are adapted from VLMP protocols and SOPs downloaded on July 14, 2005, from http://mainevolunteerlakemonitors.org/index2.htm.

Protocols for measures of water-quality vital signs in streams are based on USGS National Water-Quality Assessment Program (NAWQA) protocols (US Geological Survey, variously dated). Protocols for collecting stream discharge data are based on USGS methods (Rantz et al, 1982).

Current (2006) state and Federal protocols are adapted and included in this report for completeness. Review of future versions of NAWQA, MDEP and VLMP protocols by NPS Inventory and Monitoring staff will ensure that NETN protocols remain current.

1.1.4 Monitoring Objectives

The overall objective of a monitoring program is to monitor the status and trends of NETN aquatic resources, to assess changes in ecological integrity and the impacts of key stressors, and to guide management decisions affecting those resources. The two specific objectives of this program and the questions that frame these general monitoring objectives are:

Objective 1: Detect changes over time in the status of physical, chemical, or biological attributes of the freshwater resources in NETN parks that are outside the range of natural variability.

- Question 1: What is the natural range of temporal variability of the measures of selected vital signs of freshwater resources?
- Question 2: Are there trends in the measures of selected vital signs outside the range of natural variability?
- Question 3: Are the measures of vital signs exceeding thresholds set by states as a part of their legal mandate under the Clean Water Act?

Objective 2: Ensure the early detection of aquatic invasive plants in the freshwater resources of NETN parks and alert park and state environmental managers of any new incidences of aquatic invasive species to facilitate a rapid response.

- Question 1: What exotic invasive aquatic plant species currently exist in the freshwater resources of NETN parks?
- Question 2: Are there any new incidences of invasive aquatic plant species in NETN parks?

These objectives are used to guide management decisions affecting NETN aquatic systems such as the building and maintenance of roads and trails, the use and maintenance of Best Management Practices, and decisions regarding visitor and recreation uses.

The measurements associated with each vital sign and the specific questions to be addressed by collecting these water-quality data are outlined in tables 1 and 2 for streams and lakes, respectively.

1.1.5 State and Regional Water-Quality Standards

The NETN includes parks in seven states in the Northeast (Maine, New Hampshire, Vermont, Massachusetts, Connecticut, New York, and New Jersey). Water-quality standards have been established by each state for all freshwater bodies according to the Clean Water Act, section 305b. The goal of the Clean Water Act is to restore and maintain the chemical, physical, and biological integrity of the Nation's waters. Water-quality standards, established by states, districts, territories and tribes consist of the following four basic components: designated uses, water-quality criteria, antidegradation requirements, and general policies as outlined on the U.S. Environmental Protection Agency (USEPA) Web site, *http://www.epa.gov/waterscience/standards/about/*.

A state's designated use includes existing and desired uses of water that require good to excellent water quality. Water-quality criteria, which have been developed to protect each designated use, can be numeric or narrative descriptions of the chemical, physical, and biological conditions necessary to support each of the designated uses, and can be site-specific. The antidegradation policy for each state must ensure that no activity is allowed that (1) compromises existing uses, (2) lowers water quality that currently meets or is better than the standard, or (3) degrades Outstanding National Resource Waters (ONRWs) – a water of exceptional ecological or recreational significance. USEPA guidance for antidegradation policy implementation for high-quality waters in USEPA Region I (U.S. Environmental Protection Agency, 1987) indicates that ONRWs include all waters of national and state parks. Although individual freshwater bodies are not all individually classified by states, park streams, lakes, and ponds are held to the highest classification standards designated by each state.

NETN adheres to state water-quality standards that can and do vary across NETN; however, this means that individual parks within NETN will not be adhering to the same standards. Descriptions of each state's water-quality standards are included in the following sections and in tables that summarize state quantitative standards for streams and for lakes and ponds (tables 3 and 4, respectively).

Table 1. Monitoring questions for NETN streams.
[DO, dissolved oxygen; ANC, Acid neutralizing capacity; NETN, Northeast Temperate Network]

VITAL SIGN	MEASURE	MONITORING QUESTIONS
Water quantity	Streamflow (partial record streamflow-gaging stations and continuous-record streamflow-gaging stations)	1) What is the relation between the stage and the discharge (the rating) at each partial record and at each continuous-record streamflow-gaging station? 2) What are the long-term (>10 year) streamflow statistics such as seasonal means and medians at each streamflow-gaging station. 3) How do variations in streamflow explain deviations or trends in chemical or biological data observed in these same streams or in the park? 4) Are there long-term (>10 yr) trends in any of the annual or monthly streamflow statistics at the index station(s)?
Water chemistry	Specific conductance, pH, water temp, DO, ANC, color	1) What is the natural range in variability in water-chemistry parameters for streams in each NETN park based on streams in the park that are relatively unaffected. 2) Are water-chemistry measures exceeding thresholds indicating that they are outside the range of natural variability? What is the spatial and temporal extent of these deviations? 3) Are freshwater bodies in NETN parks in compliance with the applicable Federal and state water-quality standard for the highest use classifications in each state for water chemistry? 4) Are water-chemistry parameters showing long-term (> 10 year) spring, summer or fall seasonal trends after accounting for flow? 5) Can water-chemistry data be used to explain deviations in biological data at collocated sites? 6) Can changes in water chemistry be linked to trends in human activity in the park such as increased roads and (or) erosion?
Nutrient enrichment	Phosphorus and nitrogen	1) What is the natural range in variability in nutrients for streams in each NETN park based on streams in the park that are relatively unaffected? 2) Are freshwater bodies in NETN parks in compliance with the applicable Federal and state water-quality standard for the highest use classifications in each state for nutrients, especially total phosphorus and stream nitrates? 3) Are nutrient loads to freshwater aquatic resources in NETN parks increasing? What is the spatial and temporal extent of these increases? 4) Are freshwater aquatic resources changing in response to increased loads? Is eutrophication approaching or exceeding levels that could cause shifts in ecosystem structure and function? 5) Are nutrients showing spring, summer or fall seasonal trends after accounting for flow? Can trends in nutrient enrichment be used to explain deviations in biological data at collocated sites? 6) Can changes in nutrient enrichment be linked to trends in human activity in the park such as increased roads, erosion, and fertilizers?

Table 2. Monitoring questions for NETN lakes and ponds.
[DO, dissolved oxygen; ANC, Acid neutralizing capacity; NETN, Northeast Temperate Network]

VITAL SIGN	MEASURE	MONITORING QUESTION(S)
Water quantity	Lake levels	1) What are the long-term trends in lake levels and how are they related to climatic records? 2) Can variations in lake levels explain deviations or trends in chemical or biological data observed in these same lakes ?
Water chemistry	Specific conductance, pH, water temp, DO, ANC, color Secchi disk depth	1) What is the natural range in variability in water-chemistry parameters for lakes in each NETN park based on lakes in the park (or the region) that are relatively unaffected? 2) Are water-chemistry measures exceeding thresholds indicating that they are outside the range of natural variability? What is the spatial and temporal extent of these deviations? 3) Are freshwater bodies in NETN parks in compliance with the applicable Federal and state water-quality standard for the highest use classifications in each state for water chemistry? 4) Are water-chemistry parameters showing long-term (> 10 year) spring, summer or fall seasonal trends? 5) Can water-chemistry data be used to explain deviations in biological data at collocated sites? 6) Can changes in water chemistry be linked to trends in human activity in the park such as increased roads and (or) erosion?
Nutrient enrichment	Phosphorus, nitrogen, algal biomass	1) What is the natural range in variability in nutrients for lakes in each NETN park based on lakes in the park (or the region) that are relatively unaffected? 2) What is the trophic status of each lake based on the natural range of variability of chlorophyll *a*, phosphorus content and Secchi disk depth? Is cultural eutrophication accelerating natural eutrophication processes? Does the lake experience algal blooms? 3) Are lakes in NETN parks in compliance with Federal and state water-quality standard for the highest use classifications in each state for nutrients, especially total phosphorus? 4) Are freshwater resources changing in response to increased nutrient loads? Is eutrophication approaching or exceeding levels that could cause shifts in ecosystem structure and function? 5) Are nutrients showing spring, summer, or fall seasonal trends? Can trends in nutrient enrichment be used to explain deviations in biological data at collocated sites? 6) Can changes in nutrient enrichment be linked to trends in human activity in the park such as increased roads, erosion, and fertilizers?
Exotic plants-early detection	Presence/ absence	1) What invasive plants are established in park lakes and ponds? 2) What invasive exotic plants are a threat to park lakes and ponds on the basis of state lists of exotic plants found in the region? 3) Are there any substantiated new occurrences of invasive exotic plants in any park pond or lake based on an annual survey and (or) reports from park staff, volunteers, or visitors to the park?

Table 3. Stream water-quality standards for states in NETN

[NETN, Northeast Temperate Network; Standards given are for most restrictive classification unless otherwise noted; ug/L, micrograms per liter; mg, milligrams per liter].

State: Water-quality classification code	Maximum temperature (° F)	Minimum dissolved oxygen (mg/L)	pH range (standard units)	Maximum total nitrogen (ug/L)	Maximum total phosphorus (ug/L)
Maine: AA	As naturally occurs	7 ppm[1]	As naturally occurs	As naturally occurs	As naturally occurs
New Hampshire: A	As naturally occurs	6 (or 75 percent saturation[4])	6.5-8.0[1]	As naturally occurs	As naturally occurs
Vermont: A (1)	--	6-7 (cold[2]) 5 (warm[3])	6.5-8.5	2000	As naturally occurs
Massachusetts: A	68 (cold[2]) 83 (warm[3])	6	6.5-8.3	As naturally occurs	As naturally occurs
Connecticut: AA	85	5	6.5-8.01	--	As naturally occurs
New York: AA	--	7.0 (cold[1]) 5.0 (warm[2])	6.5-8.5	No algae growth[5]	No algae growth[5]
New Jersey: FW2	--	7.0	6.5-8.5	--	100

[1]Criteria is as naturally occurring. Numerical standards are based on next most restrictive class.

[2]Cold refers to cold water fisheries.

[3]Warm refers to warm water fisheries.

[4] In cold water, fish spawning areas from October 1 - May 14, the instantaneous minimum DO concentration shall be at least 8 mg/L

[5] There shall be no phosphorus or nitrogen that will result in growths of algae or impair the waters for their best usages.

Table 4. Lake and pond water-quality standards for states in NETN
[NETN, Northeast Temperate Network; Standards given are for most restrictive classification unless otherwise noted; ug/L, micrograms per liter; mg/L, milligrams per liter].

State: Water-quality classification code	Maximum temperature (° F)	Minimum dissolved oxygen (mg/L)	pH range (standard units)	Maximum chlorophyll *a* (ug/L)	Minimum Secchi disk depth (m)	Maximum total nitrogen (ug/L)	Maximum total phosphorus (ug/L)
Maine:GPA	As naturally occurs	As naturally occurs	As naturally occurs	As naturally occurs	As naturally occurs	As naturally occurs	As naturally occurs
New Hampshire: ponds	--	5.0	6.0-9.0	--	--	As naturally occurs	As naturally occurs
Vermont: ponds	--	--	6.5-8.5	--	--	5000	As naturally occurs
Massachusetts	--	6.0	6.5-8.3	--	--	As naturally occurs	As naturally occurs
Connecticut: Mesotrophic Eutrophic	--	--	--	2-15 15-30	2-6 1-2	200-600 600-1,000	10-30 30-50
New York lakes	--	6.0	6.5-8.5	--	--	No algae growth[1]	No algae growth[1]
New Jersey: ponds	--	7.0	6.5-8.5	--	--	--	50

[1] There shall be no phosphorus or nitrogen that will result in growths of algae or impair the waters for their best usages.

1.1.5.1 Maine

Water-quality criteria in Maine, as mandated by the Clean Water Act, on the basis of the Antidegradation policy (Maine Statutes, Title 38, Section 464(4) (F)) at *http://janus.state.me.us/legis/statutes/38/title38sec464.html*. Existing in-stream water uses and the level of water quality necessary to protect those existing uses must be maintained and protected. All waters in national parks are considered outstanding national resource waters (ONRW) in Maine. The water quality of ONRW must be maintained and protected. Class AA is the highest classification and its standards shall be applied to waters that are outstanding natural resources.

Class AA waters must be of such quality that they are suitable for the designated uses of drinking water after disinfection, fishing, agriculture, recreation in and on the water, navigation, and as habitat for fish and other aquatic life. The habitat must be characterized as free-flowing and natural. The aquatic life, DO, and bacteria content of Class AA waters shall be as naturally occur (Maine Statutes, Title 38, Section 465(1) (B)). No quantitative criteria are given for AA waters, but the DO content of Class A waters (the next lowest classification) shall be not less than 7 parts per million or 75 percent of saturation, whichever is higher.

Great ponds and natural ponds and lakes less than 10 acres in size are all classified as Class GPA waters. Class GPA waters must be of such quality that they are suitable for the designated uses of drinking water after disinfection, recreation in and on the water, fishing, agriculture, industrial process and cooling water supply, hydroelectric power generation, navigation, and as habitat for fish and other aquatic life. The habitat must be characterized as natural (Title 38, section 470-E).

Class GPA waters shall be described by their trophic state based on measures of the chlorophyll *a* content, Secchi Disk Depth (SD), total phosphorus content, and other appropriate criteria. Water-quality standards for Maine indicate that class GPA waters shall have a stable or decreasing trophic state, subject only to natural fluctuations, and shall be free of culturally induced algal blooms (Maine State Government, 1985). Bloom conditions are defined as SD measurements of less than 2 meters in lakes having color less than 30 standard platinum units (SPU). Lakes that chronically (more than 5 of the past 10 years) show algal blooms are not in attainment of state water-quality standards (Maine State Government, 1985). Trophic status break points are based on over 20 years of SD measurements in Maine lakes (Williams, 2004).

Carlson's trophic state index (TSI) (Carlson, 1977) was modified for Maine and can be calculated using the following equations:

$$TSI\ (SD) = 70 \log [(105/SD^2) + 0.7]$$

$$TSI\ (Chl) = 70 \log (chl + 0.71)$$

$$TSI\ (TP) = 70 \log (0.33TP + 0.7)$$

(L. Bacon, MDEP, written commun., 2005); where TSI is the Trophic State Index; SD is Secchi disk depth in meters; Chl is Chlorophyll *a* in ppb, TP is total phosphorus in ppb. General numerical guidelines of trophic status for Maine based on these formulas are shown in table 5. Guidance from the state of Maine Department of Environmental Protection indicates that the parameters used in the equations shall be calculated as the mean of the monthly means for each water sample. A minimum of one reading per month from May through November is used with no two consecutive months of missing data. Samples are to be taken from open water, SD must be less than total depth, and depth-integrated samples taken to a depth equal to that of the late summer epilimnion or to a concentration of 2.0 mg/L DO, (whichever is less) are used for Chlorophyll *a* and total phosphorus samples (Linda Bacon, written commun., 2005).

Table 5. Maine State lake trophic parameters and guidelines

[From: Maine Department of Environmental Protection, 2004; SDT, Secchi disk depth; chl a, chlorophyll *a*; TSI, Trophic State Index; ppb, parts per billion]

Numerical Guidelines for Evaluation of Trophic Status in Maine *			
(Note: Dystrophy is not often evaluated as a trophic category separately from categories below.)			
	Trophic Status		
Parameter[1]	Oligotrophic	Mesotrophic[2]	Eutrophic
SDT[3]	> 8 meters	4-8 meters	< 4 meters
CHL a	< 1.5 ppb	1.5 – 7 ppb	> 7 ppb
Total Phosphorus[3]	< 4.5 ppb	4.5 – 20 ppb	>20 ppb
TSI[3,4]	0-25	25-60	>60 and/or repeated algal blooms

[1] SDT, CHL a, and Total Phosphorus based on long-term means.
[2] No repeated nuisance algal blooms.
[3] If color is > 30 Standard Platinum Units (SPU) or not known, chlorophyll a concentration (CHL a), dissolved oxygen and best professional judgment used to assign trophic category.
[4] TSI = Trophic State Indices are calculated when adequate data exists and color is at or below 30 SPU.
* This table is a duplicate of Table 4-5 in the Assessment Methodology Section of this report (appears twice for the reader's convenience).

1.1.5.2 New Hampshire

Surface waters of National Forests and surface waters designated as natural are considered outstanding resource waters (ORW) in New Hampshire. Water quality shall be maintained and protected in surface waters that constitute ORW (New Hampshire Department of Environmental Services, 1999). Class A is the most protective surface-water classification in New Hampshire's Surface-Water-Quality Regulations (New Hampshire Department of Environmental Services, 1999). Standards for temperature, pH, Color, nitrogen, and phosphorus are as naturally occurring in Class A waters. The pH of class B, the next most restrictive class ranges from 6.5 to 8.0. Class A waters have a DO content standard of at least 75 percent saturation on the basis of a daily average, and an instantaneous minimum of at least 6 mg/L at any place or time except when concentrations of DO are less than 6 mg/L from natural causes. In cold water fish spawning areas from October 1 through May 14, the instantaneous minimum DO concentration shall be at least 8 mg/L.

Surface waters within the top 25 percent of depth of thermally unstratified lakes, ponds, impoundments, and reservoirs or within the epilimnion shall contain a DO concentration of at least 75 percent saturation and instantaneous minimum DO concentration of at least 5 mg/L.

1.1.5.3 Vermont

Certain waters are designated as ORW according to Vermont Water-Quality Standards (State of Vermont, Water Resources Board, 1999), where the existing quality shall, at a minimum, be protected and maintained. Class A(1) Ecological Waters are managed to achieve and maintain streams in a natural condition.

In all waters in Vermont, the change or rate of change in temperature, either upward or downward, shall be controlled to ensure full support of aquatic biota, wildlife, and aquatic habitat uses. For cold water fish habitat, the total increase from the ambient temperature resulting from all activities shall not exceed 1 ^{o}F. In lakes, ponds, and reservoirs the total increase from ambient temperature shall not exceed 1^{o}F if the ambient temperature is above 60 ^{o}F; 2 ^{o}F if the ambient temperature is between 50 and 60 ^{o}F; and 3 ^{o}F if the ambient temperature is below 50 ^{o}F. In all other waters, the total increase from ambient temperature shall not exceed 1^{o}F if the ambient temperature is above 66 ^{o}F; 2 ^{o}F if the ambient temperature is between 63 and 66 ^{o}F; 3 ^{o}F if the ambient temperature is between 59 and 62 ^{o}F; 4 ^{o}F if the ambient temperature is between 55 and 58 ^{o}F; and 5 ^{o}F if the ambient temperature is below 55 ^{o}F.

All total phosphorus and nitrate concentrations shall be limited so that they will not contribute to the acceleration of eutrophication or the stimulation of the growth of aquatic biota in a manner that prevents the full support of uses. In lakes, ponds, and reservoirs, nitrate concentrations are not to exceed 5.0 mg/L as NO_3-N regardless of classification. In class A(1) waters, nitrates are not to exceed 2.0 mg/L as NO_3-N at flows exceeding low median monthly flows.

There shall be no changes in alkalinity, pH, or color in A(1) waters that would prevent the full support of uses. Furthermore, pH values shall be maintained within the range of 6.5-8.5 standard pH units. DO concentrations are as naturally occurs in all Class A (1) ecological waters. DO concentrations in cold water fish habitat is not less than 7 mg/L and 75 percent saturation at all times, nor less than 95 percent saturation during late egg maturation and larval development of salmonids in areas that are salmonid spawning or nursery areas important to the establishment or maintenance of the fishery resource. Not less than 6 mg/L and 70 percent saturation at all times in all other waters designated as a cold water fish habitat. In warm water fish habitat DO concentrations are not less than 5 mg/L and 60 percent saturation at all times.

1.1.5.4 Massachusetts

Massachusetts surface-water-quality standards designate Class A waters as excellent habitat for fish, other aquatic life and wildlife, and suitable for primary and secondary contact recreation (Massachusetts Department of Environmental Protection, 2000). ORW is used to denote those waters, other than Public Water Supplies, designated for protection as outstanding resources. The Antidegradation policy refers to the Clean Water Act. Class A waters shall have DO concentrations of not less than 6 mg/L unless background conditions are lower. Temperatures shall not exceed 68º F in cold water fisheries or 83º F in warm water fisheries, and natural and seasonal variations shall be maintained. The pH shall range from 6.5 to 8.3 standard units but not more than 0.5 units outside of the background range. Class A waters shall be free from color in concentrations or combinations that are aesthetically objectionable or would impair any use assigned to this class.

1.1.5.5 Connecticut

Designated uses of Class AA streams in Connecticut include existing or proposed drinking water supply, fish and wildlife habitat, recreational use, agricultural, and industrial supply (State of Connecticut Department of Environmental Protection, 2002)

Class AA criteria include DO concentrations that are not less than 5 mg/L at any time, no color other than of natural origin; and no change in temperature other than that caused by natural conditions. Temperatures shall not exceed 85º F or raise the temperature of the surface water more than 4º F. There shall be no phosphorus concentrations other than that of natural origin. The range of pH shall be as naturally occurs, between 6.5 and 8.0 standard pH units as indicated for class B criterion (the most restrictive numerical criterion).

Water quality for lakes and ponds are according to the trophic status of the waterbody. Because Weir Pond (the only NETN pond in Connecticut) ranges between mesotrophic and eutrophic conditions, both criterion are included in this report. Total nitrogen (N) concentrations shall range from 200 to 600 ug/L nitrite (NO_3) in mesotrophic lakes and from 600 to 1,000 ug/L NO_3 in eutrophic lakes. Total phosphorus concentrations shall range from 10 to 30 ug/L NO_3 in mesotrophic lakes and from 30 to 50 ug/L NO_3 in eutrophic lakes. SD shall range from 2 to 6 m in mesotrophic lakes and from 1 to 2 m in eutrophic lakes.

1.1.5.6 New York

New York's Surface-Water-Quality Standards (New York State Department of Environmental Conservation, 1999) designates Class AA as the most restrictive stream classification for water quality. Class AA waters shall have no change in color that will cause a substantial visible contrast to natural conditions, and shall have no phosphorus and nitrogen that will result in of algae, weed, and slime growth that will impair the waters for their best usages. The pH shall range from 6.5 to 8.5. DO concentrations shall not be less than 7.0 mg/L for other than natural conditions in cold waters suitable for trout spawning. The minimum average daily DO concentration for trout waters shall not be less than 6.0 mg/L and at no time shall the concentration be less than 5.0 mg/L. The minimum average daily DO concentration for non-trout waters shall not be less than 5.0 mg/L, and at no time shall the DO concentration be less than 4.0 mg/L.

In rivers and the upper waters of lakes, DO concentrations shall not be less than 6.0 mg/L. For lakes and ponds, the color shall not exceed 15 color units (platinum cobalt method). The pH shall be between 6.5 and 8.5.

1.1.5.7 New Jersey

New Jersey water-quality standards (New Jersey Department of Environmental Protection, 2004) designate the general surface-water classification applied to fresh waters as FW. FW1 means those fresh waters that are to be maintained in their natural state of quality and not subjected to any man-made wastewater discharges or increases in runoff from anthropogenic activities. These waters are set aside for posterity because of their clarity, color, scenic setting, or other characteristic of aesthetic value, unique ecological significance, exceptional recreational significance, exceptional water supply significance, or exceptional fisheries resource(s).

FW1 surface waters shall be maintained as to quality in their natural state. The tributaries in the Passaic River Watershed in MORR are all listed as FW2 waters. Surface-water quality criteria for FW2 Waters states that FW2 TP waters shall have DO concentrations that shall not be less than 7.0 mg/L at any time. pH shall range from 6.5 to 8.5 standard units at all times. Phosphorus concentration as total P shall not exceed 0.05 mg/L in any lake, pond or reservoir, or in a tributary at the point where it enters such waterbodies. Concentrations of total P shall not exceed 0.1 mg/L in any stream, unless it can be demonstrated that total P is not a limiting nutrient and will not otherwise render the waters unsuitable for the designated uses.

1.1.5.8 Ecoregional Nutrient Standards

Although individual states do not often give numerical values for nutrient standards, the USEPA has established ecoregional nutrient criteria. Nutrient criteria are numerical values for cause (phosphorus and nitrogen) and response (chlorophyll *a*) variables associated with the cause and assessment of eutrophic conditions. USEPA's recommended ecoregional nutrient criteria represent conditions of surface waters that are minimally affected by anthropogenic activities (U.S. Environmental Protection Agency, 2002). The ecoregional values given in tables 6 and 7 were used as a guideline for developing nutrient criteria for NETN. Broad geographical regions are considered when using these criteria. NETN parks are found in four different USEPA ecoregions.

Table 6. USEPA Ecoregional nutrient criteria that apply to NETN streams.
[accessed at http://www.epa.gov/waterscience/criteria/nutrient/ecoregions/rivers/index.html on June 23, 2005. These numbers represent the 25th percentiles of all values compiled for the region for all seasons; ug/L, micrograms per liter; mg/L, milligrams per liter.]

Nutrient criteria	Ecoregion 7 (ROVA, SARA)	Ecoregion 8 (ACAD, MABI, SAGA)	Ecoregion 9 (MORR)	Ecoregion 14 (MIMA, SAIR, WEFA, BOHA)
Total Phosphorus-ug/L	33	10	36.56	31.25
Total Nitrogen-mg/L	0.54	0.38	0.69	0.71
Chlorophyll *a*-ug/L	1.5 fluorometric	0.63 fluorometric	0.93 spectrophotometric	3.75 spectrophotometric

Table 7. USEPA Ecoregional nutrient criteria that apply to NETN lakes and reservoirs.
[accessed at *http://www.epa.gov/waterscience/criteria/nutrient/ecoregions/rivers/index.html on June 23*, 2005. These numbers represent the 25th percentiles of all values compiled for the region for all seasons; ug/L, micrograms per liter; mg/L, milligrams per liter.]

Nutrient criteria	Ecoregion 7 (ROVA, SARA)	Ecoregion 8 (ACAD, MABI, SAGA)	Ecoregion 9 (MORR)	Ecoregion 14 (MIMA, SAIR, WEFA, BOHA)
Total Phosphorus-ug/L	14.75	8	20	8
Total Nitrogen-mg/L	.66	.24	.36	.32
Chlorophyll *a* -ug/L -fluorometric	2.63	2.43	4.93	2.9
Secchi disk depth	3.33	4.93	1.53	4.5

(m)				

1.1.6 Clean Water Act Section 303d Impairment

Impaired and threatened waters that do not meet state water-quality standards are placed on the state 303(d) list named for the section of the USEPA Clean Water Act where the list is described. This list is reviewed and updated every 2 years. If a waterbody is placed on the 303(d) list, it is placed in line for a Total Maximum Daily Load (TMDL) plan to identify the cause(s) of the impairment and outline how to clean up and restore the waterbody.

Freshwater bodies in NETN parks that have been included on the USEPA Clean Water Act 303(d) impairments list are listed in table 9. It is important to note that these lists are continually changing and need to be updated over time. The waterbodies listed on 303(d) lists are mostly large rivers. The Hudson River forms the outside boundary of two parks (SARA and ROVA), and really only affects the parks during times of major backwater. The Connecticut River is just downstream of the boundary of SAGA and also has the potential to affect the park during times of major flooding. The Concord River and the Saugus River flow through MIMA and SAIR respectively, but the part of the river in, or affected by, NETN parks is small relative to the size of the watershed. Conducting a TMDL and performing long-term water-quality monitoring on these large rivers outside of NETN parks is beyond the scope of the NPS Inventory and Monitoring program for the affected parks.

The parks can avoid adding to the impairments in these rivers by monitoring the streams that flow into these large rivers. TMDLs and (or) long-term monitoring of Saugus, Concord, and Hudson Rivers is outside the scope of these protocols. Data from the nearest up-river monitoring stations on these rivers and (or) water-quality monitoring on adjacent freshwater bodies is included in the USEPA STORET database.

Table 8. USEPA 303d impairments in freshwater resources in NETN parks,
[from USEPAs 1998 cycle of listings for New York and Massachusetts]

WATER BODY	WBID	PARK	IMPAIRMENT (S)
Concord River	MA82A-07_1998	MIMA	Metals, Nutrients, Pathogens1
Connecticut River	NHR80104060-00.0109-1998	SAGA	Pathogens, FCA (Cadmium), FCA (PCBs) 3
Hudson River	NY-1301-003-1998	ROVA	Cadmium, PCBs2
Hudson River	NY-1101-002-1998	SARA	PCBs2
Saugus River	MA93-35-1998	SAIR	Organic enrichment, low DO, pathogens1
Saugus River	MA93-14-1998	SAIR	Pathogens, thermal modifications, oil and grease1

[1] http://www.wcei.org/massachusetts/ma-contents.html

[2] http://www.wcei.org/newyork/ny-contents.html

[3] http://www.wcei.org/newhampshire/nh-list.html

1.1.7 Water-Quality Parameters

This section includes basic descriptions of the water quality parameters that are recommended for long-term data collection and analysis in NETN parks. Typical values are included in some cases to give a general range that can be expected from waterbodies in the northeast.

1.1.7.1 Secchi Disk Depth

Secchi-disk depth (SD) in NETN lakes and ponds can range from 1 to 20 meters (Breen et al, 2002; Farris and Chapman, 2000). Generally SD of greater than 8 meters indicate an oligotrophic lake, between 4 and 8 meters indicate a mesotrophic lake and less than 4 meters indicates a eutrophic lake (Maine Department of Environmental Protection, 2004). Ponds outside of Acadia are too shallow for use of a Secchi Disk, and a transparency tube will be used in these ponds instead. There is a loose relationship between SD and transparency tube values, plus transparency tubes can be used in streams as well as ponds (Dahlgren et al., 2004), and collecting transparency tube values will provide information useful for documenting trends in water clarity.

1.1.7.2 pH

Most New England states indicate that a pH between 6.5 and 8.5 meets state water-quality standards (tables 3 and 4). The documented distribution of pH in Maine lakes by the VLMP and the MDEP (Williams, 2004) indicates that the pH of most Maine lakes ranged from 6.0 and 7.0. These protocols recommend sampling monthly pH in situ with a water-quality sonde. Historical pH measurements have often been made on a discrete sample in the laboratory. Differing types of pH measurements are not expected to be equivalent. Both types of measurements can be taken for a season to determine the shift because of changing methods.

1.1.7.3 Dissolved Oxygen

Dissolved oxygen is a critical indicator of water quality because aquatic life generally needs DO concentrations at or above 5 mg/L to thrive. Individual readings are made in situ with a DO meter or with a DO probe on a water-quality sonde. Mesotrophic lakes can drop below 5 mg/L or became anoxic during the months July through September. The combination of thermal stratification and increased biological activity in lakes during the summer can result in DO concentration depletion or anoxia in lake hypolimnions. Oligotrophic lakes occasionally drop below 1 mg/L, but only at the bottom of the water column (Seger, 2005).

1.1.7.4 Specific Conductance

Specific conductance is an indicator of pollutants in the water, and is directly related to the level of dissolved ions in the water. Specific conductance values can range from less than 20 to more than 1,000 microsiemens per centimeter (uS/cm), but is most often less than 100 uS/cm (Williams, 2004). Specific conductance has been taken as a grab sample or as a depth-integrated epilimnetic sample in NETN ponds and lakes and determined in the laboratory. In the SOPs included in this protocol specific conductance readings will be taken in situ with a multiparameter sonde. Data obtained through these methods and through previous methods can be evaluated to determine the bias associated with the change in method.

1.1.7.5 Total Phosphorus

Typically, lakes have total phosphorus concentrations of between 10-50 ug/L, but can range in lakes from less than 1 ug/L to 200 ug/L (Wetzel, 1983). Data from the MDEP and the VLMP indicate that most lakes in Maine have total phosphorus concentrations of between 5-10 ppb (roughly equivalent to 5-10 ug/L) in integrated water samples taken from the epilimnion (Williams, 2004). USEPA ecoregion criteria range from 8ug/L to 20 ug/L (table 7).

1.1.7.6 Chlorophyll *a*

Chlorophyll *a* is one of the trophic-state indicators used to estimate the biological productivity of a lake. The greatest concentrations of algae are in the lake epilimnion and so an integrated water column sample is taken to best estimate productivity. Low productivity is less than 1.5 ppb, medium is 1.5 to 7.0 ppb is and high productivity is greater than 7.0 ppb. Maine lake values can range from 0.7 to 182 ppb (Williams, 2004).

1.1.7.7 Acid Neutralizing Capacity (ANC)

Most states do not have numerical criteria for ANC in their water-quality standards. ANC values greater than 100 μeq/L are considered well-buffered, while values less than zero typify acidic waters (Stoddard et al, 2003). The NWQL reports ANC as mg/L of $CaCO_3$; at 1 mg/L = 20 μeq/L, values greater than 5 mg/L are considered well-buffered.

1.1.7.8 Color

Color in SPU in lakes is caused by organic humic acids which leach from the vegetation into the lake water. Color is a rough indicator for organic acidity. Organic acidity can result in low pH. Sampling color will allow parks to determine whether a low pH is of concern or whether it is because of natural organic acidity, for example, derived from wetlands. Lakes with apparent color values of greater than 25 SPU are considered to be highly colored and in these lakes transparency is often depressed and phosphorus concentrations are often high. Values of color are usually not included in water-quality standards, except to note that they be as naturally occurs and that in highly colored lakes, it is best to use chlorophyll a as opposed to total phosphorus or SD as an indicator of trophic status. The color of Maine lakes varies from 2 to 194 SPU, with most lakes between 10 and 20 SPU (Williams, 2004)

1.1.7.9 Other Nutrients

The Network is currently measuring additional nutrient parameters: Total Nitrogen, Dissolved Total Nitrogen, Dissolved Total Phosphorous, Ammonia, Nitrite, Nitrite + Nitrate, and Orthophosphate. Sections describing the rationale for including these parameters will be provided at a later date.

1.2 Sampling Design

Sampling designs outlined in this section for each NETN park allow for the detection of changes in the status of physical, chemical, and biological attributes of freshwater resources over time. Water-quality sampling at additional sites – especially the continuation of historic sites or the sampling of sites in cooperation with other agencies – is encouraged. Consistency of sampling protocols across all sites in the park is critical in the analyses and interpretation of water-quality data in NETN parks. Although attempts were made within these protocols to continue the use of historic sites and existing methods, adjustments were made to historical methods and sites so that there would be consistency across NETN or as the result of improvements in methods. Adjustments can compromise the ability to compare new data with historical data in some cases.

1.2.1 General Sampling Design in Lakes and Ponds

The target population is the lakes and ponds with surface area greater than 1 acre in NETN parks. As all lakes and ponds greater than 1 acre will be sampled over time, this design is a census and thus there is no concern about the representativeness of the sampled population. Measurements are taken from a boat at the deepest point in the pond. A mid-lake sample of maximum depth is the conventional sampling strategy used in lake chemistry monitoring programs and lakes in ACAD have been sampled at the deepest point since 1970. Mid-lake samples have been shown to be representative of surface-water chemistry in lakes of up to 1650 acres in Sweden (Goransson et al, 2004). Results will clearly indicate that only the deepest point was sampled and thus conclusions will only be drawn for these sites. A lake water-quality study showing how well the deepest point represents water quality at other sites in the lakes at ACAD and the other parks is recommended although it is beyond the scope of these protocols.

There are a total of 44 ponds and lakes in or partially in NETN park boundaries. The 13 lakes that have a surface area greater than 15 acres are all in ACAD. Four of these lakes are partially outside the park boundary. There are 14 ponds between 1 acre and 15 acres. Seven of these are in ACAD, two in ROVA, and one each in MABI, WEFA, SAGA, BOHA and MORR.

If limited funding resources prevent all lakes from being sampled every year, sets of lakes can be revisited every x number of years (alternating sampling design) (Larsen, Urquhart and Kugler, 1995). The alternating sampling design gives more power to detect trends over the long term than does an annual revisit design in which the same subset of lakes is visited every year. The greatest increase in the power to detect trend in all cases comes from increasing the interval over which the trend is to be detected (Larsen, Urquhart and Kugler, 1995).

The sampling design at ACAD represents an alternating sampling design; at all other parks, all ponds will be sampled each year. All accessible lakes and ponds greater than one acre will be sampled monthly from May through October (April through October, conditions permitting, outside of ACAD) with the following exceptions. Nine lakes and ponds in ACAD will be monitored as a part of a rotating design where they will be sampled every third year. Two ponds in ACAD are not accessible by vehicle and will not be sampled regularly as part of these protocols. One pond in ACAD is less than 1 m in depth and it is recommended that this pond be sampled as a wetland. The pond in MORR and the two impoundments in ROVA were considered low priority for monitoring relative to the stream resources in the parks, and thus will not be monitored. The ROVA impoundments are also very shallow, with detectable flow, and are generally functioning as wetlands. The 17 small ponds of less than 1 acre in BOHA are not included in the sampling design because of their small size. The one pond greater than one acre in BOHA will not be sampled initially because of the logistical challenges of sampling in Boston Harbor. The option of partnering with other agencies already working on the islands can be pursued to track water quality in this pond.

Sonde water-quality measurements can be taken in the flowing water exiting the pond if a boat is not available for sampling. This location is less desirable than the deepest point because a SD measurement cannot be taken. Water-quality samples can be collected with the use of a throw bottle into the center of the pond.

In addition, a permanent shore site will be established for each lake from which to monitor the lake water levels. This site will be selected on the basis of access, the presence of a stable benchmark, and the ease of getting an accurate water-level measurement.

1.2.2 General Sampling Design in Streams

The challenge in creating a stream-sampling design for NETN parks was to balance the importance of using a random probabilistic design so that results could be extrapolated to all locations in each park with the sometimes conflicting priorities of selecting targeted sites based on accessibility, the ability to get an accurate discharge measurement, and the existence of historical data. A targeted design was chosen to obtain the best sites to measure discharge and water quality. The targeted design presented favors downstream integrator sites that are optimum for determining nutrient loads in park streams. As the majority of watersheds in NETN parks will be monitored over time, there is less of a concern about representativeness. Results pertain only to the sites sampled. For nutrients in streams, the downstream sites will help us to determine if the total nutrient loads draining a watershed are exceeding standards or changing over time. In cases where sampling does indicate that standards are exceeded or approached or that nutrients are increasing in a watershed, additional upstream samples can be taken to identify the cause(s) of the change.

The targeted design presented is not ideal for monitoring the status and trends of acid deposition. High elevation sites unimpacted by humans would be more appropriate for monitoring changes in acidity. It is recommended that existing acidification studies (Nelson, 2002) in ACAD be continued to better understand acidity in NETN parks. Furthermore, these long-term sites record data year round and will more quickly be able to show changes in sampled watersheds.

There are about 50 miles of perennial rivers and streams flowing through, or adjacent to, nine NETN parks (table 11). Thirty-five miles of stream are in ACAD, 8 miles in SARA, and less than 2.5 miles in each remaining park. In all parks except ACAD, every perennial stream with reasonable access to a site where streamflow can be accurately measured will be monitored monthly from April through October (conditions permitting) for fresh water-quality vital signs. In ACAD, every *watershed* (see section *1.2.3.1 Acadia, ME*) that allows reasonable access to a site where streamflow can be accurately measured will be monitored monthly from May through October as a partial record site under a rotating design. In addition, a continuous-record streamflow gage is proposed at ACAD to track water quantity in the park and to quantify and interpret water-quality data such as the estimation of nutrient loads.

Although May through October is the minimum period during which streamflow measurements can be taken, it is important to get an annual highflow spring runoff measurement when possible in each park. The timing of this type of high flow measurement will differ among parks from north to south in NETN and from year to year, but generally will occur in March or April in most parks. Note that this type of measurement is harder to schedule in advance than other measurements; requires an earlier start time for seasonal staff; requires additional equipment, safety gear, expertise; and access to seasonally closed roads.

Table 9. Number of sampling sites at each park in NETN

PARK	SIZE (acres)	PERENNIAL RIVER MILES	No. STREAM SAMPLING SITES	No. OF LAKE SAMPLING SITES	No. OF POND SAMPLING SITES	TOTAL SITES
ACAD	47,498	35	20 (12/yr)	17 (11/yr)	0	37 (23/yr)
MABI	643	0.47	1	0	1	2
MIMA	967	1.54	3	0	0	3
MORR	1,707	2.19	5	0	0	5
SAGA	150	0.62	2	0	1	3
SAIR	9	0.12	1	0	0	1
SARA	3,392	8.11	4	0	0	4
ROVA	401	1.57	6	0	0	6
WEFA	74	0.17	0	0	1	1
TOTAL	54,841	50	42 (34/yr)	17 (11/yr)	3	62 (48/yr)

Initially, sample sites were selected randomly by use of GIS coverages of linear stream features. Streams were arranged end to end, the total length of streams was divided by the by the number of stations, and a site was selected every Xth number of miles. GIS selected sites were often inaccessible, or were on reaches of stream that were inappropriate for obtaining a discharge measurement because of the presence of braided channels, steep slopes, or reaches that would likely have zero flow during a typical August (despite being labeled as perennial on USGS 1:24,000 topographic maps). This type of randomly selected site design was abandoned in favor of a targeted sampling design.

