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Natural Resource Stewardship and Science

Protocol for Long-Term Monitoring of Mountain Lakes in the North Coast and Cascades Network

Version July 9, 2012

Natural Resource Report NPS/NCCN/NRR—2012/549



ON THE COVER
Lake Heather, Olympic National Park
Photograph by: NPS staff

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Natural Resource Report NPS/NCCN/NRR—2012/549

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Wild Lake, North Cascades National Park

There are high places
that don't invite us,
sharp sharps, glacier-
scraped faces, whole
ranges whose given names
slip off. Any such relation
as we try to make
refuses to take. Some
high lakes are not for us,
some slick escarpments.
I'm giddy with thinking
where thinking can't stick.

No Names
by Kay Ryan
The Niagara River

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Executive Summary

This protocol describes the rationale, objectives, sampling design, field and laboratory methods, data analysis and data management procedures for long-term monitoring of mountain lakes in the North Coast and Cascades Network (NCCN). Lake monitoring will occur at three NCCN parks including Mount Rainier National Park (MORA), North Cascades National Park Service Complex (NOCA), and Olympic National Park (OLYM). This prototol utilizes a cost efficient comprehensive approach, applying multiple indicators representing key physical, chemical, and biological attributes (Vital Signs) which will serve to address current management issues as well as future emerging issues at park-wide and region-wide scales.

NCCN Mountain Lakes Monitoring Project Vital Signs (and measures).

Physical	Chemical	Biological
Temperature (continuous water and air temperature, temperature profiles)	Water quality (pH, specific conductance, acid neutralizing capacity, total dissolved solids, anions and cations, dissolved oxygen)	Algal biomass (chlorophyll-a as a surrogate measure)
Lake habitat (bottom substrate, aquatic plants, woody debris, riparian vegetation)	Nutrients (total dissolved phosphorus and nitrogen, dissolved organic carbon)	Zooplankton (abundance and community structure)
Lake hydrology (water level, depth, volume)		Littoral benthic macroinvertebrates (abundance and community structure)
Lake size (surface area)		Amphibians (species and abundance)
Riparian disturbance		Non-native species (fish species and abundance)
Water clarity (Secchi disk depth)		

Mountain lakes and ponds are essential park ecosystems in the NCCN, both culturally and ecologically. The NCCN contains over 1,200 mountain lakes and ponds. These waters are enormously popular visitor destinations due to their aesthetic and natural characteristics. Mountain lakes are tightly linked to their neighboring terrestrial environments, as critical breeding sites for many amphibian and insect species, and as both watering holes and feeding grounds for park wildlife. These highly sensitive ecosystems have in-lake physical, chemical, and biological processes that respond to and integrate a suite of key environmental stressors. Mountain lakes function as "Petri dishes in the sky," integrating the effects of global climate change, atmospheric deposition, visitor impacts, amphibian declines, and exotic species introductions.

Major ecosystem drivers currently influencing NCCN mountain lakes and ponds, in addition to natural disturbances, include anthropogenic disturbances resulting from atmospheric pollutant deposition, climate change, introduced species, and disturbances related to human activities both within and adjacent to park boundaries. Major natural disturbances affecting NCCN mountain lakes include episodic floods, volcanic eruptions, earthquakes, landslides and avalanches, fire, wind, insect infestations and glacial activity. Many of these drivers are closely interrelated and reflect the interaction of natural processes and human influences; their effects are intensifying with the rapid expansion of the population in the Pacific Northwest.

The overarching goal of this monitoring project is to determine the status and detect substantive trends in key ecosystem parameters, or Vital Signs, to assess whether mountain lakes are being negatively affected by anthropogenic stressors. The selected Vital Signs represent physical, chemical, and biological components of lake ecosystems that characterize the quality and natural function of these ecosystems. This monitoring protocol is designed to detect changes in Vital Signs more as an early warning system, rather than one that identifies causal agents of trends. Given the suite of parameters to be measured, it is hoped that the monitoring at least suggests possible root causes. The discovery of significant trends should serve as a trigger for further directed research to identify root causes and determine appropriate management actions.

The sampling design for the NCCN Mountain Lakes Monitoring Project was developed to specifically monitor high forest/subalpine lakes in each of the three NCCN parks. Six lakes at MORA and NOCA and eight lakes at OLYM were selected randomly from a subset of the entire population of lakes at each park such that trends in Vital Signs, represented by multiple sample elements including physical, chemical and biological parameters, could be inferred for all lakes in the target populations of each of the three parks. The subset, or sample frame, is based on a set of criteria that standardizes the type of lake monitored by size, elevation, depth, and access. After applying the criteria, the final representation will allow statistical inference to 163 NCCN lakes that are accessible on foot, found in high forest and subalpine zones, range in size from 0.4 hectares (ha) to 6.0 ha, and have maximum depths greater than 2.5 meters (m).

For any given year, all sample units will be visited once during the late summer and early fall period (August through September). Field crews, consisting of four to five members at MORA and OLYM, will primarily access lakes on foot, traveling on trails and off-trail under challenging back-country conditions. Helicopters are generally used to access monitoring sites at NOCA. Because of this, fewer crewmembers (two to three) are required and field tours are shorter (two days). Upon arrival at a lake sampling site, crew members will apply 16 of the 25 SOPs in this protocol for collection of monitoring data. The other SOPs are applied either before or after the season starts and address field season preparation and close-out, crew member training, data management, data analysis and reporting, quality assurance and control, and safety.

Data management procedures for this protocol are described in SOPs 2, 20, 22, and 23 and follow the NCCN Data Management Plan (Boetsch et al. 2009), which describes the overall information management strategy for the network. Public distribution as well as long-term archival of water quality data are provided by the NPS WRD STORET database and the National EPA STORET Data Warehouse and their associated online interfaces.

Data analytical procedures (SOP 21) are designed to extract useful information and facilitate conclusions regarding the protocol objectives by examining statistical relationships in the data. While the analytical goals and questions asked of data can and should vary depending on current needs of the parks, the important overarching analytical goals are as follows: 1) to estimate a current or past value of a parameter, 2) to estimate status (condition of the resource), 3) to detect significant abrupt changes in a parameter, and 4) to detect long-term steady trends in a parameter. These goals are applied to three inference scenarios representing the condition of aquatic resources and habitat for an individual lake or for all target population lakes in a park (park-wide inference) or for all target population lakes in MORA, NOCA, and OLYM (network-wide inference).

The reporting schedule includes production of Annual Reports and Five-year Summary Reports. Annual reports will be issued every year after field data collection and sample processing are completed. Annual reports will contain background information, routine statistics and graphical representations of the data, documentation of QA/QC results and concerns, and changes or revisions to SOPs.The Five-year Summary Reports will be completed in the year following each five-year sampling cycle. These reports will summarize routine data and statistical analyses reported in previous Annual Reports as well as results of analyses designed to detect park-wide and network-wide abrupt change and long-term trends. Five-year Summary Reports will also update progress towards the identification and development of criteria and thresholds used for assessments of site- and park-specific ecological condition of mountain lakes. Results reported in the Five-year Summary Reports will be used to develop interpretative products for distribution to the public and upper level managers at Park, Network, Regional, and National levels.

Personnel requirements for this monitoring effort identify a team approach from a variety of organizational levels. Individual park aquatic professional staff serve as Project Leads, providing overall supervision of the implementation of this protocol and are also responsible for conducting detailed analytical procedures and reporting. Field Leads are also stationed in each park and are responsible for supervising and training field crews, conducting pre- and post-season preparations, conducting field work, data entry, quality assurance and control. Field crews are made up of experienced biological technicians assisted by student interns and are responsible for field preparation, collecting field data, laboratory processing of samples, and initial data entry. The NCCN Data Managers and GIS Specialists are involved in the development and maintenance of associated databases and production of spatial data products and have the responsibility for archiving data products.

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This monitoring protocol and associated Standard Operating Procedures (SOPs) were prepared with assistance from the U.S. Geological Survey, Biological Resources Division including Gary Larson, Robert Hoffman, and Michael Adams. We also thank Stanford Loeb, Jordi Catalan, Stanley Dodson, David Donald, Paul Murtaugh, Tony Olsen, and Rolf Vinebrooke for their participation in a panel convened in 2002 and subsequent report produced to assist us in the development of monitoring protocols for mountain lakes in Pacific Northwest national parks. Much gratitude is extended to Trent McDonald and other staff at Western Ecosystems Technology Inc. for their assistance in development of the protocol sampling design and analysis methods. We would like to thank Tom Philippi for his invaluable assistance in resolving critical sampling design issues. It would also not have been possible to produce this document without the willing support of park-based staff including Bill Baccus, Rebecca Lofgren, Ashley Rawhouser, Casey Dennehy, Jake Layman, Sabrina Derusseau, Ben Wright, Michael Layes, Natasha Antonova, Lise Grace, Carmen Welch, and Hugh Anthony. Finally, we would like to thank Mark Huff for all of his efforts and support in shepherding this protocol to the finish line.

Introduction

This protocol describes the rationale, objectives, sampling design, field and laboratory methods, data analysis and management procedures for the long-term monitoring of mountain lakes in the North Coast and Cascades Network (NCCN). Lake monitoring will occur at three NCCN parks including Mount Rainier National Park (MORA), the North Cascades National Park Service Complex (NOCA), and Olympic National Park (OLYM).

Two complementary water quality related protocols are being implemented in the NCCN, the Mountain Lakes Protocol and the Water Quality Protocol (Rawhouser et al. in review). The NCCN Mountain Lakes Protocol is specifically focused on the NPS Water Resource Program (WRD) objective of maintaining the ecological integrity of relatively pristine waters, as represented by the target population of lakes located in high forest/subalpine regions of MORA, NOCA and OLYM. In contrast, the primary focus of the NCCN Water Quality Monitoring Protocol is to assess the status of rivers and streams that are of management concern among all of the park units in the network that are 1) listed as impaired or potentially impaired under sections 303(d) and 305(b) of the Clean Water Act and 2) other waters that are believed to be at risk of impairment by NPS managers.

Ecosystem Vital Signs are key to the NPS Inventory and Monitoring Program (I&M). A Vital Sign is a physical, chemical, or biological component of the air, water, or land. It is rarely possible to monitor all components, or indicators, of ecosystem health; therefore, Vital Signs are chosen because they are the most representative of an ecosystem as a whole and/or are most critical to ecosystem function. A goal of NPS Vital Signs Monitoring is to report ecosystem status and trends and to document how much confidence there is in the results of monitoring. A good summary of Vital Signs monitoring is provided in *An Overview of Vital Signs Monitoring and its Central Role in Natural Resource Stewardship and Performance Management* (Fancy 2005).

Through the NPS I&M Program, 270 national park units were organized into 32 networks. In order to improve efficiency and reduce costs, parks were organized into networks that share similar geographic and natural resource characteristics. Because these networks share funding and a core professional staff, the networks are able to cooperatively conduct long-term ecological monitoring (Fancy 2005). The North Coast and Cascade network includes four small parks and three large parks in western Washington and the northwestern corner of Oregon (Figure 1). Small parks include: Ebey's Landing National Historical Reserve (EBLA), Lewis and Clark National Historical Park (LEWI), Fort Vancouver National Historic Site (FOVA), and San Juan Island National Historic Park (SAJH). Large parks of the NCCN include: Mount Rainier National Park (MORA), North Cascades National Park Service Complex (NOCA), and Olympic National Park (OLYM).

Within the NCCN network mountainous topography and a maritime climate create notable environmental gradients. Collectively, these seven parks span an elevation gradient from just below sea level to over 4,300 m (14,000 ft). These environmental gradients result in a vast diversity of habitats and communities represented by eight major ecosystems (intertidal, coastal, lowland prairies, forests, lakes/ponds, rivers/streams, subalpine, alpine/glaciers), and five

ecoregions (Pacific Northwest Coast, Puget Trough, North Cascades, West Cascades, and East Cascades of Washington) (Figure 1).

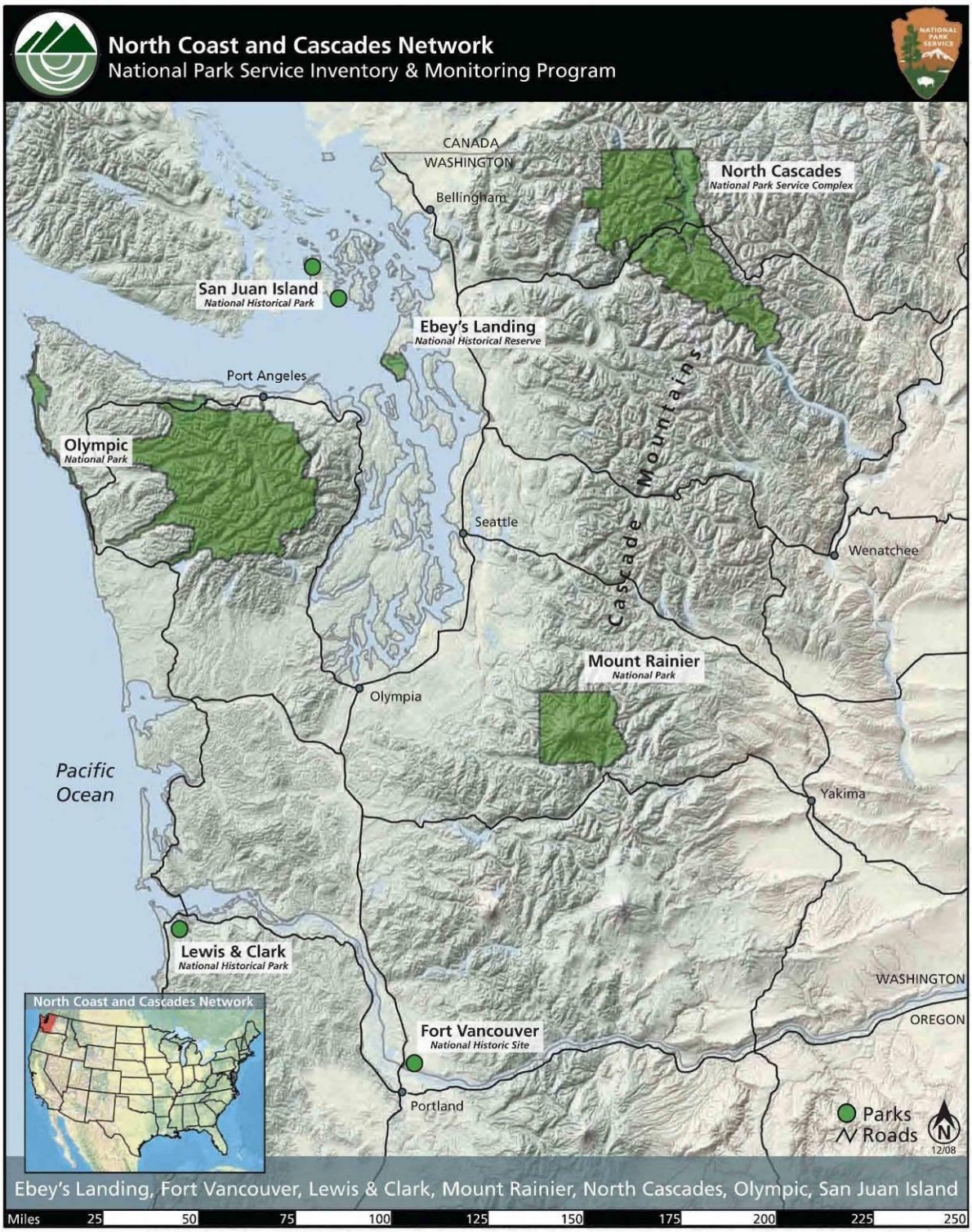


Figure 1. Map illustrating locations of parks within the North Coast and Cascades Network.

Section I. Narrative

1. Background and Objectives

1.1. Description of Study Area and Resources

1.1.1. General Description of NCCN Mountain Lake Parks

Mount Rainier National Park (MORA)
Mount Rainier National Park is located in the Southern Cascades physiographic province in western Washington and is surrounded mostly by National Forest lands, of which approximately 147,000 ha are designated wilderness. MORA encompasses 95,354 ha and is located about 100 kilometers (km) southeast of the Seattle-Tacoma metropolitan area. The park was established in 1899 to *"...provide for the preservation from injury or spoliation of all timber, mineral deposits, natural curiosities, or wonders…and their retention in their natural condition…grant parcels of ground at such places shall require the erection of buildings for the accommodation of visitors…provide against the wanton destruction of the fish and game found in the park"* (Mount Rainier National Park Act 1899; 30 Stat. 993). Mount Rainier National Park is approximately 97% wilderness and 3% National Historic Landmark District and receives approximately two million visitors per year.

At 4,392 m, Mount Rainier, an active volcano that last erupted about 150 years ago, is the most prominent peak in the Cascade Range. It dominates the landscape of a large part of western Washington State. The park contains 26 named glaciers across nine major watersheds, with more than 400 lakes and ponds (including ponds ≤0.01 ha), and 470 rivers and streams and over 1,214 ha of other wetland types. Vegetation is diverse, reflecting the varied climatic and environmental conditions encountered across the park's 3,900 m elevation gradient. Approximately 58% of the park is forested, 23% is subalpine parkland, and the remainder is alpine, half of which is vegetated and the other half consists of permanent snow and ice. Forest ages range from less than 100 years old on burned areas and moraines left by receding glaciers to old-growth stands 1,000 or more years old. Some alpine heather communities have persisted in the park for up to 10,000 years.

North Cascades National Park Service Complex (NOCA)
North Cascades NPS Complex, (North Cascades National Park, Ross Lake National Recreation Area, and Lake Chelan National Recreation Area), established in 1968, covers 276,901 ha of the Cascade Range from the Canadian border south approximately 80 km to the head of Lake Chelan. The Stephen Mather Wilderness encompasses approximately 93% of the Complex. The park complex is located in the North Cascade physiographic province, in northwestern Washington. It is surrounded on the west, south and east by 1.9 million ha of National Forest lands, of which 763,890 ha are designated wilderness. NOCA shares its northern boundary with the Canadian province of British Columbia. Adjacent to the boundary in British Columbia there are provincial forest lands, a recreation area, and just to the east is Manning Provincial Park.

The park complex is characterized by deep, forested valleys between high, glaciated mountain peaks. Watersheds typically begin in high elevation glaciers and snow fields, dropping in numerous, cascading streams down precipitous valley walls to classic, U-shaped valley floors

carved by glaciers during the Pleistocene. The topography, geology, and hydrology of the Complex are extremely varied. Local relief is approximately 2,700 m, with the lowest point at 120 m along the Skagit River at the Complex's west boundary and several peaks over 2,700 m. The North Cascades NPS Complex spans the Cascade crest, placing within its boundary two major biogeographic zones: temperate marine and semi-arid continental. Precipitation varies across elevation gradients and the crest of the North Cascade Range, with a maximum average of about 400 centimeters (cm)/year on the western peaks to a minimum average of 50 cm/year in the Lake Chelan corridor.

There are 318 glaciers in the North Cascades NPS Complex, more than in all of the other national parks within the contiguous states combined. One of the most notable characteristics of the North Cascades National Park Complex is its abundance and diversity of aquatic habitats. There are more than 550 lakes and ponds (including ponds ≤0.01 ha), and approximately 6,500 km of perennial rivers and streams located in the Park Complex. NOCA watersheds eventually flow into four major river systems: Columbia River, Fraser River, Skagit River and Nooksack River. There are three reservoirs within Ross Lake NRA, all behind dams built to provide hydroelectric power. Lake Chelan, which developed within a deep, glacial trough, is the third deepest natural lake in the United States. A dam was also constructed on Lake Chelan by the Chelan Public Utility District for the purpose of power generation.

The abundance of water and the wide variation in landforms, soil types, elevation, slope and aspect all support a great diversity of native flora and fauna. There are 75 mammal species, 200 bird species, 28 fish species, 17 reptile and amphibian species and nearly 1,600 species of vascular plants within the park complex. Primary fish species inhabiting the park include all five species of Pacific salmon, steelhead and rainbow trout, cutthroat trout, and bull trout. The natural distribution of fish within the park has been altered by construction of dams and by introduction of hatchery fish into waters that were previously barren of fish.

Olympic National Park (OLYM)

Olympic National Park protects 373,384 ha of three distinctly different, yet interwoven ecosystems – rugged glacier-capped mountains, more than 100 km of wild Pacific coastline, and magnificent stands of old-growth temperate rain forest. OLYM's 5,600 km of rivers and streams house 29 species of native freshwater fish including 70 unique stocks of Pacific salmon and steelhead. OLYM encompasses one of the largest wilderness areas in the contiguous United States with 95% of its area in congressionally designated wilderness. Bounded by the Strait of Juan de Fuca to the north, the Hood Canal extension of Puget Sound to the east, and the Pacific Ocean to the west, the Olympic Mountains are geographically isolated from other Washington mountain ranges and are characterized by glaciated peaks and steep elevation gradients (0-2428 m). A steep precipitation gradient characterizes the Olympic range where the wettest location in the contiguous United States is less than 60 km from the driest West coast site north of southern California. The mean annual precipitation ranges from around 48 cm/yr on the dry northeastern part of the peninsula to 600 cm/yr at the crest of the Olympic range. Approximately 80% of the precipitation falls from October through March, while only 5% falls in July and August.

There are 648 lakes and ponds (>0.01ha), and an unknown number of smaller vernal ponds, found in the Park, encompassing the lowland, montane, sub-alpine and alpine vegetation zones. Originally these lakes were all fishless systems, however, many were stocked from 1940-1960

with exotic trout for recreational fishing. The park is almost entirely roadless, with trails largely confined to valley bottoms along with some leading up steep ascents to ridges and glacial basins. Access off of established trails is difficult and labor-intensive.

1.1.2. Description of NCCN Mountain Lakes and Ponds

The lakes of the NCCN occupy a wide range of elevations, geologic terrains, and vegetation types. There are a variety of lake attributes, with large differences in shape, surface area, temperature, and depth. No two lakes are alike; each lake is a unique result of the physical, chemical, and biological processes that shaped the surrounding lake basin and the lake itself. These processes continue to unfold as glaciers melt and new lakes are born and as older lakes slowly accumulate sediment, organic matter, and woody debris.

The mountain lakes in the NCCN are characterized by eight morphogenic classes: cirque, trough, ice scour, moraine, bench, fault, slump, and kettle.

- Cirque lakes (tarns) exist at the head of U-shaped glaciated (or formerly glaciated) valleys.
- Trough lakes were formed in glacially scoured U-shaped valleys. They tend to be long, narrow, and wedge-shaped, with the deepest spots in the lakes near their outlets.
- Ice-scour lakes occur in irregular depressions and are often found on ridgetops. These lakes generally tend to be shallow.
- Moraine lakes formed behind terminal or lateral moraines that were deposited by receding glaciers.
- Bench lakes are literally found on topographic benches (flat areas).
- Fault lakes were formed by bedrock dams created by differential displacement of bedrock along tectonic faults.
- Slump lakes occur in the depression left by the rotational "slip" of deep seated soil.
- Kettle lakes were formed by depressions or "kettles" left after a glacier retreated.

In general, most NCCN mountain lakes are oligotrophic, are relatively cold, acidic or neutral in pH, low in concentration of dissolved solids, and also low in concentration of inorganic nutrients such as phosphorus and nitrogen but are rich in dissolved oxygen. Ponds also tend to be acidic or neutral in pH, but higher in concentrations of dissolved solids and nutrients. Although mountain lakes can be generally described as ranging from ultra-oligotrophic to mesotrophic, there is a great deal of variation in water quality among them due to a variety of factors including geographic setting, elevation, aspect, morphology of the lake basin, and geology.

The biological productivity of mountain lakes in the NCCN is strongly influenced by lake elevation and basin aspect. Deposition of organic matter is greater in lower elevation lakes of the forested zone resulting in higher productivity than found in subalpine and alpine waters. Elevation and aspect greatly affect the length of time a given lake remains frozen each year. Low-elevation lakes have the longest ice-free periods, and high-elevation alpine lakes have the shortest ice-free periods. Some high-elevation lakes may not thaw following a winter with heavy snowfall (NPS, J. Riedel, Geologist, pers. comm., 2003, NPS, B. Samora, Aquatic Ecologist, pers. comm., 2007). Most lakes, however, become ice-free by mid-July to early August and freeze over by late October to early November. At NOCA, lakes on the west side of the Cascades tend to freeze over about two weeks later than lakes on the east side. At MORA, lakes with south

facing aspects generally tend to freeze over about two weeks later than lakes with north facing aspects. The total number of lakes and ponds (>0.01 ha) by park, their mean size, and distribution by forested, subalpine, and alpine zones is shown in Table 1.

Table 1. Summary comparison of the number, size, and distribution of MORA, NOCA, and OLYM lakes and ponds >0.01ha.

Park	Total Number of Lakes*	Mean Surface Area (ha)	% of Lakes in Lowland and Montane Forested Zones	% of Lakes in Subalpine Zone	% of Lakes in Alpine Zone
MORA	304	0.88	33	60	7
NOCA	305	2.77	20	58	22
OLYM	646	0.72	32	63	5
NCCN Totals	1255	1.26	29	61	10

*Excluding three large lowland lakes (>2000 ha) and three reservoirs.

There are 304 lakes and ponds at MORA >0.01 ha (up to 45.4 ha) found at elevations ranging between 610 m and 2,500 m elevation. There are an additional 100 small ponds, most of which are dewatered by late summer. Approximately 33% occur in lowland and montane forested areas, approximately 60% occur within the subalpine zones, and the remaining 7% occur within the alpine zones of the park. Maximum depths range from less than 0.5 m to almost 60 m. Most lakes are glacial ice-scoured lakes such as cirques or tarns, moraine-dammed lakes, and kettle lakes, but some, such as Reflection Lake, were formed by mud flows. Water quality of most lakes and ponds located within MORA is generally thought to be mostly pristine (Larson et al. 1992, 1994, 1998, 1999, Larson 2000, NPS, B. Samora, Aquatic Ecologist, pers. comm.).

The North Cascades Complex has over 305 lakes and ponds >0.01 ha. There are over 250 small seasonal ponds (≤0.01 ha) that fill following snow melt but eventually dry up over the course of the summer. NOCA mountain lakes occur in four broad vegetation zones: lowland forest, montane (high) forests, subalpine parkland, and alpine. Lakes are found in all four zones on both sides of the Cascade Crest and range in size from less than 0.01 ha to approximately 65.6 ha (Silver Lake). The majority of NOCA lakes and ponds are found in the subalpine zone (58%). The total percentages of lakes found in alpine and forested zones are 22 and 20%, respectively. Although lakes at NOCA represent all eight morphogenic classes, most are cirque lakes (approximately 41%). Ice scour (20% of all lakes) and trough lakes (18%) are also common. Maximum depths of perennial lakes range from 1 m to 160 m; there are 12 lakes greater than 30 m deep and four lakes greater than 60 m deep. Silver Lake, located in the northeastern part of the park, is the largest (65.6 ha), deepest (160 m), and nearly the highest (2,042 m above mean sea level) lake. NOCA lakes exhibit a relatively narrow range of water qualities and nutrient concentrations. The most productive lakes are marginally mesotrophic (generally in the forest zone), whereas the majority of lakes are either ultra-oligotrophic or oligotrophic based on concentrations of phosphorus (Likens 1975). A detailed description of lake physical and chemical characteristics is found in Liss et al. (1995).

Olympic National Park has over 648 lakes and ponds, with an unknown number of vernal pools that appear and disappear seasonally. These waterbodies range in size from 0.01 ha to 3,007 ha (Lake Ozette), and range in elevation from 8 m to 1,983 m. OLYM lakes occur in four vegetation zones: lowland, montane, subalpine and alpine. The majority of lakes are found in the subalpine

zone (63%), while 27% of the waterbodies occur in the montane zone. Alpine and lowland lakes make up only 5% each of the total park lake population. Most OLYM lakes are assumed to be oligotrophic, however, relatively little historical data are available for the majority of lakes.

Most mountain lakes in the NCCN parks were naturally fishless. Historical fish management activities have resulted in introductions of non-native stocks of rainbow trout, cutthroat trout, brook trout, and kokanee salmon in many of the park lakes. Amphibians and invertebrates were the primary predators in many lakes prior to fish introductions. Ten species of amphibians at MORA, nine species at NOCA, and seven species at OLYM are present in and around park lakes and ponds (Galvan et al. 2003, 2006, NPS, B. Samora, Aquatic Ecologist, pers. comm., NPS, R. Glesne, Aquatic Ecologist, pers. comm.). Lakes and ponds provide habitat for seven federally listed amphibian and two invertebrate "Species of Concern."

1.2. NCCN Mountain Lakes Monitoring History

Mountain lakes and ponds in the NCCN have been studied for over two decades, with most in depth work having been conducted at NOCA and MORA. The primary emphasis of lake and pond survey efforts has been on the characterization of physical, chemical, and biological attributes of specific lakes as well as parkwide inventories. Additional studies have focused on air pollutant effects (Nelson and Baumgartner 1986, Clow and Samora 2002, Clow and Campbell 2008, Landers et al. 2008), recreational use impacts (Jetton et al. 1995), and general limnology (Hall 1973, Larson 1973, 1999, 2000, Perry 1980, Turney et al. 1986, Larson et al. 1992, 1994, 1998, 1999, Girdner and Larson 1995) in the parks. The effects of non-native fish stocking (Cory 1963, Nilsson 1972, Moyle 1976, Northcote et al. 1978, Bradford 1989, Bahls 1990, Bradford et al. 1993, Liss et al. 1995, Hoffman and Larson 1999, Larson and Hoffman 2002, and Hoffman et al. 2004) and concern over declining amphibian populations (Bury et al. 1980, Bishop and Petit 1992, Richards et al. 1993, Schlegel et al. 1993, Vial and Saylor 1993, Blaustein et al. 1994, Corn 1994, Hoffman 1999, Brokes 2000, Tyler et al. 2003, Galvan et al. 2006, Samora et al. 2009) became research and inventory priorities during the late 1980s through 2009. Much of the emphasis of research related to non-native fish stocking was focused on NOCA lakes and performed by researchers from Oregon State University between 1989 and 2000 (Appendix F, Table F-2). Much of the research on amphibians was conducted at Mount Rainier between 1991 and 2009. (Appendix F, Table F-1).

The proposed long-term monitoring project represents the first effort to monitor lakes and ponds at a parkwide scale in the NCCN. Long-term continuous monitoring of lakes within the NCCN has occurred at only one site, Mowich Lake (MORA). Long-term monitoring at Mowich Lake has been ongoing from 1988 to present, and in addition, a small subset of MORA lakes has been monitored over varying periods during the last 20 years. The present inventory now contains lakes and ponds from all geographical areas of the park and elevations from low forest to alpine vegetation zones. Physical information is available for almost all lakes through hydrography data layers in the park Geographic Information System databases including lake size, watershed area, and inlets and outlets.

A general summary of the scope of data collection efforts in the NCCN follows. A more detailed chronological summary of historical lake and pond monitoring activities for NOCA and MORA is presented in Appendix F.

1.2.1 MORA Lake and Pond Monitoring

Physical information, including information on lake bathymetry, transparency, and temperature profiles, is available for approximately 225 MORA lakes and ponds through surveys conducted from 1988 through 2007 (NPS, B. Samora, Aquatic Ecologist, pers. comm.). Biological data are available for many of the park's mountain lakes and ponds and include information on zooplankton (75 lakes), phytoplankton (20 lakes), fish presence/absence and relative abundance (225 lakes), and amphibian presence/absence and relative abundance (225 lakes). In addition, benthic macroinvertebrate data are available for at least 50 lakes and ponds. Paleolimnological data (diatoms, invertebrates, and sediment characteristics) are available for approximately 15 lakes and ponds. Chemical data are available for approximately 225 lakes and ponds and include information on pH, alkalinity, specific conductance, dissolved oxygen, and some data on nutrients, cations, anions, and metals. Data on air toxins are available for seven lakes.

1.2.2 NOCA Lake and Pond Monitoring

Physical information, including information on lake bathymetry, transparency, and temperature profiles, is available for approximately 200 NOCA lakes and ponds from surveys conducted between 1971 and 2007. Biological data are available for many of the park's mountain lakes and ponds and include information on zooplankton (106 lakes), phytoplankton (66), fish presence/absence and relative abundance (246), and amphibian presence/absence and relative abundance (298). In addition, benthic macroinvertebrate data are available for 120 lakes and ponds. Chemical data are available for approximately 190 lakes and ponds and include information on pH, alkalinity, specific conductance, dissolved oxygen, and some data on nutrients, cations, anions, and metals. Data on air toxins are available for five lakes.

1.2.3 OLYM Lake and Pond Monitoring

Historical work on the mountain lakes of OLYM is limited, mainly due to the remote nature of the lakes and the difficulty in accessing them. Prior to the I&M Program, lake research was limited to surveys of exotic fish in a subset of the mountain lake populations (Hagen 1961, Olson and Meyer 1994), physical/chemical/biological characterizations of relatively accessible lake districts (Larson et al. 1995), and contaminant studies of a few select, highly accessible lakes (Moran et al. 2007, Landers et al. 2008). Of the 616 identified mountain lakes, fish presence data are available from approximately 50 lakes, amphibian data from approximately 84 lakes, and physical/chemical data from fewer than 20 lakes. Contaminant data are available from seven OLYM lakes.

1.3. Existing and Potential Stressors/Issues

NCCN mountain lakes are influenced by both anthropogenic and natural system drivers. The rapid human population increase in the Pacific Northwest over the last century has likely increased the magnitude of human impacts, which affect the dynamics and interactions of system drivers. Ecosystem drivers affected by human activities include atmospheric deposition of pollutants, climate change, and disturbances related to human activities both within and adjacent to park boundaries (e.g., transfer of nonnative species). Natural processes that impact mountain lakes include episodic floods, volcanic eruptions, earthquakes, landslides, avalanches, fire, wind storms, insect infestations and glacial activity. A summary of anthropogenic system drivers affecting NCCN lakes, their related stressors, and potential (or existing) chemical, physical, and biological responses are shown in Table 2.

Table 2. Ecosystem drivers, stressors and responses (physiochemical, biological) for NCCN lakes.

Ecosystem Drivers	Sources	Stressors	Lake Response
Atmospheric Pollutant Deposition	Regional power generation Long-range pollutant transport Vehicle emissions Urban development/population growth Industrial/agricultural Forest Fires	Metals, pesticides, and other toxics Acidification Nutrients Ozone	Reduced pH and buffering capacity Changes in nutrients and productivity Alteration of food web dynamics Changes in community composition Changes in species abundance and distribution Alteration of colonization patterns Local extinction Changes in organism health and condition
Climate	Global anthropogenic sources Regional anthropogenic sources Natural catastrophic events	Temperature Precipitation Wind UV radiation Water storage and runoff patterns Fire	Alteration in lake thermal properties Change in lake water levels Changes in sediment delivery Changes in lake habitat characteristics Changes in allochthonous input Changes in nutrients and productivity Alteration of food web dynamics Changes in community composition Changes in species abundance and distribution Alteration of colonization patterns Changes in organism health and condition Alteration of genetic integrity Local extinction
Human Activities	Park operations/infrastructure Visitor use Roads and highways Fish management policies and actions	Erosion/sediment Organic pollutants Metals, pesticides, and other toxics Oil spills Non-point pollutants Trampling vegetation Non-native species introductions	Changes in sediment delivery Changes in lake habitat characteristics Changes in riparian vegetation Changes in nutrients and productivity Changes in bacteriological water quality Alteration of food web dynamics Changes in organic material processing Changes in community composition Changes in species abundance and distribution Alteration of colonization patterns Changes in organism health and condition Local extinction

Airborne contaminants, deposited via rain, snow, cloudwater and dry deposition, can change water chemistry and impact aquatic biota. Contaminants include nitrates, sulfates, mercury and semi-volatile organics including current use and banned pesticides. Airborne contaminants, transported from various long-distance mobile and stationary sources, have been documented in lakes from all NCCN parks (Moran et al. 2007, Landers et al. 2008). Most sources originate from the greater I-5 corridor (including Vancouver, BC, Seattle-Tacoma, WA, and Portland, OR); however trans-Pacific transport of pollutants also occurs.

Many NCCN lakes are sensitive to atmospheric deposition of sulfur and nitrogen due to their limited capacity to neutralize acid (NPS 1995a, 1995b), and some NCCN lakes may already be impacted by atmospheric deposition (Clow and Samora 2003, Clow and Campbell 2008). In MORA and NOCA, modeling and field studies suggest that sulfur and nitrogen deposition exceeds background levels (Vimont 1996, Clow and Samora 2001). NOCA is exposed to emissions from the Seattle-Tacoma area and is particularly impacted by Canadian sources in the lower Fraser River valley including Vancouver BC, while MORA is primarily exposed to emissions as far south as Portland OR and as far north as Vancouver BC. Deposition in OLYM is markedly reduced because OLYM is not exposed regularly to air masses generated from the industrialized Puget Sound region. The majority of sulfur and nitrogen oxide emissions are anthropogenic in origin (NAPAP 1991).

Climate affects both watershed and in-lake processes. Precipitation, temperature, wind, and UV radiation all affect hydrologic and nutrient cycles in lentic systems. Climate change may alter hydrologic cycles, quality and quantity of lentic habitat, thermal regimes, primary productivity, community composition, food web interactions, and the distribution and abundance of aquatic biota (Table 1). The frequency and intensity of fires is also predicted to increase. Fires can reintroduce mercury into the atmosphere from soils. Wiedinmyer and Friedli (2007) estimate that fires account for 30% of the annual averaged emissions of mercury in the United States.

Human use affects mountain lakes through impacts to the watershed, lake water quality, and lake biota from trampling, erosion, human waste and non-native species introductions. Recreational impacts on and near aquatic systems are often more extensive than on adjacent terrestrial areas because lakes tend to attract certain types of high impact recreational activities such as camping and fishing (Cole and Landres 1996). Road, trail and infrastructure development at MORA, along with associated spill contamination has impacted lake water quality and benthic habitat. Trail development around the shoreline of Mowich Lake has altered benthic habitat. Roads have been constructed within the watersheds of Reflection, Louise, and Tipsoo lakes. Frozen Lake was altered in the early 1930s when the Sunrise Visitor Center water supply system was developed. Water quality impacts from oil and sewage spills have occurred at some lakes.

Non-native fish introduction is one of the most widespread disturbances in NCCN lakes. Extensive fish stocking into previously fishless lakes to support recreational fisheries has been implicated in the reduced abundance and distribution of amphibian populations, as well as the altered composition of zooplankton and macroinvertebrate communities (Liss et al. 1995, 1998, 2002, Tyler et al. 1998, Knapp and Matthews 2000, Knapp et al. 2001, Larson and Hoffman 2002). Fish introductions into mountain lakes alter trophic interactions (Carpenter et al. 1985) that can impact lake productivity (Leavitt et al. 1994). Introduced fish are a particular management issue in NOCA which has recently completed an EIS and fish management plan to

address this issue (NPS 2005). Of the 150 NOCA lakes capable of supporting fish populations, 95 have been stocked with fish. In MORA, non-native fish populations exist in about 30 lakes. Introduced fish in mountain lakes are affecting downstream native fish populations in NCCN parks through predation, competition, and introgressive hybridization (Ostberg and Rodriguez 2006).

Amphibians are important ecological components of Pacific Northwest ecosystems as they represent a significant percentage of the total biomass in our aquatic habitats, serve as predators and prey, and because of their sensitive skin, can serve as environmental indicators given their vulnerability to stressors such as contaminants and UV radiation. Amphibians generally occupy small geographic ranges and narrow elevation limits and have a limited ability to disperse across the landscape due to their small size and their affinity for aquatic habitat. Some species, such as Van Dyke's salamander, have narrow temperature and moisture thresholds for reproduction, development, and other activities making them particularly sensitive to environmental change. In western North America, a disturbingly large percentage of native anurans have suffered severe declines and local extinctions including some in our most pristine and remote reserves (Lannoo 2005). Although some declines are the direct result of chronic and well known causal factors such as habitat loss and fragmentation, urban and industrial development, and the spread of invasive species, there remains considerable uncertainty as to the causes of well documented declines in our most pristine and remote protected areas and in the extent of declines. Stressors to amphibian populations in NCCN parks include contaminants, non-native fish, disease, climate change and park management activities. Semi-volatile organic compounds and mercury, present in several park lakes, have the potential to biomagnify in the food chain which may affect amphibian populations as the top native predator in these aquatic ecosystems. Climate change may have significant effects on amphibian populations since they are sensitive to and respond strongly to changes and variability in air and water temperature, precipitation, and hydro-period (Carey and Alexander 2003). Changes in the fire regime may also have some effects if large-scale fires affect the amounts and distribution of large woody debris delivery to riparian areas (Gustafson et al. 2001). Emerging diseases have been linked with massive declines, have been documented in the Pacific Northwest, and have affected amphibians in pristine areas and at high elevations (USGS BRD, Michael Adams, Research Ecologist, pers. comm.). It has been hypothesized that widespread anthropogenic stressors, including increased ultraviolet-B radiation, deposition of airborne chemical pollution, and global climate change, in addition to having direct impacts on amphibian survival, reproduction, and growth, also act by reducing immune system functioning and thereby facilitate the emergence of infectious diseases (Daszak et al. 2003).

1.4. Rationale for Selecting this Resource to Monitor

Mountain lakes are essential park ecosystems in the NCCN, both culturally and ecologically. The NCCN contains over 1,200 mountain lakes and ponds. These lakes are enormously popular visitor destinations due to their aesthetic and natural characteristics. Mountain lakes are tightly linked to their neighboring terrestrial environments, as critical breeding sites for many amphibian and insect species, and as water sources and feeding grounds for park wildlife. These sensitive ecosystems have in-lake physical and biological processes that respond to and integrate a suite of key environmental stressors (Thompson et al. 2005, Vinebrooke and Leavitt 2005, Christensen et al. 2006). Mountain lakes function as "petri dishes in the sky" by integrating the effects of global climate change, atmospheric deposition, visitor impacts, amphibian declines, and exotic species

introductions. As a broad-spectrum monitoring effort that is sensitive to each of the identified stressors, this proposed project addresses a range of regional and park-specific management issues that are relevant both now and into the future.

The mountain lake parks of the NCCN span a gradient of urban influence, from the highly populated greater Puget Sound region (MORA, NOCA), to the sparsely populated Olympic Peninsula (OLYM). These parks also span a west-east precipitation gradient, from the very wet OLYM, to the drier MORA and NOCA. This precipitation gradient is also present in each park, with the western areas relatively wetter than the eastern areas. Because of these gradients, network parks and areas within may respond differently to certain stressors (e.g., atmospheric deposition of contaminants), while responding similarly to others (e.g., global climate change) (Eilers et al. 1989, Cole and Landres 1996). Lake ecosystems have a rich history of ecological research and have provided fundamental ecological concepts, mechanistic explanations, and demonstrations of anthropogenic change (e.g., Goldman 2000). Lakes of the NCCN high country represent model systems for the detection of anthropogenic change. The monitoring protocol utilizes a cost-efficient comprehensive approach using multiple indicators representing key physical, chemical, and biological attributes, which will serve to address current issues as well as future emerging issues.

1.4.1 Monitoring Questions

The following monitoring questions concerning NCCN lakes have been identified:

- What are the status and trends in physical, chemical, and biological parameters of lakes that characterize the quality and natural function of these ecosystems and their ecological condition; what fraction of lakes exceed a particular impairment threshold value; how many lakes are changing and what is the rate of change; are changes occurring across the landscape or are they localized to regions of the parks or individual sites; do lakes differ in their rates of change; what park attributes can help in the prediction of lakes that are changing and be used to explain differences in rates of change among these lakes; and what are the likely causes and consequences of these changes?
- How is climate change affecting park lakes? For instance, is there a trend in seasonal water temperature patterns, such as timing of ice-out and ice formation; are there changes in biological community composition or local extinctions of temperature intolerant taxa; are there chemical changes affecting trophic conditions; are lake levels decreasing?
- Does atmospheric deposition affect lakes in the parks? What are the trends in lake indicators of air pollutant deposition (e.g., nitrogen, sulfur, pH, and acid neutralizing capacity); does precipitation affect air pollutant deposition rates of change; and are there biological trends that are consistent with trends in indicators of atmospheric deposition?
- Are there detectable impacts to nearshore areas of park lakes (e.g., trampling of vegetation, erosion etc.) related to visitor use and park operations and what are the long-term trends in the magnitude of the impacts?

1.4.2. Objectives

The fundamental goals of this monitoring project are to document the ecological condition of park lakes and to detect substantive trends in key ecosystem parameters, or Vital Signs, to assess whether mountain lakes are being negatively affected by anthropogenic stressors. These Vital Signs are parameters that characterize the quality and natural function of mountain lake

ecosystems and include responses that represent the ecological condition of our lakes as well as those that represent potential stressors.

1.4.2.1. NCCN Mountain Lakes Monitoring Project Objectives:

Evaluate the status and trends in key indicators of the ecological condition of a representative subset of annually sampled high forest/sub-alpine lakes located in accessible areas of three NCCN parks and sampled during late summer ice-free season to:

1. Determine how lakes are changing and their rate of change for; individual lakes sampled in each park, by the combined sample of all lakes in a park (park-wide), and by the combined sample of all lakes from all three parks (network-wide) *Our trend analysis objective is to detect an average annual increase or decrease in the average response of monitoring parameters of ≤3% with an 80% probability of detecting a trend and a 10% probability of incorrectly asserting a trend in a ≤15 year period (approximately a 45% change of the initial value over 15 years). Power analysis for determining preliminary sample size requirements for trend analysis is presented in the Section 2.4. Results of the power analysis (Table 7) indicate that this objective can be achieved for most of our response variables; however the actual parameter variability will ultimately determine our ability to detect trends in the future. A complete list of proposed response variables is shown in Appendix E, Tables E-1 through E-4*;
2. Determine how many lakes are changing and where changes are occurring among lakes in the three parks;
3. Identify important environmental covariates (explanatory variables) that can help in the prediction of where lakes may change and to explain differences in the magnitude of changes occurring among lakes; and
4. Provide information to support hypotheses regarding likely causes and consequences of changes occurring in park lakes.

This monitoring project is designed to detect changes in Vital Signs from a set of randomly chosen and spatially distributed lakes that represent a larger target population of lakes in the parks as described in Narrative Section 2.2 (Sample Selection Procedures). Although this project follows an inferential design, the small sample size of 20 annually visited lakes is considered to have only marginal capability of providing statistical relevance concerning the status and trends in condition of the overall set of park target population lakes. As such, the existing sampling design can provide an adequate representation of how lakes are changing and their rates of change (Objective 1), but can only provide limited insight regarding Objectives 2- 4, listed above.

To address the sample size issue, a proposal to expand the sampling effort at each of the three parks has been developed (Appendix J). The objectives of this proposal are to provide ecologically relevant data from a sufficiently representative sample of lakes to: detect spatial patterns in temporal change; estimate the fraction of lakes exceeding a management threshold; estimate the variation among lakes in magnitudes of change; identify covariates or risk factors that explain the variation among lakes in response; and to provide data for development and/or refinement of biological, chemical, and physical criteria for the future assessments of the ecological condition of mountain lakes in OLYM, MORA, and NOCA. Requested funds will be

used to expand the overall representation of the NCCN mountain lake target populations by conducting a one-time sampling effort at 30 additional lakes in each park (surveys of a total of 30 target population lakes at NOCA and MORA, in addition to the annual sampling lakes, have been already completed using other funding sources). The first visit to the broader panel of sites will provide data for development of park specific chemical, physical, and biological criteria for the assessment of change, data for calibration of biological condition metrics and predictive models, and provide a baseline to quantify changes and characterize patterns in the predictors of change following future revisits to the broader panel of sites. Revisits could occur at 10 to 20 year intervals or at minimum once change is detected in the primary annual-revisit panel.

In order to address these objectives, four basic types of analyses are proposed in this protocol (SOP 21: Data Analysis and Reporting, Section IV). One set of analyses is designed to determine status by estimation of a value for a parameter at a particular point in time. An example of this type of analysis would be an estimate of the proportion of lakes in the network with a pH value less than a standard threshold value that indicates impairment. Another set of analyses is designed to detect abrupt changes in a parameter. An example analysis of this type is detection of an atypical increase (significant departure in the current year value from the pattern of values in previous years) in average water temperature at a particular site. The third set of analyses is designed to detect the direction and magnitude of long-term steady changes. The final set of analyses is for detection of step trends which compares two sets of data for a response variable from non-overlapping time periods at a site. An example of a step trend analysis would be comparing a time series of data for a change in zooplankton density before and after the introduction of a non-native fish species.

All of the basic types of analyses are further divided into three different inference scenarios (Objectives 1.a-c). One inference scenario utilizes data from a single site (lake) and makes inference to that site. Another inference scenario assumes data from multiple sites within a park will be pooled to make inference about a parameter defined on the sampled portion of the target population of an individual park. These inferences are called park-wide. The final inference scenario pools data from the three parks of NCCN and makes inference to all lakes in the union of each park's target population. These inferences are called network-wide, and the union of target populations is called the network population. Inference can only be extended to lakes meeting target population criteria (Section 2.2, Table 3), which constrain surface area, maximum depth, elevation, fish population density, glacial influence, and accessibility. In addition, inference only represents conditions characteristic of the late summer index period which coincides with peak annual productivity levels.

Explanatory variables (Objective 2) that are known to affect responses will be incorporated into the trend analysis procedures, in particular those variables related to potential stressors of climate change and air pollutant deposition including water temperature, air temperature, and annual precipitation. Other potential explanatory variables will be screened as more information is acquired throughout the monitoring project. Incorporation of these covariates into the analyses can improve overall precision and statistical power (Urquhart et al. 1998). Additional information concerning incorporation of covariates into trend analysis is discussed in SOP 21, Data Analysis and Reporting, Section IV.C.

1.4.2.2. Water Resource Program Objectives:

The National Park Service Water Resources Division (WRD) provides funding to augment water resource related monitoring projects within the NPS Networks and has developed guidance and objectives that apply to the NPS Inventory and Monitoring Program. WRD guidance for the Inventory and Monitoring Program emphasizes the importance of understanding the condition of water resources in National Parks:

> *"Preserving water resources of the national parks unimpaired for the enjoyment of future generations is a fundamental purpose of the National Park Service. Critical to this endeavor is understanding the condition of water resources in the National Parks."*
> *http://www.nature.nps.gov/water/VitalSignsGuidance.cfm*

Specific objectives linked to the NPS Inventory and Monitoring Program are documented in: Part A: Identification of Priority Impaired and Pristine Waters for the Water Quality Vital Signs Monitoring Component (http://www.nature.nps.gov/water/Vital_Signs_Guidance/Guidance_Documents/wqPartA.pdf).

Objectives in Part A address both "Quality Impaired Waters" and "Outstanding Natural Resource Waters" (ONRW).

Quality Impaired Waters:

The Clean Water Act (CWA) requires all states to formally identify and publish all waters that do not meet, or are not expected to meet, water quality standards. The identification of these waters, officially defined as "water quality limited" is done through what has become to be known as "303d lists" after the section of the CWA where the requirement is contained. Waters may be listed if pollution exceeding water quality standards is caused by traditional point and nonpoint sources of pollution, as well as by nontraditional causes, such as atmospheric deposition.

The WRD water resource program requires that each I&M Network identify and discuss the status of each waterbody that is quality impaired, and address how each waterbody will be monitored. Generally, long-term monitoring should be conducted in these waters to achieve the following objectives:

- Gather information on pollutants that exceed standards that will assist the park and the state in designing specific pollution prevention or remediation projects through Total Maximum Daily Loads.
- Determine whether the overall program goal of improved water quality is being achieved after the implementation of effective pollution control actions.

Currently there are no 303d-listed mountain lakes in the NCCN so this objective is not addressed under the Mountain Lakes Monitoring Project.

Designated Outstanding National Resource Waters and Pristine Waters:

As part of their water quality standards, each state must develop, adopt, and implement an anti-degradation policy as a key portion of their water quality standards. The U.S. Environmental

Protection Agency (USEPA) requires that states, at a minimum, include provisions for the management of water quality in accordance with the following "Tiers":

- Tier I: Includes provisions to protect existing uses of water in the state, and it constitutes the absolute floor, or minimum level of protection, that must be provided all waters.
- Tier II: Applies to waters whose quality exceeds that necessary to protect "fishable/swimmable" goals of the CWA. Management of these waters must attempt to keep them at existing quality. Degradation may be allowed if it cannot be avoided for social or economic development reasons, but only after a public review has occurred.
- Tier III: Applies to Outstanding National Resource Waters (ONRW) where ordinary use classifications and supporting criteria may not be sufficient or appropriate. These waters are often considered to be the highest quality waters in the United States, but classification as Tier III also offers special protection to waters of ecological significance that may be sensitive ecologically and whose water quality may be poor when measured by traditional parameters. ONRWs are afforded the highest level of protection under the antidegradation policy. Existing water quality must be protected and preserved, and activities that cause only short-term and temporary degradation may be allowed.

National Parks encompass many of the most sensitive, pristine, and significant aquatic resources in the United States and many have been afforded the protection of Tier III ONRW status. Water quality management in these areas generally must aim for preserving and protecting existing water quality. The Washington State antidegradation policy requires that state water quality standards protect existing uses by establishing the maximum levels of pollutants allowed in state waters, and to protect those waters with a quality that is better than the standards. Public nominations are accepted for Tier III status as outstanding resource waters such as in national parks. Most of the mountain lakes in the NCCN would likely qualify for Tier III protection but the nomination process has not yet started. Data substantiating the quality of park waters are needed to support the nomination. Results of long-term monitoring in these waters can effectively be used to answer critical questions concerning water quality protection in our parks.

The WRD water resource program requires that each I&M Network identify and discuss the waters that now have protective Tier III or similar protective designations as well as waters that may be candidates ("otherwise pristine") for designation. Monitoring plans should be adopted that will achieve the following two objectives:

- Allow characterization of existing water quality and identify changes or trends in water quality over time.
- Identify specific existing or emerging water quality problems.

Both of these objectives are incorporated into the NCCN Mountain Lakes Monitoring Project (*see* previous Section 1.4.2.1).

2. Sampling Design and Elements

NCCN's sample design is framed by the goal to detect abrupt changes and long-term steady trends in the ecological condition of mountain lakes at network and park scales and from the perspective of climate change and atmospheric deposition. The basic sampling design is to monitor 20 high forest/subalpine lakes, six each in MORA and NOCA, and eight lakes in OLYM. The lakes chosen for each park were selected randomly from a subset of the entire population of park lakes. The subset, or target population and resulting sample frame, is based on a set of inclusion criteria (Table 3) intended to standardize the type of lake monitored and to facilitate comparisons across parks. Although restricted in scope, the resulting sample frames at each park represent a complete range of potential stressors and current issues within NCCN's high-forest and subalpine ecosystems.

In developing criteria to select lakes, many factors had to be considered, including fiscal, logistical (e.g., access), environmental, and individual park policies. Among the three parks, such factors tended to be multifaceted and provided many challenges to developing an integrated approach, primarily because they varied so much. In setting design criteria, our aim was to ensure that trends could be detected at the network and park scales. To achieve this, it was important to ensure that the lake physical features, management policies, and other characteristics of one park did not excessively constrain the network scale sampling design. We also wished to provide sufficient flexibility so that additional lakes could be sampled at any of the parks (as funds become available) using the design and field methods in this protocol to provide a larger sample size for addressing questions of status and enhancing trend detection at multiple scales. Additional effort could also be used to sample, by helicopter, the inaccessible lakes in the target population to provide data for expanded interpretation of monitoring results to the portion of the target population not currently included in the sample frame and to provide reference site information for developing criteria for assessment of questions regarding status (*see* Appendix J: Proposal to expand mountain lake sampling).

In the sub-sections below, we provide the key background information that influenced the development of NCCN's sample design and then describe our sample design to detect changes and trends at network and park scales for a broad range of chemical, physical, and biological parameters. For the few sampling design criteria that are different between parks, we provide the rationale for such differences and identify the analytical methods to reconcile these differences in order to detect status and trends at the network scale. Detailed descriptions of the analytical methods for network- and park-scale status, abrupt change, and trend analyses are found in SOP 21: Data Analysis and Reporting, Section IV, D-G.

2.1. Sampling Design: Background and Rationale

Development of a mountain lakes monitoring protocol in the NCCN started under the auspices of the NPS Inventory and Monitoring (I&M) Program in 2000, but began in earnest after a USGS-sponsored workshop in 2002 (Hoffman 2002). This workshop assembled a panel of limnology experts to review a draft set of standard operating procedures and to provide suggestions to the NPS on sampling design. This workshop was the foundation for a publication produced in cooperation with NCCN titled: *Sampling Protocol for Monitoring Abiotic and Biotic Characteristics of Mountain Ponds and Lakes* (Hoffman et al. 2005). This document describes

field techniques and procedures for sampling mountain ponds and lakes and formed the basis of many Standard Operating Procedures for data collection described in this protocol.

Even if sample design was not a primary focus of the Hoffman et al. (2005) publication, it provided an important foundation for NCCN to develop its sample design. They explained the over-arching challenges that NCCN likely would encounter in developing its sample design and sample selection--especially that the number and types of mountain lakes and ponds to sample as well as how monitoring sites are to be selected (i.e., representative or random) could be problematic. Moreover, they indicated that the large number of NCCN lakes and ponds (1,255 >0.01ha, Table 1, Section 1.1.2) made it unrealistic for a full range of lake and pond "systems" to be sampled, and that accessibility and the short time that many of these lakes are free of ice and snow can compound the difficulties associated with effectively monitoring these lentic ecosystems. At the workshop many of these challenges could not be sufficiently resolved to construct a unified, network-scale (i.e., MORA, NOCA, and OLYM) sample design. In the 2005 publication only park scale design considerations were addressed, which were dependent upon each park's objectives, policies, fiscal limitations, and logistical constraints.

The Hoffman et al. (2005) publication had two profound effects on the sample design. First, they recommended that, programmatically, lake (and parameter) selection be guided by focusing on one or more ecosystem stressors. This led NCCN to choose global climate change and transport of anthropogenic contaminants via the atmosphere as the stressors to emphasize in its Mountain Lakes and Ponds Monitoring Project. Second, among the options Hoffman et al. (2005) provided to frame the design, NCCN chose to randomize its lakes selection process, in order to make inferences at the park and network scales. The advantage of randomization is that probabilistic statements can be made about differences in (lake parameters) means and that statistical inference can be made to a larger population of lakes, adding strength to statements made about observed change in a population of lakes. This contrasts with model-based (Särndal 1978, Hansen et al. 1983, de Gruijter and ter Braak 1990) or professional judgment sampling (Edwards 1998, Stoddard et al. 1998, McDonald 2003), which do not allow statistical inferences to be made to a target population and unduly constrain inference of observed change to just the lakes sampled.

Probability sampling is required to make projections about the sampled population. Lake sampling in large, remote parks is expensive, and sample sizes required for providing statistically significant inference to all park lakes and ponds is not plausible. Because of this, the sampled populations need to be a meaningful subset of conditions where inference can be drawn within and across parks to the network scale. To explicitly define target populations and the sample frames from which lakes are randomly selected requires setting criteria to organize lakes into meaningful groups of relatively similar characteristics, which, as Hoffman et al. (2005) pointed out, could be problematic at NCCN.

From here on, it was evident that NCCN had many challenges and impediments to overcome to unify the sample design at the network scale. Most problematic were the differences between parks in basic data known about lakes and access. Developing design criteria at a network scale requires similar baseline information (i.e., to organize lakes into ecologically meaningful groups of similar physical characteristics). This type of information is readily available for most lakes at NOCA and MORA, but not for OLYM. The baseline data gap between parks caused many

problems to moving forward on developing a network-scale sample design. Retrieving such data at OLYM was too expensive and often logistically not possible because of access issues. In OLYM and NOCA, mountain lakes are situated in rugged, steep, remote wilderness terrain where only basic trail systems exist. Many of the lakes in NOCA and OLYM are off trail and are inaccessible by foot, and of the lakes that are accessible, most are difficult and time consuming to reach, often taking three or more days by foot. At NOCA, helicopters can be used to access remote lakes, whereas at OLYM more restrictive policies are in place regarding annual recurring helicopter use in wilderness. In MORA, lake access is relatively easy via a combination of roads and short (generally <1.5 days, round trip) trails. Most of the MORA lakes are readily accessible by foot and have been previously surveyed providing a database of basic lake attributes (e.g. depth, fish presence, etc.). Historical program priorities regarding inventory and non-native fish stocking at NOCA have resulted in a database of basic lake attributes similar to MORA. Most OLYM lakes have not been surveyed, and basic lake attribute information is often lacking.

In 2005, a network-scale design seemed unattainable, in the near term, because of the large differences between the parks, yet there was a pressing need to produce a protocol. To address this, NCCN decided to develop protocol sampling procedures at the park scale first, with the goal of addressing the network scale later, thus allowing the Network (parks) to continue developing pilot studies to test field techniques—albeit, using different park-based sample designs.

With the information and access issues being addressed at the park scale, NCCN developed two parallel monitoring approaches with different design elements, one at NOCA and MORA and the other at OLYM. Each approach used a common set of standard operating procedures based on Hoffman et al. (2005). The approach developed for MORA and NOCA provided inference to a broad target population of lakes, reflective of their ability to access the majority of park lakes by foot or by helicopter and of a robust knowledge of the physical characteristics of the lakes. The situation lent itself to using a Generalized Random Tessellation Stratified (GRTS) (Stevens and Olsen 1999, 2003, and 2004) procedure to select sample sites (lakes), as it was being done in other protocols produced by the NCCN (e.g., Landbirds: Siegel et al. 2007 and Vegetation: Woodward et al. 2009 and Acker et al. 2010). A reverse hierarchical ordering was used to select panels of lakes to sample annually and to sample on a five-year rotation. Pilot implementation began in 2005 at MORA where three years of data were collected for five annual panel sample sites and one year of data was collected for 15 sites from the rotating panels. Pilot implementation at NOCA began in 2006 where two years of data were collected for five annual sample sites and one year of data was collected for 12 sites from the rotating panels. OLYM developed a sample design that reflected a smaller proportion of lakes available for its target population due to inaccessibility. OLYM used a random stratified process to select lakes during pilot implementation in 2005 and 2006. Four lakes were selected, equally split between two of three strata, high and low annual precipitation, while none were selected from the moderate precipitation stratum. Of these lakes, two have been sampled for four consecutive years and two have been sampled for three consecutive years. Pilot studies using the two approaches continued through 2007.

In November 2007, a NCCN I&M Program Review was conducted by USGS scientists and NPS program managers to review the NCCN's progress on inventory and monitoring. The panel acknowledged that the protocol being developed for high-elevation mountain lakes and ponds needed to unify its monitoring approaches to address the network scale. In January 2008, NCCN

held a workshop to undertake the panel's recommendations. Here, guidelines were fleshed out by NCCN staff in collaboration with USGS for developing a unified design; these were formalized in a paper by Hoffman and Huff (2008). The key sample design factors unified at the workshop were: 1) the total number of lakes and how many from each park - 18 randomly-selected lakes, six from each of the three parks, 2) a set of lake selection criteria (to determine the target population of lakes and sampling frame), described in Section 2.2 and shown in Table 3, 3) a common set of physical, chemical and biological parameters measured at each park to detect trends at network and park scales, and 4) lakes selected for monitoring represent the range of annual precipitation in each park in order to facilitate interpretation of atmospheric deposition data. Within the NCCN there is a strong west-east gradient in exposure to atmospheric deposition of pollutants from precipitation based on proximity to emission sources and air movement patterns. OLYM, to the west and adjacent to the Pacific Ocean, receives relatively low concentrations of pollutants and the highest precipitation, while the more eastern MORA and NOCA receive relatively high concentrations of pollutants but in general less precipitation (Landers et al. 2008). Within each park a strong west-east precipitation gradient also exists.

During 2009, concerns about the lack of unification regarding sample selection procedures used for OLYM and those used for MORA and NOCA prompted additional statistical review by the NPS I&M Program Quantitative Ecologist (Tom Philippi, Ph.D.). Recommendations from this review (Philippi, Feb. 2010 correspondence) stated that using the combination of two different sample selection procedures (GRTS at MORA and NOCA and simple random stratified at OLYM) is not a problem; they are both probability samples and can be combined for data analyses, so long as a consistent target population is defined for the three parks. The greatest weakness of the proposed sampling design was the "complexity of the target population caused by the omission of the moderate-precipitation lakes at OLYM." Omission of the moderate precipitation stratum at OLYM greatly reduces the information available from the monitoring project by preventing inferences about a unified set of lakes at OLYM, precluding straightforward inferences to the population of lakes at the network scale, and reducing the ability to interpret differences between parks. Final recommendations from the review requested that a minimum of two lakes be selected at random from the OLYM moderate precipitation stratum, resulting in a total sample of eight lakes at OLYM and 20 lakes combined for the three NCCN parks.

2.2. Sample Selection Procedures

2.2.1 Target Population and Sample Frame Development

With over 1200 lakes and ponds in the three network parks, it was necessary to reduce that number into a workable set of physically similar lakes because of funding and logistic limitations as well as the need to provide a spatially representative sample from which to draw inference. To facilitate this, target population inclusion criteria were developed to reduce this large set of lakes and ponds into a workable subset. It was expected that application of these inclusion criteria would reduce noise in the data set attributed to between lake variability, thereby enhancing our ability to detect changes and trends.

Separate target populations were developed for each park. The 'Target Population' represents the set of lakes that are of interest for monitoring at MORA, NOCA, and OLYM, that meet the inclusion criteria in Table 3. The 'Sample Frame' represents the list of lakes that the samples

were drawn from and is represented by a subset of target population lakes at each park that are ice -free and safely accessible on foot by trail or off trails in August and September. Sample frame lakes are also referred to as the 'sampled population,' representing the set of target population lakes from which inference can be drawn.

Table 3. Target population inclusion criteria for selection of NCCN mountain lakes.

Criteria	Description
Political boundary	Bound entirely within the park.
Surface area	≥0.4 ha and ≤6.0 ha.
Elevation	Lower limit ≥1,220 m (4,000 ft). Upper limit represents the extent of the subalpine zone and is fixed to the elevation of the highest target population lake at each park (in Table 4): MORA=2,007 m, NOCA =2,126 m, OLYM=1,790 m.
Glacial influence	Lakes with strong glacial influence, affecting water clarity and temperature, are not included in the target populations. These lakes exhibit Secchi disk measurements of <2 m and peak season water temperature of less than 8°C.
Maximum depth (m)	>2.5 m after the beginning of the field season.
Fish density	Lakes with high fish density are not included in the target populations. High density fish populations generally represent those with natural reproduction as indicated by presence of suitable spawning habitat (e.g., inlets, outlets and/or nearshore springs with suitable spawning gravel).
Seasonal-temporal window	Inference to the target population only applies to the sampling period of August and September

Application of the surface area inclusion criterion reduced the initial set of 1,255 lakes and ponds down to a subset of 360 lakes. Nearly 95% of the sites removed were small ponds <0.4 ha with a mean size of ≤0.13 ha. Remaining target population inclusion criteria (elevation, political boundary, maximum depth, fish density, and glacial influence) further reduced the set of lakes considered for sampling down to 241 lakes constituting the target population total for the three parks. After applying the sampling frame accessibility requirement, lakes that are ice free and safely accessible on foot by trail or off trails in August and September, a total of 163 lakes remained available for selection in the sample frames of the three parks. This number may be reduced as lakes in a park's target populations are visited over time and inclusion criteria verified. Lists of target population lakes, sample frames, and lake attributes that relate to the inclusion criteria are shown in Appendix D, Tables D-1 through D-3.