The targeted sampling design used avoided the above listed complications. The best sampling site with reasonable access was selected for each stream or watershed on the basis of the ability to get a discharge measurement and water-quality sample. If multiple sites were possible, the most downstream site was selected. If a historical site on the stream met the objectives of the vital-signs program, that site was selected for the stream. Targeted sites were chosen according to the following criteria:

1. All permanent sites and access to these sites are within park boundaries and (or) on public roads.
2. Each site is at the downstream end of the section it represents.
3. The sites are accessible by vehicle or have a hike less than 30 minutes.
4. Sites are on perennial sections of the stream, have drainage areas greater than 0.3 mi^2 and (or) and have measurable flow during an average August. Sites allow for an accurate measure of discharge and the potential to define a stage/discharge rating. Sites do not have steep gradients/waterfalls, braided channels, excessive beaver presence or the inability to identify a single channel because of swamps and wetlands). Each site has a pool with a single control at its outflow in which a stable marker can be established and used to measure stage, accessible during a range of flows. Ideally there would be a location to get a high-flow discharge measurement if wading is not possible (such as a bridge).

If there was no site within the watershed that satisfied these criteria, that watershed was eliminated from the plan.

Once a sampling site was selected for sampling on a stream, all additional sites on that stream were eliminated except in the following parks. ROVA only has one stream per park unit (except HOFR, where a 2007 land acquisition added an additional stream). In the interest of sampling more than one site in each park unit, a second station was chosen on each stream. MORR and SARA have watersheds that involve multiple perennial tributaries that are entirely contained within park boundaries. Additional sites were selected to characterize the entire watershed.

ACAD has significantly more streams than any of the other parks, and its stream sampling design is discussed in section *1.2.3 Individual Park Design*.

1.2.3 Individual Park Sampling Designs

Sampling design for lakes, ponds and streams in each of NETN parks is discussed in this section. BOHA is not included as funding resources are not currently available to access this park. Vital sign data collected by other agencies willing to collaborate on this site can be included in the NETN database.

1.2.3.1 Acadia National Park, Maine (ACAD)

1.2.3.1.1 Lakes

Vital-signs monitoring of freshwater resources at ACAD will be limited to Mount Desert Island for logistical reasons. This is where most of the freshwater resources are found.

After assessing the staff available at ACAD who would be able to collaborate with NETN staff, the logistics of lake sampling (including boat access), weather and the desire to limit the sampling window to a 2 week period each month, eleven out of 20 lakes will be sampled monthly from May to October each year for water chemistry and nutrient enrichment measures. Although expanding the sampling design might identify existing trends more quickly, the lake water-quality data from the historical monitoring program at ACAD showed data gaps where samples were lost or not obtained because of weather conditions, equipment problems, or scheduling factors (Breen et al, 2002). The goal of the design is to identify the optimal sampling frequency and number of lakes that is consistent with staff availability and funding resources.

From the 11 monthly samples, a balance was obtained between permanent sites and rotating sites. Annual sampling of lakes where there is a long-term historical database is ideal, but this schedule needs to be balanced with the goal of cycling through the remaining sites within 2 to 4 years. The eight lakes sites that are currently (2004) being sampled monthly as a part of the eutrophication regime will continue to be sampled at the same frequency, as this eutrophication regime addresses the goals and objectives of the Inventory and Monitoring Program. The three lakes with long-term data (since 1980)- Bubble Pond, Eagle Lake, and Long Pond-on MDI are included in this group. Monthly samples will include all basic water-chemistry measures determined with the water-quality sonde. In June and August, in addition to water chemistry, depth-integrated epilimnetic samples will be obtained for ANC, color, nutrients, and chlorophyll *a*. As pH and specific conductance have historically been taken in the laboratory off of grab samples, both types of methods can be used for a season to determine the shift because of a change in methods.

The rotating-design schedule for ACAD parks allows the remainder of the lakes and ponds that are easily accessible and greater than 1 acre to be sampled for 3 years (appendix 4, figure A1). The nine remaining lakes and ponds were assigned to year 1, 2, or 3 to balance sampling sites according to size, location, and accessibility.

Table 10. Lake-water-quality monitoring sites at Acadia NP, Maine

YEAR 1	YEAR 2	YEAR 3
Permanent sites		
Eagle Lake	Eagle Lake	Eagle Lake
Bubble Pond	Bubble Pond	Bubble Pond

Witch Hole pond	Witch Hole pond	Witch Hole pond
Jordan Pond	Jordan Pond	Jordan Pond
Upper Hadlock Pond	Upper Hadlock Pond	Upper Hadlock Pond
Long Pond	Long Pond	Long Pond
Seal Cove Pond	Seal Cove Pond	Seal Cove Pond
Echo Lake	Echo Lake	Echo Lake
Rotating sites		
Aunt Betty's Pond	Lower Hadlock Pond	Round Pond
Lower Breakneck	Hodgdon Pond	Lake Wood
Bear Brook Pond	Seawall Pond	Upper Breakneck

The deepest point at each of lakes listed in table 12 will be sampled. Historically there have been two stations monitored on Eagle Lake and four stations monitored on Long Pond. Monitoring a single deepest point (station 1) in Eagle Lake will probably be sufficient as historical stations 1 and 2 are in the same basin, and the historical data (Bill Gawley, NPS, 2006, oral commun.) indicate that they're equally representative of the overall lake. It is recommended that the 4 stations on Long Pond continue to be monitored annually. It would be necessary to use a large boat or split the trip into approaches from several separate launch sites because of the size of the pond. Station 1 (112 ft deep) has the longest data record and would be the top priority for monitoring if only one site is visited.

Lakes and ponds will be surveyed monthly in the field for water level, specific conductance, pH, temperature, and DO; and biannual samples will be sent to a laboratory for nutrients, color, and ANC. Chlorophyll *a* will be included in the biannual samples at the lakes in ACAD. All lakes and ponds will be sampled at the location of maximum depth. For all lakes, the point of maximum depth will be located through bathymetric surveys and the use of a Global Positioning System (GPS) unit. Mid-lake deepest point sampling sites have been identified at all of the ACAD lakes and ponds included in this protocol. Coordinates for these sampling sites are listed in the ACAD lakes database maintained at the park and are available for future mid-lake sampling.

In addition to the eutrophication sampling regime, it is recommended that five lakes that are currently sampled as a part of the acidification regime (Bubble Pond, Witch Hole Pond, Jordan Pond, The Bowl, and Sargent Mountain Pond) continue to be sampled twice a year in early May and in October for the acidification analytes. Although most of these analytes will not be measured as a part of the vital-signs program for all lakes, it is within the goals and objectives of the vital-signs program to include this long-term data set at ACAD in the vital-signs database. Bubble Pond, Jordan Pond, and Witch Hole Pond can be sampled during monthly visits. Sargent Mountain Pond and The Bowl are not included in the monthly sampling schedule because the hike to the ponds is longer than 30 minutes. These two ponds can be sampled from shore with the water-quality sonde and with a throw bottle to obtain grab samples in early May and October.

1.2.3.1.2 Streams

Streams will be measured at ACAD through the use of partial-record streamflow-gaging stations which are measured once a month, and continuous-record streamflow gages in which data are collected and displayed in real time over the Internet every 15-minutes. Continuous-record streamflow-gages are the best way to track water quantity in the park, and to interpret water-quality data. Continuous streamflow data can be used to calculate total amounts of analytes (primarily nutrients) over time (loads) as compared to only the instantaneous concentrations of analytes.

One continuous-record streamflow-gage will be installed and maintained as an index of streamflow at ACAD because of the extent of the stream resources in ACAD. This gage would provide detailed streamflow information about one stream in the park, allow for estimates of loads of constituents at this site, and would provide data to make estimates of streamflow at hydrologically similar ungaged sites or partial-record sites. The selection of a streamflow-gage to serve as an index station is chosen according to the following: (1) The station must allow for accurate discharge measurements at a range of flows, (2) proximity to a location such as a bridge for measuring high flows, and (3) have similar watershed characteristics to other streams in the park for which streamflow will be estimated based on the index site. Six candidate sites for the index gage were evaluated according to historic measurements. These sites were measured concurrently up to 12 times from 1999 to 2000. Correlations of streamflow between each pair of partial record stations were compared to determine which gage site correlated with the most other stations. Otter Brook near Bar Harbor, ME (USGS station 01022840) was selected as an index gage because it had instantaneous flows that correlated well with other measured sites, had good access at low, medium, and high flows, and had a suitable site for a gaging house. Breakneck Brook (USGS station 01022825) was also considered, correlated well with other stations, had good access, but had a large beaver dam upstream.

In addition, ACAD has had two continuous-record USGS streamflow gages in operation since 1999; Cadillac Brook near Bar Harbor Maine (USGS station number 01022835) and Hadlock Brook near Cedar Swamp Mountain near Northeast Harbor, Maine (USGS station number 01022860). These gages have been operated by the University of Maine, the NPS, the USEPA and the USGS as a part of the PRIMENet (Park Research and Intensive Monitoring of Ecosystems Network) project focusing on the atmospheric deposition of nitrogen and mercury and the ecological consequences of this deposition (Nelson, 2002). Atmospheric deposition and its ecological consequences is a concern in NETN parks and was recognized as a high priority vital sign (Shriver et al, 2004) during Phase II of NETN vital-signs process. Furthermore, these streamflow gages provide detailed information about streamflow in small, high-elevation watersheds. Collaboration with the NPS will support the continuation of these gages. These two gages do not, however, work as index gages of streamflow because they do not correlate well with the streamflow in many of the other streams selected for long-term monitoring (Nielsen et al, 2002; Nielsen, M.G., U.S. Geological Survey, 2005, oral commun.).

The remaining watersheds in ACAD will be sampled by use of partial-record sites with monthly measurements of streamflow and water quality. Watersheds were delineated by

Perrin (1996) (appendix 3, figure A2). Watersheds were clipped to the park boundary by use of GIS, resulting occasionally in the creation of pieces of watersheds that had only intermittent streams or very small stream segments or drainage areas. Watersheds were eliminated from the list if sampling sites could not be found that fit with the criteria outlined in section *1.2.2 General Sampling Design in Streams*.

The sampling site within each watershed was the best section to get a discharge measurement and water-quality sample with reasonable access. If a historical site in the watershed met the objectives of the vital-signs program, that site was selected. If multiple sites met the criteria, the most downstream site was selected. Twenty-one sites including three continuous-record sites were selected (table 13). Continuous-record sites will be sampled for 6 months out of each year and partial-record sites will be sampled for 6 months every other year (sampling a maximum of nine partial-record sites and three continuous-record sites each year).

Table 11. Stream-water-quality monitoring sites at Acadia NP, Maine

[Sites at ACAD are predominately cold water fisheries. Historic sites are listed in bold; TBA, to be announced].

WATERBODY	USGS station number	LATITUDE	LONGITUDE
Permanent continuous-record sites			
Cadillac Brook	01022835	44 20 41	68 13 01
Hadlock Brook	01022860	44 19 54	68 16 48
Otter Creek	01022840	44 19 58	68 12 26
Rotating partial-record sites			
YEAR 1			
Hunters Brook	01022845	44 18 34	68 13 21
Kebo Brook		TBA	TBA
Sargent Brook		TBA	TBA
Jordan Stream		TBA	TBA
Breakneck Brook	01022825	44 24 40	68 15 05
Aunt Bettys Pond inlet		TBA	TBA
Marshall Brook	01022890	44 16 29	68 21 05
Heath Brook	01022895	44 16 40	68 22 05
Lurvey Spring-inlet to Echo Lake		44 18 38	68 20 08
YEAR 2			
Browns Brook		TBA	TBA
Man o'War Brook	01022880	44 19 06	68 19 00
Stanley Brook	01022850	44 18 20	68 14 35
Eagle Lake inlet		TBA	TBA
Duck Pond Brook-		TBA	TBA

WATERBODY	USGS station number	LATITUDE	LONGITUDE
inlet to Long Pond			
Lake Wood Outlet		TBA	TBA
Duck bk- Outlet to Eagle Lake		TBA	TBA
Lurvey Brook		44 16 44	68 21 28

1.2.3.2 Marsh-Billings-Rockefeller National Historic Park (MABI), Vermont

One stream-sampling site will be selected to represent Pogue Stream (appendix 3, figure A3). This is the only stream within the park, and there are no long-term historic stream water-quality stations. This station will be selected according to the most downstream site within park boundaries with easy access and the ability to obtain an accurate discharge measurement over a range of flows. The Pogue is a pond at the headwaters of Pogue Hole Brook and will be monitored at its deepest point.

Table 12. Water-quality monitoring sites at Marsh-Billings-Rockefeller NHP, Vermont

SITE	WATERBODY	LATITUDE	LONGITUDE
Streams			
MABISA	Pogue Hole Brook	TBA	TBA
Ponds			
MABIPA	The Pogue (pond)	TBA	TBA

1.2.3.3 Minute Man National Historic Park (MIMA), Massachusetts

There has been no routine water-quality monitoring at Minute Man NHP. There is one river, the Concord River, and two streams, Elm Brook and Mill Brook, that cut through the two park units. The monitoring site on Mill Brook is located upstream of Lowell Road with a tape-down point on the bridge. The Mill Brook monitoring site is not within park boundaries because it is intermittent where it flows through the Wayside Unit, and it is a wetland where it flows through the North Bridge Unit. (appendix 3, figure A4).

The Concord River site is at the Old North Bridge, 0.49 miles downstream from the confluence of the Sudbury and Assabet Rivers. The site is within the Minute Man NHP boundary and sampling results would represent water-quality conditions in the Concord River within the Park's North Bridge Unit. The site is accessible by vehicle. Discharge measurements could not be made by wading because of the size of the river but could be made off of the Old North Bridge (See section *3.3.2.5 Bridge measurements for large rivers).* Discharge measurements from the bridge are too expensive for the NETN to cover at this time. It would also be more difficult to get the sonde and WQ samples – doing this well would require integrated sampling, although we might be able to establish that the river is well-mixed based on sonde measurements. NETN is willing to partner with park and other interested parties to get the river sampled, and we also need to determine if existing stations are close enough to the park to be useful. For now, we propose a qualitative monitoring effort. This will include sonde measurements from numerous points along the bridge, getting stage from a tape-down point, and analyzing a WQ sample if the sonde measurements indicate that the river is well-mixed. Stage measurements could be made by taping down from the steel rail on the bridge.

The site on Elm Brook is within park boundaries at State Route 2A, 4.3 miles upstream from the confluence of Elm Brook with the Shawsheen River. The sampling results would represent water-quality conditions in Elm Brook within the Park's Battle Road Unit. The site is accessible by vehicle. Discharge measurements could be made by current meter on the downstream side of Rt. 2A. A tape down point is located on the downstream side of the box culvert where the stream passes under Rt. 2A. Field parameters and water samples would likely be collected at the center of flow, following verification of mixed conditions.

Table 13. Water-quality monitoring sites at Minute Man NHP, Massachusetts

SITE	WATERBODY	LATITUDE (NAD 83)	LONGITUDE (NAD 83)	SITE REMARKS
	Streams			
MIMASC	Concord River at Old North Bridge, Concord, MA	42°28′8.4″	071°21'2.26"	Warm water fisheries
MIMASB	Elm Brook at Rte 2A near Lincoln, MA	42° 27' 9.61''	071° 18'15.33''	Cold water fisheries
MIMASA	Mill Brook At Lowell Rd, Concord, MA			Cold water fisheries

1.2.3.4 Morristown NHP (MORR), New Jersey

Five water-quality-monitoring sites have been selected at MORR for the long-term monitoring program (appendix 3, figure A5). Sites were chosen to represent the accessible, perennial streams in the Jockey Hollow and New Jersey Brigade Units, the two park units with significant freshwater resources. Historic water-quality sampling sites were continued as these stations met the objectives of the vital-signs program.

Three of the selected sites are in the Primrose Brook Watershed within the Jockey Hollow Unit. These sites are on the East Branch of Primrose Brook, the West Branch of Primrose Brook, and the main stem of Primrose Brook. The other sites are on the Passaic River and Indian Grove Brook in the New Jersey Brigade Unit. Jersey Brook is also in the park but it is ephemeral. The largest pond in the park, Cat Swamp Pond, has no natural outlet and is connected to East Branch Primrose Brook only by an overflow outlet pipe.

In November 1996, the USGS established a water-quality-monitoring site at site EP1, just downstream of the confluence of East and West Branch Primrose Brooks, and monitors several chemical and physical parameters including stream flow on a quarterly basis (Deluca et al, 2003). The site has a staff gage, a stage discharge relation (rating), and is used as a water-quality-monitoring site by several other State and Federal agencies. The

US Fish and Wildlife Service (USFWS) has monitored 15 water-quality parameters and sampled aquatic life at this site since 1991 (Lombard, 2004). Data collected by other agencies must consistently be entered into NETN database.

Coordinate stream water-quality monitoring at MORR with ongoing monitoring at the park, especially at site EP1. Make a reading from the established staff gage each time a discharge measurement is made at upstream sampling sites.

Table 14. Water-quality monitoring sites at Morristown NHP, New Jersey

SITE	WATERBODY	LATITUDE (NAD 83)	LONGITUDE (NAD 83)	SITE REMARKS
Streams				
MORRSD	Indian Grove (IG2) USGS station # 01378680	40°44′40.9″	074°33'55.9"	Cold water fisheries
MORRSB	Primrose Brook at Morristown (EP1) USGS station # 01378780	40° 45' 54''	074° 31'47''	Cold water fisheries
MORRSA	EB Primrose Brook (EP2) USGS station # 01378778	40° 46' 13.70''	074° 31'25.50''	Cold water fisheries
MORRSC	WB Primrose Brook (WP2) USGS station # 01378775	40° 46' 11.40''	074° 32'10.00''	Cold water fisheries
MORRSE	Passaic River USGS station # 01378670			Cold water fisheries

Descriptions of recommended sites were written by the natural resources manager at MORR (R. Masson, written commun., 2004) and are the following:

Indian Grove Brook, station 2 (IG2)
Enter the fire road at the intersection of Old Jockey Hollow and Hardscrabble Roads (near the chalet). A stake is located off the bridge on the left.

West Primrose Brook, station 2 (WP2)
This sampling station is located in the inner loop of the park. From the Trail Center proceed west (do not cross Jockey Hollow Road) on the Aqueduct Trail. Approximately ½ mile in, you will see an orange flag on the stream side of the trail. The site is near the "D" self guide marker for the Aqueduct Trail. This is the sampling site.

East Primrose Brook, station 1 (EP1)
From the Trail Center, proceed in an easterly direction (cross Jockey Hollow Road) on the Patriot's Path (Old Camp Road Trail). Stay on Patriot's Path to where it breaks off from the Old Camp Road Trail (bear right). At the first footbridge, there is a yellow flag on the right designating the sampling station.

East Primrose Brook, station 2 (EP2)

From the Comfort Station, proceed southeast on the New York Brigade trail. Continue down the left branch when the trail forks. Go past Cat Swamp Pond. At the next fork, bear right (Grand Loop Trail bears left). You will immediately round a major curve on the trail. The sampling station is right after the curve, where the stream goes under the trail. The sampling station is on the right designated by flagging.

In addition, the Passaic River site was added in 2006, and has the following description:

Passaic River
[INSERT DESCRIPTION]

1.2.3.5 Roosevelt-Vanderbilt NHS (ROVA), New York

All of the basic field water-chemistry parameters and nutrients identified by the vital signs program have been collected intermittently since 1994 at 11 stations in ROVA. Although the effort ranged from monthly to quarterly, there are some years that have no data (2002, 2003), and a couple years that have only a single winter value (2000 and 2001). Field parameters of specific conductance, pH, temperature, and DO have been collected with Yellow Springs Instruments (YSI) probes, and grab samples have been sent to a local laboratory for nutrients, alkalinity, total dissolved solids, chloride and bacteria analyses. Discharge measurements have not been included in the data collection. Water-quality data have been checked for outliers, but have not been part of a rigorous quality assurance/quality control (QA/QC) program nor been analyzed (D. Hayes, NPS, written commun., 2004). The most values for any single month at any of the 11 stations over the 10 year period are four. This makes a statistical test for trend (such as the seasonal Mann-Kendall test) problematic without additional data. The available data, however, can be used to define the range of variability in the measured parameters, and to see if streams have consistently met the water-quality standards for their classification as mandated by the State of New York.

Six water-quality-monitoring sites were selected at ROVA for the long-term monitoring program (appendix 3, figure A6). These are five of the original 11 sites that are currently (2006) being monitored at the park including VAMA-1, VAMA-3, HOFR-1, HOFR-3, ELRO-3 (table 15) (National Park Service, 1997a). An additional site was chosen on the stream in the 2007 HOFR acquisition. Sites were chosen to represent the major streams in each park unit.

The NPS Water Resources Management Plan (National Park Service, 1997) reduced the number of water-quality-monitoring stations needed from 11 to 7 which matches the design plan presented here. The following sites would be eliminated: VAMA-2, HOFR-2, HOFR-4, ELRO-1, ELRO-2, ELRO-3 and ELRO-5. HOFR-4 has been identified as a high-priority site by the park because of its ecological importance as the only site in the tidal wetland. Although it is not a freshwater site and is outside park boundaries, it could be monitored through partnerships with nearby Universities, non-profit organizations, or the tidal wetland monitoring occurring as a part of the vital-signs program.

Tape-down sites can be established at all water-quality-monitoring sites. Discharge measurements are made at all stream sites.

Table 15. Water-quality monitoring sites at Roosevelt-Vanderbilt NHS, New York

SITE	WATERBODY	LATITUDE	LONGITUDE	SITE REMARKS
	Streams			
ROVASC	Crum Elbow Creek Historic site where stream enters park (VAMA-1)	TBA	TBA	Warm water- includes sunfish
ROVASD	Crum Elbow Creek Historic site; where stream exits park (VAMA-3)	TBA	TBA	Warm water- includes sunfish
ROVASB	Unnamed stream Historic site where stream enters park (HOFR-1)	TBA	TBA	
ROVASA	Unnamed Historic site; where stream exits park (HOFR-3)	TBA	TBA	
ROVASE	Meriches Kill in recent land acquisition	TBA	TBA	
ROVASF	Fall-Kill Historic site; Downstream of upper Val-Kill Pond (ELRO-3)	TBA	TBA	Warm water- includes sunfish

1.2.3.6 Saint-Gaudens NHS (SAGA), New Hampshire

Three water-quality-monitoring sites have been selected at SAGA for the long-term monitoring program (appendix 3, figure A7). The three sites selected to represent the two streams and the major impoundment in the park are all water-quality sites that have been measured by the park since 1997 (Walasewicz, 2003). One site is on Blow-Me-Down Brook (historic station 3), one site on Blow-Me-Up Brook (historic station 1), and one site behind the impoundment on Blow-Me-Down Pond (historic site 5) (table 18). The NPS recently reviewed the current water-quality-sampling strategy at SAGA, and made specific recommendations for its improvement (Ellsworth, 2005). The USGS sampling design as a part of these protocols for SAGA monitoring sites is in accordance with NPS recommendations which include the following;

1) Redesign SAGA surface-water-quality-monitoring program to include continuous flow monitoring.
2) Reduce number of sampling sites from 6 to a maximum of 2.
3) Review shipping and handling protocols for samples.
4) Review sampling parameters.
5) Review appropriate statistical comparisons, and disseminate the annual report for review.

6) Ensure that the NPS standard is for water monitoring data to be entered into STORET and the NHDES Environmental Monitoring Database for state tracking and reporting purposes.

A continuous-flow monitor would be beneficial to the park; however this did not receive a high priority in these protocols because of funding restraints. Continue to measure streamflow each time a water-quality measurement is made at the two stream sites (SAGA-1 and SAGA-3). Establish a tape-down site at station 5 on Blow-Me-Down Pond.

Table 16. Water-quality monitoring sites at Saint-Gaudens NHS, New Hampshire

SITE	WATERBODY	LATITUDE	LONGITUDE	SITE REMARKS
Streams				
SAGASA	Blow-Me-Up Brook	TBA	TBA	Cold water fisheries - includes trout
SAGASB	Blow-Me-Down Brook Below the confluence with Blow-Me-Up Brook	TBA	TBA	Warm water fisheries- includes sunfish
Ponds				
SAGAPA	Blow-Me-Down Pond	TBA	TBA	

1.2.3.7 Saugus Iron Works NHS (SAIR), Massachusetts

A continuous-record streamflow-gage has been operated on the Saugus River just upstream of the park boundary by the USGS since 1994 (USGS 01102345 Saugus River at Saugus, MA) (table 17) (appendix 3, figure A8). Temperature and specific conductance have been measured at this station continuously since 2001. The park would benefit from an annual compilation of continuous measurements of stage, temperature and specific conductance. As long as continuous measurements continue at this site, there is no need for the monthly measurements with the sonde. Although the station is upstream of the park, because the stream reach within the park boundary is only 0.25 miles, this station adequately represents water quality within the park. Data from this station can be accessed at: http://waterdata.usgs.gov/ma/nwis/uv/?site_no=01102345&agency_cd=USGS .

Water quality samples will be taken twice a year at the location of the USGS gage. Water quality samples and sonde measurements may also be added at the turning basin within the park boundaries.

Table 17. Water-quality monitoring sites at Saugus Iron Works NHS, Massachusetts

SITE	WATERBODY	LATITUDE	LONGITUDE	SITE REMARKS

Streams				
SAIRSA	Saugus River Historic site just upstream of park boundary (USGS 01102345)	42°28'05"	71°00'27"	Warm water fisheries

1.2.3.8 Saratoga NHP (SARA), New York

There are 8 miles of perennial streams divided between 4 watersheds in SARA that all flow into the Hudson River. These watersheds include the Kroma Kill, Mill Creek, American Creek and Devil's Hollow. In addition, the Champlain Canal Cuts across the downstream end of the major drainages of park, and water from the Hudson River can back up into the park. There are also two distinct channels that drain the Schuyler property, which has recently been acquired by the park. Since there are no major ponds or impoundments in Saratoga, NETN will be a designed to characterize only the streams in the park.

One fixed-monitoring site has been identified in each major watershed in the park where water-quality samples can be taken and streamflow measured (appendix 3, figure A9). In addition, there are major tributaries in the Mill Creek watershed within park boundaries, and thus an additional site has been identified on the North Fork of Mill Creek.

Kroma Kill is a 3rd order stream in the park and can be monitored upstream of the first bridge crossing along the Park Entrance Road from Route 4. The bridge will provide an adequate staff gage site, a constricted area for hydraulic control, and a platform for sampling during high flows. Historic sample sites were deemed less desirable because of potential backwater affects from the Hudson River(SARA -0044 and -0045), road (SARA0050) or Park boundary constraints (SARA0049) (for historic sites see National Park Service, 1997b).

Mill Creek enters the Hudson River as a 2nd order stream. The North Fork Mill Creek will be sampled near where the stream enters the park, just downstream of the park tour road. The stream is very small at this location but appears to be perennial and the box culvert can be used for accurate discharge measurements when flows are elevated.

The Mill Creek site is approximately 200 m downstream of the confluence of the North and South Forks (historic site SARA0053). This site provides an integrated sample for the watersheds of the North and South Forks as the South Fork can have low flow and would not be a reliable year round sampling site that meets sampling site criteria. Mill Creek has a cobbled bed and a well-defined floodplain terrace similar to the North Fork. This site can be accessed from the Park Tour Road by crossing the open field above the American Creek Fortifications, traversing the higher part of the wooded hillslope west of the private land holding along Route 4, and dropping into the valley formed by Mill Creek. Downstream sampling near private property was not feasible because of low flows and likely backwater affect from the Old Champlain Canal. The reach from the recommended site downstream to the private property was meandering, braided, or otherwise not conducive to sampling. The Mill Creek site was difficult to access but achievable within 30 minutes.

A reasonable sample site was identified for American's Creek below Bemis Point at the end of the American River Fortifications. Here the stream here flows through a narrow channel incised to bedrock. The streambed is similar to that described for Devil's Hollow above. Flow was continuous when observed. The historic sites SARA -0056, -0057, and -0058 were deemed inappropriate because of Hudson River backwater and Champlain Canal drainage.

The following stream watersheds are a lower priority for the park and will not initially have fixed monitoring sites: (1) Two channels that drain the Schuyler property that the park is acquiring at the northern end of the park; (2) the Hudson River will not be monitored because other agencies are monitoring it and only its backwater is within park boundaries; (3) the Champlain Canal will not be monitored because although it may demonstrate cumulative affects of water pollution in the park, it can be difficult to trace effects if long-term trends are detected; (4) Fish Creek, adjacent to the Schuyler House, is affected by backwater from the Hudson River during high flow events and, therefore, deemed inappropriate for the vital-signs program; and (5) Devil's Hollow, which does not have year-round flow.

Table 18. Water-quality monitoring sites at Saratoga NHP, New York

SITE	STREAM	LATITUDE * (NAD83)	LONGITUDE * (NAD83)
SARASA	Kroma Kill Upstream of the first bridge crossing of the Park Entrance Road from Route 4	73 36 55*	43 0 15*
SARASD	Mill Creek 200 m downstream of the confluence of the North and South Forks (historic site SARA0053)	73 37 32*	42 59 19*
SARASC	North Fork Mill Creek	73 37 30*	42 59 24*
SARASB	American Creek Below Bemis Point at the end of the American River Fortifications	73 37 45*	42 58 47*

* All coordinates are estimates and need to be field verified based on descriptions.

1.2.3.9 Weir Farm NHS (WEFA), Connecticut

A long-term monitoring site will be set up in Weir Pond, the largest fresh-waterbody in the park (appendix 3, figure A10). The deepest point will be monitored monthly from May-October for high priority vital signs including temperature, pH, specific conductance, DO, and SD. Grab samples will be taken from the deepest point twice a year in June and August for nutrients, color, and ANC and a tape down point established to monitor water levels in the pond. The NPS regional hydrologist recently (2005) reviewed the current water-quality-sampling strategy at Weir Farm National Historic Site, and made specific recommendations for its improvement (A. Ellsworth, NPS, written commun., 2005). Examine recommendations by Ellsworth before monitoring is initiated.

Table 19. Water-quality monitoring sites at Weir Farm NHS, Connecticut

SITE	WATERBODY	LATITUDE	LONGITUDE	SITE REMARKS
Ponds				
WEFAPA	Weir Pond	TBA	TBA	Historic site at deepest point in pond

1.3 Field and Laboratory Methods

1.3.1 Field Methods

Parameters measured monthly in the field from May through October will include stream discharge and lake water levels, pH, specific conductance, temperature, and DO (tables 22 and 23). These parameters will be measured in situ with a multiparameter probe. Maintain consistency of staff whenever possible to minimize variation from technical error. Consistency in the use of calibration and QA/QC methods is important to maintain high-quality data.

ANC, color, total nitrogen, total phosphorus, total dissolved nitrogen, total dissolved phosphorus, ammonia, nitrite, nitrate, and orthophosphate samples will be collected as grab samples in streams and ponds and depth-integrated epilimnetic samples in lakes, and then sent to a central laboratory for analyses. These samples will be collected in June and August in lakes and in May and August in streams. In addition, a chlorophyll *a* sample will be collected in lakes as a depth-integrated epilimnetic sample in June and August, filtered, and then sent to the laboratory for analysis.

Invasive aquatic plants will be surveyed once per year in lakes and ponds with boat access.

Table 20. Summary of monitoring parameters, methods, and frequency in lakes.

PARAMETER	METHOD	FREQUENCY
Dissolved oxygen, temperature, specific conductance, pH	Sonde profile	Monthly (May-October)
Lake levels	Tape down	Monthly (May-October)
Clarity	Secchi disk depth *or* Li-Cor Light Meter[1]	Monthly (May-October)
ANC	Depth-integrated epilimnetic sample	Biannually (June and Aug)
Color	Depth-integrated epilimnetic sample	Biannually (June and Aug)
Total nitrogen and total phosphorus	Depth-integrated epilimnetic sample	Biannually (June and Aug)
Total dissolved nitrogen, total dissolved phosphorus, ammonia, nitrite, nitrate, orthophosphate	Filtered depth- integrated epilimnetic sample	Biannually (June and Aug)
Chlorophyll *a*	Filtered depth -integrated epilimnetic sample	Biannually (June and Aug)
Exotic plants-early detection	Field surveys	Annually (July or Aug)

[1]Secchi disk depth will be used at all sites where the Secchi disk depth is less than the depth of the deepest point. Only in cases where the Secchi disk is visible on the bottom of the pond, will a Li-Cor Light Meter be used.

Table 21. Summary of monitoring parameters, methods, and frequency in ponds.

PARAMETER	METHOD	FREQUENCY
Dissolved oxygen, temperature, specific conductance, pH	Sonde	Monthly (May-October)
Pond water level	Stage reading	Monthly (May-October)
ANC	Grab sample	Biannually (May and Aug)
Color	Grab sample	Biannually (May and Aug)
Total nitrogen and total phosphorus	Grab sample	Biannually (May and Aug)
Total dissolved nitrogen, total dissolved phosphorus, ammonia, nitrite, nitrate, orthophosphate	Filtered grab sample	Biannually (May and Aug)
Clarity	Secchi disk depth, transparency tube, *or* Li-Cor Light Meter[1,]	Monthly (May-October)
Exotic plants-early detection	Field surveys	Annually (July or Aug)

[1]Secchi disk depth will be used at all sites where the Secchi disk depth is less than the depth of the deepest point. Only in cases where the Secchi disk is visible on the bottom of the pond, will a Li-Cor Light Meter or transparency tube be used.

Table 22. Summary of monitoring parameters, methods, and frequency in streams.

PARAMETER	METHOD	FREQUENCY
Dissolved oxygen, temperature, specific conductance, pH	Sonde in centroid of flow	Monthly (May-October)
Discharge and stream stage	Current meter	Monthly (May-October)
	Pressure sensor[1]	Continuous (all year) [1]
ANC	Grab sample	Biannually (May and Aug)
Color	Grab sample	Biannually (May and Aug)
Total nitrogen and total phosphorus	Grab sample	Biannually (May and Aug)
Total dissolved nitrogen, total dissolved phosphorus, ammonia, nitrite, nitrate, orthophosphate	Filtered grab sample	Biannually (May and Aug)

[1]Pressure sensor will be used at 1-3 continuous record gaging stations in ACAD, and 1 gaging station at SAIR, otherwise current meters will be used.

1.3.2 Laboratory Methods

Quality and consistency of data for long-term trends depends on the selection of an accredited laboratory with adequate QA/QC procedures. It is also critical that the analysis methods for each analyte are specified and clarified with the laboratory staff before analyses begin. Before sampling begins, field and laboratory staff will discuss the correct procedures for pretreatments, bottle sizes, types, and holding times to ensure high quality samples are collected.

1.3.3 Quality Assurance and Quality Control

QA and QC are important to the success of a long-term data-collection/ trend detection program. QA is achieved through the establishment and use of these Phase III protocols. Specific procedures are used to control those unmeasurable components of a project such as sampling at the right place with the right equipment and using the right methods. Over the years, staff may change, equipment may become updated, and methods may evolve. Although these changes will be kept to a minimum, changes are inevitable therefore, following established and well-documented protocols will ensure that the data remain valid.

QA, an integral part of these protocols, includes consistency and low turnover in project leaders and staff; consistency in staff training and oversight; consistency in equipment used and calibration methods; the selection of a well-established chemical laboratory with a proven track record; and a robust sample design that includes an adequate number of field and laboratory QC samples.

QC includes the assessment of bias and variability through the use of additional samples such as blank and replicate samples. QC samples are an objective assessment of whether or not QA protocols are adequate. QA is integrated into each SOP and into the protocol narrative. A section on QC is included in each SOP if appropriate.

1.3.3.1 Quality Assurance

Data representativeness and data comparability will be assured if standard protocols for lakes, ponds, and streams, are adopted. The most appropriate existing protocols for the goals and objectives of this monitoring program were selected and adapted. USGS Water Resources Division and NAWQA protocols were adopted for streams. Maine State DEP protocols were adopted for lakes as ACAD was the only park in NETN that includes lakes. All versions of each protocol that is adopted by NETN will be archived and dated so that each piece of data collected by NETN can be linked to a specific version of a protocol from another agency at a later date.

Some parks have already been collecting data for a number of years, using more than one version of a protocol. Although not all versions of all protocols were documented in the past, every attempt will be made to compare and quantify old methods with new methods before a change is adopted to avoid bias from changes in methods.

To ensure consistency in analysis results, one laboratory will be used by all parks in NETN. Any laboratory chosen must pass independent State and Federal (Federal National Environmental Laboratory Accreditation Program or NELAP, see *http://www.epa.gov/ttn/nelac/accreditlabs.html*) accreditation/approval QA/QC checks, optimally including blind-sample round-robin trial analyses of proficiency-test standards to see if the results the laboratory provides is similar to known (certified correct) ranges to pass QC performance standards. Rigorous and independent checks are needed to insure that the selected laboratory can produce accurate and comparable results. Federal and state agencies that have run round-robin testing programs have determined that many candidate laboratories cannot pass such checks (Irwin, 2004). The USGS National Water

Quality Lab (NWQL) meets these criteria, but there are other central laboratories that would be acceptable.

As one of the biggest sources of data variability can be operator error, all attempts will be made to maximize staff background, experience, and training and to minimize staff turnover. Staff responsible for collecting samples will have the experience and training necessary to routinely perform all equipment calibrations, and recognize when and address a piece of equipment not adequately meeting specifications. Furthermore, staff will be trained to follow all protocols for grab samples including bottle types, pretreatments, and holding times.

1.3.3.2 Quality Control

QC data are generated to estimate the magnitude of the bias and variability in the processes for obtaining field data. Bias is the systematic error inherent in a method or measurement caused by contamination of samples and can be identified and quantified through the use of blank samples. Precision is a measure of the variability in results when one is measuring the same (homogenous) factor repeatedly, whereas variability is the degree of random error in repeated measurements of the same quantity. Precision and variability are the opposite of each other as defined by USGS NAWQA. Sample replicates are used to control for precision or variability. In addition, reference samples are samples of sufficiently well known composition to be used for an assessment of the measurement method. Calibration includes efforts to ensure an instrument is measuring with an acceptably low amount of systematic error or bias.

Specific sections for QC are included in individual SOPs where necessary. Field QC samples are submitted by field staff to measure errors in sample collection, processing and transport in the fields. Laboratory QC samples are submitted by chemists to measure errors in sample preparation and analysis in the laboratory. It is important that adequate QC samples be taken routinely to ensure that future trend analyses are assessing true environmental trends rather than the bias and variability of the field staff or the equipment used.

1.4 Data Management

Data management will be coordinated and overseen by the NETN data manager. Desktop versions of NPS STORET can be populated at ACAD by ACAD staff and by NETN staff for the rest of NETN. All data collected and populated in NPS STORET at ACAD and at NETN headquarters will be compiled and made available to the Inventory and Monitoring Program, park managers, and the public annually as a part of the annual data report (see section *7.1 SOP 24—Annual Data Reporting for Lakes, Ponds, and Streams*.) The NETN data manager will be responsible for ensuring that all data collected are compatible between parks.

Vital signs monitoring networks will be collecting a wide variety of physical, chemical, biological, and other data in support of monitoring impaired, pristine, and other high-priority waters. The Implementation Plan for the Water-quality-monitoring component of the NPS Vital Signs Monitoring Program states that all water-quality data collected by

Vital Signs Monitoring Networks will be funneled through the NPS Water Resources Division into the USEPA modernized STORET (STOrage and RETrieval) database where the data will be available to parks, Regions, and the public on the Internet at http://www.epa.gov/storet.

STORET is the USEPA's oldest and largest database system. The Legacy Data Center (LDC) part of STORET is billed as the world's largest repository of ambient water-quality data. The LDC contains water-quality data collected from all 50 states, tribal lands, U.S. Territories, and Canada during the past 30 or more years. These data were collected by Federal, State, and other governmental entities before 1999 and entered into the old mainframe version of STORET. The NPS Water Resources Division was an active contributor to old STORET entering more than 2.5 million observations collected from 1900 to 1998 from 17,477 monitoring stations in or near 191 national park units.

More germane to the Vital Signs Monitoring Networks, however, is the new or modernized STORET (ver. 2). Modernized STORET adopts a distributed database model that relies on government agencies and other entities to operate local copies of STORET and the database software Oracle. Periodically these local STORET implementations replicate their entire database on the Web-accessible STORET National Data Warehouse. Modernized STORET is a full-featured database that allows users to enter nearly any type of environmental monitoring data and thoroughly document the results of monitoring with complete metadata. All data in modernized STORET must include the required metadata. Data collected through 1998 and entered into the mainframe version of STORET can be migrated to modernized STORET provided the responsible organization includes all the new metadata required by modernized STORET. The NPS Water Resources Division is in the process of migrating the 2.5 million observations entered into old STORET to the modernized STORET.

The primary mechanisms that will be employed to enter Vital Signs Monitoring Network water-quality data into STORET are a series of input screens (forms/templates), developed as part of the Natural Resource Database Templates (http://www.nature.nps.gov/im/apps/template), and the STORET Interface Module (SIM ver. 2). The input screens (called **NPSTORET**), developed by the NPS WRD, will allow Vital Signs Monitoring Networks to enter data about their projects, stations, metadata, and results. NPSTORET will run under Microsoft Access 2002 software or higher.