Single target populations for NOCA and MORA were defined by the inclusion criteria in Table 3. An additional step was taken at OLYM to provide contrast in the representation of the strong annual precipitation gradient in order to facilitate detection of potential differences in lake trends due to atmospheric deposition. Lakes meeting the inclusion criteria in Table 3 were assigned to one of three strata based upon their mean annual precipitation. The three strata, considered as separate target populations, were derived by dividing the mean annual precipitation range experienced by lakes into three roughly equal groups: low (155 to 315 cm/yr), moderate (316 to 450 cm/yr) and high (451 to 610 cm/yr). At MORA and NOCA, stratification of target population sites to facilitate site selection representing the range of precipitation gradients was not necessary because of the spatially balanced sample selection procedure used at these two parks (see Sections 2.2.3 and 2.2.4). A summary comparison of the sampled and unsampled portions of the target population for each of the park units is shown in Table 4.

Table 4. Summary comparison of the number, size, elevation, and range of annual precipitation for lakes included in the sampled and unsampled portions of the target populations of the NCCN park units.

Park Unit	N	Elevation Range (m)	Surface Area Range (ha)	Mean Surface Area (ha)	SDEV Area	Range in Annual Precip. (cm/yr)*
MORA						
Sampled pop.	54	1327-2007	0.49-5.74	1.73	1.24	162-304
Unsampled pop.	0					
NOCA						
Sampled pop.	42	1286-2126	0.41-5.36	2.10	1.58	157-379
Unsampled pop.	40	1250-1969	0.42-5.47	1.61	1.41	121-394
OLYM						
Low precip. stratum						
Sampled pop.	42	1241-1790	0.41-5.15	1.33	1.20	196-315
Unsampled pop.	9	1273-1777	0.41-3.64	1.57	1.21	193-315
Mod. precip. stratum						
Sampled pop.	12	1229-1529	0.62-5.11	1.53	1.27	325-418
Unsampled pop.	13	1388-1716	0.42-5.17	1.26	1.44	317-446
High precip. stratum						
Sampled pop.	13	1224-1690	0.43-2.29	1.23	0.59	480-559
Unsampled pop.	14	1287-1712	0.42-4.48	1.39	1.15	468-610

*Range of annual precipitation at MORA and NOCA was derived from the PRISM Model representing data collected between 1971 and 2000. Annual precipitation at OLYM was derived from a National Weather Service model based on data collected between 1930 and 1959.

In summary, the target population and sampling frame are defined as follows:

> *Target Population* - the population of perennial mountain lakes of interest for monitoring at MORA, OLYM, and NOCA that is found entirely within park boundaries, has surface areas ranging from 0.4 to 6.0 ha, with maximum depths >2.5 m, elevations ranging from 1,220 m extending to the upper limit of the subalpine zone at each park, does not include lakes that are heavily influenced by glacial runoff, does not include lakes that have high densities of fish, and with inference limited to the temporal sampling window of August and September .
>
> *Sampling Frame* - the list of lakes that samples were drawn from at MORA, OLYM, and NOCA that represents target population lakes that are safely accessible on foot by trail or off trails during August and September.

2.2.2. OLYM Sample Selection

All lakes meeting the selection criteria (Table 3) were assigned to one of three strata based upon their mean annual precipitation. Strata were derived by dividing the mean annual precipitation range experienced by lakes into three roughly equal groups: low (155 to 315 cm/yr), moderate (316 to 450 cm/yr) and high (451 to 610 cm/yr). Lakes were attributed with mean annual precipitation data derived from a National Weather Service model of the Olympic Peninsula for the period of 1930-1957 (Phillips and Donaldson 1972). At the time of strata definition in 2005, this model was the standard precipitation coverage in use by the OLYM GIS office. More recent precipitation models (e.g., PRISM, Parameter-elevation Regressions on Independent Slopes Model, Oregon State University) use climate-elevation regression functions from local climate

station data to simulate precipitation patterns across the landscape. However, on the Olympic peninsula few climate stations exist, with no stations in the mountains, thus, other models rely heavily on theoretical simulations with no ground-truthing in the Olympics, to simulate precipitation patterns across the landscape. Differences in the spatial distribution of precipitation patterns across the Olympic Peninsula as revealed through different models likely reflect model assumptions rather than shifts in the distribution of precipitation patterns across the Olympic landscape over the 20th century (Chris Daly, Matt Doggett, Oregon State Univ., personal communication). OLYM target population lakes by precipitation stratum are illustrated in Figure 2 and listed in Appendix D, Tables D-3.a-b.

For selection of sampling sites at OLYM, three lakes were randomly drawn from each of the sample frames representing high and low precipitation strata and two lakes were drawn from the moderate precipitation sampling frame. Four of the sites selected for sampling at OLYM (two sites randomly drawn from each of the low and high precipitation strata) were part of the initial pilot implementation project. Two additional sites were randomly drawn in 2008, adding one more site to each of the high and low precipitation strata. The two moderate precipitation stratum lakes were randomly selected in 2010. Selected sample sites at OLYM are illustrated in Figure 2 and listed in Appendix D, Tables D-3.a-b.

2.2.3. MORA/NOCA Sample Selection

Selected sample lakes and remaining sample frame lakes are shown in Figure 3 (MORA) and Figure 4 (NOCA). The GRTS ordered list of all sampled and unsampled portions of the target population lakes for MORA and NOCA is shown in Appendix D, Tables D-1 and D-2). A fixed sized equi-probable general random tessellation stratified (GRTS) (Stevens and Olsen 1999, 2003, 2004) sample with reverse hierarchical ordering was used to draw samples for MORA and NOCA.

The GRTS sampling procedure was performed by Trent McDonald (Western EcoSystems Technology, WEST, Inc.) in 2008. Samples were drawn using the free-ware computer program S-Draw (http://www.west-inc.com/computerprograms.html). Input files for the GRTS procedure included each lake's unique ID and 2-dimensional UTM coordinates (the lake's center point). The sample size parameter of the GRTS procedure was set high enough to provide a complete (census) GRTS ordered list of all target population lakes at each park. The first six GRTS ordered sample frame lakes were selected for sampling at each park. The remaining ordered sites constitute the "over-sample" which can be used to expand the monitoring project in the future if funding becomes available.

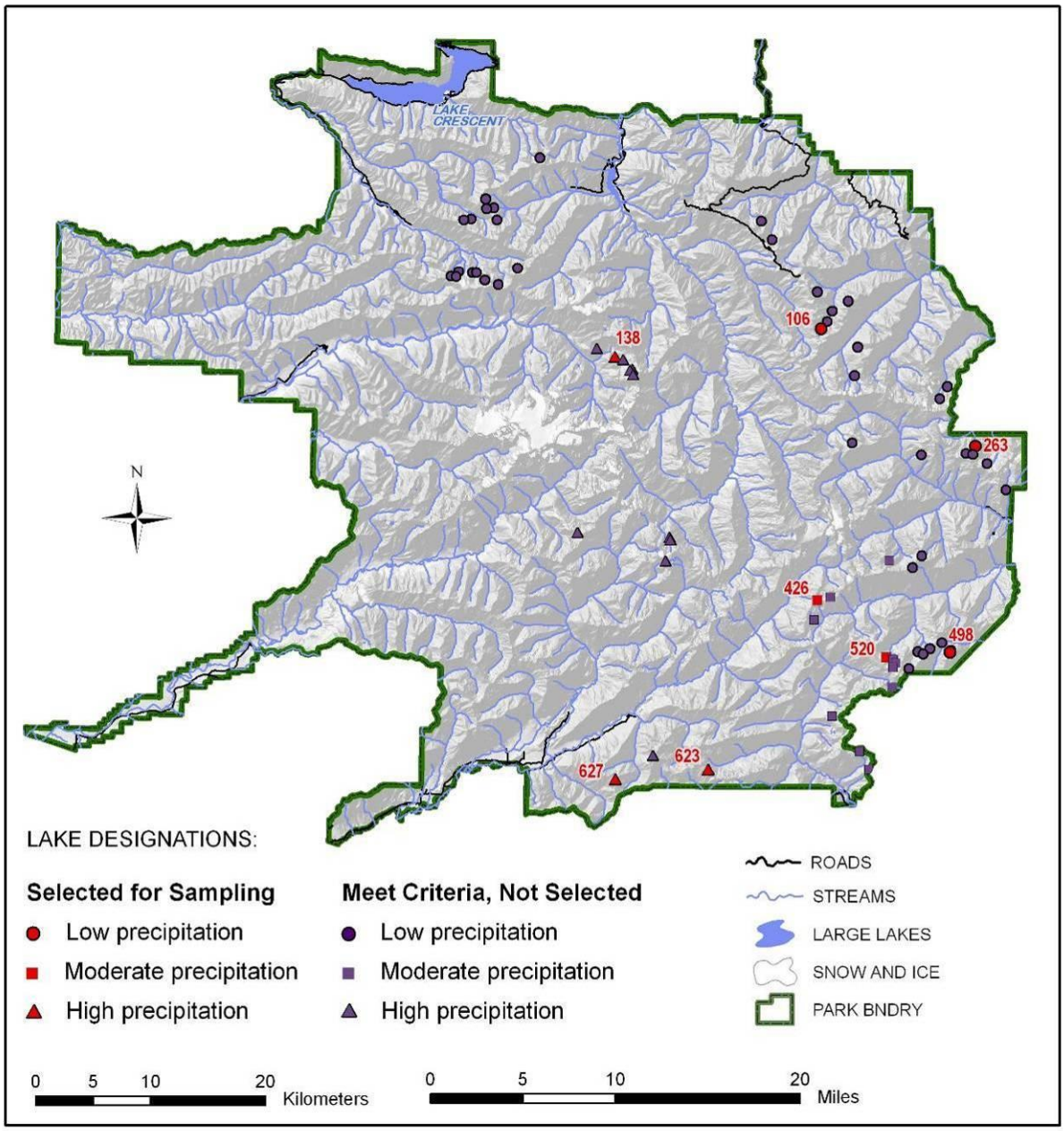


Figure 2. Map of OLYM sample frame lakes by low (155 to 315 cm/yr), moderate (316 to 450 cm/yr) and high (451 to 610 cm/yr) precipitation strata and selected sample sites (red fill with Lake ID).

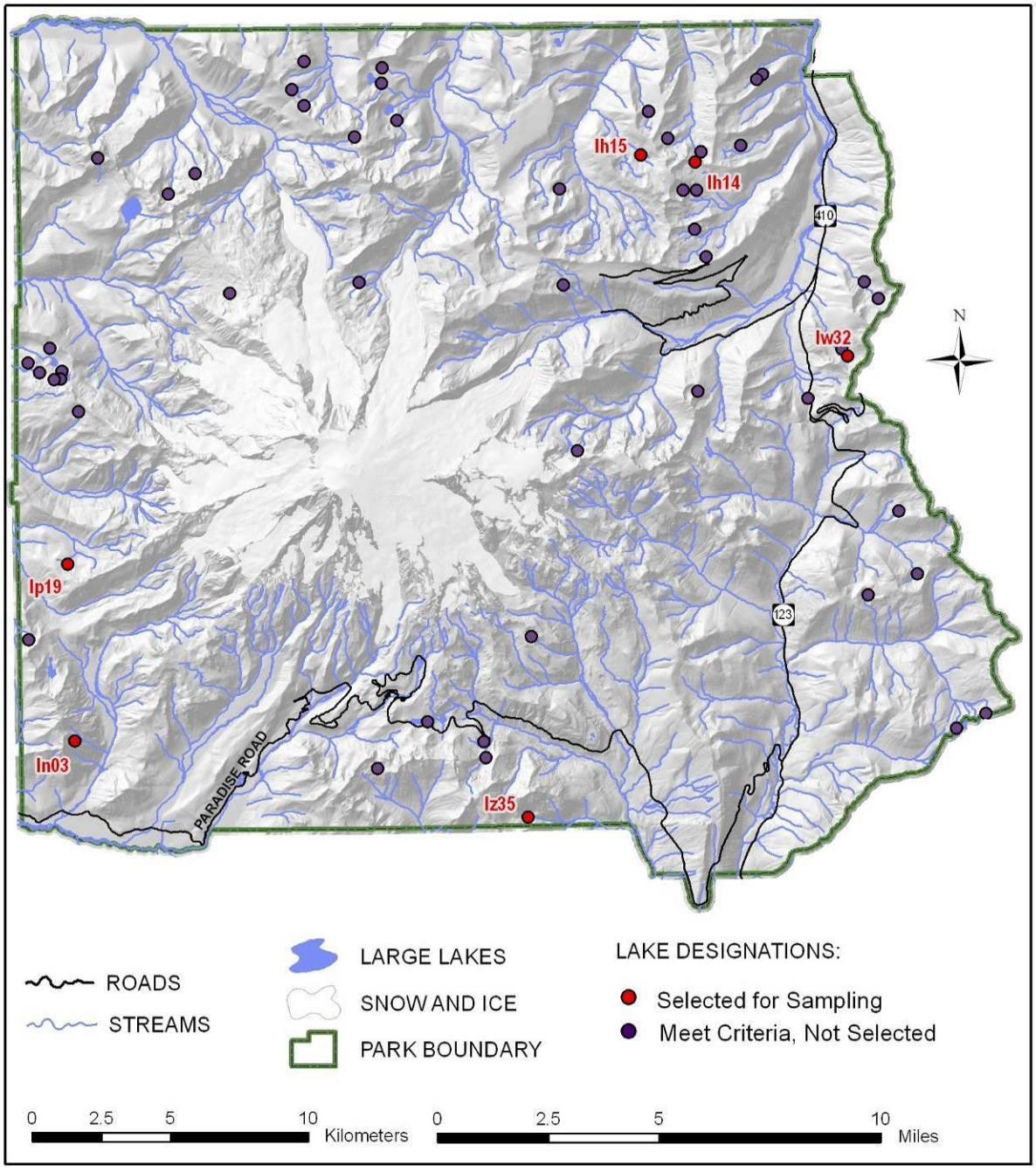


Figure 3. Map of the MORA sample frame lakes and selected sample sites (red circles with Lake ID).

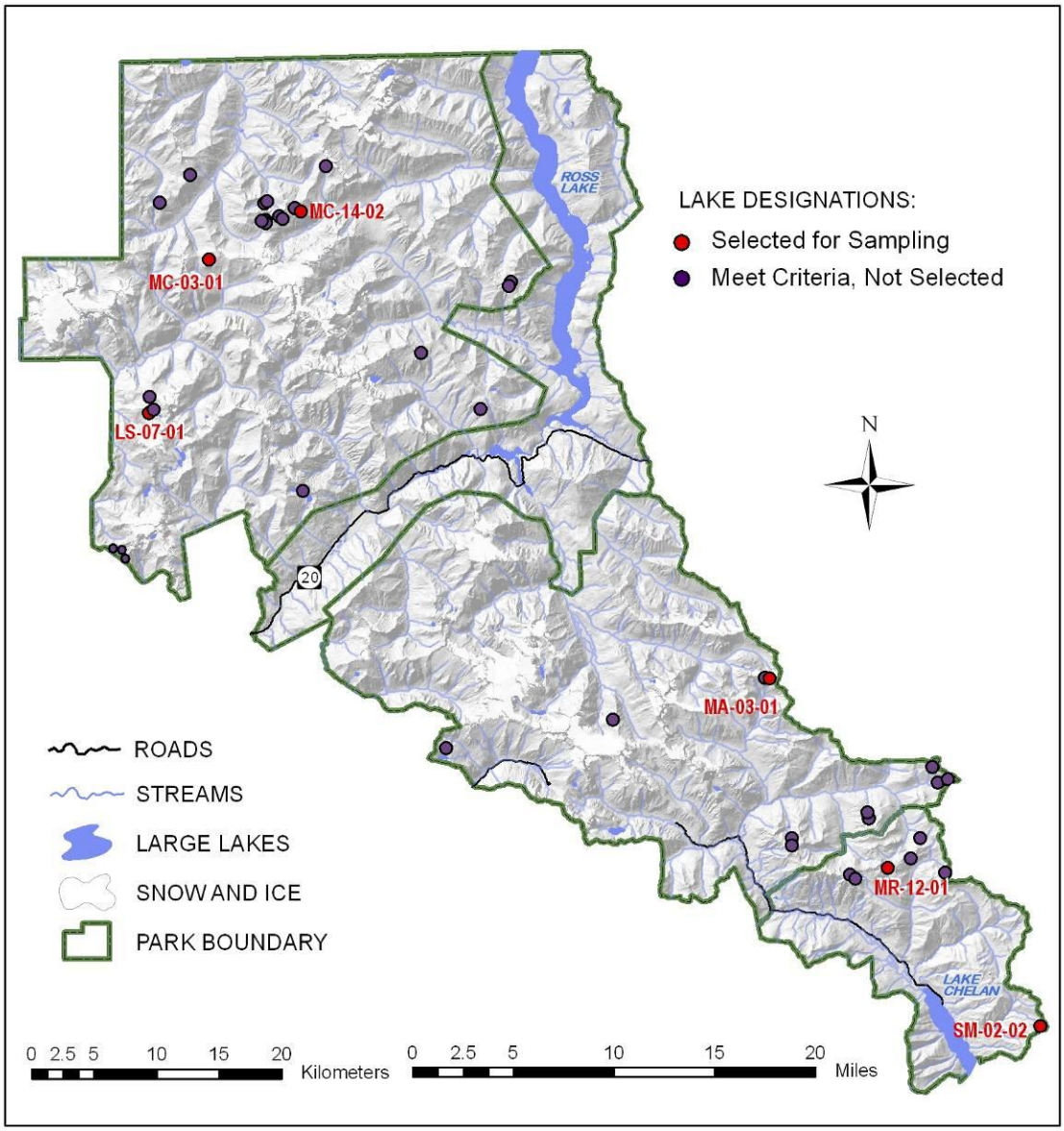


Figure 4. Map of the NOCA sample frame lakes and selected sample sites (red circles with Lake ID).

2.2.4. Distribution of Selected Lakes along Park Precipitation Gradients

A design objective was to determine the influence of precipitation on parameter trends. This required sampling procedures that resulted in selection of lakes for monitoring that represent a range of mean annual precipitation at each park (*see* Section 2.1: Sampling Design Background and Rationale). All target population lakes were attributed with mean annual precipitation data. At OLYM precipitation data were derived from a National Weather Service model of the Olympic Peninsula for the period of 1930-1957 (*see* Section 2.2.2: OLYM Sample selection). The most recent update of the PRISM model (http://prism.oregonstate.edu/), developed using precipitation data collected between 1971 and 2000, was used to derive precipitation values for all target population lakes at MORA and NOCA. Representation of lakes from MORA, NOCA and OLYM sample frames and selected samples scaled to the larger gradient of annual precipitation found at OLYM are shown in Figure 5.

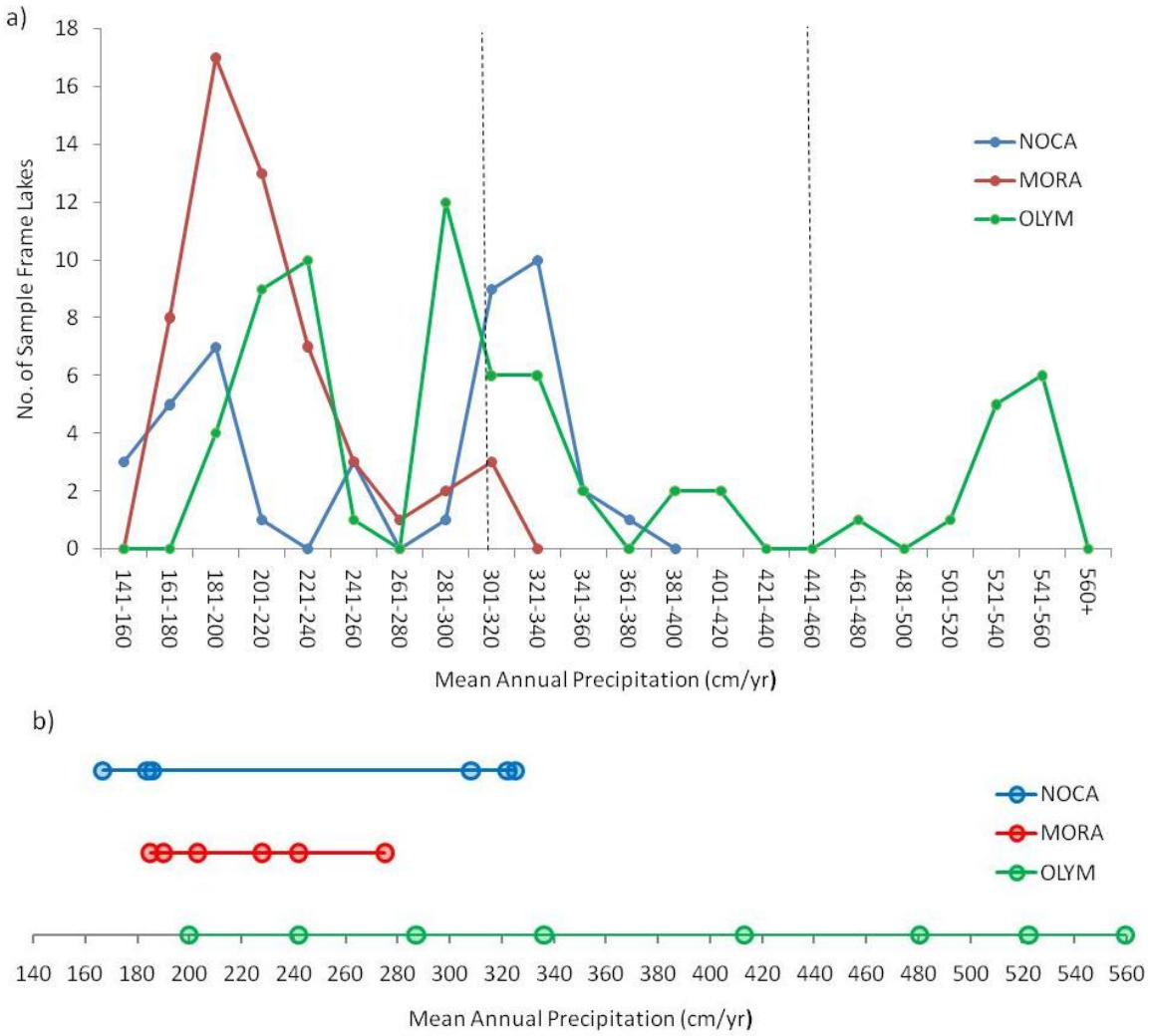


Figure 5. a) Distribution of the number of sample frame lakes at MORA, NOCA and OLYM by mean annual precipitation (cm/yr) intervals (dashed black line approximates OLYM precipitation strata), b) Selected sample (o) representation along mean annual precipitation gradients at each park.

As expected at OLYM, simple random selection of lakes from strata defined by mean annual precipitation provided a sample of lakes representing low, moderate and high segments of precipitation gradient derived from sample frame lakes (Figure 5). At MORA and NOCA, it was expected that the ability of the GRTS procedure to provide a spatially-balanced sample would also accomplish this objective. NOCA and MORA GRTS selected samples (Figure 5b) were representative of the modal distributions of sample frame lakes shown in Figure 5a. At MORA, the unimodal distribution of sample frame lakes was skewed to the left (drier) and was generally evenly represented by the selected lakes. Sample frame lakes at NOCA exhibited a bimodal distribution (Figure 5a) resulting in a sample of lakes clustered at both ends of the precipitation gradient (Figure 5b). This bimodal distribution accurately contrasts the difference in mean annual precipitation between east (dry side) and west (wet side) lakes in the park.

2.2.5. Park-scale and Network-scale Inference

Inference at the park-scale refers to all lakes in the sampled population at MORA or at NOCA. At OLYM, park-scale inference refers to the combined lakes from sampled populations of the low, moderate, and high precipitation strata. Because of this stratification, trend analysis will require weighted inclusion probabilities as discussed in SOP 21: Data Analysis and Reporting, Section IV, E and F. Un-weighted analyses are applied for determining park-scale trends at MORA and NOCA, and for separate evaluations of precipitation strata at OLYM.

For network-scale analyses, the network sample frame is viewed as being partitioned into five analysis strata which include all lakes in the sample frames for MORA and NOCA, and all lakes in the low, moderate and high precipitation strata at OLYM. When detecting network-scale trends and abrupt change (SOP 21: Data Analysis and Reporting, Section IV, E and F.), differing inclusion probabilities for the five strata must be accounted for by including weights in the Mixed Linear Analysis method.

Annual precipitation will be incorporated as a covariate in park-scale and network-scale trend analyses (see SOP 21: Data Analysis and Reporting, Section IV, C). In the absence of having specific precipitation data for target population lakes, all parks will use the best and/or most recent model for these analyses in the future. Calibration of model data using data collected at climate monitoring sites in or near each of the parks is also discussed in SOP 21, Section C.

It must be noted that six to eight lakes per park are barely enough to fit a model testing for differences among parks in slopes and intercepts of the effects covariates. Adding terms to test slopes and intercepts for covariates such as mean annual precipitation, surface area, maximum depth, and other attributes plus their interactions would require substantially larger sample sizes. Further, covariation among the monitored response variables across lakes, and correlated changes over time, contain substantial information that might be useful for understanding the changes and adapting or mitigating effects; such analyses also require a larger sample size (Tom Philippi, Ph.D, NPS I&M Program Quantitative Ecologist, email communication, February 2010). Limitations of the sample size regarding inference to the target populations of lakes at each park were previously discussed in the Objectives Section (1.4.2.1). To address the sample size issue, a proposal to expand the sampling effort at each of the three parks has been developed (Appendix J).

2.3. Sample Elements, Timing, Frequency and Replication

For any given year, all sample units will be visited once during mid-summer through early fall (August through September). Consequently, inference to the target population only applies to this seasonal-temporal window, which we call the index period. The index period provides the best window of opportunity for accessing and sampling sites. Weather and ice cover on lakes during late fall through early summer presents logistical problems that may prevent access or sampling causing a loss of data. Revisits to sites in subsequent years will occur within ± 10 days of the initial sampling date. Standardizing the time of day is also important for sampling parameters subject to diel variability (e.g., Secchi depth, zooplankton, and most water quality parameters).

A summary of lake-sample timing, frequency and replication follows:

1. During each year, sampling will occur on one occasion (with the exception of temperature data collected year-round with data loggers) at each lake during the August through September index period. Scheduling of sampling visits to each lake is generally prioritized by lake elevation, with lower elevation lakes visited earlier in the index period and higher elevation lakes visited later. Lake aspect is also a consideration in the timing of visits to lakes. Revisits to sites in subsequent years will occur within ±10 days of the initial sampling date of each site. Sampling for Secchi depth, zooplankton, and most water quality parameters will be constrained to mid-day for all lakes.

2. Collection of all chemical parameters, chlorophyll-a, zooplankton, and temperature data will occur at the location of the lake's maximum depth. Sampling locations for most other parameters correspond to points along or adjacent to the shoreline.

3. Several sampling strategies are used at each lake. All chemical parameters, chlorophyll-a, and temperature/dissolved oxygen profile data are represented by single measurements taken at specified depths. Replicated measurements are taken for water level and Secchi depth at 1 to 2 locations. The presence of fish in each lake is documented by gill net captures, observations, and angling. Continuous air and water temperature data are taken 48 times a day throughout each year using temperature data loggers. Samples taken from multiple locations around the lake shoreline are either treated separately (e.g., littoral substrate, riparian cover and disturbance) or pooled into a single sample (e.g., benthic macroinvertebrates). Replicate zooplankton tows taken from one location are combined into a pooled sample. Complete shoreline surveys are used for recording observations of amphibians.

4. Duplicate samples for all sample elements will be taken from a random subset of all lakes during each year in order to meet Quality Control recommendations for measurement precision (SOP 19: Section G.5 and Table 19.3).

The frequency and location of measurements for various lake-sample elements are summarized below in Table 5. Specific details concerning the lake-sample elements are found in the individual SOPs in Section III. Additional information concerning data summaries, specific response variables and data analysis strategies are summarized in Appendix E, Tables E-1 through E-4.

Table 5. Frequency and location of measurements for various lake physical, chemical, and biological sample elements at NCCN park units.

Parameters	SOP Number	Frequency [a] and Location of Measurements at each Lake
Physical Parameters		
Continuous water and air temperature	8	Year-round, with multiple daily measurements at LMD[b]
Temperature profile	7	1 location at LMD[b]
Lake water level	5	2 locations with three measurements at each location.
Depth	4	Bathymetric mapping with multiple recordings and locations.
Volume	4	From bathymetric maps
Surface area	4	From GIS
Littoral zone substrate	11, 14	Multiple random locations around the lake perimeter.
Riparian zone cover and disturbance classes	15	Multiple locations from 2 shoreline proximity classes.
Water clarity (Secchi depth)	6	1 location at LMD[b] – 3 measurements
Chemical Parameters		
Dissolved oxygen	7	1 location at LMD[b] with 3 or more measurements from surface to bottom of the lake.
pH		
Specific conductance		
Acid neutralizing capacity (ANC)	9	1 location at LMD[b] with 1 measurement at mid-depth if thermally unstratified. If stratified then 1 measurement from near surface and 1 near bottom.
Nutrients (e.g., TN, TP)		
Total dissolved solids (TDS)		
Anions and Cations		
Dissolved organic carbon (DOC)	9	1 location at LMD[b], 1 measurement near surface.
Biological Parameters		
Chlorophyll-a	10	1 location at LMD[b], 1 measurement at mid-depth.
Zooplankton	12	1 location at LMD[b], 1 pooled sample from 3 tows.
Littoral benthic macroinvertebrates	11	1 pooled sample from 5 subsamples collected at 5 random locations around the lake.
Amphibians	14	1 to 2 complete shoreline visual encounter surveys.
Fish	13	1 to 2 gill net locations depending on lake size.

[a] Replicates taken during the same sampling occasion at three randomly selected lakes each year.

[b] LMD = location of lake where maximum depth occurs.

A brief discussion of the importance of each of the lake-sample elements is provided below:

Acid Neutralizing Capacity (ANC) is a measure of the ability of the water to resist changes in pH. It represents the capacity of water to accept protons, or the concentration of dissolved compounds to shift pH from an acidic level to a more basic level. ANC is a sensitive measure of a lake's buffering capacity and sensitivity to acidification via atmospheric deposition or other means (Likens et al. 1972).

Amphibians are commonly found in NCCN lakes. Declines in amphibian populations have been documented by scientists worldwide from many regions and habitat types (Alford and Richards 1999, Lannoo 2005). No single cause for declines has been demonstrated, but stressors such as acid precipitation, environmental contaminants, introduction of exotic predators and disease agents, parasites, and the effects of ultraviolet radiation have all been suggested, with both individual and synergistic effects. Because of their susceptibility to these and other stressors, amphibians are important as indicators of ecosystem health (Welsh and Ollivier 1998).

Anions and Cations are distinct charged dissolved chemicals that increase the specific conductance of water (Hem 1989). The concentration and relative amount of ions influence lake primary and secondary productivity. Their measurement is often used as an indicator of atmospheric deposition of marine and anthropogenic ionic compounds and lake acidification (Wetzel 2001).

Benthic Macroinvertebrates are a key component of lake food webs and are long-term indicators of environmental quality; they integrate water, sediment, and habitat qualities (USEPA 1989). Macroinvertebrate species have sensitive life stages that respond to stress and integrate effects of both short-term and long-term environmental stressors. Classification of benthic species according to their relative sensitivity to various perturbations and their functional feeding group level provides significant information for differentiating effects on ecological health in response to a variety of stressors.

Chlorophyll-a is a major photosynthetic pigment used by lake primary producers (e.g., phytoplankton). Measurement of chlorophyll-a concentration in lake water is an accepted surrogate for measuring algal biomass, which itself is an estimate of primary production (e.g., Mazumder and Havens 1998). Direct measurement of algal biomass is problematic due to the large number of taxa present in a lake over the course of a year and the requisite taxonomic expertise and sample processing time needed to gather the data.

Dissolved Organic Carbon (DOC) is derived from the degradation of organisms and detritus in the lake ecosystem. DOC is an important resource base for the microbial component of lake ecosystems. Marked shifts in DOC can provide insight into changes in DOC inputs, changes in microbial community structure, function, and abundance (Fukushima et al. 1996). DOC also serves as a proxy for ultraviolet radiation (UVB) exposure, where higher DOC concentrations decrease UVB penetration (Williamson et al. 1996).

Dissolved Oxygen is essential for the support of key food web constituents (e.g., fish, zooplankton, algae, etc.) that respire aerobically. Lake eutrophication can increase aerobic demand causing low oxygen or anoxic areas that negatively impact aerobic organisms. Dissolved oxygen is a core water quality parameter required to be monitored by the NPS Water Resources Division (NPS 2002).

Fish have been introduced into many NCCN lakes for the purpose of creating recreational fishing opportunities and their presence in lakes has been an ongoing issue of concern over the last three decades (NPS 2005). Alteration of native aquatic communities is a primary concern as most lakes in the region were naturally fish-free. The effect of non-native fish introductions on native aquatic communities and trophic structure is a key issue for NCCN lakes and elsewhere. Introduced fish populations can alter the composition of native aquatic communities by predation on amphibians (Bradford et al. 1993, Knapp and Matthews 2000, Pilliod and Peterson 2001), zooplankton (Anderson 1980, Stoddard 1987, Carlisle 1995), and benthic macroinvertebrates (Carlisle 1995, Rowan 1996, Bradford et al. 1998). Fish introductions into mountain lakes can also initiate trophic cascades (Carpenter et al. 1985) that can greatly alter lake productivity (Leavitt et al. 1994).

Lake Morphometric Measurements including surface area, shoreline length, maximum depth, mean depth, and lake volume provide essential data for interpreting biological, chemical and other physical characteristics of a lake.

Lake Level is a measure of lake hydrology. Specifically, it is the balance of all water inputs (precipitation, streams, seeps, etc.) and outputs (drainage, evaporation, residential water use, etc.). Lake level is a valuable indicator of temporal changes in lake hydrology through climate change and watershed manipulation, and is a core water quality parameter required to be monitored by the NPS Water Resources Division (NPS 2002).

Nitrogen is one of the essential nutrients in aquatic systems that fuels primary productivity and occurs in several forms that are differentially used by organisms (Wetzel 2001). Nitrogen enrichment can lead to lake eutrophication. The forms monitored in this protocol are ammonia (NH_3), total oxidized nitrogen (nitrate-NO_3 and nitrite-NO_2), and total nitrogen. Ammonia and nitrate arises from the decomposition of organic matter and can accumulate from pollution sources such as fertilizers, animal wastes, septic tanks, and atmospheric deposition. These forms of nitrogen are readily used by primary produces as nutrient sources. Nitrite is a trace, ephemeral form of nitrogen found in well oxygenated systems such as NCCN lakes. As such, the total oxidized nitrogen measure is assumed to mainly measure nitrate. Total nitrogen is the sum of organic nitrogen (in peptides, proteins, etc), total oxidized nitrogen, and ammonia (Hem 1989). All the nitrogen sources of interest will be measured in these three forms.

pH is a measure of the acid-base balance of water relative to the concentration of hydrogen ions. The water ionic composition determines pH, which is altered by atmospheric inputs, terrestrial runoff, and lake biogeochemical processes. Aquatic communities and biogeochemical processes are potentially affected by pH (e.g., Likens 2004), and it is a core water quality parameter required to be monitored by the NPS Water Resources Division (NPS 2002).

Phosphorus is a limiting nutrient in lakes and plays an essential role in biological metabolism (Wetzel 2001). Phosphorus enrichment is a common cause of lake eutrophication. The forms monitored in this protocol are total phosphorus (suspended plus dissolved) and orthophosphate, the form directly taken up by primary producers. Anthropogenic sources of orthophosphates come from fertilizers usually in the form of phosphoric acid ions (Hem 1989).

Riparian Disturbance measures the relative impact of visitor use related to trampling and disturbance of shore-zone vegetation, campsites, informal trails and eroded areas. Information concerning the response of other lake monitoring attributes with increasing levels of human disturbance can identify minimum levels of acceptable change to provide a basis for implementing management actions.

Specific Conductance is a temperature-dependent measure of the ability of water to conduct an electrical current. It is the reciprocal of resistance. Increases in specific conductance in a system may be associated with anthropogenic inputs to the system. Specific conductance is a core water quality parameter required to be monitored by the NPS Water Resources Division (NPS 2002).

Temperature is measured to characterize the ambient environment for aquatic organisms and to determine the pattern of thermal stratification of the water column. Due to density differences

between water masses of different temperatures, the water column can become stratified during summer and potentially during winter in some systems. Stratification can lead to the accumulation of nutrients and decreases in dissolved oxygen in the hypolimnion. Spring and fall mixing of the water column can lead to nutrient releases that fuel food web productivity. Temperature is a core water quality parameter required to be monitored by the NPS Water Resources Division (NPS 2002).

Total Dissolved Solids is an expression of the combined content of all inorganic and organic substances contained in a liquid which are present in a molecular, ionized or micro-granular suspended form. Primary sources for TDS in receiving waters are from runoff, leaching of soil contaminants and point source pollutants. The most common chemical constituents found in runoff are calcium, phosphates, nitrates, sodium, potassium and chloride. More exotic and harmful elements of TDS are pesticides arising from surface runoff. Certain naturally occurring total dissolved solids arise from the weathering and dissolution of rocks and soils.

Trophic State Indices (TSI) provide a method for determining whether increases in nutrients and/or sediments, known as loading, are causing changes in a lake. Carlson's TSI uses Secchi disk depth, chlorophyll-a, and total phosphorus, each producing an independent measure of trophic state (Carlson 1977). Index values range from approximately 0 (ultraoligotrophic) to 100 (hypereutrophic). A TSI is calculated separately for Secchi depth (SD), chlorophyll-a concentration (Chl), and total phosphorus concentration (TP) (Carlson 1977, Carlson and Simpson 1996).

Trophic State Indices are used to infer the trophic state of a lake and whether algal growth is nutrient limited or light limited. For example, if the three indices are approximately equal, then phosphorus limits algal growth. Several other interpretations regarding factors limiting algal growth and light attenuation, based on examination of differences in relationships between the three indices, are discussed by Carlson and Simpson (1996). A trophic state index also has been developed for total nitrogen (TN) (Kratzer and Brezonik 1981, Carlson 1992).

The initial TSI (Carlson 1977) was developed using a set of lakes with a wide range of Secchi depths, and concentrations of chlorophyll-a and total phosphorus. NCCN Lakes exhibit a much narrower range of chlorophyll-a and total phosphorus concentrations, consequently interpretation of results may differ from those of Carlson (1977). In addition, interpretation of some TSI results may be problematic for lakes where Secchi depth extends to the bottom of the lake and for glacial systems.

Water Clarity (Secchi depth) is a measure of the transparency of water which is a surrogate measure of the cumulative concentrations of dissolved solids, pigments, algal biomass and suspended sediments. All of these factors can be altered by anthropogenic effects. The Secchi depth is a widely used measure of water clarity that measures the maximum depth at which a 20-cm diameter Secchi disk (with alternating black and white quarters) can be observed from the surface (Preisendorfer 1986, Megard 2000, Jassby et al. 2003). Water clarity is important not only for its aesthetic value to park visitors, but also for the amount of light penetrating into the lake which is a major factor regulating aquatic primary production.

Zooplankton are ubiquitous organisms found in the water column of lakes worldwide. They are a central link in lake food webs, transferring energy between primary producers and secondary consumers (e.g., fish and salamanders). Standardized methods exist for their rapid and accurate identification (e.g., Edmondson 1959, Stemberger 1979). Zooplankton species richness (total number of taxa), population structure, and abundance have been shown to be valuable indicators of lake ecosystem change due to environmental perturbations (e.g., Edmondson and Litt 1982, Arnott et al. 1998, Hampton 2005, Frost et al. 2006). Changes related to the body size of predominant zooplankton taxa in a lake also has the potential to distinguish between changes in water clarity associated with nutrient loading and changes associated with food web alterations (e.g., fish population structure) that affect grazing rates (Stemberger and Miller 2003).

2.4. Level of Change That Can Be Detected

Three primary types of analyses will be used to summarize response data collected by the NCCN Mountain Lakes Monitoring project: 1) estimates of status based on the fraction of lakes that have changed or meet/exceed a criterion, 2) abrupt change analyses applied to either a single site or group of sites (region) that determines if there is a significant change in the mean value of a response during the current year compared to the pattern of mean values from previous years, and 3) analyses designed to detect long-term steady changes within a lake or among multiple lakes within a region.

With the small sample size of 6 to 8 lakes at each park, interpretation of the question "how many of park's high elevation lakes are changing" is problematic. For example, with only six lakes sampled at NOCA, the 95% confidence interval for the fraction of lakes,when half of the lakes (three out of six) are affected, is 14% to 86%, which would not provide any relevant information on how widespread the problem is. At the Network scale, the 95% confidence interval for a total of 10 lakes affected out of 20 sampled would range from 28% to 72%, still not very informative, If the additional 30 lakes per park were sampled as proposed in Appendix J, then at total of 36 to 38 lakes at each park would be available for analyses of status. Estimation of the 95% confidence intervals for a proportion of 50% (affected lakes) out of 36 lakes in a park would be improved to 34% to 66% and for all parks combined the interval for the same fraction of lakes affected (55/110) would range from 40% to 60%. Confidence intervals would improve as the proportion of interest increases or decreases from 50%. A discussion on the sample size requirements for estimating a proportion at various levels of precision is available at the following USEPA website: http://www.epa.gov/nheerl/arm/designpages/monitdesign/sample_size.htm (accessed 27 March 2011). Details of analytical procedures for determination of status are described in SOP 21: Data Analysis and Reporting, Section D.

Levels of change and corresponding sample sizes are estimated for trends, but not for abrupt change analyses. Because abrupt change analyses and long-term trend analyses use generally similar methods (regression on time for site specific analyses and a mixed models approach for park and network-wide analyses), it is expected that sample size requirements will be relatively similar. Note that estimated sample sizes reported in this section do not apply to the non-parametric CUSUM alternative for analyzing abrupt changes. Details of analytical procedures for abrupt change and trend detection are described in SOP 21, Sections E and F).

The overall objective for trend analyses is to detect an average annual change of ≤3% with 80% probability and accepting a 10% probability of incorrectly asserting a trend. A 3% annual change

amounts to a proportional change of approximately 45% of the initial value in a 15-year period. Analyses designed to detect long-term steady changes within a lake or among lakes within a region will be applied to numerous response variables (*see* Appendix E, Table E-1). As such, this set of response variables represents a range of possible variability dependent on the particular parameter being evaluated. It is expected that some parameters will do better than the stated objective (above) while others will require more years of data collection before a trend can be realized.

A power analysis routine for estimating sample size to detect trends (for use with S+ software) was developed by Trent McDonald, West-Inc., Cheyenne, WY (Appendix D, Attachments 1 and 2). This analysis is only intended to give us an idea of sample sizes required for estimating trends, and actual sample size requirements will be evaluated in subsequent Five-year Summary Reports. The sample size (number of lakes) required to detect 2 to 4% annual trend with 80% power is based on testing the hypothesis H_0: $\beta_1 = 0$ versus the one-sided alternative H_1: $\beta_1 < 0$ in the linear regression $y_i = \beta_0 + \beta_1 x_i$, where y_i is the response value for any parameter of interest and x_i is the year. The response y_i is assumed to be normally distributed, and as such sample sizes (*n*) are the same when testing for H_1: $\beta_1 > 0$. Trend is detected if the null hypothesis of no trend is rejected in favor of H_1 (s*ee* Appendix D, Attachment 1 for description of methods.). Input parameters required to run the script include: 1) range of desired power; 2) range of *n* values, 3) within year variance of a response, 4) overall average response, 5) correlation between $year_i$ and $year_{i+1}$, and 6) the number of consecutive years sampled. Output is in the form of a graph showing required *n* corresponding to power on the y-axis and annual decline in average response on the x-axis.

Because of the large number of response variables in the monitoring project, results were summarized at different levels of variation, using coefficient of variation (CV = standard deviation/mean) values, rather than trying to apply separate assessments for each response variable. Mean CV values were calculated for 18 proposed response variables using historical data collected from MORA and NOCA lakes. Table 6 summarizes average CV values by response variable and provides the basis for evaluating sample size requirements for these variables. Detailed information concerning the CV analysis is presented in Appendix D, Table D-4.

To conduct the power analysis, the variance parameter of the power analysis routine was derived from the CV value for a mean response standardized at 1 (e.g., the variance parameter used in the power analysis for a CV of 0.2 and a mean of 1 = 0.04). The year-to-year correlation parameter in the power analysis was arbitrarily set at 0.5. Higher correlation values tend to increase required sample size and lower correlations reduce them. Examination of year-to-year correlation for six chemical parameters from 11 MORA lakes exhibited average *r* values ranging from -0.01 to 0.12. For responses that in reality have similar (low) year-to-year correlation, estimates of derived sample size will be conservative because we assumed an *r* of 0.5.

In Table 6, most of the parameters evaluated had CVs ≤ 0.20. Variability was greatest for chemical parameters that exhibit low concentrations, near detections limits, and for biological parameters such as chlorophyll-a concentration and zooplankton density. The data for these parameters were assumed to be normally distributed. However, if transformations apply it is expected that the CVs will improve.

Table 6. Potential variation (CV) for a subset of proposed NCCN lake monitoring response variables calculated from historical lake data collected at MORA and NOCA. (see Appendix D, Table D-4 for details).

	Coefficient of Variation (CV)				
Response Variables	**≤0.10**	**0.11 - 0.20**	**0.21 - 0.30**	**0.31 - 0.40**	**>0.40**
Water Temperature	X				
Secchi Depth	X				
Dissolved Oxygen		X			
Specific Conductance		X			
Acid Neutralizing Capacity		X			
pH	X				
Chlorophyll-a				X	
Total Nitrogen				X	
Total Phosphorus[1]					X
Ammonia[1]					X
Sodium	X				
Potassium		X			
Calcium	X				
Magnesium		X			
Sulfate			X		
Chloride			X		
Crustacean Zooplk (no./L)				X	
Crustacean Zooplk (no. of taxa)			X		

[1]Total phosphorus and ammonia data near detection limits. Actual CV could be much greater than 0.40.

Results of the power analysis are shown in Table 7. Interpretations of performance at an individual park are based on a sample size of six annually sampled lakes at MORA and NOCA, and eight lakes at OLYM. A sample size of 20 lakes applies to interpretations of performance at the network scale. Results of the power analysis indicate that with six lakes sampled every year, a 3% annual decline (or increase) in the average response could be detected in as little as five years (total change of 15%) for response variables with CVs ≤0.1, with an 80% probability of detecting a trend and a 10% probability of incorrectly asserting a trend. A total of 20 years or more would be required to detect a 3% average annual change (total change of ≥60%) for response variables with a CV >0.4. With a network-wide sample of 20 lakes, a 2% annual decline (or increase) could be detected in five years representing a total change of 10% for response variables with CVs ≤0.1, with an 80% probability of detecting a trend and a 10% probability of incorrectly asserting a trend. For network-wide trend analyses a 30% change in 15 years (2% average annual decline/increase) could be detected for response variables having a CV as high as 0.5.

Actual performance to detect trends vs. that estimated in Table 7 may vary for the following reasons:

1. Several methods were required to calculate CVs from historical lake datasets (*see* Appendix D, Table D-4) in order to approximate variation for the numerous response variables used in this evaluation. Methods used for many of the chemical parameters, temperature and zooplankton relied on data collected during the same temporal window, but from different

years (Methods 3 and 4, Appendix D, Table D-4), likely resulting in inflated variances for calculating CVs in Table 6, overestimating required sample size.

2. Application of simple linear regression provides only a conservative approach for estimating power to detect a trend if a trend is present (Larsen et al. 2004). Methods proposed for trend analysis in SOP 21: Data Analysis and Reporting are likely to exhibit greater trend estimation sensitivity as they are also capable of fitting curvilinear and polynomial trends in the regression.
3. Auxiliary covariates that are known to affect responses can be incorporated into the trend analyses procedures documented in SOP 21, improving precision by removing some of the coherent (year) variation (*see* Urquhart et al. 1998).
4. Year to year variations in weather patterns (e.g., precipitation and temperature) are not accounted for in the analysis and will be highly concordant among lakes resulting in underestimates of the number of years required in Table 7.

Table 7. Estimate of the number of lakes (sampled once each year) required by number of years sampled to detect a 2 to 4% annual decline (or increase) in the average response of monitoring parameters (one-sided test, 80% power, α = 0.10) exhibiting coefficient of variation (CV) values of 0.1 to 0.5. (Computational methods found in Appendix D, Attachments 1 and 2).

Variability[1] (CV)	Annual Decline (or increase) in Average Response	Required Sample Size by Number of Consecutive Years Sampled			
		5 yrs.	10 yrs.	15 yrs.	20 yrs.
0.1	2%	14	3	1	1
	3%	6	2	1	1
	4%	4	1	1	1
0.2	2%	56	10	4	2
	3%	24	5	2	1
	4%	13	3	1	1
0.3	2%	>60	21	8	3
	3%	42	10	4	2
	4%	30	5	2	1
0.4	2%	>100	40	13	8
	3%	95	18	6	4
	4%	53	10	4	2
0.5	2%	>100	60	20	10
	3%	>100	28	10	5
	4%	80	16	5	3

[1] Variance and covariance involves the within year variance of an individual object in the regression and the year to year correlation of observations measured on the same sampling units. Variance for individual objects was derived from a range of CV values expected for different lake parameters (a mean of 1.0 was used for converting the CV value to variance). Year to year correlation of observations on the same sampling unit was set at 0.5. Higher correlation values tend to increase sample size requirements and lower correlations reduce them.

3. Field Methods

3.1. Field Season Preparations, Equipment Set-up and Compliance

Tasks and responsibilities for field season preparation are described in detail in SOP 1: Field Season Preparations and Crew Training, and Appendix B: Yearly Task List. Pre-season data management preparation is discussed in SOP 2: Project Workspace and Records Management. Generally, field season preparation tasks include the following:

- Administrative procedures including preparation of budget and seasonal hiring.
- List of needs including equipment and supplies, and GIS/Data management tasks.
- Discussing protocol revision needs and revising as necessary (SOP 25: Revising the protocol).
- Meeting park compliance needs.
- Acquiring site specific aerial photos and maps, historical inventory and monitoring data, and sampling data from previous site visits.
- Various data management activities described in SOP 2.
- Training (SOP 1) including GPS navigation and mapping, use of equipment, field and laboratory methods, quality assurance and quality control procedures, amphibian and fish species identification, and safety.

Environmental and Wilderness compliance mandates have been completed for the Mountain Lakes protocol at all three NCCN parks (MORA, NOCA, OLYM). Any new or significantly revised protocols may require additional compliance procedures. Annual flight operation plans are also required for NOCA helicopter use.

3.2. Sequence of Events during the Field Season

A field season generally consists of up to six (eight at OLYM), sampling tours conducted during August through September (scheduling of site visits is discussed in Section 2.3). A typical field tour includes pre-tour preparation, site access, data collection, post-tour debriefing, sample processing and data management, and equipment maintenance.

Field Tour Preparation: The following steps are taken immediately preceding each field tour:

1. Necessary contacts are made (e.g., backcountry permits, park communications center, heli-spot manager, flight confirmation with contractor, etc.).
2. Waterproof copies of SOPs, field forms (in Appendix C: Field and Laboratory Data Forms), equipment manuals, maps and aerial photos are prepared.
3. Equipment lists are double checked as all gear is packed. Equipment needs for each field protocol are listed in each of the SOPs. When helicopters are used for site access at NOCA, all bags must be individually weighed and labeled.
4. Perform required pre-tour instrument calibrations (Datasonde pH and specific conductivity).
5. Water and air temperature loggers are set for delayed starts (SOP 8: Continuous Water Temperature Monitoring).

Site Access and Data Collection: All lakes in the NCCN park sample frames are accessible by foot, and this is the default method for site access. However, at NOCA access may be facilitated by the use of helicopters. Wilderness restrictions at OLYM currently prohibit the use of annual

recurring helicopter flights for this project, and most lakes at MORA are easily accessible due to its well developed road and trail system. Crew sizes and field tour lengths primarily depend on the method of access. At NOCA, fewer people are needed (two to three crewmembers) because sampling gear is brought in by a helicopter, and a lake can be sampled in less than two days. Because lakes at MORA and OLYM are accessed by hiking, additional crewmembers and time are needed to access the sites. The number of crewmembers varies from four to five and field tours usually require a total of two to four days depending on the distance and difficulty of travel to the site. Once at the site, field data collection usually takes from one to one and a half days depending on the time of arrival to the site (before or after mandatory time frames for collection of water chemistry data, chlorophyll a, depth profiles, and Secchi depth), the size of the lake, and if bathymetry data is to be collected. A general description of sample elements, location, timing and replication is found in Section 2.3. Field data collection procedures are described in detail in SOPs 3-18. Each SOP includes details on general procedures, sample timing, sample location, equipment operations and calibration, data recording requirements and specific quality control concerns. Prior to leaving a field site all data forms are reviewed for completion and all samples are checked for proper labeling.

Post Tour Tasks: The following steps are completed following return from the field:

1. All samples are immediately inventoried and are refrigerated or frozen as required by the SOPs.
2. Data forms are reviewed for errors and completeness. Quality control concerns are documented and data forms are filed. If time permits between successive tours, data are entered into the working copy of the database (SOP 20: Data Entry and Verification).
3. Digital photos, GPS data, and continuous water temperature data are downloaded and processed (SOP 3: GPS Data Collection, SOP 8: Continuous Water Temperature Monitoring, and SOP 18: Acquiring and Managing Photographic Images).
4. Equipment is unpacked, dried and cleaned. Required maintenance is performed.
5. Acid neutralizing capacity (ANC) is measured within 7 days from collection of the sample (SOP 9: General Water Chemistry).
6. Decontamination of sampling equipment and waders (SOP 16: Decontamination of Equipment) is required following each sample site visit.

3.3. Post Field Season Activities

Post field season activities are discussed in SOP 17 and include data review and management, sample processing and shipping, equipment inventory and maintenance, field season debriefing and follow up on quality assurance/control.

3.3.1 Data Review and Management

All field data are reviewed as soon as possible after the field season by Field and Project Leads. All quality control/assurance issues related to field data collection are documented (*see* SOP 19: Quality Assurance and Control Plan). Digital photos taken during the field season should be downloaded and labeled as soon as possible when returning from the field. They should be reviewed by each participating crew member again at the end of the season to ensure that they were labeled properly.

Continuous water temperature data recorded from before and after deployment needs to be identified and deleted. Temperature logger post deployment calibration is performed and the

results of the pre and post deployment calibration are evaluated verifying the accuracy of the temperature loggers. Any need for calibration adjustment should be applied to the collected data set (SOP 8).

3.3.2 Sample Processing and Shipping

Water chemistry, chlorophyll-a, and zooplankton samples are all delivered to contractors either as the field season progresses or immediately after the field season ends. Prior to shipment samples are logged on appropriate shipping forms (Appendix C) and all sample labels are checked for completeness. Benthic macroinvertebrate samples are sorted (SOP 11: Benthic Macroinvertebrate Collection and Processing) before they are shipped to the contractor for enumeration and identification. Benthic macroinvertebrate samples are logged in after each field tour and following sample processing (Appendix C). Documentation of sample transfer and chain-of-custody are described in SOP 23: Documenting Sample Transfer.

3.3.3 Equipment Inventory, Maintenance and Storage

Following the field season all equipment should be cleaned, repaired if necessary, and stowed in a safe orderly manner. The YSI 600XLM datasonde (and other laboratory instruments) operation manual recommendations for maintenance and probe cleaning are followed and documented. Batteries should be removed (refer to original manuals for details). An inventory of all equipment and supplies should be completed following the field season and repeated prior to the start of the next season. Lists of equipment and supplies are found at the end of each Field SOP (SOPs 3-15). Any items requiring repair or replacement should be documented. All chemicals should be stored in proper containers in their proper storage cabinet. The chemical inventory log should be updated and expiration dates of chemicals should be noted. Any chemical waste should be disposed of according to Material Safety Data Sheets (MSDS) recommendations, and local waste disposal authority requirements.

3.3.4 Field Season Debriefing and Quality Control Review

At the end of the season field crews, Project Leads, Data Manager and GIS Specialist should meet and discuss any problems that occurred during the field season. Changes that may be relevant for future monitoring are documented and considered in the process of revising the protocol according to SOP 25.

QA/QC review and compliance occurs at various stages during the year. Immediately following the field season these procedures are reviewed to evaluate problems and compliance related to data collection and sample processing. QA/QC procedures and objectives are found in SOP 19: Quality Assurance and Control Plan, and in field sampling and data management SOPs (SOPs 2-15, and 18-20). Results of this review are documented in the database and included in annual and five-year summary reporting.

4. Data Management, Analysis, and Reporting

This chapter describes the procedures for data management, analysis, and report development. Additional details and context for this chapter are provided in the NCCN Data Management Plan (Boetsch et al. 2009), which describes the overall information management strategy for the network. The NCCN website (http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm) also contains guidance documents on various information management topics (e.g., report development, GIS development, GPS use).

4.1. Project Information Management Overview

Project information management may be best understood as an ongoing or cyclic process, as shown in Figure 6. Specific yearly information management tasks for this project and their timing are described in Appendix B: Yearly Project Task List**.** Readers may also refer to each respective chapter section below for additional guidance and instructions.

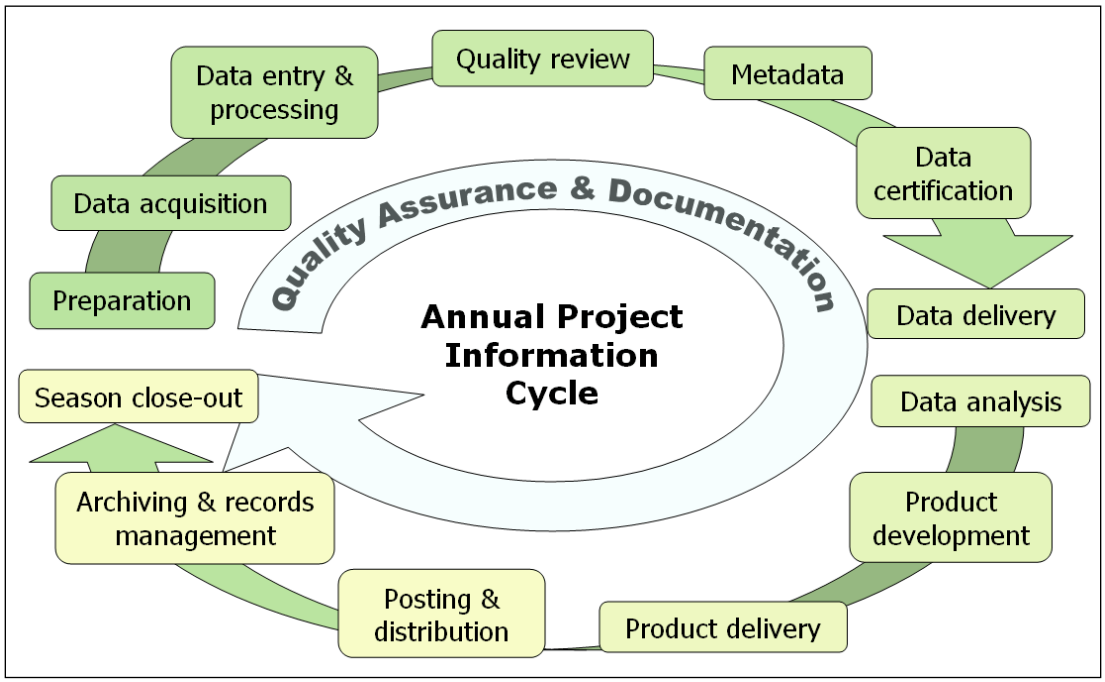


Figure 6. Idealized flow diagram of the cyclical stages of project information management, from pre-season preparation to season close-out. Note that quality assurance and documentation are thematic and not limited to any particular stage.

The stages of this cycle are described in greater depth in later sections of this chapter, but can be briefly summarized as follows:

- *Preparation* – Training, logistics planning, print forms and maps.
- *Data acquisition* – Field trips to acquire data.
- *Data entry & processing* – Data entry and database uploads, GPS data processing, etc.
- *Quality review* – Data are reviewed for structural integrity, completeness and logical consistency.
- *Metadata* – Documentation of the year's data collection and results of the quality review.

- *Data certification* – Data are certified as complete for the period of record.
- *Data delivery* – Certified data and metadata are delivered for archiving.
- *Data analysis* – Data are summarized and analyzed.
- *Product development* – Reports, maps, and other products are developed.
- *Product delivery* – Deliver reports and other products for posting and archiving.
- *Posting & distribution* – Distribute products as planned and/or post to NPS clearinghouses.
- *Archiving & records management* – Review analog and digital files for retention (or destruction) according to NPS Director's Order 19. Retained files are renamed and stored as needed.
- *Season close-out* – Review and document needed improvements to project procedures or infrastructure, complete administrative reports, and develop work plans for the coming season.

4.2. Pre-season Preparations for Information Management

4.2.1. Set Up Project Workspace

A section of a networked file server is reserved for this project, and access privileges are established so that project staff members have access to needed files within this workspace. Prior to each season, the Project Lead should make sure that network accounts are established for each new staff member, and that the Data Manager is notified to ensure access to the project workspace and databases. Additional details are provided in SOP 2: Project Workspace and Records Management.

4.2.2. GPS Loading and Preparation

The GIS Specialist and Project Lead should work together to ensure that target coordinates, background imagery and data, and data dictionaries are loaded into the GPS units prior to the onset of field work, and that GPS download software is available and ready for use. Additional details on GPS use and GPS data handling are provided in SOP 3: GPS Data Collection and in NCCN GPS Guidelines (NCCN 2009).

4.2.3. Project Database Application

Prior to the field season, the Data Manager will update the project database application as needed to ensure proper access on the part of project staff. Refer to Section 4.3 for additional information about the database design and implementation strategy.

4.3. Overview of Database Design

The NPS Water Resource Division (WRD) requires that all I&M water quality monitoring data be compatible with, and uploaded annually to, the EPA's STORET database. To facilitate this, the WRD maintains a Microsoft Access database tool, NPSTORET, which duplicates most of the data and table structures in EPA STORET. NPSTORET will be used to enter and store all NCCN water quality data; data will be entered, reviewed, certified, and sent to WRD on an annual basis for upload into EPA STORET. The NPSTORET application also has built-in tools for data summarization and output that will be used when generating summary reports.

Additional information on vital signs water quality data management and archiving, as well as a copy of NPSTORET, can be obtained at:
http://www.nature.nps.gov/water/infoanddata/index.htm.

We also maintain a customized relational database application to store and manipulate all other data associated with this project that are not currently accommodated by NPSTORET (e.g., continuous temperature data, bathymetric data, macroinvertebrate data, etc.). The design of this database is consistent with NPS I&M and NCCN standards. The Data Manager is responsible for development and maintenance of the database, including customization of data summarization and export routines.

The project database is divided into two components – one for storing data in a series of related tables composed of fields and records (i.e., the "back-end database"), and another that acts as a portal or user interface through which data may be entered, viewed, edited, error-checked, summarized and exported (i.e., the "front-end application"). By splitting the database into front- and back-end components, multiple users may interact with the data simultaneously, and user interface updates can be implemented without service disruptions.

The back-end database schema (tables, fields and relationships) is documented in Appendix H: Database Documentation. The back-end database is implemented in Microsoft SQL Server to take advantage of the automated backup and transaction logging capabilities of this enterprise database software.

The front-end is implemented in Microsoft Access. It contains the forms, queries, and formatted report objects for interacting with the data in the back-end. Its features and functionality are customized using Visual Basic for Applications (VBA) programming code. The application has separate forms for data entry that mirror the layout of hard-copy field forms used during data collection. There are also forms for browsing and editing data, for completing the annual quality review, and for summarizing and exporting data to other software (e.g., for analysis and graphics production).

4.4. Data Entry and Processing

During the field season, the project crew will be provided with a copy of the project database front-end, through which they enter, process, and quality-check data for the current season (refer to the next section and SOP 20: Data Entry and Verification).

After each field trip, technicians should enter data in order to keep current with data entry tasks, and to identify any errors or problems as close to the time of data collection as possible. The front-end database application is found in the project workspace. For enhanced performance, it is recommended that users copy the front-end onto their workstation hard drives and open it there. This front-end copy may be considered "disposable" because it does not contain any data, but rather acts as a pointer to the data that reside in the back-end database. Whenever updates to the front-end application are made available by the Data Manager, an updated front-end should be copied from the project workspace to the workstation hard drive.

The functional components of the front-end application are described in SOP 20: Data Entry and Verification. Each data entry form has built-in quality assurance components such as pick lists

and validation rules to test for missing data, outliers, or illogical combinations. Users are strongly encouraged only to use these pre-built forms as a way of ensuring maximum data quality.

4.4.1. Regular Data Backups

For water quality data, NPSTORET can create a .zip format backup file every time a user closes the application once this option is set from the 'set defaults' utility. This file includes a copy of the backend, including any associated images and documents, and is placed in the 'backups' subfolder of the NPSTORET application.

For other project data, automatic database backups are scheduled in the SQL Server database management system to help prevent data loss in case of user error, drive failure, or database file corruption. Full backups are scheduled on a weekly basis, with daily transactional backups to enable restore operations to a point in time within a moving eight-week window. Weekly backups and transaction files are retained for eight weeks to conserve drive space. Full monthly backups are stored for at least one year after data have been certified. Snapshot backup copies of certified data, made at the time of certification, are retained indefinitely.

4.4.2. Data Verification

As data are being entered, the person doing the data entry should visually review them to make sure that the data on screen match the field forms. This should be done for each record prior to moving to the next form for data entry. At regular intervals and at the end of the field season the Field Lead will inspect the data being entered to check for completeness and perhaps catch avoidable errors. The Field Lead will periodically use the report function in NPSTORET that supports reporting on portions (e.g., 10%) of randomly selected records within a set of data. This step is described in greater detail in Section 4.5 and also in SOP 22: Data Quality Review and Certification.

4.4.3. Field Form Handling Procedures

As field data forms are part of the permanent record for project data, they should be handled in a way that preserves their future interpretability and information content (refer to SOP 2: Project Workspace and Records Management). If changes to data on the forms need to be made subsequent to data collection, the original values should not be erased or otherwise rendered illegible. Instead, changes should be made as follows:

- Draw a horizontal line through the original value, and write the new value adjacent to the original value with the date and initials of the person making the change.
- All corrections should be accompanied by a written explanation in the appropriate notes section on the field form. These notes should also be dated and initialed.
- If possible, edits and revisions should be made in a different color ink to make it easier for subsequent viewers to be able to retrace the edit history.
- Edits should be made on the original field forms and on any photocopied forms.

These procedures should be followed throughout data entry and data revision. At the end of each field season, the data sheets should be scanned as PDF documents and archived (refer to SOP 2: Project Workspace and Records Management). The PDF files may then serve as a convenient digital reference of the original if needed.

4.4.4. Image Handling Procedures

Digital images acquired during the course of conducting project-related activities will be managed and stored in the project workspace along with other project data. Images that are acquired by other means – e.g., downloaded from a website or those taken by a cooperating researcher – are not project records and should be filed and named in such a way that they will not be confused with project records.

Care should be taken to distinguish data photographs from incidental or opportunistic photographs taken by project staff. Data photographs are those taken for at least one of the following reasons:

- To document a particular feature or perspective for the purpose of site relocation.
- To capture site characteristics and possibly to document gross structural changes over time.
- To document a species detection that is also recorded in the data.

Specific required data images are listed in SOP 18: Acquiring and Managing Photographic Images. Data photographs are often linked to specific records within the database, and are stored in a manner that permits the preservation of those database links. Other photographs – e.g., of field crew members at work, or photographs showing the morphology or phenology of certain plant species – may also be retained but are not necessarily linked with database records.

4.4.5. GPS Data Procedures

The following general procedures should be followed for GPS data (*see* SOP 3: GPS Data Collection):

- GPS data will be downloaded by the GIS Specialist from the GPS units at the end of each field trip and stored in the project workspace as described in SOP 2.
- The GIS Specialist will process the raw GPS data and store the processed data in the project workspace.
- The GIS Specialist will upload corrected coordinate information into the database and create or update any project GIS data sets as needed.

The Field Lead will periodically review the processed GPS data to make sure that any errors or inconsistencies are identified early.

4.5. Data Quality Review

After the data have been entered and processed they need to be reviewed by the Project Lead for structural integrity, completeness and logical consistency. The front-end application facilitates this process by showing the results of pre-built queries that check for data integrity, data outliers, missing values, and illogical values. The user may then fix these problems and document the fixes. Not all errors and inconsistencies can be fixed, in which case a description of the resulting errors and why edits were not made is then documented and included in the metadata and certification report (see Sections 4.6 and 4.7, and SOP 22: Data Quality Review and Certification).

The Project Lead and GIS Specialist may work together to review the surveyed coordinates and other geospatial data for accuracy. The purpose of this joint review is to make sure that geospatial data are complete and reasonably accurate, and also to determine which coordinates will be used for subsequent mapping and field work.

4.5.1 Data Edits After Certification

Due to the high volume of data changes and/or corrections during data entry, it is not efficient to log all changes until after data are reviewed and certified. Prior to certification, daily backups of the database provide a crude means of restoring data to the previous day's state. After certification, all edits to certified records are tracked in an edit log (refer to Appendix H.) so that future data users will be aware of changes made after certification. In case future users need to restore data to the certified version, we also retain a separate, read-only copy of the original, certified data for each year in the project workspace.

4.5.2 Geospatial Data

The Project Lead and GIS Specialist will work together to review the surveyed coordinates and other geospatial data for accuracy. The purpose of this joint review is to make sure that geospatial data are complete and reasonably accurate, and also to determine which coordinates will be used for subsequent mapping and field work.

4.6. Metadata Procedures

Data documentation is a critical step toward ensuring that data sets are usable for their intended purposes well into the future. This involves the development of metadata, which can be defined as structured information about the content, quality, condition, and other characteristics of a given data set. Additionally, metadata provide the means to catalog and search among data sets, thus making them available to a broad range of potential data users. Metadata for all NCCN monitoring data will conform to Federal Geographic Data Committee (FGDC) guidelines and will contain all components of supporting information such that the data may be confidently manipulated, analyzed, and synthesized.

NPSTORET requires complete documentation of monitoring protocol procedures. Before any results can be entered into the system, NPSTORET must be populated with metadata documenting: the field sampling/measurement procedures; gear configurations; sample preservation, transport and handling; field/laboratory analytical procedures; laboratory sample preparation; complete detail about the characteristics measured; laboratory information; staff and their roles; and any literature citations pertinent to the monitoring effort. Such internal metadata only needs to be entered once before entering results.

At the conclusion of the field season according to the schedule in Appendix B, the Project Lead will be responsible for providing a completed, up-to-date metadata interview form to the Data Manager. The Data Manager and GIS Specialist will facilitate metadata development by consulting on the use of the metadata interview form, by creating and parsing metadata records from the information in the interview form, and by posting such records to national clearinghouses.

An up-to-date metadata record is a required deliverable that should accompany each season's certified data. For long-term projects such as this one, metadata creation is most time consuming

the first time it is developed – after which most information remains static from one year to the next. Metadata records in subsequent years then only need to be updated to reflect changes in contact information and taxonomic conventions, to include recent publications, to update data disposition and quality descriptions, and to describe any changes in collection methods, analysis approaches or quality assurance for the project.

Specific procedures for creating, parsing and posting the metadata record are provided in NCCN Metadata Development Guidelines (NCCN 2007). General procedures are as follows:

1. After the annual data quality review has been performed and the data are ready for certification, the Project Lead (or a designee) updates the metadata interview form.
    a. The metadata interview form greatly facilitates metadata creation by structuring the required information into a logical arrangement of 15 primary questions, many with additional sub-questions.
    b. The first year, a new copy of the NCCN Metadata Interview form (available at: http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm) should be downloaded. Otherwise the form from the previous year can be used as a starting point, in which case the Track Changes tool in Microsoft Word should be activated in order to make edits obvious to the person who will be updating the XML record.
    c. Complete the metadata interview form and maintain it in the project workspace. Much of the interview form can be filled out by cutting and pasting material from other documents (e.g., reports, protocol narrative sections, and SOPs).
    d. The Data Manager can help answer questions about the metadata interview form.
2. Deliver the completed interview form to the Data Manager according to the product delivery instructions in SOP 23 Product Delivery, Posting and Distribution.
3. The Data Manager (or GIS Specialist for spatial data) will then extract the information from the interview form and use it to create and update an FGDC- and NPS-compliant metadata record in XML format. Specific guidance for creating the XML record is contained in NCCN Metadata Development Guidelines (NCCN 2007).
4. The Data Manager will post the XML record and certified data to the NPS Data Store and maintain a local copy of the XML file for subsequent updates. The Data Manager will also coordinate submission of the NPSTORET data file to NPS WRD.
5. The Project Lead should update the metadata interview content as changes to the protocol are made, and each year as additional data are accumulated.

4.6.1 Identifying Sensitive Information

Part of metadata development includes determining whether or not the data include any sensitive information, which is partly defined as the specific locations of rare, threatened or endangered species. Prior to completing the metadata interview form, the Project Lead and Data Manager should work together to identify any sensitive information in the data after first consulting Sensitive Information Procedures found at the website below. Their findings may be documented and communicated through the metadata interview form. Refer to Section 4.10 for more information on identifying and handling sensitive information.

4.7. Data Certification and Delivery

Data certification is a benchmark in the project information management process that indicates that: 1) the data are complete for the period of record (i.e. the annual field season), 2) they have undergone and passed the quality assurance checks (Section 4.5), and 3) they are appropriately documented and in a condition for archiving, posting and distribution as appropriate. Certification is not intended to imply that the data are completely free of errors or inconsistencies that may or may not have been detected during quality assurance reviews.

To ensure that only quality data are included in reports and other project deliverables, the data certification step is an annual requirement for all tabular and spatial data. The Project Lead is the primary person responsible for completing an NCCN Project Data Certification Form, available at: http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm. This brief form should be submitted with the certified data according to the annual task list timeline in Appendix B. Refer to SOP 22: Data Quality Review and Certification, and SOP 23: Product Delivery, Posting and Distribution for specific instructions.

4.8. Data Analysis

Data analysis is the act of transforming data with the aim of extracting useful information and facilitating conclusions regarding the project's objectives. It is facilitated by the examination of statistical relationships of the data (response variables) that meet the requirements and assumptions of the statistical procedures used in the analyses. It is assumed that estimates based on the data analyses will be made with known confidence. Throughout, it is assumed that the Mountain Lakes Monitoring project measures biological, physical, and chemical parameters at a sample of lakes that are selected with equal probability from all lakes in the sampled portion of the target population of a park.

Given this monitoring design and the types of data collected, primary analyses need to be conducted to estimate the current value of a parameter, to estimate status (condition of the resource), to detect abrupt changes in a parameter, and to detect long-term steady trends that are indicative of the condition of the aquatic resources and habitats found in NCCN mountain lakes.

The following sections summarize guidance and procedures documented in SOP 21: Data Analysis and Reporting. Additional guidance concerning quality control and quality assurance are found in SOP 19: Quality Assurance and Control Plan.

4.8.1. Preliminary Data Review and Preparation

Preliminary data review and data preparation includes data quality review procedures discussed in Section 4.5 and in SOP 21, Section I.B, Exploratory Data Analyses. Exploratory data analysis applies basic analyses and statistical tests to: 1) identify whether the data support underlying assumptions of potential statistical tests, 2) examine relationships between dependent variables and potential explanatory attributes or ancillary variables (see discussion regarding trends in Section IV.E and F of SOP 21), 3) classify sites into homogeneous subsets based on similarities in biological and/or environmental characteristics, and 4) determine if modifications are necessary prior to further statistical analysis. Modification of data prior to analysis includes treatment of outliers, data below detection limits (censored data), missing data, and transformation of data to meet test assumptions. Ideally, potential statistical tests and their assumptions will be identified prior to the exploratory analysis step, as they must also be

considered prior to making judgments concerning handling of outliers, missing data, censored data, and the application of data transformations. Numerous basic statistical quantities and graphical procedures used in exploratory data analyses are given in SOP 21, Section I.B.

4.8.2. Routine Data Summaries

Multiple field measures representing physical, chemical, and biological characteristics are collected from each lake. Routine data summaries of field measures are required to produce a single summarizing value called the "response variable" which is then applied in exploratory and final data analyses. An overview of monitoring components, measures, response variables, data summaries, reporting periods, and spatial scale inference are shown in Appendix E, Table E-1.

Some responses may only represent a single measurement from a single lake location (e.g., concentrations of unreplicated chemical parameters, maximum depth) or a single value from a collection of sub-samples taken from several locations and pooled into one sample (e.g., macroinvertebrate metrics, frequency of landcover types and riparian disturbances). Other responses are derived from multiple measurements at one or more locations (e.g., continuous water temperature parameters, lake water level, littoral zone substrate). In addition, some types of data are processed into indices representing the condition of the habitat (e.g., SOP 21, Section II.E Trophic State Indicators, Water Clarity and Chlorophyll-a).

Most response variables are reported as a value for a single-season sampling occasion. Some physical parameters such as mean depth, surface area, and shoreline development ratio will always be sampled at longer time intervals. Continuous water temperature data are collected daily throughout the year and reported by week, month, season and/or year. Descriptions of data summary methods for all response variables are given in SOP 21, Section II.A-H.

For responses that produce one number per site, (such as unreplicated chemistry parameters and zooplankton samples), the current estimate of status is the observed number. In some cases, it may be possible to compute a standard error and confidence interval for this number based on a model or past data but in general, variation of these responses will be assessed through time. Replicate sampling at some sites during each sampling season will allow for a general estimate of measurement precision, sensitivity, and bias (methods given in SOP 19: Quality Assurance and Control Plan).

4.8.3. Criteria Development

A primary goal of the Mountain Lakes Monitoring project is to monitor the condition of lakes in NCCN parks to protect against degradation. Well defined criteria, based on characteristics of lakes in the target population and/or other established criteria, provide a standard for assessments of degradation at individual sites, as well as multiple sites combined to provide park-wide and network-wide assessments of status.

Criteria can be represented as: 1) an average value of a response for a single site or for a group of sites with similar environmental characteristics, 2) an index of condition that partitions responses among categories of impairment such as the benthic macroinvertebrate Index of Biological Integrity (B-IBI), Observed/Expected ratios (O/E), and Carlson Trophic Indices, 3) criteria for assessment of site-specific impairment can also be expressed as a statistically significant change

of a certain amount over natural background levels at the site, or 4) a change of some magnitude outside the range of values representing natural conditions for multiple sites.

Park- and region-wide assessments of condition are generally reported as the number or frequency of sites that are either 'greater than' or 'less than' an ecologically relevant threshold value (e.g., how many lakes have pH values <6.0, or what percent of the park lakes have shoreline disturbance scores ≥3, indicating moderate and severe disturbance). Applications of criteria at a single site are similar but generally relate to a single sampling event (or the frequency of multiple sampling events) that either does or does not meet a criterion (e.g., how many times in a 10-year period is the pH at Lake A <6.0, or how many times is Lake A classified as impaired in a 10-year period based on the macroinvertebrate O/E predictive model, or is there an increase of >0.3^{o}C in the 7-day average daily maximum temperature between different years).

It must be noted that at the network level, the overall precision of status estimates based on the proportion of sites in the target population meeting or exceeding a criterion may be less than desired with the current sample size of 20 lakes in the network, and it is expected that park-wide status estimates will be even less precise with a sample of only six to eight lakes at each park (sample size calculations for estimates of proportions are discussed in Narrative Section 2.4). The precision of status estimates can be improved as funding opportunities become available to to sample additional target population lakes in the three parks as described in the expanded sampling proposal in Appendix J. With this approach, network-wide status reporting could be accomplished at ten-year intervals, given the timing and availability of additional funding. Currently, the Skagit Environmental Endowment Commission (SEEC) has provided funding to sample a total of 15 target population lakes over a five-year period (2009-2013) at NOCA. More information regarding status estimates is presented in SOP 21: Data Analysis and Reporting, Section D.

The NCCN Mountain Lakes Monitoring Project will follow an adaptive approach for developing and refining criteria using empirical monitoring data collected through time, data collected from other short-term projects, historical data, and existing criteria following State, Federal, or other agency recommendations (see examples in Appendix E, Table E-7) that apply to the same region and type of lakes being sampled.

4.8.4. Data Analysis Procedures

There are four basic groups of proposed analyses. One set of analyses are designed to determine status by estimation of a value for a parameter at a particular point in time. Examples of this type of analysis include estimating the current average acid neutralizing capacity (ANC) for a single lake sampled multiple times or for all lakes in a particular group of lakes. Another example would estimate the proportion of lakes (e.g., park-wide or network-wide) with an ANC value <*x* µg/L. Another set of analyses are designed to detect abrupt changes in a parameter. An example analysis of this type is detection of an atypical increase in average water temperature at a particular site. The third group of analyses is designed to detect long-term steady changes. Examples of this type include detecting a decrease in lake water level for an individual lake or for all lakes in a park, or estimating the average annual change in zooplankton density in a specific lake or for all lakes in a park. The final group of analyses is for detection of step trends, which compares two sets of data for a response variable from non-overlapping time periods at a

site. An example of a step trend analysis would be comparing a time series of data for a change in zooplankton density before and after the introduction of a non-native fish species.

These groups of analyses can be further divided into three different inference scenarios. The first inference scenario utilizes data from a single site (i.e., lake) and makes inference to that site. The second inference scenario assumes data from multiple sites within a park will be pooled to make inference about a parameter for all lakes in the sample frame for that park or, in the case for OLYM, on a single stratum (e.g., lakes in the High, Moderate or Low annual precipitation strata). These inferences will be called park-wide. An example of park-wide inference could address the question "Is the average concentration of total nitrogen increasing through time in lakes in a park?" The third inference scenario pools data from the three parks of NCCN and makes inference to all lakes in the union of each park's sampled target population. These inferences will be called network-wide, and the union of target populations will be called the network population. For example, researchers may wish to detect and quantify average annual changes in water level of lakes in the network's population of mountain lakes.

The general statistical procedures proposed to accomplish each type of analysis under all three inference scenarios are listed in Table 8. Several methods are proposed for each inference scenario to provide alternatives when specific test assumptions cannot be met, or corrected when not met. Detailed descriptions of these procedures are provided in SOP 21, Section IV. D-G and summarized in Table 21.5 of SOP 21. Many of the procedures making inference to a specific site are time series analyses because some of the responses analyzed have only a single measurement value per lake each year and repeated measurements through time are required to assess variation. That is, some responses are unreplicated within a site, while other responses are measured at multiple locations within a lake. An example of a replicated response is shoreline disturbance, which is measured at multiple systematically placed shoreline plot locations. Variation of shoreline disturbance across plots may, in some cases, be used in an analysis to judge the degree of variation in disturbance across the entire site. Most park-wide and network-wide inferences, on the other hand, utilize or incorporate site-to-site variation to quantify inferences. For example, the CUSUM function (*see* SOP 21, Section IV.E.4) utilizes variation through time at a site as well as variation across sites to determine whether the underlying system's mean has shifted recently.

Table 8. Summary of analysis procedures to detect status, abrupt change, and steady change under three inference scenarios.

Analysis Type or Goal	Inference Scenario		
	Site-specific	**Park-wide**	**Network-wide**
Status Estimation	Mean, Median, and Confidence Interval. One-sample Hypothesis Tests (t-Test, Wilcoxon Signed Rank Test, Sign Test). Histograms, Box Plots, Cumulative Distribution Functions (CDF)	Mean, Median, and Confidence Interval. One-sample Hypothesis Tests (t-Test, Wilcoxon Signed Rank Test, Sign Test). Histograms, Box Plots, Cumulative Distribution Functions (CDF)	Mean, Median, and Confidence Interval. One-sample Hypothesis Tests (t-Test, Wilcoxon Signed Rank Test, Sign Test). Histograms, Box Plots, Cumulative Distribution Functions (CDF)
Abrupt Change Detection	Prediction Intervals. Linear Regression on Time. Mixed Linear Model (for continuous temperature)	Mixed linear model; CUSUM procedure	Mixed linear model; CUSUM procedure
Steady Trend Detection	Mixed or Fixed Effect Linear Regression on Time. Mann-Kendall and Seasonal Kendall Tests with slope estimators.	Mixed Linear Model. Regional Kendall and Regional Seasonal Kendall Tests with slope estimators	Mixed Linear Model. Regional Kendall and Regional Seasonal Kendall Tests with slope estimators
Step Trend Detection	Two-sample t-Test. Mann-Whitney Wilcoxon Rank Sum Test and the associated Hodges-Lehmann estimator of trend magnitude	None Proposed	None Proposed

Statistical software and routines for running the analyses given in Table 8 are described in SOP 21, Section IV.C.

4.9. Reporting and Product Development

4.9.1. Report Content and Format

The reporting schedule includes production of annual reports and Five-year Summary Reports. Annual reports will be issued every year after field data collection and sample processing are completed. Annual reports will contain background information (including personnel, locations and dates of sampling, methods), routine statistics and graphical representations of the data (for individual sites, parks and network), documentation of QA/QC results and concerns, and changes or revisions to SOPs. A detailed list of the proposed contents of Annual Reports is given in SOP 21, Section 5.A.

The Five-year Summary Reports will be completed in the year following each cycle. These reports will contain summaries of information presented in annual reports, results of detailed exploratory analysis documenting selection of statistical tests, analyses designed to detect park-wide and network-wide status, abrupt change, and trends, summary evaluation of QA/QC compliance results (measurement precision, sensitivity, systematic error/bias, cumulative bias, and completeness, etc.; *see* SOP 19), and re-examination of sample size and the utility of all response variables. In addition, the Five-year Summary Reports will include the development of

park-specific reference conditions and identification of criteria or thresholds for assessments of site-specific and park-wide condition (SOP 21, Section III). Criteria and thresholds will be evaluated and revised, if necessary, in following Summary Reports. A detailed list of the proposed contents of Five-year Summary Reports is given in SOP 21, Section 5.B. Information reported in the Five-year Summary Reports will be used to develop interpretative products for distribution to the public and upper level managers at Park, Network, and National levels.

4.9.2. Standard Report Format

Annual reports and Five-year reports will be published in the NPS Natural Resource Publications series, using pre-formatted Microsoft Word template documents based on current NPS formatting standards. Annual reports will use the Natural Resource Technical Report (NRTR) template, and trend analysis and other peer-reviewed technical reports will use the Natural Resource Report (NRR) template. These templates and documentation of the NPS publication standards are available at: http://www.nature.nps.gov/publications/NRPM/index.cfm. Examples of statistical data summaries and figures that may be included in the reports are found throughout SOP 21.

4.10. Identifying and Handling Sensitive Information

Note: We do not currently anticipate that this monitoring project will collect, manage or report on information related to protected resources. As a result, there are no plans to implement coordinate offsets or data redaction at this time. However, project data will be evaluated on an annual basis in case information on protected resources is included. If so, data will be handled in keeping with network standards (Boetsch et al. 2009), and an SOP will be developed with handling procedures specific to this protocol.

Certain information related to the specific locations of rare or threatened taxa may meet criteria for protection and as such should not be shared outside NPS except where a written confidentiality agreement is in place prior to sharing (for example, the location of a bald eagle nest noted during a helicopter flight would be sensitive information). Before preparing data in any format for sharing outside NPS – including presentations, reports, and publications – the Project Lead should consider whether or not the resulting information might put protected resources at risk. Information that may convey specific locations of sensitive resources may need to be screened or redacted from public versions of products prior to release.

Although it is the general NPS policy to share information widely, the NPS also realizes that providing information about the location of park resources may sometimes place those resources at risk of harm, theft, or destruction. This can occur, for example, with regard to caves, archeological sites, tribal information, and rare plant and animal species. Therefore, information will be withheld when the NPS foresees that disclosure would be harmful to an interest protected by an exemption under the Freedom of Information Act (FOIA). The National Parks Omnibus Management Act, Section 207, 16 U.S.C. 5937, is interpreted to prohibit the release of information regarding the "nature or specific location" of certain cultural and natural resources in the national park system. Additional details and information about the legal basis for this policy are in the NPS Management Policies (National Park Service 2006), and in Director's Order #66 (available at: http://home.nps.gov/applications/npspolicy/DOrders.cfm).

These guidelines apply to all NCCN staff, project participants, contractors, and other partners who are likely to acquire or otherwise have access to information about protected NPS resources. The Project Lead has primary responsibility for ensuring adequate protection of sensitive information related to this project.

The following are highlights of our strategy for protecting this information:

- *Protected resources*, in the context of the NCCN Inventory and Monitoring Program, include species that have State- or Federally-listed status, and other species deemed rare or sensitive by local park taxa experts.
- *Sensitive information* is defined as information about protected resources that may reveal the "nature or specific location" of protected resources. Such information must not be shared outside the National Park Service, unless a signed confidentiality agreement is in place.
- In general, if information is withheld from one requesting party, it must be withheld from anyone else who requests it, and if information is provided to one requesting party without a confidentiality agreement, it must be provided to anyone else who requests it.
- To share information as broadly as legally possible, and to provide a consistent, tractable approach for handling sensitive information, the following shall apply if a project is likely to collect and store sensitive information:
    - Random coordinate offsets of up to 2 km for data collection locations, and
    - Removal of data fields likely to contain sensitive information from released data set copies.

4.11. Product Delivery, Posting and Distribution

A complete schedule for project deliverables and the people responsible for them are found in the annual project task list (Appendix B). To package products for delivery, refer to SOP 23. Upon delivery products such as reports and GIS data sets will be posted to NPS websites and clearinghouses (e.g., the NPS Data Store) according to SOP 23: Product Delivery, Posting and Distribution. The water quality data entered into NPSTORET will be delivered annually to WRD for upload to EPA's STORET Data Warehouse (see SOP 23: Product Delivery, Posting and Distribution).

4.11.1. Holding Period for Project Data

To permit sufficient time for priority in publication, certified project data will be held upon delivery for a period not to exceed two years after data certification. After the two-year period has elapsed, all certified, non-sensitive data will be posted to the NPS Data Store. Note: This hold only applies to raw data, and not to metadata, reports or other products which are posted to NPS clearinghouses immediately after being received and processed.

4.11.2. Special Procedures for Sensitive Information

Products that have been identified upon delivery by the Project Lead as containing sensitive information will normally be revised into a form that does not disclose the locations of protected resources – most often by removing specific coordinates and only providing coordinates that include a random offset to indicate the general locality of the observation. If this kind of measure is not a sufficient safeguard given the nature of the product or the protected resource in question, the product(s) will be withheld from posting and distribution.

If requests for distribution of products containing sensitive information are initiated by the NPS, by another federal agency, or by another partner organization (e.g., a research scientist at a university), the unedited product (i.e., the full data set that includes sensitive information) may be shared only after a confidentiality agreement has been established between NPS and the agency, organization, or person(s) with whom the sensitive information is to be shared. Refer to http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm for more information.

All official Freedom of Information Act (FOIA) requests will be handled according to NPS policy. The Project Lead will work with the Data Manager and the park FOIA representative(s) of the park(s) for which the request applies.

4.12. Archiving and Records Management

All project files should be reviewed and organized by the Project Lead on a regular basis (e.g., annually in January). Unneeded draft documents and other intermediate files should be deleted to conserve space and maintain a clear and unambiguous record for future project staff. Decisions on what to retain and what to destroy should be made following guidelines stipulated in NPS Director's Order 19 (available at: http://home.nps.gov/applications/npspolicy/DOrders.cfm), which provides a schedule indicating the amount of time that the various kinds of records should be retained. Refer to SOP 2: Project Workspace and Records Management.

4.13. Season Close-out

Because this is a long-term monitoring project, good records management practices are critical for ensuring the continuity of project information. Files will be more useful to others if they are well organized, well named, and stored in a common format. Details for handling project files are described in SOP 2: Project Workspace and Records Management. In addition, files containing sensitive information must be stored in a manner that will enable quick identification. Refer to Section 4.10, Identifying and Handling Sensitive Information.

After the conclusion of the field season, the Project Lead, Data Manager, and GIS Specialist should meet to discuss the recent field season, and to document any needed changes to the field sampling protocols, to the database structure or front-end application, or to any of the SOPs associated with the protocol.

5. Personnel Requirements and Training

5.1. Roles and Responsibilities

Oversight and implementation of the NCCN Mountain Lakes Protocol is the primary responsibility of the Project Leads: the MORA Biologist/Aquatic Program Manager, the NOCA Aquatic Biologist/Aquatic Program Manager, and the OLYM Aquatic Ecologist. NCCN Data Managers and GIS Specialists are responsible for the development and maintenance of associated databases, production of maps and spatial data products, production of reports, and archiving data products. Field Leads (NOCA Field Aquatic Ecologist, MORA Supervisory Biological Technician, and OLYM Aquatic Ecologist) are responsible for the day-to-day operations of implementing the Mountain Lakes Protocol including pre-season inventories to ensure adequate supplies and operational equipment are available, training field staff, conducting field surveys, entering field data into the project database, and inventorying and properly storing supplies and equipment at the end of the field season. Field Leads also participate in annual meetings to discuss protocol improvements or changes. Field crews are made up of experienced biological technicians assisted by student interns. Field crews are responsible for field preparation, collecting field data, laboratory processing of samples, and data entry. Field Leads are responsible for verifying data collection and entry accuracy. A comprehensive description of roles and responsibilities is presented in Appendix A: Roles and Responsibilities.

5.2. Qualifications

The Field Lead for the Mountain Lakes protocol is a GS-7/9/11/12 who is a highly skilled field biologist with experience conducting limnological surveys and familiar with Pacific Northwest amphibian and fish communities. Familiarity with one or more of the NCCN parks is also desirable. Ideally, the Field Lead will have supervised field crews before and/or previously served as an NCCN Mountain Lakes Monitoring crew member. Finally s/he must be very physically fit and prepared to spend extended periods of time traveling and working in remote, rugged backcountry locations for extended stays.

Field Technicians are GS-5/6/7. At least one field technician will have prior amphibian survey experience, including substantial experience with NCCN amphibian species or a demonstrated ability to quickly learn the identification of embryo, larvae, and adult life stages of these species. In addition, one field technician will have some experience in fish identification skills or the ability to quickly learn how to identify the primary species present in park lakes. Technicians and student interns must also be physically fit and prepared to spend extended periods of time working in the backcountry. Substantial backpacking experience, wilderness first aid, and experience conducting aquatic field surveys are also desirable.

5.3. Training Procedures

A comprehensive and well-designed training program is critical to the success of this project, as it will maximize observer consistency within and between years. Past experience has shown us that particularly experienced or talented crew members can be adequately trained in using the Mountain Lakes Protocol in two weeks or less. We recommend, however, that up to three weeks be allowed for the training period to maximize the likelihood that all observers will be qualified to conduct all of the monitoring components at the end of the training session, and to allow ample time for any required meetings between the crew, Field Lead, Project Lead, Data Manager, and GIS Specialist. Additional training time will be required to participate in and

complete required general park training sessions (e.g., computer training, ethics, purchasing, personnel, supervisory, all-park safety training).

5.3.1. Training New or Inexperienced Employees

Classroom training and field certification will be required for all new or inexperienced crew members. The objective of this training is to provide a basic understanding of the field SOPs rather than memorizing them (**Note**: In the field, all crew members will be required to always read the applicable sections of the protocol prior to data collection for any monitoring component).

Training requirements and procedures are discussed in detail in SOP 1 and the following subjects are covered:

1. Background on project objectives, sampling design, and data analysis
2. Field sampling methods and QA/QC concerns
3. Equipment operation and maintenance
4. Field and laboratory sample processing and handling
5. Fish and amphibian species identification
6. Recording data
7. Safety (e.g., first aid and CPR, defensive driving, helicopter passenger and helicopter crew member training, backcountry travel, radio communications, boat safety, etc.) issues and procedures are addressed in SOP 24: Field and Laboratory Safety and Appendix G: Safety Considerations.
8. Orienteering
9. Backcountry rules and ethics
10. Computer data entry and data management

For field certification, all new or inexperienced crew members will be required to work with experienced Field Leads or technicians until they are certified to work on their own. Field certification will be required for each SOP, and will be based on knowledge of sample collection and processing methods, correct operation of equipment, adherence to field QA/QC and safety guidelines, identification of fish and amphibian species, and where possible comparison of results between inexperienced and experienced observers.

Before observers can collect amphibian and fish data for the Mountain Lakes Monitoring Project, competency of field technicians must be verified by a qualified Field Lead or technician. It is expected that the amount of time to gain full competency in species identification will depend on the individual's ability, the number of species that are found at the park he or she is working in, and the opportunity to view these species in the field. It is always recommended that a qualified observer be present during each sampling occasion. However, if a qualified observer is not available, the instructions for collecting a voucher specimen will be followed (SOP 14: Amphibian Sampling and Processing).

5.3.2. Experienced Crew member Protocol Review and Training

Experienced field leads and technicians (with two or more years of experience) will be required to review all materials discussed in 1-10 above. Returning employees must maintain currency in all park required training.

5.4. Safety

The NCCN I&M Program places the highest emphasis on ensuring the safety and well-being of its staff as well as any person affiliated with implementing Mountain Lakes monitoring. The NCCN I&M Program Manager, Project Lead and Lead Technicians will strive to provide a safe working environment that fosters a sense of professional responsibility and cohesion among all staff. Training in Operational Leadership will be required for any staff leading or overseeing field work. Training in defensive driving will be required for all staff who could potentially operate motor vehicles while on duty.

All supervisory staff should work towards creating a work environment that:

- Encourages everyone to work together towards a common goal.
- Assigns roles and responsibilities to ensure clear lines of communication and create cohesive field operations.
- Facilitates all staff members feeling free to voice their observations and concerns related to planned or ongoing field activities. Supervisors are encouraged to incorporate staff feedback into field operations when appropriate and beneficial.
- Encourages professional development and a sense of ownership in the project and the tasks assigned to staff members.
- Stresses that each member of a field crew is responsible for the safety and well-being of the entire group and emphasizes open communication about past, present, and future safety issues among and between all staff.

6. Operational Requirements

6.1. Annual Workload and Field Schedule

Necessary tasks for implementing this protocol are presented in Appendix B: Yearly Task List, which identifies each task by project stage, indicates who is responsible for each task, and establishes the timing for its execution. Preparation for the upcoming field season starts with initiating the process of recruiting and hiring qualified crew members between November and April (*see* additional details in Section 3.1, and SOP 1 and 2) and ends in June with crew member training (including NPS and park required training) and field season mobilization. All field work is accomplished during July through September. During this time data entry is also initiated and certain chemical analyses are completed as prescribed in the SOPs (*see* Section 3.2, and SOP 9: General Water Chemistry). Post field season activities (Section 3.3, and SOP 17: Post Field Season Activities) including data review and management, sample processing and shipping, equipment inventory and maintenance, and field season debriefing start immediately upon return from the last field tour. Numerous data management and analysis tasks involved with report preparation and product delivery occur beginning immediately after the field season ends and continuing to the following November (Section 4, Appendix B: Yearly Task List, and SOPs 20, 22 and 23).

6.2. Facility and Equipment Needs

Facilities required for this protocol include office space with access to computers, laboratory facilities for minimal water quality analyses and biological sample processing, and seasonal housing. All of these facilities are available at each of the three parks. Costs for laboratory and office space are provided through park base funds but replacement lab equipment will require periodic funding from the Inventory and Monitoring Program. Seasonal housing is generally paid for by the employee with the exceptions of Student Conservation Association (SCA) volunteers and Student Interns.

A large amount of equipment including various sampling devices, measuring devices, temperature data loggers and water chemistry meters, inflatable boats, personal safety equipment, and various supplies and materials are required for this protocol. Most of this equipment has been purchased in the last five years, however funding for replacement equipment will be required from the Inventory and Monitoring Program in the future. Complete equipment lists needed for field work are listed at the end of each of the field SOPs (SOP 3-15).

6.3. Startup Costs and Budget Considerations

Startup costs are low because most of the required equipment and supplies are already available at MORA, NOCA, and OLYM. Limited equipment replacement funds are included in the budget (Tables 9-11). The budget tables provide line item costs by funding sources including: NCCN I&M $ and ONPS-Park Base $. Budget Tables 9-11 represent the costs at each park for field season preparation, data collection, sample processing, data management, GIS support, and annual reporting. A summary of total costs for the Mountain Lakes Monitoring Project is shown in Table 12. The total cost (in FY2010 $) for these basic annual project activities is $213,687 split between the NCCN I&M Program ($150,144) and from park base funds (ONPS-Operations of the National Park Service) at MORA, NOCA, and OLYM ($63,543).

An additional $38,000 will be required on every 5th year for completion of the Five-year Summary Report (SOP 21.V: Reporting). Two additional pay-periods of salary for each of the park leads ($24,000 total, from ONPS-Park Base accounts) will be needed for data analysis and report preparation. Statistical consultation will be required to assist with the more complex trend analysis procedures (SOP 21.IV.E and F) used for continuous temperature data analyses, park-wide and network-wide abrupt change, and long-term steady trend detection. It is expected that statistical consultation costs will be approximately $14,000 (100 hrs) for assistance in preparation of the first Five-year Summary Report and should be less in subsequent five-year reporting intervals. Five-year reporting costs in Table 12 were prorated over a five-year period to come up with a total annual cost of the Mountain Lakes Project of $221,287.

Table 9. Mountain Lakes Monitoring Project annual budget for MORA.

MORA Budget Components	NCCN I&M Program $	MORA ONPS $	Total $
Salaries and benefits:			
GS 12/9, Project Lead, Ecol. (4 pp.)	0	$14,105	$14,105
GS 9/5, Field Lead Tech. (5 pp.)	$14,040	$5,616	$19,656
GS 9/5, GIS Specialist (0.5 pp)	$1,500	0	$1,500
GS 7/4, Bio. Tech. (4.5 pp. total)	$9,080	0	$9,080
GS 7/1, Bio. Tech. (4 pp. total)	$7,520	0	$7,520
GS 5/1, Bio. Tech. (4 pp. total)	$5,600	0	$5,600
SCA (8 weeks with housing)	$4,100	0	$4,100
Subtotal:	**$41,840**	**$19,721**	**$61,561**
Operations and equipment:			
Vehicles (2 months @ $1350/month)	$1,350	$1,350	$2,700
Misc. supplies and equipment	$1,500	$500	$2,000
Field per-diem (50 person-days @ $20/day)	$1,000	0	$1,000
Subtotal:	**$3,850**	**$1,850**	**$5,700**
Sample analysis:			
Chlorophyll-a (1 sample depth, 6 lakes + 1 field replicate =7 samples @ $35/sample)	$245	0	$245
Anions/cations[1] – CWU (10 samples @ $80/sample)	$800	0	$800
Nutrients/DOC/TDS[1] – CCAL (10 samples @ $115/sample)	$1,150	0	$1,150
Zooplankton – Vogel (6 lakes + 1 field replicate = 7 samples @ $105/sample)	$735	0	$735
Benthic macroinvertebrates – Wisseman (6 lakes + 1 field replicate = 7 samples @ $250/sample)	$1,750	0	$1,750
Sample mailing cost	$480	0	$480
Subtotal:	**$5,160**	**0**	**$5,160**
Grand Total:	**$50,850**	**$21,571**	**$72,421**

[1] Two samples are collected at thermally stratified lakes and one sample is collected at unstratified lakes. In addition, one replicate sample and one blank sample are collected each year.

Table 10. Mountain Lakes Monitoring Project annual budget for NOCA.

NOCA Budget Components	NCCN I&M Program $	NOCA ONPS $	Total $
Salaries and benefits:			
GS 12/10, Project Lead, Ecol. (5 pp.)	0	$22,000	$22,000
GS 11/5, Data Analyst, Ecol. (1 pp.)	0	$3,460	$3,460
GS 9/1, Field Lead Ecol. (Term - 5 pp.)	$12,956	0	$12,956
GS 9/1, Helispot Mgr/Ecol. (Term - 1 pp.)	$2,565	0	$2,565
GS 9/5, GIS Specialist (0.5 pp)	$1,500	0	$1,500
GS 7/2, Bio. Tech. (Term – 5 pp.)	$9,720	0	$9,720
GS 5 or 6, Bio. Tech. (4.5 pp. total)	$6,300	0	$6,300
Subtotal:	**$33,041**	**$25,460**	**$58,501**
Operations and equipment:			
Helicopter support (6 hrs. @ $1230/hr.)	$7,380	0	$7,380
Vehicles (2 months @ $800/month)	$800	$800	$1,600
Misc. supplies and equipment	$1,700	$500	$2,200
Field per-diem (50 person-days @ $20/day)	$1,000	0	$1,000
Subtotal:	**$10,880**	**$1,300**	**$12,180**
Sample analysis:			
Chlorophyll-a (1 sample depth, 6 lakes + 1 field replicate =7 samples @ $35/sample)	$245	0	$245
Anions/cations[1] – CWU (10 samples @ $80/sample)	$800	0	$800
Nutrients/DOC/TDS[1] – CCAL (10 samples @ $115/sample)	$1,150	0	$1,150
Zooplankton – Vogel (6 lakes + 1 field replicate = 7 samples @ $105/sample)	$735	0	$735
Benthic macroinvertebrates – Wisseman (6 lakes + 1 field replicate = 7 samples @ $250/sample)	$1,750	0	$1,750
Sample mailing cost	$480	0	$ 480
Subtotal:	**$5,160**	**0**	**$5,160**
Grand Total:	**$49,081**	**$26,760**	**$75,841**

[1]Two samples are collected at thermally stratified lakes and one sample is collected at unstratified lakes. In addition, one replicate sample and one blank sample are collected each year.

Table 11. Mountain Lakes Monitoring Project annual budget for OLYM.

OLYM Budget Components	NCCN I&M Program $	OLYM ONPS $	Total $
Salaries and benefits:			
GS 12/5, Project Lead, Ecol. (4 pp.)	0	$13,712	$13,712
GS 9/5, GIS Specialist (0.5 pp)	$1,500	0	$1,500
GS 7/5, Field Lead Tech (2 pp.)	$5,272	0	$5,272
GS 6/1, Bio. Tech (6 pp.)	$8,640	0	$8,640
GS 5/1, Bio. Tech (6 pp.)	$7,746	0	$7,746
GS 5/1, Bio. Tech (6 pp.)	$7,746	0	$7,746
GS 4/1, Bio. Tech (6 pp.)	$6,924	0	$6,924
Lump sum AL (4 Seasonals x 4 hrs/pp.)	$1,550	0	$1,550
Subtotal:	**$39,378**	**$13,712**	**$53,090**
Operations and equipment:			
Vehicles (2 months @ $750/month)	0	$1,500	$1,500
Misc. supplies and equipment	$2,500		$2,500
Field per-diem (140 person-days @ $20/day)	$2,800	0	$2,800
Subtotal:	**$5,300**	**$1,500**	**$6,800**
Sample analysis:			
Anions/cations[1] – CWU (12 samples @ $80/sample)	$960	0	$960
Nutrients/DOC/ TDS[1]– CCAL (12 samples @ $115/sample)	$1,380	0	$1,380
Zooplankton – Vogel (8 lakes + 1 field replicate = 9 samples @ $105/sample)	$945	0	$945
Benthic macroinvertebrates – Wisseman (8 lakes + 1 field replicate = 9 samples @ $250/sample)	$2,250	0	$2,250
Subtotal:	**$5,535**	**0**	**$5,535**
Grand Total:	**$50,213**	**$15,212**	**$65,424**

[1] Two samples are collected at thermally stratified lakes and one sample is collected at unstratified lakes. In addition, one replicate sample and one blank sample are collected each year.

Table 12. Annual Budget Summary for the Mountain Lakes Monitoring Project.

Budget Components	NCCN I&M Program $	PARK ONPS $	Total $
Annual Data Collection and Reporting:			
MORA	$50,850	$21,571	$72,421
NOCA	$49,081	$26,760	$75,841
OLYM	$50,213	$15,212	$65,424
Subtotal:	**$150,144**	**$63,543**	**$213,687**
Five-Yr Summary Reporting (Prorated annual $):			
GS 12, Park Project Leads (tot. 6 pp. in 5 Yrs.)	0	$4,800	$4,800
Contracted Statistician (100 hrs. in 5 Yrs.)	$2,800	0	$2,800
Subtotal:	**$2,800**	**$4,800**	**$7,600**
Project Grand Total:	**$152,944**	**$68,343**	**$221,287**

7. Revising the Protocol

This protocol attempts to incorporate the best and most cost-effective methods for monitoring and information management. As new technologies, methods, and equipment become available, this protocol will be updated as appropriate, by balancing current best practices against the continuity of protocol information.

All edits require review for clarity and technical soundness. Small changes to existing documents – e.g., formatting, simple clarification of existing content, minor changes to the task schedule or project budget, or general updates to information management SOPs – may be reviewed in-house by project and NCCN staff. However, changes to data collection or analysis techniques, sampling design, or response design are usually more significant in scope and impact and will typically trigger an outside review to be coordinated by the Pacific West Regional Office of the National Park Service.

The steps for changing the protocol (either the Protocol Narrative or the SOPs) are outlined in SOP 25: Revising the Protocol. Each SOP contains a Revision History Log that will be filled out each time a SOP is revised to explain why the change was made, and to assign a new version number to the revised SOP. The new version of the SOP and/or Protocol Narrative will then be archived as explained in SOP 25.

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Section II. Standard Operating Procedures

SOP 1: Field Season Preparations and Crew Training

April 19, 2011

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Field Season Preparations and Crew Training

This Standard Operating Procedure explains the procedures and topics to cover in field season preparation and in training field crews to collect data for the NCCN Mountain Lakes Monitoring Project at MORA, NOCA, and OLYM.

A. Field Season Preparations

Table 1.1 identifies each task by project stage, indicates who is responsible for each task, and establishes the timing for its execution. Protocol sections and SOPs are referred to as appropriate.

Table 1.1. Yearly pre-season preparation task list.

Task Description	Responsibility	Timing
Initiate announcements for seasonal technician positions, begin hiring	Project Leads, Field Leads	Jan-Feb
Notify Data Manager and GIS Specialist of needs for the coming season (field maps, GPS support, training)	Project Leads	Jan-Feb
Meet (or conference call) to recap past field season, discuss the upcoming field season, and document any needed changes to field sampling protocols or the working database.	Project Lead, Field Leads, Data Manager, GIS Specialists	Feb
Ensure all project compliance needs are completed for the coming season.	Field Leads	Feb-April
Plan schedule and logistics, including initial inventory and ordering of any needed equipment and supplies (SOP 1: Field Season Preparation and Crew Training).	Project Lead, Field Leads	by Apr 30
Complete contracts for water quality analysis, chlorophyll-a analysis, zooplankton and macroinvertebrate identification.	Project Leads	by Apr 30
Inform GIS Specialist and Data Manager of specific needs for upcoming field season.	Project Leads, Field Leads	by Apr 30
Generate field navigation reports, roster of lakes and coordinates from the sample frame (*see* Appendix D: Sampling Design).	Project Leads, Field Leads	May 15 – June 15
Gather aerial photos of lakes designated for sampling and prepare and print field maps (SOP 4: Lake Features and Bathymetric Maps).	Field Leads, Technicians	May 15 – June 15
Gather historical sampling data and other information useful during field sampling. For revisit sites, make copies of previous survey bathymetric data, water level forms, continuous temperature data form, and photos helpful in relocating benchmarks.	Field Leads, Technicians	May 15 – June 15
Update and load data dictionary, background maps, and target coordinates into GPS units (SOP 3: GPS Data Collection).	GIS Specialists	by May 15

Table 1.1. Yearly pre-season preparation task list (continued).

Task Description	Responsibility	Timing
Ensure that project workspace is ready for use and GPS download software is loaded at each park (SOP 2: Project Workspace and Records Management).	Project Leads, Field Leads, Data Managers and GIS Specialists	by May 30
Implement working database copy.	Data Managers	by May 30
Initiate computer access and key requests (may need park-specific dates).	Field Leads	by May 30
Provide field crew email addresses and user logins to Data Manager.	Field Leads	June
Check all equipment (i.e., gillnets, boats, zooplankton and macroinvertebrate nets, measuring lines, etc.) to make sure that it is in workable condition. If not, replace or make needed repairs. (*see* SOPs 3 through 15).	Field Leads, Technicians	June
Complete final inventory of all equipment and supplies to ensure everything needed for field sampling is available; update inventory database.	Field Leads, Technicians	June
Test all water quality monitoring probes and equipment, calibrate depth measurement lines, check batteries and probe membranes, calibrate temperature data loggers and other thermistors.	Field Leads, Technicians	June
Prepare water filtering apparatus, filters and water sample bottles for water chemistry sampling (SOP 9: General Water Chemistry).	Field Leads, Technicians	June
Protocol training and review field and safety SOPs.	Project Leads, Field Leads, Technicians	June
Train field crew in species identification, equipment use, sampling protocols, and safety.	Field Leads	June
Certification of field observer qualifications for amphibian and fish identification.	Project Leads, Field Leads	June
Provide database/GPS training as needed (SOP 2 and 3).	Data Managers, GIS Specialists	June
Develop field sampling schedule.	Project Leads, Field Leads	June

B. **Training New or Inexperienced Employees**

Review and training will be provided for all lake monitoring staff immediately before the field season begins. Each year all new or inexperienced staff will be trained in every aspect of the Mountain Lake protocol prior to conducting field work. Training will include reading of this protocol, discussion of sections with the Field Leads and/or Project Leads, and practicing each field exercise in a front-country setting to gain familiarity with each task. New or inexperienced staff will not conduct tasks unattended until they have satisfied their supervising Field Lead and/or Project Lead of their ability to conduct tasks competently.

Pre-season training will include the following subjects:

1. Background on project objectives, sampling design, and data analysis: The purpose of this training is to provide background information on project objectives and sampling design (narrative sections of the protocol), and general information concerning how data will be analyzed (SOP 21: Data Analysis and Reporting). Poor field sampling performance will be discussed in relation to how it impacts our ability to analyze data and achieve objectives (e.g., effects of missing data on sample size).

2. Field sampling methods: The details of all field sample collection methods found in SOPs 3-15 will be covered in this section. Specific QA/QC concerns identified in each field SOP also will be covered.

3. Equipment operation and maintenance: This section provides specific information on the operation and maintenance of equipment used for sample collection. Reference information will include equipment manuals as well as instruction in the use of SOPs. The following specific items will be included:
    a. GPS equipment (SOPs 3 and 4)
    b. Depth sounding equipment (SOP 4)
    c. Laser rangefinder (SOPs 4, 14 and 15)
    d. Compass (SOP 4)
    e. Secchi Disk (SOP 6)
    f. Dissolved oxygen, specific conductance, temperature, and pH meters (SOPs 7 and 9)
    g. Water sample collection bottle (SOPs 9 and 10)
    h. Water chemistry filtration equipment (SOPs 9 and 10)
    i. Zooplankton and benthic macroinvertebrate nets (SOPs 11 and 12)
    j. Gillnets (SOP 13)
    k. Decontamination of nets and waders (SOP 16)
    l. Cameras

4. Sample processing and handling: This section will cover handling of live fish and amphibian species (SOPs 13 and 14), field processing of water chemistry (SOPs 7 and 9) and chlorophyll-a samples (SOP 10), field processing of benthic macroinvertebrate (SOP 11) and zooplankton samples (SOP 12).

5. Fish and amphibian species identification: All field crew personnel must be fully competent at identifying fish and amphibian species that occur at the park that they are working in. Soon after being hired, new technicians will be given species lists (see SOP 13, Table 13.1 for fish species, and SOP 14, Table 14.2 for amphibian species) and other training materials, and be urged to begin preparing themselves prior to the start of the training session. Trainers will provide a one-day classroom overview of fish and amphibians present in each park, their habitats, life histories, and identifying characteristics. The remainder of the training will be either conducted in the field prior to the sampling season (depending on available funds) or provided during the sampling season. In addition to observing amphibians in the field, Field Technicians will spend time throughout the training session studying field guides. Before technicians can collect

fish and amphibian data for the Mountain Lakes Monitoring Project, they must show competency based on field identifications. Identification of all specimens collected is verified by a qualified Field Lead.

6. Recording data: New technicians must be instructed on how to complete each data form, and have an opportunity to practice completing them during training, so that questions that arise can be resolved before official data collection begins. Additional details are provided in Section 4 of the protocol narrative and in SOP 20: Data Entry and Verification.

7. Safety: Safety training will include all components of SOP 24: Field and Laboratory Safety, and Appendix G: Safety Considerations. Crew members will work together for up to a week at a time in remote, rugged areas of the large parks with a substantial portion of each day spent working off-trail. It is therefore essential that everyone, to the extent possible, be prepared for emergency situations. This preparation includes mandatory park safety training, review of job hazard analysis information (Appendix G.), and routine safety tailgate sessions throughout the field season.

8. Orienteering: During the training session all technicians must become proficient at off-trail orienteering, including the proper use of a compass, altimeter, and GPS unit, and the ability to read topographic maps. GPS signals are frequently unavailable in the NCCN parks, so observers must become proficient at determining their location as well as traveling to a distant, unseen destination using only a compass and topographic map. These skills will be practiced until all observers are proficient.

9. Backcountry Rules and Ethics: New technicians will receive instruction on backcountry regulations, including permit requirements and procedures, campsite restrictions, food storage, radio communications, etc. Note that some of these rules differ among the parks.

10. Computer data entry: During the pre-season training program, new and returning technicians must receive adequate instruction on general data management practices and specific data entry procedures (see SOP 20: Data Entry and Verification), so that they can complete their data entry during the field season. If NPS computers are to be used for data entry, crew members may need security clearances or other specific authorization that requires them to complete NPS IT security training.

C. **Experienced Crew Member Protocol Review and Training**

Experienced Field Leads and technicians (with two or more years of experience) will be required to review all materials discussed in Section A.1-10 above. Returning employees must be current in all park required training.

SOP 2: Project Workspace and Records Management

April 19, 2011

Prepared by: John Boetsch, NPS NCCN-OLYM, and Ronald Holmes, NPS NCCN-NOCA.

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Overview

This SOP describes how and where project files and records are managed by project staff. Workspace structure, naming conventions, and procedures for handling project files are included.

NCCN File Workspace

NCCN has a centralized file system and project workspaces available for use by field crews and project staff at: \\inpolymfs\parkwide\NCCN. This will help avoid the problem of NCCN projects having several versions of files on different servers around the network. These folders are set up so that park and network staff members at the network parks all have read privileges throughout the directory structure. Project leads and a few other individuals associated with each project have full privileges for their project folder so they can manage their own permissions. These workspaces are intended to be a more familiar and convenient way of storing information, as an adjunct to the NCCN SharePoint site. Apart from reports and protocols, which are to be maintained in the NCCN Digital Library (a section of the NCCN SharePoint site), project leads will decide what is to be stored locally in these project workspaces as opposed to on the team SharePoint site. Examples of files kept in these project workspaces include: working files for project field crews, GPS downloads, GIS map files, database files, and other project records.

The NCCN file workspace is organized as follows under four main folders: Libraries, Projects, Temp, and Workspace. Project staff members will primarily be working in one or more of the project folders under Projects, and may wish to make desktop shortcuts to one or more of the project subfolders by right-clicking on the desired folder and selecting Send To > Desktop (create shortcut).

Project staff members should create a network shortcut to the project workspace by going to the Desktop in Windows Explorer and adding a new network place under My Network Places. Project staff located at OLYM will typically already have this path available to them via a mapped drive (e.g., the I:\ drive); however, they should still create this network shortcut where multiple parks are concerned for the sake of communications and consistency among parks. Performance is the main rationale for using network shortcuts instead of mapped drives at other parks.

Instructions for creating a network shortcut to the NCCN workspace:

1. Open an instance of Windows Explorer. One way is from the Start menu, go to: All Programs > Accessories > Windows Explorer. Another is to open My Documents, My Computer, or any other folder browser shortcut.
2. Navigate to the Desktop, and then to My Network Places.
3. Double-click the Add Network Place option to open the setup wizard.
4. Choose the option to specify the network location, then under network address, type in: \\inpolymfs\parkwide\NCCN
5. When prompted for a name for the network place, enter “NCCN” (or something similarly brief and meaningful).

6. This network place shortcut should now be available each time you log in to that particular computer, and can be accessed when navigating within most Windows software.

Project Workspace

A section of the NCCN workspace is reserved for this project. The recommended file structure within this workspace is shown in Figure 2.1. Certain folders, especially those for GPS data and images, should be retained in separate folders for each calendar year as shown in Figure 2.1. This will make it easier to identify and move these files to the project archives at the end of each season.

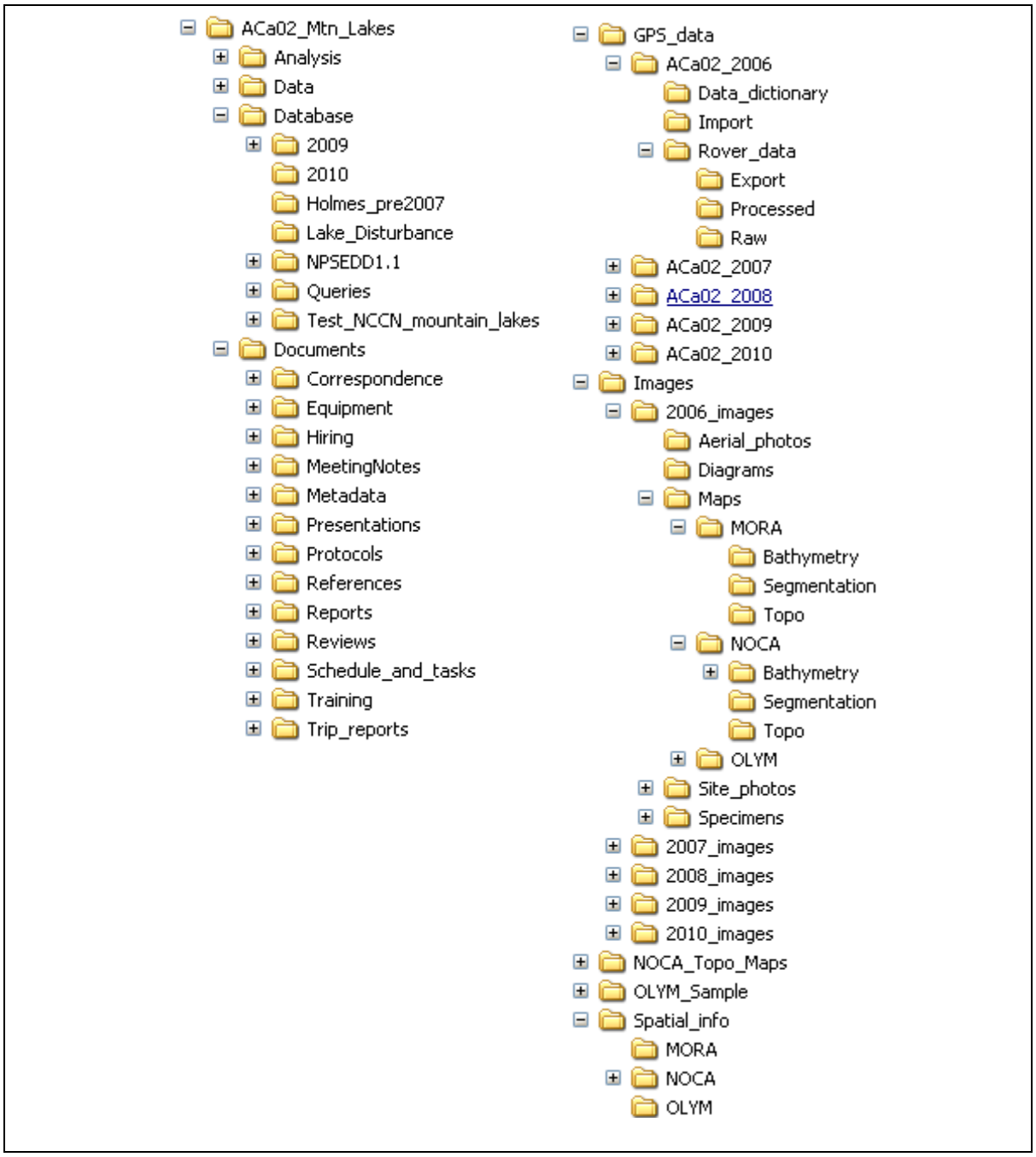


Figure 2.1. Recommended file structure for the project workspace. Note that the workspace folder name includes "ACa02", the NCCN project code. The same code is also under the GPS_data folder to make it easier to select the correct project folder within the GPS processing software.

Each major subfolder is described as follows:

- Analysis – Contains working files associated with data analysis.
- Data – Contains the front-end database application file for the season. The back-end database for the project is maintained in Microsoft SQL Server. Database exports and

other intermediate summary information can be stored here as well; these files are most effectively managed within subfolders named by calendar year.

- Documents – Contains subfolders to categorize documents as needed for various stages of project implementation. Additional folders and subfolders may be created as needed to arrange information in a way that is useful to project staff.
- GPS data – Contains GPS data dictionaries, and raw and processed GPS data files. This folder contains subfolders to arrange files by year. Each of these subfolders also contains the project code to make it easier to select the correct project folder within the GPS processing software.
- Images – For storing images associated with the project. This folder has subfolders named by calendar year to make it easier to identify and move files to the project archives at the end of each season. Refer to SOP 18: Acquiring and Managing Photographic Images, for more details.
- Spatial info – Contains files related to visualizing and interacting with GIS data.
    - GIS data – New working shapefiles and coverages specific to the project.
    - GIS layers – Pointer files to centralized GIS base themes and coverages.
    - Map documents – Map composition files (.mxd).

Seasonal Workspace

In addition to these permanent folders, a temporary seasonal workspace is established at the beginning of each field season (e.g., "2012_field_crew"). This temporary workspace provides a place for field crew members to create and modify files while limiting access privileges for the remainder of the project workspace. Subfolders are created for Images and GPS data to allow field crew members to process incoming files as needed. Temporary workspaces may also be established on other servers to provide local access to crews stationed at other parks. At the end of the season, files in these temporary workspaces are then filed in the appropriate permanent folder(s).

Folder Naming Standards

In all cases, folder names should follow these guidelines:

- No spaces or special characters in the folder name.
- Use the underbar ("_") character to separate words in folder names.
- Try to limit folder names to 20 characters or fewer.
- Dates should be formatted as YYYYMMDD (this leads to better sorting than other date naming conventions).

File Naming Standards

Unless otherwise specified, file names should follow these guidelines:

- No spaces or special characters in the file name.
- Use the underbar ("_") character to separate file name components.
- Try to limit file names to 30 characters or fewer, up to a maximum of 50 characters.

- Dates should be formatted as YYYYMMDD.
- Correspondence files should be named as YYYYMMDD_AuthorName_subject.ext.

Workspace Maintenance Procedures

Prior to each season, the Project Lead should:

1. Make sure that network accounts are established for each new staff member, or reactivated for returning staff members. By default, the IT staff puts new user accounts into a group that has read-only access to all files.
2. Create new folders named by year under the Images and GPS data sections.
3. Create the seasonal workspace, with subfolders for Images and GPS data.
4. Add user logins for the seasonal crew members to the seasonal workspace, with modify privileges. This can be done by right-clicking on the seasonal workspace folder, selecting Properties > Security, then adding users one at a time and checking the box in the Allow column for Modify privileges.
5. Provide the Data Manager with a list of user logins that need access to the database.

After each season, the Project Lead should:

1. Review the workspace organization and clean up any temporary files and subfolders that are no longer needed.
2. Move files from the seasonal workspace folders into the appropriate permanent folder(s) and archive or delete the seasonal workspace folders as desired. See SOP 18: Acquiring and Managing Photographic Images, for specific instructions for images.
3. Compare older files against the retention schedule in NPS Director's Order 19 (available at: http://home.nps.gov/applications/npspolicy/DOrders.cfm). Dispose of files that are beyond their retention schedule if they are no longer needed. As a long-term project, many files associated with this project are likely to be scheduled for permanent retention. This makes it all the more imperative to clean out unneeded files before they accumulate and make it harder to distinguish the truly useful and meaningful ones.
4. Convert older files to current standard formats as needed to maintain their usefulness.
5. Identify files that may contain sensitive information (as defined in Section 4.10, Identifying and Handling Sensitive Information). Such files should be named and filed in a way that will allow quick and clear identification as sensitive by others.
6. Post final documents and files to the NCCN Digital Library for long-term storage. See SOP 23: Product Delivery, Posting and Distribution.
7. Send analog (non-digital) materials to the park collections for archiving.

SOP 3: GPS Data Collection

April 19, 2011

Prepared by: Katherine Beirne, NPS-NCCN OLYM, and Natasha Antonova, Lise Grace, and Ronald Holmes, NPS-NCCN NOCA.

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GPS Data Collection

This SOP provides information on GPS data collection specific to the Mountain Lakes Monitoring Project, and will be used in conjunction with the step-by-step instructions in the NCCN Global Positioning System Data Acquisition and Processing guidance document (NCCN 2009) for collecting and exporting position information using Thales MobileMapper® and Trimble Geo XT® GPS receivers. This document is available at the following website: http://science.nature.nps.gov/im/units/nccn/dm_docs/NCCN_GPS_Guidelines.pdf. This document also provides information on processing GIS data once the data have been downloaded and given to the GIS Specialist.

A. **General Practices for GPS Data Collection**

Field crews are required to receive GPS training on their specific GPS units prior to field work. Contact respective park GIS Specialist to schedule the training.

Regardless of GPS receiver type, data collection standards outlined in Section 6 of the NCCN Global Positioning System Data Acquisition and Processing document must be followed. Following these standards will produce the most accurate data and eliminate most frustrations associated with inability to obtain strong and accurate satellite signals.

Whenever possible, real-time correction options for each GPS unit will be used in the field to increase accuracy of data.

GPS file names will be recorded on hardcopy data forms or in field computers. File names will be preceded by the letter assigned to the GPS unit. GPS field coordinates (coordinates shown on a GPS receiver while a GPS is receiving satellite signals) and datum will also be recorded on hardcopy data forms. In the event a GPS file is lost or corrupted, the coordinates recorded in the field from the GPS unit display window will become the best measure of location. Be aware that these coordinates cannot be differentially-corrected and are in the coordinate system and datum that were chosen for the unit's display.

B. **Field Data Collection**

Contact NCCN GIS staff to have MobileMapper Office or Trimble Pathfinder Office software installed and to have specific GPS receivers initialized. See Appendices in the NCCN GPS Data Acquisition and Processing document for specific GPS unit operation details, at the website shown above.

Data dictionary *MountLakesXXXX.ddf* (where XXXX denotes the year) will be used for collecting field data with Trimble GPS units for bathymetry and habitat mapping. Users of the MobileMapper GPS® unit should be accessing the Bathymet.mmf data dictionary. The GIS Specialist is responsible for updating and loading the data dictionaries onto the units prior to GPS training and field data collection. Below is an example of the Trimble data dictionary used on NOCA's Trimble GeoXT® unit.

```
"MountLakes2010", Dictionary
"Map Benchmark", point, "", 1, seconds, 60, Code
  "Lake_code", menu, normal, normal
    "LS-06-01"
    "LS-07-01"
    "MA-03-01"
    "MC-03-01"
    "MC-10-01"
    "MC-14-02"
    "MR-05-01"
    "MR-09-01"
    "MR-12-01"
    "PM-01-01"
    "PM-12-01"
    "SM-02-01"
  "MBM_num", text, 5, normal, normal
  "Start_T", text, 30, normal, normal, Label1
  "End_T", text, 30, normal, normal, Label2
  "Notes", text, 50, normal, normal

"Other", point, "", 1, seconds, 1, Code
  "Lake_code", menu, normal, normal
    "LS-06-01"
    "LS-07-01"
    "MA-03-01"
    "MC-03-01"
    "MC-10-01"
    "MC-14-02"
    "MR-05-01"
    "MR-09-01"
    "MR-12-01"
    "PM-01-01"
    "PM-12-01"
    "SM-02-01"
  "Type", menu, normal, normal, Label1
    "WLB"
    "AirTemp"
    "WaterTemp"
    "Inlet"
    "Outlet"
  "WLBM_num", menu, normal, normal
    "1"
    "2"
  "Notes", text, 50, normal, normal
```

GIS Specialists are also responsible for loading lake imagery onto the GPS units. These images will be clipped from the most recent NAIP 1-m resolution imagery and saved in MrSid format to minimize image size.

C. **Transferring GPS Receiver Field Data to a Computer**
Field crews are required to transfer raw GPS files from GPS receivers to computers or network folders that are routinely backed-up after each tour of duty. Files will be transferred to an appropriately-named folder, such as "Raw" or "Backup," within the project workspace (see SOP 2: Project Workspace and Records Management). Detailed instructions on data transfer for each type of GPS unit are located in the Appendices of the NCCN GPS Data Acquisition and Processing document (*see* link above).

D. **Postprocessing GPS Data**
Ths GIS Specialist is responsible for post-processing raw GPS files and exporting them to GIS format. Detailed instructions on data processing for each type of GPS unit are located in the Appendices of the NCCN GPS Data Acquisition and Processing document (*see* link above). Files will be transferred to an appropriately named folder, such as "Processed" or "Export," within the project workspace (see SOP 2: Project Workspace and Records Management). Shapefiles are the most commonly used GIS format at NCCN. After export, shapefiles are used in bathymetry and habitat mapping procedures described in SOP 4: Lake Features and Bathymetric maps.

Literature Cited

North Coast and Cascades Network (NCCN). 2009. GPS data acquisition and processing. USDI National Park Service, North Coast and Cascades Network. Available online: http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm (accessed 13 April 2011).

SOP 4: Lake Features and Bathymetric Maps

April 19, 2011

Prepared by: Reed Glesne, NPS NCCN-NOCA, Steven Fradkin, NPS NCCN-OLYM, and Barbara Samora, NPS NCCN-MORA.

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Glesne, R., S. C. Steve Fradkin, and B. A. Samora. 2011. Standard Operating Procedure 4: Lake Features and Bathymetric Maps. *In* Glesne, R. S., S. C. Fradkin, B. A. Samora, J. R. Boetsch, R. E. Holmes and B. Christoe. 2012. Protocol for long-term monitoring of mountain lakes in the North Coast and Cascades Network: Version July 9, 2012. Natural Resource Report NPS/NCCN/NRR—2012/549. National Park Service, Fort Collins, Colorado.