1.5 Analysis and Reporting

The data-reporting format and schedule are designed to meet the major goals of the Vital Signs program, which (a) determine the status and trends in selected indicators of the condition of park ecosystems to allow managers to make better-informed decisions and to work more effectively with other agencies and individuals for the benefit of park resources; (b) provide data to better understand the dynamic nature and condition of park ecosystems and to provide reference points for comparisons with other, altered environments; and (c) provide a means of measuring progress towards performance goals.

NETN emphasizes communication and reporting as one of the major goals. The reporting approach is based on the perspective that, a vital sign is useful only if it provides information to help guide management decisions or quantify the success of past decisions. This information must be presented clearly so that vital sign analyses are understood by managers, scientists, policy makers, and the public.

Data analyses and reporting consist of two components. The first component will be comprised of an annual data report with stream water-quality data checked for quality and completeness. This report will ensure that data are routinely available to the public for independent analyses, and to spur research projects that will be of benefit to the park and to NETN. Annual data reports can come from various sources and (or) cooperators and must include all specified components listed in section *7 Standard Operating Procedures for Data Analyses and Reporting*. Data reports can be digital, paper, or both as long as they are readily available to the public.

The second component of the data analyses and reporting for NETN includes trend analyses and scorecard reports. Trend analyses will be conducted on all parameters biennially by network staff on both individual waterbodies and on aquatic ecosystems as a group at a park. All measures within a vital sign will be examined in the context of other measures within that same vital sign to determine if all eutrophication parameters (for example) such as nutrients, chlorophyll *a* and SD have similar seasonal trends. These types of analyses will help managers determine whether there is problem waterbody with a new or increased stressor or whether there is an overall regional trend to be investigated.

Communicating trends in 25 or more parameter measures that relate to multiple vital signs requires a framework or scorecard that clearly and concisely conveys the state of the park ecosystems. The status and trends of parameters will be used to populate a biennial ecological integrity scorecard which will include data from all aquatic annual data reports from NETN parks and from all trend analyses.

1.6 Personnel and Operational Requirements

1.6.1 Field Crew Qualifications

Many possible models are available for staffing the water-quality and water-quantity components of the vital signs program. In some parks, existing staff may be able to perform some or all of the routine water-quality and -quantity monitoring, if given training and oversight, and a part of their time is dedicated to this work. Alternatively, NETN can hire a hydrologic technician(s) dedicated to collecting water-quality and quantity data from May through October or contract the work to an agency that routinely collects water quality and (or) water quantity measurements. Where a relationship already exists with a nearby State or Federal agency, monitoring could be contracted to this agency. The lead hydrologic technician at NETN, however, must remain in contact with the contracted agency to ensure that consistent protocols are being followed, and data are being entered or transferred appropriately. All staff decisions will be evaluated for technical expertise, ability to collect water samples on a consistent and dependable basis, and program budgetary constraints.

Any staff who are be responsible for obtaining water-quality measurements and (or) water-discharge measurements under any of the models listed will have, or obtain, training as a hydrologic technician. Minimum qualifications for a hydrologic technician are: (1) be highly organized, and comfortable interacting with a wide range of people; (2) have adequate field-sampling experience under rigorous conditions and be able to conduct reconnaissance surveys to evaluate the best sites for water-resources data collection; (3) be experienced in operation, maintenance, and calibration of multiparameter water-quality equipment to perform routine field water-quality measurements such as water temperature, specific conductance, pH, and DO; (4) be able to use well-defined methods and procedures to collect and process field water-quality samples and perform limited field or laboratory analyses of sample constituents; (5) be able to collect discharge measurements, and have experience making routine measurements of stage and discharge under a variety of field conditions applying established uniform methods; and (6) be able to use, maintain, and calibrate a Price AA current meter and a pygmy meter and to make judgments regarding the best instrument or method to use in each situation.

It is preferable to conduct all water-quality and -quantity sampling in teams of two people because of the inherent safety risks working around water. Monitoring can, however, be done by one experienced hydrologic technician who is familiar with all safety protocols if samples can be collected or measurements made from the shore or when the water velocity is slow and the depth is shallow. When two staff members are used, the lead hydrologic technician, who is the crew leader, is responsible for crew safety, sample scheduling, equipment maintenance and calibration, and performance of all sample-collection activities in accordance with procedures and QA/QC requirements specified in the USGS survey manual. Members of the sampling crew, which could be park staff or seasonal crew members, are responsible for carrying out the instructions of the crew leader and informing the crew leader of any unsafe conditions, equipment, or other problems observed that could jeopardize the health and safety of the crew or the quality of sample collections. Crew members need not have extensive water quality or quantity training, but must receive safety training requirements described in section *1.6.3.1 Health and Safety Training*.

Training, equipping, and retaining water-quality staff by NETN is essential to acquiring high-quality data. Staff turnover requires additional training, and could negatively affect data quality (National Park Service, 2002).

1.6.2 Office Crew Qualifications

The office crew consists of one staff member whose time is partially dedicated to water-quality data management including a check of all data submitted by the hydrologic technician, data entry, and QC. This person will have hydrologic training and be able to perform routine data summary statistics and trend analyses on long-term water-quality data. This person will have experience with spreadsheets and (or) databases, checking and interpreting hydrologic data, and demonstrated experience producing and publishing reports.

1.6.3 Field Crew Training

Field crew training includes safety training and field-methods training. Schedule hands-on training of new staff before the monitoring season begins and ensure that it remains a top priority.

1.6.3.1 Health and Safety Training

All field staff are required to have a recent (within 1 year) physician's approval to conduct rigorous physical work and receive safety training to include at a minimum, Basic First Aid (3-year certification) and CPR (1-year certification). Classes are offered by the Red Cross. In addition, a Hazards communication class is required for all new field staff working with chemicals or working in or around a laboratory. An online version is offered by National Oceanic and Atmospheric Administration (NOAA) at: *http://www.labtrain.noaa.gov/* (accessed June 1, 2005). The leader of each field crew using a motorboat must obtain a U.S. Department of the Interior (DOI) approved Motorboat operator certification (5-year certification).

Hydrologic technicians must be informed that field work may expose the incumbent to extreme weather conditions such as rain, snow, extreme temperatures, and hazards such as flooding, ice, and insect bites, and that field work also involves moderate risks such as measuring in swift streams. Special safety precautions are required in and around water, and technicians must wear a life jacket, and other personal protective equipment designed for each particular work assignment. Field areas are often isolated and occasionally difficult to reach. Field crew members are required to discuss routine safety precautions and actions to be taken in an emergency with the field crew leader and (or) supervisor. Each crew member is given the opportunity to obtain appropriate vaccinations such as those for tetanus and hepatitis, and is informed as to the risks and protection measures for Lyme's disease. Field staff are encouraged to participate in any safety trainings offered or required by the NPS and the park in which they are working.

1.6.3.2 Field Methods Training

All staff collecting water quality or water quantity data should have formal training and some period of field apprenticeship to be able to correctly calibrate and operate field equipment, implement sampling procedures, and document the field protocols used and sampling results with the necessary metadata. Field training is necessary to ensure that the most representative measurements possible are made, and that data are consistent and comparable throughout NETN. The hydrologic technician must have training in methodologies for (1) collecting and processing samples of surface-water for water-quality analyses, (2) completing commonly made field water-quality measurements with a multiparameter probe and (3) collecting discharge measurements. Such training includes the theory, methodology, and equipment used to measure streamflow, stream stage, lake levels, water temperature, specific conductance, DO, and pH. Annual training and apprenticeship for NPS technicians are planned and budgeted before execution of monitoring activities by NPS staff.

In addition, field staff must review all SOPs included in this protocol to become familiar or reacquainted with established monitoring methods, and any updates since the previous field season.

Field staff are experienced in the use of the water-quality probes and current meters, and must become familiar with the manufacturer's instructions for calibration and use of the specific equipment planned for use in the monitoring/sampling effort. Experience in equipment handling, calibration, and use/field deployment of the sondes/probes and (or) meters is best obtained through a combination of apprenticeship, trainings, testing of and gaining some familiarity with the equipment at the office, and becoming familiar with the manufacturers equipment operation and maintenance manual before entering the field. Improper handling and storage of the multiparameter sonde and sensors can lead to equipment damage or premature sensor failure. All staff involved in water-quality instrument calibration and maintenance should receive training from the vendor or be supervised by someone who has recently completed training (such as the crew leader).

Continuous-record streamflow-gaging stations (continuous-gaging stations) and the collection of discrete discharge measurements are operations included in these protocols. This SOP, however, must be used in combination with the instruction manuals for all field equipment, guides for the collection of streamflow data (Rantz et al, 1982), and a period of apprenticeship and training with qualified hydrologic technicians. If the collection of streamflow data is not to be contracted to an organization that routinely collects and analyzes streamflow data, it is recommended that the technicians making these measurements be overseen by such an organization. This would include routine annual reviews of data collection and (or) analysis methods, equipment calibration, and refresher courses. Familiarize field staff with travel directions to the sites.

1.6.4 Inventory and Purchase of Supplies and Equipment

The inventory and purchase or rental of supplies and equipment is planned several months in advance of the field season. This early planning will ensure adequate lead time for equipment that needs to be ordered, replaced or sent for factory calibration. Preseason preparation will include the following: (1) inventory equipment listed in Appendix 1 for each applicable SOP; (2) contact the laboratory to coordinate water sample delivery; (3) confirm that any necessary vehicles, watercraft and other associated field gear will be available and operational for scheduled monitoring trips; (4) check expiration dates and quantities of field chemicals and supplies and replenish or replace as necessary; (5) install new batteries in all meters and other electronic gear; (6) clean Secchi disks and viewing scopes; (7) verify that depth graduations on water samplers and sounding lines and cables are accurate and in good condition; and (8) establish QA/QC measures in the beginning of the field season and repeat at prescribed intervals throughout the season.

1.6.5 Calibration of Equipment

Most equipment including water-quality sonde and all sensors and thermometers are calibrated each year before the field season begins to standards in table 23. Some equipment needs to be recalibrated throughout the field season.

Instructions for calibrating and operating sampling and field-measurement equipment are not intended to replace those of the manufacturer but are to be considered as supplementary information. Field staff must be familiar with the instructions provided by equipment manufacturers. This protocol provides only generic guidelines for equipment use and maintenance or focuses on a particular instrument or instruments that currently are in common use. There is a large variety of available field instruments and field instruments and many are frequently updated or replaced with newer technology. Field staff are encouraged to contact equipment manufacturers for answers to technical questions.

Make field measurements only with calibrated instruments. Each field instrument must have a permanent log book for recording calibrations and repairs see section *2.2.4 Equipment log books*. Review the log book before leaving for the field. Test each instrument (meters and sensors) before leaving for the field and practice your measurement method if the instrument or measurement is new to any member of the field crew who will be performing those measurements. Have backup instruments readily available and in good working condition if possible. Additional calibration is required at the field site for most instruments (see section *2.3.2 Pre-deployment Preparation, Calibration and Quality Assurance*).

Table 23. Stabilization criteria for recording field measurements.

[from USGS, variously dated; ±, plus or minus; ° C, degrees Celsius; ≤, less than or equal to; >, greater than or equal to; µS/cm, microsiemens per centimeter at 25° C; mg/L, milligram per liter]

Standard direct field measurement	**Stabilization criteria for measurements (variability should be within value shown)**
Temperature:	
Thermistor thermometer	± 0.2° C
Liquid-in-glass thermometer	± 0.5° C
Specific conductance	
When ≤ 100 µS/cm;	± 5 percent
When >, 100 µS/cm	± 3 percent
pH	
Meter displays to 0.01	± 0.2 standard pH units
Dissolved Oxygen	
Amperometric method	± 0.3 mg/L

1.6.6 Sampling Schedule

Lake monitoring will begin before spring turnover of dimictic lakes (as soon as possible after maximum snowmelt runoff) and continue through fall turnover, a period that normally extends from late April to late October.

Stream sampling will occur during the months without ice, generally from April through October. In southern parks such as parks in Connecticut and (or) New Jersey, it may be possible to extend this season into April to catch a sample during spring runoff. In ACAD this early sampling schedule may be challenging because of inaccessibility of sites because of road closures, but will be considered where feasible. Inclement weather and staff workloads will preclude the scheduling of sampling events to specific annual dates, however all lake sampling will ideally be accomplished during the same two weeks of each month for each park (for example the middle two weeks from the 8th to the 21st), and all stream sampling during the same week of each month (for example, the first week from the 1st to the 7th). Sampling can occur in a different two-week period in different parks. Tentative sampling dates will be scheduled and logistics organized before the start of each field season.

Grab samples and (or) depth-integrated epilimnetic samples in lakes and ponds are taken during two trips, once in June and once in August for lakes and once in May and once in August for streams. These grab samples must be treated according to laboratory instructions with regard to filtering, acidifying and (or) chilling and sent to a laboratory within the specified time for analyses.

A two-person crew (ideally one person to observe and sample and one to assist and record data) is normally required for lake monitoring. A moderately deep lake will take approximately 2 hours to complete a full-parameter monitoring visit. Generally two and a maximum of three lakes are scheduled for completion each field day. All monitoring is performed between 0900 and 1500 hours to provide consistent observation windows for the SD measurement. Stream sampling can be conducted during daylight hours. Determine which lakes will be sampled on the same day on the basis of the most efficient travel logistics. A one-person field crew is normally required for stream sampling except if a discharge measurement is to be made during high water. For this measurement a two-person field crew is required. If the target weeks of each month cannot be obtained because of weather or scheduling constraints, schedule data collection later in the month. If, however, no data were obtained for a month, it is not worthwhile to obtain two sets of samples during the following month.

1.7 Version Control Procedures

1.7.1 Protocol Version Tracking

The Protocol version number will change only following large structural changes to the overall protocol. Protocol version numbers will progress in whole numbers only (1.0, 2.0, 3.0) The following are examples of when a Protocol version number changes:

1) Additional reports are added.
2) An SOP undergoes a major revision.

3) More parameters have been added.
4) Procedures dramatically change.

Minor revisions such as editorial changes or small structural changes will increase incrementally by hundredths (version 1.01, version 1.02).

1.7.2 SOP Version Tracking

The SOP version number will be changed following any major or minor revision. Major revisions, such as a change in method or instrumentation are designated by whole numbers (version 2.0, 3.0, 4.0). Minor revisions such as editorial changes increase incrementally by hundredths (version 1.01, version 1.02).

Documentation lists changes made to a protocol or SOP with each new version. Any major edits are done through review by NPS National and Inventory and Monitoring Staff. Minor editorial changes and edits are reviewed by NPS Regional Network Inventory and Monitoring staff. Version changes to SOPs and protocols are tracked in the format given in table 24:

Table 24. Version Tracking

Version Number	Version Date	Sections changed	Changes from previous version
1.00	12/30/04	NA	NA

Part II. Standard Operating Procedures (SOPs)

2. General SOPs

2.1 SOP 1—Background and Inventory of Freshwater Resources

2.1.1 Background and Inventory of Streams

The physical and morphological characteristics of stream channels and basins in NETN are compiled and (or) collected and entered into the NPS desktop version of the STORET database (NETN database) before a given stream is monitored. In many cases, and particularly at historical monitoring sites, watershed area, basin geologic composition, and elevation data are currently available. Where morphological information is not currently available, watershed areas must be delineated, and stream channel and basin characteristics defined.

Watershed areas will be drawn or digitized on the best available map, which at a minimum, is on a topographic map with a scale of 1:24,000, and 10 or 20 ft contour intervals. Boundaries of the watershed that cannot be accurately determined from the topographic maps are field verified.

2.1.2 Background and Inventory of Lakes and Ponds

The physical and morphological characteristics of all lakes and ponds in NETN are compiled and (or) collected and entered into NETN database before a given lake or pond is monitored. If available, bathymetric data, surface area, maximum depth and location, perimeter, inlets and outlet locations, watershed area, basin geologic composition, and elevation data are entered. For example, all of the long-term trend sites in ACAD have bathymetric maps with the maximum depth location and sampling site identified. These maps are found at the University of Maine/Senator George J. Mitchell Center for Environmental and Watershed Research Web site: http://pearl.maine.edu/. Where the above listed morphological information is not currently available, at least the maximum depth site is surveyed and documented in the NETN database.

2.2 SOP 2- Metadata Collection

Locations of sampling sites are verified before or during the first monitoring trips of the season. If sites are identified with permanent or semi-permanent markers (buoys, staff gauges, rebar, etc.) the marker placement are checked against known standards (GPS readings, compass bearings, depth measurements, and benchmarks).

2.2.1 Field Data Forms

A field data form is used to document all information collected during water-quality monitoring. All notations are made in either pencil or waterproof pen. Fill in all blanks provided that pertains to the data that you will be collecting. Indicate with a "–"if the data are not available or not applicable but do not leave the entry blank. Blank entry lines leave the QA/QC checker to wonder if the data were forgotten or not available. The following information is to be completed on all field data forms:

- **Name**- Full name and location of waterbody being monitored.
- **Station**- Numbered location of sample site. For lakes, this will be the 4 digit MIDAS number unique to each lake.
- **Surveyor**- Name of person doing the observations.
- **Date and Time**- Sample date and time you arrived at sample site.
- **Sun**- Choose and circle the selection that best describes current conditions.
- **Cloud Cover-** Estimate amount of sky obscured by clouds.

- **Wind Velocity and Direction**- Determine wind direction and record the appropriate code using the diagram on the left side of the data sheet. Determine wind velocity using a hand-held anemometer or use tree movement/wave height as a guide. Record a single value (for example 7 mph, NOT 5-8 mph) in the space provided.
- **Air Temperature**- See Section *2.2.3 Air temperature*
- **Surface-water Temperature-** Place the metal part of the digital thermometer in the water (do not submerge completely) and record the value in degrees celcius after display stabilizes.
- **Stage Height-** Note stage height from staff gage or tape down site at beginning and end of site visit.
- **Bottom (lakes)**- The depth of the lake (in meters), measured at the sampling station (obtained either with depth finder or DO probe).
- **Photo Documentation-** If a picture was taken, note picture number. See section *2.2.2 Photo Documentation*.
- **Comments**- Any additional information pertaining to the sampling session, such as water clarity, amount of emergent/floating vegetation, unusual occurrences, or equipment problems.

2.2.2 Photograph Documentation

At a minimum, a one-time, digital, photographic documentation of all monitoring sites are included in the metadata. Additional annual and seasonal photograph documentation is encouraged. Take photographs of changes in the site after construction, erosion, flooding, or debris in the channel. Each digital photograph that becomes part of the station record is identified by appending descriptive information such as site, date, or flow rate.

2.2.3 Air Temperature

Water-quality sampling includes an air-temperature measurement and a water-temperature measurement. Before measuring temperature, inspect liquid-in-glass thermometers to be certain liquid columns have not separated, inspect bulbs to be sure they are clean and inspect protective cases to be sure they are free of sand or debris. Read air temperature with a dry, calibrated thermometer.

1. Place the thermometer about 5 ft above the ground in a shaded area protected from strong winds but open to air circulation. Avoid areas of possible radiant heat effects, such as metal walls, rock exposures, or sides of vehicles.
2. Allow 3 to 5 minutes for the thermometer to equilibrate, and then record the temperature and time of day.

3. Measure the air temperature as close as possible to the time when the water temperature is measured.
4. Report and record routine air temperature measurements to the nearest 0.5°C.

2.2.4 Equipment Log Books

Maintain field log books for all field instruments such as water quality sondes and streamflow meters. Field log books contain the manufacturer, make, model, description, and serial or property number; the history and use of the instrument including the date and time used and notes about its operation; and any repairs or adjustments made to the instrument. Routine calibration details can consistently be included either in the field log book or on the field form (not both).

2.3 SOP 3—In Situ Measurements of Specific Conductance, pH, Temperature, and Dissolved Oxygen using Multiparameter Water-Quality Monitor (Sonde)

This SOP describes operation of the Yellow Springs Instrumentation (YSI) 600XL multiparameter water-quality monitor (sonde) for measuring water-quality parameters in lakes and streams. This protocol is adapted from SOP 5 – Spatial Water Quality Monitoring with the YSI Sonde *in* Monitoring Protocols for the National Park Service North Atlantic Coastal Parks: Estuarine Nutrient Enrichment (Kopp and Neckles, 2004). Although this SOP is written specifically for the YSI model 600XL and the YSI 650 Multiparameter Display System (MDS) display/logger, other sondes that meet the requirements of this SOP can also be used; however use of comparable instrumentation by NETN will simplify data management and QA/QC procedures which are integrated into the SOP and include calibration methods. The general calibration methods discussed herein are applicable to other manufacturer's sondes and displays/loggers, but consult the manufacturer's instruction manuals for specific procedures.

2.3.1 Background and Familiarization with Instruments

Data are collected using the YSI 600XL sonde connected to a YSI 650 MDS using a field cable of appropriate length for the park or waterbody. The SOP describes a standard procedure on how to prepare, calibrate, program, and upload data from these instruments. It also provides detailed methods for operating the instrument in the field.

It is beyond the scope of this SOP to review all of the information and methods that are required to operate the YSI 600XL sonde and the YSI 650 MDS and to make effective and accurate measurements. It is important that all field and laboratory staff familiarize themselves with the entire YSI 6-Series Environmental Monitoring Systems Operations Manual, the Multiparameter Display System Operations Manual, and the Technical Notes and Technical Documents available from YSI at their Web site. The purpose of this instrumentation SOP is to standardize instrument handling, maintenance, calibration, and use for all NETN parks. The SOP provides step-by-step instructions specifically pertaining to this monitoring protocol; however, it does not provide adequate guidance to ensure consistent and accurate measurements. YSI, Inc offers courses on instrument calibration and maintenance and all NETN staff involved in instrument calibration are encouraged to receive training from YSI Inc.

YSI, Inc. offers three different depth models of the 600XL: shallow (9 m), medium (61 m), and deep (200 m). Although all three models have the same resolution (0.001 m), the accuracy of the shallow depth model (±2 cm) is considerably better than that of the medium depth model (±12 cm). The shallow model is appropriate for parks where depths are not expected to exceed 9 m; the medium depth unit is appropriate for the remaining parks. In either case, the sonde will be non-vented for pressure, and equipped with the following sensors:

1) YSI 6562 Dissolved Oxygen Probe with rapid pulse technology
2) YSI 6561 pH Probe
3) YSI 6560 Conductivity and Temperature Probe

YSI, Inc. also offers several options on the 650MDS. This SOP calls for the “650-04” configuration, which includes the 1.5 MB high-memory option and an integrated barometer. The rechargeable battery pack is optional, but always carry four extra C-cell batteries. With the C-cell configuration, the 650MDS can be powered for about 45 hours of continuous operation. The rechargeable battery pack will allow for roughly 15 hours of operation.

Firmware should be updated annually at a minimum from the YSI Web site *http://YSI.com/edownloads*. Before that YSI instrument has a good power source or new batteries before initiating Firmware update. If power fails during the update, contact YSI technical support.

2.3.2 Pre-Deployment Preparation, Calibration, and Quality Assurance

2.3.2.1 Preparation and programming of the YSI 650MDS Data Logger and Display

The YSI 650MDS serves several functions. It provides a user interface to the sonde while in the field, it logs data from the sonde, and it provides a real-time display of the output from each of the sonde sensors. At the beginning of each field season, install four fresh C-size alkaline batteries according to the directions in the 650MDS Operations Manual. Pay particular attention to the installation of the battery cover O-ring. These batteries can last for the duration of the field season, but the charge level (see thermometer bar at bottom right corner of display) monitored and the batteries replaced them as needed. Bring a spare set of batteries into the field.

Before the instrument can be deployed, it must be properly programmed. There are three menu sections that need to be programmed: <File>, <Logging Setup> and <System Setup>.

2.3.2.1.1 650MDS <File> menu

Check to confirm that there are no remaining data (.dat) files stored in the 650MDS memory. All files will have been removed previously as part of the SOP for downloading data to computer; therefore, the presence of any data files will indicate a failure to follow the SOP. Proceed with caution! Download any files to a specially labeled directory and annotate the calibration log to this effect. Use YSI EcoWatch software to open the date files and examine them to ensure they have not been corrupted and rendered unreadable in the upload process. Immediately create a CD back-up of the data files and confirm that they too are readable using EcoWatch. After these steps have been completed, select <Delete all files> from the 650MDS <File> menu.

2.3.2.1.2 650MDS <Logging Setup> menu

From the main menu in the 650MDS, go to <Logging Setup> and program as follows:

5) Set the sampling interval to one second (= 00:00:01)
6) Enable “Use site list”
7) Enable “Store Barometer”
8) Enable “Store Lat and Long”
9) Enable “Store site number”
10) Select <Edit Site List> and create a new file for each site
    a. As a standardized naming convention, each file name will start with a 2-character park code followed by a 4-character site name or number and a 2-digit year.
    b. In the “Site Number” field for each site use 0 for single stream site, 89 for QC data before sonde is deployed, and 99 for QC data taken after stream/lake data obtained, at that site. For lakes, the site number will be the depth at which the measurement is taken.
    c. The “Site Name” field is for your convenience only. It does not get appended to the data file, but it can be useful for differentiating between multiple stations or for keeping track of dates associated with each unique file name for the logging station.

2.3.2.1.3 650MDS <System Setup> menu

From the main menu in the 650MDS, go to <System Setup> and program as follows:

1) Set the correct date and LOCAL TIME. For all anticipated use of the SOP, this will be Eastern Daylight Savings Time. Select the “4 digit year” option.
2) Make certain that the “Comma radix” option is NOT selected.
3) Set the “Shut off time” to 0 minutes. This will keep the unit on until manually shut off.

This menu also provides for user calibration of the barometer. Check the barometer annually for drift. Recalibration is a delicate procedure, therefore carefully follow the guidance in the 650MDS Operations Manual and be certain that you are calibrating in mmHg against barometric pressure that has not been corrected for altitude (the National Weather Service generally reports barometric pressure corrected to sea level). If in doubt, return the unit to YSI Inc. for a factory recalibration.

2.3.2.1.4 650MDS <Sonde Menu>

Each time the sonde is calibrated, check the following time intervals. From the main menu in the 650 MDS, choose <Logging Setup> and set the Interval to 1 second. Go back to the main menu and choose <Sonde Menu>, <Advanced>, <Data Filter>, and set the time constant to 12 seconds. This will average values over the previous 12 seconds and update to the screen every 1 second. DO is re-calculated every 4 seconds, so an average over 12 seconds will be made up of 3 DO values. All other parameters are updated even more frequently and will be made up of running averages.

2.3.2.2 Preparation and calibration of the YSI 600XL sonde

2.3.2.2.1 General notes

During the calibration procedure, never accept any calibrations that have produced a warning message. Instead, determine the cause of the problem, correct it, and recalibrate following this SOP and the instrument manual. Each field season, batteries and DO membranes must be replaced. The batteries can last for the duration of the field season, but the DO membrane is easily damaged.

Since DO membranes are unstable for the first 3 to 6 hours after installation, it is important to check their condition and performance in advance of any planned field work. This SOP calls for the DO membrane to be examined (and replaced if necessary) and the sonde run for 10-15 minutes. After this stabilization period, just the DO sensor is recalibrated, and the sonde is ready for use.

Digital/luminescent/optical DO is beginning to replace Clark cell membrane type DO probes and this likely will add longevity to the DO sensor stability/reduce drift in longer deployments. It is possible that this new DO measurement system will replace the older technology Clark cells in the next several years, particularly as costs come down.

Calibrate the 600XL while it is secure in a ring stand or custom-mounted hook. Allowable variations in Sonde readings are listed in table 24.

2.3.2.2.2 Standard solutions

Except where explicitly noted in the SOP, standards are NOT to be used for more than one calibration. They can, however, be saved and used to prerinse the sensors and the calibration cup before putting them into fresh standard solutions. Rather than measure calibration solutions with graduated cylinders each time they are dispensed, mark the outside of the calibration cup at the appropriate levels for each probe. Dispensing standards directly into the calibration cup will also help prevent contamination from dirty glassware. For many of the calibration steps, reaching a stable calibration point requires the probe and calibration solution to thermally equilibrate. This occurs more quickly if both the sonde and all the calibration solutions are at laboratory temperature. Be sure to prepare deionized water in advance and store an ample supply in a carboy. pH standard is waste and must be disposed of according to state and local regulations.

Deionized Water

Deionized water is required for calibration of many of the sensors so some guidance is provided here on the quality of water that should be used for these purposes. Purchase water or purify it on site to a quality equal to, or better than American Society for Testing and Materials (ASTM) standards for Type III (Laboratory Grade) water. Deionized water used must have a maximum conductance of 1.0 µS/cm. Note that a sampling of supermarket distilled waters from around the country found hydrologic conductivity values well outside the standard for even ASTM Type III Laboratory Grade water (USGS Office of Water-quality Technical Memorandum 92.01). Use ASTM Type II (Reagent Grade) water for mixing buffer solutions. This SOP calls for the use of pre-prepared conductivity standards for calibration of the sonde. Do not prepare or dilute customized standards. Water prepared by distillation or ion exchange includes a polishing step by passing the water through a 0.45µm filter to remove some bacteria and any ion-exchange medium that escapes the columns. The following calibration procedure must be completed in the order it is presented.

2.3.2.2.3 Instrument Preparation

Before the water-quality sonde can be used, it must be calibrated and several maintenance steps performed. Assemble the individual sensors onto the sonde per instructions in the manual using extra care not to cross-thread the sensors when installing them onto the softer PVC sonde bulkhead. Before calibration, visually inspect the sonde for any abnormalities. Attach the Dry Calibration Cable between the sonde and the 650MDS, and establish communication with the sonde.

Before beginning, verify the accuracy of your sondes temperature probe with a traceable thermometer or other reference. Temperature compensation is used in almost every sonde measurement so its accuracy must be verified and recorded each time the sonde is calibrated.

2.3.2.2.4 Calibration of Dissolved Oxygen Sensor

1) Inspect the DO probe anodes. If they are darkened or gray in color, recondition using the 6035 reconditioning kit that is supplied with the probe.
2) Inspect the DO membrane. It must be undamaged, tightly stretched, wrinkle free, and free of air or gas bubbles beneath the membrane. If necessary, install a new membrane following guidance in the YSI 6-Series Operations Manual and Technical Notes. To install the membrane it is often easier to remove the sensor from the sonde and then install the membrane.
3) Place the sonde in the ring stand or custom support bracket. Put approximately 0.5 cm of water in the bottom of the calibration cup (do not allow water to touch the membrane) and loosely attach it to the sonde (engaging several threads). Go to the sonde <Report> menu and enable the <DO Charge> option.
4) Go to the sonde <Advanced> <Setup> menu and disable the "RS-232 auto-sleep" function.
5) If a new membrane has just been installed, go to the "<Run> menu and start the sonde in the <Discrete Sample> mode with a 4-second sample interval. Allow the

sonde to run for 10 minutes to "burn in" the new membrane. Record the DO charge. The number should be 50 plus or minus 25.

6) Perform a High-to-Low Transmission Test: Start the sonde in <Discrete Sample> mode with a 4-second sample interval. Disregard the first two DO percent saturation samples, and then record the next 10 samples. The DO percent saturation values must start high and drop with each 4-second reading. It does not matter if the readings do not reach 100percent, but there must be a high to low trend. If the recorded values start low then climb upward, the sensor has a problem and must be reconditioned or replaced. Record the 10 readings and the pass-fail status of the test on the calibration log. Escape from the <Run> mode.

7) Wait at least 5 minutes in the idle (not <Run>) mode before proceeding. Wait at least 10 minutes from the time the calibration cup (with 0.5 cm water in bottom) was attached to the sonde body. Once these minimum times have been reached, calibrate the DO sensor using the <percent Saturation> method. If the sonde is properly programmed (auto-sleep off) then you will be prompted to accept the calibration once the values have stabilized (display will update with each reading). NOTE that this is different from the method used for continuous monitoring where the calibration is accepted automatically following a 60-second sensor warm-up. Be sure to check and enter the current barometric pressure. Note that laboratory barometer readings are usually "true" values of air pressure and can be used "as is" for oxygen calibration. The barometer on the 650MDS (if properly calibrated) also reports "true" barometric pressure and can be used "as is." Pressure reported by the National Weather Service, however, is usually "corrected" to sea level and cannot be used in raw form. See the YSI Operations Manual for correction methods. Record the DO Charge on the calibration log. It should be 50 ± 25.

8) When the calibration has been accepted, check the "DO gain" for the sensor and record it on the calibration log. This is found under the sonde's <Advanced Menu> under the <Cal Constants> option. The target value for gain is 1.0, with an acceptable range from 0.7 to 1.4.

Note: If technicians are seeing DO values less than roughly 2 mg/L, a zero DO solution can be prepared in the field or can be taken to the field to check the DO sensor. A sodium sulfite solution is made by Dissolving 1 gram of sodium sulfite (Na2S03) and a few crystals (about 1 mg) of cobalt chloride (CoC12) in 1 liter of distilled water. The zero DO solution is used as a check standard and should read less than 0.5 mg/L. Sodium sulfide can compromise the gold cathode of the DO sensor so use only as necessary.

2.3.2.2.5 Calibration of Conductivity Sensor

Calibrate conductivity before pH on each sampling day. At Acadia, perform a two-point calibration (using 12.9 and 100 µS/cm standards) following the directions below for a one-point calibration with 1 mS/cm standard. At other parks, perform a three-point calibration using 12.9, 100, and 1,000 µS/cm standards. At Acadia, perform a three-point calibration monthly.

1) Calibration of the conductivity probe is very vulnerable to contamination. Before performing the calibration, the calibration cup and all the surfaces of all the probes must be triple rinsed with a small amount of conductivity standard. Used standard from a previous conductivity calibration is acceptable.
2) Pour approximately 50 mL of 1 mS/cm conductivity standard into a clean and dry calibration cup and attach it to the sonde body. Swirl, tip, and gently shake the sonde to thoroughly wet all of the probe and bulkhead surfaces. Discard this standard solution (do not re-use rinse standards). Repeat this step two more times.
3) Pour enough fresh 1 mS/cm conductivity standard into the calibration cup to fully cover the conductivity probe.
4) Insure that the conductivity probe is completely submerged in the standard. The hole in the side of the probe must be under the surface of the solution and not trap bubbles in the opening.
5) Initiate calibration of the probe selecting the <specific conductance> option and entering "1" for the conductivity of the standard (Be sure to enter the conductivity of the standard in <u>mS/cm</u>, not µS/cm).
6) Allow the sonde to run for at least 1 minute to ensure thermal equilibration (wait longer if the sonde, the conductivity standard, and the deionized water from previous steps are not all at the same laboratory temperature). After no changes occur in the reading for approximately 30 seconds, accept the calibration (hit <enter>) and record on the calibration log the last value reported before pressing <enter>. With an NBS-traceable thermometer, verify the accuracy of the sonde temperature reading and record it on the calibration log.
7) When the calibration has been accepted, check the "Conductivity Cell Constant" for the sensor and record it on the calibration log. This is found under the sonde's <Advanced Menu> under the <Cal Constants> option. The target value for this probe is 5.0 ± 0.45. Numbers outside this range usually indicate a problem in the calibration process or a contaminated standard. Never override a calibration error message and investigate any "Out of Range" report. Typical causes for error messages are incorrect entries. For example, entering 1000 microsiemens instead of 1.0 millisiemens (Note: the sonde requires the input in millisiemens). Low fluid level and (or) air bubbles in the probe cell can also cause error messages to appear.

2.3.2.2.6 Calibration of pH Sensor

pH probes generally last 2 years and cost approximately $200. Old probes can be reconditioned. Calibrate the pH sensor every week, and conduct a check against pH 4 and pH 7 buffers every morning. If the check values are within specifications (± 0.2 pH units), then there is no need to calibrate the pH.

1) Go to the sonde's report menu and turn on the pHmv output. This will allow the sonde to display the millivolts or the probes raw output and the pH units during the calibration process
2) Recondition the probe if a slow response in the field has been reported. The procedure to do this can be found in the YSI manual under "Sonde Care and Maintenance."
3) Usually, a two point calibration is all that is required. Bracket the expected in situ pH values. Always start with buffer 7 and then use buffer 4 or buffer 10. Use the three-point calibration only if the in situ pH value is unknown.
4) Calibrate the pH. Type in pH 7 (4 or 10) when prompted. Insure that the temperature probe is in solution with the standard, record the pH millivolts at each calibration point. The millivolt output is the unprocessed pH output; the acceptable tolerance for each buffer is shown below.
   a. Buffer 4 = +180 +/-50mv
   b. Buffer 7 = 0 +/- 50mv
   c. Buffer 10 = -180 +/-50mv

   When a probe is new, the ideal numbers are close to the 0 and 180. As the probe begins to age, the numbers will move and shift to the higher side of the tolerance. Buffer 4 response has a tendency to drift slightly out of the acceptable range of 180 mv ± 50. If this occurs, recondition the PH probe per the procedure in the YSI manual. If the probe has a response time of less then 60 seconds in buffers and the slope remains within spec, you can continue to use it. If you start to see slow response in the field or in the standards when checking calibration, then consider replacement.
5) After recording the pH millivolts for the calibration points, determine the slope of the sensor. The slope is the difference between the two calibration points that were used. For example, if a +3mv we recorded for buffer 7 and a -177 for the buffer 10, then the slope would be 180. The acceptable range for the slope is 165 to 180. Once the slope drops below 165, the sensor must be taken out of service.
6) WARNING: Never override any "calibration error" or "out of range" warnings without fully understanding the reason for the message. In most cases, the warning indicates that there is a problem that will result in suspect field readings.
7) Treat pH standard as waste and dispose according to state and local regulations.

2.3.2.2.7 Calibration of Pressure/Depth Sensor

1) From the <Calibrate> menu, select <Pressure-Abs>.
2) Input 0.00 (or a known sensor offset in ft if working far from sea level).
3) Wait until no significant change occurs for approximately 30 seconds, then press <enter> to confirm the calibration.
4) Calibrate Pressure/depth again in the field just before taking sample measurements

2.3.2.2.8 Miscellaneous preparations

When preparing the sonde for discrete sampling, realize that all data will be logged directly to the YSI 650MDS data logger and display. Program the 650MDS with the correct date and LOCAL TIME. For all anticipated use of this SOP, this will be Eastern Daylight Savings Time. The following report parameters can be enabled in the <Report> menu: date, time, temperature, specific conductance, DO saturation, DO concentration, DO charge, depth, and battery voltage. Set the sampling interval to 1 second. This option is found under the <Run> <Discrete Sample> menu.

Set up a user site list on the YSI 650 before taking readings in the field by selecting <Logging Setup> and activate <Use site list>.

2.3.2.2.9 Final laboratory Calibration of Dissolved Oxygen Sensor and Preparation of the Sonde for Field Work

1) Remove the calibration cup from the sonde body and install the sensor guard. It is best not to attempt this in the field since the oxygen membrane is vulnerable to being damaged if it is bumped by the guard.
2) Wrap the sonde in a white towel that has been soaked in tap water. Cover the entire sensor guard with the towel and wrap it around it at least twice. This cover will provide a humid environment for the sensors, protection from thermal extremes, and some degree of shock protection.
3) Transport the sonde to the field in a specially-modified white 5-gallon plastic bucket (or the equivalent). To prepare the bucket, place approximately 8 kg of lead weight in its bottom. Neoprene-covered soft weight packs containing lead shot that are used by SCUBA divers are excellent because they will not risk damaging the sonde. Also, put approximately 2 cm of water in the bottom of the bucket. Cut a hole in the middle of the lid that will accommodate the sonde body wrapped in the towel. The lid will support the sonde, help to maintain the humid environment, and keep water from spilling or sloshing out.
4) As much as possible, keep the sonde and bucket out of direct sunlight to prevent thermal extremes.
5) Just before making measurements, perform a final check of the DO probe at the field site. Dissolved oxygen concentrations should be plus or minus 0.2 mg/L for the barometric pressure. If the DO% Local option is being used, readings should be 100% ± 2%, otherwise the reading should be roughly plus or minus 2 percent of the appropriate (not adjusted for pressure) DO percent saturation. If the probe needs to be recalibrated, go to the <calibrate> menu and repeat the last two steps from the DO calibration section.

2.3.3 Making Measurements

Data can be logged either as a discrete point (after the user has verified stabilization) or as a continuous data stream at a fixed sample interval. Both of these types of data can be recorded in the same file. Set up a user site list on the YSI 650 MDS before taking readings in the field by selecting <Logging Setup> and activate <Use site list> (see YSI Inc. Operators Manual section 3)

1) Allow the sonde to warm up for 4 to 5 minutes before taking measurements. Turn on the sonde by powering up the 650MDS and selecting <Sonde run> from the main menu.
2) Once the sonde has warmed up, and with the unit still wrapped in the wet towel inside the transportation bucket, check the DO percent local saturation ("DOpercent") and record this value on the Spatial Survey Station Data Sheet.
3) Confirm that it reads 100percent ± 2percent. If the DO percent local saturation has drifted beyond these tolerances, the DO channel must be recalibrated on the spot. This is accomplished as follows:
    a. Press <Escape> to get to the 650MDS Main Menu
    b. Select <Sonde Menu>
    c. Select <Calibrate>
    d. Select <Dissolved Oxy>
    e. Select <DOpercent>
    f. Update the barometric pressure used for the calibration (large font numerals) so that it exactly matches the barometric pressure as measured by the 650MDS (small font numerals in the bottom right corner of the screen).
    g. Press <enter> and wait for the sensor to stabilize and the sensor to calibrate. Should the sensor fail to calibrate, follow trouble-shooting guidance in the YSI 6-Series Environmental Monitoring Systems Operations Manual.
    h. Press <Esc> to escape back to the 650MDS main menu, and then select <Sonde Run>.
    i. Confirm that the DO percent local saturation ("DO percent") reads 100 percent ± 2 percent and check off the box on the Spatial Survey Station Data Sheet that the sensor was successfully recalibrated.
4) Select the pre-deployment site code (89) and when readings are stable select **Log one sample** (upper left) and press enter.
5) Place the sonde in the water and wait for readings to stabilize.
6) When readings are stable select the correct site code, then select **Log one sample** (upper left) and press enter.
7) Readings are also noted in the field log.
8) Remove the sonde from the water and wait for readings to stabilize. Select the post-deployment site code (99) and when readings are stable select **Log one sample** (upper left) and press enter.