Lake Features and Bathymetric Maps

Lake features and bathymetric maps provide basic information concerning lake depth, inlets and outlet locations, woody debris and aquatic plant locations, and riparian zone characteristics, and they also provide a map record of locations of water level benchmarks and bathymetry reference points and transects. Lake bathymetry data are used for calculating morphometric measurements including: surface area, shoreline length, maximum depth, mean depth, lake volume and retention time, and littoral zone area. Bathymetric mapping will be completed at the initial implementation of the monitoring project and every 20 years, thereafter. However, bathymetric maps would be completed following significant disturbance events in the lake catchment that affect lake morphometry, such as landslides or alterations of tributary inflow. Other lake features are updated on all subsequent visits. Methods were adapted from Hoffman et al. (2005).

Equipment and Materials

- Field Protocol Manual
- Laser TechTruPulse™ 200 laser rangefinder (with user manual and spare batteries)
- Compass (with user manual)
- Aerial photos
- Data forms
- Camera (with extra batteries)
- GPS receiver (MobileMapper® or Trimble GeoXT®)
- AA batteries for GPS receiver (4 per day)
- Short-range two-way radios (with extra batteries)
- NPS radio (with extra battery)
- Monopod or tripod (optional)
- Inflatable boat (1-2 boats with life jackets, paddles, pump)
- Handheld Sonar depth finder (with extra batteries)
- Clipboards and pencils

A. **Base Map Preparation**

1. Geo-referenced aerial photos are used to prepare working maps and for assistance in location of bathymetry reference points and transects, and water level benchmarks.

2. If aerial photos are not available, then lake maps are developed on site by taking additional distance and azimuth measurements (following methods in Section B.) at various points along the shoreline–water interface that define the shape of the lake.

3. General lake features such as talus slopes, bedrock outcrops, boulders, inlet and outlet streams, campgrounds, trails, and riparian vegetation characteristics within at least 100 m from the lake shoreline are obtained from aerial photos, GIS, and field observations, and sketched on the map. Riparian vegetative characteristics to be mapped include the following categories: meadow, shrub/meadow, shrub, conifer forest, mixed conifer/deciduous forest, bedrock, boulder, talus, alluvial deposition, and snow/ice. In addition, large woody debris accumulations, emergent, floating, and submergent categories for aquatic plants are sketched on the map.

B. **Bathymetry-Azimuth and Distance Method Option (NOCA)**

1. Mapping reference points and transects orginating from these points, for recording depths and distances, are established near the shore land-water interface and documented on the lake map. Detailed descriptions (including distances and azimuths to other benchmarks or landmarks) and GPS coordinates (if available) are recorded.

2. The number of survey reference points and transects required depends on the size and shape of the lake and distance from the reference point to the end of the transect. It is possible to have multiple transects on different azimuths originating from one mapping reference point. Reference points will be set <250 m from the farthest point along any transect to assure accurate laser distance readings (using a Laser Tech TruPulse™ 200). Generally, three to five mapping reference points are sufficient for lakes <6 ha. Additional reference points may be required for lakes with irregular shorelines.

3. Each transect follows a single azimuth with depth and distance from the reference point recorded along its course.

4. Bathymetric map data are collected by one crew member measuring depths from an inflatable boat and two crew members on shore. One shore-based crew member records distance and depth, while the other provides directions to keep the boat on course, measures distance with the rangefinder, and communicates depth information (via radio) from the boat operator to the data recorder.
   a. Short-range two-way radios are required for communication between crew members.
   b. The ends of each transect will extend from the land-water interface on one shore to the land-water interface of the opposite shore.
   c. A minimum of six to eight transects will be completed. Large lakes (i.e., >1 ha) and lakes with complex shorelines require additional transects to accurately record contour intervals.
   d. Transect start and end points are marked on the site aerial photo or map and are documented by azimuths (recorded in degrees, clockwise from true north – compass corrected for declination) and distance from survey map benchmarks (UTM coordinates from GPS can also be used if available) so that these points can be relocated during subsequent sampling visits to the site. In addition, photos of transect start and/or endpoints will be taken.

5. A handheld sonar device is used to record depths along each transect. A calibrated line can also be used to measure depth if a handheld sonar device is not available, but this method will take significantly longer to complete transects. Depth measurements will be made at approximately 5-10 m (horizontal) intervals.

6. During surveys, transect numbers, their corresponding depths and azimuth and distance from a mapping reference point are recorded on the Lake Mapping Data Form. (**Note**: if lake maps are not available, additional distance and azimuth measurements will be made to various points along the shoreline that define the shape of the lake.)

C. **Bathymetry – Radial Transect/GPS Option** (MORA)

1. The radial transect method requires two boats. One boat is anchored at the lake center point, or lake location where maximum depth is measured. Depth and GPS locations along transects radiating from the anchored boat are recorded by personnel in the second boat (methods following Section B are recommended where GPS reception is poor).

2. Generally, depths and locations are recorded along six to eight radial transects. The crew in the anchored boat guides crew in the other boat to keep the boat on course. The crew records azimuths for each transect and the GPS location of the anchored boat.

3. Transect start and end points are marked on the site aerial photo or map and are documented by azimuths (recorded in degrees, clockwise from true north – compass corrected for declination) and UTM coordinates from GPS (methods for GPS use are found in SOP 3) so that these points can be relocated during subsequent sampling visits to the site. In addition, photos of transect endpoints will be taken.

4. A handheld sonar device is used to record depths along each transect. A calibrated line can also be used to measure depth if a handheld sonar device is not available, but this method will take significantly longer to complete transects. Depth measurements will be made at approximately 5-10 m (horizontal) intervals.

5. During surveys, transect numbers, their corresponding depths and GPS locations are recorded on the Lake Mapping Data Form. (**NOTE**: if lake maps are not available, additional GPS locations will be taken for various points along the shoreline that define the shape of the lake.)

D. **Bathymetry: MobileMapper GIS Option (OLYM)**

This bathymetric determination method uses a combination of a high resolution GPS unit and a manual hand-held depth sonar. Staff use inflatable boats to survey the lake surface in a grid pattern, collecting coordinated GPS locations and depth measurements. Depth measurements at each GPS point are entered directly in the MobileMapper GPS unit. NCCN GIS staff download data once the unit is back from the field.

1. <u>General Considerations</u>
   a. Operation instructions for the MobileMapper GPS unit are found in SOP 3: GPS Data Collection.
   b. Battery life for the MobileMapper is ~ 8 hours with and ~16 hours without backlight. Unless needed, turn backlight off to conserve battery power. Press the PWR button for >2 seconds then release the button. Backlight will change from high to low. Repeat process to change from low to off.
   c. A minimum of four satellites are needed for the necessary 3D position calculation.
   d. Bathymetric measurements are best done when the PDOP (measurement of GPS error) is less than 8.
   e. For best data collection, hold the GPS vertically with the antenna up. Avoid blocking the signal with your head, body or other equipment.

2. <u>Starting a new set of bathymetric readings</u>

a. Turn on MobileMapper GPS and acquire at least four satellites.
b. When ready to collect a location, push the LOG button. Highlight Create New Job (Figure 4.1.A) and push **Enter**. Use the scroll arrows to get to **Clear** and push **Enter**. Use the scroll arrows and Enter button to type in a job file name. Scroll to OK when you are finished. File names are limited to eight characters.
c. Select **Bathymet.mmf** from the list of feature libraries as shown in Figure 4.1.B.
d. Select Post-processing from the **Job Mode**.
e. Open a file 10-15 minutes prior to collecting data at the first point.

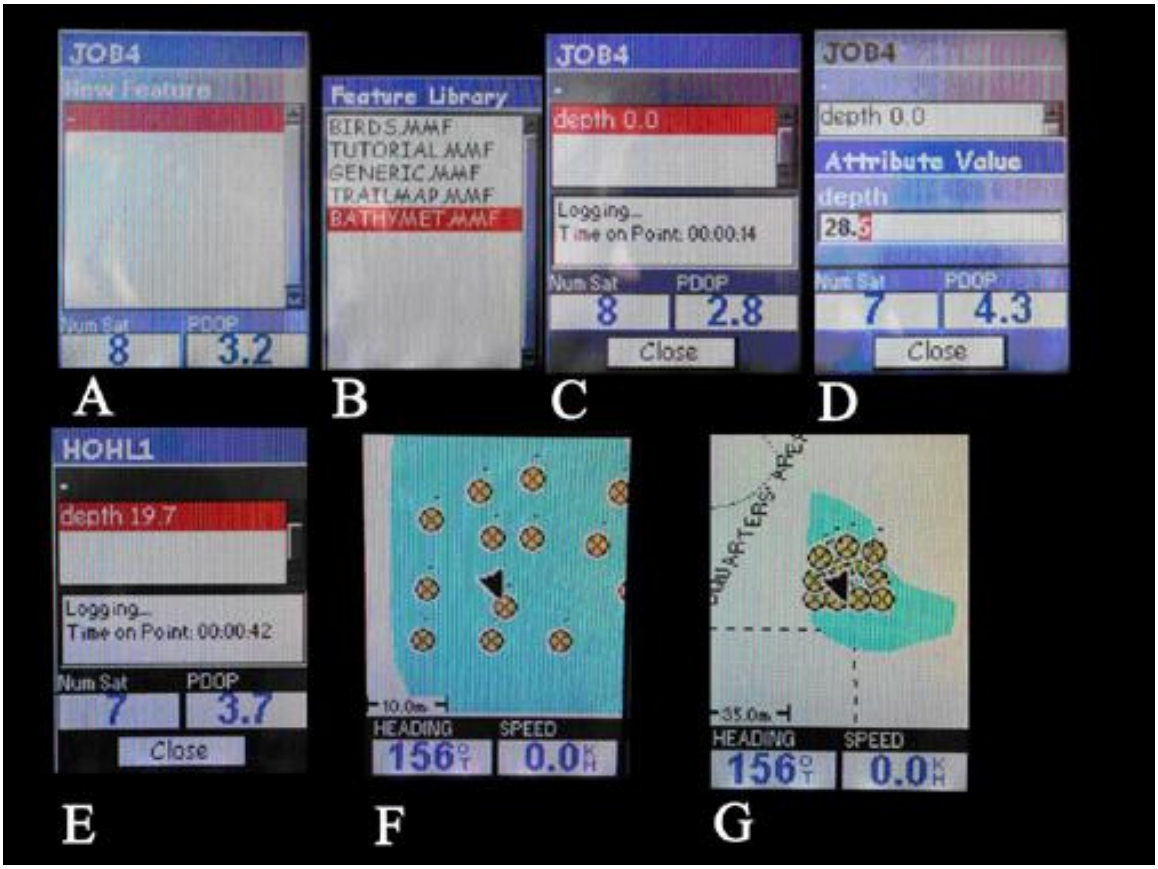


Figure 4.1. A-G: Screen captures from MobileMapper GPS unit illustrating key screens for conducting bathymetry.

3. Logging Readings
   a. At each sample point, stabilize position for 10-15 seconds before recording the sampling point.
   b. The GPS unit will not record data until at least four satellites are present. The number of satellites and the PDOP (an estimate of error) appears at the bottom of the screen.
   c. Hit **enter** at the new feature screen shown in Figure 4.1.C. to begin collecting data (Figure 4.1.D).
   d. To enter the depth measurement for this position, hit **enter** and you will see a screen like Figure 4.1.E. Using the cursor button to scroll to the correct value and hit **enter**. Wait approximately 30 seconds to fix the point and hit **close**.
   e. Repeat this process for each point where you take a depth reading.

f. At any time, you can press the NAV button to see a map view (Figure 4.1.F) of the data points you have collected and any available background map. The GPS unit will have an outline of the lake you are mapping in the background (as a blue polygon). Zoom in and out with the IN and OUT buttons (*see* Figure 4.1.G for a different scale). The yellow circles are your depth readings. The black arrowhead is your current location. North is up on the map screen.
g. After you have taken your last reading, press the menu button and chose "Close Job". Then acknowledge with "Yes".
h. Turn off the MobileMapper by pressing the PWR button followed by pressing ENTER.
i. If a break in logging points is needed, new points can be added to the same file via the **Open Existing Job** tab.

E. **Basin Aspect**
The basin area is delineated as a polygon in GIS, and then a Digital Elevation Model (DEM) is used in GIS to calculate the average aspect for that area. The average aspect for the basin is then reported in degrees.

F. **Maximum Depth**
A handheld sonar device or calibrated line is used to determine a site's deepest point. Additional depth soundings are required to verify the deepest point of the lake. When determined, the maximum depth, benchmark, azimuth and distance from the benchmark of its location are recorded on the Lake Mapping Data Form.

G. **Shoreline Perimeter**
Shoreline perimeter is initially determined using GIS with ortho-rectified aerial photos. In addition, perimeter is measured at the lake while collecting riparian disturbance data (*see* SOP 15). The entire shoreline length is measured using a metered tape, metered-marked line, or laser rangefinder. Length measurements are made at the water-land interface. The unit of measure is meters. Shoreline perimeter is measured during each visit and recorded on the Lake Mapping Data Form.

H. **Operation of Laser Tech TruPulse™ 200 Rangefinder** (Refer to User's Manual for details)
1. The laser rangefinder emits invisible, eye safe, infrared energy pulses to determine distance by measuring the time it takes for each pulse to travel to the target and back. Accurate targeting is facilitated by 7x optics with crosshairs.

2. Maximum measurement distances vary with target quality and environmental conditions. High quality targets are obtained from brighter colors and shiny surfaces. Overcast skies and shooting perpendicular to targets will increase maximum range. When shooting to a non-reflective target the maximum distance is approximately 1000 m, and 2000 m to a reflective target.

3. Accuracy is variable depending on the target quality (30 cm to high quality targets and 1 m to low quality targets). Target quality is indicated by the distance measurement.

Measurements taken on high quality targets will show a decimal place and measurements taken on low quality targets will show only whole numbers.

4. The rangefinder is capable of measuring inclination, slope distance, vertical distance, and horizontal distance using five different target modes. Distance measurements are recorded as follows:
   a. Press "FIRE" button (located on top) to turn power on.
   b. Looking through the eyepiece, if "METERS" are not already indicated use system setup mode to select measurement unit. Enter setup by holding the down arrow button (located on left side) for 4 seconds. Look through the eyepiece and press up or down buttons until "Units" are displayed on the screen. Press fire button to display unit of measurement (Yards, Meters, Feet) and move through choices with up or down arrows to METERS and select by pushing the "Fire" button.
   c. Either continuous or standard single shot target modes can be used. If not already indicated in the initial powering up, then enter the setup for target mode holding the up arrow button for 4 seconds. Use up or down arrows to highlight continuous mode (Con) or standard mode (Std). Select by pushing the "Fire" button.
   d. Look through eyepiece and press up or down buttons (located on the left side) to select the HD mode (Horizontal Distance). Horizontal distance is calculated by the rangefinder accounting for its tilt when the measurement is taken.
   e. To take a measurement, aim crosshairs at target and press and hold the "Fire" button until a target is acquired and a measurement is displayed. The "LASER" status indicator is displayed while the unit is active. If a target is not acquired then release the "Fire" button and repeat. Repeat measurement several times until a consistent reading is displayed. Slope distance, vertical distance, and inclination results can also be displayed by pushing the up or down arrows after a measurement is taken.
   f. Calibration of the inclination measurement is normally not required unless the instrument is dropped. However, re-calibration should be completed prior to each field trip. See user manual for details regarding calibration, precautions, and care and maintenance of this instrument.

I. Quality Assurance and Quality Control Procedures

1. Review measurement procedures with all employees each year. Conduct pre-season and on-site training for new employees.

2. Calculate and document observer bias and conduct QA audits as described in SOP 19, Section G.6.

3. Immediately following survey and before leaving the site, check to verify that all forms are complete and readable.

4. Calibrate inclination measurement of laser rangefinder prior to each field session and if the unit is dropped (*see* user's manual).

5. Perform a calibration field check of the sonar depthfinder during the beginning and midpoint of each field season. Calibration check requires three measurements with

depthfinder at or near the deepest part of the lake and is compared to measured depth using a meter-marked weighted line. Record results on Lake Mapping Data Form.

6. Refer to SOP 3 for GPS quality control procedures.

7. Bathymetric Mapping reference points should be documented with GPS coordinates and drawn on aerial photos.

J. **Data Forms** (*see* Appendix C: Field and Laboratory Data Forms)
   1. Mountain Lake Daily Sampling Checklist
   2. Trip Photo Log
   3. Lake Bathymetry Data Form (includes bathymetric and shoreline mapping data, maximum depth and lake perimeter data)

K. **Specific Safety Considerations** (*see* SOP 24: Field and Laboratory Safety)
   1. Use of Laser Tech TruPulse™ rangefinder (*see* Laser Tech TruPulse™ rangefinder User Guide)
   2. Water safety (using inflatable boat and wading)
   3. Hypothermia

Literature Cited

Hoffman, R. L., T. J. Tyler, G. L. Larson, M. J. Adams, W. Wente, and S. Galvan. 2005. Sampling protocol for monitoring abiotic and biotic characteristics of mountain ponds and lakes: U.S. Geological Survey Techniques and Methods 2-A2. U.S. Geological Survey, Reston, VA.

SOP 5: Water Level Measurement

April 19, 2011

Prepared by: Steven Fradkin and Bill Baccus, NPS NCCN-OLYM, and Reed Glesne NPS NCCN-NOCA.

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Water Level Measurement

Water level is an important index that provides information on lake hydrology. Water level relates directly to the hydrologic cycle and water balance of lakes. When combined with additional measures it can help determine the residence time of lake waters and associated nutrient fluxes. As lake levels change, either seasonally or inter-annually, shoreline and littoral biota can be affected as shoreline habitat characteristics change. Long-term shifts in lake level patterns can aid in the interpretation of climate fluctuations or other external processes within the watershed or region.

Mountain lakes in the NCCN parks typically occur in small watersheds comprised of glacial cirques or bedrock benches. The water in these lakes originates from a variety of sources: snow melt and surface streams within the drainage basin, groundwater seepage below the lake's surface, and precipitation (rain or snow) directly onto the lake surface. Water exits the lake either from an outlet stream, seepage into the groundwater table, or by evapotranspiration. Lake level at a point in time is the difference between net inflow and net loss of water from the lake as previously described.

Maximum water level typically occurs in NCCN mountain lakes shortly after snow melt when the winter's precipitation, captured and stored as snowpack, rapidly flows from the basin into the lake. This is followed by a steady draw down, as inflow decreases and outflow remains steady. In most cases, the minimum water level is determined by the bedrock elevation of the existing lake outlet. An exception may occur in lakes where seepage plays a large role in outflow. In these lakes, no water will flow from the outlet in late summer and lake level can be drawn below the elevation of the outlet.

Water level methods adapted with modification from Hoffman et al. (2005).

Equipment and Materials

General

- Field Protocol Manual
- Data forms
- Camera (with extra batteries)
- Clipboards and pencil

Water Level Method

- Clear plastic tubing (6 mm inside diameter, ~20 ft length)
- Measuring tape (centimeters)
- Tent rods (2)
- Velcro Straps
- Backpacker water filter (pump)

String Level Method

- Line level
- Measuring staff (metric)
- Marine epoxy glue

- Nylon cord

A. **Water Level Benchmark Location**

1. On the initial lake visit, park staff will identify and permanently mark two benchmark locations for measuring lake level. More than a single benchmark is established to ensure that if one benchmark is destroyed, either through catastrophic change or human tampering, a second benchmark is still available. This second benchmark and associated lake level measurement also allows for a redundant measurement which can be referenced in the case of unusual or questionable data results at the first benchmark.

2. Benchmark locations will meet the following criteria
   a. Benchmark will be located on bedrock or large boulders whose position and integrity are not easily altered by natural processes or human tampering.
   b. Benchmark will be established at an elevation at least 1 m above the "normal" high water mark (as determined by establishment of shoreline plants, lichens, and mineral staining).
   c. Duplicate benchmarks will be separated geographically, occurring on different ends or sides of the lakeshore.

3. Lake Level benchmark locations are permanently marked using marine epoxy (i.e., ZSpar® Splash Zone, Figure 5.1). A small amount of marine epoxy is mixed and then affixed to a level rock surface. The epoxy marker will be roughly the size of a silver dollar, flattened and 5-10 mm thick. A pencil or tent pole tip is inserted into the center of the wet epoxy marker to create a permanent divot (marked with crosshairs as in Figure 5.1 below) used for later measurements. The wet epoxy is also scribed (e.g., "L1" or "L2") to identify the type and number of the benchmark.



Figure 5.1. Water level benchmark example.

4. Benchmark locations are marked on the lake aerial photo and/or map(s) and detailed descriptions (including azimuth and distance to other landmarks or mapping bench marks) with GPS coordinates (if available) are recorded.

5. In addition to establishing GPS coordinates, locations of benchmarks are photo documented as described in SOP 18, Section B.2. Photo number, type, date, and description are recorded on the Trip Photo Log Form (Appendix C).

B. **Lake Water Level Measurement**

1. Lake level will be measured from each benchmark at each lake during every visit.

2. Measurement of water level will be completed around the same date during each sampling season. However, replication of sampling dates among years will vary with seasonal temperature patterns affecting ice-out and snowmelt conditions.

3. The time of measurement will be recorded (some lakes that drain snowfields or glaciers can show significant daily fluctuations in lake level). Measurements of lake water level in subsequent visits will be taken near the same time of day as the initial visit.

4. Lake level determination can be accomplished through either the "Water Level" or "Line Level" methods. Each method results in a determination of the distance from the lake water surface to the top of the epoxy benchmark. The particular measurement method chosen for any lake will be used in successive years at that lake. If the method is changed in the future, then the reason for the change must be documented and comparisons of the two methods are conducted and documented following the procedures in SOP 19, Section H: Cumulative Bias.

5. Both methods require a minimum of two crew members.

6. <u>"Water Level" Method</u> (*see* Figure 5.2)
   a. Locate the lake level benchmark.
   b. Assemble tent poles.
   c. Attach tubing to the inlet nipple of a backpacker water filter. Use the pump to completely fill the tube with water. Detach the tube from the pump and cover both ends to ensure the tube remains filled with water.
   d. Place one tent pole in the divot on the water level benchmark. Place the second tent pole anywhere along the lakeshore with the bottom end of the pole on the surface of the substrate below water level. Hold both poles vertically.
   e. Attach (with zip-ties) the water-filled tubing to both tent poles. Then drain enough water from the tubing (if needed) to ensure that the resulting meniscus is in the viewable part of the tubing on each pole.
   f. Using a flexible tape measure, measure the vertical distance from the meniscus on each pole to either the top of the benchmark (measurement "A" in Figure 5.2), or the surface of the water (measurement "B" in Figure 5.2). Record both values on the data form.

g. Determine relative lake level by subtracting the value of A from the value of B (Relative Lake Level = B-A) and record on the data form. When the first measurement is subtracted from the second, the result is the distance from the surface of the benchmark to the water. When that distance is greater than previous measurements, it means that the water level of the lake has gone down. If the distance is less than previous measurements, the water level of the lake has risen.
h. Repeat the measurements for a total of three replicate measurements.

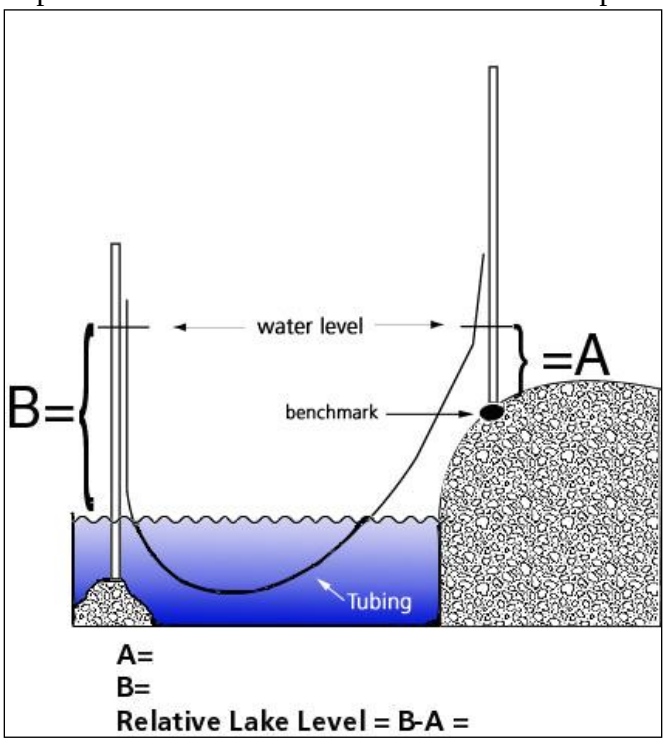


Figure 5.2. Set-up diagram of the "water level" method of lake level determination.

7. Line Level Method (*see* Figure 5.3.)
   a. Place a measuring staff into the water a minimum of 1 m distant from the benchmark. Make sure that the bottom of the staff will rest below water level on the surface of the bottom substrate. Check the staff to make sure that it is in a vertical position.
   b. Using small diameter nylon cord, hold one end of the cord to the top of the epoxy benchmark.
   c. Extend the cord from the benchmark to just past the tent pole.
   d. Attach the line-level to the cord and make certain that the cord is taught and level. Mark the point where the extended cord crosses the measuring staff and measure the distance from this point to the surface of the water. Record this distance in centimeters as relative lake level (L).
   e. Repeat the measurement for a total of three replicate values.

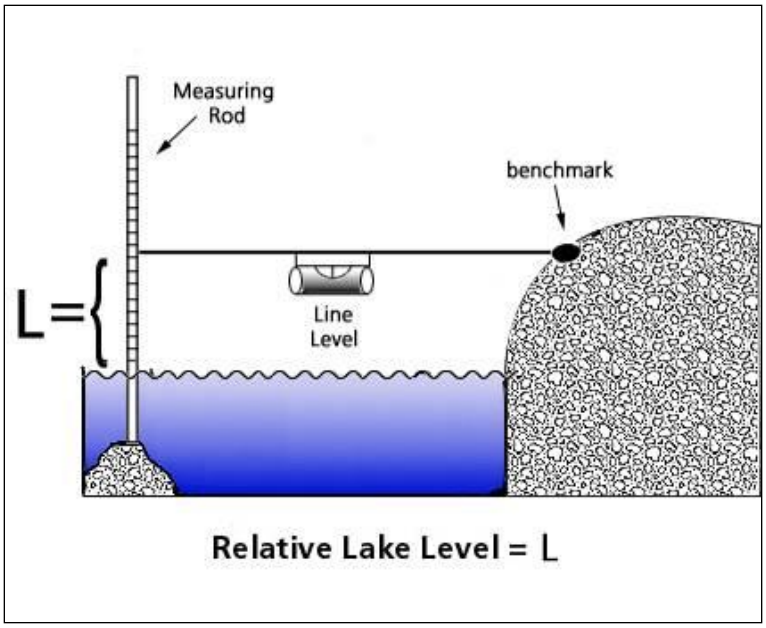


Figure 5.3. Set up diagram of the "Line Level" method of lake water level determination.

C. **Quality Assurance and Quality Control Procedures**

1. Review measurement procedures with all employees each year. Conduct pre-season and on-site training for new employees.

2. Calculate and document observer bias and conduct QA audits as described in SOP 19, Section G.6.

3. Follow procedures in SOP l9 for determining measurement precision and sensitivity (frequency of measurement, sample size requirements, calculation methods, and documentation are described in SOP 19: Sections G.4-5, Section I.2, Tables 19.2-19.3, and in SOP 22).

4. Procedures for documenting and assessing cumulative bias (SOP 19, Section H) must be followed for any changes in key field staff, contactors, instruments, methods, or indicators.

5. Immediately following survey and before leaving the site check to verify that all forms are complete and readable.

6. Time of recording water level during successive visits will be standardized to minimize diel variation.

7. Replicate measurements of water level are required.

8. GPS coordinates and photos (recorded in the Trip Photo Log form) for water level benchmarks should be documented.

D. **Data Form** (*see* Appendix C: Field and Laboratory Data Forms)
   1. Mountain Lake Daily Sampling Checklist
   2. Trip Photo Log
   3. Water Level Form (string level method)
   4. Water Level Form (Tygon tube method)

E. **Specific Safety Considerations:** (*see* SOP 24: Field and Laboratory Safety)
   1. Water safety (lake and stream wading)

Literature Cited

Hoffman, R. L., T. J. Tyler, G. L. Larson, M. J. Adams, W. Wente, and S. Galvan. 2005. Sampling protocol for monitoring abiotic and biotic characteristics of mountain ponds and lakes: U.S. Geological Survey Techniques and Methods 2-A2. U.S. Geological Survey, Reston, VA.

SOP 6: Water Clarity Measurement

April 19, 2011

Prepared by: Steven Fradkin and Bill Baccus, NPS NCCN-OLYM, and Reed Glesne NPS NCCN-NOCA.

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Fradkin, S. C., B. Backus, and R. S. Glesne. 2011. Standard Operating Procedure 6: Water Clarity Measurement. *In* Glesne, R. S., S. C. Fradkin, B. A. Samora, J. R. Boetsch, R. E. Holmes and B. Christoe. 2012. Protocol for long-term monitoring of mountain lakes in the North Coast and Cascades Network: Version July 9, 2012. Natural Resource Report NPS/NCCN/NRR—2012/549. National Park Service, Fort Collins, Colorado.

Water Clarity Measurement

Water clarity is an index of light transmission through lake water. Transparency of mountain lakes water is affected by the cumulative concentrations of dissolved solids, pigments, phytoplankton and suspended sediments. Each of these substances is important to the function of lake biogeochemical processes and biological productivity. Water clarity is also an important aesthetic characteristic of mountain lakes.

While light transmission can be determined using modern electronic instrumentation, NCCN parks use the simple and widely accepted Secchi disk depth methodology. In this method, the depth of transparency is determined as the mean depth of the point where a weighted black & white 20-cm diameter disk disappears when viewed from the lake surface, and the point where it reappears upon raising it after it has been lowered beyond visibility. This SOP is modified from Hoffman et al. (2005).

General Considerations

- Secchi depth will be measured between 10:00 am and 2:00 pm to standardize ambient light levels.
- If possible, Secchi disk depth will be measured under calm conditions.

Equipment and Materials

- Field Protocol Manual
- Data form
- Secchi Disk with carabiner
- Measured line (0.5 m marks)
- Ruler in centimeters
- Viewing tube
- Small stuff sack/mesh bag (for weighting down disk)
- Inflatable boat, life jacket, paddles
- Sonar depth finder (with extra batteries)
- Clipboard and pencils

A. **Site Selection**

Water clarity is always measured at the permanent buoy sampling station at the deepest point in the lake.

B. **Water Clarity Measurement**

1. Place several small rocks in a small mesh bag and attach it to the clip on the bottom of the Secchi disk. Attach the disk to a measured line marked with 0.5 m intervals.

2. Paddle to the deepest point of the lake and attach the inflatable boat to the continuous temperature array monitoring buoy.

3. On the non-sunny side of the inflatable boat, use a viewing tube that penetrates the lake surface. Allow the disk to descend until it disappears from view. Raise and lower the disk

several times to obtain consistency in the measurement of the depth of disappearance of the disk.

4. When the disk has disappeared from view, hold the disk in the same location, lift your head from the water and using a ruler record the distance in 0.1 m units from the nearest 0.5 m mark on the line to the Secchi measurement location on the line at the surface of the water. Record this as the first descend depth.

5. Returning your face to the water, slowly pull the disk towards the surface. When the disk returns to view, hold the disk in the same location, lift your head from the water and repeat measurement (as in 4 above). Record this as the first ascend depth measurement.

6. Secchi disk depth is calculated by the recorder as the average of the recorded descend depth and ascend depth.

7. The observer should then pull the Secchi disk towards the surface until it is several meters above the previous disappearance point and then repeat the descending and ascending depth measurements two more times.

8. The time, lake surface condition, and weather at the time of the Secchi disk depth measurements should be clearly and accurately recorded on the data form.

C. **Quality Assurance and Quality Control Procedures**

1. Review measurement procedures with all employees each year. Conduct pre-season and on-site training for new employees.

2. Calculate and document observer bias and conduct QA audits as described in SOP 19, Section G.6.

3. Follow procedures in SOP l9 for determining measurement precision and sensitivity (frequency of measurement, sample size requirements, calculation methods and documentation are described in SOP 19: Sections G.4-5, Section I.2, Tables 19.2-19.3; and in SOP 22).

4. Procedures for documenting and assessing cumulative bias (SOP 19, Section H) must be followed for any changes in key field staff, contactors, instruments, methods, or indicators.

5. Do not rely on memory – always read protocol.

6. Immediately following survey and before leaving the site check to verify that all forms are complete and readable.

4. It should be remembered that nylon lines or ropes used for any depth related measurements will be checked to determine if recalibration related to stretching of the line is needed at the beginning of each field season. Additional measurement error can

result in how the measuring line is attached to equipment. For each type of equipment, the distance between the equipment and the first mark on the line will always be checked. This is necessary for sampling trips where the same depth measuring line is used for water sample bottles, plankton nets, and the Secchi disk. Measurement error also can be associated with how the line is secured to the equipment and how far it is located from the effective sampling surface of the equipment (e.g., the measuring line for the plankton net is attached to a bridal that extends several centimeters in front of the net opening). Deployment depth measurement must be adjusted to account for the discrepancy in distance from the net opening to the first depth mark on the line. Metal clips are recommended for marking depth intervals on lines or ropes, although lines or ropes can also be marked using a pen with permanent ink (e.g., Sharpie).

D. **Data Forms** (*see* Appendix C: Field and Laboratory Data Forms)
   1. Mountain Lake Daily Sampling Checklist
   2. Water Clarity, Zooplankton and Lake Profile Form

E. **Specific Safety Considerations** (*see* SOP 24: Field and Laboratory Safety)
   1. Water safety (using inflatable boats)
   2. Hypothermia

Literature Cited

Hoffman, R. L., T. J. Tyler, G. L. Larson, M. J. Adams, W. Wente, and S. Galvan. 2005. Sampling protocol for monitoring abiotic and biotic characteristics of mountain ponds and lakes: U.S. Geological Survey Techniques and Methods 2-A2. U.S. Geological Survey, Reston, VA.

SOP 7: Instrumented Water Column Profiles (Temperature, Dissolved Oxygen, Specific Conductance, pH)

April 19, 2011

Prepared by: Steven Fradkin, NPS NCCN-OLYM, and Barbara Samora, NPS NCCN-MORA.

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Instrumented Water Column Profiles

Vertical profiles of physical and chemical parameters provide key information on the vertical structure of the water column. The standard profiles considered in this SOP are temperature, dissolved oxygen (DO), specific conductance, and pH, all of which are required core water quality parameters by the NPS Water Resources Division (NPS 2002). This information provides insight into the fundamental processes that govern lake ecosystem dynamics. Temperature profiles illustrate the degree of thermal stratification occurring between the warmer upper water layer (epilimnion) and the colder lower water layer (hypolimnion). Presence of stratification is used to determine sampling depths for chemical parameters (SOP 9: General Water Chemistry). Dissolved oxygen profiles illustrate the amount of oxygen available for organism respiration. Specific conductance and pH provide indices of the ionic strength and concentration of dissolved ions that affect organismal growth and metabolism. The methods described in this SOP are modified from Hoffman et al (2005). Water column profiles at all NCCN parks will be conducted via a YSI 600XLM datasonde that continuously measures and records temperature, DO, specific conductance, and pH.

General Considerations:

- Water column profiles are conducted from inflatable boats at the permanent sampling station in the deepest part of the lake adjacent to the continuous temperature monitoring buoy array (*see* SOP 8: Continuous Temperature Sampling).
- Temperature, DO, specific conductance, and pH are measured at 1-m intervals from the lake surface to within 1 m of the lake bottom for lakes with maximum depth ≥5 m. Measurement intervals of 0.5 m are used for lakes with maximum depths <5 m.
- Water column profiles are to be conducted between 10:00 am and 2:00 pm.
- Units of measurement for profiles are: depth in meters (m), temperature in ºC, DO in mg/l, specific conductance in µS/cm, and pH in pH units.

Equipment and Materials

- Field Protocol Manual and appropriate data forms
- Temperature/DO/specific conductance/pH instrument (YSI Model 600XLM) and operation manual
- Extra probe membranes (where appropriate)
- pH 7 and 4 buffer solution
- Conductivity 1413 µS and 100 µS standard solution
- C-cell batteries (4) for YSI meter
- Small stuff sack (for weighting of probe)
- Inflatable boat, air pump, life jacket, paddles

I. Stratification Criteria

Thermal stratification occurs when the warm upper water layer (epilimnion) and cold lower water layer (hypolimnion) are separated by a third layer (metalimnion) that is characterized by rapidly decreasing water temperature. When strong stratification occurs, the epilimnion and hypolimnion are isolated from mixing by a strong thermal density gradient. In NCCN mountain lakes, such stratification can only occur during the brief (~3 month) ice-free summer season. The sampling period proposed in this protocol (mid-August through September) coincides with the period when lakes would be stratified, if they ever are during the year. Prior to the sampling period, lakes are still warming up post-thaw-out, and after this period lakes begin to cool, breaking down any stratification with the onset of cooler fall weather. Stratification is of interest in this protocol because increases in the frequency and intensity of stratification would suggest trends in lake warming, possibly due to climate change. Additionally, strong stratification triggers a change to our sampling strategy for water chemistry analyses because strongly isolated water layers may have very different chemical properties (see SOP 9: General Water Chemistry: Filtered and Unfiltered Samples).

Weakly stratified lakes have a relatively small vertical water temperature gradient, resulting in a metalimnion that presents a low thermal resistance to mixing. This low resistance allows wind-induced currents to gradually entrain deeper waters into the mixed zone, thereby inhibiting substantial differences in vertical chemical concentrations (Bukaveckas and Driscoll 1991). By contrast, strong stratification results in a metalimnion that presents a high thermal resistance to mixing, allowing epilimnetic and hypolimnetic chemical concentrations to deviate substantially. The Relative Resistance to Thermal Mixing (RTRM) can be calculated and used to identify strongly stratified lakes (Wetzel 1983, Buckaveckas and Driscoll 1991). The RTRM is calculated as the ratio of the water density difference between the top and bottom of the metalimnion and the density difference between 5 and 4 °C (Wetzel 1983), or:

$$RTRM = \frac{(\partial M_{top} - \partial M_{bot})}{(\partial W_{5^\circ} - \partial W_{4^\circ})}$$

Where ∂M_{top} = water density at the top of the metalimnion, ∂M_{bot} = water density at the bottom of the metalimnion, ∂W_{5° = water density at 5°C, and, ∂W_{4° = water density at 4°C.

Lakes with an RTRM >100 are considered to be strongly stratified (Bukaveckas and Driscoll 1991). RTRM values can be calculated for all of the combinations of top and bottom metalimnetic water temperatures likely to be encountered in NCCN mountain lakes to determine which combinations denote strongly stratified lakes (i.e. RTRMs >100). These latter combinations are illustrated in Table 7.1.

Table 7.1. Top and bottom metalimnetic water temperatures and corresponding Relative Resistance to Thermal Mixing values.

Top °C	Bot °C	RTRM	Top °C	Bot °C	RTRM	Top °C	Bot °C	RTRM	Top °C	Bot °C	RTRM	Top °C	Bot °C	RTRM	Top °C	Bot °C	RTRM
20	15	112	19	14	105	18	12	113	17	11	104	16	9	105	15	7	100
20	14	130	19	13	121	18	11	126	17	10	115	16	8	113	15	6	105
20	13	146	19	12	136	18	10	138	17	9	126	16	7	120	15	5	108
20	12	161	19	11	150	18	9	148	17	8	134	16	6	124	15	4	109
20	11	175	19	10	162	18	8	156	17	7	141	16	5	127			
20	10	187	19	9	172	18	7	163	17	6	145	16	4	128			
20	9	197	19	8	180	18	6	168	17	5	148						
20	8	205	19	7	187	18	5	171	17	4	149						
20	7	212	19	6	192	18	4	172									
20	6	217	19	5	195												
20	5	220	19	4	196												
20	4	221															

From Table 7.1, one can see that strong thermal mixing occurs only in lakes where the top of the metalimnion reaches at least 15°C. When the top of the metalimnion is greater than 18°C, lakes are usually strongly thermally stratified. In practice, the top and the bottom of the metalimnion will be estimated conservatively using data from the automated datasonde profile on the day of sampling. When there is doubt which depth is the true top or bottom of the metalimnion, the top of the metalimnion will always be estimated to the uppermost plausible depth, provided that it is at least 1 m below the surface. The bottom will always be estimated to be the lowermost plausible depth, thus ensuring the strongest gradient for consideration. Preliminary analyses with a Mount Rainier dataset from six lakes across three years showed this method for determining strong stratification to be very effective.

II. Automated Datasonde Profiles

A. **Calibration of the 600XLM Sonde** (pg. 29 in the YSI instruction manual)

1. The 600 XLM is calibrated using either a connected laptop computer or a YSI Model 650 MDS handheld interface.

2. Follow in-lab calibration procedures for the YSI 600XLM Sonde setup (pg. 29, YSI instruction manual) and calibration of Specific Conductance (pg. 33, YSI instruction manual). A 1413 µS standard is used for calibration of Specific Conductance, and an optional calibration check is done using a 100 µS standard to confirm linearity. A two-point calibration is used for pH (pg. 35, YSI instruction manual). pH buffers used in the two point calibration are selected based on the range of expected field values (NOCA and MORA use pH 4 and 7 buffers, OLYM uses pH 7 and 10 buffers).

3. Field calibration is required for setting the altitude and calibrating Depth and Level (pg. 35, YSI instruction manual), and Dissolved Oxygen (pg. 33, YSI instruction manual) (**Note**: do not let DO probe dry out).

B. **Start Logging before deploying the Sonde** (pg. 110, YSI instruction manual)

1. Connect the datasonde to either a laptop or a handheld 650 MDS. Check to make sure that the **Power Sonde** function is not selected (the box is unchecked) in the **650 Main Menu/System setup**. This will ensure that the sonde is not being powered by the handheld unit and the actual battery life of the sonde is being read. If the Power Sonde box is not selected and the batteries in the sonde are dead, the handheld unit cannot

connect to the sonde. The default setting is for the Power Sonde function to be selected on the handheld unit and must be examined each time the sonde is used.

2. In the **Sonde Menu** select **Run** on the main menu. Next select **Unattended Sample** under the run menu followed by selection of **Start Date and Time**

3. Check to make sure these settings are selected:
   a. **Interval = 5 sec** (00:00:05)
   b. **Duration** (days = 365)
   c. **File** Structure**,** save as: MMDDYY_ _ (where _ _ = Lake Name)
      press the same button several times to select a new number or letter
   d. **Site** (leave blank)

4. Check **Battery Life** (displays battery life in days/hours; if battery life is below 1 day, change batteries.). Next, check **Free Memory** and remove any "test" files. Go to **Menu** and **Delete All Files** after ensuring that previous sampling data files have been downloaded and backed up at the lab.

5. Check first sample time and check the parameters that will be logged (i.e., Temp., Specific Cond. µS/cm, DO sat%, DO chg, Depth meters, pH, pH mv, Battery volts). To disconnect any parameters not being used, go to **System Setup** and select **Parameters**. Deselect the parameter(s) that is (are) not needed.

6. Select **Start Logging** at the bottom of the run menu (It will ask you if you are sure and answer "Yes").

7. Press **Esc** until the sonde disconnects, and then turn off the power to the handheld unit.

8. Remove cable and **put waterproof cap on cable connection on Data Sonde!!**

9. Replace calibration cup with field protection cup before deploying.

C. **Deploying the YSI 600XLM Sonde**

1. Attach the YSI unit to a marked line, using a locking carabiner.

2. Ensure that the marked line is locked to the loop in the inflatable boat.

3. Lower the YSI unit attached to the line, stopping at the surface and then each 1 m interval (0.5 m for lakes <5 m maximum depth) until reaching a depth of 1 m above the bottom of the lake. (**Note**: The line should be calibrated to make sure that probe end of the Sonde is located at the interval depth being measured). The instrument should remain suspended at each depth station for 2 minutes to allow the instrument to stabilize and collect sufficient data.

D. **Field Data Downloading, Data Checking, and Procedure for Stopping Logger**
The YSI 650 MDS handheld unit is used for downloading data from the YSI 600XLM Sonde and for checking the data collected.

1. Downloading Sonde data to the 650 MDS handheld unit
   a. Select **Sonde Menu** from the 650 MDS main menu (handheld unit will connect to sonde).
   b. Select **File** then **Upload.**
   c. Select the desired file then **Upload** and **proceed.**
   d. Select **PC 6000**, file will download to handheld unit.
   e. Press **Esc** to go back to the main menu and disconnect from the sonde.
   f. Turn off the power to the handheld unit.
   g. Remove the handheld unit from connection to the sonde.

2. Checking Data in the field using the Handheld 650 MDS
   a. From the 650 MDS main menu, select **view file** (see data)
   b. Select file to view and press **Enter** or select **plot file** (see graph).
   c. Select parameter to view then select **plot**.
   d. Check to see if the data collected makes sense.

3. Procedure to Stop Logging (pg. 111,YSI instruction manual)
   a. Connect the handheld unit to the sonde using the adapter cable.
   b. Turn on the power to the handheld 650 MDS.
   c. Select **Run** from the **Sonde Menu**.
   d. Select **Unattended Sample** from the run menu.
   e. Scroll to the bottom of the screen and select **Stop Logging** (the unit will ask you to verify that answer, select **Yes**).
   f. Press **Esc.** to go back to the **Sonde Menu**.
   g. Go to **File** and select **Upload**.
   h. Select **File By Name** and press **Enter**.
   i. Select **Proceed**.
   j. Select **PC6000**. Now the file has successfully been downloaded.

E. **Quality Assurance And Quality Control Procedures**

1. Review measurement procedures with all employees each year. Conduct pre-season and on-site training for new employees.

2. Calculate and document observer bias and conduct QA audits as described in SOP 19, G.6.

3. Temperature probe calibration is completed at the beginning and end of the field season following procedures in SOP 8, A.6-7.

4. Instrument calibration for pH, and Specific Conductance require calibration before each site visit and before and after sample measurement in the field (QC assessment of instrument bias in the field requires multiple calibration checks, *see* SOP 19, Section G.6).

5. The condition of the DO probe is checked for air bubbles or wrinkles in membrane, and replaced if necessary, prior to each application. DO is calibrated in the field immediately prior to taking measurements.

6. Follow procedures in SOP l9 for determining measurement precision and sensitivity for pH, Specific Conductance, DO, and Temperature (frequency of measurement, sample size requirements, calculation methods, corrective actions and documentation are described in SOP 19: Sections G.4-5, Section I.2, Tables 19.2-19.3; and in SOP 22).

7. Procedures for documenting and assessing cumulative bias (SOP 19, Section H) must be followed for any changes in key field staff, contactors, instruments, methods, or indicators.

8. Immediately following survey and before leaving the site check to verify that all forms are complete and legible.

9. Note any discrepancies or measurement problems and corrective actions taken on the field data form.

10. YSI operation manual maintenance and probe cleaning recommendations are followed and documented (*see* SOP 17: Post Field Season Activities).

F. **Data Forms** (*see* Appendix C: Field and Laboratory Data Forms)
   1. Mountain Lake Daily Sampling Checklist
   2. Water Clarity, Zooplankton and Lake Profile Form
   3. Temperature Sensor Calibration Form
   4. YSI 600 XLM – Lab Calibration Record Log (OLYM)
   5. YSI 600 XLM – Lab Calibration Record Log (NOCA/MORA)

G. **Specific Safety Considerations** (*see* SOP 24: Field and Laboratory Safety)
   1. Water safety (using inflatable boat and wading)
   2. Hypothermia

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SOP 8: Continuous Air and Water Temperature Sampling

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Continuous Air and Water Temperature Sampling

Temperature is a major driver of the physical, chemical, and biological processes within lakes. The dominant source of heat to mountain lakes is direct absorption of sunlight. Additional heat can also be transferred directly from air masses, water vapor, sediments, precipitation, and surface and groundwater inputs. Dominant annual heat loss stems from conduction to colder air masses and to a lesser extent evaporation and outflow of heated surface waters.

During winter months, lakes in the NCCN are ice covered and the water column of the lakes are generally isothermal (uniform temperature) just above freezing. In early summer, shortly after ice-off, surface waters of the lakes begin to heat and thermal stratification (the heating of lake waters in distinct density/temperature layers) begins, with warmer, less-dense water at the lake surface. In late fall, decreasing solar input and air temperatures rapidly cool the surface waters of mountain lakes. In deeper and larger lakes, the surface temperature change, combined with turbulent mixing by winds leads to a breakdown of stratification known as "fall turnover". By winter, mountain lake water returns to a cold, isothermal state and ice cover returns to the lake surface.

A number of temperature response variables representing degree days and seasonal minimums, maximums, and mean temperatures are proposed (SOP 21: Data Analysis, Table 21.5) for interpreting trends in water temperature. These are also important covariates used in the interpretation of biological and chemical parameters sampled in the monitoring project. In addition, the timing of "ice-on", "ice-off", and "fall turnover" are also determined. Ice-on and ice-off dates are useful indicators of climate change (Magnuson et al. 2000).

Equipment and Materials

- Six temperature data loggers (Top/Mid/Bottom, Backup 1 and 2, and Air Temperature), base station, and software (commonly used options available through Onset Computer Corporation)
  - HOBO® Water Temperature Pro v2 data loggers (Onset Part # U22-001)
  - TidbiT® data loggers (Onset Part # UTB-001)
  - HOBOware® Pro software
  - Optic USB Base Station (for U22-001)
  - HOBO® Waterproof Shuttle with appropriate coupler (for use with both loggers)
- Certified Reference Thermometer (HB Instruments, -8°C to 32°C, 0.1^{o}C accuracy, 0.1^{o}C reporting limit – VWR Part # 61099-035).
- Hand held sonar device (depth finder)
- Solid braided nylon rope (3/16th in. diam.)
- Two heavy duty nylon mesh bags (canoe anchors)
- One small mesh bag for weighting surface buoy
- One surface buoy
- One smaller sub-surface buoy
- Meter tape
- Small loop ties.
- Six nylon cable ties (6-7 in. long)
- Watch

- Knife
- Compass
- Lake map
- Field Protocol Manual
- Data Forms

A. **Pre- and Post- Field Calibration Checks**

Calibration checks (following Schuett-Hames et al. 1999 and Ward 2003) are used to document logger bias and performance to assure the quality of the data. Calibration checks are completed in advance of logger deployment and the post-deployment calibration checks are done shortly after the sampling results have been downloaded and backed up. (**Note**: other field thermometers or thermistor thermometers used in the study to collect site temperature measurements also need to be checked during this process so any necessary correction factors can be applied to results from these devices.).

1. Temperature loggers undergoing a calibration check should be programmed for a delayed start and set to record point measurements every (1) minute (refer to temperature logger manufacturer's software manual and Section E below).

2. Temperature logger calibration checks require at least two water bath temperatures that bracket the expected sampling range (near 20 and 0°C) during checks. The preferred method is to place one open cooler half full of water over night in a room that has a constant air temperature near the upper end of the temperature sampling range. For the lower end of the temperature range, crushed ice with a little water is placed in an insulated container (the container is placed in a refrigerator during the calibration check).

3. At least ten measurements per temperature logger at one minute intervals should be obtained at each of the two target temperatures. The temperature loggers are started and given about 15 minutes of acclimation time after they have been transferred into a water bath (the sensor end of the logger should be placed down and completely submerged). The water should be gently stirred to ensure a uniform temperature.

4. A Certified Reference Thermometer must be used to obtain accurate temperature measurements that can be used to evaluate the logger results. Time and temperature measurements from the Reference Thermometer are recorded for each of the one minute intervals on the Calibration Check Form (Appendix C.).

5. Logger results should be downloaded soon after the testing process has been completed and the loggers should be shut off to minimize battery life impacts. Logger results are then evaluated by calculating the mean absolute value of the difference between the logger measurements and the Reference Thermometer. This difference indicates the accuracy range of the instrument.

6. Temperature loggers evaluated during a pre-deployment check that have a mean absolute value difference beyond 0.2°C for water sampling (-5°C to +37°C Stow-Away TidbiT®, -0°C to +50°C HOBO® Water Temp Pro) or 0.4°C for air sampling (-20°C to +50°C

Stow-Away TidbiT®, -20°C to +70°C HOBO® Water Temp Pro) should be rejected for use until the calibration error has been corrected and the logger passes another calibration check. (**Note**: Only those temperature loggers that pass the calibration check requirements may be programmed for deployment.)

7. If a temperature logger fails a post-sampling calibration check, then another calibration check must be performed. If it fails a second calibration check, then the raw data should be adjusted by the mean difference of the pre- and post- calibration check results to correct for the instrument bias (Schuett-Hames et al. 1999). If batteries should fail during deployment, the manufacturer (Onset Computer Corporation) can perform a post-sampling calibration check by comparison with a Standard Reference Material (SRM) certified by the National Institute of Standards and Technology (NIST).

B. **Temperature Loggers**

Temperature loggers must be lightweight, self contained, rugged, and waterproof. The loggers should have a minimum battery life of 4-5 years. Memory capacity must allow at least 15 months of data to be stored, although a minimum of 24 months is preferred.

In addition, each of these instruments must meet the following criteria:

- waterproof to 30 m
- temperature accuracy of ±0.2°C
- operational range of -20° to 30°C
- resolution of 0.1°C at 0°C
- response time of 5 minutes in water
- stability (drift) of less than 0.1°C per year

NCCN parks currently use two sensors manufactured by Onset Computer Corporation, the TidbiT® v2 Temp Logger (Onset Part # UTB-001) and the HOBO® Pro v2 Water Temperature Data Logger (Onset Part # U22-001).

C. **Site Selection**

The water temperature array is always anchored at the deepest point in the lake as determined by bathymetry measurements. This buoyed temperature array represents the permanent sampling station for all water collection, vertical profiling, and Secchi depth measurements.

An air temperature logger should be placed in a shaded and sheltered area within 30 m of the lakeshore. If there are no suitable locations within the first 30 m, then the nearest suitable location after that will be selected. Placement should be away from potential avalanche chutes or areas of high snow drift. A clump of mature trees is generally preferred.

D. **Pre- Deployment Programming**

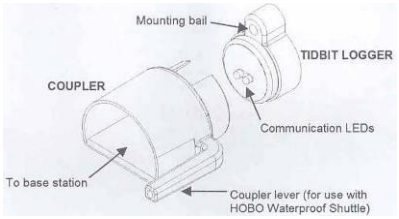
Temperature loggers should be programmed prior to departure using HOBOware® Pro.exe. Before starting the program, the computer clock should be checked to ensure that the time and date are accurate. The date should be correct and time should be accurate within ±1 minute of the Official Pacific Standard Time as determined by the National Institute of

Standards Technology (NIST). The Data logger and the Optic shuttle both reference the computer time during launch and download of data, so accurate date and time on this computer is very important.

1. Connecting a Data Logger to Shuttle/Computer
   a. Open the "HOBOware® Pro" program on the computer.
   b. Unscrew the clear, center cap on the "HOBO® Waterproof Shuttle" (which also serves as a base station for the Tidbit® v2 logger) and plug the small end of the black USB interface cable into the USB port on the shuttle. Connect the other large end of the USB cable into a USB port on a computer. (Note: both the Onset "USB Base Station" and "HOBO® Waterproof Shuttle" can be used for the "HOBO® Water Temperature Pro" logger).
   c. Attach appropriate coupler to the HOBO® Waterproof Shuttle.

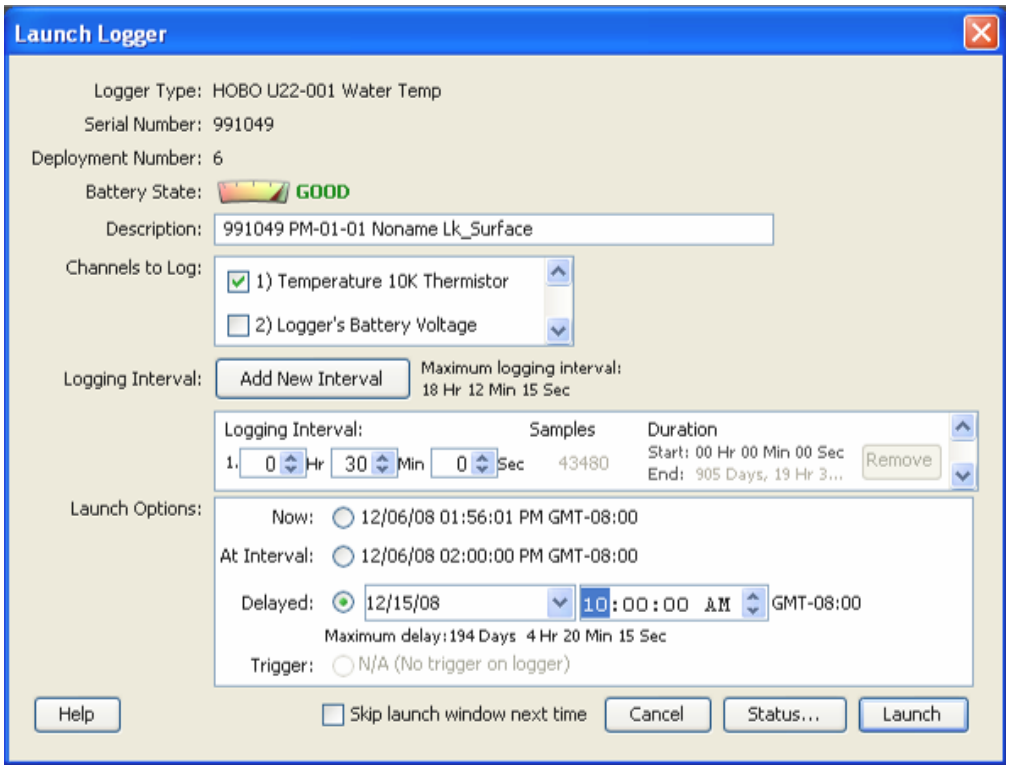


   d. Insert the temperature logger into the coupler with the LEDs facing into the coupler as shown in the diagram.



   e. When properly seated, the logger should be nearly flush with the top of the coupler.
   f. Briefly press the coupler lever to put the shuttle into "base station mode" and allow the shuttle to recognize the logger. The computer will make a noise and the green **OK** light on the side of the shuttle will light up (and remain on until the logger is removed). If the logger has never been connected to the computer before, it may take a few seconds for the new hardware to be detected by the computer. Once the device is detected the connection will be displayed at the bottom of the HOBOware® Pro face page.

2. Launching a Data Logger in the Lab
   a. Under the **Device** tab in the drop down menu, select **Launch**. A **Select Device** screen will pop up. If the computer recognizes the HOBO® logger the logger Serial Number will be shown and is the default selection. Press **Ok**. If the computer does not recognize the logger, reinsert the logger into the coupler and press in the magnetic black bar on the coupler once so that the green light on the shuttle blinks a green **OK.**
   b. Once you select the logger, a launch screen will appear.



c. Record the Serial Number of the logger, Lake Name, Position or other use (water depth at top, mid, bottom; air; backup), Launch Date, Launch Time and Launch Location on the Continuous Water Temperature Survey Form (Appendix C). After deployment staff will also record **Deployment Date** and **Deployment Time**.
d. Check the battery level to be sure that the logger is functioning at full capacity.
e. Change the **Description** field to indicate the deployment location, lake code, sample depth and serial number (e.g., Noname Lk. - Top).
f. Make sure that the **Channels to Log** field has the **Temperature 10 K Thermistor** checked.
g. Uncheck the **Logger's Battery Voltage** (if the loggers battery voltage is checked it will reduce the number of temperature recordings available).
h. Set the **Logging Interval** field to log at **30 minutes** and 0 seconds interval.
i. Change the **Launch Options** field to either sample **Now** if you are heading out into the field immediately, or **Delayed** if you want the logger to have a delayed start time. If using the delayed time feature, input the appropriate date and time to start the logger and record it on the Temp Logger Pre/Post Deployment Record Sheet (Appendix C).
j. Select the **Status** button at the bottom of the screen and double check the settings that you have programmed on the data logger.
k. Select the **Launch** button at the bottom of the screen to begin logging and the red light on the logger will begin to blink. The rate of the blinking light will indicate the status of the logger.

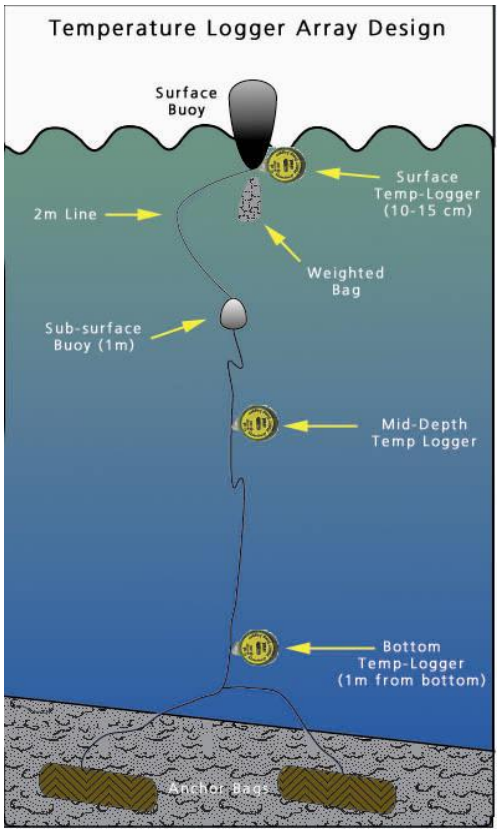
When:	The "OK" light:
The logger is logging	Blinks once every one to four seconds (the shorter the logging interval, the faster the light blinks); blinks when logging a sample
The logger is awaiting a start because it was launched in Start At Interval or Delayed Start mode	Blinks once every eight seconds until logging begins

l. The **Launching Logger** screen will appear, indicating that the **Logger is now logging**, **do not unplug while logger is being configured**. When this screen disappears, it is safe to remove the logger from the coupler. When you disconnect the logger from the coupler the green, LED **OK** light on the shuttle should turn off.

m. Once programmed, label each logger with a piece of tape. Mark the name of the lake and position or other use (water depth at top, mid, bottom; air; backup) for deployment on the tape. In addition the office phone number should be written on the logger with permanent ink.

E. Water and Air Temperature Array Design

To continuously monitor temperatures occurring within a mountain lake and to understand the timing and degree of thermal stratification, temperature loggers are placed at three depths within the lake water column (*see* figure below). In addition, ambient air temperature is measured to aid with interpretation of lake temperature variations. The air temperature data also supplements the NCCN Climate Monitoring Project by adding instrumentation in remote mountainous locations and increasing spatial understanding of temperature variations within mountainous regions.



The lake water temperature array consists of a nylon rope which is anchored to the lake bottom using two rock filled mesh bags (commercially available canoe anchors or nylon mesh bags). The rope is held vertically in the water column by a Styrofoam float which is attached to the rope about 1 m below the lake surface. An additional surface buoy is attached to the top of the rope. Self-contained temperature loggers are fastened to the rope at three locations to provide measurements near the lake bottom, at mid-depth, and at the water surface. Wilderness compliance at some lakes makes it necessary to sink the surface buoy so that it is not visible to park visitors. This is done by adjusting the amount of weight in the attached net bag. The line attaching the surface logger is then adjusted to make sure that it is located at 10 to 15 cm below the surface.

Air temperature is measured using a single logger, surrounded by a white, reflective radiation shield. This sensor is generally hung from a rope and pulley

assembly in a shady location at least 6 m above the ground surface to avoid winter burial by snow.

F. **Water Temperature Array Deployment**
The maximum depth of the lake must be determined prior to construction of the array.

1. Collect the appropriate sized rocks to fill the small mesh bag and two canoe anchors.



2. Measure the appropriate length of nylon rope based on the bathymetry data from the deepest part of the lake. The rope should be approximately 2 m longer than the lake depth.

3. Working from the anchors up, tie off the nylon line to both metal anchor loops leaving 1 m of rope between each anchor. Measure 0.5 m up from the second anchor and tie a loop in the main rope. Once deployed, this loop should be 1 m up from the bottom of the lake and provide the attachment point for the bottom temperature logger.

4. Moving up the rope, tie another loop at a point where it will be **mid-way** up the array. This will provide the attachment for the mid-point temperature logger.



5. Thread the rope through a small white buoy. Tie the top end of the rope off with a washer at a point that will be 1 m below the water surface. This knot will secure the subsurface floats and keep them submerged 1 m under water.

6. Attach the main array rope to the nylon rope already attached to the surface buoy. The total array length, including surface buoy line should now be 1 m longer than the depth of the lake. (The additional meter of slack line will allow for some rise in lake water level).

7. Attach the small (rock-filled) mesh bag to the surface buoy line. (**Note**: The bag should be weighted to ensure the surface buoy is kept upright and submerged at least ¾ of its

length. This will ensure that the surface temperature logger will always be submersed in water).

8. Using a nylon cord, tie a loop through the knot at the base of the surface buoy. This will be the attachment point for the surface logger.



9. Attach the temperature loggers to the appropriate loops (i.e., logger marked top is attached to crab buoy). The loggers are already labeled (top, mid, bottom) and have another small length of roped looped onto them. To attach the loggers, use a slip knot to attach the two loops together. Finally, use a zip tie to also fasten the tidbits to the mainline loop as a backup.

10. As you attach each logger, make sure they have a green blinking light signaling **OK**. If the logger is not blinking green use a backup and record the backup number in your notebook.

11. Navigate to the deepest part of the lake. Using the hand held sonar device, check depth to ensure proper location. Carefully lower the temperature array. Observe the array to make sure the rope has no tangles and that the sub-surface (small white) float is approximately 1 m below the surface and that the surface buoy is properly weighted with the surface (top) logger at least 10 cm below the water surface.

12. GPS coordinates and/or bearing and distance to landmarks from the logger assembly should be recorded on the Continuous Water Temperature Form (Appendix C: Forms). Photographic documentation is also required for relocating air temperature loggers following procedures in SOP 18, Section B.2. Photo number, type, date, and description are recorded on the Trip Photo Log Form (Appendix C: Forms).

G. Air Temperature Array Deployment

1. Determine an appropriate location to deploy the air temperature sensor. The air temperature logger should be placed in a shaded and sheltered area within 30 m of the lakeshore. If there are no suitable locations within the first 30 m then the nearest suitable location after that will be selected. Placement should be away from potential avalanche chutes or areas of high snow drift. A clump of mature trees is generally preferred where the logger is placed at least 6 m above the ground surface to avoid winter burial by snow.

2. Attach the air temperature logger in its radiation shield to one end of the black nylon rope. Make sure it has a green blinking light signaling **OK**. If the logger is not blinking green use a backup and record the backup number in your notebook.

3. Throw a weighted nylon line over a branch at a height above the winter snow line. This can sometimes be determined by observation of lichen growth or estimated by tree height.

4. Lower the weighted line and attach the logger assembly with the radiation shield to the weight. Hoist the line back up to the appropriate height. Measure the height of the line during this process.

5. Tie the running end of the rope in order to anchor the air temperature logger in place. This should be done in a way that minimizes visibility of the line and logger assembly.

6. Record logger serial number, date, and time deployed, and description of location (also GPS coordinates or compass azimuth to or from a specific and easily identified location) on the Continuous Air Temperature Form (Appendix C: Forms).

H. **Water Temperature Data Retrieval**

During each annual lake visit, park staff will upload temperature data from the temperature array to a shuttle device or, if necessary, replace the temperature array loggers with new loggers (in this case, the data from the old loggers will be downloaded back in the office).