2.3.4 Data Upload

Upload data from the 650MDS to computer at the end of each field day. Connect the 650MDS to your computer using the YSI 655174 PC interface cable, launch YSI EcoWatch software, and establish communication with the 650MDS. From the <File> menu, <Upload> all the data files collected that day using the PC6000 format. This format results in a computer file with a .dat file extension. The default program for this extension will be YSI EcoWatch, and the file will not be readily editable (making it ideal for archiving purposes). Note that file names entered as part of the "Site List" are not created until data is logged into them. Only stations where data was collected will have data files.

Use EcoWatch to open each date file that you just downloaded and examine them to ensure they have not been corrupted and rendered unreadable in the upload process. Immediately create a CD back-up of the data files and confirm that they too are readable using EcoWatch. After these steps have been completed, reestablish communication with the 650MDS, select the <File> menu and <Delete all files>.

2.3.5 Data Reduction and Quality Control

Data collected by YSI sondes is uploaded from the sonde in PC6000 format. This format results in a computer file with a .dat file extension. The default program for this extension is YSI EcoWatch, and the file will not be readily editable, making it ideal for archiving purposes. To perform the data-reduction steps in this SOP, use the <export> feature in EcoWatch to create a comma-delimited file (.cdf), which can then be imported by most spreadsheet and database programs. To assist in file tracking and management, change only the file extension when converting from one format to another, but do not alter the filename. Also create a text document (.txt) with this same filename for documenting all data-reduction steps that are specific to that data file (data rejection). For each station sampled perform the data checks and data-reduction steps described below.

2.3.5.1 Dissolved Oxygen Calibration Check

Check the calibration of the DO sensor before and after each site. These calibrations are part of the data stream for each station since the sonde starts logging while still in water-saturated air. The in-air data (identified using the depth channel) at the beginning and end of each site should read between 97-103percent. If this is not the case, then proceed as follows:

1) If the pre-deployment DO percent saturation fails this test, then omit the entire profile from the data analysis. This occurrence will be rare since the operator is instructed to perform a check in the field and take corrective action if necessary.
2) If only the post-deployment DO percent saturation fails this test, if bottom water DO concentrations were less than 1 mg/L, or if there is a record of the sonde having hit the substratum, then use only the downcast for data analysis
3) If only the post-deployment DO percent saturation fails this test but a low DO concentration was not encountered, examine the DO and DO charge channels carefully and use best professional judgment on whether data can be salvaged.

2.3.5.2 Dissolved Oxygen Membrane Check

Check the "DO charge" for each reading to see that it ranges between 25 and 75. If the reading is outside this range, discard the DO readings (percent saturation and concentration) associated with this failed "DO charge" reading.

2.3.5.3 Sulfide-Interference Check

The presence of hydrogen sulfide will interfere with the Clarke-type electrode used for DO and make the output "jumpy". This effect is seen when the bottom water is anoxic and H_2S is present or when the sensor is run into anoxic sediments. Reject faulty data as follows:

1) Check to see if the sonde touched the bottom during the deployment (reported on the Station Data Sheet). If so, and if the DO channels show erratic performance on the upcast, use only the downcast DO data for further analysis.
2) Check to see if the sonde encountered low DO during the profile. If so, then use only the downcast data for further analysis and use best professional judgment to clean up DO data from the downcast data.

2.3.5.4 Sensor-Performance Specification Check

Reject data outside the design specification range for each sensor. These specifications are currently as follows:

Temperature .... -5 to 45 ˚C
Conductivity .... 0 to 100 mS/cm
Dissolved Oxygen, percent saturation .... 0 to 500percent air saturation
Dissolved Oxygen, mg/L .... 0 to 50 mg/L
Dissolved Oxygen charge 25-75
Salinity .... 0 to 70 ppt

2.3.5.5 Absolute Data Rejection

Absolute data rejection is a means of removing erroneous values from the data record because the data do not meet basic principles of sensor behavior and (or) proper sonde deployment. Because absolute data rejection is based upon basic principles, data can be rejected using automated computer scripts with conditional arguments. Data must be rejected when the recorded value for any sensor is outside its performance specifications. Environmental specifications for each sensor are listed in section *2.3.5.4 Sensor Performance Specification Check*. Any data that fall outside the specification intervals must be removed from the official record.

2.3.5.6 Discretionary Data Rejection, Drift Correction, and Data Reduction.

Data rejection, drift correction, and data reduction must be carried out manually under the supervision of a program manager with experience in water-quality monitoring and knowledge of the YSI sonde and its application in this data-collection Protocol. Ideally, these steps are taken as soon as possible after completing a site so that corrective action can be attempted for any subsequent measurements. A rapid evaluation for any gross problems with the data record can be made using the graphing features of YSI's EcoWatch software. Examine the output from each sensor individually for any discontinuity in the data, which generally indicates catastrophic failure during the measurement. Sensor-specific details for data rejection and drift correction are provided in the following sections.

2.3.5.6.1 Temperature

The temperature sensor on the YSI 6560 temperature and conductivity probe is robust and unlikely to fail. Rare failure has been observed, however, and is most often associated with an irreversible malfunction from leakage of the sensor housing. Incorrect temperature data are indicated by a clear point of temperature discontinuity followed by unreasonable and erratic values or unreasonable drift. If clearly incorrect temperature data are observed, all data from that point on must be removed from the official record. Since all the other sensors are temperature compensated using values from the 6560 thermistor, ALL data following failure of a temperature probe are suspect and must be removed from the official record.

2.3.5.6.2 Conductivity

Like the thermistor on the YSI 6560 temperature and conductivity probe, the conductivity cell is robust and rarely shows catastrophic failure. If an error occurs, it is usually a drift of the output from biofouling within the water ports of the conductivity cell. This results in a change in the effective volume of the cell, which, in turn, results in drift of the output. The post-deployment calibration indicates whether such a drift has occurred. Cleaning of the sensor ports usually resolves the issue.

In the unlikely event of catastrophic sensor failure, a sharp discontinuity is evident in the output, and all subsequent data must be removed from the record.

2.3.5.6.3 Dissolved Oxygen

The YSI 6562 DO probe is susceptible to both drift and catastrophic failure.

Catastrophic failure of the DO probe is more common, and is usually the result of a puncture in the membrane, either by debris or organisms, or from an improperly installed membrane. Under these scenarios, output is generally characterized by a large discontinuity. Readings then become unreasonably high quickly and either become noisy or drift. The likely cause of this behavior is “crosstalk” through the membrane hole caused by electrical continuity between the DO and conductivity sensors through the brackish estuarine water. All data after the initial discontinuity must be removed from the record, regardless of later probe behavior. After this type of catastrophic failure, recondition the probe surface before it is put back in service. Follow guidance in the YSI 6-Series Environmental Monitoring Systems Manual. Occasionally the DO probe fails because of structural failure of the Clark-type electrodes. The symptoms are similar, and are accompanied by high DO-charge values. All data after the initial discontinuity must be removed from the record.

2.3.6 Probe Care and Storage

Of the probes used for this protocol, the YSI 5662 Dissolved Oxygen Probe has the most limited life expectancy. Under normal circumstances, the probe performs well for at least 2-3 years, and requires resurfacing during this period. Consequently, it is important to keep replacement probes on hand to replace a probe that fails to calibrate properly. Note, however, that this DO probe also has a limited shelf life, so do not purchase replacements too far in advance of need.

pH probe electrodes also have limited life expectancy and must be kept clean and stored properly. If the response of the probe seems slow or contaminants or deposits appear on the glass or platinum surfaces, carefully clean the probe. Use clean water and a soft clean cloth or a cotton swab to remove all foreign material fr0m the glass bulb. Be careful not to wedge swab tips between the guard and the glass sensor. If good pH response is not restored by the above procedure, perform the following additional procedure:

1. Soak the probe for 10-15 minutes in clean water containing a few drops of commercial dishwashing liquid.

2. GENTLY clean the glass bulb and platinum button by rubbing with a cotton swab soaked in the cleaning solution.

3. Rinse the probe in clean water, wipe with a cotton swab saturated with clean water, and then re-rinse with clean water.

If good response is still not restored by the above procedure, clean with hydrochloric acid or return to YSI for cleaning or replacement.

Because pH probes can dry out if improperly stored it is important for both short and long-term storage to make sure that the reference electrode junction does not dry out.

YSI recommends that short-term storage of all multiparameter monitoring instruments be done by placing approximately 0.5 inch of water in the calibration and (or) calibration cup, that was supplied with the instrument, and by placing the sonde with all of the probes in place into the cup. The use of a moist sponge instead of a half-inch of water, is also acceptable as long as its presence does not compromise the attachment of the calibration cup to the sonde. The calibration cup should be sealed to prevent evaporation.

The long-term storage protocol for model 600XL, 6820, 6600 and 6920 systems are as follows:
Remove the pH or pH/ORP probe from the sonde and seal the empty port with the provided plug. Place the probe in the storage vessel (plastic boot or bottle) which was in place on delivery. The vessel should contain a solution which is 2 molar in potassium chloride. Make certain that the vessel is sealed to prevent evaporation of the storage solution. Electrical tape can be used to provide a removable seal between the boot and the module body.

2.3.7 Health and Safety Warnings

The standard solutions for calibrating conductivity contain Iodine and Potassium Chloride. Standard solutions for the calibration of pH contain the following compounds:

pH 4 Solutions-- potassium hydrogen phthalate, formaldehyde, water; pH 7 solutions-- sodium phosphate (dibasic), potassium phosphate (monobasic), water; pH 10 Solutions-- potassium borate (tetra), potassium carbonate, potassium hydroxide, sodium (di) ethylenediamine tetraacetate, water.

When using the above mentioned standards, avoid inhalation, skin contact, eye contact, or ingestion. If skin contact occurs remove contaminated clothing immediately. Wash the affected areas thoroughly with large amounts of water. If any solutions are inhaled, ingested or contact eye surfaces, consult the Material Safety Data Sheets (MSDS) that are sent with the standards for prompt action, and immediately seek medical attention.

2.4 SOP 4—Grab Samples and Depth-Integrated Samples

A grab sample is a discrete sample taken at a selected site, depth, and time; and analyzed for the constituents of interest (Table 25). A depth integrated sample is a composite sample taken with a collection bottle or tubing across a range of depths at a single vertical, and a width integrated sample is taken at more than one vertical in a stream cross-section. See section *3.2 Grab Samples in Streams* for a description of the method for collecting grab samples in streams and section *4.3 Grab Samples in Lakes and Ponds* for a description of the method for collecting grab samples in lakes and ponds. Depth-integrated epilimnetic samples in lakes are composite samples that contain water which is representative of a range of depths, or a specific layer of the lake. See section *4.4 Depth-Integrated Epilimnetic Samples in Lakes and Ponds* for a description of the method for collecting depth-integrated epilimnetic samples in lakes. The decision on what sampling method to use will be dictated by both the existing field conditions and the judgment of the sampling team.

2.4.1 Sample Container Preparation

For single point grab samples, the sample bottle can be used as the sampling device. For composite samples such as depth and (or) width integrated samples, an isokinetic bottle sampler is used in conjunction with a churn in order to collect the sample and ensure it is well-mixed. Select the appropriate sized precleaned and relabeled sample bottle. Samples should be taken in a prearranged priority so that all sample handling and preservation can take place as rapidly as possible. Sample containers, sample size, and preservation requirements for water samples are presented by parameter. Bottles are purchased annually.

2.4.2 Cleaning of Bottles and Equipment

Clean the sample bottle, churn splitter, and all tubing before each field trip.
Use a non-phosphate detergent (such as Liquinox) with tap water. Soak in detergent solution for 30 minutes. Wearing disposable, powderless latex or vinyl gloves, scrub with a soft brush. Rinse well with tap water and then rinse with deionized water. Upon arriving at each field site rinse the sample bottle and churn with native water. Place cleaned equipment in clean storage bags. Rinse all sample bottles and (or) collection

bottles three times before filling with sample water. After sampling, rinse equipment used (such as the sample bottle, tubing and churn) with deionized water.

2.4.3. Sample Filtering and Preservation

If an appropriately clean location for filtering is not available, samples can be stored in bottles and kept cold until a more suitable filtering location is available. Sample filtering, preservation and splitting are done as soon after collection as is possible. Samples that will be filtered (dissolved constituent samples) can be collected into a clean collection bottle and then pumped directly from the collection bottle, through the filter and into the sample bottle

Filtering: A battery-powered peristaltic pump is commonly used for filtration of samples for the analysis of dissolved constituents. The pump forces the water through tygon tubing and through a 0.45-mm-pore-size capsule filter. The particulate matter is retained by the filter while the filtered water passes through to the sample bottle. Use filters for one site only and then discard. Filters are not to be reused.

1) Clean the tubing by washing in a Liquinox solution and rinsing with tap water and then deionized water (as with sampler bottle and churn).
2) Filtered samples are drawn directly out of collection bottle, through the filter and into the sample bottle. If a churn is being used for a composite sample, filter the water remaining in the churn after all “total” samples have been drawn off from the churn splitter. The sample to be filtered does not need agitating.
3) Connect the pump discharge tube to the capsule filter. Be sure that the direction of flow through the capsule filter matches the arrow on the side of the filter. Rinse the intake tube with sample water and place the tube into the sample to be filtered.
4) Connect the pump to the appropriate power supply with power switch off.
5) Turn the pump on low speed and allow air to vent. Do this by holding the filter so that the arrow is pointing up.
6) Flush the system (tubing and filter) with at least three times the filter capacity of sample water. If the sample water is full of particulate matter, first filter deionized water through the system.
7) Rinse the bottles three times. Fill all appropriate subsample bottles with the filtered sample. Include total dissolved nitrogen, total dissolved phosphorus, ammonia, nitrite, nitrate, and orthophosphate samples.
8) Fill the container to the desired volume (leave about 1 percent of the container's capacity to allow for the addition of preservatives (if necessary) and expansion if samples are to be shipped).
9) Insure that all bottle caps are screwed on tight. Verify the sample labels are correct and complete. Place the labeled sample container in a cooler packed with ice.

10) Rinse the container's outside surface with clean water and dry with a paper towel. Rinse the hoses with deionized water.

11) Dispose of used ampules properly.

12) Maintain an up-to-date field book in which to note setting, staff, equipment used, environmental conditions, and problem areas.

Preservation: Samples for some constituents must be stabilized by preservative treatment. Preservative treatment includes refrigeration or acidification. Sample bottles must be labeled to indicate how the sample was treated. The designations used are: R = unfiltered, F = filtered through 0.45 um filter, A = acidified, C = chilled to 4 C, U = untreated. Preservatives such as sulfuric acid (H_2SO_4) are available in ampules. It is important to reduce the possibility of contaminating samples during the preservation process. Be sure the outside of the ampules are clean. Place bottles in the shipping container after the following steps are taken:

1) Wearing latex or vinyl gloves, add the required acid to appropriate samples.
2) Insure that all bottle caps are screwed on tight.
3) Dispose of used H_2SO_4 ampules properly.

Table 25. Collection and preservation of stream-water-quality parameters including ANC, color, total nitrogen, total phosphorus, ammonia, nitrate, nitrite, orthophosphate, and algal biomass

[mg/L, milligram per liter; W, whole; R, unfiltered; F, filtered through 0.45 um filter; A, acidified; C, chilled to 4 C; U, untreated; To facilitate the goal of consistently using one laboratory with adequate QA/QC procedures, this table pertains specifically to the USGS NWQL. Other laboratories may be acceptable]

Parameter Name	USGS Parameter code	USGS NWQL Lab code	Treatment	Bottle type	Bottle code	Reporting limit	Reporting unit
Stream Samples							
Total nitrogen	62855	2756	Unfiltered, acidify	125 mL plain poly	WCA	0.06	mg/L
Total phosphorus	00665	2333	Unfiltered, acidify	125 mL plain poly	WCA	0.02	mg/L
Total dissolved nitrogen	62854	2754	Filter, chill	125 mL brown poly	FCC	0.06	mg/L
Total dissolved phosphorus	00666	2331	Filter, chill	125 mL brown poly	FCC	0.006	mg/L
Nitrogen, ammonia	00608	3116	Filter, chill	125 mL brown poly	FCC	0.02	mg/L
Nitrite	00613	3117	Filter, chill	125 mL brown poly	FCC	0.002	mg/L
Nitrite + Nitrate	00631	1979	Filter, chill	125 mL brown poly	FCC	0.016	mg/L
phosphate, ortho	00671	3118	Filter, chill	125 mL brown poly	FCC	0.006	mg/L
ANC	90410	70	Raw, untreated	250 mL plain poly	RU	5	mg/L CaCo3
Color	00080	20	Raw, chill	250 mL plain poly	RCB	1	Pt-Co unit

Lake samples

Total nitrogen	62855	2756	Unfiltered, acidify	125 mL plain poly	WCA	0.06	mg/L
Total phosphorus	00665	2333	Unfiltered, acidify	125 mL plain poly	WCA	0.02	mg/L
Total dissolved nitrogen	62854	2754	Filter, chill	125 mL brown poly	FCC	0.06	mg/L
Total dissolved phosphorus	00666	2331	Filter, chill	125 mL brown poly	FCC	0.006	mg/L
Nitrogen, ammonia	00608	3116	Filter, chill	125 mL brown poly	FCC	0.02	mg/L
Nitrite	00613	3117	Filter, chill	125 mL brown poly	FCC	0.002	mg/L

Parameter Name	USGS Parameter code	USGS NWQL Lab code	Treatment	Bottle type	Bottle code	Reporting limit	Reporting unit
Nitrite + Nitrate	00631	1979	Filter, chill	125 mL brown poly	FCC	0.016	mg/L
phosphate, ortho	00671	3118	Filter, chill	125 mL brown poly	FCC	0.006	mg/L
Color	00080	20	Raw, chill	250 mL plain poly	RCB	1	Pt-Co unit
Chlorophyll *a*	70953	2645	Filter, rec. volume	Glass fiber filter	CHY (filter)	0.1	ug/L
ANC	90410	70	Raw, untreated	250 mL plain poly	RU	5	mg/L CaCo3

2.4.4. Field Quality Assurance

The Field QA program is a systematic process which, together with the laboratory and data storage QA programs, ensures a specified degree of confidence in the data collected for an environmental survey. The Field QA program involves a series of steps, procedures, and practices described in the following sections.

2.4.4.1. General Measures

All equipment, apparatus, and instruments must always be kept clean and in good working condition by means of the methods and practices given elsewhere in this protocol. Records are kept of all repairs to the instruments and apparatus and of any irregular incidents or experiences that affect operation. It is essential that standardized and approved methodologies, such as those recommended in this protocol, be used by field staff. If any changes to the approved methods are made, they must be documented and experimental data obtained to ensure that the results are valid and comparable to the earlier data.

2.4.4.2. Prevention of Sample Contamination

The quality of data generated in a laboratory depends primarily on the quality of the samples received at the laboratory. Consequently, the field investigator must take the following precautions to protect samples from both contamination and deterioration. There are numerous routes by which samples can become contaminated. Potential sources of trace-metal contamination during sampling include metallic or metal-containing sampling equipment, containers, labware, reagents, and deionized water; improperly cleaned and stored equipment; atmospheric inputs such as dirt and dust from automobile exhaust, cigarette smoke, nearby roads, and wires. Human contact can also contaminate the samples. The following are some of the basic contamination prevention methods:

1) Clean collection bottles according to recommended methods.
2) Use only the recommended type of sample bottle for each parameter.
3) Use only water sample bottles for water samples. Do not use bottles that have been used for other purposes, such as storing concentrated reagents.
4) Follow recommended preservation methods. All preservatives must be of analytical grade and included as field blanks for identification of potential contamination.
5) Minimize the possibility of adding the wrong preservative to a sample or cross-contaminating the preservative stocks when preserving samples by preserving all the samples for a particular group of parameters together.
6) Do not touch the inner part of sample bottles and caps with bare hands, gloves, mitts.

7) Keep sample bottles in a clean environment, away from dust, dirt, fumes and grime. Vehicle cleanliness is an important factor in eliminating potential contamination of samples and equipment.
8) Keep petroleum products (gasoline, oil, exhaust fumes), prime sources of contamination, away from samples. Exhaust fumes and cigarette smoke can contaminate samples with lead and other heavy metals. Air conditioning units are also a source of trace-metal contamination.
9) Keep filter units and related apparatus clean using procedures such as acid washes and soaking in special solutions, and protected from field contamination.
10) Keep bottles or sample bags, which have been sterilized, sterile until the sample is collected.
11) Keep all foreign, especially metal, objects out of contact with acids and water samples.
12) Store out of the sunlight in the upright position at 4^oC in a cool place, ice chest, or equivalent.
13) Ship samples to the laboratory without delay.
14) Keep hands clean while working with water samples and field equipment.

2.4.5 Field Quality Control

The total number of field QC samples will be at least 10% of the number of samples collected. At Acadia, one blank will be collected in May (streams), and one in August (lakes). Replicates will be collected in May (1 stream), June (1 lake), and August (1 stream and one lake). For the rest of the network, one blank will be collected in May (streams) and one in August (streams). Replicates will be collected in May (2 stream), June (1 lake), and August (2 stream). Given an overall number of 92 or 93 samples per year, these numbers mean that QC samples equal approximately 13% of the total samples. If multiple labs are used for any analyses, replicates will be swapped between labs to provide a check on procedures plus laboratory results. In the event of a discrepancy, additional replicates will be needed to isolate the source of the problem (e.g. lab versus field procedures).

2.4.5.1 Blanks for the assessment of contamination

Blank QC samples are free of the analyte(s) of interest and are used to test for bias from the introduction of contamination into field samples during collection, handling, and processing. Contamination results in a positive bias in the concentration. Field blanks measure nearly all of the sources of error that can affect field samples, and thus they are used to document data quality and to identify data-quality problems. If a data problem is found, topical blanks are used to locate the source of the problem and could consist of equipment blanks, source water blanks, trip blanks, or laboratory blanks. Protocols for grab samples must be followed for the collection of blank samples to ensure that blanks are representative of the type of field sample being tested. All blanks that are taken must be well documented as to how, when, why, and where they were taken. Environmental samples are labeled with the time to the nearest 5 minutes. Add a time tag for each blank sample that is 2 minutes after the time for the grab sample so that these blank samples can be easily identified.

See section on deionized water in section *2.3.2.2.2 Standard Solutions* for a justification of the importance of purchasing a laboratory grade water to be used for blank samples. Use inorganic blank water or universal water.

Blanks are taken for each analyte at the beginning of each field season and then each time there is a change in equipment and staff. For example, if more than one field crew or park manager is collecting water samples, each crew collects a minimum of 1 blank for each schedule of analytes with the potential for contamination, mainly the nutrients. Throughout the season, collect a blank sample for each trip. For example, if one technician is going around to all of the parks in May and in August, collect one blank on each of these trips, at different parks each time. Initially, blanks are used singly to compare blank analysis to critical concentrations such as water-quality standards, and to alert staff of contamination problems and identify the need for topical blanks, if necessary. As enough blanks are collected throughout each park and throughout NETN, nonparametric statistics can be done on the blanks to obtain confidence limits for selected percentiles of contamination that can be estimated based on concentrations of the analytes in the blanks (see section *7.1.1 Quality Control Reporting*).

Examine blank samples when returned from the laboratory so that if contamination is occurring, topical blanks and (or) adjustment of methods can be made as soon as possible. Confidence limits for selected percentiles of contamination and bias are calculated and reported annually as a part of the annual data report.

2.4.5.2 Replicate Samples for the assessment of precision

Collect field replicates at the beginning of the season and then each time there is a change in equipment or staff. If possible, have old staff members and new staff members collect replicate samples to ensure that each staff member is following protocols adequately and not introducing additional variability. Collect one field duplicate for every 10 samples to assess measurement precision. Collect one set of replicates on each trip around NETN, making sure that it is collected in different parks on different trips so that over time, the set of replicates can be used to determine QC across NETN. Do not to take replicate samples in waters in which one would expect a non-detect because the usefulness of two replicate “non-detects” is limited.

2.4.5.3 Measurement Sensitivity and Detection Limits

Censoring to quantitative detection limits, though not often optimal or even desirable for trend assessment, is appropriate when a data user is assessing compliance with environmental regulations or trying to determine if a concentration or summary statistic is below a concern threshold for endangered species or other special-value resources in National Parks. If such especially high-value resources are at risk, it is appropriate to apply the precautionary principle and avoid false negatives (saying the contaminant is below a certain concentration, when it really is not).

Some pristine waters in the NPS have low concentrations of nutrients, and the parks want to ensure that nutrient levels remain low. Thus it is beneficial to document and control measurement sensitivity with the lowest practicable low-level detection limits. For some parameters measured in the field such as pH, temperature, conductivity, biological observations, physical habitat observations, extremely low levels are rare. In the high measurement ranges, the smaller the (true) change that a measuring system can reliably and accurately detect, the more sensitive the instrument is.

2.5 SOP 5—Safety

Safety of field staff is always the first concern in conducting a sampling program and in the selection of sampling sites. The desired sampling frequency for most monitoring exposes sampling technicians to a variety of potentially hazardous field conditions across all seasons and climatic conditions, in addition to unforeseen, potentially catastrophic, short-term natural events (floods, storms) that can occur during the field effort.

As a result, field sampling requires planning that anticipates the risks and dangers to field staff so that precautions can be taken to limit threats to human safety as much as possible. NETN staff must produce a safety plan, or job hazard analysis (JHA) before conducting field work. This plan includes a description of general hazards for field sampling and hazards that are unique to particular monitoring stations within NETN. In addition, the plan includes the nearest hospital facilities to each sampling site, the most direct route from various sampling sites to the hospital, and emergency phone numbers. Applicable elements for a network-specific water-quality-monitoring safety plan that address physical hazards common around water and biological hazards, poisonous plants and animals are also included. A thorough review and familiarity with the safety plan is required of all sampling staff and a copy of the plan for ready reference always accompanies field staff to the field (Penoyer, 2003).

Always check weather conditions before departure, and leave an itinerary with a supervisor or other designee. The safety plan includes at a minimum, the following:

1) Date and purpose of trip,
2) Name of all staff and volunteers on trip,
3) Destination and route,
4) Time of departure and estimated time of return,
5) Radio frequency or cell phone number, and
6) Type of watercraft, if applicable.

All safety procedures included here are adapted from Chapter A9 of the USGS National Field Manual and staff performing hydrologic field work must familiarize themselves with that document found at: *http://water.usgs.gov/owq/FieldManual/Chap9/content.html*. Included in this protocol in the following sections are some safety concerns related specifically to working in and around the water and water-quality sampling.

2.5.1 Surface-water Activities

2.5.1.1 Wading

Examine the section of a stream or river you plan to wade. Check the field folder for information relating to safety, including maximum depths in relation to stage, wading-section anomalies such as slippery conditions and drop-offs or holes (a wading rod can be used to help assess streambed conditions), and velocity curves for determining wadable stages. **Do not attempt to wade a stream for which values of depth multiplied by velocity equal or exceed 10 ft^2/s.** For example, a stream only 2 ft deep but with velocities of 5 ft/s or more can be dangerous to wade.

1) Always wear an approved personal floatation device (PFD) when wading in streams. The PFD must fit properly, be rated for your weight, be in good condition, and be kept dry and indoors between trips. Whenever chest waders are worn, a PFD also must be worn.
2) Wear hip boots or chest waders. Boots and waders provide protection from cold and pollutants, as well as from underwater objects. Be aware of the possibility of slipping and going underwater (ft up, head down) while wearing them. Practice wearing hip boots and waders in a controlled, group-training situation that includes immersion in a swimming pool before using for field work. Avoid hip boots with tight ankles or chest waders that are tight fitting at the top. These are difficult to remove in an emergency situation. Hip boots and chest waders with a strap that is pulled closed allow reduce water coming into the boot.

Watch for debris floating downstream, such as logs, aquatic vegetation, or "rafts" of animals seeking higher ground. Watch for sand channels that can shift under foot and become quicksand. Watch the stream stage, especially when it could rise rapidly. When wading below a dam or control structure, contact the gate operator before entering the stream.

2.5.1.2 Working from Boats

All boats must carry equipment as required by the U.S. Coast Guard (USCG). Checklists are useful for ensuring that all the proper equipment is in place. Safety regulations for the various types of boats used by the NPS when obtaining water-quality samples are comprised of USCG and Occupational Safety and Health Administration (OSHA) rules.

Before working from a boat, obtain the appropriate training for the vessel being used. This training will cover all the specifics regarding boat operation as per USCG regulations. Before taking a boat on the water, ensure that the vessel is in operating condition. Boats are to be inspected annually. If a vehicle is being used to trailer the boat to the site, the vehicle and trailer are to be included in the preliminary inspection. Equip the boat with all items that the study team deems appropriate for emergencies or equipment failures.

2.5.2 Chemicals

Employees may be routinely exposed to chemicals during the water-quality sampling process. Chemicals--as solids, liquids, or gases--range from dilute salt solutions to strong acids, bases, dyes, and organic compounds. Field measurements and the processing of sample water can cause chemical reactions that generate dangerous fumes and by-products.

Be cognizant of the regulations that govern the use, transportation, and disposal of chemicals and wastes. Because regulations vary greatly from state to state, contact your safety officer or state agency for the proper procedures in your locality. Use proper personal protective equipment, and apply common sense when working with dangerous substances. Adhere to the following safety guidelines:

1) Avoid unnecessary exposures and spills. Never place chemical containers where they can be knocked over.
2) Clean up chemical residues or spills immediately and appropriately. Keep chemical spill kits near the work area.
3) Work with adequate ventilation or under a hood when working with hazardous or reactive chemicals and gases.
4) Keep eye wash kits readily accessible while working with chemicals.
5) Handle and mix chemicals and compounds appropriately (check the MSDS). For example: when transferring flammable liquids, all metal containers must be grounded to eliminate igniting the liquid with an electrical spark.
   When preparing a hydrochloric or nitric acid cleaning solution, the sequence is to put water in the vessel first and then add the acid.
6) Open chemical containers slowly and carefully, wearing proper personal protective equipment. Open frozen or encrusted lids with caution. For example, to open fused-glass ampules, break the ampule at the base of neck, in a direction away from you and others. Use an ampule breaker if it is safer for you, and wear latex gloves.
   Check containers and ampules for contents lodged near the container top or neck. Dislodge trapped material by gently tapping the container at the top.
7) Properly dispose of all parts of the spent ampule. Temporarily store used ampules in an appropriate container. Do not let these wastes accumulate in your vehicle or work area--they produce corrosive and potentially explosive fumes. Do not discard any wastes into the environment.

2.5.3 Environmental Conditions

Field work often is necessary under adverse atmospheric and other environmental conditions. Prepare for extreme temperature conditions that might be experienced in your area of the country. Before leaving for the field, check the weather forecast. Be familiar with temperature-related conditions such as hypothermia and sun exposure including how to recognize and treat them.

Thunderstorms, which can be accompanied by hail, are common throughout the United States. Some are predicted by weather forecasters. Others can move into an area with almost no advance warning. Watch the sky for signs of thunderstorms, and seek shelter before the weather deteriorates.

Rain can fall at a rate of several inches per hour and rapidly create dangerous flash flood conditions, either in the area where you are working or several miles away. Weather forecasts will be helpful in planning your activities accordingly to ensure your safety. Maintain an updated copy of your district flood plan. Always be aware of rapidly rising stages in rivers and creeks. Beware of dry creek beds that can become raging rivers in a short period of time.

Working on ice requires experience, training, and knowledge of the waterbody over which the ice has formed. Wear layers of appropriate clothing and work in teams.

Safety precautions as listed previously are not all-inclusive, but rather pertain to those commonly encountered while working in and around water. Adhere to additional environmental and safety hazards as identified by the NPS.

3 SOPs for Monitoring Streams

The standard operating procedure (SOP) for streams includes SOPs for the collection of streamflow data and for the collection of stream water-quality data, including water chemistry and nutrients. Water-quality SOPs follow the USGS's National Field Manual for the Collection of Water-quality Data (U.S. Geological Survey, variously dated) and from a Water-quality Inventory Protocol for Riverine Environments prepared for the NPS (Stednick and Gilbert, 1998) unless otherwise noted**.** Properties such as temperature pH, specific conductance, and DO concentration are measured directly in situ. Other parameters such as color, nutrients, algal biomass, and ANC are collected as grab samples and analyzed in a laboratory. Water quantity or streamflow SOPs follow USGS protocols in all cases (Rantz et al, 1982). Water-quality measurements in streams are taken according to the schedule outlined in *1.2 Sampling Design*.

3.1 SOP 6—In Situ Measurements of Specific Conductance, pH, Temperature, and Dissolved Oxygen in Streams

Measurements with the water-quality sonde are made following protocols outlined in section *2.3 SOP 3—In Situ Measurements of Specific Conductance, pH, Temperature, and DO using Multiparameter Water-quality Monitor (Sonde).*

Set the YSI sonde to update its readings every 1 second with an time constant of 12 seconds as outlined in section *2.3.2.1.4 650MDS <Sonde Menu>*. Set up a user site list on the YSI 650MSD before taking readings in the field by selecting <Logging Setup> and activate <Use site list> (see YSI Operators Manual Section 3)

1) The sonde must be allowed to warm up for 4 to 5 minutes before taking measurements. Turn on the sonde by powering up the 650MDS and selecting <Sonde run> from the main menu.
2) Once the sonde has warmed up, and with the unit still wrapped in the wet towel inside the transportation bucket, check the DO percent local saturation ("DOpercent") and record this value.
3) Confirm that it reads 100 percent ± 2 percent. If the DO percent local saturation has drifted beyond these tolerances, the DO channel must be recalibrated on the spot. (See section 2.3.3)
4) Log pre-calibration sample in the 89 file
5) Place the sonde in the water and wait for readings to stabilize.
6) When readings are stable, select the *Log one sample* (upper left) and press enter.
7) Note readings in the field log.
8) Record at as many points as is appropriate for the given site and cross section. If the stream is fully mixed and small, only one point is needed from the middle of the channel. The only site within NETN that needs multiple points is the Concord River.
9) Log post-calibration sample in the 99 file

Make measurements on predefined waterbodies at predefined sampling sites according to section *1.2 Sampling Design*. Flowing-water sampling sites optimally are located:

1) At or near a streamflow-gaging station, to obtain concurrent surface-water discharge data required for computing constituent-transport loads and to determine discharge/constituent-concentration relations. (Measure discharge at time of sampling if a gaging station is not at or near the sampling site or if discharge cannot be rated or estimated with sufficient accuracy);
2) in straight reaches with uniform flow, with a uniform and stable-bottom contour, and where constituents are mixed along the cross section. Sample streams at a pool below a riffle or quickwater section. This ensures mixing just before the

sample site, resulting in a more integrated sample, and minimizes inclusion of large particles of litter, soil, etc. in the sample;

3) far enough upstream and downstream of confluences of streamflow or point sources of contamination to avoid sampling a cross section where flows are poorly mixed or not unidirectional;
4) in reaches upstream from bridges or other structures, to avoid contamination from the structure or from a road surface;
5) in unidirectional flow that does not include eddies. (If eddies are present within the channel, sample only the unidirectional flow);
6) at or near a transect in a reach where other data are collected (such as data for suspended sediment, bedload, bottom material, or biological material) and (or) for which historical data are available; or
7) at a cross section where samples can be collected at any stage throughout the period of study, if possible.

Note that the optimal flowing-water-sampling site can vary depending on the flow. Adjust sampling site, if warranted, on each trip as long as the sampling site consistently remains within the same reach, there are no inflows or outflows between the original sampling site and the new sampling site, and there is reason to believe the stream is well-mixed at various stages.

3.2 SOP 7- Grab Samples in Streams

Grab samples are made at predefined sampling sites (section *1.2 Sampling design*) according to protocols outlined in section *2.4 Grab Samples and Depth-Integrated Samples*. The following SOP is adapted from Stednick and Gilbert (1998) and U.S. Geological Survey (variously dated) and outlines the sample collection for both grab and depth-integrated samples.

Grab samples are often used for small streams where depth integration is not possible or on small well-mixed streams where a grab sample taken at the centroid of flow represents the water quality throughout the cross-section (Stednick and Gilbert, 1998). Single point grab samples are sufficient for well-mixed streams that are less than 2 ft in depth, which includes many NETN streams during summer lowflows. Samples that will be filtered can be collected into a clean collection bottle and then pumped directly from the collection bottle, through the filter and into the sample bottle. Any other samples should be collected directly into the sample bottle or into a churn to ensure that they are well mixed.

For sampling sites located on a nonhomogeneous reach of a river or stream, it is necessary to sample the channel cross section at multiple points and depths in order to obtain a composite sample. In these cases, isokinetic bottle samplers should be used to collect the sample which is then composited and mixed in a churn splitter. Sample wide shallow streams at a single depth at several points. If sampled at several points, the samples can be analyzed either as individual samples to define variability and confirm that the stream is well mixed, or the samples can be combined as a composite sample to define the water quality of the entire stream cross section. If a shallow cross section is not well mixed, width integrated samples can be collected with a 1L wide mouthed collection bottle, and mixed and subsampled with an 8 L churn splitter to maintain the same basic chemical and physical properties of the original sample. Use an isokinetic bottle sampler if the cross section is greater than 2 ft in depth (Stednick and Gilbert, 1998). To obtain composite samples that are correctly weighted for concentrations and discharge, see U.S.Geological Survey, variously dated.

The following SOP outlines the process for colleting a single point grab sample in the centroid of flow. The appropriately sized bottle, treatment and label for each sample are listed in table 27. Water samples are collected using the following procedure:

1) Label all of the sample containers to be used with the site name or number, date, time and bottle treatment (table 27).
2) Put on latex or vinyl gloves (do not use nitrile gloves for nutrient samples).
3) Rinse the sample bottles and collection bottle with native water three times. Dispose of rinseate downstream or away from sample point to avoid potential contamination/site disturbance.
4) Collect the sample where the water is well mixed, immediately downstream from a point of hydraulic turbulence such as a knick point or flume or where streamflow appears laminar. Do not sample streams immediately below tributaries or other significant points of inflow. Sample far enough downstream for thorough mixing to have occurred (approximately 6 - 8 stream widths downstream should be adequate)
5) Do not walk on, or in any way disturb, the stream bottom upstream from the sampling site. Collect the sample upstream of where the sample taker is standing. Clear surface debris if present. Avoid water-quality sampling in pools or standing water where floating solids tend to accumulate.
6) Submerge the sample container below the water surface to the appropriate depth. To avoid contaminating the sample, collect samples with the mouth of the sample bottle or collection container pointed upstream. Keep hands and other potential contaminants away from the mouth of the collection container. If stream depth is inadequate for submersion of bottle, move upstream or downstream within the same reach. Collecting flowing water from flow off of a rock or small waterfall is a possibility.
7) Filter dissolved samples from collection bottle into sample bottles (see section 2.4.3 Sample filtering and preservation).
8) Preserve all samples according to section 2.4.3 Sample filtering and preservation and table 27.

3.3 SOP 8- Collection of Stage and Streamflow Data

The purpose of this SOP is to document the standards, policies, and procedures for the collection, processing, storage, and analysis of stream stage and streamflow. Use this SOP in concert with more specific instructions as outlined in Rantz et al (1982).

Streamflow is one of the most fundamental measurements of a stream ecosystem, and is necessary for the interpretation of water-quality measurements and the calculation of loads of those water-quality parameters including total maximum daily load (TMDL) calculations as specified in the Clean Water Act. It is useful to normalize water chemistry and water-nutrient measurements by flow in freshwater streams because many constituents tend to have strong relations with flow. Therefore, trend work in running waters is difficult unless one calculates flow-adjusted concentrations.

Discharge measurements can be made each time an estimate of streamflow is desired, or streamflow can be calculated from continuous or discrete readings of stage. A continuous record of stage is obtained by installing instruments that sense and record water-surface elevations. Stage can also be obtained for discrete measurements by reading water levels off of a staff plate or tape down from a fixed point (tape down) whenever the site is visited. Survey each year to ensure that the tape down point has not shifted from year to year. Make discharge measurements at periodic intervals to define or verify the stage-discharge relation (the rating). Establish tape down sites in pools that can be measured at a range of flows and that have a single stable controlling feature at their outflow.

Continuous measurement of stage verified by several annual measurements of discharge to define or verify the rating is the most accurate and complete method for estimating temporal fluctuations in streamflow. The installation and maintenance of this type of continuous gaging station may be cost prohibitive for most parks. Where a continuous-gaging station is not feasible, or where additional streamflow information is desired to interpret water-quality measurements across the park, there are two options.

Option 1 is to measure discharge each time an estimate of streamflow is desired. The advantages of option 1 are that an on-site or roving hydrologic technician can make these discharge measurements *if* given the proper training and support. One disadvantage of this option is that the streamflow measurements must be made on the same day that the water-quality sample is collected. If one agency is collecting streamflow data and another agency is collecting water-quality samples, these efforts must be closely coordinated. Another disadvantage is that ideally more than one field staff member is trained and available at each park (or in NETN) to make discharge measurements when the first field staff member is sick or on vacation. Training, support and a back-up plan for when the trained staff member is unavailable, is critical to the success of this option. Following QA procedures is vital including periodic check measurements by another qualified individual.

Option 2 is to install a staff plate or tape down point, develop a rating based on several calibration streamflow measurements per year, and then read off of the staff plate each time an estimate of streamflow is desired. The advantages of developing a rating are that just about any field staff member can quickly take a reading or make a tape down from a fixed point, as many times as necessary throughout the year (including every time a water-quality sample is collected), once the rating is established. This option requires a lesser degree of training and thus more field staff members can be efficiently trained to obtain the reading. The disadvantages include the expense of obtaining and maintaining the rating. The development and maintenance of a rating curve at a site can be contracted out to trained technicians who do this type of work on a regular basis. A minimum of three stable reference points must be maintained and surveyed every year to ensure that the tape down point has not shifted in elevation over time. Set reference marks in boulders, bedrock or manmade structures that are anchored below the frost line and marked for easy identification. The establishment of a rating curve requires several measurements per year for at least the first 3 years. If the rating is stable, discharge measurements can be made less frequently in subsequent years.

Establish staff plate or tape down points, and develop ratings at all stream water-quality-monitoring stations in all parks that do not have a continuous-record streamflow-gaging station (Option 2 as explained above). If Option 2 is not feasible because of funding or logistical constraints, a discharge measurement can be made each time water-quality measurements are taken (Option 1 as explained above). If Option 1 is adopted, it is still desirable (but not necessary) to measure stream stage each time a discharge measurement is taken so that a rating can be developed sometime in the future.

3.3.1 Continuous-Record Streamflow-Gaging Stations

Continuous-record gaging stations consist of the instrumentation necessary to have continual (at least every 15-minute) readings of water level or stream stage. In addition, several discharge measurements are made each year (see section *3.3.2 Direct Measurement with Current Meters).*

3.3.1.1 Installation and Maintenance

Proper installation and maintenance of continuous-record streamflow-gaging stations are critical activities for ensuring quality in streamflow data collection and analysis. Effective site selection, correct design and construction, and regular maintenance of a gage can make the difference between efficient and accurate determination of drainage-basin discharge or time-consuming, inadequate estimations of flow.

Sites for installation of continuous-gaging stations are selected with the intent of achieving ideal hydraulic conditions to the greatest extent possible. This includes unchanging natural controls that promote a stable stage-discharge relation, a stable pool to monitor stage, a satisfactory reach for measuring discharge throughout the range of stage, and the means for efficient access to the gage and measuring site (Rantz et al, 1982).

A program of careful inspection and maintenance of gages and gage houses promotes the collection of reliable and accurate data. A visual inspection is performed at sites by field staff during each site visit, approximately every two months. Other maintenance activities performed on a regular basis include the running of levels each year, checking battery voltage, cleaning the gage house, painting, and cutting brush near the gage house.

3.3.1.2 Measurement of Stage

Many types of instruments are available for measuring the water level, or stage, at gaging stations. There are non-recording gages and recording gages (Rantz et al, 1982). Collect surface-water stage records at stream sites with instruments and procedures that provide sufficient accuracy to support computation of discharge from a stage-discharge relation. In general, operation of gaging stations for the purpose of determining daily discharge includes collecting stage data at the accuracy of ±0.01 foot.

The simplest measurement of stage is a discrete measurement taken off of a staff plate with numbers marked on it or taping down from a fixed benchmark or bolt (tape down). Establish tape down sites in pools that can be measured at a range of flows and that have a single stable controlling feature at their outflow.

Procedures:

1) Note weather conditions and surface-water temperature on stage monitoring field form. Weather conditions (especially the wave conditions) are important for interpreting the accuracy of the stage measurement.
2) Place one of the nails in the end of the extension wand into the benchmark. Use the level bubble (keep bubble in the center of the circle) to keep wand straight and level.
3) Use folding ruler to measure from the exact surface of the water to the center of the nail on the other side of the extension wand. Double check to make sure the wand is level at the time of measurement.
4) Write the measurement on the field sheet (to the nearest hundredth of a foot), along with all other required information.

Typically, pressure-sensor recorders are installed as water-level recorders. Proper maintenance of gage instrumentation or replacement, if appropriate, of equipment is the responsibility of the individual who services the gage.

Accurate stage measurement requires not only accurate instrumentation but also proper installation and continual monitoring of all system components to ensure the accuracy does not deteriorate with time. To ensure that instruments, located within the gage house, record water levels that accurately represent the water levels of the body of water being investigated, "inside" and "outside" water-level readings are obtained by independent means.

At pressure-sensor gaging stations, the reference gage is a sturdy low-water outside staff gage or reference point of known elevation. Reset the instrument to the reference gage only when the stage in the stream is low, there is little wind or wave action, and there is minimal pile-up or draw-down around the reference gage. At high stages, the instrument is often a more reliable index of gage height than the high water outside gages. Smaller gage-height differences can be corrected later if additional inspections and (or) analysis show that the instrument was truly in error.

Field staff servicing the gage are responsible for comparing inside and outside readings during each site visit to determine if the outside water level is being represented correctly by the gages. Ensuring that instrumentation installed at gaging stations is properly serviced and calibrated is the responsibility of the field staff servicing the gaging stations. This responsibility is accomplished by routine review of all raw data and periodic checking of instrument calibrations. When deficiencies are identified, field staff are responsible for recalibration or replacement of the faulty equipment.

3.3.1.3 Station Documents

Certain documents are placed in each gage house for the purpose of keeping an on-site record of observations, equipment maintenance, structural maintenance, and other information helpful to field staff. Documents maintained at each gage house include (1) a table of the most recent stage-discharge relation (rating); (2) the most recent station description listing locations of measurement cross sections with guidance on which to use at various stages, information related to extreme events, and other information; (3) the level summary, listing all gages and reference marks and points at the site and associated elevations; and (4) the job-hazard analysis for the station. It is the responsibility of the field staff who service each station to exchange outdated material with updated gage documents as needed. When field staff visit a gage house and identify a need to update one or more of the documents, a note is made and the needed documents are replaced on the next visit to the gage.

The various instruments at a gaging station are set to register a water surface level above a selected level reference surface called the gage datum. The supporting structures of the gage such as backings, shelters, bridges, and other structures, tend to settle or rise as a result of earth movement, frost action, static or dynamic loads, vibration, or battering by floodwaters and flood-borne ice or debris. Vertical movement of a structure makes the attached gages read too high or too low and, if the errors go undetected, can lead to increased uncertainties in streamflow records. Leveling, a procedure by which surveying instruments are used to determine the differences in altitude between points, is used to set the gages and to check them from time to time for vertical movement (Kennedy, 1990). Levels are run periodically to all bench marks, reference marks, reference points, and gages at each station for the purpose of determining if any datum changes have occurred (Rantz et al, 1982).

Run levels at newly installed gaging stations at the time of construction and annually thereafter. Outside water-surface elevations are determined during each level run by direct leveling whenever possible, or through the use of a nearby reference point if direct leveling is impractical. Only automatic or tilting instrument levels are acceptable for level runs.

Levels are run by use of field methods and documentation methods described in Kennedy (1990). Level procedures followed by field staff pertaining to circuit closure, instrument reset, and repeated use of turning points are described in Kennedy (1990). The level instruments are kept in proper adjustment by use of peg tests (Kennedy, 1990) at least twice annually. In addition, level instruments are cleaned and recalibrated by a commercial surveying instrument company at least once every three years. Documentation of all tests, adjustments, and service is maintained for each instrument in a level log book.

It is the responsibility of the crew leader to ensure that all field level notes are checked in the field. The level information is entered in the level-summary form in the field by the crew leader. After returning to the office, the results of the levels are transferred to the level-results summary sheet, which shows the results of each set of levels at a station by year.

3.3.1.4 Site Documentation

Thorough documentation of qualitative and quantitative information describing each gaging station is required. This documentation, in the form of a station description and photographs, provides a permanent record of site characteristics, structures, equipment, instrumentation, altitudes, location, and changes in conditions at each site.

3.3.1.5 Station descriptions

A station description is prepared for each gaging station, and becomes part of the permanent record for each station. The station description is started at the time the gaging station is installed and completed when the first year's records are computed. Station descriptions are written and updated by the staff that run each gaging station. Station descriptions are reviewed and updated annually.

Station descriptions are written to include specific types of information in a consistent format (Kennedy, 1983). The description includes a sketch showing the location of all gages and measuring sections, a map of the gage location, a cross-section plot of the most commonly measured section, and a description of the gage in paragraph format such as that found in Kennedy (1983). All station descriptions are prepared and maintained in electronic format in files.

3.3.1.6 Photographs

Photographs of newly installed gage houses, station controls, and reference marks are made by field staff for the purpose of documenting gage-house construction, changes in control conditions, or to supplement various forms of written descriptions. Each digital photograph that becomes part of the station record is identified by appending descriptive information such as location, date, or flow rate on the electronic photograph. Electronic photographs are stored in files maintained by the field staff. Historic paper photographs are kept in office photograph files.

3.3.2 Direct Measurements with Current Meters

Discharge generally is measured in cubic ft per second or cubic meters per second and most often is determined by making measurements of a particular cross-sectional area of the river and the velocity of the water past that cross section. Velocity is typically measured by using a current meter. The meter consists of cups that are rotated by the action of flowing water. The speed of the rotation depends on the velocity of the water passing by the cups. Discharge then is calculated by multiplying the width, depth, and velocity of that section of the river.

Direct measurements of discharge are made with any one of a number of methods; the most common being the current-meter method. A current-meter measurement is the summation of the products of the subsection areas of the stream cross section and their respective average velocities (Rantz et al, 1982). Procedures used for current-meter measurements are described in Rantz et al (1982); Carter and Davidian (1968), and Buchanan and Somers (1969).

When field staff make measurements of stream discharge, attempts are made to minimize errors. Sources of errors are identified in Sauer and Meyer (1992). These include random errors such as depth errors associated with soft, uneven, or mobile streambeds, or uncertainties in mean velocity associated with vertical-velocity distribution errors and pulsation errors. These errors also include systematic errors, or bias, associated with improperly calibrated equipment or the improper use of such equipment. Current meters are also inspected before and after each measurement and tested at the conclusion of each field trip. The test results are recorded in the current meter log maintained for each meter and reviewed annually by the lead surface-water technician. All meters are also inspected annually by someone other than the person to whom the meters are assigned.

Field staff select the type of current meter to be used for each discharge measurement on the basis of general criteria presented in Buchanan and Somers (1969) and Rantz et al (1982). In general, a Price AA meter is used when most depths are greater than 1.5 ft across the section, and a Pygmy meter is used for depths between 0.3 and 1.5 ft. Rantz et al point out that at depths below 0.75 ft, the Pygmy meter under registers the velocity because of the boundary effects of the surface and stream channel. Despite this, the Pygmy meter is still recommended at depths down to 0.3 ft as the error associated with under registration, estimated in Rantz et al to be up to 5 percent at 0.3 ft, is considered acceptable when compared to the complexity of other measurement methods at these depths. When depths are consistently below 0.3 ft, modify the section to produce the desired depths or an alternative measuring method used. Meters are used with caution when a measurement must be made in conditions outside of the recommended ranges. Any deviations from these criteria are noted and the measurement accuracy is downgraded accordingly.

Do not make a change of meter during a measurement in response to the occurrence of two or more subsections in a single measurement cross section that exceed the stated ranges of depth and velocity. A change of meter is allowed when multiple measurement methods are used. For example, one meter can be used from a cableway for the main part of a channel, and a second meter used for wading a shallow overflow reach.

The spacing of observation verticals in the measurement section can affect the accuracy of the measurement (Rantz et al, 1982). Make observations of depth and velocity at a minimum of about 30 verticals where possible, to ensure that no more than 5 percent of the total flow is measured in any one vertical. Even under the worst conditions the discharge computed for each vertical should not exceed 10 percent of the total discharge and ideally not exceed more than 5 percent (Rantz et al, 1982). Exceptions to this policy are allowed in circumstances where accuracy would be sacrificed if this number of verticals were maintained, such as for measurements during rapidly changing stage (Rantz et al, 1982). Fewer verticals than are ideal are sometimes used for very narrow streams (about 12-ft wide when an AA meter is used and about 5 ft wide when a pygmy meter is used). Measurement of discharge is essentially a sampling process, and the accuracy of sampling results typically decreases markedly when the number of samples is less than about 25.

Use procedures for the computation of mean gage height during a discharge measurement presented in Rantz et al (1982). Mean gage height is one of the coordinates used in describing the stage-discharge relation at a streamflow-gaging site.

3.3.2.1 Quality Control

A second discharge measurement is made for the purpose of checking a first discharge measurement when the first measurement differs from the current stage-discharge relation by more than the estimated accuracy of the measurement, or when the first measurement is of lesser accuracy (for example, rated fair or poor), and a second measurement of greater accuracy (for example, rated good) is possible. When a check measurement is made, as many factors affecting the measurement as possible are changed, including staff, instruments, and measuring section.

Since the stage-discharge relationship is not established and maintained for most NETN streams, field staff should verify their accuracy with one second measurement each month at a randomly selected site, and three measurements per season taken at a USGS gaged station.

3.3.2.2 Field Notes

Thorough documentation of field observations and data-collection activities performed by field staff is a necessary component of data collection and analysis. To ensure that clear, thorough, and systematic notations are made during field observations, discharge measurements are recorded by field staff on the discharge-measurement note sheet or in an electronic format. Original observations, once written on the note sheet, are not erased. Original data are corrected by crossing the value out then writing the correct value. Some examples of original data on a discharge-measurement note sheet include gage readings, depth, distance from initial point, water surface to bottom of ice, revolutions, vertical or horizontal angles, and time. Examples of information on a discharge-measurement note sheet that is derived from original data, but not in itself original data, include total discharge on the front sheet, mean gage height, width, area, and velocity. Derived data can be erased for the purpose of correction.

Compute all discharge measurements before leaving the measurement site, unless emergency evacuation is required for reasons of safety. Information required to be included by field staff on the measurement note sheet includes, at minimum, the initials and last name of all field-party members; date; times associated with gage readings and other observations; suspension weight used; coefficients used; type of meter used; meter number; location of measuring site; measurement rating; condition of the meter before and after the measurement; and descriptions of the cross-section, flow, weather conditions, and control. A review of field note sheets is required after each field trip by the crew leader. Field notes are also reviewed as a part of records computation to insure that all computations have been checked and that numbers have been transferred correctly from the interior of the measurement form to the front sheet.

3.3.2.3 Acceptable Equipment

The meters most commonly used historically for measuring surface-water discharge are the Price AA current meter, and the Price pygmy current meter. These meters have known accuracy and precision and are frequently used to evaluate newer technology. Other meters may be acceptable for making discharge measurements, but adequate testing and QC is vital to ensure that the demonstrated degree of accuracy and precision is acceptable.

Methods for inspecting, repairing, and cleaning Price AA current meters and Price pygmy current meter are described in Smoot and Novak (1968), Rantz et al (1982), and Buchanan and Somers (1969). A timed spin test made a few minutes before a measurement does not ensure that the meter will not become damaged or fouled during the measurement. Field staff must assess apparent changes in velocity or visually inspect the meter periodically during the measurement to ensure that the meter continues to remain in proper operating condition.

Spin tests are required following each field trip. Spin-test results are documented in a log that lists all spin tests for all current meters in chronological order. Repairs are made to meters when deficiencies are identified through the spin test or inspection. All meters are spin tested by another employee not normally assigned the meters during an annual meter inspection day. All deficiencies are noted in the spin test log and corrected immediately.

In addition to the timed spin tests performed following field trips, field staff are required to inspect the meter before and after each measurement to see that the meter is in good condition, the cups spin freely, and the cups do not come to an abrupt stop. Descriptive notations are made at the appropriate location on the field-note sheet concerning the meter condition, such as “OK” or “free” or other such comments.

An exception to the above policy is when the current-meter measurement is made at a site where it is not used as a check of a stage-discharge relation, dam outflow, or other known value. In these cases, where the discharge measurement is the only source of streamflow information, a spin test is required before and after each measurement. Examples of these types of measurements are those at low-flow partial record stations or during seepage runs. Where several measurements are to be made with the same meter on the same day, one spin test between each pair of measurements is sufficient to document the condition of the meter.

3.3.2.4 Low-Flow Conditions

Streamflow conditions encountered by field staff during periods of low flow are typically quite different from those encountered during periods of medium and high flow. Lowflow conditions can be roughly characterized by from 1 to 2 cubic ft per second per square mile (cfsm); flows typically seen from June through September in most streams during a typical year. Low-flow discharge measurements are made to define or confirm the lower parts of stage-discharge relations for gaging stations, to identify channel gains or losses as part of seepage runs, and to help in the interpretation of associated data. Additionally, low-flow measurements are made to define the relation between low-flow characteristics in one basin and those of a nearby basin for which more data are available.

In many situations, low flows are associated with factors that reduce the accuracy of discharge measurements. These factors include algae growth that impedes the free movement of current-meter buckets and larger percentages of the flow moving in the narrow spaces between cobbles. When natural conditions are in the range considered by the field staff to be undependable, the cross section is physically improved for measurement by removal of debris or large cobbles, construction of dikes to reduce the amount of nonflowing water, or other such efforts (Buchanan and Somers, 1969). After modification of the cross section, the flow is allowed to stabilize before the discharge measurement is initiated. Channel modifications are noted on the measurement sheet, including whether or not the stage at the gage was affected by the modification. The use of alternative flow measurement methods such as the use of flumes or volumetric methods are encouraged as alternative methods for measuring low-flow conditions when appropriate for the situation (Kilpatrick and Schneider, 1983).

Controls are cleaned of debris or aquatic growth whenever it is possible to completely clean the control. A measurement is made before cleaning the control to document the effect of the debris or aquatic growth on the stage-discharge relation.

3.3.2.5 Bridge measurements for large rivers

If discharge measurements are made during high flow or when a river is so large that a wading measurement is not practical or safe (see section *2.5.1.1 Wading*), measurement of discharge can be made from a bridge, boat or cableway. These types of measurements require significant training and experience and should always be done in pairs of two people. As this type of measurement requires a substantial outlay of equipment such as a sounding reel supported by a bridge board or a portable crane, and sounding weights, or a boat or cableway setup, it is recommended that NETN can contract out any bridge measurements to an organization that routinely makes these types of measurements. There are very few rivers within NETN in which these types of measurements would be necessary, so it may not be worth obtaining the necessary equipment and training for NETN. Furthermore, these types of measurements are frequently being made with the more costly new acoustic doppler current profiler (ADCP) technology.

4. SOPs for Monitoring Lakes and Ponds

SOPs for measuring lakes and ponds are adapted from the MDEP's Lake Assessment Program Standard Operating Procedures (Maine Department of Environmental Protection, 2005) unless otherwise noted. The SOPs are consistent with Maine's Volunteer Lake Monitoring Program (VLMP) protocols (Williams, 2004). Properties such as specific conductance, pH, temperature, and DO concentrations are measured in situ. Other parameters such as color, nutrients, algal biomass, and ANC are collected as a grab sample and analyzed in a laboratory.

Sample all lakes at the deepest point of the lake. See section *2.1.2 Background and Inventory of Lakes and Ponds* for SOP for locating the deepest location of each lake or pond. Tie off to marking buoy or drop anchor at sites indicated by shoreline landmarks or GPS coordinates.

4.1 SOP 9 – Secchi Disk Depth

Transparency, measured by viewing a Secchi disk, is one of the simplest methods for estimating lake-water quality. The SD measures water clarity, a parameter that can be affected by the presence of algae, plankton, water color, or suspended sediment. Transparency is inversely related to lake productivity- shallow SDs indicate a productive lake. To measure transparency in a pond or lake

Procedures

1) Take transparency readings between 9:00 AM and 3:00 PM (0900-1500).
2) Lower Secchi disk on the shady side of the boat while observing its descent with the viewing scope. DO NOT WEAR SUNGLASSES!
3) STOP lowering when the Secchi disk disappears completely from view.
4) Pull disk up slightly until it is just visible. (The disk may be seen as just a whitish-green "glow".)
5) Lower disk until it just disappears again.
6) Note the demarcation on the measuring tape at the point where the tape meets the surface of the water. Record this value to the nearest hundredth of a meter (0.01m) in the space marked "SECCHI DEPTH" on the field-data form.
7) Take a duplicate reading by a second staff person if available, and mark the results in the field data form in the space marked "QC READING". Check to ensure readings are within 0.1 m.

4.1A SOP 9A – Transparency Tube

A 120cm Transparency tube can be used as a surrogate for water clarity measurements in ponds that are too shallow to obtain a Secchi Disk measurement.

1) Fill sample container at about 0.5 m (18 in.) below the surface of the water. Point the container opening in the direction of the waves or current. Avoid collecting sediment or debris floating in the water.
2) Vigorously shake the sample bottle to resuspend any sediments that may have settled.
3) Pour contents of sample bottle into transparency tube and drain off the water until the Secchi pattern is visible at the bottom of the tube.
4) Record the water height where the Secchi pattern is visible.

4.2 SOP 10 – Profiles of Specific Conductance, pH, Temperature, and Dissolved Oxygen in Lakes taken with Water-Quality Sonde

Measurements of Temperature, DO, specific conductance, and pH are taken monthly at the deepest point in each lake using the YSI water-quality sonde following section *2.3 In Situ Measurements of Specific Conductance, pH, Temperature, and Dissolved Oxygen using Multiparameter Water-quality Monitor (Sonde*.

Collect a minimum of one reading per meter to get a profile of the lake at the deepest point. Set the YSI sonde to update its readings every 1 second with an time constant of 12 seconds as outlined in section *2.3.2.1.4 650MDS <Sonde Menu>*. Set up a user site list on the YSI 650 before taking readings in the field by selecting <Logging Setup> and activate <Use site list> (see YSI Operators Manual Section 3)

1) The sonde must be allowed to warm up for 4 to 5 minutes before taking measurements. Turn on the sonde by powering up the 650MDS and selecting <Sonde run> from the main menu.
2) Perform pressure/depth calibration of sonde see *2.3.2.2.7 Pressure/Depth calibration*
3) Once the sonde has warmed up, and with the unit still wrapped in the wet towel inside the transportation bucket, check the DO percent local saturation ("DO percent") and record this value.
4) Confirm that it reads 100 percent ± 2 percent. If the DO percent local saturation has drifted beyond these tolerances, the DO channel must be recalibrated on the spot. (See section *2.3.3 Making Measurements*)
5) Record a pre-deployment QC reading as site "89"
6) Lower the sonde over the side, submerging it in the water, and wait for the temperature to equilibrate. The length of time will depend upon the temperature differential between the air and water. Watch for the temperature readout to stabilize.
7) Once the temperature has stabilized, raise the sonde so that the middle of the pressure transducer on the side of the sonde is at the water surface. This will be a depth of 0 at the surface of the water.
8) Slowly lower the sonde through the water column, stopping at 1m intervals to obtain readings.
9) When readings are stable at the desired depth select the *Log one sample* (upper left) and press enter.
10) Note readings on the field log.
11) Continue lowering the sonde and recording readings.
12) If pond is shallow (less than 4 m) take an additional reading approximately 10cm above the bottom

13) After taking readings, place the probe in the "wet-towel" saturated environment and take an additional QC reading, indicating it as site "99".

14) Leave the sonde running between stations if the interval of time before the next warm-up is expected to be less than 5 minutes. Otherwise, power off the unit to conserve battery power.

4.3 SOP 11- Grab Samples in Lakes or Ponds

Grab samples are used to study the water quality unique to a specific depth. Grab samples are collected just below the surface of the water (0.5 m) from a boat at the deepest point in any of the ponds in NETN. Collect and transport samples in either wide mouth sample bottles or syringes. See section *2.4 Grab and Depth Integrated Epilimnetic Samples* for specific information about bottles, pretreatment, and labeling.

In general, the preservation methods and analytical methods do not allow the submission of one sample in a single container to the laboratory for analysis. The sample must be subdivided into a number of subsamples in bottles of the specified sizes through the use of a churn splitter. See section *3.2 Grab samples in streams* and section *4.4 Depth Integrated Epilimnetic Samples in Lakes and Ponds* for a full description of how to split, filter, and preserve samples. There can be some instances where a single sample is being collected that does not need to be filtered. If a sample is not filtered it can be collected by the following SOP:

1) Carefully lean over the side of the boat.
2) Remove cap from sample container (bottle or syringe), fill with lake water, and empty. Repeat this THREE TIMES to rinse container. *Do not touch inside or rim of bottle, tip of syringe, or cap!*
3) Fill sample container a final time at about 0.5 m (18 in.) below the surface of the water. Point the container opening in the direction of the waves or current. Avoid collecting sediment or debris floating in the water.
4) Cap the sample container while it is still underwater. Fill container completely, allowing no air in the container.
5) Record sample collection time on field data form, and record lake, date, time, sample type (grab), and sample depth on container label.
6) Store sample container in a cooler packed with ice for transport to laboratory.

Send samples the NWQL with an Analytical Service request form (ASR). This form lets the laboratory know which analyses are being run for the site, the date and time of collection, and any pertinent field information. See section *5.1 Shipping Samples to the Laboratory* for an address and shipping directions.

It is not feasible to get a sample at the deepest point in two high-elevation ponds at ACAD, Sargent Mountain Pond and The Bowl, because of the difficulty of getting a boat to the site. It is reasonable, however, to get a grab sample with the use of a throw bottle. Use this method only when necessary as it does not allow for in situ field measurements of SD or lake profiles. The sonde measurements for the parameters of specific conductance, pH, temperature, and DO are made from the shore. If possible, make in situ measurements without stirring up bottom sediments and note the location of the measurements.

For epilimnion grab samples in lakes with poor accessibility by boat, a throw bottle is used to collect samples at a depth of 0.6 meters, and a distance of about 9 meters from shore. A location is chosen along the shore that is free of aquatic vegetation, snags, and is deep enough so as throw bottle is not resting on the lake bed. A 500-mL HDPE bottle and lid with two holes cut into it (one holding a short piece of tygon tubing to let water flow into the bottle) are attached to the throw bottle apparatus by rubber bands. The 500 mL "throw bottle" used to obtain the samples at one site was acid washed and is part of the set of bottles used to send samples to the UMO laboratory for analysis. The first four throws are used to rinse (three times) the sampling lid, 500 mL throw bottle, and other sampling bottles. It will take about three to four additional throws to obtain samples, pouring water from the 500 mL throw bottle to the other bottles and syringes. After each site sampled, the throw bottle lid is rinsed three times in hot tap water, and then 3 times in DI water. Filter and treat samples as soon as possible back at the vehicle (see section *4.4 SOP 12 Depth-Integrated Samples of Epilimnion in Lakes or Ponds*, step 12).

4.4 SOP 12- Depth-Integrated Samples of Epilimnion in Lakes or Ponds

Depth-integrated composite samples contain water that represents a range of depths, or a specific layer of the lake. To take a depth-integrated sample of the epilimnion lower a 10 meter by half-inch inside diameter, flexible, weighted tube into the water column (subsequently referred to as tube sampler). When the bottom of the tube reaches the desired depth, pinch off the top of the tube to trap all the water inside. Lift the tube into the boat and transfer the sample to a churn to further homogenize the sample. Transfer water from the churn to bottles for transport. SOP to take a depth-integrated sample is as follows:

1) Take temperature and DO profiles to determine the depth of the epilimnetic layer according to figure 1. Carefully consider the temperature profiles to avoid sampling from an ephemeral epilimnion caused by calm, warm, weather. This condition is characterized by a temporary thermocline ($1^{o}C/m$ change), which will quickly disappear when the wind blows.
2) The person in contact with the water should put on latex gloves.
3) Start with a clean churn splitter (section *2.4.2 Cleaning of bottles and equipment*).
4) Fill the churn with native water to be sampled and let the water sit in the churn while other work is being accomplished at the site. This allows the churn splitter to equilibrate to the temperature and to any ionic exchange capacity.
5) Rinse tube sampler with lake water by lowering the weighted end of tube into water at least 1 meter deeper than the epilimnetic depth. Then lift the tube so that all water drains back into lake. REPEAT THREE TIMES.
6) Empty the churn splitter of all water before beginning to collect a sample.
7) Clear surface debris if present.

8) Slowly lower the tube sampler to the desired depth. Check to make sure the water level inside the tube equals the level outside the tube.

9) Close the top of the tube with the pinch clamp and carefully raise the weighted end into the boat.

10) Hold the weighted end over the mouth of the churn and open the pinch clamp to empty sampler contents into the churn. Do not pour water over hands to avoid sample contamination.

11) Take a sufficient number of samples (repeat steps 8-10) to fill the churn. If a large sample volume must be obtained from a relatively shallow depth (less than or equal to 2 m) a composite sample made up of grab samples from several depths in the water column can be used. For example, a 2 m composite can be made up from 0.5 m, 1.0 m, 1.5 m, and 2.0 m grab samples.

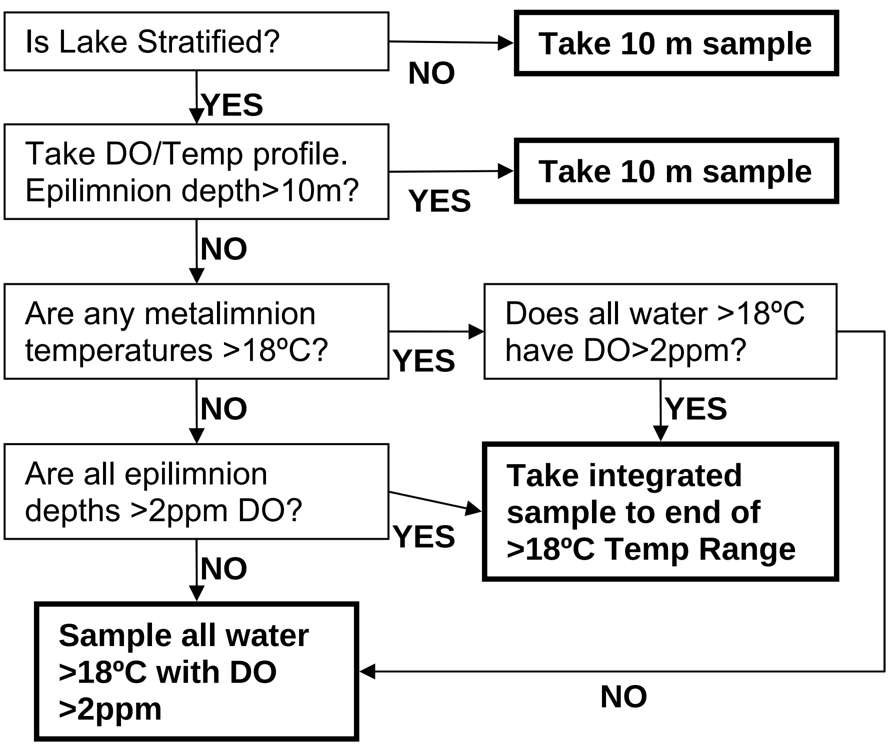

Figure 1. Method for determination of depth-integrated sample for lake water-quality samples

[m, meters; DO, Dissolved oxygen; >, greater than; ºC, degrees Celsius; ppm, parts per million; temp, temperature]

The following steps can be completed back at the vehicle, but as soon as possible after obtaining samples.

12) Label all of the subsample containers to be used (see table 27) and place them within easy reach of the churn splitter.

13) Rinse bottles for whole water samples while operating the churn.

14) Continue to operate the churn and withdraw subsamples for total N, Total P, ANC, and color (all analytes that are unfiltered or raw).

15) Connect the pump discharge tube to a 0.45 um capsule filter. (See section *2.4.3 Sample filtering and preservation)*. Be sure that the direction of flow through the capsule filter matches the arrow on the side of the filter. Rinse the intake tube with sample water and place the tube into the sample to be filtered.

16) With the power switch off, connect the pump to the appropriate power supply.

17) Turn the pump on low speed and allow air to vent. Do this by holding the filter so that the arrow is pointing up.

18) Flush the system (tubing and filter) with about 1 L of sample water if possible. If the sample water is full of particulate matter, first filter deionized water through the system.

19) Rinse the bottles three times with the filtered water. Fill all appropriate subsample bottles with the filtered sample. The churn splitter does not need to be operated for filtered samples. Samples collected include total dissolved nitrogen, total dissolved phosphorus, ammonia, nitrite, nitrate, and orthophosphate.

20) Fill the container to the desired volume (leave about 1 percent of the container's capacity to allow for addition of preservatives (if necessary) and expansion if samples are to be shipped. Preserve each sample as required in table 27 and according to section *2.4.3 Sample Filtering and Preservation*.

21) Screw all bottle caps on tight. Verify the sample label is correct and complete. Place the labeled sample container in a cooler packed with ice.

22) Rinse the container's outside surface with clean water and dry with a paper towel. Rinse the hoses with DI water.

23) Empty the churn and clean thoroughly with deionized water.

24) Dispose of used preservation ampules properly.

4.4.1 Sample Collection / Filtration for Chlorophyll *a* Analysis

Sample collection, filtration preservation, and storage methods for chlorophyll *a* analysis are on the basis of USEPA method 445.0. Collect triplicate samples to assess accuracy. Use glass fiber filters with an effective pore size of 0.45-0.7 um (WhatmannGF/F). Check that all apparatus are clean and acid free.

SOP to collect and filter chlorophyll *a* samples is as follows:

1) Collect enough water to concentrate phytoplankton on at least three filters which will be the triplicate samples. Filtration volume size will depend on the particulate load of the water, but 1 L or less is generally sufficient for a lake. Sample is subsampled from churn into a 1 L amber polypropylene bottle.
2) Filter water samples in as subdued light as soon as possible (several hours maximum) after sampling. Algal populations, thus chlorophyll *a* concentration, can change in relatively short periods of time.
3) Assemble the filtration apparatus and attach the vacuum source with vacuum gauge and regulator. Vacuum filtration should not exceed 6 in. Hg (20 kPa). Higher filtration pressures and excessively long filtration times (greater than10 min) can damage cells and result in loss of sample analyses.
4) Agitate the container thoroughly, but gently before drawing a subsample from the water sample container, to suspend the particulates (stir or invert several times).
5) Pour the subsample into a graduated cylinder and accurately measure the volume. Pour the subsample into the filter tower of the filtration apparatus and apply a vacuum (not to exceed 20 kPa). A sufficient volume has been filtered when a visible green or brown color appears on the filter. Do not suck the filter dry with the vacuum; instead slowly release the vacuum as the final volume approaches the level of the filter and completely release the vacuum as the last bit of water is pulled through the filter.
6) Remove the filter from the fritted base with tweezers, fold once with the particulate matter inside, lightly blot the filter with a tissue to remove excess moisture and place it in a petri dish or other suitable container. If the filter will not be immediately extracted, then wrap the container with aluminum foil to protect the phytoplankton from light and store the filter at -20 to -70º C. Short term storage (2 to 4 h) on ice is acceptable, but store samples at from -20 to -70º C as soon as possible.
7) Store frozen (-20 C to -70º C) filtered samples in the dark until extraction. Filters can be frozen at from -20 to -70º C for as long as 3½ weeks without significant loss of chlorophyll *a*.

4.5 SOP 13 – Light-Penetration Profiles

SD and instantaneous photosynethetic photon flux density (PPFD) with a light meter are two approaches to measuring light in lakes. The advantages to use of a SD are that it is an inexpensive, rapid, and simple to use piece of equipment. The disadvantages are that it cannot be used when SD is greater than actual depth, and thus a light-attenuation coefficient can only be approximated (Short and Cole, 2001).

Light-penetration profiles indicate conditions affecting lakes because nearly all the energy that drives and controls lake processes is derived from solar energy. This energy is converted to chemical energy through photosynthesis, and then is transported to other areas of the ecosystem in various forms of organic matter. Solar energy that is absorbed by a lake and dissipated as heat plays a large role in defining the thermal structure, stratification, and circulation patterns of a lake, which in turn affect nutrient cycling and distribution of dissolved gasses. By understanding the quantity and behavior of light entering a lake system, how the light is used in the system is better understood. PPFD is measured with a light meter in lakes with average SD readings deeper than 5 meters, or in any lake where at least one SD reading has been greater than the lake depth.

SOP for measuring light-penetration profiles in lakes is as follows:

1) Connect the deck cell and the submersible cell sensor cables to a datalogger.
2) Connect a graduated cord to a frame that can be used for lowering the light meter into the lake. The frame MUST be lowered using this cord- do not suspend using only the sensor cable of the meter!
3) Lower the frame into the water
4) Turn the datalogger on and wait at least a minute for the logger to begin averaging readings. Scroll through the datalogger readings and note when they begin to stabilize.
5) Press the "Enter" key to record values to memory when readings become relatively stabile (often hard to tell!). Record the values on the field form in the spaces for the appropriate depth (for example 0.1 meters).
6) Repeat steps 1 through 5 at 0.5 meters (upper loop of lowering frame just below water surface) and then at 1 meter (first graduation on the cord). Repeat at 1 meter intervals until the percent transmission is less than 1 percent for two readings.

4.6 SOP 14 – Lake-Stage Monitoring

This SOP for lake-stage monitoring is used to track water levels throughout a season and from year to year. This lake SOP is adapted from ACAD's lake-monitoring protocols (Gawley, 1996).

4.6.1 Establishment of lake-stage monitoring benchmarks

To establish a lake-stage monitoring benchmark, set one tape down site and a minimum of three additional benchmarks are set at each lake level monitoring site. Benchmarks and tape down sites are set in ledge, large boulders or manmade structures that are anchored below the frost line. In cases where a stable benchmark does not exist at a lake, pound in a cedar post into the lake somewhat near the shore, but below the low water line. The post must extend below frost line and be perfectly stable. Leveling, a procedure by which surveying instruments are used to determine the differences in altitude between points is used to set the gages and to check them from time to time for vertical movement (Kennedy, 1990). Run levels at newly installed lake-monitoring tape down stations at the time of construction, annually for the first 3 years and every 3 years after that to all bench marks at each station to determine if any datum changed (Rantz et al, 1982).

Run levels according to field and documentation methods described by Kennedy (1990). Level procedures followed by field staff pertaining to circuit closure, instrument reset, and repeated use of turning points are described in Kennedy (1990). Keep the level instruments in proper adjustment by use of peg tests (Kennedy, 1990) at least twice annually. In addition, have level instruments cleaned and recalibrated by a commercial surveying instrument company at least once every 3 years. Documentation of all tests, adjustments, and service is maintained for each instrument in a level log book. This work can be contracted out so that the parks do not have to maintain costly leveling equipment.

4.6.2 Monthly lake- or pond- stage monitoring measurements

Tape down measurements to measure lake stage are taken every time water-quality parameters are collected, and at least once monthly during the ice-out season. This measurement is the distance between an identified stable point and the water surface.

The SOP for making monthly lake or pond stage measurements is as follows:

1) Note weather conditions and surface-water temperature on stage-monitoring field form. Weather conditions (especially the wave conditions) are important for interpreting the accuracy of the stage measurement.
2) Find the benchmark on the rock. Each benchmark is marked with orange nail polish. If the orange has worn off, re-mark when finished taking measurements.
3) Place one of the nails in the end of the extension wand into the benchmark. Use the level bubble (keep bubble in the center of the circle) to keep wand straight and level.
4) Use folding ruler to measure from the exact surface of the water to the center of the nail on the other side of the extension wand. Double check to make sure the wand is level at the time of measurement.
5) Write the measurement on the field sheet (to the nearest hundredth of a foot), along with all other required information.

4.7 SOP 15- Invasive Aquatic Plant-Screening Survey Procedures

The purpose of the survey is to screen parts, or all of a waterbody, for target invasive plants. The early detection of an invasive plant infestation can make eradication or control more feasible, and it can lead to efforts that can reduce the spread of the plant to other areas of the waterbody. This SOP is adapted from Maine Center for Invasive Aquatic Plant (MCIAP) screening survey procedures (Maine Center for Invasive Aquatic Plants, 2006). The survey process described here is semi-quantitative. Volunteers can effectively do screening surveys with a minimum of training if basic procedures are followed carefully, and questionable plants are inspected in the field, or sent to professionals for identification. Surveys are done from mid-July through September so that plants will be sufficiently developed to allow for identification.

Level I Survey of all lakes and (or) ponds in NETN with a public boat launch is done annually. Level II surveys are done on all ponds and impoundments in NETN every year except for in ACAD. Because of the large number of ponds and lakes in ACAD, Level II surveys for high risk lakes can be done on a rotating basis. It is important that field staff who suvey for invasive plants surveys attend a training that includes invasive plant identification methods and a field survey in a lake or pond. This training is offered by the MCIAP.