1. Make sure the shuttle's large cap and center cap are closed securely. Tighten the center cap until it is just flush with the large cap, or until the O-ring is no longer visible. Check that the communication end of the shuttle is clean.

2. Before leaving shore, place the shuttle and other equipment in a safe location within the inflatable boat. Navigate to the array and prepare to lift it from the water. It is often helpful to have a second boat and person to help support the weight of the anchors while data are uploaded.

3. Identify multiple targets (e.g., trees, boulders, snags) on the shoreline to help you triangulate back to the array deployment location once data collection is completed. This is necessary, as the boat may drift from the location during uploading.

4. Using the depth finder, determine the current depth of the lake at the location of the array. (**Note**: always take three measurements and make sure you have consistent readings).

5. Raise the main array line until the first logger is in an accessible location for uploading data.

6. Shade the logger and check for the blinking red LED indicating that the logger is running. Gently wipe the logger to remove any bio-fouling or sediment that may affect its ability to communicate optically during the downloading process.

7. Attach the coupler to the shuttle and insert the logger into the coupler.

8. Momentarily press the coupler lever and the data should upload immediately. The amber **Transfer** LED light on the shuttle will blink continuously while the readout is proceeding and re-launch is in progress. Do not remove the logger while the amber **Transfer** LED light is still blinking. When it is done uploading, the green LED **OK** light

on the shuttle will blink. Check to make sure that the red **OK** light on the data logger is still logging. Now it is okay to disconnect the logger from the coupler. (**Note**: If data upload fails, try it a second time. If it fails again, remove the logger and replace with a backup).

9. Repeat this procedure with the mid and bottom loggers.

10. Data including sampling event information, time logger was removed from the water, logger ID numbers, deployment depth, and any other observations need to be recorded in the retrieval section of the Continuous Temperature Station Survey Form that was used for the initial deployment during the previous year. (**Note**: comments are required if the logger has moved or been disturbed in any way)

11. As the array is lifted from the water, check the condition of the rope and loops, looking for signs of wear or damage to any components. If these are noted, the array should be repaired or replaced.

12. Using your shoreline targets, navigate back to the original location of the array. Confirm the appropriate depth. If the depth is significantly different (+/-0.2 m), search in the area for the exact point. (Your GPS unit can also be used, but remember these can also be off by several horizontal meters.)

13. Once the correct depth and location has been determined, slowly lower the array back to the lake bottom.

I. Air Temperature Data Retrieval

1. Using a map, photos or GPS, locate the air temperature logger.

2. Find the running end of the rope and loosen it to lower the air temperature sensor.

3. Follow the same data retrieval method as with water temperature loggers

4. Raise the sensor back to the elevation of the pulley and tie in place.

J. Logger Replacement

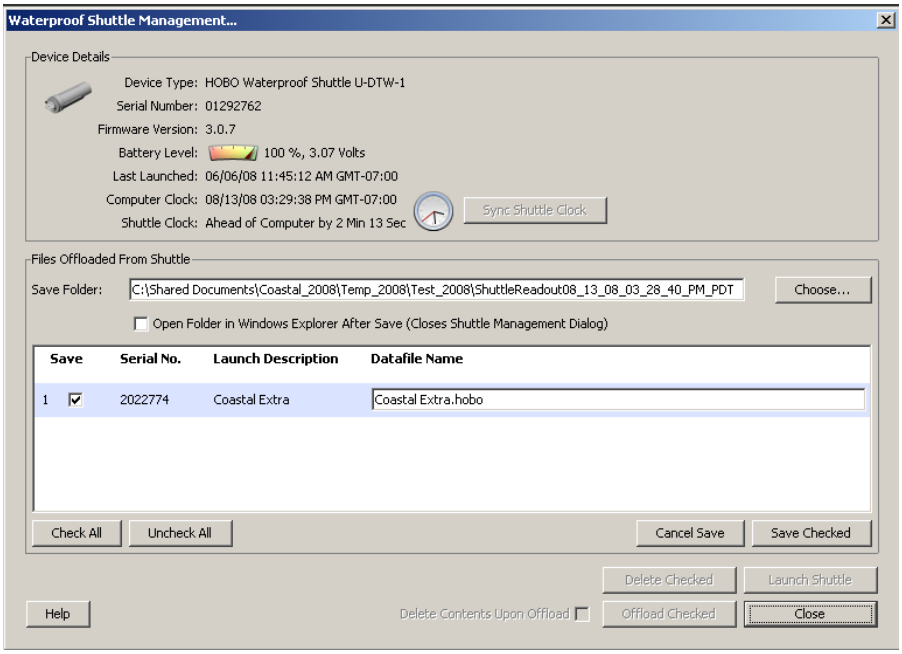
When gathering hourly temperature data, a typical logger will have a battery life of 5 years. Despite this, loggers should be replaced every 3 years to ensure that there is no data loss from early battery failure.

K. Data Management

1. <u>Uploading Data from the Shuttle</u>
   a. After returning from the field, connect the shuttle to a computer using the black USB cable. Follow all the steps found in Part D (Pre-Deployment Programming), under the heading “Connecting a Data Logger to Shuttle/Computer”.
   b. Under the **Device** tab in the drop down menu, select **Readout**. A **Select Device** screen will pop up. If the computer recognizes the shuttle, the **HOBO® Waterproof**

Shuttle, S/N: _____ will appear as the default selection. Press **OK**. If the computer does not recognize the shuttle, reinsert the black USB cable into the shuttle and press in the magnetic black bar on the coupler once so that the green light on the shuttle blinks a green **OK** (and makes a noise).

c. A **Waterproof Shuttle Management…** screen will appear and allow you to select which data file you want to upload from the shuttle onto the computer.



d. On this screen, you will have the **Device Details** displayed for the shuttle (i.e., **Device Type, Serial Number, Firmware Version, Battery Level, Last Launched** date, **Computer Clock** time, and **Shuttle Clock** time). On the **Save File** screen, the program will also ask you where you want to put **Files Offloaded from Shuttle**. Select which **Data Filename** you want to upload and select **Save Checked**.

e. Pressing the **Save Checked** button will refresh the **Waterproof Shuttle Management…** screen. At this point you will be able to **Sync the Shuttle Clock** so that it reads **Matches the Computer**. This is only necessary if the program is showing you that the shuttle clock is ahead of the computer clock.

f. If you select the **Offloaded** file from the **Files on Shuttle** section of this screen, you can select the **Delete Checked** option and remove all the files from the shuttle that have already been saved to your computer.

g. A small **HOBOware®** pop-up screen will appear asking you "**Are you sure you want to delete the selected banks**". Make sure to check that your files have been correctly saved to the computer before selecting **YES** and deleting all your files from the shuttle.

h. Once completed, disconnect the shuttle from the computer.

2. Uploading Data Using the Base Station (alternate method for HOBO® Temp Pro loggers)
   a. After returning from the field, open the HOBO® Pro software and connect the Onset Base Station to a computer using the black USB cable. Insert the LED end of the logger into the base station making sure that the arrows on the logger and the base station are aligned (**Note**: the LED end of the logger should be thoroughly cleaned before the data retrieval process).
   b. Under the **Device** tab in the drop down menu, select **Readout**. When the **Stop Logger** box will appears then select the **Stop** button. Following this a **Save File** screen will appear showing the logger description information (*see* Section D.3: Pre Deployment Programming, Launching Data Logger in the Lab) entered in the launching process with the default software extension (.hobo). To avoid overwriting this file during future uploads of data, immediately rename the file using a standard convention: "Lake Name – Position_Upload Date", (e.g., Connie - Top_090508.hobo). **Save** file to selected folder.

3. Data Quality Control Procedures:
   a. Data from Onset Loggers is initially uploaded using the HOBOware® Pro program. Each time a logger is downloaded, it will save the dataset as a **.hobo** file using the name given to the logger when it was first programmed. To avoid overwriting this file during future uploads of data, immediately rename the file using a standard convention: "Lake Name – Position_Upload Date", (e.g., Connie - Top_090508.hobo). **Save** file to selected folder.
   b. Using HOBOware® Pro, select the dropdown **File** menu and then select '**Open Datafile**, select the **.hobo** file, and **Open**. Following this action the **Plot Setup Screen** opens. Select temperature units and click on **Plot** to review logger data (the logger data screen is split showing both tabular and graphic temperature data).
   c. Following review of the logger data go to the **File** dropdown menu and select **Export files as Excel text** then select **Export to single file** in the **Export Options** box. Click on **Export** and a **Save** file with same name as the .**hobo** file except now in the **.csv** format.
   d. Open the data into Excel for graphing and editing.
   e. Check field notes and graphed values to determine the water temperature data recorded before and after the lake deployment period. Delete this data from the spreadsheet data set.
   f. Observe data and flag any anomalous data from the deployment period.
   g. Once again save this data (including data and flags) as an MS Excel© spreadsheet. This will become the working data. The **.hobo** file remains archived as a backup.

L. **Post Deployment Check**

Following the download of the data, the post-deployment calibration check should be completed according to Section A. If the logger does not meet the requirements of Section A.7 after two separate tests, then the raw data should be adjusted by the mean difference of the pre- and post-calibration check results to correct for instrument bias (Schuett-Hames et al. 1999).

M. **Quality Assurance and Quality Control Procedures**

1. Review logger calibration results, QC procedures, and deployment procedures with all employees each year. Conduct pre-season and on-site training for new employees.

2. Conduct and document QA audits as described in SOP 19, Section G.6.

3. The accuracy of the temperature loggers need to be verified by evaluating the results of pre- and post-deployment calibration checks. If the results indicate a consistent bias of more than 0.2ºC, then the raw data need to be flagged in the database and adjusted as described in Section L of this SOP and in Section G.6 of SOP 19.

4. Measurement precision (RPD+) and sensitivity (AMS+) for continuous temperature loggers will be calculated for one or more randomly selected sets of two consecutive measurements for precision and seven consecutive measurements for sensitivity, taken during the pre- and post-season calibration checks when water temperatures are held at nearly constant temperature. Follow procedures in SOP l9 for determining measurement precision and sensitivity (MQOs, frequency of measurement, sample size requirements, calculation methods, and documentation are described in SOP 19: Sections G.4-5, Section I.2, Tables 19.2-19.3; and in SOP 22).

5. Procedures for documenting and assessing cumulative bias (SOP 19, Section H) must be followed for any changes in key field staff, contactors, instruments, methods, or indicators.

6. Immediately following survey and before leaving the site check verify that all forms are complete and readable.

7. Water temperature data, recorded before and after the deployment period, must be identified and deleted from each raw data set based on the information noted on the Continuous Temperature Station Survey Form.

8. Anomalous data, from the deployment period, related to equipment malfunctioning, movement of the logger assembly, or for other reasons may be identified by reviewing a plot of water temperature and field notes. Questionable results may be deleted from the record provided the reason has been noted on the Continuous Temperature Station Survey Form for the station and also noted in the electronic version of the data record.

N. **Data Forms (*see* Appendix C: Field and Laboratory Data Forms)**

1. Mountain Lake Daily Sampling Checklist
2. Trip Photo Log
3. Continuous Temperature Data Field Form
4. Temperature Logger Pre/Post Deployment Record Sheet
5. Temperature Sensor Calibration Form
6. YSI 600 XLM – Lab Calibration Record Log (OLYM)
7. YSI 600 XLM – Lab Calibration Record Log (NOCA/MORA)

O. **Specific Safety Considerations (*see* SOP 24: Field and Laboratory Safety)**
   1. Water safety (using inflatable boats)
   2. Hypothermia

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SOP 9: General Water Chemistry: Filtered and Unfiltered Samples

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General Water Chemistry: Filtered and Unfiltered Samples

Water samples are collected for measuring a suite of water chemistry variables including nutrients, dissolved organic carbon (DOC), anions/cations, pH, specific conductance, total dissolved solids (TDS), and acid neutralizing capacity (ANC). The water chemistry of mountain lakes is a fundamental driver of ecosystem processes from biogeochemical cycles to the regulation of biological communities. Characteristics of water chemistry are also key indicators of ecosystem change due to the effects of global climate change, atmospheric deposition, and visitor impacts. The various analytical procedures for measuring water chemistry properties require laboratory conditions and equipment not available in the field. Mountain lake water samples are processed in the field and transported back to the park laboratory for analysis, or shipped to commercial analytical labs. A portion of these methods have been adapted from Hoffman et al. (2005). General references for water chemistry sampling and analysis include: Lind (1979), APHA (1998), and Wetzel and Likens (2000).

General Considerations

- All water samples are collected at the permanent sampling station (water temperature array buoy) located at the deepest point of each lake.
- All water samples should be kept as cool as possible while in the field. Keep samples out of direct sunlight, preferably in a thermal bag filled with snow from a nearby snowfield, or submerged in a shaded portion of a lake or stream.
- Water chemistry samples are to be collected between 10:00 am and 2:00 pm.

Equipment and Materials

Field Preparation

- Forceps
- 0.5 N hydrochloric acid (acid washing) with MSDS sheet(s)
- De-ionized (DI) water
- Safety gloves and glasses
- Aluminum foil
- Sample bottles and filters (*see* Table 9.1 below)
- Sample bottle labels
- Conductivity standard (1413 and 100 µS) with MSDS sheet(s)
- pH 4.0, 7.0, and 10.0 buffers with MSDS sheet(s)

Field Sample Collection

- Field Protocol Manual
- Field Data Forms
- Clipboard, pencils, permanent ink pens
- Inflatable boat(s), life jacket, patch kit, pump, paddles
- Life jackets, dry suits
- Horizontal Beta® bottle water sampler or vertical Van Dorn water sampler
- Meter marked retrieval line
- Water sample bottle messenger
- 0.45 µm membrane filters (Millipore HA)

- 0.7 µm glass-fiber filters (Whatman GF/F)
- Forceps
- Wide-mouth Nalgene® HDPE Bottles (250 mL, 500 mL or 1000 mL)
- Amber glass widemouth bottles (60 mL) with PTFE faced PE-lined caps.
- 500 mL Nalgene® polysulfone filtering setup (stand-alone or bottletop unit) with hand pump, or a Nalgene® polysulfone syringe-type filter holder.
- Opaque thermal bag (for field storage of water samples)

Laboratory sample processing and shipping

- Conductivity meter and calibration solution (1000 µS)
- pH meter with pH 4 and 7 buffer solution
- Hach digital titrator (for ANC)
- 0.1600 N H_2SO_4 digital titrator cartridge
- Safety gloves and glasses
- Graduated cylinder (250 mL)
- Beakers (150 mL and 250 mL)
- De-ionized water
- Lab Data Form for ANC/specific conductance/pH
- Sample shipping form and shipping logbook
- Shipping cooler, blue ice packs, and packaging

A. **Preparation of Filters, Wide-mouth Nalgene® High-density Polyethylene (HDPE) and Amber Glass Bottles, and Filtration Apparatus (*see* Table 9.1)**

1. Filters
   a. Prepare a relatively contaminant-free space for cleaning and drying the cleaning supplies and sample-collection and sample-processing equipment. This space should also be free of methanol and other organic compounds that potentially could contaminate apparatus to be used for the collection of dissolved organic carbon samples.
   b. **0.7 µm glass-fiber filters (Whatman GF/F)** used to filter water for the analysis of DOC, nutrients, and TDS. Filters should be combusted in a muffle furnace at 500°C for 4 hours inside folded packets of aluminum foil with the dull side of the foil against the filters. Do not combust filters at temperatures above 500°C. CCAL can supply treated filters if a muffle furnace is not available.
   c. **0.45 µm membrane filters (Millipore HA)** used to filter the anion/cation samples as well as chlorophyll-a samples. **Note:** these filters do not need to be pre-washed or combusted.
   d. All filters, new and combusted, should always be handled with clean forceps.

2. Bottles
   a. Wide-mouth Nalgene® HDPE bottles for nutrient samples, amber glass bottles and their caps for DOC samples, glass Wheaton bottles, and all filtering equipment should be acid-washed prior to use. Sample bottles used for specific conductance, pH, ANC, and cation/anion sample bottles are processed with DI water as in 2.b (below). **Note**: Amber glass bottles having caps with PTFE faced PE-lined caps are preferred over

aluminum lined caps. If the amber glass bottle caps have aluminum liners, they should be removed from bottle caps and discarded prior to acid-washing; in this case, parafilm is used to seal the bottle as in 2.c (below). Bottles should be filled with 0.5 N hydrochloric acid and allowed to sit for 24 hours. Lids and filtering equipment should be soaked for 24 hours in 0.5 N hydrochloric acid. The bottles are then emptied and filled with DI water and allowed to sit for 24 hours. Lids and filtering equipment are soaked in DI for 24 hours. The DI water rinse is repeated. Bottles are then emptied, lids and filtering equipment are removed from their soaking tub and rinsed continuously for 8 minutes with DI water. This can best be done in a dishwasher connected to a DI water source (In addition, contracting labs can pre-wash all bottles at a nominal cost.). Bottles, lids, and filtering equipment are allowed to air-dry.

b. For specific conductance, pH, ANC, and cation/anion sample bottles, wash bottles in DI water and store filled with DI water until they are needed for sampling. After emptying the bottle of DI water, rinse it three times with the water you are sampling before filling it completely with the final sample. A field blank will be taken for every tenth sample. Bottles for field blanks will be filled with DI water but not emptied. Field blanks will be filtered and treated identical to the actual samples.
c. After being acid-washed, the amber 60-mL glass bottles for DOC samples and bottle caps of the bottle lids are placed into a muffle furnace and heated at 475°C for at least 8 hours. **Note**: if bottle caps have aluminum liners that are adhesive backed, the liners should be discarded then replaced with parafilm over the bottle top prior to capping the sample - also *see* D.4.g of this SOP. CCAL can provide treated bottle lids. Bottles should be allowed to cool to room temperature. The cooling process should not be hurried as cooling too quickly can cause bottles to crack. Cracked bottles should be considered contaminated and discarded.
d. Lids should be secured to the cleaned Nalgene® and amber glass bottles and these bottles should not be opened until used in the field.
e. All sample storage bottles should be equipped with labeling tape on which is recorded sample site identifier, sample number, sample date, sample depth, and sample type (i.e., unfiltered water sample, filtered water sample – nutrient and TDS or anion/cation and DOC). If possible, labeling should be completed before field collection of samples. This information should also be recorded on the appropriate sample collection form.

Table 9.1. Sample volumes and preparation.

Parameter(s)	Min. sample vol./bottle	Bottle prep.	Filtered	Filter size/type
ANC	250 mL – HDPE Nalgene	Distilled water	No	Not Applicable
Anions and cations	250 mL – HDPE Nalgene	Distilled water	Yes	0.45 µm –Membrane
Nutrients, Total dissolved solids	500 mL – HDPE Nalgene	Acid washed	Yes	0.7 µm – Glass Fiber
Dissolved organic carbon	60 mL – amber glass	Acid washed	Yes	0.7 µm – Glass Fiber

B. **Collection of the Water Sample**

1. Water samples can be collected using a horizontal Beta® Water Bottle or a vertical Van Dorn-style water sampler.

2. Prior to collection of the water sample(s) the collection bottle or sampler should be triple-rinsed with water from the collection site.

3. All water samples for nutrients, TDS, and anions/cations should be collected at the location on the lake where maximum depth occurs. The collection bottle or sampler is attached to the end of a line marked at 0.1-m intervals and lowered to a depth that is at the **midpoint** of the maximum depth for each site. If the lake exhibits strong thermal stratification, then two samples will be collected: one just below the water surface and one at 1 m above the bottom. Sampling at these lakes will continue in this manner even in years when stratification is not apparent. A detailed method for distinguishing between strongly stratified and weakly stratified lakes is given in Section I of SOP 7: Instrumented Water Column Profiles.

4. DOC samples are always collected at 1 m below the surface, at the location of maximum depth in the lake. DOC serves as a proxy for ultraviolet radiation (UVB) exposure, where higher DOC concentrations decrease UVB penetration of the water column.

5. A weighted messenger is attached to the line and upon being released by the technician slides down the line to the collection bottle or sampler closing trigger mechanism. This procedure and the action of the messenger closes the collection bottle or sampler end plugs.

6. The water-filled collection sampler is then retrieved to the surface, placed into the inflatable boat, and returned to shore for processing.

7. Field replicate water chemistry samples will be collected at one lake each year at each park. The replicate lake will be randomly determined each year by park staff. **Note**: replicates are collected by separate deployments of the water sampler during the same sampling period.

C. **Processing Unfiltered Water Samples (ANC, Specific Conductance, pH)**

1. A minimum of 250 mL of lake water should be collected per site, although 500 mL of sample is preferred.

2. After the sample is collected, the water collection sample bottle is secured in the boat and brought to shore for processing.

3. The Nalgene® HDPE sample bottle should be pre-rinsed twice with 25-30 mL of the collected sample water and then filled with 250 mL or 500 mL of water.

4. Unfiltered water should be poured into the sample storage bottle up to the rim of the bottle prior to securing the bottle lid. Be extremely careful not to introduce foreign

particulate material into bottle during this process. **Note**: All samples should be inspected to make certain that they are free of floating or suspended debris, and sample storage bottles should be filled completely to eliminate trapped air in the bottles before lids are securely fastened.

5. While in the field, water samples should be kept as cool as possible and shaded from direct sunlight. Bottles containing water samples can be placed into opaque thermal bags and either buried in snow, if available, or placed in a shaded area of a stream or lake.

6. Unfiltered ANC samples are refrigerated at 4°C immediately following return from the field. ANC is measured within 7 days from collection of the sample.

7. Specific conductance, DO, and pH are measured as part of the vertical water column profiles (*see* SOP 7: Instrumented Water Column Profiles) using a YSI 600XLM sonde.

8. ANC is measured in the laboratory following procedures in Section E of this SOP.

D. **Processing Filtered Water Samples (Nutrients, Total Dissolved Solids, Anions/Cations, and Dissolved Organic Carbon)**

1. Variables measured using filtered water include total nitrogen, ammonia, total phosphorus, orthophosphate, TDS, chloride, nitrate, sulfate, sodium, ammonium, potassium, magnesium, calcium, and total DOC.

2. Sample volumes and filter sizes for variables are summarized in Section B of this SOP. Filter types and preparation of filters is explained in Section A.1of this SOP. Bottle types and preparation are explained in section A.2 of this SOP.

3. Special considerations for processing filtered water samples.
   a. Prior to sampling and during transport between sites, the filter apparatus and filters should be stored in clean Ziploc® bags to avoid contamination. In addition, filters should be stored in aluminum foil before being placed in Ziploc® bags.
   b. Direct handling of the filter, apparatus surfaces that house the filter, and interiors of the water sampler and sample bottles should be avoided. Filters should be handled only with forceps.
   c. When filtering samples in the field, take care to keep the sample covered and not exposed to sunlight.
   d. Always place filter in filtering apparatus using clean forceps.
   e. Never pour or rinse bottom chamber of filter unit or sample storage bottle with unfiltered water.
   f. All samples should be inspected to make certain that they are free of floating or suspended debris.
   g. Sample storage bottles should be filled completely to eliminate trapped air in the bottles before lids are securely fastened.
   h. No preservatives are added to water samples.
   i. While in the field, water samples should be kept as cool as possible and shaded from direct sunlight. Bottles containing water samples can be placed into opaque nylon

stuff sacks and either buried in snow, if available, or placed in a shaded area of a stream or lake.

4. Sample water is filtered using a 500 mL Nalgene® polysulfone filtering setup (stand-alone or bottletop unit) with hand pump, or a Nalgene® polysulfone syringe-type filter holder.
   a. Before filtering the sample, pour 25-30 mL of sample into the top chamber of the stand-alone filtering unit or the single water holding chamber of the bottletop unit. Swirl to rinse sides of chamber and discard water. Repeat. If using a 60-mL syringe with syringe-type filter holder, flush 25-30 mL of sample water through syringe. Repeat.
   b. For the nutrient and TDS samples: place filter in filtering apparatus using a clean forceps and pour another 25-30 mL of sample into the top chamber of the filtering apparatus. Using hand pump, filter water into lower chamber of filtering apparatus (if using a stand-alone unit) or into an acid-washed wide-mouth HDPE sample storage bottle if using a bottletop unit or syringe-type filter holder. Swirl to rinse bottom chamber or sample bottle and discard. Repeat.
   c. If using a stand-alone filtering unit, fill top chamber with sample water and pump water through filter (s*ee* Table 9.1 for sample volumes and filter sizes).
   d. For the nutrient and TDS samples: When water has been filtered, pour a small amount (25-30 mL) of the filtered water into an acid-washed 500 mL (or 1 liter) wide-mouth HDPE sample storage bottle. Rinse bottle and discard water. Repeat.
   e. For the DOC sample: follow steps D.4.a-d above, except, use 10 mL of filtered sample water to rinse the 60-mL amber glass bottle. Discard water and repeat.
   f. For the anion/cation samples: When water has been filtered, pour a small amount (25-30 mL) of the filtered water into a clean (**NOT acid-washed,** *see* A.2.b) 250-mL HDPE sample storage bottle. Rinse bottle and discard water. Repeat.
   g. Fill sample storage bottles completely to the rim with filtered water prior to securing the bottle lid. Be extremely careful not to introduce any particulate material into bottle during this process. **Note**: for DOC samples, some aluminum bottle cap liners are adhesive backed and can contaminate samples. To prevent contamination, a single square of parafilm should be placed over the top of the sample bottle, using a clean forceps, then sealed with the bottle cap (Cameron Jones, CCAL, pers. comm.).
   h. Take filter apparatus apart and discard filter.
   i. Before and as soon as possible after field use, the filtering unit should be washed in 0.5 N hydrochloric acid, profusely washed and rinsed with low-carbon DI water, and allowed to air-dry without contamination by dust.

5. Post field processing of filtered water samples (*see* Table 9.2)
   a. The filtered nutrient/TDS water samples should be frozen as soon as possible after leaving the field. Prior to placing water samples into a freezing unit, a small quantity of water should be poured from each sample bottle to permit water expansion during the freezing process and prevent rupturing sample bottles. Generally, sample bottles should be emptied down to the bottle shoulder prior to freezing. Samples should be stored frozen and in the dark and transported frozen to the facility where analyses will be conducted.

Table 9.2. Laboratory sample storage and holding times.

Parameter(s)	Holding time	Storage Procedure
ANC	7 days	Stored at 4°C
Anions and cations	28 days	Stored at 4°C
Nutrients, TDS	2 days chilled in field	Samples stored on ice in thermal bag in field
	4 months frozen in lab	Samples emptied to shoulder of the bottle and frozen upon return from the field.
Dissolved organic carbon	28 days	Stored at 4°C

b. DOC and anion/cation samples should not be frozen. Rather, upon returning from the field, samples should be stored in a refrigerator at 4°C until they can be delivered to the laboratory for processing (preferably no longer than 28 days after collection). Samples should also be kept in the dark at all times.

6. Sample transfer to contract laboratories
   a. Samples are placed in soft-sided ice chests with one to two blue ice packs (approximately 3" x 7" size ice packs) sufficient to keep samples cool but not frozen, and the ice chests are packed in cardboard boxes. **Note**: keep DOC samples isolated from frozen water samples to prevent freezing during shipment.
   b. A Sample Shipping Form is placed in each box, noting each sample shipped by site code, date, analyses to be performed, sample volume, and filtration status. Samples are shipped via United Parcel Service (UPS). A designated field crew member will contact UPS the day before scheduled shipping, providing weight, address, and contents information. This crew member also will be responsible for assuring that package pickup is completed and that delivery to the contracting lab is acknowledged. **Note:** it is essential that samples arrive at the contract lab within approximately 48 hours of shipping. It may be preferable to personally transport all of the frozen samples to the contract lab at the end of the field season. Unfrozen samples should be shipped weekly.
   c. Upon receipt of the samples, the contract lab assigns lab numbers and containers are checked for leaks, cracks, and any conditions that might affect sample integrity.

7. Water chemistry will be processed by the following labs
   a. Nutrients, TDS, and DOC: Cooperative Chemical Analytical Laboratory, 3200 Jefferson Way, Corvallis, OR 97331.
   b. Anions/cations: Central Washington Chemistry Laboratory, Central Washington University, Ellensburg, WA.
   c. Laboratory QAPP are found at: http://science.nature.nps.gov/im/units/nccn/vs/mountain_lakes/NCCN_Mountain_Lakes_Contract_Laboratory_QA_QC_Procedures.pdf (accessed 16 April 2011).

E. **Acid Neutralizing Capacity (ANC)**

Unless stated otherwise, methods follow "Alkalinity and acid neutralizing capacity (version 3.0): U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A6, section 6.6" (Rounds 2006).

ANC is most commonly determined by analyzing acidimetric-titration data with either the inflection point titration (IPT) method or the Gran function plot method. The USGS (Rounds 2006) recommends the Gran method for water in which the ANC is expected to be less than about 0.4 meq/L, or specific conductance is less than 100 µS/cm, or if there are appreciable non-carbonate contributors or measurable concentrations of organic acids. The Gran method criteria apply to the vast majority of NCCN mountain lakes with possibly a few exceptions, in which case the IPT method would be applied. Methods require measurement of initial pH followed by titration of a sample with incremental additions of sulfuric acid (H_2SO_4) while measuring the amount of acid and resultant pH of the sample. USGS methods described by Rounds (2006) have been adopted for measurement of ANC in the NCCN.

1. Titration System and Procedures

   NCCN parks are all using Hach® digital titrators. Preparation and use of Hach® digital titrators is presented in the following. **Note**: buret systems may also be used; *see* USGS methods for preparation and use of buret titrators, Section 6.6.4.A in Rounds (2006).

   a. Equilibrate titrant temperature to sample temperature.
   b. Assemble the digital titrator. Depress the plunger-release button and retract the plunger. Insert the titrant cartridge into the titrator and twist the cartridge one-quarter turn to lock it into position. Carefully depress the plunger-release button and push the plunger forward until it makes contact with the Teflon® seal inside the cartridge.
   c. Remove the vinyl cap from the cartridge (save the cap) and insert the straight end of the delivery tube into the cartridge. Do not push the delivery tube beyond the cartridge tip. Do not alter the delivery tube.
   d. Use of a new delivery tube is recommended for each assembly of the titrator. Discard a tube that shows wear. If tubes are reused, store them in separate, clean plastic bags after rinsing with DI water. Do not reuse a tube for a different titrant normality.
   e. To ensure that no air bubbles or water are in the delivery tube, hold the titrator with the cartridge tip up and turn the delivery knob to force a few drops of titrant through the end of the delivery tube (**Note**: Rinse tube exterior with DI water and blot acid or water droplets from the tube before inserting it into the sample).
   f. Set the digital counter to zero using the counter-reset knob (taking care not to turn the delivery knob).
   g. After completing the titration, remove the digital titrator from the sample, depress the plunger release, retract the plunger, and remove the titrant cartridge. Immediately replace the vinyl cap on the cartridge tip. Rinse the delivery tube with DI water or discard.

2. Sample Volume and Normality

   Suggested sample volumes and titrant normality by ANC range following recommendations in Round (2006) are shown in Table 9.3.

Table 9.3. Suggested sample volume and titrant normality.

ANC (meq/L)	Sample Volume (mL)	Titrant Normality
0 -1.0	100 (or larger)	0.1600 (or lower)
1.0-4.0	50	0.1600
4.0 -20	100	1.600

The majority of lakes in the NCCN have ANC values <1.0 meq/L and would require a sample volume of 100 mL and a titrant normality of 0.1600. For these lakes, greater accuracy can be achieved by using a lower normality titrant, decreasing the volume of acid increments, or by using a larger sample volume.

3. Measurement Vessels
   For ANC, sample volumes are measured using a graduated cylinder. Use a 100 mL sample in a 150-mL beaker for processing samples with low ANC. For lakes with expected ANC values over 1.0 meq/L, a 50 mL sample is used in a 100-mL beaker.

4. Stirring Method
   a. If using a magnetic stirrer, stir the sample slowly and continuously using a small stir bar and avoid creating a vortex.
   b. Keep the delivery tube of the digital titrator immersed throughout the procedure but keep the aperture of the tube away from the stir bar (**Note**: this avoids bleeding acid from the tube to the sample between titrant additions).
   c. Allow sufficient time between titrant additions for the pH value displayed on the instrument to equilibrate (**Note**: emphasis should be placed on maintaining a consistent technique, such as titrant additions every 30 seconds, rather than waiting for the instrument to "lock on" to a particular pH value).

5. Gran Titration Method
   a. Prior to measurement allow samples to reach room temperature.
   b. Rinse with DI water only: electrodes, sensors, beaker, graduated cylinder, stir bar, and digital titrator delivery tube.
   c. Place small size stir bar in beaker.
   d. Select and record titration method, subsample volume, and titrant normality.
   e. Assemble titrator, bleed the delivery tube, and set counter to zero.
   f. Set up pH meter and calibrate if required (refer to operators manual for calibration and operation instructions).
   g. Measure sample using a graduated cylinder and transfer sample to beaker.
   h. Place beaker on stirrer.
   i. Measure specific conductance and temperature of the sample (applied in calculation of functions using the USGS Alkalinity calculator).
   j. Insert pH electrode/temperature sensor away from bottom or sides of beaker and turn on stirrer. **Note**: use a low setting on stirrer that minimizes creation of a vortex.
   k. Record, start time, specific conductance, pH, temperature, and initial digital titration counter setting (0000). **Note**: on some equipment it may be necessary to wait 5 to 10 minutes before reading the initial pH.

l. Immerse end of digital titrator delivery tube in the sample. Keep the aperture of the delivery tube away from the stir bar.
m. Titration:
   i. For titration of pH in the range <8.1 to ≥5.5 (most NCCN lakes fall into this category. However, if the initial pH is ≥8.1 and the IPT method is used, then titrate to pH 8.0 using small increments of acid, *see* Rounds (2006)), titrate with larger increments of acid to pH 5.5. **NOTE**: collect data points at least every 0.2 to 0.3 pH units. Record counter digits and pH at each increment.
   ii. After reaching pH 5.5, continue to titrate in smaller increments (equal increments of 10 to 20 digital counts) down to pH 3.5 or lower (pH 3.0 is used for samples high in organic acids or other non-carbonate contributors). Smaller increments of acid and titration to lower pH will provide a sufficient number of points (minimum of six points) beyond the bicarbonate equivalence point to ensure accuracy, and will also allow calculation of the bicarbonate equivalence point required for the IPT method.

6. Calculation of ANC using the Gran Method

Calculation methods taken from Rounds (2006), Sections 6.6.6.4 and 6.6.6.5. Additional methods information can be found at the USGS Alkalinity Calculator website http://or.water.usgs.gov/alk/methods.html (accessed 16 April 2011).

a. Gran function plots commonly are used to determine ANC in low ionic-strength water, water with low carbonate concentrations, and water with measurable concentrations of organic compounds. The Gran Method does not rely on the presence of inflection points in the titration curve; therefore, the method is particularly useful for waters with low ANC values where it is more difficult to determine these points. The Gran Method linearizes a set of functions that describe parts of the titration curve. The linearizing assumptions used by this method are valid only for data that are some distance away from the equivalence points making it necessary to collect a sufficient number of titration points beyond the equivalence point (*see* E.5.m.i in this SOP).
b. During an ANC titration, the added hydrogen ions convert carbonate to bicarbonate and then bicarbonate to carbonic acid. The titration continues until no more species are reacting. When this process is complete, additional hydrogen ions will be in excess in the solution. The plot of the F_1 Gran function values (y-axis) vs. corresponding amounts of acid added (x-axis) identifies the point at which all alkalinity has been titrated (bicarbonate equivalence point) and hydrogen ions begin to be in excess. Beyond the bicarbonate equivalence point, the shape of the curve becomes linear. The intercept with the x-axis, based on a line fit to the linear portion of the plot, equals the equivalence point volume of titrant used in the final calculation of ANC (*see* ***B*** in the section 6.c table below). Similar relations are used with other Gran functions to calculate equivalence points for hydroxide, carbonate, and bicarbonate *see* Rounds (2006).

$$\mathbf{F_1 = (V_o + V_t)\,(10^{-pH})}$$

$\mathbf{V_o}$ = initial sample volume, in mL

$\mathbf{V_t}$ = total volume of titrant added = digits/800 (Hach titrator using 0.1600 N H_2SO_4)

c. Calculation of alkalinity or ANC is a simple accounting of the amount of acid used to neutralize the sample, calculated using the following formula (Rounds (2006), Section 6.6.5.A):

$$Alk\left(\frac{meq}{L}\right) = \left[\frac{B\ (mL) \times C_a\left(\frac{meq}{mL}\right) \times CF}{V_s\ (mL) \times \left(\frac{1\ L}{1000\ mL}\right)}\right] = 1000(B)(C_a)(CF)/V_s$$

and

$$Alk\left(\frac{mg}{L}\ \text{as}\ CaCO_3\right) = Alk\left(\frac{meq}{L}\right) \times \left(\frac{1\ mmol\ CaCO_3}{2\ meq}\right) \times \left(\frac{100.087\ mg\ CaCO_3}{1\ mmol\ CaCO_3}\right)$$
$$= 50044(B)(C_a)(CF)/V_s$$

where:

Alk	is alkalinity or ANC of the sample.
B	is volume of acid titrant added from the initial pH to the bicarbonate equivalence point (near pH 4.5), in mL. To convert from digital counts to mL, divide by 800 (1.00 mL = 800 counts).
C_a	is concentration of acid titrant, in milliequivalents (***meq***) per mL (same as equivalents per liter, or ***N***).
CF	is correction factor (*see* below).
V_s	is volume of the sample, in mL.
mmol	is millimoles of calcium carbonate.

The correction factor CF is equal to 1.01 as determined by the USGS, National Water Quality Laboratory, resulting from a bias caused by the configuration of Hach® digital titrator cartridges.

Equations for calculation of individual carbonate species can be found in Section 6.6.5.B of the USGS National field manual for the collection of water-quality data (Rounds 2006). Additionally, the USGS provides a Web-based Alkalinity/ANC calculator that allows users to analyze titration data and determine alkalinity or ANC with several different methods (IPT, GRAN, fixed endpoint, and a theoretical carbonate titration curve method). The calculator also provides simple and advanced calculations of carbonate species and can be accessed at http://or.water.usgs.gov/alk/ (accessed 16 April 2011).

d. Report ANC to three significant figures. Only the value from filtered samples is to be published as alkalinity. Titration values from unfiltered samples are to be entered and published as ANC. ANC should be reported in microequivalents per liter. ANC

values may be negative; report negative values with the same number of significant figures that would be used if the values were positive.

e. Report the average value for duplicate samples or the median when more than two replicate samples are used for quality control and the value falls within the appropriate quality-assurance criterion for variability.

F. **Quality Assurance and Quality Control Procedures**

1. Review measurement procedures with all employees each year. Conduct pre-season and on-site training for new employees.

2. Do not rely on memory – always read protocol.

3. Conduct and document QA audits as described in SOP 19, Section G.6. Work with contracted laboratory to ensure that instrument bias is measured and documented according to SOP 19, Section G.6.

4. One sample blank will be processed in the field, from one lake at each park, in each year, to check for sample contamination attributed to field collection, processing and handling. Directions for preparation and labeling are described in SOP 19, Section G.6. Analyte concentrations in blank samples should be <MDL. If values in blank samples are greater than the MDL (exhibiting positive bias), then the PD (percent difference) should not exceed 10% (more details given in SOP 19, Section G.6).

5. Procedures for documenting and assessing cumulative bias (SOP 19, Section H) must be followed for any changes in key field staff, instruments, methods, or indicators.

6. Field duplicate samples are collected from one lake at each park, in each year, for evaluation of measurement precision (RPD+). Field Leads and Lead Aquatic Ecologists will work with contracting laboratories to ensure that procedures for determining measurement precision and sensitivity in SOP l9 are followed (MQOs, frequency of measurement, sample size requirements, calculation methods, documentation, and corrective actions are described in SOP 19: Sections G.4-5, Section I.2, Tables 19.2-19.3, and in SOP 22).

7. If the ANC is about 20 µeq/L or less, differences between duplicate samples are likely to exceed 10% because of rounding errors alone. Using a larger sample volume or a lower normality of titrant may reduce rounding errors.

8. Water chemistry data will be validated by performing internal sample consistency checks. These checks will include charge balance calculations and comparisons of measured vs. calculated specific conductance (*see* SOP 19, Section G.6).

9. In the analysis of lake chemistry data, comparisons across time may become complicated where lakes are sampled as unstratified (one mid-depth sample) and strongly stratified (one epilimnetic and one hypolimnetic sample). To facilitate analysis, the average of the epilimnetic and hypolimnetic sample chemical concentrations will be used as a surrogate

for mid-point sample concentration in analyses for comparison with non-stratified samples. Data from previously sampled strongly stratified NCCN lakes show no substantial differences between epilimnetic and hypolimnetic chemical concentrations, thus averaging them appears to reasonably approximate mid-point concentrations.

10. Immediately following survey and before leaving the site check to see if all forms are complete and readable.

11. Remember that nylon lines or ropes used for any depth related sampling equipment should be checked to determine if recalibration due to stretching of the line is needed at the beginning of each sampling trip. Additional measurement error can result from how the measuring line is attached to the equipment. For each type of equipment, the distance between the equipment and the first mark on the line should always be checked. This is necessary for sampling trips where the same depth measuring line is used for water sample bottles, plankton nets, and the Secchi disk. Measurement error also can be associated with how the line is secured to the equipment and how far it is located from the effective sampling surface of the equipment (e.g., the measuring line for the plankton net is attached to a bridal that extends several centimeters in front of the net opening). Deployment depth measurement must be adjusted to account for the discrepancy in distance from the net opening to the first depth mark on the line. Metal clips are recommended for marking depth intervals on lines or ropes, although lines or ropes can also be marked using a pen with permanent ink (e.g., Sharpie).

12. Follow procedures given in this SOP to prevent contamination of samples.

13. Keep samples cool and away from sunlight in the field and store in a refrigerator or freezer (as required by protocol) upon returning from the field. Document exceedance of holding times and sample temperature requirements given in Table 9.2 of this SOP.

G. **Data Forms (*see* Appendix C: Field and Laboratory Data Forms)**
1. Mountain Lake Daily Sampling Checklist
2. Water Sample Collection Field Form
3. Water Chemistry Sample Shipping Log
4. Acid Neutralizing Capacity Lab Sheet

H. **Specific Safety Considerations (*see* SOP 24: Field and Laboratory Safety)**
1. Water safety (using inflatable boats)
2. Hypothermia
3. Laboratory procedures and chemical handling

Literature Cited

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SOP 10: Chlorophyll-a Concentration

April 19, 2011

Prepared by: Steven Fradkin, NPS NCCN-OLYM, and Barbara Samora, NPS NCCN-MORA.

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Chlorophyll-a Concentration

Chlorophyll-a is the major pigment used by most phytoplankton to convert sunlight into chemical energy, which is needed for CO_2 fixation into carbohydrates during photosynthesis. Chlorophyll-a concentration is a standard index of algal biomass, itself a useful indicator of the trophic status and productivity of mountain lakes. A detailed microscopic examination of phytoplankton species is beyond the scope of this SOP, yet determination of chlorophyll-a concentration is feasible and within the scope. Water samples are collected and filtered in the field. Filters retaining all phytoplankton in the sample are transported to a laboratory where the chlorophyll-a is extracted with a solvent and quantified on a fluorometer (Arar and Collins 1997). The methodology in this SOP has been adapted from Hoffman et al. (2005).

General Considerations

- Chlorophyll samples are to be collected between 10:00 am and 2:00 pm.

Equipment and Materials

Field equipment

- Field Protocol Manual
- Van Dorn water sampler
- 0.45 µm membrane filters (Millipore HA)
- Forceps
- 500 mL Nalgene® polysulfone filtering setup
- 25 mL plastic scintillation vial
- Aluminum foil
- Thermal bag.
- Field Data Forms, clipboard, pencils
- Inflatable boat (with life jacket, patch kit, pump, paddles)

Laboratory equipment (if analyzed in NPS Lab)

- Fluorometer
- HPLC grade acetone
- Refrigerator
- Laboratory tissues
- 1-5 mL, 2-20 µL, 20-200 µL pipettors
- Disposal pipette tips for pipettors
- Glass cuvettes for Fluorometer
- 0.1 N hydrochloric acid (HCL) solution
- Distilled, RO water
- Purified chlorophyll-a standard

A. **Collection of the Water for Chlorophyll-a Concentration Sample**

1. Sample water should be collected using a Van Dorn water sample at the same time as water chemistry samples (SOP 9: General Water Chemistry). Sample water is immediately transferred into prewashed amber HDPE bottles before transport back to shore.

2. Chlorophyll-a sample water is collected at the mid-water depth at the permanent sampling station located over the deepest point in each lake. In cases where lakes are strongly stratified (as defined in SOP 7: Instrumented Water Column Profiles), a second chlorophyll-a sample will be collected at 0.5 m above the lowest point of the epilimnion.

B. **Filtering the Water for Chlorophyll-a Concentration Sample**

1. 500 mL of water should be filtered through a 0.45 µm membrane filter, using a Nalgene® polysulfone filtering apparatus.

2. Place filter in filtering apparatus using forceps.

3. Pour 25-30 mL of sample into top of filter chamber and swirl to rinse sides of chamber and discard water.

4. Using a graduated cylinder, fill top of filter pod with 500 mL of sample water and filter the water. The hand pump pressure gauge should not register higher than 5 PSI.

5. After filtering 500 mL of water, continue suction to remove residual water from filter. Fold filter in half and place into a 25-mL plastic scintillation vial.

6. The sample vial should be wrapped in aluminum foil, placed into a thermal bag, and kept cool until returned to the laboratory.

7. The sample should be labeled with site identifier, sample number, sample collection date, sample time, depth at which water was collected, and volume of water filtered. This information also should be recorded on the data form.

C. **Lab Preservation and Shipping**

1. Upon returning from the field, the scintillation vial containing the sample filter should be placed in a freezer at -20ºC and kept frozen until the sample is processed in the laboratory.

2. NOCA and MORA are not equipped to conduct chlorophyll-a analyses and use a contract laboratory. Prior to shipment to the laboratory all samples are logged into the Chlorophyll-a Sample Shipping Log. Information recorded into the form includes park and contractor contact information, analysis type, sample volume, filter size, lake code, lake name, collection date, sample number, shipping date, and date received by the contractor.

3. Samples should be shipped overnight on dry ice in an insulated container to ensure that samples remain frozen and don't degrade. The shipping date should be discussed with the contractor and the contractor should be notified as soon as the samples are shipped. Arrangements should be made with the contractor to provide notification of the arrival of samples.

4. The Lake Crescent Laboratory at OLYM is equipped to conduct quantitative analyses of extracted chlorophyll-a. Procedures associated with this analysis are detailed below in Section E of this SOP.

D. **Contract Laboratory Analysis (MORA &NOCA)**

The contract laboratory will determine total chlorophyll-a concentrations using the EPA Method 445.0 fluorometric procedure (Arar and Collins 1997). The contract laboratory used is:

The Cascade Research Group
John Salinas
P.O. Box 5208
Grants Pass, OR 97527
(541) 479-7351
johnsalinas@charter.net

E. **Chlorophyll-a Laboratory Analysis at OLYM**

The Lake Crescent Laboratory at OLYM conducts extracted chlorophyll-a analysis following the EPA Acidification Method 445.0 (Arar and Collins 1997). This method is the standard method for measuring extracted chlorophyll-a and pheophytin-a in marine and freshwater algae by fluorescence. The Lake Crescent Laboratory uses a Turner Designs Trilogy Laboratory Fluorometer equipped with a Chlorophyll-a Acidification Fluorescence Module. Prior to each use, this instrument is calibrated using known standard concentrations of pure chlorophyll-a. The following procedures are modified from Arar and Collins (1997) and Turner Designs (2006).

1. Sample Collection and Filtration
   Water samples are collected and filtered in the field according to Sections A and B above.

2. Sample Storage
   Once samples arrive at the Lake Crescent Laboratory, they are logged and frozen at -20 ºC until analyzed. The maximum holding time for samples prior to analysis is 1 month.

3. Extraction
   a. Extraction and measurement are conducted under low light conditions. Workspace lighting is held to the minimum necessary to read instructions and operate instruments accurately and safely.
   b. Prior to extraction, a set of clean, acid-washed film canisters are labeled and a sample tracking data form is filled out that relates the sample to the extraction film canister.
   c. Samples are removed from the freezer to the bench workspace. Using forceps, filters are removed from sample scintillation vials and are placed in individual film canisters.
   d. Using a volumetric pipet, 10 mL of 90% aqueous acetone is added to each sample film canister. Each canister is capped and placed in a dark chamber within the laboratory refrigerator at 4ºC.
   e. Approximately 5 minutes after adding the acetone, each film canister is vigorously shaken and placed back in the 4ºC environment.
   f. Sample canisters are incubated for 12-24 hours. (**Note**: **do not exceed 24 hrs of incubation**).

4. Trilogy Fluorometer Calibration
   Fluorometer calibration is conducted prior to each batch of analyses using a three-step calibration. The steps are: 1) 0 μg/L blank, 2) ~2 μg/L pure chlorophyll-a standard in acetone, and 3) ~20 μg/L pure chlorophyll-a standard in acetone. The actual high and mid-values depend upon the concentrations reported for the standard lots used (obtained from Turner Designs chlorophyll-a standards documentation). The calibration procedure instructions are on page 20 of the Trilogy User's Manual.

5. Sample Measurement
   a. Prior to measurement, the Trilogy instrument is connected to a laboratory computer using a serial connection and the Turner Designs Spreadsheet Interface Software is run. This program enables automatic recording of measurement results to an Excel spreadsheet. After every 10 measurements, the spreadsheet is checked to ensure data are being recorded. The Trilogy instruments automatically stores the last 20 instrument readings, thus a malfunction of the spreadsheet interface software should not result in lost data.
   b. Prior to measurement, samples are removed from the refrigerator and allowed to come to room temperature (~10 minutes) in a dark holding chamber.
   c. On the Trilogy HOME SCREEN, select the **Mode** and **Direct Concentration Mode** buttons.
   d. Pipette 1.8 mL of sample volume into a clean 2-mL cuvette.
   e. Open the Trilogy lid, insert the sample cuvette, and close the lid.
   f. Select the **Sample ID** button and name the sample using the keypad. The sample naming convention is in the form of LLLDDMMYYR, where LLL= the three-character lake code, DD = two-digit day number, MM = two-digit month number, YY = two-digit year number, and R = replicate measurement number.
   g. Add 54μL of 0.1 N HCL and mix with a disposable glass pipet.
   h. Wait 90 seconds before measuring the post-acidification reading.
   i. Repeat steps iv-viii above with a new cuvette sample.
   j. Retain excess sample volume to conduct repeat measurements of each sample.

6. Trilogy Fluorometer Performance Specifications
   - Minimum Detection Limit: Chlorophyll-a = 0.02μg/L
   - Linearity: R^2= 0.99
   - Excitation wavelength: 485nm
   - Emission wavelength: 685/50nm

F. **Quality Assurance and Quality Control Procedures**
1. Review measurement procedures with all employees each year. Conduct pre-season and on-site training for new employees.

2. Do not rely on memory – always read protocol.

3. Conduct and document QA audits as described in SOP 19, Section G.6. Work with contracted laboratory to ensure that instrument bias is measured and documented according to SOP 19, Section G.6.

4. Immediately following survey and before leaving the site check to verify that all forms are complete and readable.

5. Follow procedures to prevent sample contamination, exceedance of sample holding times, and sample temperature requirements as described in Sections B and C of this SOP. Keep samples cool and away from sunlight in the field and store in freezer upon returning from the field.

6. Procedures for documenting and assessing cumulative bias (SOP 19, Section H) must be followed for any changes in key field staff, instruments, methods, or indicators.

7. Follow sampling frequency and sample size requirements in SOP l9 for determining chlorophyll-a measurement precision and sensitivity (MQOs, frequency of measurement, sample size requirements, calculation methods, and documentation are described in SOP 19: Sections G.4-5, Section I.2, Tables 19.2-19.3, and in SOP 22). Field Leads and Lead Aquatic Ecologists will work with the contracted laboratory to ensure that procedures for determining measurement precision and sensitivity in SOP l9 are followed.

8. One sample blank will be processed in the field, from one lake at each park, in each year, to check for sample contamination attributed to field collection, processing, and handling. Directions for preparation and labeling are described in SOP 19, Section G.6. Analyte concentrations in blank samples should be <MDL. If values in blank samples are greater than the MDL (exhibiting positive bias) then the PD (percent difference) should not exceed 10% (more details given in SOP 19, Section G.6).

9. For Chlorophyll-a analyses conducted at the Lake Crescent Laboratory (OLYM), duplicate measurement of sub-samples will be conducted for all samples, including replicate lake samples (Section E.5 of this SOP). Additionally, the Trilogy Fluorometer automatically computes chlorophyll-a concentrations, reducing the potential for calculation errors, and the instrument also employs spreadsheet interface software to automatically record measurement values.

G. **Data Forms** (*see* Appendix C: Field and Laboratory Data Forms)

1. Lake Temperature, DO, Secchi, and Chlorophyll-a Form
2. Chlorophyll-a Sample Shipping Log
3. Chlorophyll-a Sample Storage Log Form (OLYM)
4. Chlorophyll-a Analysis Log Form (OLYM)

H. **Specific Safety Considerations** (*see* SOP 24: Field and Laboratory Safety)

1. Water safety (using inflatable boats)
2. Hypothermia

- Laboratory acetone and HCL handling requires proper ventilation and eye protection

Literature Cited

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SOP 11: Benthic Macroinvertebrate Collection and Processing

April 19, 2011

Prepared by: Reed Glesne, NPS NCCN-NOCA, and Ashley Rawhouser, NPS NCCN-NOCA.

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Benthic Macroinvertebrate Collection and Processing

The benthic macroinvertebrate (BMI) communities found in mountain lakes are primarily composed of immature insects, oligochaetes, amphipods, and mollusks. These communities are capable of representing a range of environmental conditions and stressors giving a long-term integrated assessment of a lake's ecological condition. Ecological changes are reflected in the invertebrate community composition and are often expressed by the number of species (or taxa richness) present, trophic class composition, indices of taxa richness and abundance (diversity and evenness), and tolerance to various perturbations. BMI samples are collected annually from all monitoring sites. The objectives of this protocol are to provide information to determine within-site and regional trends, as well as provide an assessment of the status of these communities at all lakes sampled. BMI are sampled using a semi-quantitative time- and area-constrained, kick-and-sweep technique where all habitat types, within randomly selected locations found within the 1-m depth contour of the lake, are sampled.

Equipment and Materials

General (field and laboratory)

- BMI Sampling SOP
- BMI data forms
- Pencils and alcohol proof pen
- photographic/sorting tray (white, plastic)
- Forceps (both flat and pointed tipped)
- 95% ethanol (in the field use 1 liter for lakes with low amounts of organic debris and 2 liters for lakes with high amounts of organic debris)

Field sampling:

- Rite in the Rain® labels
- Aerial Photo (1:12,000 scale) and Lake Map
- Stop watch
- D-frame kick net (500-µm mesh, 305 by 254-mm mouth opening, 2-m handle)
- Hand-held 500-µm mesh net
- Plastic bucket (5 gallon recommended)
- WHIRL-PAK® bags (4.5 x 9 inches recommended)

Laboratory processing

- 500-µm sieves or cones
- Framed sheet of 500-µm mesh net (sized to fit sorting trays)
- Small bucket
- Spatula
- Plastic spoon and cups
- Alcohol-filled squeeze bottle
- Water-filled squeeze bottle
- Binocular dissecting microscope (7-20x magnification)
- Fiber optic light source
- Clicker/counter

- Vial holder (vial sized holes drilled into a wooden block)
- Scintillation vials (4 and 15 mL)
- Desk lamp with magnified circular lens (3-10x)
- Waterproof label paper
- Rubber bands
- Lab bench sheet

A. **Sample Locations**

The sampling objective is to collect a single pooled sample (total of 500 to 600 specimens) for each lake that represents the heterogeneity of littoral zone substrates around the shoreline. The pooled sample consists of five subsamples which are collected at randomly selected locations around the perimeter of the lake.

1. A sampling frame is developed by equally dividing the shoreline perimeter into 20 to 25 numbered segments on an aerial photograph. Shoreline areas near major inlets and outlets are excluded from the sampling frame because many specimens collected in these areas often represent stream dwelling taxa. In addition, areas of the shoreline that are unsafe or inaccessible by wading (e.g., bedrock cliffs) are not included in the sample frame. Using a random number table, five numbers are selected (without replacement) to represent the sample segments.

2. If a replicate sample is to be taken, then another random allocation of five subsample sites is required. These subsample sites are drawn, without replacement, from the set of lake shoreline locations remaining after the initial sample selection (above).

3. All sample location numbers will be recorded on a copy of the lake aerial photo.

4. Determine the sampling time and length of the area to be sampled from Table 11.1. The area and time constraints were developed to provide a rapid assessment method of BMI sampling that roughly represents the heterogeneity of bottom substrates in lakes of varying size and that minimizes sampling disturbance in smaller lakes.

5. Locate the center of each sample segment and define a linear distance along the shoreline where one-half of the distance found in Table 11.1 is sampled on either side of the center point. The width of the sample area extends out to 1 m depth

Table 11.1. Benthic macroinvertebrate time and area constrained kick subsampling effort by lake size.

Lake Surface Area (ha)	No. of Subsamples	Time (min.)	Linear Distance (m)
0.4 to 1.0	5	2.0	5
1.1 to 4.0	5	2.5	10
4.1 to 6.0	5	3.0	15

B. **Sample Effort**

1. Each location is sampled for the total minutes listed in Table 11.1.

2. The person collecting the sample should not keep track of the time. Instead designate another crew member located on the bank as the timekeeper; this will ensure accurate and repeatable sample efforts. Start and end time of the sample effort is recorded on the data form.

3. Samples are collected by sweeping through suspended material kicked up from the lake bottom or brushed from large woody debris, rocks, and vegetation using a 500-µm mesh D-frame kick net. Be careful not to drag the net across the bottom of the lake. **NOTE**: Care should be taken to minimize turbidity during the sampling procedure. The primary objective is to sample the different types of substrate in each plot area. It is not necessary to disturb the entire surface area of each plot, particularly for those locations that are mostly silt. Before moving to another sample plot, field staff should immerse samples in a shallow white pan to assess the density of collected specimens to ensure that the specimen collection objective of at least 500 specimens combined for all five subsamples can be met.

4. In locations with high amounts of fine particulate organic matter, the net should occasionally be lifted from the water allowing the organic matter to settle. This will facilitate clearing the net and allow the water to flow through the mesh rather than over the edges of the mouth of the net as it is swept through the water.

C. **Field Sample Processing and Preservation**

1. All the contents (i.e., substrate, woody debris, and organisms) of the sample in the net are emptied directly into a bucket or tray.

2. Ensure the entire sample contents are removed from the net. Make a close inspection of the net for any remaining organisms, which can be removed with forceps if necessary.

3. Samples with large amounts of debris can be elutriated in a white photographic or similar tray to remove large pieces of wood and other debris. This is accomplished by agitating the sample and pouring off the smaller sized organic particles that are washed through a hand-held 500-µm mesh net. Be sure to inspect all discarded debris for organisms. This process reduces the amount of organic matter from the sample and insures better specimen preservation.

4. If Step 3 is not necessary, pour the entire sample into the small hand held mesh net.

5. Gently squeeze the sample in the mesh cone to remove excess water.

6. Repeat this process for each of the randomly selected sample locations.

7. Samples can be individually bagged, split into more than one bag or field composited depending on the amount of material in the sample. No more than half of the volume of the bag should be filled with sample material in order to leave adequate room for the preservative. All samples must be double bagged in WHIRL-PAK® bags, labeled (duplicate labels-one in each bag), and preserved with 95% ethanol which should fill the

remaining space of WHIRL-PAK® to within one inch of the top. In situations where large amounts of fine organic material are collected, it may be necessary to reduce the sample size by field splitting. When this is done the fraction of the sample discarded should be recorded and the material discarded should be inspected for any organisms with a body larger than approximately 1 cm in length or if they are mayflies, caddisflies, stoneflies, damselflies, or dragonflies.

8. Labels will include the park code, lake name, lake code, sample number, number of bags for each sample, and sample date and initials (First, Middle, Last) of collector(s). Replicate samples taken at the same lake will be denoted by the letter 'R' followed by the sample number. Primary samples will be denoted by the letter 'S' followed by the sample number.

9. Record number of sample containers for the primary sample and for the replicate sample, if taken, on the Benthic Macroinvertebrate Field Form.

D. **Sample Site Habitat Characterization**

1. Characterize the predominant features of lake habitat at each BMI sample site according to substrate type and class (Table 11.2) and record on the Benthic Macroinvertebrate Field Form.

2. The four dominant substrate classes, including classes from all types, are recorded on the data form in order of their dominance in the plot area. Dominance is estimated by visual observation of the percentage of the sample area covered by each substrate class. Percentage of sample plot for dominant substrate classes must be at least 10% to be recorded.

3. In addition to item 2 above, the percentage of CWD should always be recorded on the data form; and, the presence of CPOM and aquatic vegetation types in the sample plot should always be indicated by a check mark in the appropriate box of the data form.

Table 11.2. Lake habitat parameters.

Type	Class	Size (Diameter in mm)
Inorganic	Silt (smooth between fingers)	<0.06
	Sand	<2
	Gravel	2 to 64
	Cobble	65 to 256
	Boulder	257 to 4096
	Bedrock	>4096
Organic	Fine Particulate Organic Matter (FPOM)	<2
	Coarse Particulate Organic Matter (CPOM)	2 to 100
	Coarse Woody Debris	>100
Vegetation	Emergent	
	Floating	
	Submergent	

E. **Laboratory Processing and Specimen Identification**

1. Sample Log-in Procedure
   a. When benthic invertebrate samples are brought in from the field the sample containers should be inspected for leaks and checked to insure that the ethanol adequately covers the sample by roughly equivalent to half of the sample container volume. If samples are to be left for long periods of time before they are processed the alcohol in the samples should always be decanted and replaced with new 95% ethanol.
   b. Check to insure that sample labels are visible and legible. If necessary re-label the samples.
   c. Each sample should be logged into the Lake BMI Sample Log Form. The information should be recorded as follows:
      - Park Code = four-letter park acronym
      - Lake Code = park determined GIS identification ID
      - Lake Name = name of the lake, if not named than designate as "unnamed"
      - Collection Date = record the date the sample was collected in the YYYYMMMDD format (example: 2007AUG02 would signify August 2, 2007)
      - Subsample # = Subsample # from Zooplankton and BMI Sample Form, if samples were field composited signify as "COMP" (for example: COMP S1-3 would signify that subsamples 1 through 3 were combined)
      - % Collected = the amount of the original sample which was preserved and brought back to the lab for processing
      - Notes = any relevant information related to deviations in the benthic macroinvertebrate SOP
   d. Immediately refrigerate (4°C) all samples.

2. BMI sample sorting procedure:
   The goal of these processing and subsampling procedures is to remove an unbiased, random representation of BMI specimens from a composite of the five benthic kick samples taken from each lake. Sorted samples will be used to develop reporting output variables based primarily on taxa richness and composition related metrics (Note: sample collection procedures are semi-quantitative, therefore an estimate of the density of organisms in the samples is not one of the data analysis objectives). A minimum of 500 organisms should be removed from each composited sample using an area-based sieve splitting approach. Methods are adapted from those developed by the USGS (Cuffney et al. 1993, and Moulton et al. 2000), and the Utah State University, Bug Lab (http://www.usu.edu/buglab/SampleProcessing/labProcedures.cfm, accessed 31 March 2011).
   a. Gather all of the samples from a lake checking the total number of sample containers against the sample log.
   b. Combine all of the samples in a bucket and cover it with water. Make sure each container is empty of all contents before proceeding.
   c. Assign the sample an ID. This should consist of the lake's GIS Code followed by an underscore plus the sample date in the YYYYMMMDD format (example: 2006AUG02) followed by an underscore plus the sample type (comp=composited

subsamples and Rcomp= composited replicate subsamples). See k below for an example of a sample ID.

d. Elutriate the composited sample and pour it through a 500-μm mesh cone rinsing thoroughly with fresh water until most of the fine sediments and silt are flushed. Large debris can be rinsed into the mesh cone and discarded. If the sample contains significant amounts of sand and gravel you will need to swirl and decant it several times to separate the mineral and large organic material. The sand and gravel can be discarded after it has been closely examined for caddisflies, snails, clams, or other organisms which should be added to those in the cone. At the end of this step the organisms and organic matter should be separated from the majority of the sand and gravel.
e. Decide if the sample requires splitting. Samples with little debris and with less than approximately 600 organisms do not require splitting, otherwise splitting is required.
f. The first step in splitting the sample is to place a framed sheet of 500-μm mesh net into a tray and add approximately 3 cm of water to facilitate the even distribution of debris. The mesh should be evenly divided into 5-cm x 5-cm blocks. Each block should be permanently delineated and numbered to facilitate accurate identification of the subsample size.
g. Evenly distribute the material from the cone on the surface of the mesh and gently lift it out of the water. Use a random number table to select a random number corresponding to one of the marked squares. Using a knife or spatula, separate the sample material along the marked line of the randomly selected block and remove this material placing it in a tray for sorting. Leave the rest of the sample intact on the screen.
h. Remove all organisms from the sorting tray using a lighted 3 to 10x magnifying lens and place into a vial containing a preservative of 70 to 90% ethanol. If you are introducing small droplets of water into the vial with the specimens you will need to decant the vial and refill with the concentrated preservative.
i. Oligochaetes should be picked and preserved but are not counted as part of the 500 organism total because they tend to break into several pieces in the preservation process. If possible, try to remove 25 intact or mostly intact specimens from this group.
j. Continue to randomly select blocks from the screen until all of the blocks have been removed or you have reached the 500 organism total, whichever comes first. IMPORTANT: Once you start a sorting a block you must finish it in its entirety.
k. Label every vial using Rite in the Rain® paper and a pencil. It is important to use pencil because ink can dissolve in ethanol. Each label should contain the Park Code, Project Name, Habitat Type, Sample Type, total number of vials, Lake Name (use "unnamed" if lake is not named), Sample ID, and the initials of the person who collected the sample.

NOCA LTEM Lake BMI Sample
1 of *5*
Lake Name: *Lonesome*
Sample ID*:* *M-12-01_2006AUG02_comp*
Collected by: *RSD*

l. Before discarding any processed debris it must be checked by another person to ensure that no organisms are being lost. If you are processing samples by yourself, put the debris in a WHIRL-PAK® with preservative to be held until a second person can look through the debris.
m. When you have removed 500 organisms, spread the remaining unprocessed fraction of the sample evenly throughout the sorting pan. Systematically search this pan and remove any organisms that you think you might not have found in your split samples. Look for new or different bugs and large crustaceans having different colored head capsules, body postures, sizes or coloration. When in doubt pick it out; it is better to pick up duplicates than to miss something. **(Note:** Keep these organisms in a separate vial and label them as qualitative).
n. After completing the qualitative subsampling you can discard the remaining debris.
o. If the organisms fill more than one vial, combine all of the vials from the same sample together with a rubber band.
p. Record the following information on the Lake BMI Processing Bench Sheet: Park Code, Lake Name, Sample ID, total number of vials for each category, percentage of sample sorted, total number of specimens sorted, the initials of the person who processed the sample, and the date the sample was processed.

3. Sample packaging and delivery
   a. Prior to packing, the caps of all vials are checked to see if they are secure.
   b. All vials from the same sample are individually wrapped with padded packaging material and bound together with tape or a rubber band.
   c. All samples are placed in a shipping container with additional packing material placed around them and with a copy of the Lake BMI Processing Bench Sheet.
   d. All samples must be hand delivered to the contractor performing the specimen identification work. Private shipping companies cannot be used because of the training and high cost required to meet their regulations concerning transport of Ethanol. The delivery date should be discussed and confirmed with the contractor. A receipt of the samples should be provided by the contractor at the time of delivery.

4. Specimen identification
   a. BMI specimen samples are counted and identified by the following contractor:

      Dr. Robert Wisseman
      Aquatic Biological Associates, Inc.
      3490 NW Deer Run Rd.
      Corvallis, OR 97330
      Phone: (541) 752-1568
      Email: wisseman@aquaticbio.com

   b. All specimens (including chironomids) are identified to the lowest possible taxonomic level. When necessary, the contractor consults with specialists from throughout North America concerning identification/verification of rare and/or problematic specimens.

c. Data outputs provided by the contractor include Excel spreadsheets containing the taxa counts for each taxon. Taxa should be identified by their scientific name and Taxonomic Serial Number (TSN) specified by the Integrated Taxonomic Information System available at the following website: http://www.itis.gov/ (accessed 14 April 2011). The contractor will ensure that specimen samples are properly labeled and that a record of specimen identifications and abundance, by their Sample ID, are maintained. The contractor will also provide, or maintain on file, all BMI sample identification bench sheets for future reference if needed.
d. Following completion of identification work, all specimens will be returned to the park. In addition, the contractor will provide a reference/synoptic series of specimens of each taxa identified.

F. **Quality Assurance and Quality Control Procedures**

1. Review all field procedures with all employees each year. Conduct pre-season and on-site training for new employees.

2. Conduct at least one mid-season field QA audit (focus on sampling procedures) for all field technicians working on this SOP. Follow procedures in SOP 19, G.6 for calculation of observer bias related to estimation of habitat attributes.

3. Do not rely on memory – always read protocol.

4. Immediately following survey and before leaving the site check to verify that all forms and labels are complete and readable.

5. The goal of subsampling is to provide an unbiased representation of a larger sample. The first requirement is that subsample fractions are all selected randomly. Additionally, sorter bias can be minimized by requiring each fraction to be sorted in its entirety, eliminating individual bias towards selecting organisms that are more visible. In each year, laboratory QC personnel or a qualified co-worker should examine three samples from each sorter. The QC worker will examine the selected fractions used for sorting and will look for organisms missed by the sorter. Organisms found will be added to the sample vials. If the QC worker finds less than 10% remaining in the subsample fractions, the sample passes; if more than 10% are found, the sample fails. If any of the three samples fail then all of the remaining samples for the individual sorter will be checked by the QC worker. Sorters in-training will have their samples 100% checked until the trainer decides that training is complete. Quality control checks are recorded on the Lake BMI Sample Processing Bench Sheet.

6. Many of the BMI metrics used in data analyses (particularly taxa richness related metrics) are affected by the number of organisms sorted, so for comparative purposes it is necessary to set a target number of organisms that are sorted from each sample. A minimum number of 500 organisms are required to be removed from each sample. The Pacific Northwest Monitoring Partnership and the Northwest Biological Assessment Workgroup have adopted the 500 count procedure. All organisms should be extracted

from selected fractions, subsampling should be designed to avoid exceeding the targeted number by more than 20% (Barbour and Gerritsen 1996).

7. In order to assess the reproducibility of BMI data, including variability attributed to sample processing and to within-site natural variability, duplicate pooled samples will be collected (during the same sampling occasion) at one randomly chosen lake from each park during each year. Calculated RPD values (Precision-plus method in SOP 19, Table 19.2) should be <40% for individual metrics used in reporting. Documentation and reporting requirements are discussed in SOP 19, I.2 and in SOP 22.

8. Following species identification, all samples and laboratory identification bench sheets and voucher samples will be returned to the originating park. In order to check the quality of BMI identifications, a random sample of approximately 10% of all samples collected at three year intervals will be identified by a second taxonomist. (Note: contractors are responsible for consulting with taxa-specific experts concerning rare/problematic specimens prior to the QC process). The number of taxa will be compared for each QC sample collected, and bias will be calculated as PD (see SOP 19, G.6) by comparing the results of both taxonomists for metrics based on the number of taxa (e.g., Total Taxa, EPT Taxa, etc.). PD should not be greater than ±10%. Additionally, if there is disagreement in identifications between the two taxonomists, then they should be consulted to resolve those differences. If differences cannot be resolved, then samples of the problematic specimens will be sent to a third taxonomist for resolution. Identification QC results and required data management actions are summarized by year, lake, and the particular specimen of concern on the Lake BMI/Zooplankton Identification Quality Control Summary Form.

9. In addition to the QC identification process (above), each year the contractor will provide a reference/synoptic series of specimens for each taxon identified. This provides a useful reference for changes in specimen names and data revisions. Reference collections will be maintained at one or two of the protocol park curation facilities (to be determined).

10. Procedures for documenting and assessing cumulative bias (SOP 19, Section H) must be followed for any changes in key field staff, contactors, instruments, methods, or indicators.

G. **Data Forms (*see* Appendix C: Field and Laboratory Data Forms)**
   1. Mountain Lake Daily Sampling Checklist
   2. Benthic Macroinvertebrate Field Form
   3. Lake BMI Sample Log Form
   4. Lake BMI Sample Processing Bench Sheet
   5. Lake BMI/Zooplankton Identification Quality Control Summary Form

H. **Specific Safety Considerations (*see* SOP 24: Field and Laboratory Safety)**
   1. Water safety (inflatable boats and wading)
   2. Hypothermia
   3. Laboratory procedures and chemical handling

Literature Cited

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SOP 12: Zooplankton Collection and Processing

April 19, 2011

Prepared by: Steven Fradkin, NPS NCCN-OLYM, Barbara Samora, NPS NCCN-MORA, and Reed Glesne, NPS NCCN-NOCA.

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Zooplankton Collection and Processing

Pelagic zooplankton are important constituents of mountain lake food webs. Zooplankton contribute to secondary productivity and provide a significant prey base for other aquatic vertebrates and invertebrate predators, including predaceous zooplankton taxa. NCCN mountain lakes are dominated by rotifer and crustacean taxa, along with predatory dipteran larvae. Changes in zooplankton species richness (number of taxa), community composition, and abundance provide insight into the effects of changes in lake productivity, water quality, competitive interactions, predator-prey interactions, and the introduction of non-native species on lake ecosystems. Methods in this SOP are adapted from Hoffman et al. (2005).

General Considerations

- Chlorophyll samples are to be collected between 10:00 am and 2:00 pm.

Equipment and Materials

- Zooplankton net (64 μm) and collecting cup
- Net cord marked in 0.5-m increments
- 250-mL HDPE sample bottle
- Squirt bottle
- Alka-Seltzer
- Sample labeling materials (permanent ink pen and tape)
- Field Protocol Manual
- Field data form
- Preservative: 95% ethanol or Lugol's solution
- Inflatable boat, pump, paddles, life jacket

General Considerations

- All zooplankton samples are collected at the permanent sampling station (temperature array buoy) located at the deepest point of each lake.
- All zooplankton samples should be kept as cool as possible while in the field. Keep samples shaded, preferably in a thermal bag filled with snow when available from a nearby snowfield, or submerged in a shaded portion of a lake or stream.

A. **Sample Collection**

1. Zooplankton samples are collected using a 64-μm mesh Wisconsin-type zooplankton net, with a 20-cm diameter opening and 1 m long from the bottom of the collecting cup to the top of the opening. Net efficiency is assumed to be 100%.

2. The collecting cup is attached to the net and the net is attached to one end of the marked (0.5-m interval) line.

3. The net is lowered from an inflatable boat to where the bottom of the collecting cup is within 1 m of the lake bottom.

4. The net is then retrieved through the water column to the surface by pulling the rope or line vertically at a constant rate of approximately 0.5 m/sec.

5. When a vertical tow is completed, each sample is inspected for organic and inorganic debris (e.g., fir needles, pollen, parts of leaves, silt and bottom sediment). Samples with excessive amounts of debris are discarded and the preceding procedures are repeated until an acceptable sample has been collected.

6. Three acceptable vertical tows are performed at each site. **Note**: during processing the three tows are pooled into one sample container.

7. At the surface, the net contents are rinsed into the zooplankton collecting cup by slowly lowering the net into the lake to within inches of the net opening and raising the net out of the water. Water from the lake surface can be gently splashed on the exterior of the net to further concentrate the contents into the cup. Care should be taken not to flush net contents out of the net into the lake, or to introduce additional lake water into the net through the net opening.

8. After several rinses of the net, the cup is detached from the net and its contents are again inspected for excessive debris. The amount of water in the cup is then reduced by swirling the contents of the cup so that the water filters out of the cup through the 0.64-µm mesh screens on the side of the cup. Care should be taken not to spill the sample. Alternately, the sample can be concentrated by holding the cup at an angle allowing the contents to drain through the mesh of the cup without swirling the contents. This can be facilitated by gently placing a finger on the outside of the cup mesh to draw water through it.

9. The concentrated sample is then rinsed from the cup into a 250-mL HDPE sample bottle using a squirt bottle filled with lake water filtered using a drinking-water filter.

10. Steps 7-9 above are repeated for each vertical tow.

11. After transfer to the HDPE sample bottle, the sample should be lightly carbonated to relax zooplankton prior to fixation. Relaxation aids the identification of soft-bodied zooplankters that can normally contract upon fixation. Carbonation is achieved by adding a small piece of an Alka-Seltzer® tablet to the sample bottle and sealing it with the lid.

12. Sample bottles should end up being approximately one-quarter to one-third full with zooplankton and water.

13. Concentrated zooplankton samples are then preserved with either 95% ethanol (added to attain a 70% solution), or by adding 1-2 mL of acid Lugol's solution.

14. Site identifier, sample number, sample date, and **total length** of the three tows (i.e., distance in meters of water column through which the collecting unit was retrieved) should be marked on the sample bottle label and appropriate data form.

B. **Lab Preservation and Delivery**

1. Samples are stored in a dark refrigerator until delivered to the contractor.

2. Prior to delivery all samples are logged into the Zooplankton Sample Shipping Form. Information recorded into the form includes park and contractor contact information, lake code, lake name, collection date, sample number, tow length, and delivery date.

3. All samples must be hand delivered to the contractor performing the specimen identification work. Private shipping companies cannot be used because of the training and high cost required to meet their regulations concerning transport of Ethanol. The delivery date should be discussed and confirmed with the contractor. A receipt of the samples should be provided by the contractor at the time of delivery.

C. **Specimen Processing and Identification**

1. Zooplankton samples will be counted and identified (to lowest taxonomic level) by the following contractor:

   Sample Delivery
   Dr. Allan Vogel
   ZP's Taxonomic Services
   3303 Windolph Loop NW
   Olympia, WA 98502
   allenvogel@comcast.net

   Correspondence
   Dr. Allan Vogel
   ZP's Taxonomic Services
   3303 Windolph Loop NW
   Olympia, WA 98502
   (360) 593-7230

2. Contract Laboratory Specimen Processing. The standard zooplankton sample enumeration uses the following methodology.
   a. Pooled samples are split with a Folsum plankton splitter until an approximate subsample size of 400 total individual arthropod zooplankters, including at least 100 individuals of the most abundant arthropod species, are reached. If the initial split does not achieve both of these criteria, then increasingly larger splits will be enumerated until both criteria are met, or until the entire sample is counted.
   b. All rotifers and protozoans in the split are completely enumerated as well unless their numbers significantly exceed 400 individuals, in which case, a separate rotifer subsplit is made and then counted for rotifers and protozoans.
   c. The statistical methodology for this approach is based upon Edmondson and Winberg (1971, p. 178), and assumes that the sampling methods (both in the field and during the splitting) follow a Poisson distribution. This assumption is violated for larger species; thus, all individuals of those species found in a sample will be enumerated. The selected values of 400 and 100 individuals provide a maximum statistical

standard error of the mean of 5 and 10%, respectively (The formula used is: $s = 1/\sqrt{N}$). While only the confidence limits for total numbers and most abundant species are set by this procedure, the standard error of the mean for each species can be determined from the original tallies, using the previous formula for the Poisson distribution.

d. Results will be reported in numbers per cubic meter, along with the standard error for each value (also in units of numbers per cubic meter).

3. Contract Laboratory Specimen Identification
   a. The standard zooplankton enumeration is done with a Wild M-3 microscope at 32X magnification.
   b. Samples are counted in an open counting chamber with six parallel channels following the procedures described in Edmondson and Winberg (1971, p. 131). Species identifications are made at higher levels of magnification as needed.
   c. General taxonomic identifications follow Edmondson (1959), Pennak (1989), and Thorp and Covich (1991). Specific group references used include Brooks (1957), Deevey and Deevey (1971), Brandlova et al. (1972), Pontin (1978), and Stemberger (1979), and Patterson (1996).
   d. Identifications are to species for all adult and subadult crustaceans, except harpacticoid copepods, and for most rotifers. Immature copepods through copepodite stage IV are identified as far as their developmental stage allows.
   e. Confirmation of the identifications is made using appropriate past local investigations. When necessary the contractor consults with specialists from throughout North America concerning identification/verification of rare and/or problematic specimens.

4. Data outputs provided by the contractor include Excel spreadsheets containing the taxa counts for each taxon. The contractor will ensure that specimen samples are properly labeled and that a record of specimen identifications and abundance by their Sample ID are maintained. The contractor will also provide, or maintain on file, all sample identification bench sheets for future reference if needed.

D. **Quality Assurance and Quality Control Procedures**

1. Review all field procedures with all employees each year. Conduct pre-season and on-site training for new employees.

2. Conduct at least one mid-season field QA audit (focus on sampling procedures) for all field technicians working on this SOP.

3. Do not rely on memory – always read protocol.

4. After a site has been sampled, the net, collecting cup, and retrieval rope or line should be thoroughly rinsed (i.e., 2-3 times) with water from the site and allowed to dry if possible.

5. Prior to use at another site, the net, collecting cup, and retrieval rope or line should be preconditioned by rinsing 2-3 times with water from the new site.

6. Bottle lids should be checked to make certain that they are securely fastened. In addition, samples to be stored for a lengthy period of time prior to processing should have their lids taped.

7. Remember that nylon lines or ropes used for any depth related measurements should be checked to determine if recalibration related to stretching of the line is needed at the beginning of each sampling trip. Additional measurement error can result in how the measuring line is attached to the equipment. For each type of equipment, measurement of the distance between the equipment and the first mark on the line should always be checked. This is necessary for sampling trips where the same depth measuring line is used for water sample bottles, plankton nets, and the Secchi disk. Measurement error can be associated with how the line is secured to the equipment and how far it is located from the effective sampling surface of the equipment (e.g., the measuring line for the plankton net is attached to a bridal that extends several centimeters in front of the net opening). Deployment depth measurement must be adjusted to account for the discrepancy in distance from the net opening to the first depth mark on the line. Metal clips are recommended for marking depth intervals on lines or ropes, although lines or ropes can also be marked using a pen with permanent ink (e.g., Sharpie).

8. Immediately following survey and before leaving the site check to verify that all forms and labels are complete and readable.

9. In order to assess the reproducibility of zooplankton data, including variability attributed to sample processing and to within-site natural variability, duplicate pooled samples will be collected (during the same sampling occasion) at one randomly chosen lake from each park during each year. Calculated RPD values (Precision-plus method in SOP 19, Table 19.2) should be <40% for individual metrics used in reporting. Documentation and reporting requirements are discussed in SOP 19, I.2 and in SOP 22.

10. Following identification, all samples and laboratory identification bench sheets and voucher samples will be returned to the originating park. In order to check the quality of zooplankton identifications, a random sample of approximately 10% of all samples collected at three year intervals will be identified by a second taxonomist. (Note: contractors are responsible for consulting with taxa-specific experts concerning rare/problematic specimens prior to the QC process). The number of taxa will be compared for each QC sample collected and bias will be calculated as PD (see SOP 19, G.6) by comparing the results of both taxonomists for metrics based on the number of taxa (e.g., Total Taxa, Crustacean Taxa, Rotifer Taxa, etc.). PD should not be greater than ±10%. Additionally, if there is disagreement in identifications between the two taxonomists, then they should be consulted to resolve those differences. If differences cannot be resolved, then samples of the problematic specimens will be sent to a third taxonomist for resolution. Identification QC results and required data management actions are summarized by year, lake, and the particular specimen of concern on the Lake BMI/Zooplankton Identification Quality Control Summary Form.

11. Voucher samples for the QC identification process (above) will be maintained at one or two of the protocol park curation facilities (to be determined).

12. Procedures for documenting and assessing cumulative bias (SOP 19, Section H) must be followed for any changes in key field staff, contactors, instruments, methods, or indicators.

E. **Data Forms** (*see* Appendix C: Field and Laboratory Data Forms)
1. Mountain Lake Daily Sampling Checklist
2. Water Clarity, Zooplankton, and Lake Profile Form
3. Zooplankton Sample Shipping Log
4. Lake BMI/Zooplankton Identification QC Summary Form

F. **Specific Safety Considerations** (*see* SOP 24: Field and Laboratory Safety)
1. Water safety (using inflatable boats)
- Hypothermia

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SOP 13: Fish Sampling and Processing

April 19, 2011

Prepared by: Reed Glesne, NPS NCCN-NOCA, and Robert Hoffman, USGS, FRESC, Corvallis OR.

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Fish Sampling and Processing

Salmonids (*Oncorhynchus* spp. and *Salvelinus* spp.) are the most common fish encountered in mountain lakes of the Pacific Northwest, although salmonids are not native to most of these systems. Mountain lakes were originally stocked with fish by private individuals and various agencies beginning in the early 1900s. The impact of fish on native communities of invertebrates and amphibians has been well documented (Knapp and Matthews 2000, Parker et al. 2001, Pilliod and Peterson 2001, Liss et al. 2002). Gill net and angling catch per effort and observations are used to assess the relative abundance of fish in lakes selected for the monitoring project.

Equipment and Materials

- Fish Sampling SOP
- Past survey reports and information
- Field data forms
- Fish key
- Multi-panel monofilament gill nets
- Gill net float, cord, mesh bag for anchor
- Bucket or tub for processing fish
- Weighing scales (g)
- Measuring board or tape (mm)
- Angling equipment
- Clipboard and pencils
- Inflatable boat, paddles, pump, life jackets

A. **Fish Capture** (methods modified from Hoffman et al. 2005)

1. Gill net sampling is used as the primary method for definitive presence/absence determination, species identification, and index of fish density. At minimum, gill nets must be used at five-year intervals at each lake. Their use in intervening years is optional depending on park and lake specific management objectives. When gill nets are not used, visual observations and/or angling methods are used to verify presence of fish in a lake.

2. One or two multi-panel monofilament gill nets are set overnight at each lake. Recommended net length is 30 to 40 m with a depth of 1.5 to 2 m. All nets should have a poly-core float line and lead-core lead line. Nets should have multiple panels of different mesh sizes which should primarily include 12.5-, 18.5-, and 25-mm bar mesh panels. The configuration of nets used by NOCA that have proven to be very effective for collecting the range of sizes of fish found in mountain lakes are shown in the following figure:

   Material: monofilament.
   - Length and depth: 36 m long and 1.8 m deep
   - Panels: 6 panels, with each panel 6 m in length
   - Mesh size, panel order, and diameter of monofilament (*see* diagram)
   - Float Line: poly-core
   - Lead Line: lead-core

12.5 mm bar 0.12 mm dia.	18.5 mm bar 0.15 mm dia.	25.0 mm bar 0.15 mm dia.	18.5 mm bar 0.15 mm dia.	25.0 mm bar 0.15 mm dia.	33.0 mm bar 0.17 mm dia.

The fine diameter of the net minimizes the weight (<3lbs) for backpacking and reduces its visibility in the water resulting in increased sampling effectiveness. The nets can be purchased at the following website: http://www.lundgrensfiske.com/index_eng.html (accessed 14 April 2011).

3. Gill net catch rates are recorded as number of fish by each species collected per hour of gill net effort. Gill nets are generally fished overnight for 12 to 16 hrs.

4. Crew members should select gill net fishing locations that will provide optimum fish capture and minimum damage to nets. Littoral areas of moderate depth are ideal locations for setting gill nets overnight. Care should be taken to not set the net in extensive areas of submerged objects (e.g., large boulders, large woody debris, etc.).

5. Gill nets should be set with the smallest mesh end of each net affixed to shore and the other end of the net extending out toward the center of the lake. A weight or rock-filled bag is attached to the lead-line on both ends of the net. A float, such as a 250 to 500-mL Nalgene® bottle, is attached to the poly-core line at the end of the net. To deploy gill nets, a float is secured to the end of the float line on the large mesh end of the net with sufficient cord to allow the float to surface after the net is deployed. An anchor or mesh bag filled with rocks is attached to the end of the lead-line on the large mesh end (cord length may vary if net is to be set off the bottom to avoid snagging on woody debris or rocks). The net is carefully loaded into the front of the boat starting with the large mesh end float and weights followed by the net so that it will not tangle as it is being deployed. After the net is loaded into the boat, a cord is attached to the smallest mesh end of the float-line and secured to rocks or woody vegetation (the shore end of the net is positioned at the water-land interface to reduce incidental capture of birds or mammals). The net self-deploys as the boat moves out into the lake. When the end of the net is ready to be dropped the anchor is deployed, and the boat is then paddled while holding on to the float until the net is straight. The float is then released.

6. As the net is deployed, crew members in the boat should visually inspect the gill net for tangles, snared woody debris, or other anomalies that may affect the ability of the gill net to capture fish.

7. Nets are always retrieved from the offshore end to the shore by pulling the boat inshore as the net is retrieved into the boat. This helps to avoid snagging the net on debris while it is being retrieved.

8. Data including time of deployment, time of removal of the net, total hours fished, total catch/gill net hr., and information concerning weather are recorded on the Gill Net Survey Form. Data on individual fish captured by gill net is also recorded on the Gill Net

Survey Form and includes species code (Table 13.1), total and fork lengths (mm), and weight (g). Net locations are also sketched onto a map displaying the lake aerial photo.

9. Fish can also be captured by rod and reel. Equipment includes the use of spinning or fly fishing rods using only small spinners (1/32 – 1/16oz) or wet and dry flies (no.12 to 16 hook size). Natural bait is not allowed. Angling effort should be recorded on the Angler and Visual Observation Data Form as total hrs fished with start and finish times. The name of the angler(s) also should also be recorded. The number of fish caught of each species/life stage (*see* Tables 13.1 and 13.2) is recorded, along with comments concerning the fish condition, habitat etc.

Table 13.1. Fish species coding.

Species	Code	Species	Code
West-slope Cutthroat	WCT	Golden Trout	GOT
Coastal Cutthroat	CCT	Bull Trout	BUL
Yellowstone Cutthroat	YCT	Brook Trout	BRK
Rainbow Trout	RBT		

Table 13.2. Fish Life Stage and Size Classes.

Life Stage	Size Class (mm)
Fry	<50
Fingerling	50 – 150
Adult	>150

10. Visual observations also are recorded on the Angler and Visual Observation Data Form. Data are recorded similar to angler effort data.

B. **Processing of Fish**

1. All fish are carefully removed from the gill net and placed into a plastic container or garbage bag until all captured fish are removed from the net.

2. The processing of captured fish includes species identification, measurement of total length, fork length, and the weight of each fish.
   a. Length measurement: Total length is measured from tip of snout to maximal extent of caudal fin (**Note**: during measurement the caudal fin is squeezed together to achieve the maximum extent). Fork length is determined by measuring from tip of snout to end of median caudal fin rays.
   b. Weight measurement: All fish collected are weighed (report in g). Care must be taken to maintain fish weighing scales and all scales must be periodically calibrated to standard weights. Deviation between standard weights and scale weights should be noted, with correction factors applied to fish weights in the field.
   c. Photographic documentation is required for species that cannot be verified in the field following procedures in SOP 18, Section B.3. Photo number, type, date, and description are recorded on the Trip Photo Log Form (Appendix C). In addition, voucher specimens can be collected and preserved with 70% ethanol.

3. All data should be recorded on the Gill Net Data Form.

C. After the collection of data and samples has been completed, carcasses should be properly disposed. Each fish's swim bladder is punctured and carcasses are deposited in the deeper portion of the lake, but away from the location of sample collection for water chemical analyses. Proper disposal of fish carcasses and washing of equipment used to sample fish reduces the probability of carnivore encounters and criticism from the public.**Quality Assurance and Quality Control Procedures**

1. Review sampling procedures and species identification with all employees each year. Conduct pre-season and on-site training for new employees.

2. Conduct QA audits as described in SOP 19, Section G.6.

3. Do not rely on memory – always read protocol.

2. Immediately following survey and before leaving the site check to verify that all forms are complete and readable.

3. Care must be taken to maintain fish weighing scales and all scales must be periodically (at least preseason and midseason) calibrated with reference standard weights. Deviation between standard weights and scale weights should be noted with correction factors attached to scales and applied to fish weights in the field.

D. **Data Forms** (*see* Appendix C: Field and Laboratory Data Forms)

1. Mountain Lake Daily Sampling Checklist
2. Trip Photo Log
3. Fish Gill Net Survey Form
4. Fish Angling and Visual Observation Form

E. **Specific Safety Considerations** (see SOP 24: Field and Laboratory Safety)

1. Water safety (using inflatable boats)
- Hypothermia

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SOP 14: Aquatic Amphibian Sampling and Processing

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Prepared by: Barbara Samora, NPS NCCN-MORA, Reed Glesne, NPS NCCN-NOCA, and Steve Fradkin, NPS NCCN-OLYM.

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Aquatic Amphibian Sampling and Processing

Widespread stocking of fish into naturally fish-free mountain lakes of protected areas in the western United States (Bahls 1992) has resulted in reduction or elimination of amphibians in many of these waters (Tyler et al. 1998, Funk and Dunlap 1999, Knapp and Matthews 2000, Pilliod and Peterson 2001, Larson and Hoffman 2002). Additional impacts to amphibians associated with habitat alteration, climate change, chemical contamination, and disease have been reviewed by Semlitsch (2000).

The main objective of this SOP is to document the presence or absence of amphibian species at our long-term monitoring sites. This SOP provides step-by-step instructions for performing visual encounter surveys (VES) and snorkel surveys for lake and pond-breeding amphibians and details the methods for quantifying habitat variables at survey sites. VES data are required from all sites. Replicate VES and/or snorkel surveys will be completed at a minimum of one lake from each park during the same sampling visit. Procedures were modified from Hoffman et al. (2005).

Equipment and Materials

- Amphibian SOP
- Past survey reports and information
- Data forms
- Clipboard and pencils
- Amphibian identification guide
- Fish identification guide
- Thermometer – for measuring air and water temperatures.
- Re-sealable plastic bags
- Waders and wading shoes
- Metric ruler (to measure amphibian lengths)
- Hand lens (for examining features on larval salamanders and tadpoles)
- Snorkel gear (optional): drysuit, neoprene hood, neoprene gloves, neoprene boots, mask, snorkel, and handheld dive light
- A small aquarium net
- Vinyl disposable surgical gloves
- Plastic container (quart size)
- Meter marked tape (50m)

Appropriate disinfection strategies for equipment are listed in SOP 16.

A. **Visual Encounter Surveys (VES)**

1. VES Procedures
   a. Surveys will generally be conducted by crews of two usually during the daylight hours. Note on survey form whether survey was conducted during the day or night. At sites where replicate surveys are to be conducted, two hours must pass after the first survey before the second survey can be conducted.
   b. Surveyors walk the entire perimeter of the lake continuously searching for amphibians and stopping every 50 m to search more intensively for embryos and larvae. Note on the data form whether observation was made at a station (record

station number) or in between stations (e.g., between #3 and #4). The VES start point is selected at random. Selection of this start point is accomplished by using the lake aerial photo or map and dividing the lake shoreline into 20 to 30 approximately equal sections. The sections are numbered and a random number is drawn. The start point is located at the center of the section that has been randomly selected. The start point is documented on the on the aerial photo and with GPS coordinates. **Note**: Step 1 is repeated for successive year surveys at each lake.

c. The first intensive search plot is located at the random start point. Plots are sampled in a counter-clockwise direction around the lake perimeter from the random start point. The search area is a rectangular 1 x 2 m plot extending 1 m from the shoreline toward the center of the lake. Vegetated areas and other habitats likely to harbor amphibian embryos and larvae that fall between stations should be intermittently searched with dip nets.
d. At each intensive search station, surveyors search for amphibians in hidden microhabitats (including searches under shoreline cover objects) and, if visibility is limited, make sweeps with a dip net to capture individuals to verify the species identification. If there are movable cover items at a station, move them to see if there are any amphibians beneath the items.
e. In the comments field, note any voucher specimens collected and photographs taken (document photos on photo log).

2. Sample Site Habitat Characterization
   a. Characterize the predominant features of lake habitat at each intensive amphibian sample site according to substrate type and class (Table 14.1) and record on the Amphibian Visual Encounter Survey #1 form.

Table 14.1. Lake habitat parameters.

Type	Class	Size (Diameter in mm)
Inorganic	Silt (smooth between fingers)	<0.06
	Sand	<2
	Gravel	2 to 64
	Cobble	65 to 256
	Boulder	257 to 4096
	Bedrock	>4096
Organic	Fine Particulate Organic Matter (FPOM)	<2
	Coarse Particulate Organic Matter (CPOM)	2 to 100
	Coarse Woody Debris (CWD)	>100
Vegetation	Emergent	
	Floating	
	Submergent	

b. The four dominant substrate classes, including classes from all types, are recorded on the data form in order of their dominance in the plot area. Dominance is estimated by visual observation of the percentage of the sample area covered by each substrate class. Percentage of sample plot for dominant substrate classes must be at least 10% to be recorded.
c. In addition to item b. above, the percentage of CWD should always be recorded on the data form; and, the presence of CPOM and aquatic vegetation types in the sample plot should always be indicated by a check mark in the appropriate box of the data form.

3. VES Replication
   a. A minimum of one complete VES is conducted at each lake. An additional VES will be completed at one lake from each park every year. Replicated sites will be randomly selected from the set of six monitoring sites at each park. A new random start point will be determined for each replicate survey.
   b. Snorkel surveys are optional but can be used to replace the replicate VES.
   c. The replicate survey will be performed during the same site visit no sooner than two hours after completion of the first survey.
   d. Collection of habitat information is not required during replicate surveys.

4. Adjacent Lakes: If time allows, amphibian searches should be conducted on nearby lakes following the procedures in Section A.1-2, of this SOP.

B. **Snorkel Survey Sampling Procedures (optional)**
   1. Determination of Survey Transects
      a. Snorkel survey nearshore transects, 25 m long, should be selected after the lake habitat survey conducted during the VES has been completed and all major nearshore habitats have been identified. The number of nearshore transects selected for each habitat should be roughly proportional to the estimated percent of the lake nearshore area represented by each habitat. Determination of the proportion of shoreline by major habitat types is estimated based on the VES habitat survey information and additional observations recorded outside of sample plots. An example of allocation of snorkel survey transects follows: if a lake habitat survey determines that CWD occurs along 50% of the lake nearshore, FPOM along 25%, and Boulder along 25%, then two 25-m transects should be selected for CWD, and one 25-m transect selected each for FPOM and Boulder. Transect selection does not need to be random.
      b. Nearshore and offshore snorkel transect surveys are conducted at the same shoreline location. The nearshore surveys are constrained to a horizontal distance of 2 m from the water-land interface. The offshore surveys are conducted at a point beginning between 3 to 5 m from the water-land interface and ending at 25 m toward the center of the lake.
      c. A minimum of four nearshore and four offshore transects should be snorkeled at each survey lake; however, at least one nearshore transect should be snorkeled for each major habitat.
      d. If the length of a habitat type along the nearshore of a lake is ≤25 m, then the entire length of the habitat should be snorkeled, and the total length snorkeled should be

entered on the appropriate data form. All transect lengths surveyed should be entered on the appropriate data form regardless of whether they are ≤25 m long.

e. Measured transects are marked at both ends with colored surveyor's tape.
f. General locations of survey transects are identified on a aerial photo of the lake and GPS coordinates for transect end points are recorded on the Amphibian Snorkel Survey Form. This will facilitate relocation of transects on subsequent sampling visits.

2. Conducting the Nearshore Snorkel Survey
   a. After survey transects have been determined, the snorkeler looks for amphibians in the open and by searching through substrate materials in the nearshore area of each transect.
   b. The survey is conducted from shore to an approximate water depth of 1 m along each of the four survey transects.
   c. The snorkeler reports amphibian species, number observed, estimated total lengths of individuals, and microhabitat substrate type associated with observed amphibians to an onshore crew member recording information on a data form. Amphibians observed in the water column are recorded in the Microhabitat column as WC.

3. Conducting Offshore Snorkel Surveys
   a. Offshore survey transects run perpendicular to the center of the nearshore survey transects and begin 3-5 m from the water-land interface.
   b. The snorkeler swims the transect recording the number of each species/life stage and the estimated total lengths of the individuals observed within the water column and on the bottom substrate microhabitat of the deep water area being surveyed.
   c. The crew member on shore records the observations of the snorkeler and notifies the snorkeler when an estimated 25 m has been surveyed.
   d. All survey information should be recorded on the Amphibian Snorkel Survey Form (*see* Section B.4 below).

4. Information to be Collected and Recorded during Snorkel Surveys
   a. General information - site identifier, survey date, survey time, type of survey, weather conditions, water and air temperature, and transect location. **Note:** transect location information should be recorded on an aerial photo of the lake and GPS coordinates should be recorded on the data form.
   b. For each observed individual – species, life stage, length, habitat (e.g., aquatic vegetation, CWD, Gravel, Cobble, Boulder, Silt, etc.), location (nearshore or offshore), and transect number.

C. **Data Recording**

1. Observed and captured individuals should be identified to species when possible. Amphibian species determination is performed in the field using distinguishing characteristics outlined in regional field guides (e.g., Leonard et al. 1993, Corkran and Thoms 1996). Instructions for processing animals are provided below. Specimens should be released at the point of capture. **NOTE**: All amphibian observations must be verified

by the Field Lead. Follow procedures in Section D of this SOP if verification cannot be made in the field.

2. Each species, identified by its species code (Table 14.2) and its life stage, should be recorded on a separate line of the data form. **For egg masses**: count or estimate the number of masses seen and indicate EM as the life stage on the data form. Do not remove individual embryos from masses and do not detach masses from supporting vegetation. **For single eggs or small egg clusters**: count or estimate individual embryos and indicate E as the life stage on the data form.

Table 14.2. Amphibian species names and codes.

Species Code	Scientific Name	Common Name
AMGR	*Ambystoma gracile*	northwestern salamander
AMMA	*Ambystoma macrodactylum*	long-toed salamander
AMSP	*Ambystoma species*	larval Ambystomatid salamander
DICO	*Dicamptodon copei*	Cope's giant salamander
DITE	*Dicamptodon tenebrosus*	Pacific giant salamander
ENES	*Ensatina eschscholtzii*	Ensatina
PLLA	*Plethodon larselli1*	Larch Mountain salamander
PLVA	*Plethodon vandykei1*	Van Dyke's salamander
PLVE	*Plethodon vehiculum*	western red-backed salamander
BUBO	*Anaxyrus boreas* (formerly *Bufo boreas*)[1,2]	western toad
ASTR	*Ascaphus truei*	tailed frog
PSRE	*Pseudacris regilla*	Pacific treefrog
RAAU	*Rana aurora*	red-legged frog
RACAS	*Rana cascadae*	Cascade frog
RALU	*Rana luteiventris*[1]	Columbia spotted frog
TAGR	*Taricha granulosa*	rough-skinned newt

[1]Species of Concern including Washington State listed and Federal proposed or listed species.

[2]Genus *Bufo* revised to *Anaxyrus* in Olson (2009).

3. If there is time, measure the snout-vent length (SVL) and total length (TL) of up to 10 individuals of each life stage of each species observed during the survey and record on the data form. Count and record all individuals seen. If large numbers of individuals are encountered, then estimate the total numbers observed and record on the data form. The number of individuals observed can be estimated by counting all of the individuals in a smaller area and extrapolating to estimate the total number observed. Identify this number as an estimate rather than an actual count.

4. Record the collection method (H – Hand collected, V – Visual only).

5. While characterizing habitat and surveying for amphibians, look for any evidence of the presence of fish. If fish are not detected in the main body of water, search inlets and outlet streams where fish may be more visible. If fish are detected, indicate the species (*see* SOP 13: Fish Sampling and Processing, Table 13.1, for fish species codes) in the species column of the fish angling or visual observation data form.

D. **Voucher Specimens and Photographic Documentation**

1. When amphibian identification proves too difficult to determine in the field, a voucher specimen should be collected, unless you suspect it may be a Species of Concern. Generally one or two specimens are collected for this purpose.

2. If specimens are to be preserved they should be stored in a glass vial containing 70% ethanol. Voucher specimen labels (completed in pencil) should include: site identifier, collection date and time, specimen life stage, habitat from which specimen was collected, and the name(s) of the individual(s) who collected the specimen. This information also should be recorded on the Amphibian Snorkel Survey Form and the label should be placed into the vial with the specimen.

3. Alternatively, representative larvae may be transported to the laboratory where they can be reared to a size sufficient to confirm identification. Live larvae are readily transported from the field in plastic containers provided water is kept cool and replenished when possible. Any transport of live larvae to and from the field will follow disinfection protocols outlined in SOP 16.

4. Field Leads should check to be certain that the project has applied for and received the appropriate collecting permits and that the project is in compliance with applicable Animal Care guidelines.

5. Crew members should have access to, read, and be familiar with the American Society of Ichthyologists and Herpetologists/Society for the Study of Amphibians and Reptiles publication "Guidelines for Use of Live Amphibians and Reptiles in Field Research." This publication is available only online at http://www.asih.org/files/hacc-final.pdf (accessed 15 April 2011).

6. Photographs should be taken of any Species of Concern, unique species, deformed specimens, as well as of those that cannot be verified in the field. See SOP 18: Acquiring and Managing Photographic Images (Section B.3) for additional documentation requirements. Photo number, type, date, and description are recorded on the Trip Photo Log Form (Appendix C).

E. **Processing amphibians** (adapted from Corkran and Thoms 1996 and Phillott et al. 2010)

1. Handling amphibians

Capture, handling, and housing of wild amphibians should be minimized where possible, as stressed animals are at greater risk of infection (Carey et al. 1999, Daszak et al. 2003).

a. Single-use disposable (preferably vinyl) surgical gloves are worn while handling adult amphibians. Handling tadpoles should be avoided since tadpoles are sensitive to nitrile, latex, and, to some extent, vinyl gloves (Gutleb et al. 2001, Cashins et al. 2008). Gloves are rinsed with water from the site or filtered water prior to handling each amphibian. Gloves are changed for each new water body before handling amphibians. Change to new gloves if any unusual pathogens are noted on amphibians. Used disposable gloves should be retained for safe disposal in sealed bags.

b. Because of their skin permeability, amphibians also desiccate quickly. They should be kept moist and cool at all times, and hands should be wet when directly handling amphibians.
c. Salamanders are capable of tail autonomy and therefore should not be held by their tails. Tail loss is highly stressful on an animal and should be avoided.
d. Tadpoles, hatchlings, and larval salamanders should be placed in individual plastic bags with at least enough water from the capture site to cover the entire body. The bags should be kept cool and shaded. The animals should be processed as quickly as possible and released at the point of capture.
e. Adult salamanders may be held in the hands, but placing them in a plastic bag reduces heat and desiccation stress. Keep bags cool and shaded, process animals as quickly as possible, and release them at point of capture.
f. Adult frogs and toads are best examined when the hind legs are fully extended and gently held together, and the body is supported by either hand. Keep the animal moist and cool, process quickly, and release it at point of capture.
g. Sick and dead frogs should be collected for disease diagnosis. Follow instructions provided by the U.S. Geological Survey National Wildlife Health Center at http://www.nwhc.usgs.gov/mortality_events/reporting.jsp (accessed 15 April 2011).

2. Measuring amphibians
   a. Total length (TL): For hatchling salamanders, total length should be measured instead of snout-to-vent length because of the difficulty in determining where the body ends and the tail begins. The total length is measured from the tip of the snout to the tip of the tail. When recording the length for a hatchling salamander on the data form, indicate (TL) after the number on the data form for clarity.
   b. Snout-to-vent length (SVL): Because salamander tails are often shortened due to autotomy or tail bites, SVL is the preferred metric for gauging size. SVL is measured from the tip of the snout to the anterior corner of the vent.
   c. Measuring frogs and toads other than tadpoles: With the exception of the male tailed frog, anurans do not have tails and are therefore measured from snout to vent. SVL includes the length of the head and the body, and is measured from the most anterior end to the most posterior end of the body.
   d. Measuring frog and toad tadpoles: SVL for tadpoles includes the length of the head and body but not the tail muscle and fin. If the tadpole is out of water, measure along its dorsum from the tip of the snout to where the body ends. If the tadpole is contained in a plastic bag with water, view the tadpole from underneath and measure along its ventrum.

F. **Quality Assurance and Control Procedures**

1. Review SOP procedures with all employees each year. Conduct pre-season and on-site training for new employees that includes sampling procedures, specimen processing, handling, decontamination of equipment (SOP 16), and specimen identification.

2. Conduct at least one mid-season field QA audit (focus on sampling procedures and species identification) for all field technicians working on this SOP.

3. Do not rely on memory – always read protocol.

4. Immediately following survey and before leaving the site check to verify that all forms are complete and readable.

5. All amphibian observations must be verified by the Field Lead. Follow procedures in Section D (collection of voucher specimens) of this SOP if identification cannot be confirmed in the field.

G. **Data Forms** (*see* Appendix C: Field and Laboratory Data Forms)
1. Mountain Lake Daily Sampling Checklist
2. Trip Photo Log
3. Amphibian Visual Encounter Survey (VES) Form (number/length/life stage)
4. Amphibian Visual Encounter Survey Habitat Form
5. Amphibian Snorkel Survey Form (number/length/life stage)

H. **Specific Safety Considerations** (*see* SOP 24: Field and Laboratory Safety)
1. Water safety inflatable boats, wading)
2. Hypothermia

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SOP 15: Lake Riparian Disturbance Monitoring

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Lake Riparian Disturbance Monitoring

Human disturbance along lakeshores and within a lake basin can adversely affect lake ecosystems. Trails, campsites and trampled areas of vegetation can increase erosion potential and contribute sediment to a lake. Human waste associated with concentrated human use can introduce nutrients and pathogens into lake waters. Human use also can provide a source for introduction of exotic plant and animal species.

Human impacts have been monitored in the NCCN wilderness parks for nearly 30 years. Established protocols for quantifying impacts of campsites and campsite areas to wilderness have been developed and are currently used to monitor long-term impacts to wilderness resources. This protocol focuses mostly on nearshore vegetation disturbance and soil erosion with the intent of providing a lake-wide assessment of disturbance for monitoring trends rather than tracking individual disturbances through time. Park staff, using visual surveys, will describe vegetation types and assign human-influenced condition classes to a complete sample of equal-sized plots located along the entire perimeter of the lake shoreline.

Equipment and Materials

- Field Protocol Manual
- Aerial photos and/or lake map
- Data Forms
- Meter marked measuring tape (50 m)
- Laser rangefinder or GPS unit
- Camera
- Clipboards and pencils

A. **Sampling Design and Sample Site Location**

A complete census of contiguous 10 x 10 m plots, around the entire lake shoreline, is completed once every three years at each lake. The survey start point is located at one of the two permanent Water Level Benchmarks (see SOP 5) along the shoreline and documented on the Lake Riparian Disturbance Form. The first plot is centered on this point and successive plot centers are established at 10 m intervals as the survey progresses in a counter-clockwise direction around the entire lake shoreline.

B. **Data Collection**

1. Sample plots (10 m wide x 10 m long) are established starting from the land/water interface to 10 m landward along a line perpendicular to the shoreline at the plot center. Plots are centered on the sample point.

2. Effort should be made to minimize disturbance prior to conducting and during the survey. In order to minimize disturbance, it is recommended that the survey be simultaneously conducted with the amphibian VES (SOP 14).

3. Distances between successive plots should be measured with a meter-marked measuring tape (50 m) or by using the laser rangefinder (*see* operation details of Laser Tech TruPulse™ 200 in SOP 4). Use of an inflatable boat and a laser rangefinder work well for

portions of the shoreline that are inaccessible by foot. Measured distances must follow the shoreline.

4. At each plot, observations and determinations of land cover class (Table 15.1) and condition class (Table 15.2) are made based on two shoreline proximity categories and recorded on the Lake Riparian Disturbance Form. The shoreline proximity categories are based on distance from the land-water interface: 1) Shore Zone: 0 to 3 m and 2) Near Shore Zone- 3.1 to10 m.

Table 15.1. Land cover classes.

Code	Class	Code	Class
MD	Meadow	SH	Shrub
SH/MD	Shrub/Meadow	CF	Conifer Forest
MXF	Mix Conifer/Deciduous	DF	Deciduous Forest
BR	Bedrock/Boulder	SN/I	Snow or Ice
TA	Talus	AL	Alluvium

Table 15.2. Human influence condition classes (modified from Rochefort and Swinney 2000).

Code	Description
0 – Pristine, no visible use.	No signs of human use of the area.
1 – Minimal human use.	Small and temporary indications of use caused by people or animals, such as litter, trampled vegetation, scuffed soil, footprints but no lasting damage such as plant loss (bare ground), erosion, or broken stems.
2 – Moderate use and disturbance	Human impacts are easily recognizable but limited in severity or distribution. Examples include uprooted plants, clearing of forest litter, clearing of pebbles or rocks in fell fields or compacted soils, but not erosion; area of individual impacts should be small (<0.8 sq. ft. or 1 ft. in diameter) and covering less than 15% of the sub-plot area (shore zone 0-3 m, near shore 3.1-10 m, and far 10.1-20 m).
3 – Significant disturbance	Few severe or many moderate impacts. Severe impact examples include walled campsites in an alpine area, eroded social trails (>1 in. deep), large compacted sites (>0.8 sq. ft.), extensive moderate use impacts. Combined severe and moderate impacts covering 15 to 50% of the sub-plot areas.
4 – Severe disturbance	Greater than 50% of the sub-plot areas covered by combined severe and moderate use impacts.

5. The entire Plot (10 m x 10 m) and sub-plots (i.e., Shore Zone and Near Shore Zone) boundaries can quickly be delineated by using a laser rangefinder. When using the rangefinder the horizontal distance function is used to measure the width of the plot. For measurements perpendicular to the shoreline, sloping banks are measured using the slope distance function, otherwise use the horizontal function. For land cover, select the cover type that is found in the majority of the sub-plot area.

6. Photographs of plots with disturbance scores >1 are also required as described in SOP 18, Section B.4. Photo number, type, date, and plot number are recorded on the Trip Photo Log Form (Appendix C). In addition, a description of impact type is recorded in the comments section of the Trip Photo Log Form.

C. **Quality Assurance and Quality Control Procedures**

1. Do not rely on memory – always read protocol.

2. Review measurement procedures with all employees each year. Conduct pre-season and on-site training for new employees. Compile photos for documenting examples of condition class ratings for future training reference.

3. Calculate and document observer bias and conduct QA audits as described in SOP 19, Section G.6.

4. Substantial effort should be made to minimize any disturbance to plot areas from activities associated with this protocol or from other sampling protocols that require work at multiple locations around the lakeshore (i.e., SOPs 4, 11 and 14).

5. Immediately following survey, check to see if all forms are complete and readable.

D. **Data Forms** (*see* Appendix C: Field and Laboratory Data Forms)

1. Mountain Lake Daily Sampling Checklist
2. Trip Photo Log
3. Lake Riparian Disturbance Form (Human Use Condition Class definitions on back side)

E. **Specific Safety Considerations** (*see* SOP 24: Field and Laboratory Safety)

1. Use of Laser rangefinder – See user guide, do not point at eyes
2. Water safety (inflatable boats, wading)
3. Hypothermia

Literature Cited

Rochefort, R. M., and D. D. Swinney. 2000. Human impact surveys in Mount Rainier National Park: past, present, and future. Pages 165-171 i*n* Wilderness science in a time of change conference: Volume 5: Wilderness ecosystems, threats, and management: May 23-27, 1999, Missoula, MT. USDA Forest Service Proceedings RMRS-P-15-VOL-5, Rocky Mountain Research Station, Ogden, UT.

SOP 16: Decontamination of Equipment

April 19, 2011

Prepared by: Barbara Samora and Rebecca Lofgren, NPS NCCN-MORA, and Ashley Rawhouser, Lise Grace, and Carmen Welch, NPS NCCN-NOCA.

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Decontamination of Equipment

This SOP provides general decontamination procedures for field crews to minimize the risk of accidental transport of aquatic invasive species, and transmission of pathogens and contaminants between water bodies during monitoring activities.

Aquatic invasive species (AIS) are waterborne, non-native organisms that often out-compete, prey upon or bring diseases or parasites to native species, often adversely changing the ecosystem in the process. Humans unwittingly assist the spread of these organisms by transferring them from one body of water to another on footwear, waders, nets, and other equipment. Amphibian diseases can be spread in a similar manner. Decontamination of equipment will help prevent the transport of aquatic invasive species and the transmission of diseases, pathogens and contaminants between water bodies. Table 16.1 provides a list of documented and potential invasive species of concern in NCCN parks. The following are also of concern to amphibians in water bodies within the NCCN:

Amphibian Diseases

Chytridiomycosis (chytrid fungal disease), caused by the fungal pathogen *Batrachochytrium*, is a recently emerged infectious disease implicated for amphibian population declines and extinctions on multiple continents (Berger et al. 1998, Bosch et al. 2001, Lips et al. 2006, Rachowicz et al. 2006). The Declining Amphibian Population Task Force, established in 1991 by the Species Survival Commission of the World Conservation Union, and other amphibian focused organizations have recommended the need for a hygiene protocol for field workers to minimize the spread of the Chytrid fungus and other pathogens among sites where frogs occur and between individual frogs and/or tadpoles (Speare et al. 2004, Phillott et al. 2010).

Ranaviruses belong to the Iridovirus family and infect insects, fish, and amphibians. In the western United States, most die-offs attributed to ranaviruses have occurred in tiger salamanders, although recent testing has detected the virus in Columbia spotted frogs in Montana and mountain yellow-legged frogs in California. Large numbers of sick and dead amphibians can be found at affected sites. Usually, the virus infection occurs in larvae (tadpoles and aquatic salamanders with gills) and frogs that have just completed metamorphosis. Sick and recently dead amphibians show small ulcers in the skin and extensive reddening of the skin along the ventrum (stomach) and base of the limbs. Internally, the virus affects and destroys many organs including blood vessels, skin, stomach, liver, kidneys, and spleen. Die-offs of amphibians due to ranavirus have occurred in at least 15 states including California, Arizona, Utah, Idaho, Montana, North Dakota, Wyoming, and Colorado. *Ranavirus* species have been recently isolated in several other amphibians (Zupanovic et al. 1998, Mao et al. 1999).

Saprolegnia: The Saprolegniasis fungus *Saprolegnia ferax* has been associated with embryonic die-offs of amphibian populations in the Cascade Mountains of Oregon. Saprolegniasis is a common disease found in fish, especially those reared in hatcheries (Richards and Pickering 1978). Many fish stocked in Pacific Northwest lakes are common carriers of *Saprolegnia*, including *S. ferax* (Wood and Willoughby 1986). *S. ferax* has been identified in western toad eggs and appears to be largely responsible for egg mortality in several amphibian species (Blaustein et al. 1994). Kiesecker et al. (2001) proposed that increased exposure of amphibian

embryos to UVB radiation, as a result of climate change effects on precipitation, may be making them more susceptible to *Saprolegnia* infections.

Fish Diseases

***Whirling Disease** (WD)* is a parasitic infection caused by the non-native microscopic parasite, *Myxobolus cerebralis* and threatens native trout populations. The WD pathogen has been confirmed in Washington State, but not the disease itself. Most salmonids (salmon, trout and whitefish) are susceptible to infection. Some rainbow and cutthroat trout appear to be more susceptible than other trout species.

Equipment and Materials

- Plastic bucket with handle for sterilization and holding cleaning gear or 3 gallon collapsible bucket or dry bag.
- Dry chlorine bleach 56% (pre-measured, labeled packages for each sample site) or 1 gallon of liquid chlorine bleach (6% concentration of sodium hypochlorite).
- Two stiff scrub brushes with handles, one for sterilization, and one for cleaning off mud/dirt.
- Rubber dishwashing gloves or latex gloves.
- Spray bottle.

Table 16.1. Documented and potential invasive species of concern in NCCN parks.

Common name	Scientific name	Present in park[1]	Probably present in park
Invertebrates			
quagga mussel	*Dreissena bugensis*		
zebra mussel	*Dreissena polymorpha*		
ringed crayfish	*Orconectes neglectus*		
rusty crayfish	*Orconectes rusticus*		
northern crayfish, virile crayfish	*Orconectes virilis*		
New Zealand mudsnail	*Potamopyrgus antipodarum*		
red swamp crayfish	*Procambarus clarkii*		
Aquatic plants and algae			
giant reed	*Arundo donax*		
Didymo	*Didymosphenia geminata*		
Brazilian elodea	*Egeria densa*		
hydrilla, waterthyme	*Hydrilla verticillata*		
yellow flag	*Iris pseudacorus*	LEWI	OLYM
parrot feather watermilfoil	*Myriophyllum aquaticum*	LEWI	
Eurasian watermilfoil	*Myriophyllum spicatum*	NOCA	
White waterlily	*Nymphaea odorata*	LEWI, OLYM	
Common reed	*Phragmites australis*	LEWI, OLYM	
Riparian plants			
garlic mustard	*Alliaria petiolata*		
old man's beard	*Clematis vitalba*	NOCA	
English ivy	*Hedera helix*	LEWI, NOCA, OLYM, SAJH	
giant hogweed	*Heracleum mantegazzianum*	FOVA, MORA	NOCA
purple loosestrife	*Lythrum salicaria*		LEWI, OLYM
reed canary grass	*Phalaris arundinacea*	EBLA, FOVA, LEWI, MORA, NOCA, OLYM, SAJH	
Japanese knotweed	*Polygonum cuspidatum*	MORA, NOCA, OLYM	
cultivated knotweed	*Polygonum polystachyum*	OLYM	
giant knotweed	*Polygonum sachalinense*	OLYM	NOCA
Himalayan blackberry	*Rubus discolor*	EBLA, FOVA, LEWI, NOCA, OLYM, SAJH	
Vertebrates			
American bullfrog	*Rana catesbeiana*	LEWI	
eastern brook trout	*Salvelinus fontinalis*	MORA, NOCA, OLYM	

[1] Park status ('Present in park' and 'Probably present in park') from NPSpecies, accessed 1/4/2011.

Disinfection Procedures

The following procedures were adapted from the Southwest Alaska Network Standard Operating Procedure 9: Field Equipment Decontamination of Aquatic Invasive Species (Shearer and Moore 2009), Upper Columbia Basin Network Standard Operating Procedure 8: Decontamination of Equipment for Aquatic Invasive Species (Starkey et al. 2009), Sierra Nevada Network Standard Operating Procedure 7: Equipment Disinfection (Schweizer 2007), the California Center for Amphibian Disease Control (2007), and Phillott et al. 2010.

The following procedures must be followed before entering any waterbody for sampling purposes. All sampling equipment that may have come in contact with site water must be decontaminated, including but not limited to:

- Waders
- Shoes/boots (including water sandals)
- Neoprene socks
- Dip nets
- Rulers and other instruments
- Specimen bags/containers
- Gillnets
- Plankton nets
- Macroinvertebrate nets
- Rafts
- Dry suit and snorkel gear
- Tarps
- Buckets

A. Chemical Disinfection in the Field

Prior to disinfecting equipment, all mud, snails, algae, and other debris will be removed from nets, boots, waders, and other equipment utilizing brushes, screwdrivers, or other tools. Chlorine bleach (4% to 6%) is generally used to disinfect. Granulated chlorine bleach is preferred over liquid bleach because it is lighter and easier to transport. Granulated chlorine bleach can be purchased at swimming supply stores. We recommend transporting granulated bleach in a ziplock bag placed inside a light but puncture-proof container (such as a bear-proof food storage container). **All equipment must be disinfected prior to going in the field and while in the field, between two different water bodies**.

We recognize that felt wading soles provide a good media for transporting aquatic invasive and are more difficult to disinfect. We will continue to investigate safe options and focus extra attention to thoroughly scrub and disinfect felt soles.

1. Prior to going into the field, package and label the disinfectant.
    a. Get labels and containers to package the dry bleach. Containers can be plastic storage bags, plastic bottles, etc. If using plastic storage bags, put all bags for the trip into one dry bag, stuff sack, or hard sided container that can protect the plastic storage bags from being punctured.

b. Measure 1 cup of 56% available dry chlorine bleach (to get a 2% bleach solution when added to a 60% full 3 gallon bucket of water in the field).
c. Place dry bleach in plastic storage bag.
d. Label plastic storage bag.
e. Label the puncture resistant bag (stuff sack, dry bag, or hard sided container).
f. Repeat to have individual pre-measured containers for each lake.

2. The first step in the field is to thoroughly clean equipment.
   a. Remove all organic matter (mud, plants, algae, etc.). Particular attention should be given to the treads of boots, sandals, and waders. A stiff brush should be used if needed (disinfected). Run hand up and down ropes attached to all equipment and anchor to dislodge mud, plant material, and organisms
   b. Ensure no water remains in any equipment by removing any residual water from all pumps, hoses, etc.
   c. Dry as thoroughly as possible. When practical and appropriate, wipe dry.
   d. Let all equipment air dry as long as possible.

3. After the equipment is thoroughly cleaned, use the following steps to disinfect.
   a. For small equipment such as dip nets and ropes:
      i. Use a 2% solution of bleach.
      ii. Fill the 3 gallon collapsible bucket a little over half (60% full) with water at the new survey site.
      iii. Mix the pre-measured quantity of dry bleach into the water in the bucket.
      iv. Soak all items (that have been cleaned of mud, etc.) for 2 minutes.
      v. If the solution becomes noticeably dirty, dispose of it and mix up a new batch.
      vi. After disinfecting your gear, rinse with water from the new survey site.

   b. For large equipment that cannot be soaked, such as float tube, boat, and waders:
      i. Use the 2% solution of bleach.
      ii. Fill spray bottle with solution.
      iii. Spray cleaned surfaces. If needed, use a sponge to make sure all surfaces get covered with the spray solution.
      iv. Let air dry.
      v. Rinse thoroughly with water from the new survey site to remove all disinfectant to avoid sample contamination and getting bleach on clothing.

4. Dispose of bleach solution at least 100 meters from water over organic matter where the compound will break down (e.g., trail soil, decomposing log, duff).

B. Disinfection in the Laboratory

Follow steps 2 and 3 listed above. Clean and rinse with tap water and dispose bleach solution properly.

C. Physical Treatment

If using a decontamination solution is not practical, physical treatments may be applied. In all instances, remove all organic matter (mud, plants, algae, etc.). Particular attention should be

given to the treads of boots, sandals, and waders. A clean, stiff brush should be used if needed. After scrubbing equipment choose one of the following options for additional treatment:

- Freeze gear overnight at 26°F (-3°C) or below.
- Soak for at least 10 minutes in hot water (at least 140°F). NOT RECOMMENDED FOR GORE-TEX.
- Dry gear at least 48 hours under low humidity (or 2 hours in a clothes dryer). Gear must be completely dry at least 24 hours, so total drying time may be 3-5 days. Felt-soled waders require additional drying time.

D. **Specific Safety Considerations** (*see* SOP 24: Field and Laboratory Safety)
- Chemical Handling

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SOP 17: Post Field Season Activities

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Prepared by: Carmen Welch and Reed Glesne, NPS NCCN-NOCA.

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Post Field Season Activities

This Standard Operating Procedure provides details describing end of field season activities. Post season activities primarily include data review and management; sample processing and shipping; equipment inventory, maintenance, and storage; and communication between all staff concerning the need for protocol revisions.

A. **Data Review and Management:**

1. Data Forms
   Review of data forms should be conducted after every field day, every sampling trip, and at the end of the season. It is always helpful to have more than one person review the data forms because it reduces potential data gaps or mistakes. The review should be completed as soon as possible because it increases the rate of information recovery.

2. Digital Photos
   Digital photos taken during the field season should be downloaded and labeled as soon as possible after returning from the field. Photos should be reviewed by each participating crew member again at the end of the season to ensure that they were labeled properly (*see* SOP 18: Acquiring and Managing Photographic Images).

3. Continuous Temperature Data
   Downloaded data from the continuous temperature monitoring array (SOP 8: Continuous Water Temperature Sampling) should be reviewed to detect anomalous data signifying that a temperature data logger malfunctioned. The results of the pre- and post-deployment calibration must be evaluated verifying the accuracy of the temperature loggers. Any need for calibration adjustment should be applied to the collected data set. This procedure is described in detail in SOP 8.

   More detailed information concerning post-field season data management is given in SOP 2: Project Workspace and Records Management, SOP 19: Quality Assurance and Control Plan, SOP 20: Data Entry and Verification, SOP 22: Data Quality Review and Certification, and SOP 23: Product Delivery, Posting and Distribution.

B. **Sample Processing and Shipping**

1. Water Quality Samples
   a. Shipping form: A sample shipping form should be completed for every contractor to whom samples are being sent. For each sample shipped the shipping form must include the following information: site code, date, analyses to be performed, sample volume, and filtration status.
   b. Sample Shipment: After collection, water samples must be shipped to contracted laboratories (*see* SOP 9: General Water Chemistry, Section D.6-7). Chlorophyll-a samples will be shipped according to instructions in SOP 10: Chlorophyll-a Concentration. Following shipment, confirmation of sample arrival should be obtained from the contractor.

2. Benthic Macroinvertebrate Samples
   a. Sample sorting: Sample sorting is conducted after conclusion of the field season by the crew members. The sorting objective for each sample is to remove an unbiased subsample of individuals that represents a random representation of BMI specimens from a composite of the five benthic kick samples taken from each lake. The procedure is outlined in detail in SOP 11: Benthic Macroinvertebrate Collection and Processing.
   b. Sample shipment: Sorted samples will either be hand delivered or packaged and shipped to the contracting lab according to SOP 11, and confirmation of their arrival should be obtained from the contractor.

3. Zooplankton samples
   Post-season activities for zooplankton samples involve completing a zooplankton sample shipping form and either hand delivering or shipping the samples to the contractor. SOP 12: Zooplankton Collection and Processing, Sections B and C, provide detailed information on handling and shipping the samples. When samples are shipped, confirmation of their arrival should be obtained from the contractor.

C. **Equipment Inventory, Maintenance and Storage**

1. Equipment treatment
   Any repairs or replacement to equipment should be made at the conclusion of the field season. Ropes and nets should be stretched out, dried, and coiled in an orderly fashion. All other sampling equipment should be cleaned and placed back in protective storage containers. All gear should be cleaned and placed back into protective storage containers or storage cabinets. All chemicals should be stored in proper containers in their proper storage cabinet(s). The chemical inventory log should be updated and expiration dates of chemicals should be noted. Any chemical waste should be disposed of according to MSDS recommendations and local waste disposal authority requirements.

2. Decontamination of Equipment
   SOP 16: Decontamination of Equipment outlines steps to be taken to avoid the possible transfer of contaminated water from one site to another. It provides a complete list of equipment and materials to be cleaned.

3. Instrument Storage
   YSI 600XLM operations manual maintenance and probe cleaning recommendations are followed and documented. Dissolved oxygen probes can be cleaned with a Kimwipe and rubbing alcohol. Make sure that the sponge inside the chamber is always kept moist. Batteries should be removed (refer to the instrument manuals for details). Documentation of maintenance will help explain or support any unusual data.

4. Inventory Equipment and Supplies
   An inventory of all equipment and supplies should be completed following the field season. Lists of equipment and supplies are found at the end of each SOP. Any items requiring repair or replacement should be documented.

D. **Protocol Revisions**

Field crew, Project Leads, Data Manager and GIS Specialist should meet and discuss any problems that were identified during the field season, and any changes that may be relevant for future monitoring. Any changes suggested will be discussed among the three Project Leads who will make the final decision, and they will document this according to the guidelines detailed in SOP 25: Revising the Protocol.

E. **Quality Assurance and Quality Control Procedures**

Proper care of lab and field instruments and sampling equipment helps to provide the best quality data. Follow up on QA/QC for each SOP should be conducted to ensure the highest quality work possible (*see* SOP 19: Quality Assurance and Control Plan).

SOP 18: Acquiring and Managing Photographic Images

April 19, 2011

Prepared by: Barbara Samora, NPS NCCN-MORA, Reed Glesne, NPS NCCN-NOCA, and John Boetsch, NPS NCCN-OLYM.

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Acquiring and Managing Photographic Images

This SOP describes procedures for acquiring, downloading, processing, and naming photographic images collected by project staff or volunteers during the course of conducting project-related activities. Images that are acquired by other means (e.g., downloaded from a website or those taken by a cooperating researcher) are not project records and should be handled separately and named in such a way that they can be readily identified as non-NPS images and not be mistaken for project records.

To effectively manage potentially hundreds of photographic images requires a consistent method for downloading, naming, editing and documenting. The general process for managing data photos proceeds as follows:

- Prepare image workspace – Set up the file organization for images prior to acquisition
- Acquire images
- Download and process
    - Download the files from the camera
    - Rename the image files according to convention detailed below
    - Copy and store the original, unedited versions
    - Review and edit the photos; delete unneeded or poor quality photos
    - Move into appropriate folders for storage
- Deliver image files for final storage

Data Photos Defined

Care should be taken to distinguish data photos from incidental or opportunistic photos taken by project staff. Required data photos for this protocol include:

- Permanent benchmarks for water level measurement
- Panoramic lake watershed photos and the location where these photos are taken
- Lake riparian disturbances in sampled plots
- Fish an amphibian photos for the purpose of species verification.
- Location of continuous air temperature data loggers

Data photos are often linked to specific records within the database and are stored in a manner that permits the preservation of those database links. Other photographs -- e.g., showing field crew members at work, or documenting the morphology of the lake basin -- may also be retained but are not necessarily linked with database records.

Image Workspace Setup

1. Workspace Setup: Prior to data collection for any given year, the Project Lead (or a designee) will need to set up a new set of image folders, both under the Images section of the project workspace as well as under the current season year section of the seasonal workspaces (refer to SOP 2). The workspace subfolders are as follows:

[Year]	The appropriate year – 2012, 2013, etc
[Park code]	Arrange files by park – MORA, NOCA and OLYM
1_Originals	Unedited versions of image files
[Site_code]	Arranged by lake code, for images taken at lakes
[Date]	Arranged by date, for images not taken at lakes
2_Processing	Temporary processing workspace
3_Data	Data images
[Site_code]	Arranged by lake code, for images taken at lakes
[Date]	Arranged by date, for images not taken at lakes
4_Miscellaneous	Non-data images taken by project staff
[Site_code]	Arranged by lake code, for images taken at lakes
[Date]	Arranged by date, for images not taken at lakes
5_Not-NPS	Images acquired from other sources

This folder structure permits data images to be stored and managed separately from non-record and miscellaneous images collected during the course of the project. It also provides separate space for image processing and storage of originals. For additional information about the project workspace, refer to SOP 2: Project Workspace and Records Management.