Level I and Level II surveys include the following:

Level I: Survey points are of public access and other areas of concentrated boat traffic such as marinas and narrow navigation channels. Boat launch survey areas extend horizontally along the shoreline at least 100 meters (~300 ft) on either side of the boat launch area, and offshore along the entire length to the depth at which rooted plants are no longer observed (the outermost extent of the littoral zone.) If the access area is in a distinct cove, the survey includes the entire littoral zone of the cove, even if the shoreline distance from the launch area to the mouth of the cove is greater than 100 meters.

Level II: Survey all Level I areas, plus all areas of the shoreline that are likely to provide suitable habitat for aquatic plants, such as shallow, sheltered coves. Floating leaved plants are often a good indicator of a rich plant community below the surface. In addition to supporting native plants, these areas can provide suitable habitat for invaders.

4.7.1 Equipment Needs

See appendix 1 for the list of equipment necessary for invasive aquatic plant surveys. Please note that a boat is always needed for safety and documentation, and the survey can be accomplished much more easily with at least two persons in the boat. Large boats and motors make the process of data collection more difficult, and could destroy sensitive aquatic vegetation A diver outfitted with snorkel or SCUBA apparatus is helpful in getting close to the plants, and for obtaining specimens, but can also stir-up bottom sediments, reducing visibility.

4.7.2 General Guidelines

Mid-July is generally the best time to begin Invasive Aquatic Plant screening surveys, but the process can begin as late as mid-August. Prior to July, many aquatic plants are not fully developed. Emergent flowering structures are sometimes needed for plant identification and for many species. For example, variable milfoil, flowers do not typically start to develop until July with one exception. Curly leaf pondweed, (*Potamogeton crispus)*, one of the plants on Maine's watch list, usually reaches maturity by late spring to early summer. Lakes that are at high risk for an invasive plant infestation can be checked more than once during the season.

The survey can be conducted over a period of time (it does not have to be completed in one day). Survey when there is adequate light, and when conditions are relatively calm. Early morning conditions are often ideal because the water is calm and reflection on the water surface is minimal. It will be difficult to conduct an effective survey during windy conditions. Weekends can be problematic because of heavy powerboat activity on some lakes and ponds.

To begin a survey, fill in section 1 of the Screening Survey Documentation Form. Data to be recorded here includes an estimate of the lake water level at the time of the survey using "water marks" on shoreline rocks to help determine whether or not the level is high, average, or low and a SD (clarity) reading if possible. Use a lake depth map to help determine where plant communities may be situated, and to mark the location of the surveyed areas.

Begin the survey. No matter which level of survey is undertaken, the survey area extends from the shoreline to the outer depth of the littoral zone--the point at which it is no longer possible to see the lake bottom with a viewing scope or diving mask. The depth of the littoral zone will vary, depending on the clarity of the water. Clear lakes can support rooted plants at depths of 15-20 ft. Shallow ponds can support rooted plants from shore to shore.

In areas where the lake bottom drops steeply from the shore, plotting a straight course roughly parallel to the shore generally allows adequate screening of the area from both sides of the boat. Working in teams of two, scan the area from the boat toward the shore with one surveyor, the other surveyor scans from the boat toward the outward extent of the littoral zone. The surveyor in the bow also watches for hazards and the surveyor in the stern steers the boat. The distance from the shore the boat travels is determined by water clarity, wind and wave activity, cloud cover, the angle of the sun, plant density, and the width of the littoral zone. The width of the littoral zone can be verified occasionally by "spiking out" (heading out perpendicular to shore). The "straight" line of travel along the shore can wiggle and contort from time to time to conform to, and accommodate, shoreline features, docks, moored boats, floats, etc. Be alert to submersed mooring pulley lines!

In areas where the littoral zone is wider, in shallow coves, inlets and outlets, and where the plant community is dense and complex, use other course patterns including point-to-point transects. The configuration and spacing of the patterns and transects will vary according to the observation conditions, and density of the plant communities. The overall goal in selecting a proper course pattern is to optimize direct observation of the littoral zone.

A number of native plants look similar in appearance to the 11 invasive species that are of greatest concern. The most common of these are bladderwort, coontail, elodea, water marigold, common pondweeds, and others. Several species of milfoil are native to Maine and it can be difficult to distinguish between native and invasive species of milfoil without assistance. If field staff learn the structural characteristics of the look-alike plants before beginning the survey less time is needed for identification. Some native plants, such as bladderwort and coontail, grow in large dense stands, giving the impression of being invasive. When a plant has been identified as suspicious, indicate on the survey form and lake map the status of the plant using the following code::

S = Submerged – the entire plant is growing underwater (except possibly for a short stalk supporting the flower)

E = Emergent – parts of the plant grow above the water surface

FL = floating leaved – Underwater stem and roots, but most of the leaves float on the surface

FR = free floating – plants may have stems, but they are not rooted, and they float on the surface

Collect a plant specimen, but do not remove the entire plant from the water.

The SOP for collecting a plant specimen is as follows:

1) Clean-cut the plant specimen. Carefully avoid fragmenting the plant because this could result in an invasive plant spreading to other areas of the lake. . Scoop up any and all fragments with a net.
2) Collect several (3-5) healthy stems of the plant in question if possible. The flower, fruits, and winter buds of many aquatic plants are helpful in the identification process. If these structures are present, be sure to include them in your sample. Gently break off stem sections about 6-8 in. long, from the top part of the plant. For rooted floating leaved plants, Include as much of the stem as possible.
3) DO NOT attempt to pull the plant out by its roots. (This is very important!)
4) Mark the location of the plant with a weighted buoy. A small buoy (plastic milk jug) attached to string and a cored brick or rock is sufficient.
5) If possible, mark the location on a map. Indicate local landmarks such as shoreline cottages or unusual rocks or trees to help others re-locate the site.
6) If the plant is covered with algae or tangled in debris, remove as much of the unwanted material as possible, without damaging the specimens.
7) Carefully place the plant in a sealable bag with sufficient water to prevent the plant from becoming damaged. Immediately place the bag in a cooler in the refrigerator until you are ready to ship the specimens.

If a positive identification is not possible after checking the list of common look-alikes, seek assistance. If a plant, or plants that are thought to be on the list of invasive aquatic species, or a suspicious plant needs to be identified, please contact the appropriate state agency immediately to confirm the species identification and initiate a rapid response if warranted. If the specimen must be mailed for identification, follow the guidelines listed for mailing specimens. Follow up with the appropriate agency after a week without a response. The names and contact information for the appropriate state agencies are listed in appendix 2. .

Preparation guidelines for mailing specimens:

1) Place wet specimens a water-tight plastic bag.
2) If the plant is delicate and (or) flimsy, add enough water to the bag to cushion the plant and keep it wet.
3) Remove all air from the bag and seal if the plant is relatively sturdy. DO NOT wrap the plant in a wet paper towel or other absorbent material.
4) Seal the bag securely and place it in a small box with enough packing material to prevent movement. Cardboard mailing envelopes are fine for sturdy specimens

that are not packed in water. Padded envelopes do not work well for plant specimens.

5) Fill out and include a suspicious plant form (can be downloaded from: *http://www.mainevlmp.org/mciap/SuspiciousPlantForm.pdf*) in the box with the specimens. This information is critical to tracking plants submitted for identification, and ensuring a timely response.
6) Mail the specimen to the appropriate agency on a Monday or Tuesday, to minimize the possibility of weekend delays.

Who to Contact for invasive species identification:

Each state has its own state agency responsible for the early detection and rapid response of aquatic invasive species. These organizations, listed in appendix 2, conduct trainings, have lists of the most problematic or potentially problematic aquatic species in the state, and have technical assistance for the positive identification of species. Although aquatic invasive species data will be compiled for NETN, it is important that any new outbreaks of aquatic invasive species be reported to the appropriate state agency as soon as possible. Natural resource managers and volunteers should attend annual trainings organized by the state in which they reside so that they will be apprised of new problematic species, new outbreaks of known invasive species, and the current procedures and contacts for the identification and reporting of species.

5. SOPs for Laboratory Analyses

To ensure consistency of results and QA/QC, use a central laboratory for all samples. If private laboratories are used, they must pass independent State and Federal (Federal National Environmental Laboratory Accreditation Program or NELAP, see *http://www.epa.gov/ttn/nelac/accreditlabs.html*) accreditation/approval QA/QC checks, optimally including blind-sample round-robin trial analyses of proficiency test (PT) standards to see if the answer the laboratory provides is close enough to known (certified correct) ranges to pass QC performance standards. Review the choice of laboratory periodically to ensure that methods have not changed, and that routine QC samples are included in analyses. Make arrangements with the laboratory preceding the field season to ensure that the samples are expected, and adequate bottles and ASRs are available. QC charts produced by the laboratory will be reviewed biannually. A means control chart is constructed using the average or mean value and the standard deviation from a group of about 20 standard solution measurements. Usually, +2 standard deviations are used to establish the upper and lower warning limits and +3 standard deviations are used to determine the upper and lower control limits. A means chart can be constructed from the calculated mean and standard deviation from measured concentration or percent recovery values.

Inquire if the laboratory participates in a standard reference sample program such as that outlined in Long et al. (1998) for nutrients and other inorganic constituents. This is not a certification program, but the program is used to detect and correct possible analytical deficiencies and problems.

The USGS NWQL water-quality analytical methods are published in the Techniques of Water-Resources Investigations (TWRI) series or in the Open-File Report (OFR) series (U.S. Geological Survey, variously dated). The data collected by these methods are entered in the Water Data Storage and Retrieval System (WATSTORE).

ANC, color, nitrogen and phosphorus are collected biannually as grab samples (or depth-integrated epilimnetic samples for lakes at ACAD) and sent to a certified laboratory for analysis. Collect samples in May and August for streams and in June and August for lakes. In addition, collect algal biomass samples for the lakes at ACAD. These samples are identified and preserved according to the SOP in sections *2.4 Grab and Depth Integrated Epilimnetic Samples*. Table 27 in that section indicates the pretreatment necessary if sending to the USGS water-quality laboratory; the type of bottle; and USGS laboratory and parameter codes; and the level of precision and units that are appropriate for reporting. Pretreatments such as bottle size and type, acidification, filtering and chilling, holding times and labeling must be strictly adhered to to ensure a consistency of results. It is critical that all methods and pretreatments be stated when reporting results.

Laboratory analyses are discussed in the following sections with the NWQL code number (Lab code: #) and reference for each analyte.

5.1 SOP 16 – Shipping Samples to the Laboratory

Send all samples to a central laboratory such as the USGS NWQL. The following SOP assumes that the NWQL is used. If another laboratory is used, directions for sending samples can be obtained directly from the laboratory.

1) Mark each sample-container sent to the NWQL with a permanent, waterproof marking pen or with a waterproof preprinted label securely attached to the sample container. If preprinted labels are used, take precautions to ensure that the label and the information on it remain intact and legible throughout the shipping process. Pack bottles in waterproof Ziploc baggie and if bottles are breakable include packing material in addition to ice.

2) Include the following information on all sample container labels:

   Station ID.
   Date of collection
   Time of collection
   Bottle type
   Field ID (if applicable)

   This information serves as a link between the sample container and the ASR form. Always include the schedule number and laboratory code adds and deletes on the ASR.

3) Include at least one ASR and all sample containers associated with that ASR in each shipping container. Do not send samples in a shipping container without an ASR. Likewise, ASRs must not be sent without sample containers. If a sample set

has sample containers that can be shipped separately (for example, chilled and unchilled), then each shipping container must have an ASR listing only the applicable schedules or laboratory codes.

4) Place ASRs in sealed, watertight bags. When shipping samples in coolers, the ASR packet are taped to the inside lid of the cooler, along with the **return address label** with street address and account number.
5) Send all sample containers for a particular laboratory schedule together. If a schedule contains chilled and unchilled sample containers, send all the samples with the chilled sample containers separately. Field staff can "delete" the schedules or laboratory codes for sample containers not included in the shipment. These sample containers can be sent separately with ASRs that request only the applicable schedules or laboratory codes.
6) Ensure that samples are not discarded or set aside by the carrier by taking special precautions to make certain that the coolers or boxes are not leaking, and, in the case of coolers, that they can remain leak-proof even after the ice has begun to melt. None of the package-carrier services will deliver leaking coolers or boxes.
7) Send chilled and time-dependent samples to the NWQL by the most expedient means possible. The temperature of the cooler will be measured during sample login and documented in the Laboratory Information Management System (LIMS). In general, ship all time-dependent samples by a reliable express delivery service, such as Federal Express, Priority Overnight. Samples shipped on Friday by Federal Express will be picked up Saturday by the NWQL. However, the samples are not logged in for analysis until Monday. Please indicate "Priority Overnight and Saturday Delivery" on the Federal Express air bill. The NWQL is closed on all Federal holidays; therefore, extremely time-dependent samples are not to be shipped in conjunction with a holiday. Use the following address when shipping samples to the NWQL:

   National Water-quality Laboratory
   Building 95, Ent E-3
   Denver Federal Center
   Denver, CO 80225-0046

5.2 SOP 17- Acid Neutralizing Capacity

Beginning in 2007, Acid Neutralizing Capacity will be analyzed by the University of Maine's Sawyer Environmental Chemistry Research Laboratory. Acid Neutralizing Capacity (ANC) is the capacity of solutes plus particulates in an aqueous system to neutralize acid and is thus determined on an unfiltered sample. Water's ability to neutralize acid (i.e. buffering capacity) is largely a function of the bicarbonate and carbonate ions derived from dissolution of calcium carbonate in the drainage basin. When there is little input of calcium carbonate to a surface-waterbody, the dissociation of dissolved carbon dioxide is the reaction that predominates resulting in slightly acidic waters with little buffering capacity.

NWQL analysis information:

Lab Code: 70, Electrometric Titration, Acid Neutralizing Capacity as $CaCO_3$

SOP for ANC analyses:

TWRI B5-A1/89
Fishman, M.J., and Friedman, L.C., 1989, Methods for determination of inorganic substances in water and fluvial sediments: U.S. Geological Survey Techniques of Water-Resources Investigations, book 5, chap. A1, 545 p.
Method ID: I-2030-89

At the Sawyer Environmental Chemistry Research Laboratory (SECRL), University of Maine, ANC is analyzed using Gran Titration. References are:

1. Standard Methods for the Examination of Water and Wastewater, 20th edition, copyright 1998. Method 2320.

2. EPA Handbook of Methods for Acid Deposition Studies, Laboratory Analyses for Surface Water Chemistry, Section 5.0, 1987.

5.3 SOP 18 – Apparent Color

Beginning in 2007, apparent color for Acadia samples will be analyzed by the SERCL. Other samples will be analyzed by the NWQL. Color in water results from natural metallic ions, humus, and peat materials, plankton, weeds, and industrial wastes. True color is the color of water from which turbidity has been removed. Apparent color is determined on original samples without filtration.

Lab Code: 20, Color reported in Pt-Co units

SOP for color analyses:

TWRI B5-A1/89
Fishman, M.J., and Friedman, L.C., 1989, Methods for determination of inorganic substances in water and fluvial sediments: U.S. Geological Survey Techniques of Water-Resources Investigations, book 5, chap. A1, 545 p.
Method ID: I-1250-89

At the Sawyer Environmental Chemistry Research Laboratory (SECRL), University of Maine, apparent color is analyzed with a spectrophotometer (457.5 nm) References are:

1. Standard Methods for the Examination of Water and Wastewater, 20th edition, copyright 1998. Method 2120.

2. Milton Roy Spectronic 601 Operator's Manual, 1991.

3. Spectronic Geneysis 5 Operator’s Manual, 1997.

5.4 SOP 19- Phosphorus

Beginning in 2007, phosphorus for Acadia samples will be analyzed by the SERCL. Other samples will be analyzed by the NWQL. The total phosphorus occurring in water includes orthophosphate, condensed phosphates and organically bound phosphates. Phosphates are in solution, in particles, or in aquatic organisms. Phosphorus originates from water treatment, laundering, or agricultural or residential fertilizers and often indicates agricultural pollution. It is essential to the growth of aquatic organisms and is thus frequently a limiting nutrient in aquatic systems. The addition of phosphates to a waterbody usually results in the growth of aquatic microorganisms in nuisance quantities (APHA, 1998) and thus it is an indicator of trophic status or the productivity of a waterbody.

Lab Code: 2333, Total Phosphorus, Water, Unfiltered, Acidified, mg/L as P, Alkaline persulfate digestion

SOP for phosphorus analyses:

WRIR 03-4174
Patton, C.J., Kryskalla. J.R., Methods of Analysis by the U.S. Geological Survey National Water-quality Laboratory: Evaluation of alkaline persulfate digestion as an alternative to Kjeldahl digestion for determination of total and dissolved nitrogen and phosphorus in water: U.S. Geological Survey Water-Resources Investigations Report 03-4174, 33 p.
Method ID: I-4650-03

Lab Code: 2331, Colorimetry, ASF, Microkjeldahl Digestion, P, Phosphorus as P, Filtered

OFR 92-146
Patton, C.J., and Truitt, E.P., 1992, Methods of analysis by the U.S. Geological Survey National Water-quality Laboratory--Determination of total phosphorus by a Kjeldahl digestion method and an automated colorimetric finish that includes dialysis: U.S. Geological Survey Open-File Report 92-146, 39 p.
Method ID: I-2610-99

Lab Code: 3118, Colorimetry, ASF, Phosphomolybdate, P, Orthophosphate as P, Filtered

OFR 93-125
Fishman, M.J., ed., 1993, Methods of analysis by the U.S. Geological Survey National Water-quality Laboratory--Determination of inorganic and organic constituents in water and fluvial sediments: U.S. Geological Survey Open-File Report 93-125, 217 p.
Method ID: I-2601-90

At the Sawyer Environmental Chemistry Research Laboratory (SECRL), University of Maine, total phosphorous, total dissolved phosphorous, and orthophosphate are analyzed by persulfate digestion/ascorbic acid using manual colorimetry. References are:

1. Standard Methods for the Examination of Water and Wastewater, 20th edition, copyright 1998. Methods 4500-P-B-5 and 4500-P E.

2. Maine Department of Environmental Protection. Preliminary method for automated determination of low level phosphorus. November 20, 1973.

3. Methods for the Determination of Inorganic Substances in Environmental Samples, EPA600/R-93-100, 1993.

5.5 SOP 20- Nitrogen

Beginning in 2007, total and total dissolved nitrogen for Acadia samples will be analyzed by the SERCL. Other samples and analytes will be analyzed by the NWQL. Nitrogen is found in freshwaters in the following forms; nitrate, nitrite, ammonia, and organic nitrogen. Nitrate is an essential nutrient for many photosynthetic autotrophs and is thus a major limiting nutrient in most aquatic systems. An increase in nitrogen usually results in accelerated eutrophication. Nitrogen is indicative of agricultural pollution or acid rain. The drinking-water standard for nitrate, the most highly oxidized state of nitrogen is 10 mg/L (APHA, 1998), but nitrate can be found in concentrations up to 30 mg/L in wasterwater effluent.

Lab Code: 2756, Total Nitrogen, (NO_2+NO_3+NH_3+Organic-N), Water, Unf, acidified, mg/L as N, alkaline persulfate digest

SOP for nitrogen analyses:

WRIR 03-4174
Patton, C.J., Kryskalla. J.R., Methods of Analysis by the U.S. Geological Survey National Water-quality Laboratory: Evaluation of alkaline persulfate digestion as an alternative to Kjeldahl digestion for determination of total and dissolved nitrogen and phosphorus in water: U.S. Geological Survey Water-Resources Investigations Report 03-4174, 33 p.
Method ID: I-4650-03

Lab Code: 2754, Total Dissolved Nitrogen, (NO_2+NO_3+NH_3+Organic-N), Water, Fil, mg/L as N, alkaline persulfate digestion

WRIR 03-4174
Patton, C.J., Kryskalla. J.R., Methods of Analysis by the U.S. Geological Survey National Water-quality Laboratory: Evaluation of alkaline persulfate digestion as an alternative to Kjeldahl digestion for determination of total and dissolved nitrogen and phosphorus in water: U.S. Geological Survey Water-Resources Investigations Report 03-4174, 33 p.
Method ID: I-2650-03

At the Sawyer Environmental Chemistry Research Laboratory (SECRL), University of Maine, Total Nitrogen and Total Dissolved Nitrogen are analyzed using automated colorimetry. References are:

1. Ebina J. (1983), Simultaneous determination of total nitrogen and total phosphorous in water using peroxodisulfate oxidation. Water Res. vol 17, pp 1721-1726.

2. Nydahl F. (1978), On the peroxodisulfate oxidation of total nitrogen in waters to nitrate. Water Res. vol 12, pp 1123-1130.

3. D'Elia C. (1977), Determination of total nitrogen in aqueous samples using persulfate digestion. Linmol Oceanogr. vol 22, 760-764.

4. Smart M. (1981), A comparision of a persulate digestion and the kjeldhahl procedure for determination of total nitrogen in freshwater samples. Water Res. v15, pp 919-921.

5. Handbook of Methods for Acidic Deposition Studies, Laboratory Analysis for Surface Water Chemistry, EPA 600/4-87/026 1987.

6. Bran & Luebbe, Method 818-87T, Nitrate/Nitrite in water and seawater, 1987.

7. Nitrate and Nitrite Nitrogen and Nitrite Nitrogen Method (P/N 000142 and P/N 000143), Doc. 000589, Rev. 1/94, OI Analytical, College Station, TX 77842-9010.

8. RFA Methodology, Nitrate and Nitrite Nitrogen, Rev. 4-90.

9. Cadmium Coils, Continuous Flow News, 20, 1994.

10. Handley M., Total Nitrogen Method, Environmental Chemistry Laboratory, Sawyer Research Center, University of Maine, Orono, ME 04469.

Lab Code: 1979, Colorimetry, ASF, cadmium reduction - diazotization, N, Nitrite + Nitrate, N, Filtered

OFR 93-125
Fishman, M.J., ed., 1993, Methods of analysis by the U.S. Geological Survey National Water-quality Laboratory--Determination of inorganic and organic constituents in water and fluvial sediments: U.S. Geological Survey Open-File Report 93-125, 217 p.
Method ID: I-2545-90

At the Sawyer Environmental Chemistry Research Laboratory (SECRL), University of Maine, nitrate is analyzed directly using Ion Chromatography. References are:

1. EPA Method 300.0, Methods for the Determination of Inorganic Substances in Environmental Samples, EPA 600/R-93-100, 1993.
2. Dionex model 2010i Ion Chromatograph manual.
3. Dionex model DX-500 manual and assorted components manuals

Lab Code: 3116, Colorimetry, ASF, Salicylate-hypochlorite, N, Ammonia, Filtered

OFR 93-125
Fishman, M.J., ed., 1993, Methods of analysis by the U.S. Geological Survey National Water-quality Laboratory--Determination of inorganic and organic constituents in water and fluvial sediments: U.S. Geological Survey Open-File Report 93-125, 217 p.
Method ID: I-2522-90

At the Sawyer Environmental Chemistry Research Laboratory (SECRL), University of Maine, ammonium (NH4) is analyzed by an autoanalyzer. References are:

1. Standard Methods for the Examination of Water and Wastewater, 18th ed., copyright 1992. Method 4500-NH3 H.

2. Ammonia Nitrogen (P/N 000156 and P/N 000157), Doc. 000578, Rev. 12/93, OI Analytical, College Station, TX 77842-9010.

5.6 SOP 21- Algal Biomass

Chlorophyll *a* analysis is conducted by the SERCL. The amount of chlorophyll *a* in a water sample is a measure of the concentration of suspended phytoplankton and can be used as an indicator of algal biomass and thus of water quality. Chlorophyll *a* is responsible for photosynthesis and is found in various forms within the living cells of algae, phytoplankton, and other plant matter of water environments. Like other biological response variables, chlorophyll *a* tends to integrate the stresses of various parameters over time, and thus is often an important nutrient-stress parameter to measure.

Lab Code: 2645, Chlorophyll *a*, Phytoplankton, Fluorometric

SOP for chlorophyll *a* analyses:

USEPA 445.0
Arar, E.J., and Collins, G.B., 1997, In vitro determination of Chlorophyll *a* and Pheophytin a in Marine and Freshwater Algae by fluorescence:, U.S. Environmental Protection Agency, National Exposure Research Laboratory, Office of Research and Development, Revision 1.2 September 1997
Method ID: USEPA 445.0

At the Sawyer Environmental Chemistry Research Laboratory (SECRL), University of Maine, chlorophyll *a* is analyzed with a spectrophotometer. References are:

1. Spectronic 1201 Operators Manual, Milton Roy. Section 4.6.8

2. Standard Methods for the Examination of Water and Wastewater, 18th ed., 1992. Method 10200H

3. Technology Applications Inc. SOP #IN-027-00, Aug. 1993, Spectrophotometric Determination of Chlorophyll 'a'.

4. USEPA method 445.0, In Vitro Determination of Chlorophyll 'a' and Phytoplankton by Fluorescence, Version 1.1, Nov. 1992, Section 7.0.

6. SOPs for Data Management

6.1 SOP 23- Data Management

6.1.1 The NPSTORET Database

All data collected by vital signs water-quality-monitoring activities will be entered in the park's local (desktop) copy of the NPSTORET database. This database was developed by the NPS Water Resources division to serve as a portal to the USEPA STORET Oracle database. NPSTORET ensures that monitoring data are in the proper format and contain the appropriate metadata for migration to STORET.

Guidance for using NPSTORET is available in the on-line Help System, system documentation, the Vital Signs Water-quality Data Management and Archiving Web site (http://www.nature.nps.gov/water/infoanddata/index.cfm), and in the *Guidance on Water Quality, Contaminants, and Aquatic Biology Vital Signs Monitoring Under the Natural Resource Challenge Long-Term Water-quality Monitoring Program - Part E: Draft Guidance on Data Reporting and Archiving in STORET* at http://www.nature.nps.gov/water/infoanddata/wqPartEtest.pdf.

6.1.2 Data Entry

Data entry is the initial set of operations in which raw data from paper field forms or field notebooks are transcribed into a computerized form (into a database). Several methods (electronic datalogger or paper field form) are used to record data in the field; therefore, there will be several ways of inputting data into NPSTORET.

Data entry is best performed by a person who is familiar with the data, and ideally takes place as soon as data collection is complete. It becomes more difficult to track down questionable information on a field form as the time period increases after data collection. Since there can be a considerable lag time for analytical results to be sent from off-site laboratories, results are usually added by editing an existing record that was created when field data were entered for that monitoring visit.

General procedures for data entry are as follows:

1) *Become familiar with the data forms.* Some errors or omissions are detectable or suspected at this point and can necessitate setting aside some of the forms for clarification or correction by the field staff *before* attempts of entering such data into the computer. Identify in the documents a good stopping point to prepare for interruptions or the end of the work day. The best stopping point is at the completion of the entry of any single, complete field form rather than in the middle of a logically single operation.
2) *Transcribe the data.* Data are entered in one logical set at a time--usually one complete field form. Errors or questions about the data content can be recorded in separate data entry notes; such notes are useful during data verification. Initial each paper form after data are entered to avoid confusion about whether it has been processed (a colored pen is useful for this purpose). Interrupt data entry only at logical stopping points.
3) *Create a hardcopy of the data.* Print a copy of all the entered data for later verification (Consult the Project Leader for formatting details). Do not sort the file because it must be checked in the same order as it was entered to speed verification from matching field forms. Check whether *all* the data were printed and are readable (font size and attributes) for later use. Carefully formatted reports are not prepared at this stage because the data have not been checked and probably contain some errors.
4) *Document the data entry.* Indicate on a cover sheet or other suitable location the name or initials of the operator and the date of entry completion. Record identical information at the top of the printout of the entered data. The field data and the printout are kept together from this point on for use in data verification.

6.1.2.1 Manual Data Entry

Information exclusively residing on paper field forms is manually keypunched into the system, although this method is the least desirable because of the increased likelihood of transcription errors.

From the main menu of NPSTORET, enter the data by use of the following steps:

1) Select your organization from the pick list in the lower part of the menu.
2) Select your Log-in ID from the pick list and click on the "Results" button.
3) Select your Project, Station List, and Characteristic list and click the "OK" button.

4) If you are creating a new record, click the "Add New Visit" button, or select the appropriate date and station of the visit you want to edit from the "Jump to Station Visit" pick list.
5) Enter or edit the appropriate information in the Activity screen.
6) Enter or edit the appropriate information for each of the sample parameters in the Characteristics list.
7) Repeat for each new sample or visit.

6.1.2.2 Electronic Data Entry into NPSSTORET

Data captured on field dataloggers (such as the YSI sonde, DO meter, LiCor light meter) can be imported into the NPSTORET interface using customized import routines. Similar routines can be developed for data delivered from analytical laboratories in standardized electronic formats. Once an import routine has been developed to accept the output from a field datalogger or electronic laboratory result report you can follow steps 1 through 5 using NPSTORET and then click the "Import" button to associate the data with a particular visit/activity.

Data verification ("proofing") immediately follows data entry and involves checking the accuracy of computerized records against the original source—usually paper field records. Although the goal of data entry is to achieve 100 percent correct entries, this is rarely accomplished. To minimize transcription errors, 100 percent of records are verified to their original source during the first review. Further, 10 percent of records are reviewed a second time by a different person (preferably the Project Leader) and the results of that comparison reported with the data. If errors are found in the second review, then the entire data set is verified again. Once the computerized data are verified as accurately reflecting the original field data, the paper forms are archived and the electronic version is used for all subsequent data activities.

Data sets are rarely static. They often change through additions, corrections, and improvements made from summary and analysis. There are three main exceptions to this process:

- Only make changes that improve or update the data while maintaining data integrity.
- Document any changes made to the data set, especially once archived.
- Be prepared to recover from mistakes made during editing.

The project leader edits all archived data. Document every change in an edit log and accompany it by an explanation that includes pre- and post-edit data descriptions. Practice careful version control during editing to ensure that changes are incremental and that roll-back to a previous editing session is possible until such time as the file being changed is certified as correct, up to date, and ready for archiving.

6.1.3 Metadata Procedures

Metadata (which typically answers the question of “How” something was done) is the most critical improvement to modernized STORET. At a time when states are increasingly passing “Credible Data” statutes and ignoring improperly documented data, the NPS must ensure that metadata about sample collection, preservation, transport, and storage; laboratory preparation and analytical methodology; quantification and detection limits; and other metadata that help users judge the usefulness of data are stored with the data. In short, poorly documented data are a waste of money and effort.

NPSTORET allows users to document the entire monitoring procedure, from field-data collection to final result generation. Before any results can be entered into the system, NPSTORET must be prepped with the appropriate metadata documenting the field sampling/measurement procedure; gear configurations; sample preservation, transport, and handling; field/laboratory analytical procedure; laboratory sample preparation; complete detail about the characteristics measured; laboratory information; staff and their roles; and any literature citations pertinent to the monitoring effort. Metadata only needs to be entered once in one place in the database before entering results.

6.1.4 Data Verification

Verification is often best accomplished using teams of two people, with one person reading the original data sheets (the reader) and the second person reading the same data on the printout (the checker). In the following SOP, a reader and a checker work together. The checker needs a fine-tipped marker for identifying errors and for indicating corrections. The reader needs to use a different color marker. Use of a straight edge make reading aligned tabular data easier. A notepad is important for making notes that are useful during validation.

1) *Compare entered data with field forms.* The reader reads the original data (field forms) out loud so that the checker can compare the original data with the data entries on the printout. The three common types of error are; duplicated records (entered twice), missing records (inadvertently skipped during entry), and misspellings (wrong number or code). The checker controls the speed of the reader and halts the reader when a discrepancy is found. When an error in the printout (=computerized records) is found, the correction to be made is noted in red on the printout and *not on the original data sheets.*

2) After verifying the data from each field sheet, the reader dates and initials the original field form at the top (or where indicated), indicating that verification was done. The reading and checking is continued until all the data sheets in a data set are compared. Thereafter, an original set of data sheets with completion marks (for entry and verification) and a set of printouts with needed corrections marked in red are available.

3) *Correct identified errors in the computer files*. An application for data entry (or one provided specifically for editing) is used to correct the errors as indicated on the printout. Each correction is made separately in the computer file. Do not use the *search and replace* as it creates unexpected consequences). As each correction is made, check the red mark on the printout with a green check mark. Check mark when all identified errors are corrected in the computer file, the printout is

inspected again for any corrections that were missed (a red check without a green check). Finally, intial and date the printout at the top to indicate that all errors were corrected. Save the printout with the original field form because it serves as direct evidence of the completion of entry and verification.

4) *Complete a simple summary analysis*. Run simple summary statistics of the entered data on the computer. This is important because even when care is taken up to this point, a duplicate or omitted entry could have been overlooked. For example, the number of known constant elements, such as the number of sampling sites, samples per site, or sites per date can be viewed. Ask the same question in different ways to find differences in the answer that will provide clues to errors. The more variety of checks to test the completeness of the data, the greater is the confidence that the data are completely verified.

6.1.5 Data Validation and Quality Control

The Project Leader must validate the data after verification is complete. Validation is the process of reviewing computerized data for range and logic errors. Although data are correctly transcribed from the original field forms, the results may not be accurate or logical. For example, a stream pH of 25.0 or a temperature of 95°C is illogical and almost certainly incorrect, whether or not it was properly transcribed from field forms.

Step-by-step instructions are not possible for data validation because each data set has unique measurement ranges, sampling precision, and accuracy requirements. Nonetheless, validation is an important step in the certification of the data. Certain components of data validation are built into data entry forms (such as range limits). Additional data validation can be accomplished during verification, if the operator is sufficiently knowledgeable about the data. Data can be compared to previous years to identify gross differences. Validation procedures will identify generic errors such as missing, mismatched, or duplicate records, or errors specific to particular projects.

One of the most important tasks of rigorous validation is when the checker returns to the original data media (*and* the printout or 2nd copy) to make corrections and notations about the errors that were found and fixed in the digital files. Without annotating the original field forms, the digital and paper records do not match. If this mismatch is discovered without adequate documentation, *all* data are rendered suspect.

The following generic procedures can be used to develop a validation strategy for most data sets. Examples of validation strategies (and strange errors) are also provided.

- *Catalog the error types found in each data set*. When particular validation errors are found, it is important to catalog them in an error log for that data set. Notes on the error(s) include a description, how detected, and how corrected. Simple, generic errors and more esoteric and cryptic errors must be documented. This list of errors is a valuable reference for the next validation session and will ultimately be used for building formal validation procedures into the data entry process and other automated, post-entry error-checking routines.
- *Perform exploratory data analysis to look for outliers*. Database, graphic, and statistical tools can be used for ad-hoc queries and displays of the data.

Histograms, line plots, and basic statistics reveal possible logic and range errors. Such exploratory methods identify obvious outliers. Some of these data results could appear unusual but prove to be quite valid after confirmation. Noting correct but unusual values in documentation of the data set saves other users from repeating the same confirmation.

- *Modify field data forms to avoid common mistakes*. With a list of validation errors and exploratory data results in hand, the field-data forms as the source of the logic errors can be reevaluated. Often minor changes, small annotations, or adding check boxes to a field form remove ambiguity about what to enter on the form. In fact, any time the same type of validation errors occurs repeatedly in different data sets, the field form --not the field crew-- is usually at fault. Repeated validation errors can also mean that protocol(s) or field training is faulty, which must be recognized and corrected.

Data generated from digital dataloggers such as the YSI 650MDS must be reviewed for validity, especially values indicating that the sensor(s) failed or were improperly calibrated. More detailed instructions for detecting and deleting these types of errors are found in the SOP for the specific monitoring equipment. This proofing and validation process can be performed in the datalogger's computer data-viewing application (such as YSI's EcoWatch software), *before* the data are imported to NPSTORET.

6.1.6 Backup and Archiving

After each month's monitoring data are entered, verified, and validated, the local NPSTORET databases (typically one for ACAD and one for the rest of NETN) are backed up to an archive on an NPS computer server, and two backup copies are created. One backup (on disc or removable hard drive) is kept in a secure storage location by the park or cooperator and the other backup copy is sent (or “transferred”) to NETN Data Manager for offsite storage. The edit log files, documenting major edits and changes to the database, is also backed up and stored with the database copies. NPSTORET is a complex database containing many linked files and documents. To ensure that all of the NPSTORET information is copied or backed up, always copy the entire NPSTORET folder (at the highest level under the root drive).

The annual roll up and archiving of NETN’s NPSTORET databases will occur at the end of each calendar year, once all laboratory results from offsite analyses have been entered and all corrections and edits are complete and fully documented in the edit log. The project leader will conduct a final "spot check" of randomly selected records representing 10 percent of the data from the monitoring year. The resulting end-of-year copies of the NPSTORET database will reflect the complete annual water-quality-monitoring information for NETN parks, and will be used by NETN Data Manager for submission to the NPS WRD for transfer to the National STORET database.

6.1.7 Digital-data forms

As digital technology advances, more options for collecting field data on rugged, compact dataloggers, laptops and personal data assistant (PDA)s will become available.

Selecting which digital data collection platform is most useful is best done by the NETN data manager.

7. Standard Operating Procedures (SOPs) for Data Reporting and Analyses

Data reporting will follow the data-reporting guidelines detailed in Chapter 7 of the Inventory and Monitoring Program's Monitoring Plan. Data analyses and reporting will consist of an annual data report, and biennial trend analyses and scorecard reports. The annual data report will ensure that all data are being checked for quality and completeness, and will be available to the public. Trends will be analyzed biennially on all vital-sign measures for each park. Where statistically and ecologically significant trends are found, further analyses will be conducted to determine if these trends hold across waterbodies in a park or a region or if they are unique to one waterbody in a park. Results of the trend analyses will be published in a biennial scorecard report for park managers and the public.

7.1 SOP 24 – Annual Data Reporting for Lakes, Ponds, and Streams

All data and QC samples that are collected as a part of NETN vital-signs program will be included in the annual upload of each local database to the NPSTORET database as described in section *6 Standard Operating Procedures for Data Management*. In addition, an annual data report will be published that will make the data and basic summary statistics available to cooperators, park managers, state databases, and the public.

An annual data report will be prepared following each field season summarizing the status of each metric at each park for the previous water year (October 1- September 31). Annual data reports will be produced by individual parks and (or) cooperators, and delivered to NETN by the February following the field season. For example, ACAD will continue to produce an annual lake data report with all individual results of data collection listed. USGS routinely publishes all streamflow data as a part of their annual state water resources data report. In addition, all data that are not routinely published as a part of an independent report shall be compiled and reported by NETN staff. The NETN data report will include links or references to all other cooperator data reports, and will be available to the public.

Data reports include all vital-signs data values, all QC samples, basic summary statistics for the data and the QC data, descriptions of field and laboratory methods, and the name, number, and description of each site where data were collected. An assessment of the data quality includes minimum reporting limits, estimates of precision and accuracy, and sources of error. Annual data reports also include any new instances of invasive plant species, although substantiated new outbreaks of invasive plant species will already have been brought to the attention of park managers and the appropriate state agencies.

Data values less than state water-quality standards will be flagged in these reports. Much of this data report can be standardized by use of a template that includes all methods and background information. This background data information is usually similar from year to year. Interpretive work is not included in these data reports. Annual reports are compiled and reviewed by NETN and made available to the public in the April of the year following data collection before the upcoming field season begins.

Data reports and any concerns with the data including QC concerns are discussed during the annual Inventory and Monitoring "Road Shows" as outlined in NETN monitoring plan. These road shows offer an opportunity for all those concerned about the monitoring program to discuss the results of the monitoring, water-quality concerns, training and staff needs. Feedback from these meetings will be used to guide monitoring effort in the following year and to refine protocols where appropriate.

7.1.1 Quality-Control Reporting

All QC data are included in the annual report. It is the responsibility of the field staff to bring QC problems to the attention of NETN and to suggest solutions to improve the monitoring program. NETN reviews all QC data and ensures that problems are addressed before the next field season begins.

Data quality must be indicated whenever data are reported. Data quality is most easily indicated by estimates of precision and accuracy and by the results of blank analyses. Each analytical batch includes an estimate of precision and accuracy. Raw data used in estimates of precision and accuracy and in results of blank analyses are to be reported with all data. Summaries of estimates of precision and accuracy for a sampling period can be used when data reports are prepared. Precision data can be included by listing the range of precision values obtained in percent relative standard deviation (RSD) by variable for each year or sampling period, noting the number of duplicates, and the number of duplicates that exceeded the QA objectives.

Accuracy data can be included by listing the range of accuracy values in percent difference by variable for each year or sampling period, noting the number and type of samples used to determine accuracy, and noting the number of samples that did not meet the QA objectives. Similarly, summaries of blank analyses can be included by listing the range of blank values by variable for each sampling period, the number and concentration of blanks that exceeded the concentration values listed, and the total number of blank analyses. If the total number of duplicates or blanks is 10 or less, report results from all duplicates or blanks is included , instead of a written a summary. Field blanks are used to identify contamination being introduced through field procedures.

7.1.1.1 Analyses for Field Blanks

Results of field blank sample analyses from the laboratory are examined immediately to see if contamination is occurring. These results can then be used to adjust collection methods ant the use of topical blanks before sampling continues. Confidence limits for selected percentiles of contamination and bias are calculated and reported annually in the annual data report. Initially, blanks are used singly to compare blank analysis to critical concentrations, such as water-quality standards, and to alert staff of contamination problems and identify the need for topical blanks if necessary. When enough blanks are collected throughout each park and throughout NETN, use nonparametric statistics on the blanks to obtain confidence limits for selected percentiles of contamination that are estimated based on concentrations of the analytes in the blanks (see section *7.1.1 Quality control reporting*.