2. Folder Naming Standards

In all cases, folder names should follow these guidelines:

- No spaces or special characters in the folder name
- Use the underbar ("_") character to separate words in folder names
- Try to limit folder names to 20 characters or fewer
- Dates within folder names should be formatted as YYYYMMDD (for better sorting)
- Lake codes are typically a one- to eight-character alphanumeric codes (e.g., LS-05-01 at NOCA or lm01 at MORA)

B. Image Acquisition

1. General

Capture images at an appropriate resolution that balances space limitations with the intended use of the images. Although photographs taken to facilitate future navigation to a site do not need to be stored at the same resolution as those that may be used to indicate gross environmental change at a site, it may be more efficient initially to capture all images at the same resolution. A recommended minimum raw resolution is 1600 x 1200 pixels (approximately two megapixels). Higher resolutions may be available but are undesirable from the perspective of data storage and information content.

Photographs will be taken to document water level benchmarks (SOP 5: Water Level Measurement), species presence (SOP 13: Fish Sampling and Processing, and SOP 14: Aquatic Amphibian Sampling and Processing), riparian disturbances (SOP 15: Lake Riparian Disturbance Monitoring), location of air temperature data loggers (SOP 8: Continuous Air and Water Temperature Sampling), and watershed panoramic photos and the location where these photos are taken (Section B.5 of this SOP).

With digital cameras, typically medium or higher resolution is preferred. This should result in photos that are about 1,000 Kb or more in .jpg format that can be somewhat enlarged. Photo quality and content are checked after taking each picture. If the original photo is not suitable it is deleted and another photo is taken. All photos are documented on the Trip Photo Log field form (Appendix C). Documentation codes and descriptions are given on this form.

2. Point Location Photographs
   Point location data photos include those captured for relocating water level benchmarks, air temperature data logger deployment sites, and photo points used for panoramic watershed landscape photos. A progression of at least three photos should be taken to document point locations, starting at a distance far enough away to capture landscape features that would bracket the location of the point to a distance in the immediate vicinity of the point that clearly shows its location. In addition to photos, GPS waypoints and descriptive notes are also taken to aid in future location of these points.

3. Fish and Amphibian Specimen Photographs
   Fish and amphibian specimen data photos are taken when positive identification cannot be verified in the field. In addition, photos should be taken of amphibian 'Species of Concern', unique species, and specimens with deformities. If available, a camera with a macro lens, having a shorter focal length, works better for these photos. Photos should be taken for dorsal, lateral, and ventral views and from several individual specimens if possible. A ruler should be used in at least one photo of each specimen to give some perspective of the size of the specimen. In general, a light colored background with direct lighting works best for these photos. Equipment used for other purposes during data collection, such as a shallow white plastic photographic tray used for elutriating macroinvertebrate samples or a light colored plastic fish measuring board provide a suitable background for taking the photos. Amphibians should be placed in a clear plastic quart size bag with water to minimize direct contact while handling during photographic documentation (refer to Amphibian Handling Procedures in SOP 14, Section E.1.a).

4. Riparian Disturbance Photographs
   Moderate to Severe ground and vegetation disturbances encountered within sample plots during the lake riparian survey are documented with data photos. A significant disturbance is defined as codes 2-4 in Table 15.2 of SOP 15: Lake Riparian Disturbance Monitoring. A minimum of two photos should be taken, with a measuring tape included in the photo to provide some perspective of the extent and size of the disturbance.
   The intent of the Lake Riparian Disturbance SOP is to provide a lake-wide assessment of disturbance for monitoring trends rather than tracking individual disturbances through time. As such, documentation of the location of individual disturbances is not required. The purpose of these photos is to provide visual representations of the types of disturbance linked to descriptive criteria (SOP 15, Table 15.2) used in their assessment. These photos can also be used to perform quality control checks regarding the assignment of disturbance codes.

5. Panoramic Lake Watershed Landscape Photographs
   Lake and watershed landscape panoramic data photos are taken once every five years at each site. A view of the entire lake watershed is desirable. Landscape views are achieved by creating panoramas from an overlapping sequence of photos. Wide angle lenses, equivalent to 28 and 35 mm focal lengths and mid-morning through mid-afternoon lighting is best for landscape photo documentation. When taking panoramas, make sure that there is overlap from one photo to the next (typically 5-15% of the frame width) so that the photos can be adequately pieced together. It is helpful that the first and last picture overlap as well, to insure that the full circuit has been completed and to be able to reconstruct the photo sequence many weeks or months later. Panoramas can be side-to-side, or up-and-down, or both. These can later be combined to form mosaics so that all of the relevant main features can be shown at once. Also consider adding familiar objects to show scale, especially in panorama views. When taking panoramas, stand at the photo point, and starting in the north most direction, sweep from left to right making sure each image overlaps by 15%. Keep the relationship of the station constant to the horizon. Panoramic photographic information is documented on the Trip Photo Log Form. For each photo, record the photo number and compass bearing. Photo point documentation is previously described in item 2, above.

C. **Download and Processing Procedures**

1. Under the appropriate "Originals" subfolder, create a subfolder for the download date (e.g., 20120615). Other suffixes may be used to distinguish downloads when multiple sites or parks are downloaded on the same date.
2. Download the raw, unedited images from the camera into the new subfolder. Depending on the operating system used by the person downloading, it may be possible to greatly reduce the time and effort it takes to rename the images in subsequent steps.
   - Plug in the camera to the USB port and turn the camera on.
   - From the Start menu, select All Programs > Accessories > Scanner and Camera Wizard (or select this option if a dialog box appears upon plugging in the camera).
   - Follow screen prompts until reaching the 'Picture Name and Destination' screen. You will be able to select name prefix/suffix, image format, and photo destination.
     - For name prefix, use the naming conventions indicated later in this SOP.
     - For image file format, select the default (JPG).
     - For photo destination, browse to the appropriate "Originals" subfolder.
3. Copy the images to the "Processing" folder and set the contents under "Originals" as read-only by right clicking in Windows Explorer and checking the appropriate box. These originals serve as backups in case of unintended file alterations (e.g., incorrect names applied, file deletion, loss of resolution, or loss of image metadata upon rotation).
4. Finish renaming the images in the "Processing" folder according to convention (refer to the image naming standards section).
   - If image file names were noted on the field data forms, be sure to update these to reflect the new image file name prior to data entry. Field form annotations should be done in a different color ink from the original notation, after first drawing a line through the original entry (for more information, refer to Section 4D, Data Entry and Processing).

- Renaming may be most efficiently done as a batch using image processing software such as Microsoft Office Picture Manager, which allows a standard prefix or suffix to be added to the camera file name. After batch renaming, a descriptive component may be added manually to each file name.

5. Process the images in the "Processing" folder, using the edit features built into image software programs such as ThumbsPlus or Microsoft Office Picture Manager. At a minimum, the following processing steps should be performed on all image files:
   - Delete photographs of poor quality – e.g., out of focus, poor light levels, etc. Low quality photographs might be retained if the subject is highly unique, or the photo is an irreplaceable data photo.
   - Duplicates should also be deleted unless they provide unique information. Other non-data photographs should be evaluated for their potential long-term value.
   - Rotate images to make the horizon level.
   - Remove 'red eye' glare in photographs of people.
   - Crop non-data images to remove edge areas that grossly distract from the subject.
6. Optional processing steps may include enhancing contrast or brightness, or resizing images to make them small enough for use in documents or on the web. These steps are not recommended for data photos.
7. When finished processing the current download, move the image files that are to be retained to the appropriate folder – i.e., data images to the appropriate "Data" subfolder, other images under the appropriate "Miscellaneous" folder.
8. Photos of potential interest to a greater audience should be uploaded to the NCCN Digital Library.
9. Delete files from the "Processing" folder between downloads to minimize the chance for accidental deletion or overwriting of needed files.

D. **Image File Naming Standards**

1. In all cases, image names should follow these guidelines.
   - No spaces or special characters in the file name.
   - Use the underbar ("_") character to separate file name components.
   - Try to limit file names to 30 characters or fewer, up to a maximum of 50 characters.
   - Park code and year should either be included in the file name (preferred), or specified by parent folders in the directory structure.
   - Dates should be formatted as YYYYMMDD (this leads to better sorting than other date naming conventions).

2. The image file name should consist of the following parts, separated by an underbar character:
   - The date on which the image was taken (formatted as YYYYMMDD)
   - The NCCN lake code
   - Optional: a brief descriptive word or phrase
   - Optional: a sequential number if multiple images were captured
   - Optional: time (formatted as HHMM)

Examples:

- 20070621_LS0501_Tran01_start.jpg…Start of depth transect 1 at Lake LS-05-01 on June 21, 2007.
- 20070621_lm10_WLBM1.jpg…Water level benchmark #1 at Lake lm10 on June 21, 2007.

E. **Post-Season Cleanup Procedures**

At the end of the season, field crew members should organize images within the seasonal workspace and notify the Project Lead, after making sure that all processing folders are empty. For crew members stationed at remote parks who need to work on local copies, a CD or DVD should be prepared and delivered to the Project Lead.

After each season, the Project Lead (or a designee) should:

1. Review the seasonal workspace folders to make sure that all images are properly named, filed, and accounted for.
2. The "Processing" folder should be empty and may be deleted.
3. Files in the "Not_NPS" folder may be refiled as appropriate.
4. The contents of the "Originals" folder may be deleted once all desired files are accounted for. Originals of data images may be retained as desired, depending on the size of the files and storage limitations. If storage space is limiting, originals may be stored on a local hard drive or external drive.
5. Copy the entire contents of the "Images" subfolder from the seasonal workspace to the main project workspace, and delete the images subfolders from the seasonal workspace.
6. Set the images in the project workspace to read-only to prevent unintended changes.

F. **Data Forms** (*see* Appendix C: Field and Laboratory Data Forms)

1. Mountain Lake Daily Sampling Checklist
2. Trip Photo Log

SOP 19: Quality Assurance and Control Plan

April 19, 2011

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Quality Assurance and Control Plan

A. Purpose

This standard operating procedure (SOP) is the functional equivalent of a quality assurance project plan (QAPP) for the NCCN protocol to monitor the long-term ecological conditions in mountain lakes. The purpose of the QAPP is to document the planning results for environmental data operations and to provide a program- or project-specific "blueprint" for obtaining the type and quality of environmental data needed for a specific decision or use. The QAPP documents how quality assurance (QA) and quality control (QC) at both the monitoring plan design and measurement process levels are applied to an environmental data operation to assure that the results obtained are of the type and quality needed and expected (USEPA 2001).

Quality assurance (QA) is the planned and systematic pattern of all actions necessary to provide adequate confidence or assurance, that a project outcome optimally fulfills expectations. It encompasses the broad management concept of maintaining the ability to furnish reliable information and incorporates all peripheral yet essential operations, such as the monitoring plan design, survey design, field and laboratory systems for sample collection and measurement, equipment preparation and maintenance tasks, personnel training data handling, quality control, documentation, evaluation, and reporting activities (Irwin 2008, O'Ney 2006).

Quality control (QC) is the systematic evaluation of the various aspects of a project to ensure or control that the standards of quality are being met. Quality control is generally represented by quantitative statements regarding specific tasks undertaken to determine the reliability of field and laboratory data. Together, quality assurance/quality control (QA/QC) is a substantial part of any monitoring project. The objective of QA/QC is to ensure that the data generated by a project are meaningful, representative, complete, precise, comparable, scientifically defensible, and reasonably free from bias (Irwin 2008).

B. Applicability

The procedures in this SOP will be implemented during all work pertaining to the protocol for monitoring MORA, NOCA and OLYM mountain lakes as described in the protocol narrative and SOPs to assure that all data obtained will contribute quality information to an understanding of the ecological condition of these lakes. Specific QA/QC issues are addressed in pertinent SOPs and will be referred to when necessary to avoid redundancy. For example the calibration check for continuous temperature monitoring data loggers is detailed in SOP 8: Continuous Water Temperature Monitoring, training is covered in the protocol narrative and SOP 1: Field Season Preparation and Training, and data management and analysis procedures are described in Section 4 of the narrative and in SOP 21: Data Analysis and Reporting.

Contracted laboratories conducting water chemistry and chlorophyll-a analysis as well as invertebrate identification will follow guidelines established by the National Environmental Laboratory Accreditation Program when applicable. QAPP for contracted laboratories can be found at the following website:

http://science.nature.nps.gov/im/units/nccn/vs/mountain_lakes/NCCN_Mountain_Lakes_Contract_Laboratory_QA_QC_Procedures.pdf (accessed 18 April 2011).

C. Revisions

This QAPP should be reviewed on an annual basis by park staff and Lead Aquatic Ecologists and revised as necessary. The steps for changing the protocol are outlined in SOP 25: Revising the Protocol. Only after the revision has been received and approved (at least verbally with written follow-up) by the Lead Aquatic Ecologists and the WRD staff involved with the initial review shall the change be implemented.

D. Project Management

This plan is intended to be a long-term (30+ years) monitoring plan and will be managed and largely implemented by MORA, NOCA and OLYM personnel with technical assistance from the NPS Water Resources Division (WRD) and local experts when necessary. A summary of project tasks and responsibilities is presented in Table 19.1 of this SOP.

Table 19.1. Project tasks and responsibilities.

Name	Title/Responsibility
Lead Aquatic Ecologists (MORA, NOCA, & OLYM)	Technical Leads, oversee collection of monitoring data and data management, conduct data analysis and summary, coordinate report writing and protocol revisions
Quality Assurance Manager (Lead Aquatic Ecologists)	Develops and ensures implementation of the QAPP (SOP 19)
I&M NCCN Program Manager	Coordinates with Lead Aquatic Ecologists on reporting requirements, assists with peer review process
Lead Field Biologist/Technician	Trains field personnel, ensures data collection complies with appropriate SOPs, reviews field data forms for completeness
Lead Laboratory Technician	Conducts equipment inventory, preparation and calibration; analyzes pH, ANC and specific conductance; reviews data forms and laboratory logs for completeness
Field and Lab Personnel	Collect monitoring data, process benthic macroinvertebrate samples, enter monitoring data into database
Contracted Water Chemistry Laboratory	Conducts analysis of water chemistry samples for anion/cations, nutrients, total dissolved solids and dissolved organic carbon
Contracted Chlorophyll-a Laboratory	Determines chlorophyll-a concentration
Contracted Benthic Macroinvertebrate Laboratory	Identifies and enumerates benthic macroinvertebrate samples
Contracted Zooplankton Laboratory	Identifies and enumerates zooplankton samples
Spatial Data Analysis Personnel	Create bathymetric maps
Data Management Lead	Database development, data validation, database upload to WRD STORET

The I&M Mountain Lakes project will remain adaptive to changing park and network needs. Future decisions regarding the Mountain Lakes I&M project will continue to be informally made by consensus of the NCCN Aquatic Technical Committee. This group consists of key network staff and includes the Lead Aquatic Ecologists from MORA, NOCA and OLYM and the Network Program Manager. Broader-based, long-term decisions are approved by the NPS-WRD. These include approval of WRD-funded staff work plans and approval of the overall monitoring plan.

E. Project Background

A detailed description of mountain lake stressors and issues are discussed in the protocol narrative Section I.1.3. Rationale for selecting mountain lakes for monitoring and monitoring questions and objectives are discussed in Section I.1.4.1-2.

F. Project Task Descriptions

Project tasks, descriptions and time lines are detailed in the protocol narrative, individuals SOPs, and in Appendix B: Yearly Task List.

G. Data Quality Objectives and Criteria for Measurement Data

Data Quality Objectives (DQOs) are qualitative and quantitative statements of the quality of data needed to support specific decisions or actions. DQOs are also used to assess the adequacy of data in relation to their intended use. Data acceptability criteria are included in the DQOs. The purpose of DQOs follow California Department of Water Resources (CDWR) guidelines and are to document 1) the intended use of the data in order or importance, 2) decisions to be made when data are obtained, and 3) the decision makers who will use the data (CDWR 1998). All data generated by this project have the same intended use because they all help identify the effects of stressors and areas of concern with respect to aquatic resource conditions in mountain lakes. Specific details relating to the intended use of the data and relevant management actions can be found in the protocol narrative, SOP 21: Data Analysis and Reporting, and other relevant SOPs.

Recommendations based on I&M data will be developed by park aquatic professionals. These recommendations, in the form of data summaries, or annual reports and five-year summary reports, will be presented to managers such as the Directors of Resource Management and Park Superintendents who primarily act as the final decision makers for the respective parks. The decision makers for MORA, NOCA and OLYM will generally be the same for each parameter; however, other decision makers may include professionals from other federal, state, and local agencies.

Data quality objectives will be achieved in a number of ways including:

- Developing standard operating procedures (SOP) with standardized field and laboratory methods
- Forming and convening a NCCN external scientific review committee which will serve to bring together scientists that are external to the NCCN or NPS to provide on-going peer review of all NCCN monitoring activities, with QA oversight being one of the primary focuses

- Documenting the comparability of laboratory and field methods that are consistent with the DQOs

The intent of these objectives is to provide the minimum standards and guidelines that NCCN parks should utilize for project review, with strong encouragement to use more stringent criteria and to adopt methodologies that improve upon these minimum standards. Revising the Protocol (SOP 25) is aimed specifically at these modifications and improvements. The major goal that this QAPP can accomplish is to have representative, comparable, accurate, and precise data that are reasonably free of bias and that can be shared locally, regionally, and nationwide, to the extent possible.

QA/QC requirements specific to a measurement task, collection technique or sample handling can be found in the following SOPs, prepared as part of the DQO process.

SOP 1:	Field Season Preparations and Training Crews
SOP 2:	Project Workspace and Records Management
SOP 3:	GPS Data Collection
SOP 4:	Lake Features and Bathymetric Maps
SOP 5:	Water Level Measurement
SOP 6:	Water Clarity Measurement
SOP 7:	Instrumented Water Column Profiles
SOP 8:	Continuous Water Temperature Sampling
SOP 9:	General Water Chemistry: Filtered and Unfiltered Samples
SOP 10:	Chlorophyll-a Concentration
SOP 11:	Benthic Macroinvertebrate Collection and Processing
SOP 12:	Zooplankton Collection and Processing
SOP 13:	Fish Sampling and Processing
SOP 14:	Aquatic Amphibian Sampling and Processing
SOP 15:	Lake Riparian Disturbance Monitoring
SOP 16:	Decontamination of Equipment
SOP 17:	Post Field Season Activities
SOP 18:	Acquiring and Managing Photographic Images
SOP 19:	Quality Assurance and Control Plan
SOP 20:	Data Entry and Verification
SOP 21:	Data Analysis and Reporting
SOP 22:	Data Quality Review and Certification
SOP 23:	Product Delivery, Posting and Distribution
SOP 24:	Field and Laboratory Safety
SOP 25:	Revising the Protocol

Data quality will be attained by maximizing and documenting the data quality indicators (DQIs) for the overall monitoring plan design and methods used. DQIs are qualitative and quantitative descriptors used in interpreting the degree of acceptability or utility of data. For the purposes of this project the principal DQIs will be defined as precision, accuracy, representativeness, comparability, completeness, bias (systematic error), and sensitivity. However, it should be noted that DQIs for sensitivity, precision, and bias (Table 19.2) are often placed into a separate category as measurement quality indicators. Establishing

acceptance criteria for the DQIs sets quantitative goals for the quality of data generated in the analytical measurement process.

Table 19.2. Guidance for calculating the data quality indicators for water chemistry parameters and biological indicators.

Data Quality Indicator	Metric Acronym	Metric + Brief STORET Note	Minimum Frequency of Reporting	Description	Sample Size	Equation
Sensitivity EPA, State, and some USGS labs Low Level Sensitivity As Detection Limits (usually lab)	MDL: for control of very low level sensitivity. This is the standard MDL.	Method Detection Level. Put MDL in the detection limit field. If the result is <MDL, STORET Detection Condition is "Not Detected."	One/year or when methods change.	Lowest value that can be differentiated from zero, the lower Semi-Quantitative type of detection limit, based on short term data.	Seven	Obtain MDL from laboratory. For field work calculate as 3.134*SD of a blank or very low signal solution.
Sensitivity USGS NWQL Low Level Sensitivity As Detection Limits (usually lab)	LT-MDL: NWQL control of very low level sensitivity.	Long Term Method detection level. USGS Long-Term version of MDL.	Every few years.	Lowest value that can be differentiated from zero, but based on long-term data.	High, based on multi-year data. Get the LT-MDL from USGS.	Obtain from USGS laboratory, based on F-pseudosigma rather than SDs.
Sensitivity EPA and State Quantitative Sensitivity As Detection Limits (usually lab)	ML: Higher than this. Values are quantitative.	Minimum level of quantitation, In STORET, record at LQL.	One/year or when methods change.	Lowest quantitative value above the ML values are quantitative	Based on Single MDL.	3.18 * (MDL)
Sensitivity (Usually field, or whenever MDL is NA)	AMS: Lowest Change Possibly Real.	Alternative Measurement Sensitivity, For ± STORET "analytical procedure description" field.	Beginning and end of field seasons.	Determines instrument noise in both directions (up or down). How big of a change is real?	Seven measurements from the same field sample.	3.708*SD, where SD = sample standard deviation.
Sensitivity AMS Plus (Usually field, or whenever MDL is NA)	AMS+: Total Variability of Close Replicates	Alternative Measurement Sensitivity Plus, Record in STORET as stated above if no other form of AMS is reported.	Beginning and end of field seasons (see Table 19.3 for exceptions)	Includes instrument noise and natural heterogeneity	Seven measurements of nearby but not identical samples, in-situ for sondes only	SD * 3.708

Table 19.2. Guidance for calculating the data quality indicators for water chemistry parameters and biological indicators (continued).

Data Quality Indicator	Metric Acronym	Metric + Brief STORET Note	Minimum Frequency of Reporting	Description	Sample Size	Equation
Precision (Lab and field)	RPD: QC Precision Control	Relative Percent Difference. In STORET include both values RPD was based on and optionally include RPD as a comment.	One for every 6-8 samples, lab or field. In the field, also used for every core parameter calibration check.	Variability of repeated measures (precision).	One sample but two values (one comparison of two values measured on one single sample).	RPD = $\left[\frac{S_1 - S_2}{(S_1 + S_2)/2}\right] \times 100$
Precision PLUS (Usually for field measurements only)	RPD: QC Precision+ Control	Relative Percent Difference: Include in STORET as suggested above in no other form of precision is reported.	One for every 6-8 samples, lab or field (see Table 19.3 for exceptions)	Variability of repeated measures (precision) PLUS potentially some additional true variability (two samples not one).	Two (one comparison of two values, *see* measurements of two samples collected in close proximity, not one sample).	RPD = $\left[\frac{S_1 - S_2}{(S_1 + S_2)/2}\right] \times 100$
Bias (Lab and field)	PD: QC Bias Control	Percent difference: In STORET include both values PD was based on and optionally include PD as a comment, Choose reference sample or field spike.	QC control one for every 20 samples, lab or field. In the field, also used for every core parameter calibration check.	Difference between measured result and expected result based on a reference sample standard or a spike.	Two (one comparison of two values, one of which is a known correct or expected value and the other is the measurement result.)	PD = [Y - X) / X] * 100, where X is the known (usually "correct" or "expected") or spiked amount, and Y is the measured conc.
Bias Blank Control Bias (usually for lab measures only)	PD: QC Blank Control Bias	Percent difference, Positive bias is reported if the value meas. is higher than the MDL. Record both meas. value and MDL in STORET.	No less stringent than the State, often QC blank sample minimum of once every 20 lab samples or once per field site.	Difference between measurement result and blank sample expected result (usually no greater than the MDL.	Two (one comparison of two values, one of which is the expected value [no greater than the MDL] and the other of which is a measurement of a blank sample.)	PD = [Y - X) / X] * 100, where X is the MDL and Y is the measured concentration.

Quantitative acceptance/rejection measurement quality objectives (MQOs) representing field and laboratory assessments of sensitivity, precision, and bias are presented in Table 19.3. Data quality review and corrective actions for violation of MQOs are discussed in Section I,

of this SOP. Guidance and methods for the following sections are provided by Irwin (2008) and can be found at the following website: http://www.nature.nps.gov/water/Vital_Signs_Guidance/Guidance_Documents/PartBLite.pdf (accessed 16 January 2011).

1. Representativeness

   Representativeness is a qualitative term that expresses the degree to which data accurately and precisely represents a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition. Representativeness starts at the monitoring plan design level with the identification of the target population and sample selection process and addresses both spatial and temporal aspects of sampling at several scales. In addition, adding the condition of randomness in selection of sampling locations provides statistical relevance regarding the entire population of sites that the samples were drawn from. Examples of design level steps regarding representativeness for this monitoring project include:

   a. An initial large number of lakes were considered for monitoring and later reduced a smaller more manageable set of lakes by development of definitive selection criteria.
   b. Random spatially balanced and stratified sample selection procedures were used to assure that the selected sample sites were representative of the sampled population as well as for the spatial distribution of its sites within each park.
   c. At the site scale some sampling locations were fixed to a specific lake location (e.g., water column parameters at the lake location where maximum depth occurs, SOP 6-10) while others require random sub-sampling locations distributed around the lake perimeter (e.g., benthic macroinvertebrates in SOP 11 and amphibians in SOP 14).
   d. Temporal aspects of the monitoring plan design also assure representativeness of the timing of annual site visits and timing of sample collection within a given day (e.g., parameters exhibiting diel fluctuations).

   Spatial and temporal aspects related to monitoring plan design representativeness are discussed in more detail in the protocol narrative (Sections 1-2) and related SOPs.

   Good QA/QC practices and calibration practices will help assure that the measured values are representative of the magnitude of the signal being measured at the particular time and place of measurement. The Field Lead should have knowledge of the range of values expected at any given site, with results from previous sampling trips being annually updated and included in materials brought to the field. Strict adherence to methods given in the SOPs and equipment manuals must be followed with copies of these always available in the field.

Table 19.3. Measurement quality objectives (MQOs) as acceptance/rejection criteria (*see* Table 19.2 for more detail on Quality Control parameter descriptions, frequency of reporting, sample size and calculation).

Parameter	Instrument or Method	Precision: Relative Percent Diff. (RPD)	Precision (+) Relative Percent Diff. (RPD+)	Field Blanks % Diff. (PD) <MDL	Bias / Systematic Error: % Diff. (PD)	Alternate Measurement Sensitivity (AMS)	Alternate Measurement Sensitivity (+) (AMS+)	Method Detection Limit (MDL)	Minimum Level of Quantitation (ML)
CCAL Lab Parameters	TN, NO_4, NH_4, TP, PO_4, DOC, TDS	RPD≤10% from one set of duplicates taken from every 6-8 samples/yr	RPD≤15% from one set of duplicates taken from every 6-8 samples/yr	<MDL or PD≤10% (if + bias), one blank for every 10 samples	PD ±10%, observed compared to standard, one for every 10 samples	NA	NA	TBD, one time/yr or when method changes	TBD, one time/yr or when method changes, 3.18*MDL
CWU Lab Parameters	Cl, NO_3, SO_4, Na, NH_4, K, Mg, Ca	RPD≤10% from one set of duplicates taken from every 6-8 samples/yr	RPD≤15% from one set of duplicates taken from every 6-8 samples/yr	<MDL or PD≤10% (if + bias), one blank for every 10 samples	PD ±10%, observed compared to standard, one for every 10 samples	NA	NA	TBD, one time/yr or when method changes	TBD, one time/yr or when method changes, 3.18*MDL
pH	Orion 370 (lab)	RPD ≤10% One set of duplicates taken from every 6-8 samples/yr	NA	NA	PD ±10%, comparison of pre- and post-calibration check results (SOP 9)	TBD, once at the beginning and end of field season	NA	NA	NA
	YSI 600XLM (field)	NA	RPD ≤10% One set of duplicates taken during each field deployment	NA	PD ±10%, comparison of pre-mobil, field and post-calibration check results (SOP 7)	NA	TBD, once at the beginning and end of field season	NA	NA
Specific conductance	Hach SensION 7 (lab)	RPD <10% One set of duplicates taken from every 6-8 samples/yr	NA	NA	PD ±10%, comparison of pre- and post-calibration check results (SOP 9)	TBD, once at the beginning and end of field season	NA	NA	NA

Table 19.3. Measurement quality objectives (MQOs) as acceptance/rejection criteria (*see* Table 19.2 for more detail on Quality Control parameter descriptions, frequency of reporting, sample size and calculation) (continued).

Parameter	Instrument or Method	Precision: Relative Percent Diff. (RPD)	Precision (+) Relative Percent Diff. (RPD+)	Field Blanks % Diff (PD) <MDL	Bias / Systematic Error: % Diff (PD)	Alternate Measurement Sensitivity (AMS)	Alternate Measurement Sensitivity (+) (AMS+)	Method Detection Limit (MDL)	Minimum Level of Quantitation (ML)
Specific conductance	YSI 600XLM (field)	NA	RPD ≤10% One set of duplicates taken during each field deployment	NA	PD ±10%, comparison of pre-mobil, field and post-calibration check results (SOP 7)	NA	TBD, once at the beginning and end of field season	NA	NA
Dissolved oxygen	YSI 600XLM (field)	NA	RPD ≤10% One set of duplicates taken during each field deployment	NA	TBD	NA	TBD, once at the beginning and end of field season	NA	NA
Temperature	YSI 600XLM (field)	NA	RPD ≤10% One set of duplicates taken during each field deployment	NA	See SOP 8, Section A.6-7, done at the start and end of field season	NA	TBD, once at the beginning and end of field season	NA	NA
	HOBO® U22 v2, HOBO® Tidbit (field)	NA	RPD ≤10% One set of duplicates taken once at the beginning and end of field season	NA	See SOP 8, Section A.6-7, done at the start and end of field season during calibration checks	NA	TBD, once at the beginning and end of field season during calibration checks	NA	NA
Acid neutralizing capacity	Gran Titration Method (lab)	RPD ≤20% One set of duplicates taken from every 6-8 samples/yr	TBD- from one set of duplicates taken from every 6-8 samples/yr	TBD, One blank for every 10 samples	PD ±10% for each observer vs. expert, until competent	TBD, once at the beginning and end of field season	NA	NA	NA

Table 19.3. Measurement quality objectives (MQOs) as acceptance/rejection criteria (s*ee* Table 19.2 for more detail on Quality Control parameter descriptions, frequency of reporting, sample size and calculation) (continued).

Parameter	Instrument or Method	Precision: Relative Percent Diff. (RPD)	Precision (+) Relative Percent Diff. (RPD+)	Field Blanks % Diff (PD) <MDL	Bias/Systematic Error: % Diff (PD)	Alternate Measurement Sensitivity (AMS)	Alternate Measurement Sensitivity (+) (AMS+)	Method Detection Limit (MDL)	Minimum Level of Quantitation (ML)
Lake water level	SOP 5 (field)	NA	RPD ≤10% One set of duplicates taken from every 6-8 samples/yr	NA	PD ±20% for each observer vs. expert, beginning until competent and mid-season	NA	TBD, at minimum, once for every 20 samples	NA	NA
Secchi depth	SOP 6 (field)	NA	RPD ≤10% One set of duplicates taken from every 6-8 samples/yr	NA	PD ±20% for each observer vs. expert, beginning until competent and mid-season	NA	TBD, at minimum, once for every 20 samples	NA	NA
Chlorophyll-a	EPA method 445.0: Fluorometric procedure (lab)	NA	RPD <40% One set of duplicates taken from every 6-8 samples/yr	<MDL or PD≤10% (if + bias), One blank for every 10 samples	NA	NA	TBD, once every 2 years	NA	NA
Zooplankton	Taxa richness, density, metric values SOP 12	NA	RPD <40% One set of duplicates taken from every 6-8 samples/yr	NA	PD ±10% taxa ID between two experts for one out of every 10 samples/yr	NA	TBD, once every 2 years	NA	NA
Benthic invertebrates	Taxa richness, metric values SOP 11	NA	RPD <40% One set of duplicates taken from every 6-8 samples/yr	NA	PD ±10% taxa ID between two experts for one out of every 10 samples/yr	NA	TBD, once every 2 years	NA	NA

2. Completeness

The completeness of data is basically a relationship of how much of the data are available for use compared to the total potential data before any conclusion is reached. Ideally, 100% of the data should be available. However, the possibility of data becoming unavailable due to laboratory error, insufficient sample volume, samples broken in shipping, and data associated with sample holding times that have been exceeded or for samples that were not adequately preserved (SOP 9 and 10) must be expected. Also unexpected situations may arise where field conditions do not allow for 100% data completeness. Additional factors affecting data completeness for some response variables includes how nondetects and outliers are handled (SOP 21) in the data analyses. Efforts to assure data completeness is addressed in each of the field data collection SOPs and associated field forms (Appendix C).

A data completeness goal of 90% is required by NCCN parks to obtain sample sizes large enough to meet our objectives described in the narrative of this protocol (Sections 1.4 and 2.4). The Lead Aquatic Ecologists and Field Leads are primarily responsible for determining that the 90% data completeness criteria are met or for justifying acceptance of a lesser percentage.

3. Data Comparability (Internal and External)

Comparability is another qualitative term that expresses the measure of confidence that one data set can be compared to another and that data can be combined for the decision(s) to be made. Comparability of data produced by MORA, NOCA and OLYM is predetermined by the commitment of staff and contracted laboratories to use standardized methods, where possible, including EPA and USGS approved analytical methods or documented modifications that provide equal or better results. Sampling bias related to changes in sampling and laboratory methods or observers will be documented, with measures taken to assure future comparability (*see* following Item 6: Systematic Error/Bias, and Section H: Cumulative Bias). Documentation of changes in observers, methods, instruments, indicators, and sampling design that may bias results are described in Section H.2 of this SOP. More information on how changes in SOPs are made and archived is described in the protocol narrative (Section 7) and SOP 25.

4. Sensitivity

Measurement Sensitivity

Measurement sensitivity is the capability of a method or instrument to discriminate between measurement responses representing different levels of the variable of interest. Sensitivity is a concern for water quality variables that are present in very low levels or for those variables that are likely to change in very small amounts over time (*see* chemical parameters in SOP 9: General Water Chemistry). This is measured as the method detection level or minimum level of quantitation (MDL and ML, *see* Table 19.2 in this SOP). The MDL is the lowest value that can be distinguished from zero and the ML is the lowest value that can be reliably measured. The ML is simply an expression of the MDL with 99% confidence. NPS monitoring program standard methods for calculating MDL and ML values, following USEPA guidance, are given by Irwin (2008). These values will be updated and reported by the contracted laboratories at least once a year and when methods change and will become part of the permanent data record.

Values below the MDL and ML will be reported as per the NPS guidance (Irwin, 2008) which follows the recommendations of Helsel (2005). Measurement Quality Objectives for sensitivity are given in Table 19.3 of this SOP.

With field measurements MLs and MDLs are not a concern. For example, specific conductance in a natural stream cannot be zero; there are always ions present resulting in some level of electrical conductivity. Measurement Sensitivity is used for laboratory parameters while the term "Alternative Measurement Sensitivity" (AMS and AMS+, Table 19.2) is used for field parameters. The AMS is more specifically defined as "the measurement precision uncertainty based on a sample size of seven environmental replicates (not blank) taken from the same sample (note for AMS+, replicates are taken from different samples but within close proximity and time) and with 99% confidence" (Irwin 2008). Most of the field measures given in SOPs 5-8 and 10-15 use the AMS+ procedure for sensitivity. AMS methods are explained in more detail by Irwin (2008).

AMS+ is calculated at the beginning of the field season and at the end of the field season for field instrument measured parameters such as temperature, pH, specific conductance, and dissolved oxygen (Table 19.3). Measurement sensitivity (AMS+) for continuous temperature loggers will be calculated for at least one set of seven consecutive measurements taken during the pre- and post-season calibration checks (SOP 8, Section A.6-7) when water temperatures are held at nearly constant temperature (field logger data cannot be used for this calculation because of the variability associated with the greater time lag between consecutive measurements).

AMS+ for lake level and Secchi depth is calculated for at least one sample out of every 20 (this equates to one sample at each park every 2 to 3 years based on six lakes sampled/yr at MORA and NOCA and 8 lakes sampled/yr at OLYM). AMS+ may be calculated less frequently for chlorophyll-a, zooplankton, and benthic macroinvertebrate samples due to the effort and cost involved in collecting and processing the required seven samples needed for the calculation.

The AMS (and AMS+) is calculated as follows:

a. Follow the steps outlined in the appropriate SOP for equipment equilibration, stabilization, and taking a water quality measurement.
b. Take seven distinct measurements for each parameter at regular intervals.
c. Take the standard deviation of the seven samples (this can be calculated in Excel) and multiply by 3.708, the two-sided *t*-value for a 99% confidence interval and a sample size of seven. This number is taken from a standard table of *t*-distribution critical values.

Monitoring Design Sensitivity

Factors influencing sensitivity at the monitoring plan design level are primarily focused on minimizing total variation which can be moderated by project design choices. Larsen et al. (2004) provide a breakdown of variance components for consideration at the design level including: a) residual variation - accounting for measurement precision, observer bias, and short term variation (e.g., diel fluctuations), b) site variation – persistent differences among lakes across a region. For example, lake type, size, depth, and

catchment characteristics will vary across the landscape, c) year variation – synchronous yearly variation among all sites in the network (e.g., regional-scale climate changes or broad-scale disturbances), and d) interaction variation – independent, desynchronized yearly variation among all sites in a network, subject to local-scale influences. For example, runoff into some lakes may be greater than other lakes in some years where the reverse may be true in other years. Residual variation can be controlled by application of QA/QC procedures for sample collection and measurement. Site and interaction variance components can be controlled by increasing sample size and incorporation of patterned revisits (annual visits). The year component of variation can be moderated by data analysis procedures that identify explanatory attributes that affect interpretation of changes in response variables.

In addition to implementing QA/QC procedures, several different design based strategies were chosen for this protocol to reduce total variability, consequently enhancing our ability to detect a difference where one exists. These include:

a. Narrowing the target population using criteria (e.g., lake size, elevation, depth, etc., Narrative Section 2.2) that provides a set of lakes that are more similar in physical and chemical characteristics.
b. Implementing an annual sampling effort with visits standardized to the same time period each year. Sampling times for parameters exhibiting diel fluctuations were also standardized. Both of these design choices help to reduce both within-site and between-site variability (protocol Narrative Section 2.3).
c. Selection of response variables with a previous record of having acceptable levels of measurement precision and true variability in the environment.
d. Selection of analysis methods for detecting changes that can incorporate explanatory environmental attributes that contribute to the 'year' component of variation (SOP 21, IV.C).

Minimum Detectable Difference (MDD)
MDD can be used to estimate monitoring design sensitivity and represents the smallest difference or change in a mean or median result that is statistically different given stated power, significance level, and sample size. It is influenced by variability of measurement results and when solved for sample size rather than power it determines the duration of fixed frequency sampling required to detect a change of a given magnitude. Our MDD objective for trend analysis is to detect an average annual increase or decrease in the average response of monitoring parameters of ≤3% with an 80% probability of detecting a trend and a 10% probability of incorrectly asserting a trend in a ≤15 year period (approximately a 45% change over 15 years). Results of the power analysis in the protocol narrative (Section 2.4) indicate that this objective is reasonable for most of our response variables.

5. Measurement Precision
The precision of data is determined by particular actions of the analytical laboratory and field staff. For this monitoring project measurement precision will be considered as the measure of agreement among repeated measurements of the same property under identical or substantially similar conditions. Two methods for calculating measurement

precision are given in Table 19.2 of this SOP. Both methods are based on calculation of Relative Percent Difference (RPD). It is less rigorous measure than sensitivity using AMS (sample size of 2 rather than 7), but is used more frequently to assure that measurements are in 'control' where 7 replicates are not practical. For laboratory analyses of water chemical parameters RPD is calculated from duplicate measurements of the same sample and is simply referred to as 'Precision.' The alternative measurement of precision is referred to as 'Precision PLUS or (+)' for which RPD is calculated from duplicate measurements of different but closely related samples in time and space. Precision (+) is used for most parameters measured in the field or for those where duplicate measurements cannot be taken from the same sample (e.g., zooplankton and benthic macroinvertebrates).

MQOs for 'Precision' and 'Precision (+)' and frequency of calculation are given in Table 19.3. MQOs for the various parameters shown in Table 19.3 represent a starting point for assessing precision in this project and will be re-evaluated in the future. Current RPD criteria were selected based on what others have found to be acceptable and/or from analysis of duplicate samples collected during the pre-implementation sampling phase of this project (chlorophyll-a, zooplankton, benthic macroinvertebrates).

The frequency of calculation of measurement precision varies with the type of parameter (Table 19.3). Laboratory chemical analyses, lake level, Secchi depth, zooplankton, and benthic macroinvertebrate measurement precision is calculated at minimum once for every set of lakes sampled at each park every year (6 lakes at MORA and NOCA and 8 lakes at OLYM). Field measurement precision for parameters measured by the YSI 600XLM datasonde (pH, specific conductance, dissolved oxygen, temperature) will be calculated from duplicate samples collected during every field deployment. Measurement precision (RPD+) for continuous temperature loggers will be calculated for one or more sets of two consecutive measurements taken during the pre- and post-season calibration checks when water temperatures are held at nearly constant temperature.

6. Systematic Error/Bias

Bias is the systematic or persistent distortion of a measurement process that causes errors in one direction. Percent difference (PD) will be used as the primary method for assessing bias and represents the difference between a measured result and a known correct or expected value. The description and method of calculation of PD is shown in Table 19.2 of this SOP. MQOs for assessment of bias attributed to laboratory sample processing, field instrument calibration and observer error are described in Table 19.3 and are discussed in the following sections.

Laboratory Water Chemistry Sample Processing

For each analyte, calibration standards are run in rotation every 10 samples to monitor potential measurement bias and validate the calibration. The MQO for bias (Table 19.3) requires that the PD between the measured value and standard is within ±10%. Details of laboratory preparation of standards, equipment calibration and calibration documentation are given at the following website:

http://science.nature.nps.gov/im/units/nccn/vs/mountain_lakes/NCCN_Mountain_Lakes_Contract_Laboratory_QA_QC_Procedures.pdf (accessed 16 January 2011).

Internal Sample Consistency Checks
Water chemistry data will be validated by performing internal sample consistency checks. These checks will include charge balance calculations and comparisons of measured vs. calculated specific conductance.

For charge balance consistency checks, the total anion charge must have a PD of ≤10% of the total cation charge (Carleton et al. 2005). The charge balance error (CBE) is calculated as:

$$CBE = \frac{\sum cations - \sum anions}{\sum cations + \sum anions} = 100$$

where ion values are in equivalents (molarity x charge). Samples that fail the consistency check will be flagged.

For measured vs. calculated specific conductivity consistency checks, the measured specific conductivity must have a PD ≤20% of the specific conductivity calculated from major cation concentrations (calcium, magnesium, sodium, and potassium). Calculated specific conductance will be derived from the USGS program geochemical calculation program PHREEQC (http://wwwbrr.cr.usgs.gov/projects/GWC_coupled/phreeqc/ accessed 16 April 2011). Samples that fail the consistency check will be flagged.

Blank Control Bias
An additional source of systematic error is from cross contamination of samples attributed to field collection, handling and processing. Blank sample bottles prepared with de-ionized water are taken into the field and are processed in the same manner as the actual water samples. Blank samples are labeled in a way that the contracting laboratory has no knowledge that they are actually blanks. Analyte concentrations in blank samples should be <MDL (Table 19.3). If values in blank samples are greater than the MDL (positive bias) then the PD (percent difference) should not exceed 10%. Percent difference for blank samples is calculated as follows: PD = [(Y-X)/X]*100, where X is the MDL and Y is the measured concentration of the analyte in the blank sample.

Acid neutralizing capacity (ANC) is always measureable; therefore blank control MQOs for this parameter will need to be based on some minimum acceptable concentration instead of an MDL. The MQO will be developed in the future when more information regarding low ANC values is available for the network parks.

Field Instrument Calibration (pH, Specific Conductivity, and Temperature)
Field calibration procedures using NIST traceable standards are given in the YSI 600XLM operation manual. Comparisons of pre-mobilization, field and post-calibration check results will be used to minimize bias in field measurements of pH and specific conductivity using multiparameter probes. PD is calculated as the difference between the measured value of the instrument, when immersed in the standard, and the value of the

standard (*see* Table 19.2). PD values should not exceed the MQO of 10% (Table 19.3). If this MQO is violated the field technician must either determine the source of the problem and ensure that it did not jeopardize previous sample run data or discard the data and resample after steps are taken to resolve the issue (e.g., maintenance procedures in the operator manual). Calibration details are recorded on the Instrumented Water Column Profile data form (Appendix C: Field and Laboratory Forms).

Temperature calibration procedures are given in SOP 8: Continuous Air and Water Temperature Sampling, Section A. Calibration check methods given in SOP 8 apply to both continuous temperature loggers and the YSI 600XLM datasonde temperature probe. Calibration checks are conducted prior to the first sampling event of each year and at the end of the season. Thermistors are calibrated at 0°C (ice bath) and 20°C using an NIST certified reference thermometer. The mean acceptable absolute difference for both calibration temperatures should be $\leq 0.2^{o}$C for water temperature measurement and $\leq 0.4^{o}$C for air temperature measurement (SOP 8, Section A.6). Continuous temperature loggers that fail the first pre-deployment check are calibrated a second time. If the logger fails both tests it is rejected for use. If the datasonde temperature probe fails both pre-deployment tests then maintenance procedures in the operator manual should be followed or the probe should be replaced. Similar calibration checks are completed at the end of the field season (SOP 8, Section A.7). If a thermistor fails both of the post-season calibration checks, then the raw data should be adjusted, prior to analysis, by the mean difference of the pre- and post-season calibration tests to correct for instrument bias. Temperature calibration data are recorded in the Continuous Temperature Calibration Check Form (Appendix C).

Observer Bias

Field observer variability related to sampling technique (e.g., water level and Secchi depth measurement), estimation of habitat variables (*see* SOP 11 and 14), interpretation of categorical rating criteria (*see* SOP 15), and species identification will be estimated by pairing an expert observer/technician with a less experienced technician. The technique and observations of the expert (Field Leads and Lead Aquatic Ecologists) will be considered to be correct/unbiased 100% of the time and provide the basis evaluating the PD (percent difference) MQO in Table 19.3 (data will be considered unbiased when the PD does not exceed ±20%).

Proper training of field personnel represents a critical aspect of minimizing bias attributed to observer error. Details of staff training are presented in the protocol narrative and in SOP 1. Staff competency in field sampling and measurement methods will be evaluated on an individual basis by park Lead Aquatic Ecologists or Field Leads. PD for observer bias will be used to evaluate individual observer competency for the appropriate field SOPs prior to allowing them to work independently. An additional field check will be conducted during mid-season. Observer Bias results will be recorded on duplicate SOP data forms noting results of the technician on one form and results of the expert on the other form.

All field identification of fish and particularly amphibians will require verification by the Field Lead until repeated consistent agreement is obtained. Voucher specimens will be collected if species verification in the field cannot be documented (*see* SOP 14).

Bias in the identification of zooplankton and benthic macroinvertebrate specimens will be evaluated by having a second taxonomic specialist identify 10% of the samples collected at three year intervals. Bias will be calculated as PD by comparing the results of both taxonomists for metrics based on the number of taxa (e.g., Total taxa, EPT taxa, etc.). PD should not be greater than ±10%. In any case, taxonomists will work together to reach agreement on questionable identifications and if agreement cannot be reached a third taxonomist will be consulted.

H. Cumulative Bias

It is expected that equipment, staff, field methods and parameters may change over time. In order to ensure comparability of data in the future it is extremely important to quantify how any of these changes affect pre-existing data. The following discussion provides an overview of possible changes, and how they can be mitigated or reported to ensure change detection is due to environmental conditions rather than observer, instrument or methodology.

1. Changes in Staff, Instruments, Methods, Indicators and Design

Changes in Field Staff

In addition to training, new employees will be required to demonstrate competency (as described in the previous section) for all assigned activities. Single (identical) samples will be measured by old and new personnel at least seven times when the only thing changing is staff doing the measuring or observations.

Changes in Instruments

For changes in instruments or an individual sensor, a minimum of 30 overlap measurements will be made on the same sample with each instrument. Samples for datasonde measurements should be placed in a container to avoid natural variation. Dissolved Oxygen measurements should be made in an agitated sample. The same calibration standard should be used for both instruments.

Changes in Methods or SOPs

Changes in methods or SOPs may be necessary as new techniques are developed and proven to be superior to older ones. When a change in method or SOPs occurs at least 30 paired measurements will be made.

Changes in an Indicator or in One Surrogate Measure to Estimate Another

At least 50 overlap measurements will be made and results recorded. The bigger the method or SOP change, the more repeat sampling may be appropriate. Sampling overlap for surrogate measures and indicators that are sampled only once a year will require replication within and among years to meet the goal of obtaining a sample of 50 paired measurements.

Changes in taxonomic resolution for macroinvertebrates and zooplankton represent a special case worth noting and which will likely happen throughout the future of the

monitoring project. Changes in resolution from parent taxa (existing level of resolution) to increased levels of resolution (e.g., family to genus or genus to species) will be documented in the protocol database. Incorporation of higher levels of resolution of individual taxa used in calculating community metrics (metric examples given in Appendix E, Tables E-5 and E-6) will be carefully considered prior to any changes in existing indicator metrics. Voucher specimens of parent taxa from previous samples, for all sample sites, must be re-examined to ensure accurate separation of parent taxa into new taxonomic units before indicator metrics can be changed. Metrics would then be re-calculated for all samples from all years.

Changes in Sampling Design
Statistical consultation will be required regarding any significant future changes to the sampling design. Types of design changes considered here include selection of additional sites, replacement of existing sites or any substantial change in how sample sites are selected. Statistical consultation will be used to evaluate the need and consequences of design changes on interpretation of existing trend data and provide methods for separating the effect of these changes to ensure future comparability of trend data. For sampling design changes, 30-50 overlapping measurements under the old and new designs are recommended by NPS Water Resource Program (Irwin 2008).

2. Cumulative Bias Documentation Requirements
Documentation required for evaluating bias (Irwin 2008, pg. 166 and below) shall be archived in the protocol database. In addition, changes will be documented in the appropriate SOP Revision History Log (SOP 25: Revising the Protocol), entered as part of the metadata record in NPSTORET, reported in Annual Reports as they occur, and summarized in Five-year Summary Reports. Specific bias data and other QC data documentation requirements for NPSTORET are described in SOP 20, Table 20.20, and by Irwin (2008, pg. 168). **NOTE**: It is important that adjustments to data only be made during the analysis process – only original data are recorded in the long-term databases (NPSTORET and the protocol database). The following are documented for all changes:

   a. The sample size, standard deviation, and average % bias change from the old measurement system to the new, calculated as an average of percent differences (PD).
   b. In the case of sample sizes of less than 25 pairs of old and new data, the results of a paired t-test of the differences of the two means, based on alpha of 0.10, power of no less than 90%.
   c. The measurement precision as reproducibility or repeatability RPDs or RSDs.
   d. Measurement sensitivity, as either a MDL (if some measurements are near or below the MDL) or AMS (if all measurements are well above the MDL) for both the old and new measurement systems.
   e. The date that the overlapping measurements started.
   f. The date that the overlapping measurements stopped.
   g. The date that the average percent difference bias change from old to new measurements was calculated.
   h. All paired raw values, should future statistician desire to normalize values a different way when estimating trends.
   i. There should be a clear statement of which way the bias went (positive or negative).

j. Trends are then based on values normalized to the original numbers. If the average PD based on the 30 samples was a plus 5% (the new meter on average read 5% higher than the old meter), for purposes of trend analyses, the new values can then be normalized to old by multiplying the new values times the calculated fraction of change, so one would multiply the new values times 0.95.

I. Data Management and Data Quality Assessment

Details related to data management, verification, quality review and verification, archiving, reporting and retention of records can be found in Section 4 of the protocol narrative and in SOP 2: Project Workspace and Records Management, SOP 3: GPS Data Collection, SOP 18: Acquiring and Managing Photographic Images, SOP 20: Data Entry and Verification, SOP 22: Data Quality Review and Certification, and SOP 23: Product Delivery, Posting and Distribution.

1. Data Quality Assessment

   Data quality review and assessment (SOP 22: Data Quality Review and Certification) are conducted following data entry/verification (SOP 20: Data Entry and Verification). Data quality assessment includes a holistic evaluation of the data including assurances that:

   a. Proper field methods were followed (Field QA checks and observer comments).
   b. Equipment was in good condition and working properly (maintenance records, calibration results, observer comments).
   c. Blanks and replicates had acceptable values (see MQOs for sensitivity, precision, and bias in Table 19.3).
   d. Holding times and sample temperatures were not exceeded (see Section J.4, below for review of field documentation, laboratory custody logs and shipping manifests; also see Table 9.2 of SOP 9: General Water Chemistry and SOP 10: Chlorophyll-a Concentration).
   e. Data completeness goals were met (see Section G.2 of this SOP).
   f. Data were quality controlled and uploaded with appropriate flags if necessary.
   g. Cumulative bias has been evaluated and controlled or data normalized prior to analysis (see Section H of this SOP and SOP 21: Data Analysis and Reporting).

2. Violation of MQOs

   Quantitative acceptance/rejection measurement quality objectives (MQOs) representing field and laboratory assessments of sensitivity, precision, and bias are presented in Table 19.3. The following summarizes corrective actions taken for measurements that do not meet the standards given in Table 19.3.

   It must be realized that simply rejecting data for parameters (e.g., benthic macroinvertebrate, zooplankton, and chlorophyll-a) that cannot be re-sampled within season (results are not available until the post-season laboratory analysis is completed) would result in the complete loss of all data for that year. In addition, QC results for precision and sensitivity calculated for these types of parameters only represent a fraction of the samples collected in any given year and do not necessarily represent the quality of all of the samples collected. For this situation, data will be flagged in the database rather than automatically rejected based on precision and sensitivity QC results. However, QC results will be used to document the quality of the data, as represented by the sub-sample

of replicates, and to verify sample collection and laboratory analysis procedures is consistent problems occur.

Sensitivity
Water chemistry results that are higher than the MDL but lower than the ML will be recorded in the database as "Present, below Quantification Limit." Handling of nondetects in the data analysis will follow recommendations in the recent Helsel book, Nondetects and Data Analysis: Statistics for censored environmental data (Helsel 2005) as discussed in SOP 21: Data Analysis and Reporting, Section I.B.2.

Historically data has typically not been censored based on AMS or other expanded uncertainty values. However, as a statistical analysis strategy for looking at a single data point only, one could take the worst case end of the range (Irwin 2008) and flag those measurements that exceed the criterion. Flagged data would be reviewed prior to analyses and recommendations for evaluating sampling procedures may be warranted in the future.

Measurement Precision
Unless otherwise flagged and justified, precision MQOs specified in Table 19.3 will be used as data acceptance/rejection criteria. If RPD exceeds the MQO in Table 19.3, then the other values associated with that batch will be discarded, with the exception of parameters previously discussed at the beginning of this section. Generally data completeness objectives (Section G.2 of this SOP) can be maintained by taking new measurements in the field or re-analyzing samples in the laboratory. Equipment maintenance and calibration checks may be required prior to re-sampling.

Bias/Cumulative Bias/Field Blanks
Corrective actions for bias related error are discussed in Section G.6 and Section H of this SOP.

3. Data Quality Certification
   Data quality certification is described in SOP 22: Data Quality Review and Certification. NPSTORET provides a reporting function (SOP 22) which identifies records requiring attention by the Lead Aquatic Ecologists and is useful in producing the final NPS Project Data Certification Form.

J. Data Generation and Acquisition

1. Sampling Process and Design
   The NCCN Mountain Lakes Monitoring Project is structured on a probability-based sampling design (see protocol narrative Section I.2). The schedule for sampling and analytical activities along with the total number of samples, number of sampling locations, the number of samples at each location, number of sample composites, support for the sample number of field and laboratory replicates and the plan for obtaining replacement samples essential to the integrity of this project are detailed in the protocol narrative and associated SOPs.

2. Sampling Methods
   Consistent methods are important to long-term quality data. All measurements and sampling associated with monitoring activities will be conducted according to the protocol narrative and associated SOPs. If there is a change in the protocol, such as a change in sampling method, equipment, or staff, then there will be overlap of methods and personnel where possible (*see* SOP 25: Revising the Protocol).

   Specific methods regarding collection techniques, equipment requirements, sample area, sample volumes, containers, storage and preservation methods, as well as data summary and analysis techniques can be found in the relevant SOPs.

3. Site Locations
   To make sure that field crew members are at the correct lake selected for monitoring (SOP 1: Field Season Preparations and Crew Training), the location for each field visit will be verified with multiple lines of evidence. This includes 1:24,000 maps, high resolution aerial photographs, altimeters, and coordinates derived with a GPS unit. UTM coordinates and elevation of all sample sites are provided in Appendix D, Tables D-1 through D-3. Access routes by trail and off-trail to each sample site are archived in individual park GIS databases.

   Specific onsite benchmarks and reference points include benchmarks at two sites where water level is measured, and reference points for the location of maximum lake depth for measurement of water column parameters, the location of the photo point used for watershed landscape panoramic photos, and the location of the continuous air temperature logger. Previous field notes, GPS coordinates, and photographs will be used for location of these benchmarks and reference points. Any deviations from standard sampling locations will be documented in the comments sections of the appropriate field forms and database fields that are specific to the measurements taken at that sampling location.

4. Handling and Custody
   One part of proper data and sample handling procedures is to provide a complete record of the methods and procedures followed. Complete records are important to long-term monitoring so that anyone using the data may trace the sampling history. Chain-of-custody documentation will be maintained by the Lead Aquatic Ecologist, or designee, in each park. The chain-of-custody will include the data forms and all references to the sample in any form, document, or log book that allow tracing the sample back to its collection, and will document the possession of the samples from the time they were collected until the sample analytical results are received. The handling of field data forms, use of unique site and sample identity codes, data entry, as well as holding and transfer specifications for biological and water quality samples are covered in detail in the relevant SOPs. The general flow of samples and data will follow a sequence of:

   a. Sample collection and data acquisition
   b. Field preservation of samples
   c. Transporting samples and data forms to local NPS laboratories and resource management offices
   d. Logging samples into local NPS laboratories for temporary storage

e. Preparation and processing of samples for contracted taxonomists and laboratories or conducting in house analysis
f. Documenting the sample preparation and processing and/or recording analysis results
g. Packaging and logging samples to be sent to contracted facilities
h. Compiling the shipping manifest
i. Documenting receipt of samples at contracted facilities
j. Documenting receipt of data from contacted laboratories and
k. Data entry into NPS database, which includes verification of accurate transcription, data validation, and data certification

Field personnel will have custody of samples during field sampling. Upon returning from the field all samples will be logged into the MORA, NOCA and OLYM and laboratories receiving/storing the samples. Chain-of-custody forms will accompany all samples during transport/shipment to the contract laboratories. Field personnel will enter sampling time and other relevant data on the chain-of-custody forms. Water quality and biological samples will be transported to the contracted laboratories directly by the field crew or by overnight courier. Shipping requirements are detailed in the relevant SOPs (*see* Appendix C. for data forms).

Field Documentation
The following items will be recorded on data forms for each sampling station:

- Time and date of sample collection
- Sample ID numbers
- The results of any field measurements (temperature, DO, pH, specific conductance, TDS) and the time that measurements were made
- Qualitative descriptions of relevant water conditions (e.g., color, flow level, clarity) or weather (e.g., wind, rain) at the time of sample collection
- A description of any unusual occurrences associated with the sampling event, particularly those that may affect sample or data quality
- The number of containers holding the sample (for biological collections)

MORA, NOCA and OLYM and Laboratory Sample Custody Log
The following items will be recorded for each sample:

- Unique sample ID
- Type of sample
- Time and date sample was collected
- Initials of collector(s)
- Number, type, and size of containers holding the sample
- Location of sample
- Initials of the person logging the sample into the laboratory
- Date sample was logged into the laboratory

Shipping Manifest
One copy of the shipping manifest will be sent with the samples to the contracted laboratory and one copy will be held at each respective park. It is also advisable to transmit electronic copies of the shipping manifest to contracted laboratories in advance of shipment. The following items will be included as part of the shipping manifest:

- Type of sample
- Unique sample ID
- Date sample was collected
- Initials of collector(s)
- Number, type, and size of containers holding the sample
- Initials of the person packaging and compiling the shipping manifest
- Date sample was packaged and shipped

Contracted Laboratory Custody Log
Contract laboratories will be National Environmental Laboratory Accreditation Program (NELAP) certified and this is discussed further in the protocol narrative. Therefore, they are expected to follow standard procedures. Laboratories will maintain custody logs sufficient to track each sample submitted, and to analyze or preserve each sample within specified holding times.

5. Analytical Methods
The analytical procedures for taking habitat and water quality measurements in the field, NPS laboratories, and/or the office are identified in each associated SOP. Data summary and analysis methods can be found in SOP 21. Contracted laboratories conducting water chemistry and chlorophyll-a analysis will follow the EPA or USGS approved standardized methods.

Field and contract laboratory instruments are likely to change during the course of this long-term monitoring project. Documentation in the protocol database will be maintained regarding each instrument and contract laboratory's ability to meet the data quality objectives of the project. Procedures described in Section H, above (Cumulative Bias) will be followed for any of these changes.

6. Quality Control
The lakes sampled in the NCCN parks will predominantly represent subalpine conditions typically considered pristine relative to lowland areas with higher levels of human activity. Therefore, it is critical that laboratories be able to provide low-level detection limits of pollutants and nutrients.

Laboratories providing analytical support for chemical and biological analyses will have the appropriate facilities to store, prepare, and process samples as well as the appropriate instrumentation and expertise to provide data of the required quality within the timeframe dictated by the project.

Laboratories will be able to provide information documenting their ability to conduct analyses with the required level of data quality. Such information might include results

from inter-laboratory calibration studies, control charts, summary of QA/QC checks and results from certified reference material analyses. Laboratories will also provide a Quality Assurance Project Plan for their operations.

Field duplicates will be collected annually for all parameters from at least one of the sites selected for monitoring at each park. The duplicate sample will be collected in the same manner and as close in time as possible to the original sample. This effort is an attempt to examine field homogeneity as well as sample handling, within the limits and constraints of the field and laboratory settings.

Field blanks are to be collected from at least one site at each park, during each sampling year, for nutrients, anions/cations, DOC, ANC, and chlorophyll-a samples. A field blank is designed to assess potential sample contamination levels that could occur during field sampling and sample processing. Field Blanks (DI water) are taken to the field, transferred to the appropriate container, preserved (if appropriate), and otherwise treated the same as the corresponding sample type during the course of a sampling event. Field blanks for other media and analytes should be conducted upon initiation of sampling. If field blank performance is acceptable, further collection and analysis of field blanks for these other media and analytes need only be performed on an as-needed basis or during field performance audits.

7. Instrument Calibration Frequency, Inspection and Maintenance
   To minimize or avoid downtime of measurement instruments, all field sampling and laboratory equipment will be maintained in good working order. Spare equipment or common spare parts (e.g., batteries, DO membranes, pH electrodes) also will be available so that repairs or replacement can be made as quickly as possible and measurements will not be lost. All field equipment having manufacturer-recommended schedules of maintenance will receive preventive maintenance according to that schedule (*see* SOP 1: Field Season Preparations and Crew Training and SOP 17: Post Field Season Activities). After use in the field, all equipment will be re-checked for needed maintenance and stored according to manufacturer specifications.

K. Training and Contracted Laboratory Oversight

Personnel Training and Education

Details of staff training are presented in the protocol narrative and in SOP 1: Field Season Preparation and Training Crews, and SOP 24: Field and Laboratory Safety. Formal training including field preparation, equipment use and maintenance, sampling methods, species identification, sample handling procedures, QA/QC, and safety will be completed prior to initiation of the field season. Field personnel will be evaluated on their performance during annual or more frequently held field QA audits conducted by the either the Lead Aquatic Ecologist or the Field Lead. Any deficiencies will be remedied prior to continuation of field sampling. Percent difference (PD) for observer bias will be used to evaluate individual observer competency for the appropriate field SOPs prior to allowing them to work independently (see Observer Bias in Section G.6).

All technical staff involved in data collection will have an educational background in biological or physical sciences. The Park's Supervisory Aquatic Ecologist will have

specialized experience in water quality or closely related aquatic resource management activities. Where necessary (e.g., with staff turnover, adoption of new methods, etc.) local technical experts (universities/agencies) will be called upon for training assistance.

Contracted Laboratories
Meetings will be held with the laboratory contacts at regular intervals, by phone or in person, to review QA/QC procedures and to make recommendations for future revisions to the NCCN Quality Assurance and Control Plan. The more frequent the interactions with laboratory staff the better the understanding of any key issues or correction of problems will be. Issues such as timing of sample transport and analysis and laboratory capability and capacity for samples are important to QA/QC data completeness objectives.

Corrective actions which require modifying or establishing new SOPs will follow the methods outlined in SOP 25: Revising the Protocol.

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SOP 20: Data Entry and Verification

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Prepared by: John Boetsch NPS NCCN-OLYM.

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Data Entry and Verification

This SOP describes the general procedures for entry and verification of field data into the project database application for most project data, and into NPSTORET for basic water quality parameters. For related guidance, refer to Section 4.3, Overview of Database Design, and Section 4.4, Data Entry and Processing. The following are general guidelines:

1. Data should be entered as soon after data collection as possible so that field crews remain current with data entry tasks, and identify any errors or problems as close to the time of data collection as possible.
2. The front-end database application (both the primary project application and NPSTORET) is a Microsoft Access file maintained in the project workspace (see SOP 2). This front-end copy may be considered "disposable" because it does not contain any data, but rather acts as an interface with data residing in the back-end database. It contains the forms, queries, and formatted report objects for interacting with the data in the back-end.
3. The primary back-end database for this project is implemented in Microsoft SQL Server to take advantage of the automated backup and transaction logging capabilities of this enterprise database software. The back-end database for NPSTORET is implemented in Microsoft Access and needs to be backed up regularly.
4. Each data entry form is patterned after the layout of the field form, and has built-in quality assurance components such as pick lists and validation rules to test for missing data or illogical combinations. Although the database permits users to view the raw data tables and other database objects, users are strongly encouraged only to use the pre-built forms as a way of ensuring the maximum level of quality assurance.
5. As data are being entered, the person entering the data should visually review each data form to make sure that the data on screen match the field forms. This should either be done for each record prior to moving to the next form for data entry, or preferably as a separate step after all of the data for a sampling trip has been entered. Important: It is a requirement that all events must be entered and verified at the end of the field season.
6. At regular intervals and at the end of the field season the Crew Lead should inspect the data that have been entered to check for completeness and perhaps identify avoidable errors. The Crew Lead may also periodically run the Quality Assurance Tools that are built into the front-end application to check for logical inconsistencies and data outliers (this step is described in greater detail in Section 4.5, Data Quality Review and also in SOP 22: Data Quality Review and Certification).

Database Instructions

Getting Started

The first action to be taken is to make sure the project workspace is set up properly on a networked drive. Refer to SOP 2 for instructions on how to set up and access the project workspace.

Important Reminders for Daily Database Use

- If accessing the database from a remote park (i.e., other than OLYM), do not open and use the front-end application outside the remote desktop environment as it will run very

slowly and likely stall. Instead, refer to the following instructions on remote access before using the application.