Rank the blank data from lowest to highest. The rank (*u*) that equals or exceeds the selected 1-α confidence limit for the selected percentile (*p*): $100 (1- \alpha) \geq B \{p, n, u-1\}$ can be determined, where B is a binary probability. The upper 1-α confidence limit for the percentile is the value of the rank *u* observation: $C_{ucl} = X_{(u)}$ where C_{ucl} is the concentration that goes with the rank *u* (Helsel and Hirsch, 1992).

Systematic error or bias is expressed as a as percent recovery (with the correct or expected answer at 100 percent). The systematic error or bias measurement-quality objective (MQO) percent recovery ranges from 80 to 120 percent. If the MQO for a particular parameter is outside of that range (70 to130 percent), all values associated with that blank batch qualify as an error, and recalibration or other adjustments to the blanks must be done until the MQO can be met. The raw values used to calculate these percentages are also reported in the annual data report to allow for future statistical analyses (such as long-term or multi-laboratory means or standard deviations).

7.1.1.2 Analyses for Replicates

Replicates measure both field variability and method variability. Results of field replicate sample analyses from the laboratory are examined immediately to check these sources of variability among samples. These results can then be used to adjust collection before sampling continues. Standard deviations and means are calculated from the analyses results and reported annually in the annual data report.

The mean and the standard deviation are calculated for replicate samples as

$C_{ave} = (C_1 + C_2 + \ldots C_n)/n$

$SD = ((\sum [C_i - C_{ave}]^2) / (n-1))^{1/2}$

where *C* is the concentration and *n* is the sample size (Helsel and Hirsch, 1992). The RSD is calculated so that the standard deviation does not depend on the concentration of the sample.

$RSD = 100 * (SD / C_{ave})$.

With the RSD and SD, variability for ranges of mean concentration can be graphed and estimated (Helsel and Hirsch, 1992). In this way an estimate of the uncertainty of the concentration measured in a single sample can be obtained for a given degree of confidence as

$\text{Confidence Interval} = C_{samp} \pm Z_{(1- \alpha/2)} SD_{reps}$

For a 90 percent confidence interval ($\alpha /2 = 0.05$, $z = 1.645$).

QC measurement quality objectives (MQOs), should not exceed a relative percent difference of 10 percent (RPD, for a sample size of two –(duplicates) or a RSD for sample size of three or more). Field-probe measurements for this performance standard are specific conductance, pH, temperature, DO, light transmittance (PAR), and SD. Measurement precision for nutrients and chlorophyll *a* are less stringent and should not exceed 30 percent. Although RPDs are sometimes reported for a sample size as small as two, two is not a large enough sample size for a reliable estimate of precision, and 8-20 replicates, (perhaps by pooling data over time), is necessary to keep measurement uncertainty to reasonable levels (Irwin, 2004). If MQOs are not met, all values associated with that batch of QC samples are discarded, and recalibration or other adjustments are done until the MQO is met.

7.2 SOP 25 – Biennial Data Analyses and Scorecard Report for Lakes, Ponds, and Streams

Biennial data analyses and reports are the responsibility of NETN staff. In the analyses for long-term continuous streamflow gages, analyses could be contracted out to the agency performing the work, but it remains the responsibility of NETN to compile and integrate all reports from all contractors and network staff into a single summary document that is useful for NPS managers and Inventory and Monitoring staff at a national level.

Biennial data analyses include the following: 1) basic statistics such as maximums, minimums, means, and standard deviations for each analyte and 2) seasonal and annual trend analyses. Data analyses are designed to answer the following questions:

1) What is the range of variation of water-chemistry parameters in pristine waters with minimum anthropogenic stressors?
2) What are the long-term trends in water chemistry in each waterbody, each park, and in the region? Are these trends statistically and ecologically significant?
3) Can trends in water chemistry be explained by changes in flow and(or) climate?
4) Are trends among all of the measures in a vital sign changing in the same way?
5) Are waterbodies meeting state water-quality standards?
6) Have invasive plant species been introduced into any new ponds or lakes in the park network?

The presence of trends can be tested with the nonparametric Seasonal Kendall Test (a seasonal extension of the nonparametric Mann-Kendall test) (Helsel and Hirsch, 1992), and the slope of the linear trend is estimated with the nonparametric Sen's method (Gilbert, 1987). Seasons are defined as months when sufficient data is available for the analyses. If monthly data are not available, groups of months that would not be expected to differ significantly from one another can be combined into larger seasons as long as these seasons are consistent from year to year. The data must be tested for trends within that period. The longer the defined season, however, the more variability there will be in the data, and the more difficult it will be to demonstrate a trend or lack thereof.

Alternatively, variability can be determined and summarized for the single month for which the most data is available (often August). Trends are reported whether or not they are statistically significant, but are highlighted if they are statistically significant at $p \leq 0.05$. An excel template (MAKESENS) is used for all calculations (Salmi et al, 2002).

Measures and trends are also analyzed for each vital sign. Indices for each vital sign can be developed so that all measures within a vital sign can be compared with one another. These indices will help resource managers understand an integrated picture of the aquatic resources at each park. The index will be numerical, such as the trophic status index in lakes or the indices will be graphed side by side and compared to one another such as an acidification index. Examples of the types of information to be included in biennial data analyses are included for lakes and for streams.

Categories such as good, concern and caution are included on figures 3 and 4 as examples and are primarily based on water-quality standards when available. These categories can change as more data are collected. How these categories apply to management is beyond the scope of this report.

7.2.1 Lake Analyses

Measures of lake water quality are separated into those measures that are indicators of a lake or pond trophic status and those measures that are indicators of water chemistry. Water quality implies a subjective judgment depending on water-chemistry measures and the desired uses and attainment classes of the water. Water quality is different from the more objective trophic status which offers a framework within which evaluations of water quality can be made (Carlson, 1977). Eutrophication of lakes and ponds is a natural process and unaffected lakes and ponds are at all points along the trophic continuum. Eutrophication only becomes a problem when it is accelerated from anthropogenic causes.

For the parameters used to estimate the trophic condition of lakes such as SD, total phosphorus and chlorophyll a, population variance or (lake-to-lake variance) dominates all other variance components including within-year variance, year-to year variance and sampling error by a substantial amount (Larsen et al, 1995). Thus it is most meaningful to calculate summary statistics, (including an estimation of the variability of the statistics) on individual lakes- and then summarize the variability and trends across all sites. The report could then include a number or proportion of sites with statistically significant trends upward or downward. Likewise standard deviations or estimates of seasonal or year to year variability are most meaningful if the variability of individual sites is summarized.

A trophic status index can be calculated based on measurements of SD, Total Phosphorus and Chlorophyll *a*. For Maine, this index can be calculated with the equations generated by the state of Maine as listed in the section on Maine in section *1.1.5 Water-quality Standards*. Each of these three measures, when converted to the trophic scale, will give a similar estimate of the trophic state index. Arguably, only one of these measures is needed to estimate the trophic state of a lake. The calculated trophic state number, however, is only an index of trophic status, or a lake or pond's productivity. Having more than one measure of a lake's productivity allows for a QA check, options for estimating trophic state during various seasons of the year, and a better understanding of why the trophic state is changing if it is in fact fluctuating.

Each of these measures is used to understand lake processes throughout the year. Phosphorus is relatively stable throughout the year, and can be used as an index in the fall and spring when algal biomass is limited by other factors than phosphorus and thus may be below its maximum potential. The measurement of chlorophyll *a*, however, can be used in the summer for the best estimate of algal biomass. Chlorophyll *a* will be used to calculate the TSI if values of Apparent Color are greater than 25CPU. SD is the least expensive and easiest measurement to make, is widely measured, and allows for comparison across many lakes in the region. It usually provides an index very similar to that determined with measurements of chlorophyll *a*.

Currently (2006), SD is the only parameter that are measured monthly, and thus TSI for the example scorecard is calculated based on the monthly means for each sample. A minimum of one reading per month from May through November is used with no two consecutive months of missing data (see section *1.1.5.1 Water-quality Standards: Maine*). Five lakes in Maine were chosen in 1995 to be more intensely monitored for trophic status (Witch Hole Pond, Upper Hadlock Pond, Echo Lake, Seal Cove Pond and Jordan Pond). These lakes vary in their vulnerability to accelerated eutrophication and in their physical characteristics. In addition, Long Pond is included as it has sufficient SD measurements for analysis as a part of its long-term monitoring history. Although many of these Maine lakes have SD measurements back through 1982, a modified SD viewing scope came into use in 1995, therefore pre-1995 measurements may not correspond to post 1995 measurements (Breen et al, 2002). Furthermore, trophic status in some lakes appears to have decade-long cyclic trends, indicating that it may be most appropriate to look at linear trends for only the most recent period (L. Bacon, MDEP, written commun., 2005).

For some lakes, up to 30 years of SD data are available. Test these longer datasets for cyclical trends. An example of the type of graph that could be used in the biennial scorecard based on ten years of data is given in figure 2.

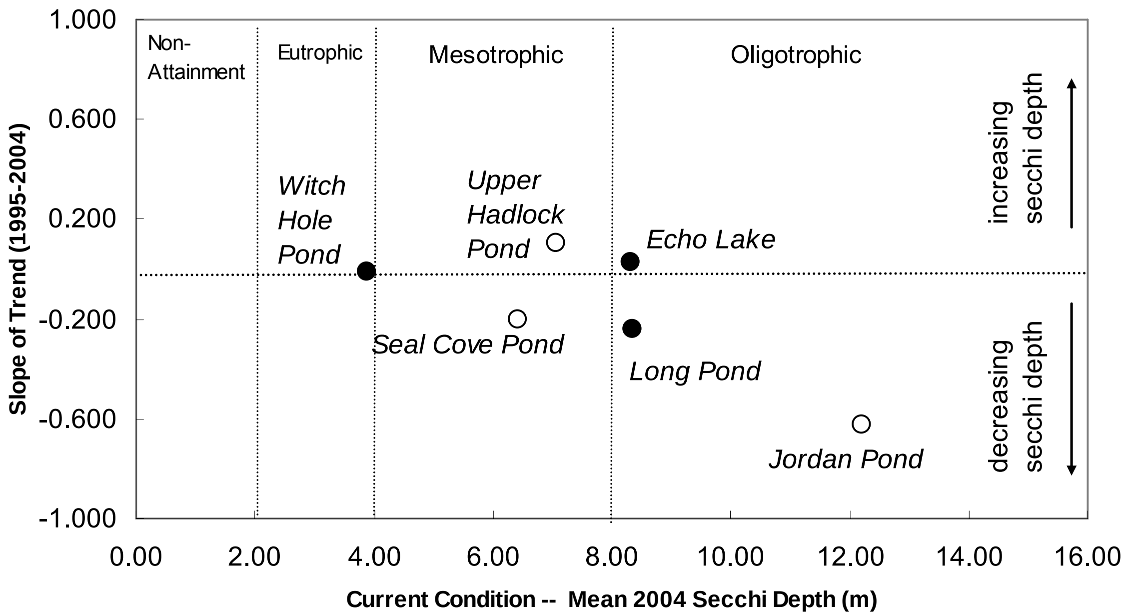

Figure 2. Example of a biennial trophic scorecard for current condition and slope of trend of yearly mean Secchi disk depths in Acadia National Park lakes from 1995 to 2004. Hollow circles indicate that trend is significant at $p \leq \mathbf{0.05}$.

The graph shows the mean 2004 SD for each lake as the current condition against the slope of the trend for the period of record. The presence of a trend is tested with the nonparametric Mann-Kendall test, and the slope of the linear trend is estimated with the nonparametric Sen's method (Gilbert, 1987). Trends are shown whether or not they are statistically significant, but hollow circles indicate that the trend is statistically significant at $p \leq 0.05$.

Lakes with a negative slope of trend have decreasing SDs that perhaps indicate accelerated eutrophication. Jordan Pond and Seal Cove Pond are the only lakes in which negative trends are statistically significant. When trends in August SDs are examined, Seal Cove Pond is the only lake with a downward trend in SDs from 1995 to 2004 that is statistically significant. Although some trends are statistically significant, trends might not be ecologically significant. Ecologically significant trends in trophic status usually indicate an acceleration of natural eutrophication processes, which usually indicates declining water quality. This graph is an example and not a comprehensive evaluation of trends at lakes in ACAD.

As more monthly data are collected, longer time frames will allow for better evaluation of documented trends, causes, and ecological significance. Additional lakes at ACAD could be included in the analyses, and monthly analyses would then be possible for all parameters. Scorecards show the status and trends of various indices of water quality such as an index for trophic status and acidification. Categories of trophic status equate to state water-quality standards.

Water-quality judgments for a lake consider not only trophic status, but also water-chemistry measures, changes in trophic status, and the presence and extent of invasive plant species. The graphs of the condition and trends of pH and ANC in ACAD lakes (figures 3 and 4) indicate the acidification status of ACAD lakes. Five lakes have been monitored consistently since 1995 to evaluate long-term acidification status. Jordan and Bubble Ponds represent the large deep water lakes in ACAD; Sargent Mountain Pond and The Bowl represent smaller headwater and (or) high-elevation lakes most likely to show chronic acidification; and Witch Hole Pond represents a lake affected organically by its adjacent wetland (Breen et al, 2002). Samples are half-meter deep grab samples taken from the deepest point in all lakes. These lakes have intermittent pH and ANC data since 1982. These earlier data are included in trend analyses despite large data gaps, in 1984-85, 1987-88, and 1990-97.

Both graphs show the current condition as of October 2004 against the slope of the trend for the period of record. The presence of a trend is tested with the nonparametric Mann-Kendall test, and the slope of the linear trend is estimated with the nonparametric Sen's slope estimator method (Gilbert, 1987). Trends are shown whether or not they are statistically significant, but hollow circles indicate that the trend is statistically significant at $p \leq 0.05$. Lakes in ACAD tend to be poorly buffered (low ANC) and with low to neutral pH values; thus pH and ANC indicate improvement in lake water quality if trends show a significant increase (Breen et al, 2002).

Maine does not currently (2006) have numerical water-quality standards for pH and ANC. Lake standards are "as naturally occurs" (Maine State Government, 2005). In the absence of numerical standards, the categories of good, caution, and concern for current condition are determined on the basis of the documented distribution of pH in Maine lakes (Williams, 2004). Most Maine lakes have pH values between 6.0 and 7.0, which met the standards for other New England states. ANC categories are determined on the basis of documentation that values above 100 uq/L are insensitive to acidification, and values below zero typify acidic waters (Stoddard et al, 2003).

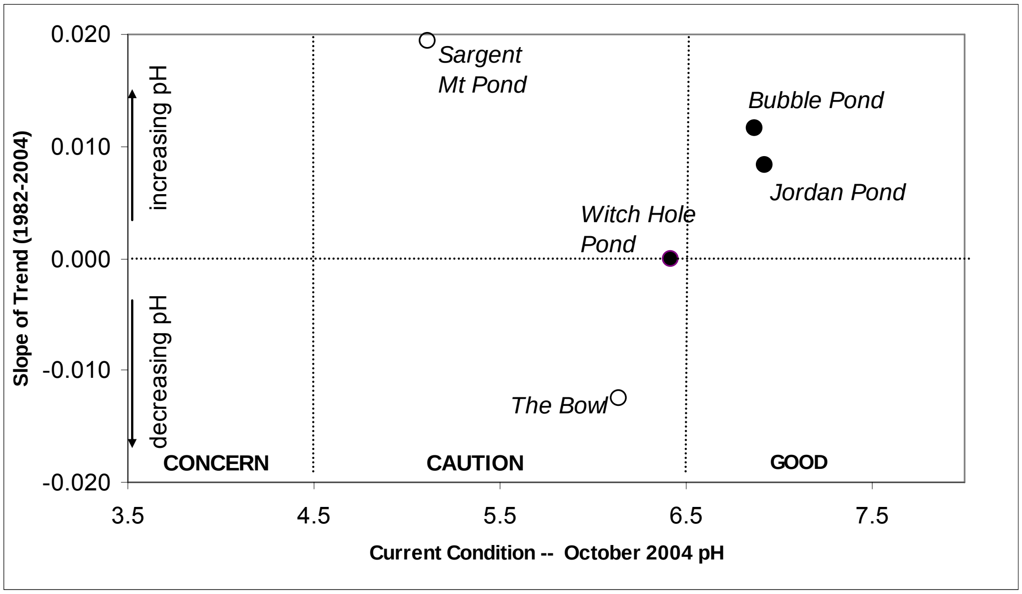

Figure 3. Current condition (2004) and slope of trend of October pH grab samples in lakes in Acadia National Park from 1982 to 2004. Hollow circles indicate that trend is significant at $p \leq 0.05$.

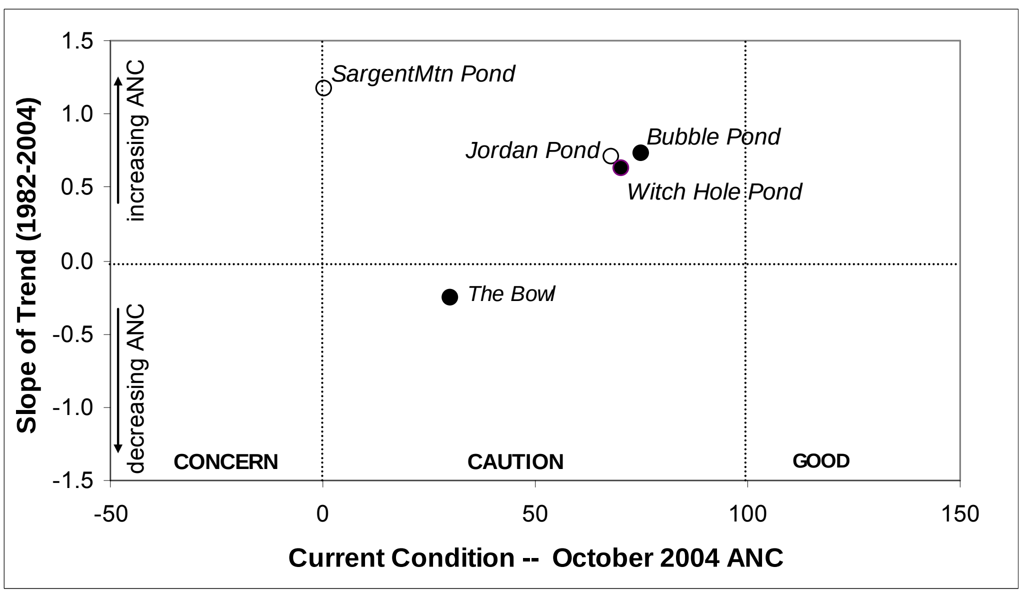

Figure 4. Current condition (2004) and slope of trend of October Acid neutralizing capacity grab samples in lakes in Acadia National Park from 1982 to 2004. Hollow circles indicate that trend is significant at $p \leq 0.05$.

Of the five lakes shown, all have average pH as compared to other lakes in Maine, except for Sargent Mountain Pond with a pH of 5.11. Sargent Mountain Pond is also poorly buffered with an ANC of 0.41, but shows a trend towards improving conditions of both acidification parameters. The Bowl is the only lake showing decreasing trends in ANC and pH, although only the trend in pH is statistically significant. Although some trends were statistically significant, trends might not be ecologically significant. As more data are collected, longer time frames will allow for better evaluation of documented trends, causes, and ecological significance. These graphs are examples and not comprehensive evaluations of trends at lakes in ACAD

7.2.2 Light-Penetration-Profiles Analyses

Photosynethetic photon flux density (PPFD) is measured with a light meter in lakes with average SD readings below 5 meters, or in any lake where at least one SD has been greater than the lake depth. A relation between SD and PPFD has been established for lakes in ACAD. A non-linear relation between SD and the light attenuation coefficient that has often been cited in the literature is $K_d = 1.7/ Z_{SD;}$ where K_d is the light attenuation coefficient and Z_{SD} is SD (Poole and Atkins, 1929; Short and Cole, 2001). Although this may be a reasonable approximation if site-specific data are not available, a more specific relation was approximated from 6 years of data on 7 lakes in ACAD; $K_d = 4.7/ (Z_{SD})^{1.18}$ (fig. 5). The average summer SDs in the 7 lakes ranged from 4 to 14 m. Deeper than 5 m, the relation between depth and PPFD is more variable. It is not appropriate to use this relationship outside the range of variables from which the equation was developed. In lakes at ACAD with average SDs of 5 meters or greater, the light attenuation coefficient can be estimated based on the relationship; $K_d = 4.7/ (Z_{SD})^{1.18}$ (fig. 5).

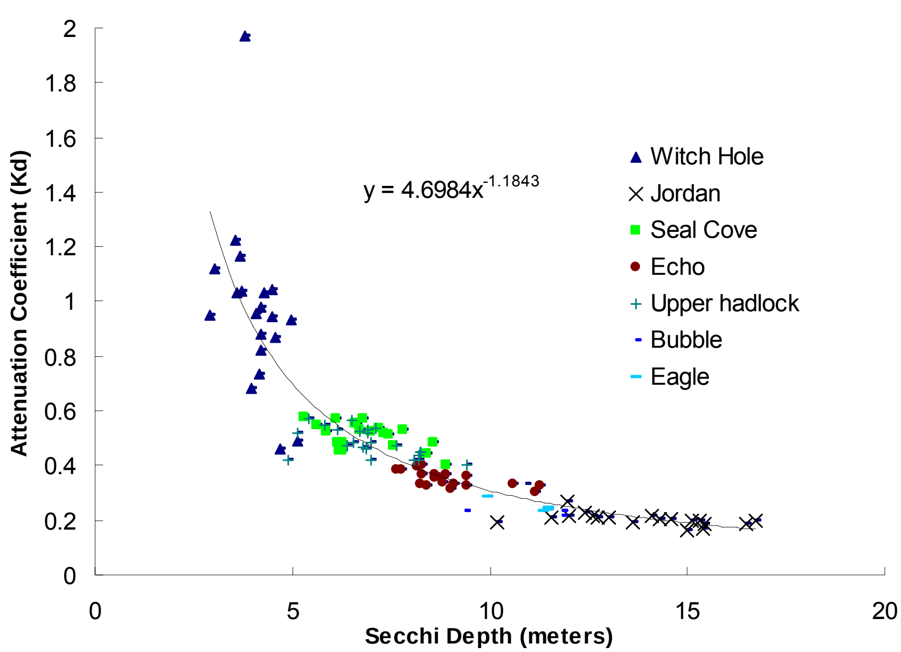

Figure 5. Relation between Secchi disk depth and light attenuation coefficient calculated from light meter data in seven lakes in Acadia National Park.

7.2.3 Water-Level and Streamflow-Data Analyses

The purpose of this SOP is to outline the procedures and policies pertaining to the processing and analysis of data associated with the computation of streamflow records. This section includes data processing and analysis for partial-record streamflow-gaging stations, and continuous-record streamflow-gaging stations. The procedures are adapted from Rantz et al (1982) and Kennedy (1983).

The computation of streamflow records involves the analysis of field observations and field measurements, the determination of stage-discharge relations, adjustment and application of those relations, and systematic documentation of the methods and decisions that were applied.

Streamflow records are computed and checked by those field staff making the measurements. Rating curves for continuous-record stations are the responsibility of staff maintaining the station.

7.2.3.1 Measurements and Field Notes

All discharge measurements are checked by a second party. The measurements are checked by reviewing the mathematics and other items listed in Kennedy (1983) as soon as possible after the measurement is made. Measurement gage-height information is checked against the recorded data at the time the gage records are computed.

The gage-height information, discharge information, control conditions, and other field observations written by field staff onto the measurement note sheets and other field note sheets form the basis for records computation for each gaging station. Measurements and field notes that contain original data are required to be stored indefinitely (Hubbard, 1992).

7.2.3.2 Continuous-Record Streamflow-Gaging Stations

Surface-water gage-height data are collected as continuous record (hourly, 15-minute, or 5-minute values, for example) in the form of electronic storage on data loggers. Streamflow records are computed by converting the gage-height record to a discharge record through application of stage-discharge relations. Ensuring the accuracy of the gage-height record is, therefore, a necessary component of ensuring the accuracy of computed discharges.

The gage-height record is assembled for the period of analysis in as complete a manner as possible. Periods of inaccurate gage-height data are identified, then corrected (see section *7.3.2.5 Datum corrections, gage-height corrections, and shifts*) as appropriate. Items included in the assembly of gage-height record and procedures for processing the data are discussed in Kennedy (1983), and Rantz et al (1982). Logged data are downloaded at least twice each year.

7.2.3.2.1 Records and Computation

Records are computed on a continual basis as much as possible to improve the accuracy of provisional records and to minimize the work needed at the end of the water year. All initial computation for a station is done by the individual responsible for the field work at the station. When completed, the records are checked by a second hydrographer. Changes to the records by the checker are coordinated with the individual who computed the record.

7.2.3.2.2 Gage height

The accuracy of surface-water discharge records depends on the accuracy of discharge measurement, the accuracy of rating definition, and the completeness and accuracy of the gage-height record. Computation of streamflow records includes ensuring the accuracy of gage-height record by comparisons of gage-height readings made by use of independent reference gages, comparison of inside and outside gages, examination of high-water marks, comparisons of the redundant recordings of peaks and troughs by use of crest stage gages, and confirmation or updating of gage datum by levels.

Records computation includes examination of the gage-height record to determine if the record accurately represents the water level of the body of water being monitored. Additionally, it includes identifying periods of time during which inaccuracies have occurred and determining the cause for those inaccuracies. When possible and appropriate, the inaccurate gage-height record is corrected. When the record is available from a backup of the same gage as the primary record, the backup record is directly substituted for the missing record. When the backup record is available from an independent gage at the station, the backup record is used in place of the primary record without actual substitution of the backup record for the primary record. This allows for adjustments and corrections to be applied independently to the two gages involved. Any adjustments and corrections to gages are documented on the datum summary sheet, which is kept in the primary folder for the station. Adjustments and corrections are also summarized and discussed in the station analysis. In addition, the station analysis clearly documents the source of all of the gage-height record used during the year. No recorded record is ever deleted or removed from the database in the process of records computation.

7.2.3.2.3 Rating Curve

The development of the relation between gage height and discharge, also called the rating curve (or rating), is one of the principal tasks in computing the discharge record. A rating curve allows discharge measurements to be calculated from stage measurements, which are less expensive and easier to obtain, and can be determined continuously. Rating curves can take several years to develop and can change over time as stream-channel conditions change. All measurements, which are not affected by ice, are plotted each year on the graphical rating plot. Ratings are checked immediately when developed, and the plotting of new measurements is checked each year.

Each rating at a station is given a unique identification number beginning with 1.0. New ratings, which are the result of a physical change in the stage-discharge relation are given a new identification number of the next unit higher than the previous rating (for example

2.0). New ratings that are extensions of old rating or are corrections to errors in old ratings are given identification numbers one-tenth higher than the previous rating (for example 1.1).

At most stations, a minimum of three discharge measurements are made to confirm the accuracy of the rating each year. One measurement, made either directly or indirectly, is made as close as possible to the highest discharge experienced during the year, one is made as close as possible to the lowest discharge experienced during the year, and one is made at an intermediate discharge. If the three measurements are within 5 percent of the rating in effect, the rating is presumed to be valid for the entire year. If any of the measurements are more than 5 percent different than the rating, additional field measurements are made as needed to confirm and define the change in the rating. At stations which are known to have unstable ratings, measurements are made at each site visit to the station to continually document changes to the rating.

7.2.3.2.4 Elevation Levels

Elevation levels are run annually to all permanent reference marks established in and around the gaging station. Errors in gage-height data caused by changes in elevation of the gage or gage-supporting structure can be measured by running levels. Gages can be reset or gage readings can be adjusted by applying corrections based on levels (Kennedy, 1983).

Procedures for computing elevation records for each station include filling out summary front sheets and checking levels and front sheets in the field, listing and checking level information on the level-results summary, and applying and checking needed corrections to the gage-height record on the basis of the levels. The individual computing the record is required to check field notes for indications that the gages were reset correctly by field staff. If corrections are found to have been needed but not applied, or if a gage was reset incorrectly, the gage is reset on the next visit to the station. The individual computing the records makes appropriate adjustments to the gage-height record by applying datum corrections. All corrections are noted on the datum summary front sheet and in the station analysis and are checked.

7.2.3.2.5 Datum corrections, gage-height corrections, and shifts

A correction applied to gage-height readings to compensate for the effect of settlement or uplift of the gage is usually measured by levels and is called a "datum correction" (Kennedy, 1983). Datum corrections are applied to gage-height record in terms of magnitude (in ft) and in terms of when the datum changed. In the absence of any evidence indicating exactly when the change occurred, the change is assumed to have happened at the last significant hydrologic event, such as spring high water or ice out. Lacking such an event, the change is assumed to have happened gradually from the time the previous levels were run, and the correction is prorated with time (Rantz et al, 1982). Datum corrections are applied when the magnitude of the vertical change is greater than 0.010 ft.

A correction applied to gage-height readings to compensate for differences between the recording gage and the base gage is called a "gage-height correction" (Rantz et al, 1982). These corrections are applied in the same manner as datum corrections by use of the same computer software. Gage-height corrections are applied so the recorded data are made to agree with base-gage data. These corrections are applied when the difference between the recording gage and the base gage is equal to or greater than 0.01 foot, or whenever the recording gage was reset in the field.

A correction applied to the stage-discharge relation, or rating, to compensate for variations in the rating is called a shift. Shifts reflect the fact that stage-discharge relations are not permanent but vary from time to time, either gradually or abruptly, because of changes in the physical features that form the control at the gaging station (Rantz et al, 1982). Shifts can be applied to vary in magnitude with time and with stage (Kennedy, 1983). The use of shifts is encouraged over development of new rating until stability of the shift is established and enough data have been collected to develop a new rating, usually 1 to 3 years. Shifts are documented through the use of a stage-shift diagram, on which all measurements used to define the shift are plotted and which is placed in the primary folder. The shift is also summarized and explained in the station analysis and, if practical, is plotted on the graphical rating plot. Daily mean discharges are then computed by applying the stage heights to the ratings.

Data recorded on field forms include a description of the station, the distance from the edge of water, the total depth of the stream at that location, the observation depth at which velocity is measured and the velocity at that point. From these data, a discharge for the cross section of the river channel is calculated as the area times the velocity for each point and then summed from all points across the cross section. Discharge calculations are completed in the field and then checked by another technician in the office.

There are a number of analysis methods that can be used to document the status and trends of water quantity in water resources in NETN parks. Graphical and numerical methods can indicate spatial or temporal trends in streams, lakes, and ponds. More than one continuous-record streamflow-gaging station is needed, however, to determine if long-term trends in streamflow are related to long-term climatic records.

7.2.3.3 Analyses of streamflow statistics at continuous-record streamflow-gaging stations

Hydrographs show water levels as a function of time and are the best visual description of seasonal and annual water-level fluctuations. Once significant data have been collected, simple statistics such as maximums, minimums, means, medians, and 25th and 75th quartiles can all be included in a hydrograph made up of either daily or monthly values. Regulatory values such as minimum low flows (August median) can be plotted to see visually how much of the time the streamflow went below this line.

It is also useful to calculate a duration curve to show how often the discharge of a stream meets or exceeds a given value. To create a duration curve, start by ranking the discharge data (for example 1 year) from the highest value to the lowest value. The chance that a given flow will be equaled or exceeded, expressed by a percentage, can be calculated as $P = 100(m)/(n+1)$, where P is the percentage; m is the rank, and n is the total number of values. This type of a graph can show if streamflow is adequate to meet designated requirements.

7.2.3.4 Analyses of streamflow statistics at partial-record streamflow-gaging stations

After significant data have been collected, discharge measurements at partial-record streamflow-gaging stations are correlated with concurrent mean daily streamflow measurements at nearby continuous-record streamflow-gaging stations with similar hydrological and (or) geomorphological characteristics to determine if a relation can be established between the two stations. If a relation can be established, daily mean discharges, and streamflow statistics such as monthly means and medians can be estimated at the partial record station on the basis of the streamflow measurements at the continuous-record stations. Estimates can only be made for the season in which measurements have been taken at the partial-record station.

7.2.4 Stream water-quality analyses

Stream water-quality status is evaluated on the basis of state water-quality standards for its fisheries classification (tables 4 and 5). Most streams and (or) watersheds in NETN parks have been classified by the state either directly or indirectly. Streams have been identified as cold water fisheries or warm water fisheries. See the table in each park's sampling design *1.2.2 Sampling Design in Streams* for the fisheries classification of each stream if available. These classifications are important to defining water-quality standards and thus will be the framework used to evaluate stream water quality standards.

In cases where a stream does not meet one or more of these water-quality standards for chemistry or nutrients, it will be flagged in the annual data report and analyzed for trends in the biennial scorecard report.

For streams, most water-quality parameters, including nutrients, are strongly correlated with streamflow. Streamflow data analyses are addressed in section 7.2.3 and once completed are used to calculate streamflow-adjusted concentrations or loads. If there is a strong correlation between the concentrations and flow, streamflow-adjusted concentrations or loads are included in trend analyses of streams. Load is calculated as the discharge (Q) times the concentration (C) for a given time period such as a day. Trend analyses are analyzed for all parameters by use of the seasonal Mann-Kendall test for trend. Seasons are comprised of monthly data for any month with sufficient data.

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Appendixes

Appendix 1: Sampling Equipment and Supplies for Field Sampling

General-All Field Standard Operating Procedures (SOPs)

1) Personal flotation devices for each crew member
2) Waders or hip boots
3) Rain gear
4) Clipboard, pencils and permanent markers
5) All applicable field-data sheets (Rite in Rain), notebooks and sampling forms
6) All applicable protocols
7) Label tape
8) Disposable latex gloves for collecting samples
9) Kimwipes
10) Digital camera
11) GPS unit
12) Calculator
13) Thermometer
14) Field maps
15) Ziploc® bags (pint, quart, gallon)
16) Measuring staff
17) Compass
18) First aid kit
19) Sunscreen, bug repellent
20) Cell phone
21) Knife/scissors
22) Drinking water/food

General-All lake and pond SOPs

1) 2-3 person boat, paddles and (or) motor, gas
2) Anchor
3) Depth meter or weighted calibrated sounding line for measuring depth

4) Bathymetric map of lake with sampling sites and landmarks marked

SOP 3, SOP 6 and SOP 10- In situ measurements of temperature, dissolved oxygen, specific conductance, and pH using multiparameter water-quality monitor (sonde)

1) Yellow Springs Instrument (YSI) sonde with attached pH, conductivity and dissolved oxygen probes
2) YSI 650MDS Multiparameter Display System (display data logger)
3) Field cable: YSI 6091-10 ft (for shallow-depth sonde) or 6092-50 ft (for medium-depth sonde)
4) YSI 6067B Dry calibration cable
5) YSI 655174 PC Interface cable for YSI 650MDS
6) YSI 5775 Oxygen probe service kit (These are expendable items provided in limited quantity with the original purchase of YSI 600XL sondes).
7) Deionized water (ASTM type III , Laboratory Grade, or better) with squeeze bottle
8) pH standards of 4, 7, and 10
9) Conductivity standards -1 mS/cm, 10 mS/cm (additional concentrations dependent upon expected field conditions) (YSI # 3163 or equivalent)
10) Serial port (or USB to serial converter) to run the current version of YSI EcoWatch software
11) YSI 6-Series Environmental Monitoring Systems Operations Manual and YSI 650MDS multiparameter display System Operations Manual
12) C-size alkaline batteries: 4 for the 650MDS (if you substitute with a rechargeable NiMH battery pack, make sure to always have a complete spare set of alkaline batteries).
13) 1 large ring stand or other homemade bracket that will allow for the sonde to be suspended from its bail
14) Modified 5-gallon plastic bucket (or equivalent) for transporting moist sonde wrapped in a wet towel
15) Calibration logging form

SOP 4, SOP 7, SOP 11 and SOP 12 - Grab and Depth-Integrated Epilimnetic Samples

1) Bottles - all appropriate sizes with labels
2) Cooler with ice
3) 8 liter churn splitter
4) Peristaltic pump and tubing for filtering samples

5) Sulfuric acid ampules for sample preservation
6) Waste container for waste ampules
7) 0.45 um capsule filters (supor, nylon or glass fiber)
8) ASRs
9) Packing tape
10) Fed Ex mailing labels
11) **ACAD lakes only:** 10 meter x ¾ inch i.d. Tygon weighted depth-integrated epilimnetic sampler (graduated in 1m intervals)
12) **ACAD lakes only:** Kemmerer-style grab sampler on graduated line
13) **ACAD lakes only:** Glass fiber filters (Whattman GF/F) for chlorophyll *a* samples

SOP 8 –Collection of Stage and Streamflow Data

1) Flow meters - AA Price or Pygmy with wading rod, extra batteries, headphone, stopwatch and copy of rating table, or direct reading instrument
2) Tape measure – minimum 50 ft cloth tape recommended
3) Stakes - end stakes for anchoring tape measure to stream banks
4) Discharge and sampling forms
5) Folding ruler
6) Extension wand
7) Level
8) Throw rope for rescue

SOP 9- Secchi Disk Depth

1) Secchi disk
2) 50 m measuring tape with clip
3) Viewing scope

SOP 13 –Light Penetration Profiles

1) LiCor Model ## solar radiation cell (for surface measurements)
2) LiCor Model ## PAR cell (mounted on lowering frame w/ cable)
3) LiCor Model LI-1400 Datalogger

SOP 14- Lake-Stage Monitoring

1) Folding ruler
2) Extension wand
3) Level
4) Orange nail polish

SOP 15 – Invasive Aquatic Plant Screening Survey

1) Small boat, canoe, or kayak. Note that large boats and motors can make the process more difficult, and could destroy sensitive aquatic vegetation
2) IAP Screening Survey documentation sheets (available from VLMP/MCIAP), pencil, and clipboard
3) Pocket knife, scissors, or hand pruner for snipping specimens
4) Small grass rake for grabbing specimens and retrieving fragments
5) Secchi disk depth viewing scope- available commercially, or construct from 5 gallon. bucket and Plexiglas. (Constructions plans available from VLMP/MCIAP)
6) Weighted measuring tape, or Secchi disk to determine depths
7) Large and small Zip-Lock plastic bags and cooler for storing specimens (bags must contain enough water to float the specimens)
8) Boat anchor
9) Polarized sunglasses (not essential, but very helpful)
10) Plant identification guides and keys, (available through VLMP/MCIAP)
11) Makeshift buoys to mark the location of suspicious plants (1/2 gallon jugs, string and brick or rock)
12) Permanent marker pens to mark specimen containers
13) Magnifying glass or hand lens for examining plant specimen structure (5-10X pocket magnifiers)
14) Small white tray or shallow plastic dish for floating and observing specimens in the field

Appendix 2: State Agencies for Reporting Invasive Aquatic Plants

Contact the organizations listed below for aquatic invasive identification survey trainings for individual sates, for the most current list of potentially problematic and (or) illegal plants in each state, for technical assistance in the positive identification of aquatic species, and for the initiation of rapid response actions. If instructed to send in a specimen, see instructions in SOP 14 for mailing specimens.

Maine:

Maine Center for Invasive Aquatic Plants

Tel. 207-783-7733

24 Maple Hill Road, Auburn ME 04210

mciap@mainevlmp.org

See their virtual online herbarium at at: http://www.mciap.org/herbarium/invasive.php for aid in identifying invasive plants. This agency will contact you within 72 hours of receiving your plant sample, identify the plant and confirm whether or not it is an invasive species. If the plant is invasive, the Maine Department of Environmental Protection will be notified, and a rapid response action plan will be initiated.

Maine Department of Environmental Protection

17 State House Station; Augusta, ME 04333

Tel. 1-800-452-1942

New Hampshire:

Exotic Species Coordinator
NH Department of Environmental Services
29 Hazen Drive
Concord, NH 03301

http://www.des.state.nh.us/wmb/exoticspecies/

asmagula@des.state.nh.us

Vermont:

Vermont Department of Environmental Conservation
Water-Quality Division
103 South Main Street
Building 10 North
Waterbury, Vermont 05671-0408

1-802-241-3777

http://www.anr.state.vt.us/dec/waterq/lakes/htm/ans/lp_ans-index.htm

<u>Massachusetts:</u>

Weed Watchers Program

http://www.mass.gov/dcr/waterSupply/lakepond/weedwatch.htm

Department of Conservation and Recreation

Lakes and Ponds Program

251 Causeway St. Suite 700 Boston, MA 02114

Or fax: 617-626-1349

<u>Other States:</u>

To find lists of invasive plants that have been found in each state or to report an invasive plant for any state in New England, contact Invasive Plant Atlas of New England (IPANE) at the website listed below.

http://invasives.uconn.edu/ipane/earlydetection/early.htm

The Northeast Aquatic Nuisance Species Panel (NEANS) lists contacts for reporting aquatic invasive plants in northeastern states at their Web site: http://www.northeastans.org/sitemap.htm

Appendix 3: Maps of Proposed Monitoring Locations for all Northeast Temperate Network Parks

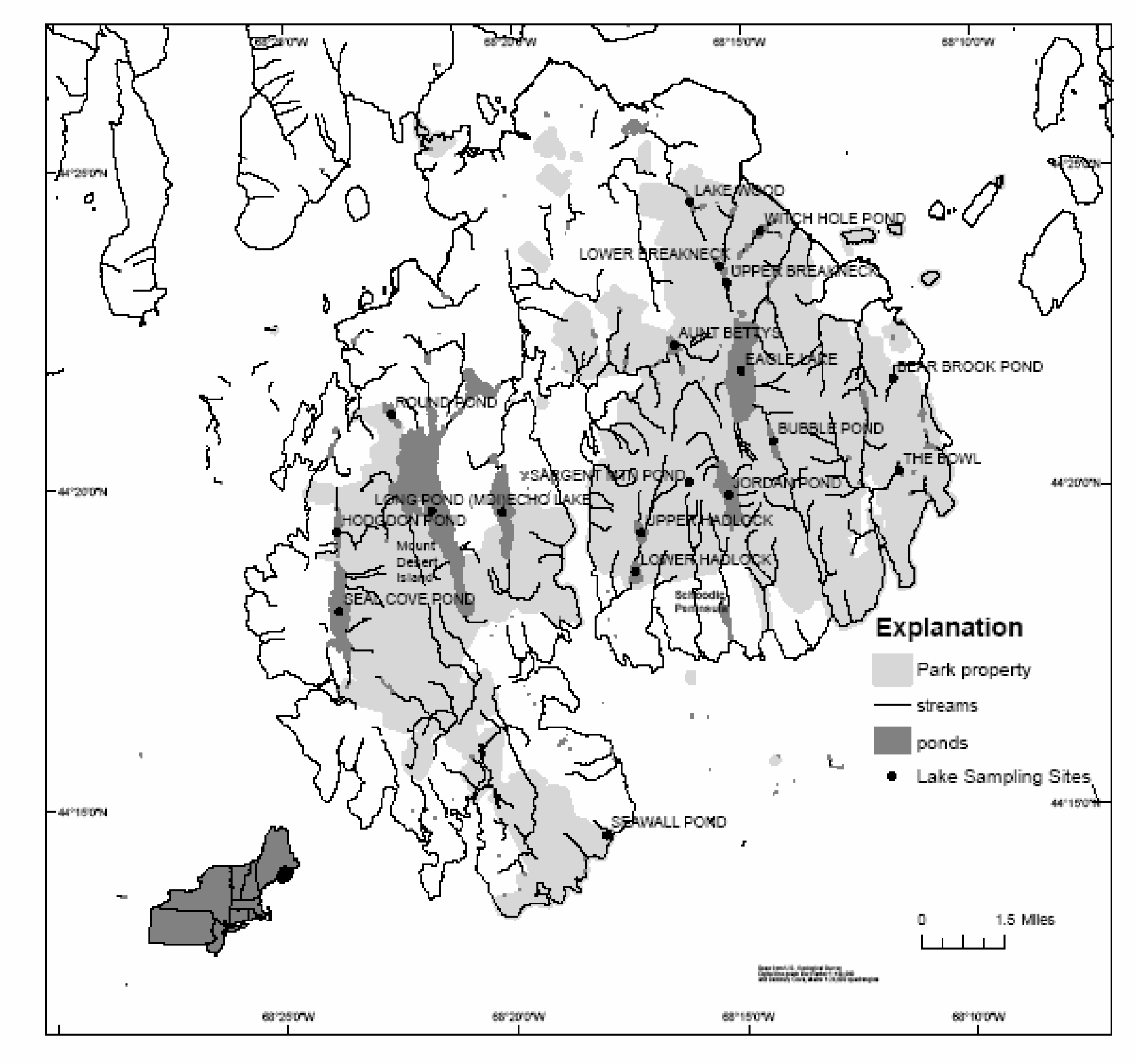

Figure A1. Location of lake-sampling sites at Acadia National Park, Maine.

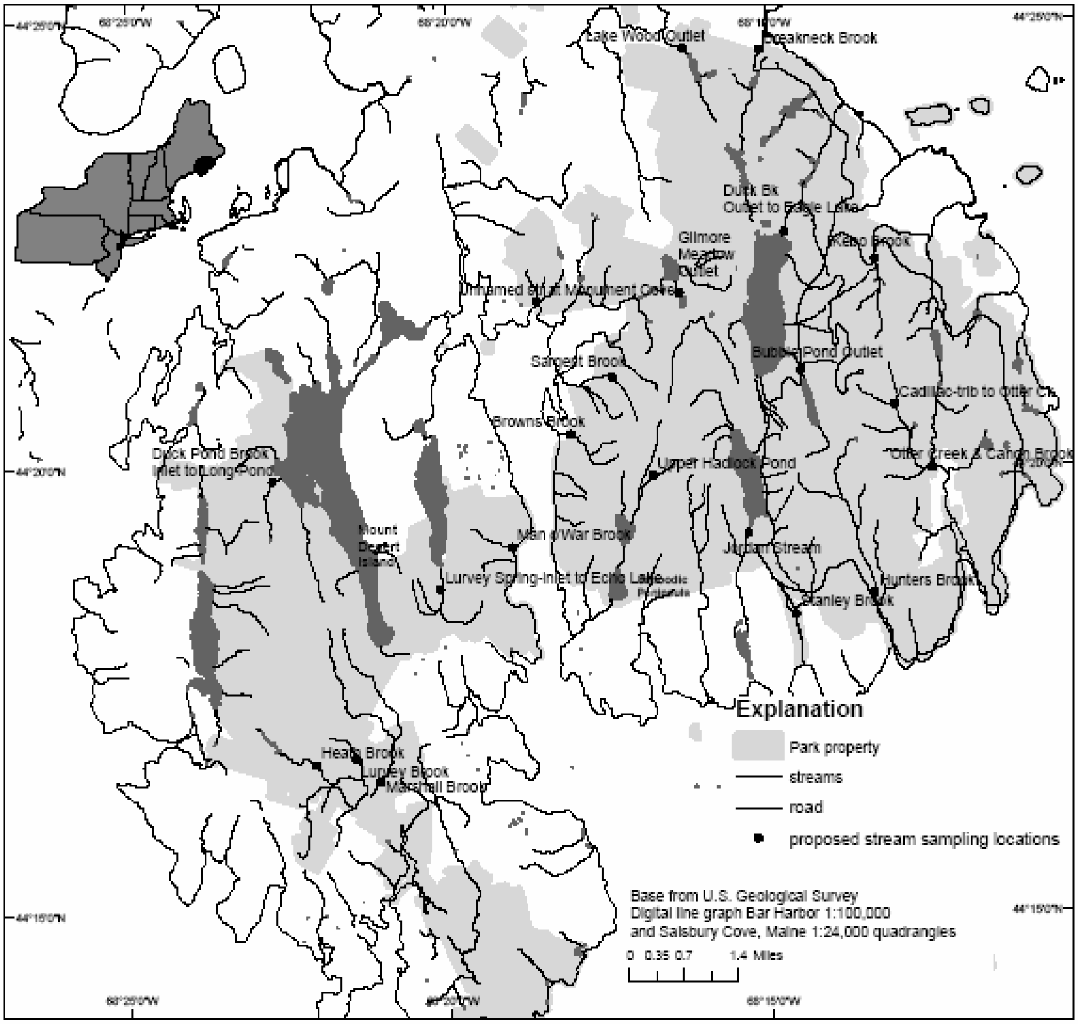

Figure A2. Location of stream sampling sites at Acadia National Park, Maine.

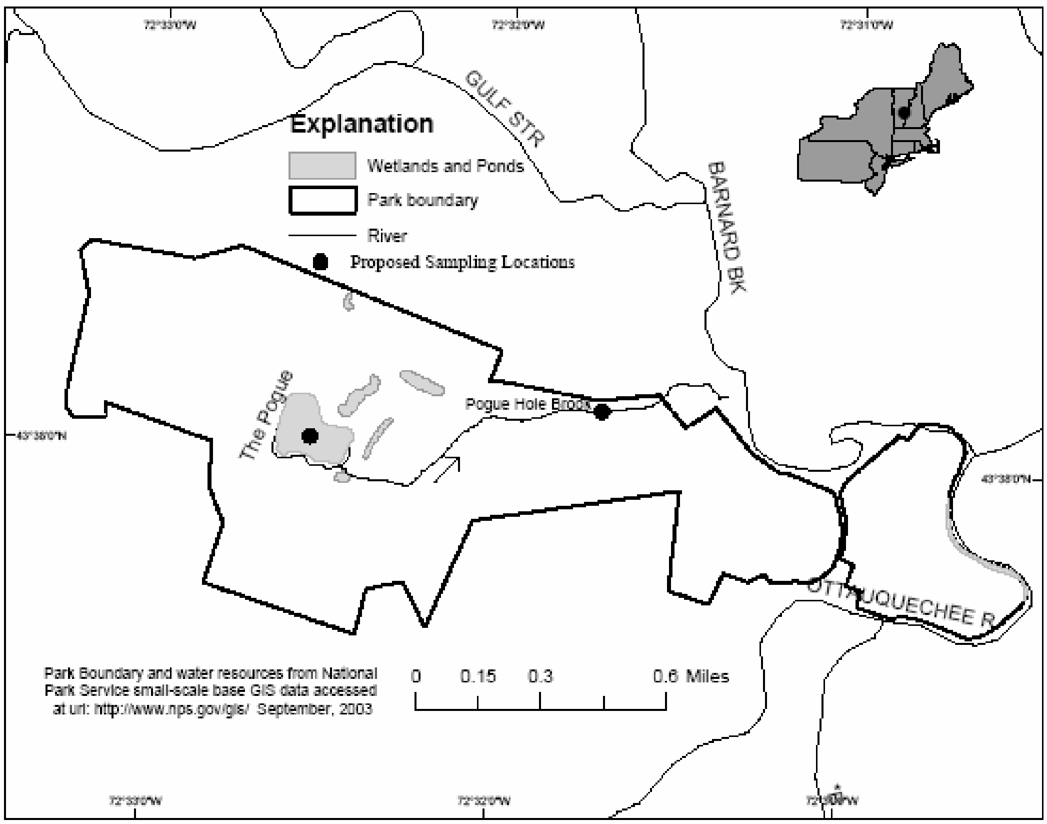

Figure A3. Approximate location of pond and stream sampling sites at Marsh-Billings-Rockefeller National Historical Park, Vermont.

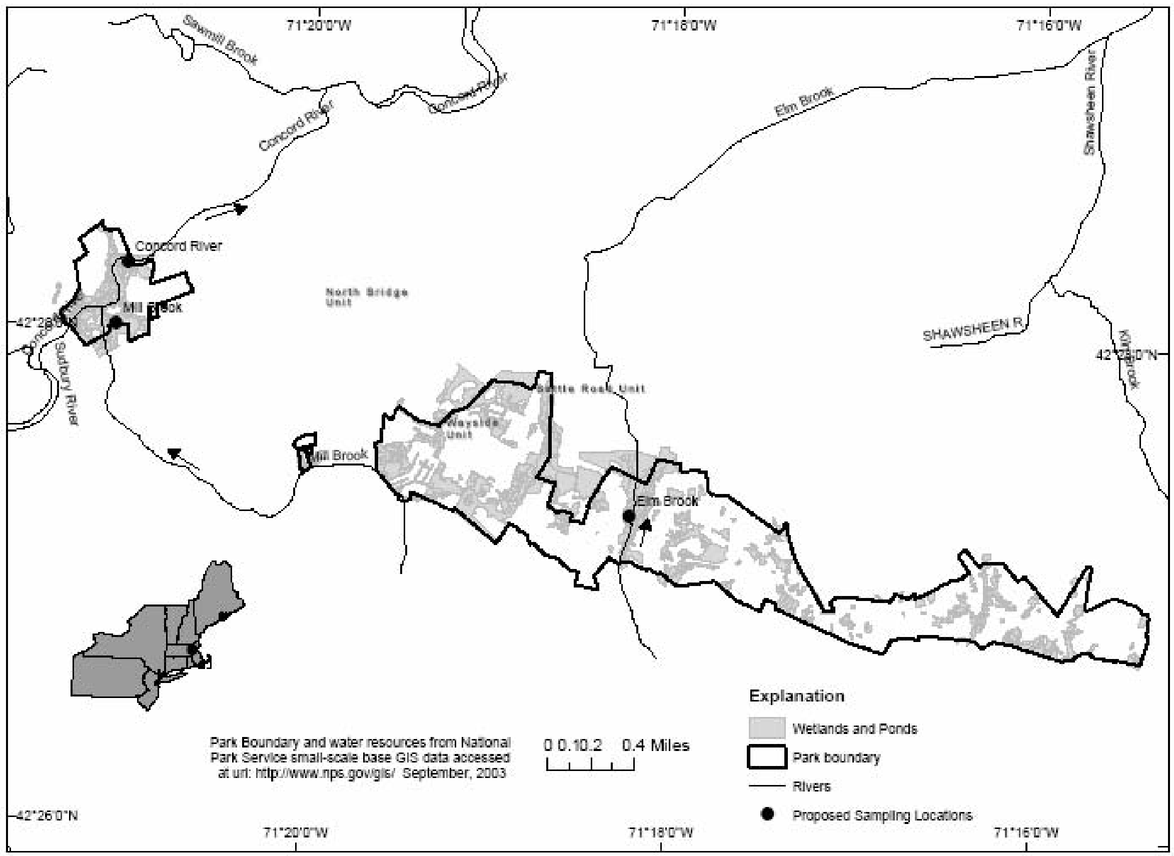

Figure A4. Location of stream-sampling sites at Minute Man National Historical Park, Massachusetts.

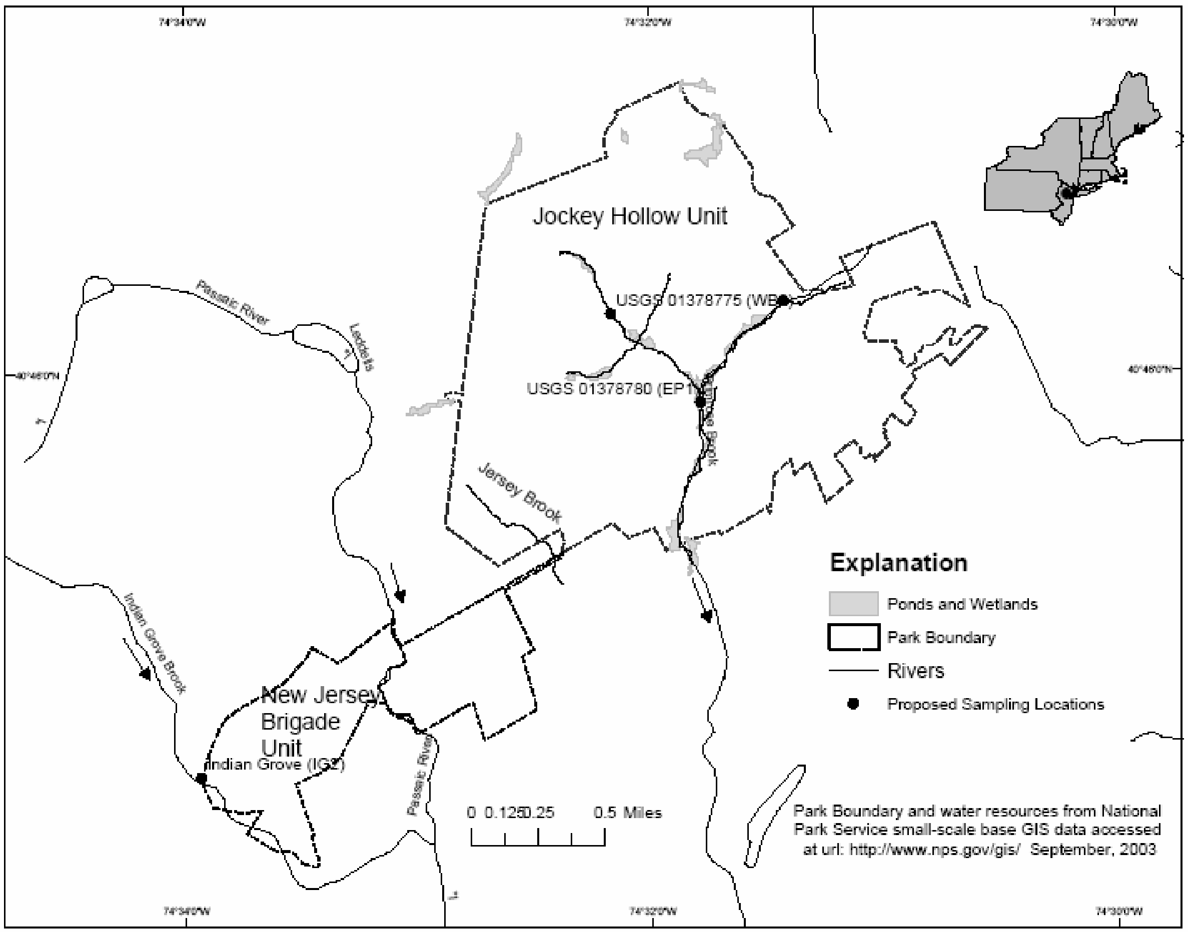

Figure A5. Location of stream-sampling sites at Morristown National Historical Park, New Jersey.

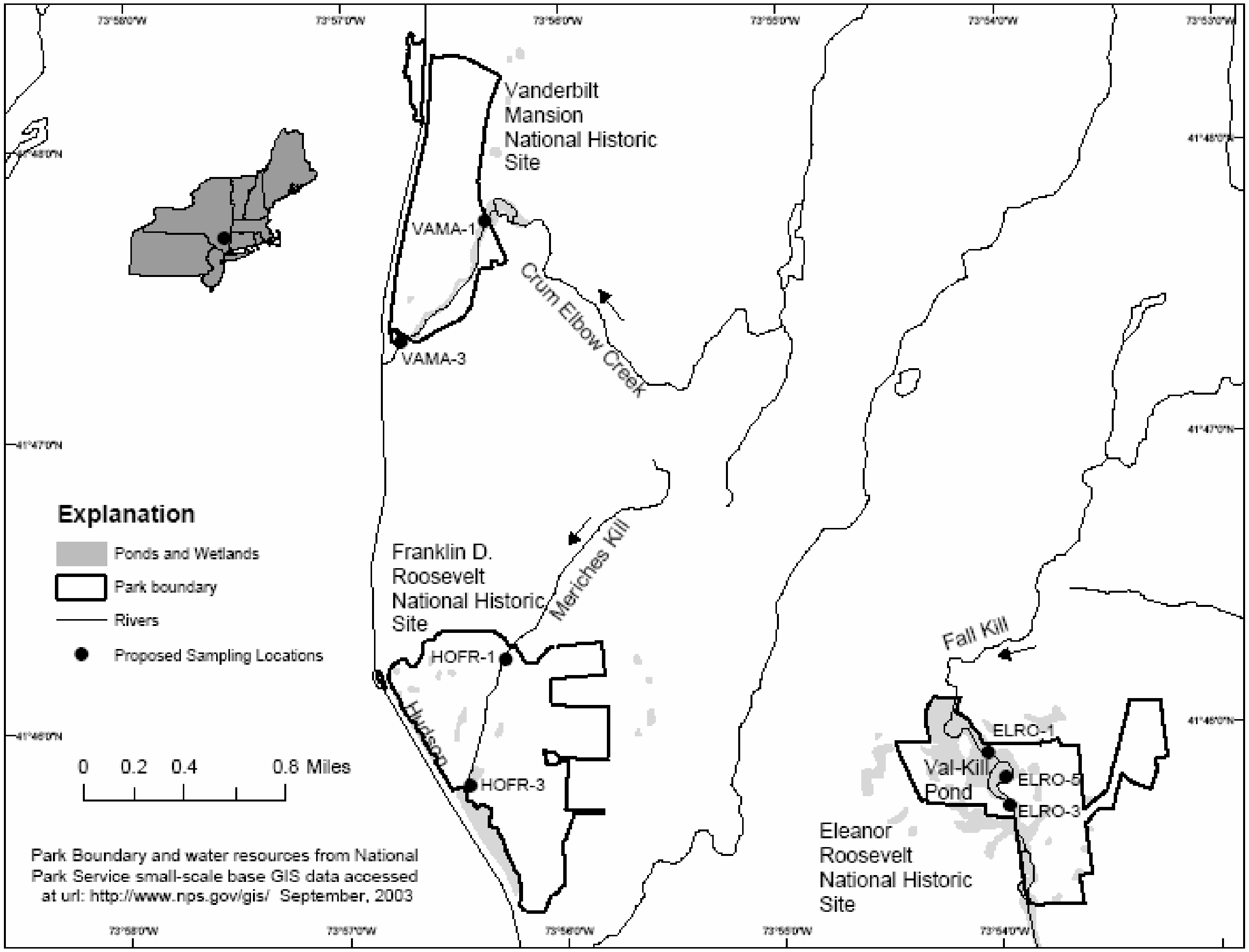

Figure A6. Location of stream- and pond-sampling sites at Roosevelt-Vanderbilt National Historic Site, New York.

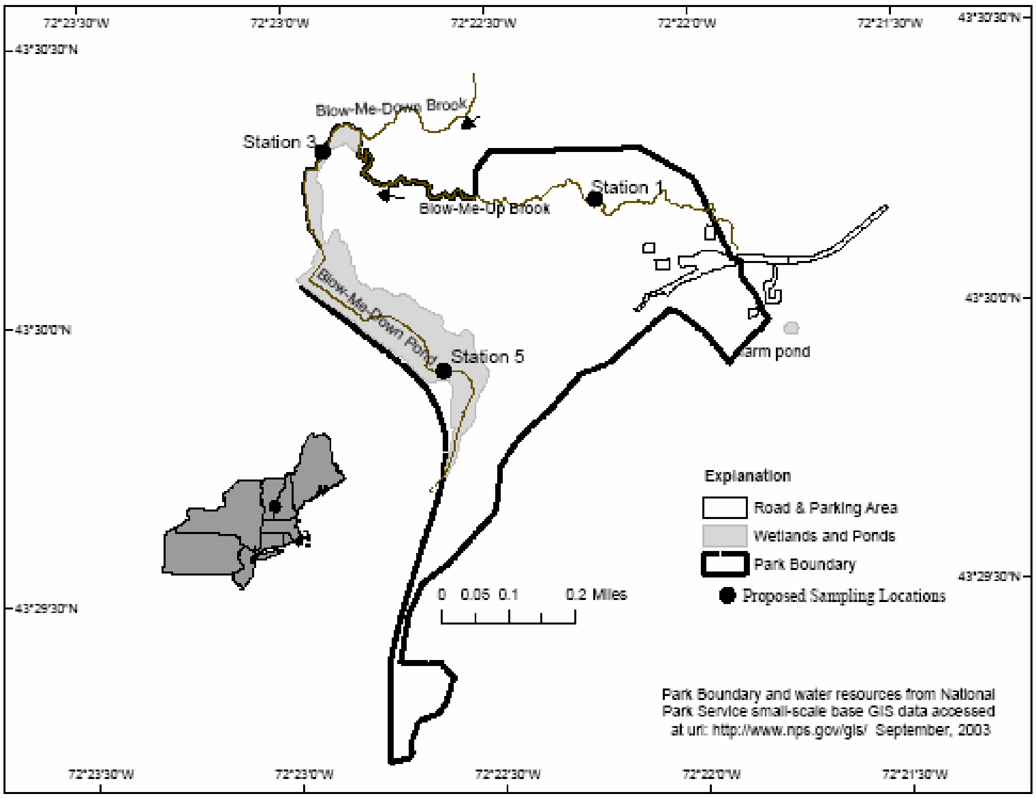

Figure A7. Location of stream- and pond-sampling sites at Saint-Gaudens National Historic Site, New Hampshire.

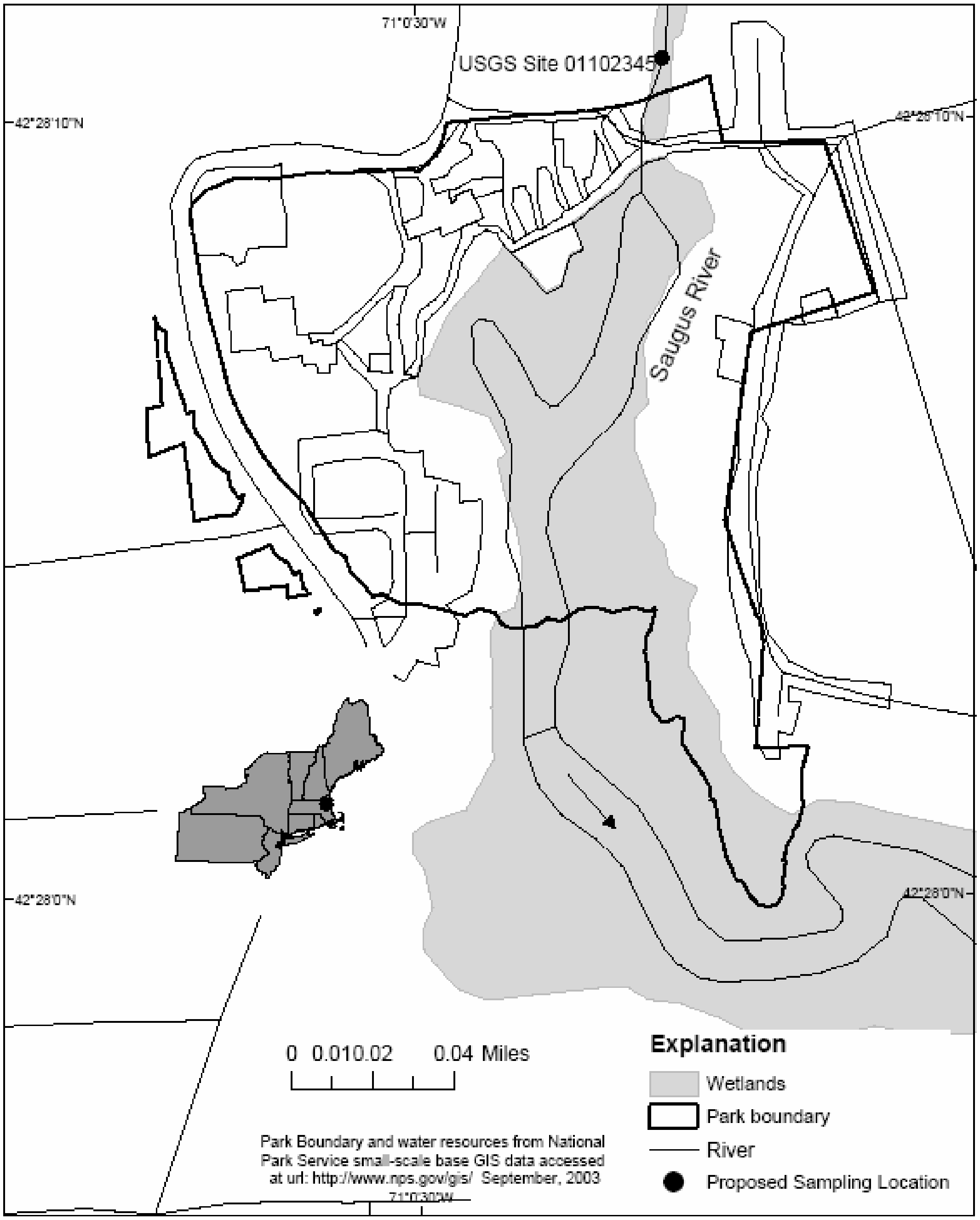

Figure A8. Location of stream-sampling site at Saugus Iron Works National Historic Site, Massachusetts.

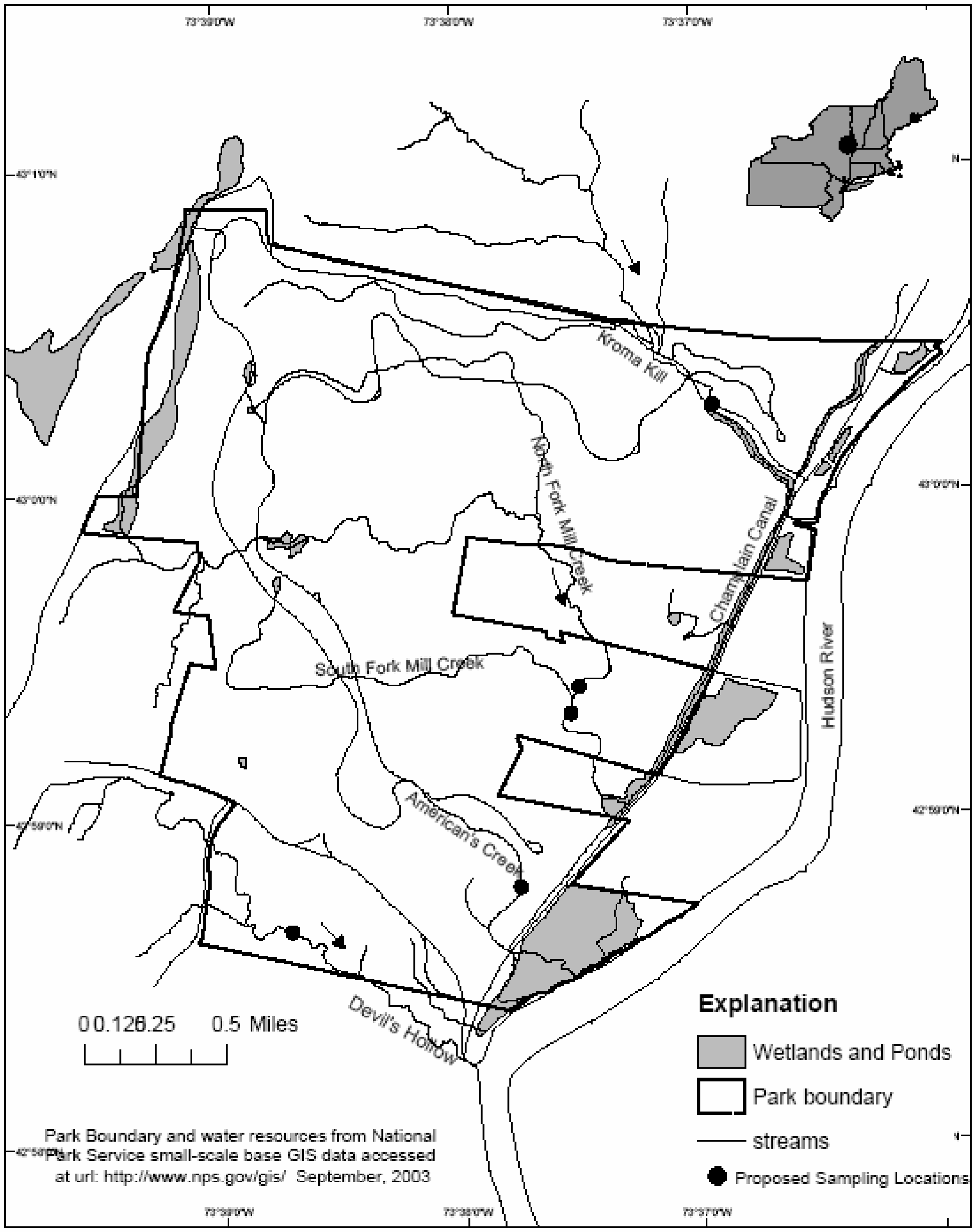

Figure A9. Location of stream-sampling sites at Saratoga National Historical Park, New York.

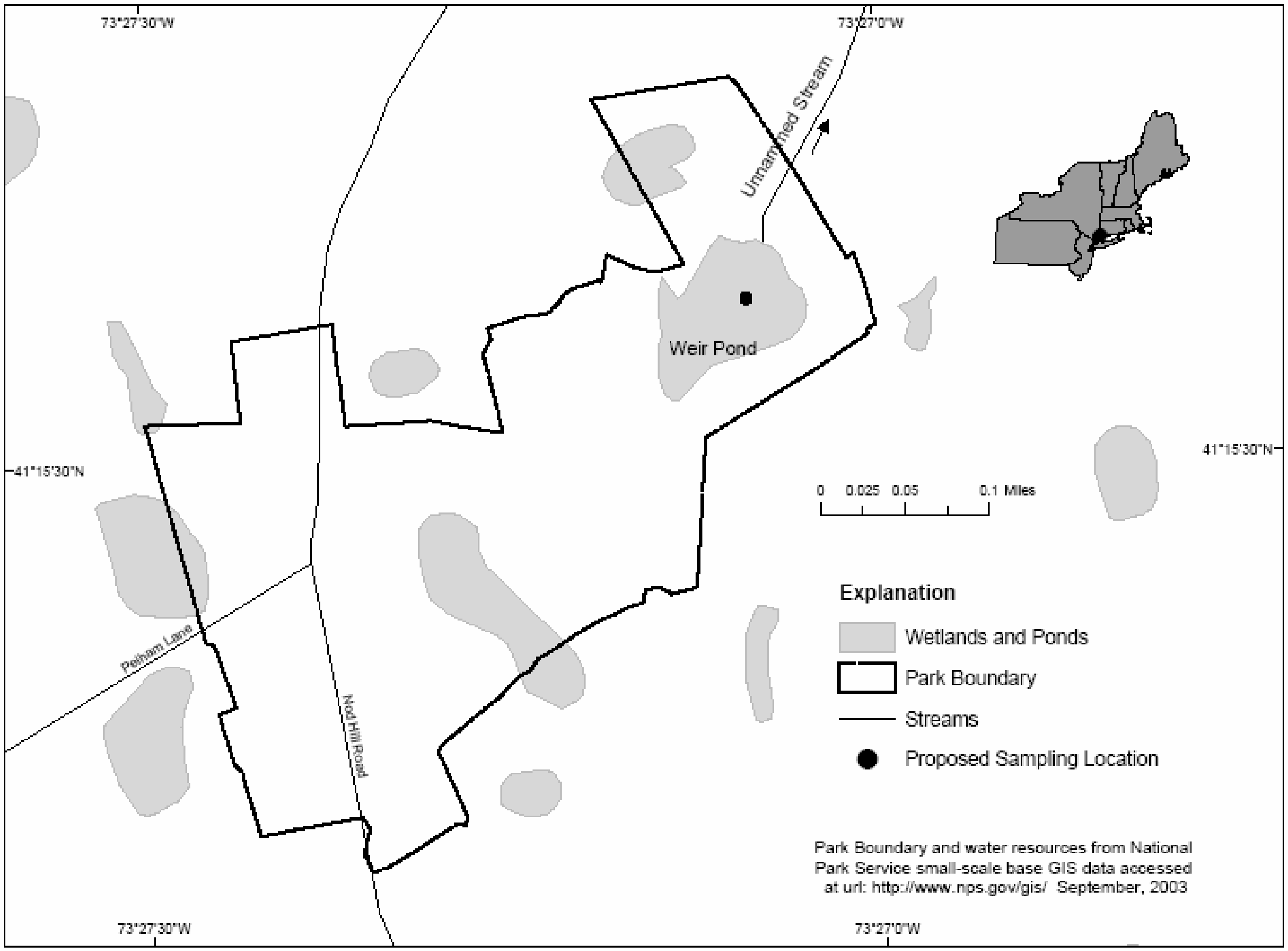

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Figure A10. Location of pond-sampling site at Weir Farm National Historic Site, Connecticut.

Appendix 4: Revision Log

Version 1.0 to 2.0:

Updated title page and version number

1.1: Added Appalachian NST to list of parks, plus comment that A.T. is outside of the scope of this protocol.

1.1.7.1: Secchi Disk Depth: Added comment that SD does not work outside of ACAD, and that we will begin using a transparency tube in 2007. Added citation for transparency tube.

1.1.7.9: Other Nutrients: This section is new, and is a placeholder until documentation of the rationale for the additional nutrient measures can be added.

1.2.1: 4th paragraph: Outside of ACAD, ponds measured April (not May) to October, conditions permitting. 2 impoundments at ROVA (rather than 1) will not be monitored, due to shallow depth and detectable flows.

1.2.2: 3rd paragraph: Stream measurements April to October, conditions permitting, not May to October.

Table 9: MIMA has 3 sites now, with addition of Concord River.

MORR has 5 sites now, with addition of Passaic River.

SARA has 4 sites now, with removal of Devil's Hollow.

ROVA has 6 sites now, with removal of ELRO pond.

Table 12: Updated with current site identifiers.

1.2.3.3: Added information about Mill Brook site, Concord river site and methods, and Elm Brook site.

Table 13: Updated site identifiers and add Mill Brook site.

1.2.3.4: Updated site info in paragraph 2. Passaic River site description is still needed.

Table 14: Updated site identifiers and added Passaic river site.

1.2.3.5: Updated site information in paragraph 2.

Table 15: Updated site identifiers and remove pond site.

Table 16: Updated site identifiers.

1.2.3.7: Updated to reflect twice yearly nutrient samples and sonde samples, and possibility of samples at the turning basin.

Table 17: Updated site identifier.

1.2.3.8: Updated site information, including removal of Devil's Hollow.

Table 18: Updated site identifiers.

Table 19: Updated site identifier.

1.3.1: Paragraph 2: added that pond samples will be grabs.

Table 21: Transparency tube for clarity measurements if Secchi disk can't be used.

1.6.6: Paragraph 3: stream grab samples only in May (not earliest trip of season).

2.3.2.1.2: Site Number = 0 (not 1) for stream sites. Pre-deployment QC check is 89 (Joe used 99 outside of ACAD in 2006), and post-deployment QC check is 99.

2.3.2.2.5: Added informational paragraph at start of section. Acadia uses a 2-point calibration daily, and a 3-point calibration monthly, while other parks use a 3-point calibration daily.

2.3.2.2.6: Added information to start of section. Calibration should be performed weekly, with a 2-point field check each morning.

2.3.2.2.9: In step 5, add information referring to the DO% Local option. This makes it easier to tell if the sensor is within specifications, since it automatically adjusts the DO% for local barometric pressure.

2.3.3: Refer to DO percent local rather than DO percent in step 2 and 3. Inserted step 4 – recording pre-deployment data to site 89. Revised step 6 to include selection of proper site code. Added step 8 – recording post-deployment data to site 99.

2.4.3: Added first sentence; if clean filtering location is not available, samples can be stored and kept cold until a suitable location is available.

Table 25: Lab code changed for total phosphorus; code and reporting limit changed for total dissolved phosphorus, ammonia, nitrite, nitrite + nitrate, orthophosphate.

2.4.5: Added paragraph specifying numbers and times for collection of blanks and replicates, and that replicates should be swapped between labs if multiple labs are being used.

3.1: For first series of steps: Refer to DO percent local saturation in steps 2 and 3. Insert step 4 (log to 89 file). Clarify step 8 (only one point needed in well-mixed, small streams; multiple points only needed for Concord River). Add step 9 (log to 99 file).

3.3.2.1: Added second paragraph, specifying that QC for discharge must be done monthly (one second measurement), plus an additional 3 measurements per field season at a USGS gaged station.

4.1A: Added this SOP (SOP 9A) to cover Transparency Tube readings.

4.2: Changed steps 3 and 4 to refer to DO percent local. Insert step 5 (pre-deployment "89" reading). Insert step 12 (reading just above bottom for shallow ponds). Insert step 13 (post-deployment "99" reading).

5.2: Added information for Sawyer Lab ANC analysis, and specified that the Sawyer lab will process all ANC samples starting in 2007.

5.3: Title changed to apparent color. ACAD samples will be analyzed by Sawyer; others by NWQL. Added information for Sawyer Lab color analysis.

5.4: Updated to correct lab codes. ACAD samples will be analyzed by Sawyer; others by NWQL. Added information for Sawyer Lab color analysis.

5.5: Updated to correct lab codes. ACAD samples for total N and total dissolved N will be analyzed by Sawyer lab. Added information for Sawyer analysis.

5.6: Updated to state that chl *a* analysis is conducted by the Sawyer lab. Added Sawyer lab info.

Literature Cited: Added Dahlgren paper on transparency tubes.

Appendix 4: This Appendix is new, and documents revisions to the protocol.

THE FOLLOWING UPDATES ARE NEEDED BUT NOT YET INCORPORATATED:

Section 1.1.7.9 – justification of nutrient indicators

Table 10 – Table 19 – update to include sample site coordinates… should these be UTM?

Section 1.2.3.4 – Needs description of Passaic River site

Section 2.1 – Has this SOP been followed?

Section 2.2 – Do the fields listed here match our data collection? E.G., are we getting sun / cloud / wind info?

Section 2.3.2.1.2 – Fred needs to know that pre-measurement calibrations will use 89 as the site number.

Section 2.3.2.2.5 – Probably needs to be re-written to correctly cover a 3-point calibration.

Section 5.1 – Need UMO shipping procedures.

Appendix 3 Maps – Corrections to MORR (A5), ROVA (A6), and SARA (A9)

IN ADDITION:

ROVA may want monitoring of ELRO pond dredging; this is no longer an NETN site.

SAIR site in turning basin needs to be established. Need to discuss with park staff and Charley Roman any potential lab analyses.

Rapid Ecological Assessment SOP is needed.

Need to continue discussion about macroinvertebrate sampling.

Determine if existing stations on the Concord and Hudson rivers can provide useful information for MIMA, ROVA, and SARA.

Version 2.00 to 2.01:

Section 1.1.7.7: Added mg/L to ueq/L conversion factor