- If accessing the database from OLYM, do not open and use the front-end application on the network as this makes it run more slowly. Instead, copy the front-end file from the project workspace to your local desktop and open it there. This copy can be replaced with new versions as they are released.
- New versions of the front-end application may be released as needed through the course of the field season. When this happens, you may see a notification about a new release when opening the current or older versions of the front-end. Copies of the outdated version of the front-end file should be deleted and replaced with the new version, which will be named in a manner reflecting the update (e.g., Mtn_Lakes_2012_v2.mdb).
- Upon opening the front-end application for the first time, there may be a need to reconnect the front-end to the back-end, depending on how the project workspace is mapped on your computer. This database connection update should only need to be done once for each new release of the front-end database.

Remote Connections for Data Entry and Database Access

Most of our project databases are hosted on a server at OLYM. Due to bandwidth limitations, project database users accessing these databases from other parks (or from remote locations at OLYM) may encounter slow performance or application errors when accessing the database directly via a networked drive or a local front-end file. Therefore, to make data entry as smooth and efficient as possible, such users will typically need to use a remote desktop connection each time they need to access the database.

Remote desktop connections access what is called a "terminal server" at OLYM. In doing so, all of the processing is occurring on a server collocated with the database server, thus minimizing the negative effects of bandwidth on application performance. Through such a connection, the remote user is essentially sending mouse moves and keystrokes to the terminal server, and receiving screen updates in return. There may be some noticeable lag time in mouse moves and screen updates, but the performance is often much better than when accessing the data through other means.

Instructions for Using Remote Desktop

1. From the Start menu, go to: All Programs > Accessories > Communications > Remote Desktop Connection. You may wish to create a desktop shortcut by right clicking on the Remote Desktop Connection icon in the menu and selecting Send To > Desktop.
2. With the Remote Desktop window open, type in the terminal server name: "inpolymts1".



3. Click on the Connect button.
4. Enter your NPS login and password. Note that the login must be preceded by "NPS\", for example: "NPS\gwashington".
5. The remote desktop session will open and you will see a blank desktop that represents what you would see if you were sitting at the computer at OLYM. The first time you use it you may need to map network drives you use frequently and create other useful shortcuts (e.g., to the project workspace), and you will need to use the Access 2010 first-time setup instructions (see the following section) so that the project database functions properly. These initial setup steps should only need to be done once, however.
6. You may switch back and forth between your remote session and your local session (i.e., on your local workstation) using the connection bar across the top of the remote desktop screen.
7. When using the project database, you may need to make a copy of the front-end application if someone else is already using the file (evidenced by a ".ldb" lock file with the same name and in the same folder as the front-end file). You may also want to create your own subfolder in the project workspace for your own front-end copy to avoid these conflicts with other users.
8. When you are finished with your remote session, log off by clicking on Start > Log Off.

The first time you use Remote Desktop, you may wish to select Options from the first Remote Desktop Connection screen to enter more specific information for your frequent remote desktop sessions (e.g., enter "inpolymts1" for the computer, your NPS login, and "NPS" for the domain so you don't have to enter "NPS\" in front of your login each time). Do NOT enter your password or check the box to save your password, as this may present a security risk.

Special Instructions for Access 2010

If you are going to be using Access 2010, make sure the security settings will allow the database to function properly. This is necessary because Access 2010 may have been installed in a very restrictive security mode that disables the functionality built into the project database. Note: This setting change should only need to be performed once. However, if you move to a different workstation, these steps may need to be repeated to allow the database to perform properly. You will know the difference if none of the buttons or form functions on the main database switchboard form work properly, or if you get the following warning message across the top of the window:



To enable the database content to run properly on a consistent basis, do the following:

1. Prior to using the front-end database, open Access 2010 from the Start menu.
2. Go to Start > All Programs > Microsoft Office > Microsoft Office Access 2010.
3. In the upper left corner, click on the Office Button.
4. At the bottom of the menu page, click the Access Options button.
5. Select the Trust Center category on the left panel.
6. In the lower right, click the Trust Center Settings button.
7. Select the Macro Settings category on the left panel.
8. Select the option "Enable all macros". Then hit OK, and exit Access.
9. From this point forward the project database application should function properly on that computer.

User Roles and Privileges

The database application provides different levels of access privileges: read-only, data entry, power user, and administrator. These privileges are assigned based on user login by the Project Lead or a designee at the beginning of each field season. Most field crew users will be granted "data entry" rights, which allow one to enter and edit data for the current field season only. Certified data and lookup domains may only be edited by users with power user or administrator privileges. If a user name is not granted explicit rights to the database, the application will open in "read-only" mode.

Overview of Project Application Components

The front-end application has multiple functional components, which are accessed from the main application switchboard form that opens automatically when the application starts. Several buttons are found on the form to provide access to different components of the application, and are arranged in functional categories:

- Data Entry and Edits
    - Enter / edit data – Opens a form to confirm default settings (e.g., park, coordinate datum) prior to continuing to the project-specific data entry screens.
    - Task list – Keeps track of unfinished tasks associated with sample locations (for example, forgotten equipment, unfinished data collection) that one field crew can use to communicate with a future field crew.

- Database Admin
    - Db connections – Manage and update the connections to the back-end database(s).
    - Set user roles – Manage the list of users who may view, enter and edit the database. Provides four levels of access: read-only, data entry, power user, and admin. This button is only enabled for power users and administrators.
    - View db objects – Allows the user to view and edit database objects (tables, queries and forms). This button is only enabled for power users and administrators.

  - Backup data – Makes a zipped copy of the back-end file and stores this backup in a subfolder. This button is visible only when one or more of the back-end databases is implemented in Microsoft Access.

- Management Tools
  - Data browser – Opens a tabbed form that provides comprehensive access to data arranged by sampling location. This form has headers for filtering by park, location code, location type and status.
  - Lookup tables – Opens a tool for managing the lookup values for the project data set (e.g., species list, list of project personnel).
  - Sampling schedule – Opens a form to view and edit the sampling schedule.
  - QA checks – Opens the data validation and quality review tool, which shows the results of pre-built queries that check for data integrity, missing data, and illogical values, and allows the user to fix these problems and document the fixes. See SOP 22: Data Quality Review and Certification.
  - Edit log – Opens a form for documenting edits to certified data records.

- Summaries and Output
  - Data summaries – Opens a form for viewing and exporting summary queries for data exploration, analysis and reporting.
  - Task list report – Generates a report of tasks that need to be accomplished for a specified park or sample location (default is for all locations).
  - Quality review report – Generates the data quality review results for a selected year or all years.
  - Navigation report – Generates the field season Navigation Report used to relocate sample locations and brief the crew on tasks that need to be accomplished.
  - Navigation coords – Provides current, best navigation target coordinates for sample locations so these can be loaded into GPS units for navigation, or GIS for display and map production.

Verifying Data Records

Field crews must verify all sampling events throughout the field season. The recommended approach is for one crew member to do all of the data entry for one sample location, then have another crew member review and verify records for that location. The current record status for each sampling event is shown in the Data Gateway Form. To see all of the sampling events in the database, be sure to turn off the filters to show all of the sampling points and events. By double-clicking on the record status field in the Data Gateway Form, the appropriate data entry form will be opened for verification.

To complete the verification step: After all data for a given transect have been entered completely, the database entries should be compared against the original field forms. Each of the main data entry screens has a footer containing fields for storing quality assurance information about the event, and information on who created the sampling event record, who last updated it, etc. When all data for the sampling location have been verified, click on the button that says "Verify this sampling event" to indicate that the event record is complete and accurately reflects the field forms. Clicking this button instantly updates the record status in the Data Gateway for

that sampling event. Remember that both transect and quadrat data will need to be verified before clicking the "Verify" button on the main Data Entry form.

NPSTORET Data Entry

A series of NPSTORET training videos are located in a folder in the project workspace which contain individual training videos for each of the main forms within the NPSTORET database. Project staff, especially those entering, summarizing or analyzing data, need to study these training videos to become familiar with the NPSTORET database functioning.

Unique identifiers for each sampling location (Station ID used in NPSTORET) are developed by combining Park code and Site Codes. The format is: four letter park code, underbar, two character water body prefix, and the local site code (PPPP_ww_ccccccc [15 character limit total]). The local site code is the water body name (or abbreviation thereof to meet the 15-character limit). A list of Station IDs is generated by the GIS Specialist working in conjunction with the Project Lead. Consult these staff before entering any new Station IDs.

SOP 21: Data Analysis and Reporting

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Prepared by: Trent McDonald, WEST, Inc., Cheyenne, WY, and Reed Glesne, NPS NCCN-NOCA.

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Data Analysis and Reporting

Introduction

This document outlines a number of alternative statistical procedures for analyses of data collected in MORA, NOCA, and OLYM as part of the NCCN Mountain Lakes long-term monitoring project. Overall, these analyses are designed to extract useful information and facilitate conclusions regarding the project objectives by examining statistical relationships in the data. While the questions asked of data and types of analyses can vary depending on current needs of the parks, it is important to describe analyses that meet overarching analytical goals which include the following:

1. Estimation of current (or past) values of a parameter.
2. Estimation of the proportion of samples or sites that meet or exceed a criterion.
3. Detecting significant abrupt changes in a parameter.
4. Detecting long-term steady trends and step trends in a parameter.

Combinations of these analyses will indicate the condition of aquatic resources and habitat found in MORA, NOCA, and OLYM mountain lakes. The Mountain Lakes Monitoring Project will measure biological, physical, and chemical parameters at a probabilistic sample of lakes to provide lake, park and network inference. It must be noted that future analyses are not limited to only the statistical procedures given in this SOP. Additional tests or improvements may prove to be more applicable in future evaluations of the monitoring results. It is expected that consultation with a statistician will be required preceding the completion of Five-year Summary Reports, for changes in sampling design, and for significant modifications of sampling methods.

The following sections discuss initial review and preparation of the data, routine data summaries, and methods for statistical analyses designed to evaluate status, changes and trends at individual sites and for network extrapolations. In addition, development of criteria for assessments of the condition of biological and chemical attributes of mountain lakes is discussed. Reporting schedules and content are given in the last section.

I. Preliminary Data Review and Preparation

A. Data Management Error Checking

Prior to data analyses, error checking procedures found in SOP 22: Data Quality Review and Certification are performed and reported by the Project Lead. These procedures provide (using standard queries) information regarding transcriptional errors, missing data, preliminary screening of out of range values, and flagging entries that are below detectable limits (nondetects). These procedures provide (using standard queries) information regarding transcriptional errors, missing data, preliminary screening of out of range values, and flagging entries that are below detectable limits (nondetects). During this process, only known transcriptional errors are corrected by the technician entering the data, after cross-checking the original data. Additionally, data forms should be reviewed to flag records and comments regarding atypical weather conditions, equipment failures and calibration issues, and problems concerning sample processing, storage, and preservation, etc. Decisions regarding quality control violations of MQOs (*see* Section I

and Table 19.3 of SOP 19) and the need for adjustments related to changes in observers, instruments, methods, indicators, or sampling design should be evaluated and corrected prior to analysis (*see* SOP 19, Section H: Cumulative Bias).

B. Exploratory Data Analyses

Exploratory data analyses apply basic analyses and statistical tests to 1) identify whether the data support underlying assumptions of potential statistical tests, 2) examine relationships between dependent variables and potential explanatory attributes or ancillary variables (see discussion regarding trends in Section IV.E and F of this SOP), 3) classify sites into homogeneous subsets based on similarities in biological and/or environmental characteristics, and 4) determine if modifications are necessary prior to further statistical analysis. Modification of data prior to analysis includes treatment of outliers, data below detection limits (censored data), missing data, and transformation of data to meet test assumptions. Ideally, potential statistical tests and their assumptions should be identified prior to the exploratory analysis step, as they must also be considered prior to making judgments concerning handling of outliers, missing data, censored data, and the application of data transformations.

Much of the following discussion and methods generally follow those from USEPA (2006): Data Quality Assessment: Statistical Methods for Practitioners QA/G-9S, http://www.epa.gov/quality/qs-docs/g9s-final.pdf (accessed 14 March 2011). Discussion and methods concerning basic statistical quantities and graphical representations are found in Chapter 2, and specific information on statistical tests, their assumptions and limitations can be found in Chapters 3 and 4 of USEPA (2006).

1. Basic Statistical Quantities and Graphical Representations

Basic statistical quantities and graphs are generated by the data analyst to learn about the structure of the data, identify patterns and relationships, and potential anomalies in the data. Statistical quantities numerically describe the data set. Some examples include mean, median, percentile, range, inter-quartile range, *t*-distribution confidence interval, variance, standard deviation, and skewness (Table 21.1). They can be used to provide a mental picture of the data and are useful for making inferences concerning the population from which the data were drawn. Most of these measures can easily be calculated using the Microsoft Excel Analysis ToolPak. It is useful to look at these measures during the EDA process, but it is not always necessary to report all of them.

Table 21.1. Basic statistical quantities.

Measure	Description
Measures of Relative Standing	Quantiles - data ≤ or ≥ to a given percentage of data values including the Median, Upper and Lower Quartiles.
Measures of Central Tendency	Mean, Median, Mode
Measures of Dispersion	Range, Variance, Sample Standard Deviation, Coefficient of Variation, Interquartile Range, t-distribution confidence interval.
Measure of Asymmetry	Skewness
Measures of Association	Pearson's Correlation Coefficient, Spearman Rank Correlation Coefficient, Serial Correlation

Some examples of graphical representations of the data, used to identify patterns and relationships within the data and identify potential problems, are described in Table 21.2. Brief summaries and examples for these plots are given below. Additional information and examples for some of the following plots (as well as others not mentioned here) are presented in USEPA (2006) and in the NIST e-Handbook of Statistical Methods, available at the following website: http://www.itl.nist.gov/div898/handbook/eda/section3/eda33.htm (accessed 15 March 2011).

Table 21.2. Graphical presentations and their application.

Plot Type	Application
Histogram	Assessing location, shape and spread of the data depicting symmetry and potential outliers.
Box- and-Whisker Plot	Schematic of statistical quantities including interquartile range, sample median and mean, outliers. Assessment of symmetry of data.
Cumulative Frequency Distribution Plot	Plot of running total of frequencies for a parameter. Useful for assessing status where the value of the cumulative frequency indicates the number of elements in the dataset that lie below a threshold or criterion.
Ranked Data and Quantile Plots	Assessment of variability and symmetry showing all data points in rank order.
Normal Probability Plot	Determine how well the data are modeled by a normal distribution.
Scatter Plots	Assessing relationships between two or more variables.
Time Plot	Plot of data over time for initial examination of overall trend, cyclical patterns, changing variability over time.
Lag Plot	Determines the randomness of a dataset or time series and provides interpretation of serial correlation, cyclical patterns, and outliers.
Plot of Autocorrelation Function (Correlogram)	Used to display serial correlation when data are collected at equally spaced intervals.
Multivariate Methods (Ordination and Classification)	Examining complex datasets for relationships between species composition patterns and the underlying environmental gradients which influence these patterns

Histograms - A histogram (Figure 21.1) is a bar graph depicting the frequency of data collected into groups providing an overall visual representation of the shape and spread of the data distribution, number of modes, and potential outliers.

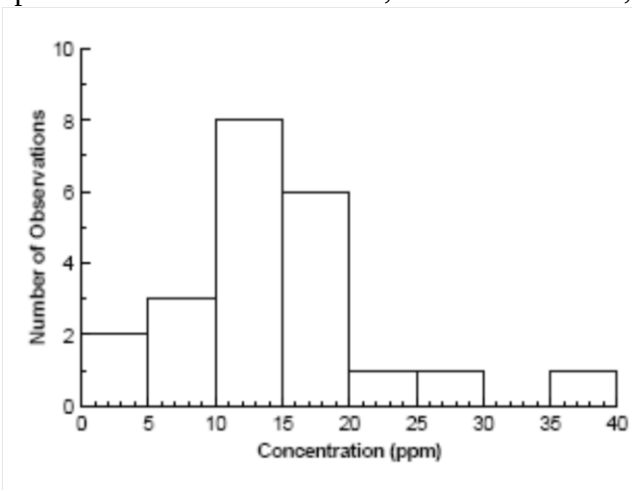


Figure 21.1. Example of a histogram. From USEPA (2006).

Box- and-Whisker Plots - Box and whisker plots (Figure 21.2) provide a visual summary of the data distribution including measures of central tendency (mean and/or median), dispersion (range of values and interquartile range), and potential outliers. The shape of the data is represented by examination of the whiskers. If the upper and lower whiskers are similar in length, then the data are distributed symmetrically. Skewness in the data is present if the whiskers are different in length. If both the mean and median values are presented in the box-plot, then a comparison of these provides insight on symmetry of the distribution (USEPA 2006).

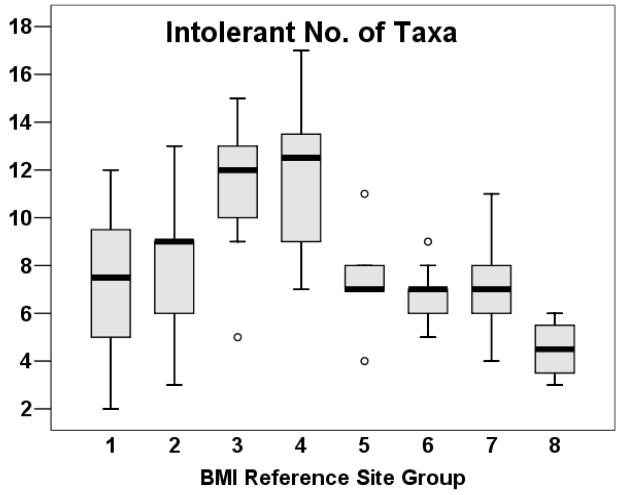


Figure 21.2. Box-plots representing differences in basic statistical quantities of benthic macroinvertebrate number of intolerant taxa among NOCA stream reference groups (horizontal bar = mean, box = central 50% of the data, whiskers = min and max values, open circle = potential outlier).

Box-plots are also useful for initial interpretation of differences among groups for a particular variable of interest. For example, in Figure 21.2 the number of intolerant taxa in reference site groups 3 and 4 appear to be different than in reference site groups 5-8 as evidenced by the lack of overlap in the boxes (central 50%).

Cumulative Frequency Distribution Plot - Cumulative frequency represents a running total of frequencies and can also be defined as the sum of all previous frequencies up to the current point. The cumulative frequency is important when analyzing data, where the value of the cumulative frequency indicates the number of elements (e.g., number of times or number of sites) in the dataset that lie below an established or proposed criterion (Figure 21.3). The cumulative frequency plot is also useful in depicting percentile values for the dataset.

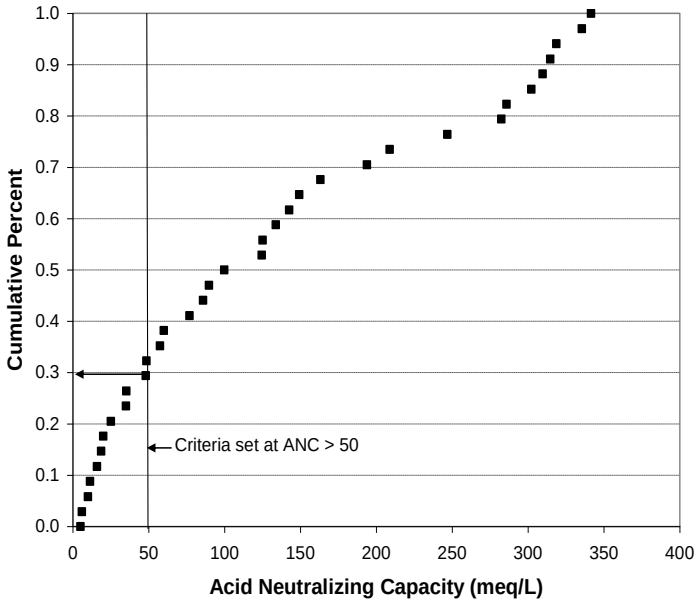


Figure 21.3. Example of a cumulative frequency distribution for acid neutralizing capacity (ANC) from 35 lakes sampled in a 5-year reporting period. From the graph, 70% of the sites met a criterion of ANC >50 and 30% of the sites (ANC ≤50) may be considered as sensitive to lake acidification.

The cumulative distribution function (CDF) provides a statistical method of interpreting values derived from a cumulative frequency distribution. CDF describes the probability that a random variable X with a given probability distribution will be found at a value less than or equal to x, and is proposed for statistical assessments of status in this protocol (*see* Section IV.D.3 in this SOP).

Ranked Data and Quantile Plots - These are additional options used to visualize the location, shape and spread of the data based on displays of ranked data. More details are presented in USEPA (2006).

Normal Probability Plot (Normal q-q Plot) - This plot provides a visual method for determining how well the data match the theoretical normal distribution and may allow an analyst to quickly discard an assumption of normality in order to pursue other options for analyzing the data (e.g., transformations or non-parametric tests). An example normal probability plot is shown in Figure 21.4. Methods for generating and interpreting normal probability plots are given in USEPA (2006).

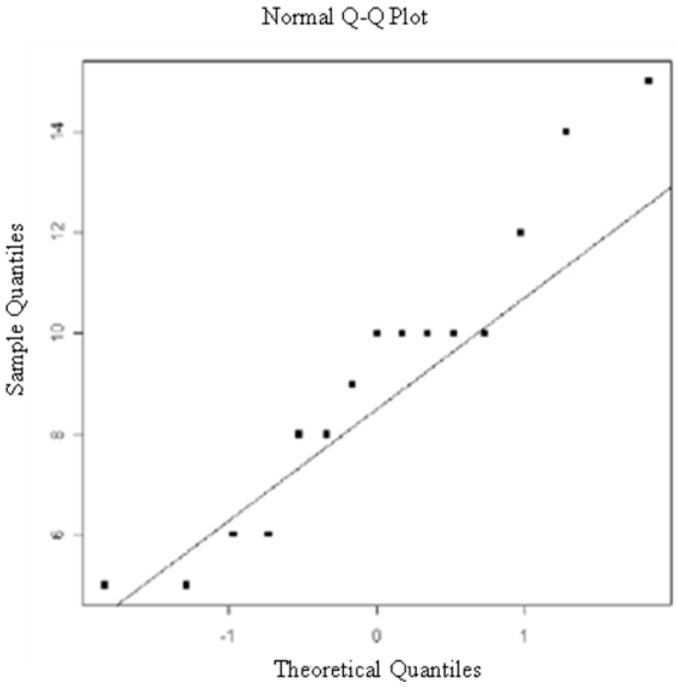


Figure 21.4. A normal probability plot is a graph of the quantiles of data compared with the quantiles of a standard normal distribution. Normality of data distribution may be assumed if the points in the graph roughly follow a straight line, however a formal test of normality should be performed. A solid line is drawn through the first and third quartiles to provide a guide to evaluate the linear fit. Points in the graph appear to be linear but deviate from the quartile line in the upper tail. From USEPA (2006).

Scatter Plots - Construction of a scatter plot is a common exploratory data analysis procedure used to evaluate relationships between two or more variables and is usually done before working out a linear correlation coefficient or fitting a regression line. It gives a good visual picture of the relationship between the two variables, and it aids in the interpretation of the strength and direction of the relationship (correlation coefficient) and type of regression model (e.g., linear, non-linear).

Time Plots - Time plots simply represent the data collected over specific equal time periods. They provide a quick assessment of the possible presence and direction of trends, cyclical patterns (stationarity), and changing variability over time. The addition of a Lowess smoothed line (Cleveland 1979, Cleveland and Devlin 1988) fitted to the points in the scatter plot can aid in interpretation of seasonally changing data.

Lag Plots - Lag plots determine if the structure of the data is non-random, as indicated by pattern in the dataset. Linear patterns in the plot indicate a directional trend, and elliptical patterns indicate that the data contain a seasonal component. Non-random patterns are associated with data that are autocorrelated, indicating serial correlation. Serial correlation is a measure of the strength of the relationship between successive observations. If serial correlation exists, then the relationship must be accounted for in the data analysis. Examples of lag plots exhibiting random and non-random structure are shown in Figure 21.5.

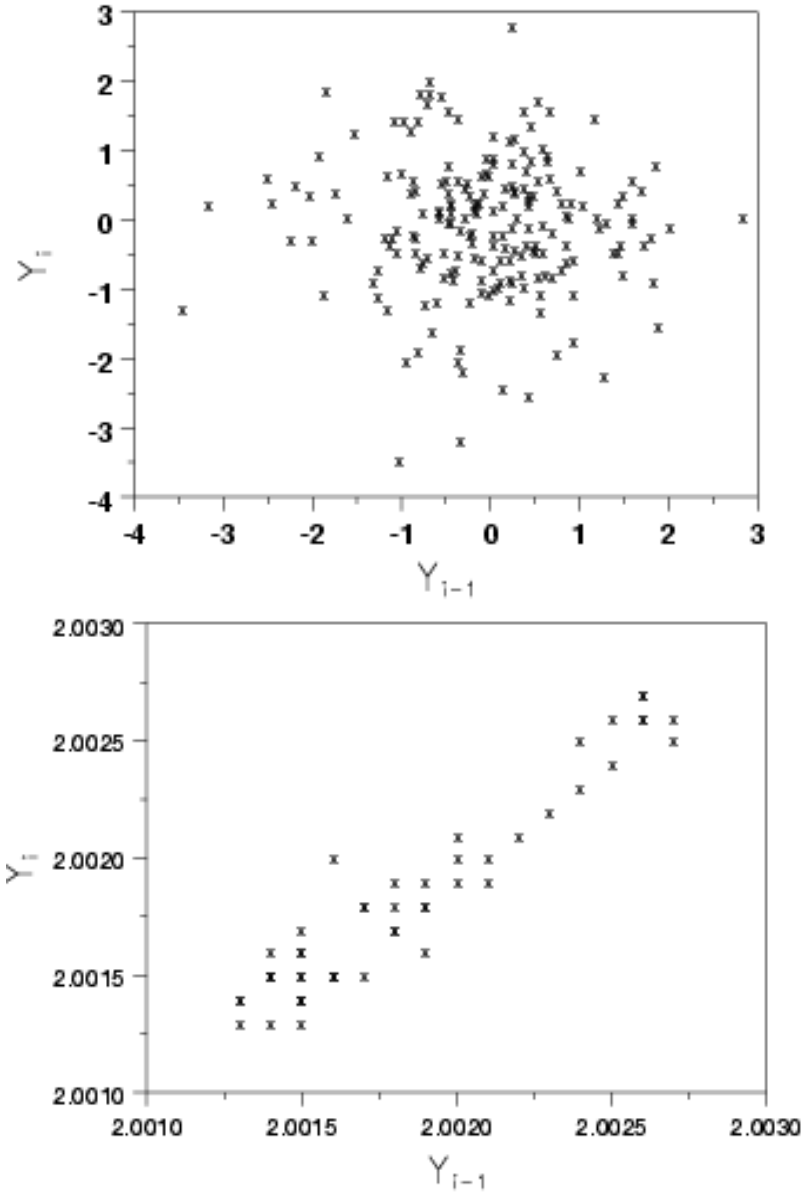


Figure 21.5. Lag plots without pattern (top) indicating the data are random and that there is no autocorrelation, and (bottom) with a linear pattern showing that the data are strongly non-random and suggesting that the data may be autocorrelated. From NIST e-Handbook of Statistical Methods website.

Plot of Autocorrelation Function (Correlogram) - In addition to the lag plot, the correlogram (Figure 21.6) is another plot that is used to display serial correlations when the data are collected at equally spaced time intervals. The autocorrelation function used for constructing a correlogram provides a summary of the serial correlations of data where the 1st sample autocorrelation coefficient, $r1$, is the correlation between points at lag 1 (points that are 1 time unit apart), $r2$ is the correlation between points at lag 2, etc. A correlogram is a plot of the sample autocorrelation coefficients, rk, versus time k (USEPA 2006). For a large independent data sequence of n time points, autocorrelations are approximately normally distributed with mean zero and variance $1/n$. Therefore, to determine if the time points are independent, first plot the approximate 95% confidence lines $\pm 2 / n$ (shown as dashed lines in Figure 21.6) on the correlogram. If any of the autocorrelations lie outside the confidence lines, then there is evidence of serial correlation, and it can be concluded that the time points are not independent (USEPA 2006).

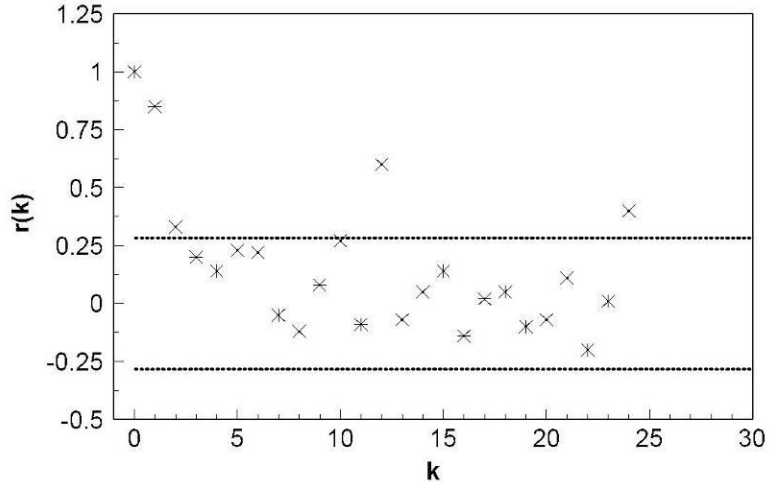


Figure 21.6. Correlogram plot showing evidence of serial correlation with points located outside of the 95% confidence limits (dashed lines). From USEPA (2006).

Multivariate Methods (Ordination/Classification) - Multivariate graphical procedures including ordination and cluster analysis are important exploratory tools for examining relationships between species composition patterns and the underlying environmental gradients which influence these patterns, including those that are otherwise too complicated to interpret. Ordination and classification (or clustering) are the two main types of multivariate methods that community ecologists employ. To some degree, these two approaches are complementary. Classification, or putting samples into (perhaps hierarchical) classes, is often useful when one wishes to assign names to, or to map, ecological communities. However, ordination is generally considered to be a more appropriate approach, given the continuous nature of communities.

A common approach to classification and ordination of species community data is to first conduct a cluster analysis to initially group biological community samples by sites or years (Figure 21.7), followed by conducting ordination with samples coded by

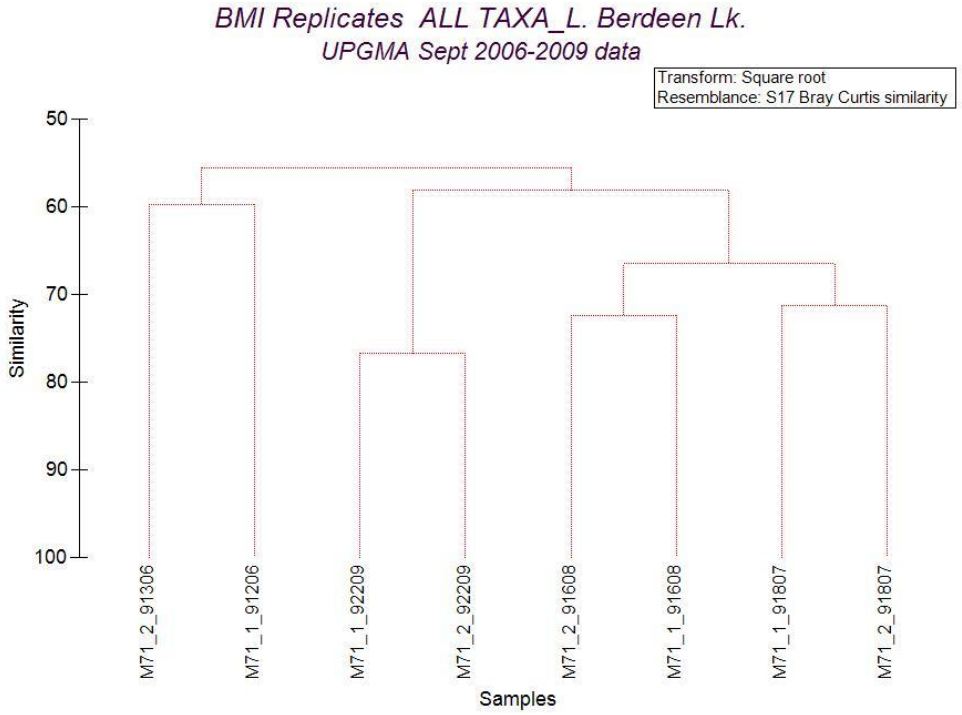


Figure 21.7. UPGMA cluster analysis dendogram of replicated benthic macroinvertebrate (BMI) samples, collected prior to non-native fish removal (2006) and after removal (2007-2009), Lower Berdeen Lake, NOCA (sample year = last two digits of label code).

cluster results (Figure 21.8). Comparisons of the spatial representations of samples by both methods may provide additional support for interpretation of the results (e.g., comparisons of Figures 21.7 and 21.8, which were constructed with the same sample data, showed similar results in the grouping of replicate samples and differences among samples by year).

There are numerous ordination methods to choose from representing both indirect gradient and direct gradient analyses. Indirect gradient analysis utilizes only the species by sample matrix. Interpretation of environmental attributes occurs after indirect gradient analysis. Direct gradient analysis utilizes external environmental data in addition to the species data, providing information about the relationship between species composition and measured environmental attributes, similar to regression. Excellent general references concerning multivariate techniques in community ecology include the following publications: Gauch (1982), Pielou (1984), Digby and Kempton (1987), and Jongman et al. (1995).

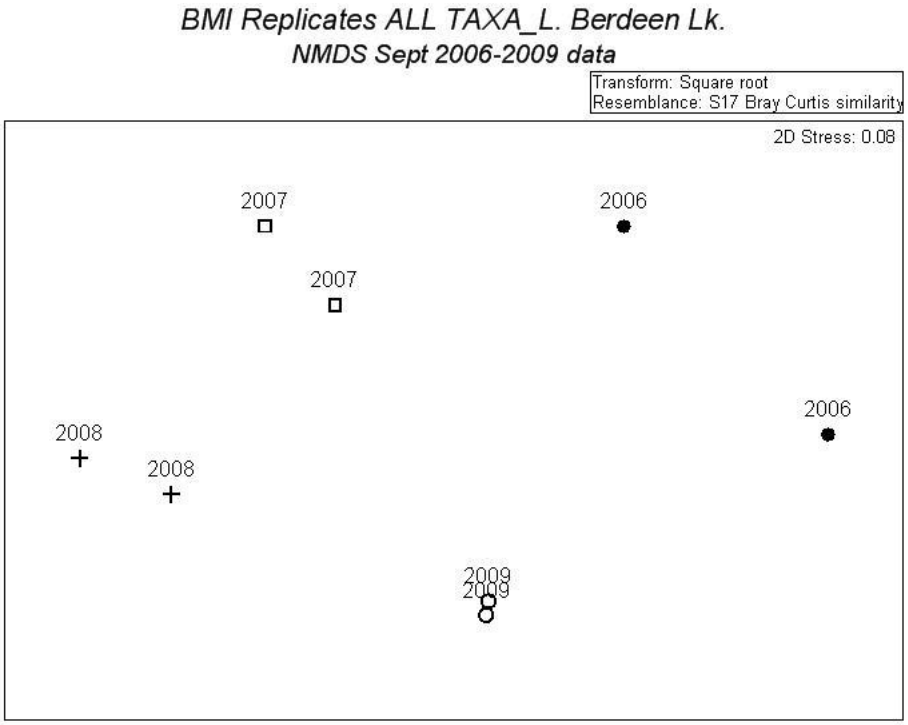


Figure 21.8. Non-metric multidimensional scaling (NMDS) plot of replicated benthic macroinvertebrate (BMI) samples, collected prior to non-native fish removal (2006) and after removal (2007-2009), Lower Berdeen Lake, NOCA. (Note: same sample data as used in Figure 21.7).

Legendre and Legendre (1998) describe numerous measures of ecological distance (similarity) used in many ordination procedures. Primer-E software (Clarke and Warwick 2001) provides a range of alternatives for examining species community and environmental attribute data and is currently being used by Ecologists at OLYM and NOCA (e.g., Figures 21.7 and 21.8).

2. Evaluating Assumptions of Potential Statistical Tests

In some situations, graphical information from the preliminary data review may serve as sufficiently strong evidence to support the assumptions of a given statistical test. However, in most cases, assumptions about distributional form, independence (including serial and spatial correlation), and dispersion should be formally verified using such statistical tests as those described in USEPA (2006) and other statistical references. All statistical tests require that the data constitutes a random sample of the population. In addition, the ability of a statistical test to handle outliers and nondetects must also be considered (*see* Section 3 and 4, below). In general, non-parametric methods handle outliers and nondetects better than parametric methods. Specific tests used to verify assumptions should be documented for statistical methods used in final analyses.

3. Outliers

Outliers are measurements that are extremely large or small relative to the rest of the data. Outliers may result from transcription errors, data-coding errors, or measurement system problems such as instrument breakdown. However, outliers may also represent true extreme values of a distribution and indicate more variability in the population than was expected. Not removing true outliers and removing false outliers both lead to a distortion of estimates of population parameters (USEPA 2006).

Graphs such as the box and whisker plot, ranked data plot, normal probability plot, and time plot can all be used to identify observations that are implausibly larger or smaller than the rest of the data. In addition, a rapid approach used by many investigators for identifying potential outliers from normally distributed datasets simply involves looking at points that are 2 or more standard deviations from the mean.

Statistical outlier tests give the analyst probabilistic evidence that an extreme value (potential outlier) does not "fit" with the distribution of the remainder of the data; however, these tests should only be used to identify data points that require further investigation. Recommended statistical outlier tests based on sample size are shown in Table 21.3.

Table 21.3. USEPA (2006) recommendations for selecting a statistical test for outliers.

Sample Size	Test	Assumes Normality	Multiple Outliers
n ≤25	Extreme Value Test	Yes	No/Yes
n ≤50	Discordance Test	Yes	No
n ≥25	Rosner's Test	Yes	Yes
n ≥50	Walsh's Test	No	Yes

The decision to discard or include an outlier data point should be based on scientific reasoning in addition to the results of the statistical test (USEPA 2006). For instance, data points containing transcription errors should be corrected, whereas data points collected while an instrument was malfunctioning may be discarded. One should never discard an outlier based solely on a statistical test. Instead, the decision to discard an outlier should be based on some scientific or quality assurance basis. Discarding an outlier from a data set should be done with extreme caution, particularly for environmental data sets which often contain legitimate extreme values. If an outlier is discarded from the data set, all statistical analysis of the data should be applied to both the full and truncated data set so that the effect of discarding observations may be assessed (USEPA 2006). If scientific reasoning does not explain the outlier, it should not be discarded from the data set. The entire process should be documented.

4. Censored Data

Data that include both detected and non-detected results are called "censored data" in the statistical literature. Treatment of censored data to meet NPS Data Quality Objectives is discussed in Irwin (2008). Data generated from chemical analysis may

fall below the detection limit (ML; Minimum Level of Quantitation, *see* Table 19.2 of SOP 19) of the analytical procedure. These measurement data are generally described as nondetects where the concentration of the chemical is unknown, but lies somewhere between zero and the ML. Nondetect data are recorded in NPSTORET as present but less than the quantification limit ("Present <QL"). The advantage of this approach is that no "estimates" are treated as quantitative when they are not quantitative (Irwin 2008). In addition, the MDL (Method Detection Limit, see Table 19.2 of SOP 19) and ML limits are also entered into NPSTORET to prevent entry of values below the ML and to query the number of values below the MDL, or between the MDL and ML.

There are a variety of ways to evaluate data that include values below the ML. However, there are no general procedures that are applicable in all cases; it is no longer appropriate to report nondetects as one half of the ML value (Helsel 2005). For most cases data handling and transformation (censoring) recommendations found in Helsel (2005) will be followed.

Generally, if the degree of censoring (the percentage of data below the ML) is relatively low, reasonably good estimates of means, variances and upper percentiles can be obtained. However, if the rate of censoring is very high (≥50%), then little can be done statistically except to focus on some upper quantile of the parameter's distribution or on some proportion of measurements above a certain critical level that is at or above the censoring limit (USEPA 2006). A review of some recent and historical water chemistry data from MORA and NOCA indicates that the percentage of nondetects is ≥50% for nitrate (NO_3) and ammonium (NH_4), with intermediate percentages of nondetects (15 to 30%) for total nitrogen, total phosphorus, phosphate (PO_4) and potassium. Low numbers of nondetects (<10%) were observed for sulfate (SO_4) and total dissolved solids. Solutions for studies where all data or most data are below detection limits are discussed in Helsel (2005).

For datasets with multiple detection limits for a single parameter, the Kaplan-Meier (KM) method often works the best (Irwin 2008). KM transformations of nondetects and subsequent summary statistics (mean, median, standard deviation, and percentiles) can be performed within NPSTORET.

For compliance related objectives where comparisons are made with water quality criteria or other protection benchmarks, the NPS guidance (Irwin 2008) recommends censoring nondetects to the quantification detection limits (ML) before averages or confidence intervals are calculated. This is only used as a precautionary approach which provides a higher level of certainty to account for the possibility of reporting that a certain analyte or contaminant is absent when, in fact, it is present.

In selection of statistical procedures used for final analyses, the analyst must consider the method's suitability for use with nondetects. A number of nonparametric alternative tests are relatively insensitive to nondetects. Some examples of one- and two-sample hypothesis tests include the Wilcoxon Signed Rank Test, the Sign Test,

and tests for proportions (USEPA 2006). Alternative nonparametric trend tests that are relatively insensitive to nondetects include the Sen's Slope Estimate, used for determining the magnitude of a trend, the Seasonal Kendall (SK) and Seasonal Kendall with Serial Dependence (SKSD) tests, and the Mann-Kendall test (Irwin 2008).

5. Missing Data

Missing data points can arise from a number of factors such as physical loss of data, malfunctions in equipment, unreconciled transcriptional errors, damage to samples in the laboratory or in transit, and improper preservation and storage. Results of missing data reduce the sample size with consequent reduction of inferential power. NPS DQOs for "Completeness" (Irwin 2008) require that estimates of missing data be included in the analysis of sample requirements needed to meet analysis objectives for each response parameter. If any essential information is missing, either collect the missing information before proceeding, or select a different approach to resolving the problem.

Traditional options available for handling missing data are found in many statistical software programs and include listwise, casewise, or pairwise data deletion, and mean substitution. However, there are additional methods available that perform much better. A good summary of assumptions and procedures is presented by the Information Technology Services Program at the University of Texas, General FAQ #22: Handling missing or incomplete data, available at: http://ssc.utexas.edu/software/faqs/general#General_22 (accessed 20 March 2011).

The Mountain Lakes Monitoring Protocol includes multiple response variables and analysis procedures. This, coupled with a variety of treatments for missing data, their assumptions, and effects on each particular analytical procedure, will require consultation with a statistician.

6. Data Transformations

Most statistical tests and procedures contain assumptions about the data to which they will be applied. For example, some common assumptions are that the data are normally distributed, variance components of a statistical model are additive, two independent data sets have equal variance, and there is no spatial or temporal serial correlation in the data set. If the data do not satisfy such assumptions, then the results of a statistical procedure or test may be biased or incorrect. Fortunately, data that do not satisfy statistical assumptions may often be converted or transformed mathematically into a form that allows standard statistical tests to perform adequately. However, some statisticians recommend bootstrap methods over "normalizing" transformation for two reasons. First, bootstrap methods utilize original measurement units that do not need to be back-transformed for interpretation, and second, confidence intervals based on transformations only approximate confidence intervals produced by bootstrapping (Manly 1997). Another alternative is to use distribution free, non-parametric methods for analyses.

Some commonly used transformations include:

Logarithmic (Log X or Ln X): This transformation may be used when the original measurement data follow a lognormal distribution or when the variance at each level of the data is proportional to the square of the mean of the data points at that level. For example, if the variance of data collected around 50 ppm is approximately 250 ppm, but the variance of data collected around 100 ppm is approximately 1000 ppm, then a logarithmic transformation may be useful. The logarithmic base (e.g., either natural or base 10) needs to be consistent throughout the analysis, but otherwise is inconsequential. If some of the original values are zero, it is customary to add a small quantity to make the data value non-zero as the logarithm of zero does not exist. The size of the small quantity depends on the magnitude of the smallest non-zero data and the consequences of potentially erroneous inference from the resulting transformed data.

Square Root (X): This transformation may be applied to small whole numbers, such as the occurrence of rare events, or the number of times a parameter exceeds a criteria over a set period of time. The underlying assumption is that the original data follow a Poisson-like distribution in which case the mean and variance of the data are equal. It should be noted that the square root transformation overcorrects when very small values and zeros appear in the original data. In these cases, $\sqrt{X+1}$ is often used as a transformation.

Arcsine (Arsine $\sqrt{p}$): This transformation may be applied to binomial proportions (*p*) based on count data to achieve stability in variance with a distribution that is nearly normal. The resulting transformed data are expressed in radians. Special tables must be used to transform the proportions into degrees or multiplied by 57.29577…. degrees. The arcsine transformation should be used with caution and the understanding that it causes nominal scale data to appear continuous and lead to inappropriate application of statistical tests. When possible, it is advisable to use non-parametric tests or to conduct testing with the appropriate link function after determining the distribution (e.g., binomial, Poisson etc.) of the data.

These are the most commonly used transformations, but others are available and may require consultation with a statistician concerning their application and limitations. Once the data have been transformed, all statistical analysis must be performed on the transformed data. No attempt should be made to transform the data back to the original form because this may lead to biased estimates. For example, estimating quantities such as means, variances, confidence limits, and regression coefficients in the transformed scale typically leads to biased estimates when transformed back into original scale. It also may be difficult to understand or apply results of statistical analysis expressed in the transformed scale.

II. **Routine Data Summaries**

Multiple field measures representing physical, chemical, and biological characteristics are collected from each lake. Routine data summaries of field measures are required to produce a single summarizing value called the "response variable" which is then applied in exploratory and final data analyses (i.e., changes and trends). In some cases, a single response variable may also serve as an explanatory variable or attribute (also known as "covariate" or "independent variable"). For example, water temperature measures may be used to evaluate changes in benthic macroinvertebrate response variables, or certain nutrient concentrations may be used to evaluate changes in chlorophyll-a concentrations. Identification of explanatory attributes and relationships with response variables will be documented in Annual and Five-year Summary Reports. An overview table of measures, data summaries, response variables, reporting periods, and final data analyses are shown in Appendix E, Tables E-1 through E-4.

Some responses may only represent a single measurement from a single lake location (e.g., concentrations of unreplicated chemical parameters and maximum depth) or a single value from a collection of sub-samples taken from several locations and pooled into one sample (e.g., macroinvertebrate metrics, frequency of landcover types, and riparian disturbances). Other responses are derived from multiple measurements at one or more locations (e.g., continuous water temperature parameters, lake water level, and littoral substrate). In addition, some types of data are processed into indices representing the condition of the habitat (e.g., Trophic State Indicators, Section II.E) or structure of biological communities (e.g., IBI, O/E, etc., Section II.F).

Most response variables are reported as a value for a single-season sampling occasion. Some physical parameters such as mean depth, surface area, and shoreline development ratio are expected to change little over long periods of time and will be sampled at 20-year intervals (with the exception of sampling following catastrophic events). Continuous air and water temperature data are summarized by week, month, season, and/or year.

Routine data summaries and methods by lake monitoring component categories are discussed in the following sections. In addition, a number of other basic statistical quantities described in Table 21.1 of this SOP will be calculated and summarized in Annual Reports.

A. **Water Temperature**

1. Continuous Air and Water Temperature: Data loggers are used to continuously monitor temperature throughout the year at each lake. Logger memory limitations allow a total of 48 measurements per day for lakes that are visited annually. Water temperature loggers are set near the surface, at mid-depth, and near the bottom at all lakes. Air temperature loggers are deployed in a shady location at least 6 m above the ground. The surface water temperature and air temperature loggers are also used to determine the time of "ice-on" and "ice-off". Data summaries for continuous water temperature response variables are shown in Table 21.4.

Table 21.4. Continuous air and water temperature response variables and calculation.

Response Variable[1]	Calculation	Reporting Period[2]
MDMT	Maximum value of daily maximum temperatures recorded during the reporting period.	Month and Season (with occur. dates)
ADMT[3]	Average of daily maximum temperatures for the reporting period.	Month
MWMT	Maximum weekly maximum temperature-representing the highest 7-day moving average of daily maximum temperatures during the year.	Year (with occur. dates)
ADMinT[3]	Average of daily minimum temperatures for the reporting period.	Month
MAXDIURN	Maximum diurnal fluctuation- maximum value for the reporting period of daily maximums minus daily minimums.	Month and Season (with occur. dates)
ADAT[3]	Average of daily average temperatures for the reporting period.	Month
MDAT	Maximum value of daily average temperatures recorded during the reporting period.	Month and Season (with occur. dates)
MWAT	Maximum weekly average temperature-representing the highest 7-day moving average of daily average temperatures during the year.	Year (with occur. dates)
DEGDAY	Degree days derived from the sum of differences between daily average temperatures and a base temperature of 0°C.	Season and Year (starting Jan. 1)
Ice-on and off	Determined by observation of daily air and surface water temperatures.	Occurrence Date

[1]All temperature data are recorded in ^{o}C.

[2]Dates of seasonal reporting periods correspond to winter, spring, summer, and fall seasons.

[3]Also reported as median values.

2. Temperature-Depth Profile: A single temperature-depth profile is measured at the point on a lake corresponding to the maximum depth during each sampling occasion. Temperature measurements are recorded at 1-m depth intervals from the surface of the lake to the bottom. Temperature-profile response variables include the following:
   a. Mean and median temperatures (^{o}C) for depth profile (all lakes)
      And for thermally stratified lakes:
   b. Mean and median temperature (^{o}C) for hypolimnion, metalimnion, and epilimnion
   c. Metalimnion upper limit depth (m)
   d. Difference (m) between upper and lower depth limits of the metalimnion.

B. **Lake Morphology**

1. Lake Water Level: Water level is measured at two locations at each lake during each annual sampling occasion. At each location a benchmark reference point for measurement is established and given an arbitrary elevation of 100 m. The elevation

of the benchmark above the water surface is measured three times, and the average of three measurements is subtracted from 100 m. The response value is recorded as the mean water level (m) for the location. Water level results are reported separately for each location because actual elevations of each benchmark reference point are not determined. However, differences in water level between successive sampling occasions at the same location can be averaged across all measurement locations.

2. Basin Aspect: Basin aspect will be determined by GIS and reported in degrees, corrected for inclination.

3. Surface Area: Surface area (ha) is measured once every 20 years (with the exception of sampling following catastrophic events) by GIS using the latest available aerial photographs. If necessary, corrections to the aerial photos will be made based on field observations.

4. Shore Line Length and Development (D_L): Shoreline length is determined by complete measurement of the shoreline in the field and/or by GIS using recent aerial photographs, and is reported in meters. The shoreline development ratio *(D_L)* is a measure of the irregularity of the lakeshore, representing the potential for development of littoral communities, which are usually of higher biological productivity (Wetzel 2001). D_L represents the ratio of the length of the shoreline to the length of the circumference of a circle with an area that is equal to that of the lake:

$$(D_L) = \frac{SL}{2\sqrt{\pi A_o}}$$

Where: SL equals the shoreline length (m), A_o equals the area (m^2) of a circle (the same as the sample lake area).

A D_L close to 1 would indicate that the sample lake is nearly circular. Values greater than 1 indicate increasing irregularity of the shoreline and greater development of littoral communities in proportion to the volume of the lake.

5. Maximum Depth: Maximum depth (m) of the lake is located by multiple depth soundings taken during the initial sampling visits and relocated during each sampling occasion.

6. Lake Volume and Mean Depth: Calculations of lake volume and mean depth will be done at 20-year intervals for all lakes or sooner if there is evidence of catastrophic disturbance. Volume and mean depth are calculated in GIS from the modeled bathymetry (*see* SOP 4: Lake Features and Bathymetric Maps). The GIS software is used to generate a surface representing the bottom of the lake by interpolation from the point depth measurements made in the field. From this surface, the GIS can be used to calculate lake volume and mean depth. Alternatively, the formula for calculating the volume of a frustum of a circular cone has been applied by limnologists to compute the volume of a lake. This formula is:

$$V_L = \frac{1}{3} H (A_1 + A_2 + \sqrt{A_1 \times A_2})$$

Where: V_L = volume of water in a layer.
H = difference in depth between two successive depth contours.
A_1 = area of the lake within the outer depth contour being considered.
A_2 = area of the lake within the inner contour line under consideration.
The procedure consists of determining the volumes of successive layers of water (frustums), and then summing these volumes to obtain the total volume of the lake. Lake volume is reported as m^3. Mean depth (m) is calculated by dividing the total lake volume by the surface area of the lake.

7. Littoral (nearshore) Substrate and Aquatic Vegetation Composition: Percent coverage of different substrate and aquatic vegetation classes (SOP 11: Benthic Macroinvertebrate Collection and Processing and SOP 14: Aquatic Amphibian Sampling and Processing) are estimated from plots at multiple random locations around the lakeshore during amphibian and benthic macroinvertebrate surveys. These data are collected during each sampling occasion. The four dominant substrate classes are recorded on the data form in order of their dominance in the plot area. Dominance is estimated by visual observation of the percentage of the sample area covered by each substrate class. Percentage of sample plot for dominant substrate classes must be at least 10% to be recorded. Separate responses for all substrate types (those found to be dominant in any plots) are summarized for the entire lake by summing the number of occurrences from all plots and dividing by the total number of plots.

C. **Lake Riparian Zone Characteristics**

Land cover types and categories of human disturbance (condition class) are recorded based on their proximity to the lake at multiple randomly selected plots (10 x 10 m) in vegetated areas around the shoreline (land cover types and condition classes are found in Tables 15.1 and 15.2 of SOP 15: Lake Riparian Disturbance Monitoring). Proximity zones are based on distance intervals from the land-water interface (shore zone = 0-3 m and nearshore = 3-10 m).

1. Land Cover Type (LC): The single most dominant cover type for each proximity zone within a plot is recorded. Separate responses for all cover types (those found to be dominant in any plots) are summarized for the entire lake by summing the number of occurrences from all plots within a particular proximity zone and dividing by the total number of plots.

   For example:
   Twenty plots were sampled at Lake A. Within the shoreline proximity zone (SH), the meadow cover type was found to be dominant at 15 plots and conifer forest was dominant at five plots. The following responses are reported: $MD\_LC_{SH} = 0.75$ and $CF\_LC_{SH} = 0.25$, *where* MD = meadow, CF = conifer forest, and LC_{SH} = land cover type in the shoreline proximity zone.

2. Disturbance Condition Class (CC): A single condition class is selected for each proximity zone within a plot and summarized the same as described for land cover type. In addition, for each proximity zone, the proportion of plots by land cover types with disturbance scores indicating moderate to severe disturbance will be reported (disturbance score of 2 to 4, Table 15.2, SOP 15).

D. **Water Chemistry**

A total of 18 water chemistry response variables are being measured during each annual sampling occasion at a lake. All water chemistry samples are collected at one lake location (where maximum depth occurs).

Multiple measurements of dissolved oxygen (DO), pH, and specific conductance are recorded for each 1 m interval from the surface to the bottom of the lake. The mean, standard deviation, and median for these response variables are reported for each depth interval and summarized for a range of depths, or the entire profile.

A single sample will be collected for DOC, always taken 1 m below the surface. One sample (unstratified lakes) or two samples (stratified lakes) will be taken for the remaining response variables from depth locations described in SOP 9 (Section B.3). In the analysis of lake chemistry data, comparisons across time may become complicated where lakes are sampled as unstratified (1 mid-depth sample) and strongly stratified (1 epilimnetic and 1 hypolimnetic sample). To facilitate analysis, the average of the epilimnetic and hypolimnetic sample chemical concentrations will be used as a surrogate for mid-point sample concentration in analyses for comparison with non-stratified samples. Data from previously sampled strongly stratified NCCN lakes show no substantial differences between epilimnetic and hypolimnetic chemical concentrations, thus averaging them appears to reasonably approximate mid-point concentrations.

Field duplicate samples for all chemistry response variables will be collected from one to two lakes, selected at random, at each park in any given year. Responses are reported as the single measured value or by the average of value and relative percent difference (RPD+, Table 19.2 of SOP 19) for lakes where all parameters are duplicated.

1. DO (mg/L), pH, and Specific Conductance (µS/cm) Profile Data: The last seven measurements following stabilization of the datasonde at each 1 m depth interval are used to calculate the mean and standard deviation for that interval, depth zone, or entire depth profile. In addition, a depth profile graph for each response variable is plotted (response values on the x-axis and depth on the y-axis). QC documentation of precision (RPD+) and sensitivity (AMS+) are described in Tables 19.2 and 19.3 of SOP 19.

2. Dissolved Organic Carbon (DOC): A single DOC sample is taken at 1 m below the surface for all lakes. DOC concentration (mg/L) is reported as a single measurement or as the mean and RPD+ for lakes where duplicates are collected.

3. Acid Neutralizing Capacity (ANC): Normally, a single sample is collected from the depth at the midpoint of the water column. Samples from 1 m below the surface and 1 m above the bottom are collected for lakes that are thermally stratified. ANC concentration (µeq/L) is reported as the measured value for the depth that was sampled. Mean values are reported for lakes where duplicate samples are collected. In addition, and as described in Table 19.2 of SOP 19, RPD (separate aliquots of the same sample) and RPD+ (separate samples) are also reported for lakes where duplicate samples are collected.

4. Nutrients and Total Dissolved Solids (TDS): Specific nutrient response variables include total nitrogen, ammonia, total phosphorus, and orthophosphate. Normally, a single sample is collected from the depth at the midpoint of the water column. Samples from 1 m below the surface and 1 m above the bottom are collected for lakes that are thermally stratified. TDS and nutrient concentrations (mg/L) are reported as the measured value for the depth that was sampled. Average values are reported for lakes where duplicate samples are collected. In addition, and as described in Table 19.2 of SOP 19, RPD (separate aliquots of the same sample) and RPD+ (separate samples) are also reported for lakes where duplicate samples are collected. Total nitrogen and total phosphorus also are used in the calculation of Trophic State Indices (*see* following section).

5. Anions and Cations: Anions and cations measured include chloride, nitrate, sulfate, sodium, ammonium, potassium, magnesium, and calcium. Normally, a single sample is collected from the depth at the midpoint of the water column. Samples from 1 m below the surface and 1 m above the bottom are collected for lakes that are thermally stratified. Anion and cation concentrations (µeq/L) are reported as the measured value for the depth that was sampled. Average values are reported for lakes where duplicate samples are collected. In addition and as described in Table 19.2 of SOP 19, RPD (separate aliquots of the same sample) and RPD+ (separate samples) are also reported for lakes where duplicate samples are collected.

E. **Trophic State Indices, Water Clarity and Chlorophyll-a**

1. Water Clarity: Secchi disk depth (m) is measured three times at one location and the average of the three measurements is reported as the response. In addition, Secchi depth is included as one of several different responses representing trophic state (*see* E.3 below).

2. Chlorophyll-a: Chlorophyll-a concentration (µg/L) is normally determined from a single sample collected at mid-depth (unstratified lakes) or two samples (stratified lakes) collected at different depths (SOP 10), at the lake location of maximum depth. Mean values are reported for lakes that are thermally stratified (two sample depths) and for field replicate samples. A Trophic State Index for chlorophyll-a is also calculated and explained below.

3. Trophic State Indices (TSI): Trophic state determinations provide a method for determining whether increased nutrients or sediments (loading) are causing changes

in a lake. Carlson's TSI uses Secchi disk depth, chlorophyll-a, and total phosphorus, each producing an independent measure of trophic state (Carlson 1977). Index values range from approximately 0 (ultraoligotrophic) to 100 (hypereutrophic).

The Secchi disk based index is scaled so that TSI = 0 represents a Secchi disk depth transparency of 64 m. Each halving of transparency represents an increase of 10 TSI units. For example, TSI of 50 represents a transparency of 2 m, the approximate division between oligotrophic and eutrophic lakes (NALMS 1990). A critical assumption in interpretation of TSI values is that transparency is related to biological productivity and not inorganic turbidity.

A TSI value is calculated from each of Secchi depth (SD), chlorophyll-a concentration (Chl), and total phosphorus concentration (TP) (Carlson 1977, Carlson and Simpson 1996).

$$TSI(SD) = 60\text{-}14.41 \ln(SD)$$
$$TSI(Chl) = 9.81 \ln(Chl) + 30.6$$
$$TSI(TP) = 14.42 \ln(TP) + 4.15$$

Where: SD is in meters, and Chl and TP are µg/L.

Trophic State Indices are used to infer the trophic state of a lake and whether algal growth is nutrient limited or light limited. If the three indices are approximately equal, then phosphorus limits algal growth. Several other interpretations regarding factors limiting algal growth and light attenuation, based on examination of differences in relationships between the three indices, are discussed by Carlson and Simpson (1996).

A Trophic State Index has also been developed for total nitrogen (TN) (Kratzer and Brezonik 1981, Carlson 1992):

$$TSI(TN) = 54.45 + 14.43 \ln(TN)$$

Where: TN is in mg/L.

The initial TSI (Carlson 1977) was developed using a set of lakes with a wide range of Secchi disk depth transparencies and concentrations of chlorophyll-a and total phosphorus. NCCN lakes exhibit a much narrower range of chlorophyll-a and total phosphorus; consequently interpretation of results may differ from those of Carlson (1977). In addition, interpretation of some TSI results may be problematic for lakes where Secchi disk visibility extends to the bottom of the lake, and for systems with glacially influenced turbidity. For a more complete discussion of Trophic State Indices and their interpretation refer to Carlson (1992) and Carlson and Simpson (1996).

F. **Zooplankton and Littoral Benthic Macroinvertebrates (BMI)**

Basic data summaries for zooplankton and benthic macroinvertebrates are derived from single or replicated pooled samples. A single zooplankton pooled sample consists of three separate vertical tows located at the point of maximum lake depth. A benthic macroinvertebrate pooled sample consists of five subsamples collected at random locations along the lake shoreline. Responses are reported as the single measured value for each pooled sample. The mean is reported for lakes where all parameters are duplicated.

1. Basic Data Summaries for Zooplankton: The following basic zooplankton data summaries will be used for reporting changes and trends information:
   a. Total abundance of all taxa (no./m^3).
   b. Abundance of individual taxa and grouped taxa (no./m^3).
   c. Total richness and richness by taxa groups (taxa counts).

2. Basic Data Summaries for Benthic Macroinvertebrates: A standard sample of 500 organisms is randomly sorted from each pooled sample during laboratory processing. Sample processing procedures based on a fixed count of organisms are semi-quantitative; therefore an estimate of the density of organisms in samples is not one of the data analysis objectives. The following basic data summaries will be used to calculate BMI metrics for final analyses of status and trend information:
   a. Composition by individual taxa and by groups of taxa (no. per taxon/500 count organism sample).
   b. Total richness and richness by taxa groups (no. or taxa/500 count organism sample).

Basic data summaries also will be used to develop additional metrics and indices as more information becomes available concerning relationships between individual taxa and groups of taxa with environmental attributes and anthropogenic stressors. These metrics may provide a much more comprehensive and ecologically meaningful assessment of the condition of a lake. For assessments of biological condition, metrics represent attributes of the biota that respond to anthropogenic stressors in consistent ways and can be used for detecting impairment singularly, such as weight of evidence approach, or in combination with other metrics, such as benthic IBI (Kerans and Karr 1994).

Both traditional metric approaches (i.e., multimetric) and predictive models (O/E-Observed/Expected ratio) can be used for assessments of biological condition. Establishment of appropriate reference conditions is required for each of these approaches for site assessments of biological condition and development of biocriteria. The reference or expected condition for target population lakes provides the basis for development of most criteria and is derived from conditions defined from multiple sites within the target population. Current predictive models (O/E) and multimetric indices exist for NOCA and MORA (R. Glesne, "Methods for evaluating biological condition in NOCA mountain lakes," in prep., A. Rawhouser, "Biological condition assessment of lakes in Mt. Rainier National Park using zooplankton and benthic invertebrates," in prep.). These were developed using an extensive set of both "reference" and "test" lakes. With only six to eight lakes selected for monitoring at each park it will be necessary to

acquire additional funding (*see* Appendix J) to expand sampling to other target population lakes in order to develop a predictive model and metrics for application at OLYM and for refining and improving existing models and metrics at MORA and NOCA.

Metric selection and development of multimetric indices for the traditional approach have been described in numerous publications (Plafkin et al. 1989, Barbour et al. 1996, USEPA 1998, Barbour et al. 1999, Stribling et al. 2000, and others). Multimetric indices, such as the IBI, incorporate multiple biological community characteristics and measure the overall response of the community to environmental stressors (Karr et al. 1986, Barbour et al. 1995). This approach starts by calculating values of multiple biotic metrics (e.g., total richness; combined mayfly, stonefly, and caddisfly richness; proportion of tolerant individuals, etc.), and rescales these values against the values obtained from reference sites (Barbour et al. 1999). These rescaled metrics are then summed to estimate the IBI, a measure of overall biological integrity. The value estimated at an assessed site is then compared to the distribution of values observed at reference sites.

Individual metrics are generally derived from community assemblage data including: abundance (zooplankton only), taxa richness and diversity measures, composition measures for identity and dominance, tolerance measures to represent sensitivity to perturbations, trophic measures for information on feeding strategies and guilds, and life history strategies. A detailed description and the literature review of metric categories is presented in Barbour et al. (1999, Section 7.4).

An initial list of potential metrics that may be used for assessments of impairment in NCCN lakes are shown in Appendix E, Table E-5 (Zooplankton) and Appendix E, Table E-6 (BMI). These metrics have either been used for biological assessments in other programs, or are those that are recommended or that may be representative of results found in other studies. Other metrics will be defined as more information about the community assemblages and environmental covariates are gathered from the NCCN Mountain Lakes Monitoring Project. For example, continuous temperature data can be used to determine species tolerances to water temperature. With this information, specific metrics and criteria for NCCN lakes can then be defined to assess or predict community responses to changes in temperature. Final selection of metrics used in the assessment of status and trends are discussed by Barbour et al. (1999) and Stribling et al. (2000).

The predictive model approach (also known as ‘Multivariate’ and ‘Reference’ approach) uses BMI data (methods may also be applied to zooplankton, separately or combined with BMI) from a set of unimpaired sites that represent a wide range of environmental variation (e.g., park-wide sample across elevation strata and range of lake size and depth). The predictive model approach (River Invertebrate Prediction and Classification System or RIVPACS) was developed in the United Kingdom in the 1980s. The RIVPACS method (Moss et al. 1987, Wright 1995, 2000) assesses site condition based on a comparison of observed and predicted taxa. In contrast, the multimetric Index of Biotic Integrity or IBI assesses condition based on a comparison of observed values of an index that is the sum of several indices with values expected under reference conditions.

The RIVPACS approach starts by classifying reference sites based on similarity in their taxonomic composition. The class membership of an assessed site, and hence information regarding that site's expected taxa, is predicted with discriminant functions models based on a set of time-invariant environmental features (e.g., catchment size and elevation). By weighting frequencies of detection of each taxon within reference classes by derived probabilities of class membership from discriminant function models, RIVPACS predicts the probabilities of detecting specific taxa at individual sites under reference conditions.

Assessments are based on a comparison of the number of predicted taxa that are observed at a site (O) with the number of taxa that were expected (E). Deviation in the observed vs. expected frequencies (O/E Ratio) of occurrence of taxa between the reference data set and the test-site data set are used to evaluate impairment. Additional evaluations based on the absence of individual species that are expected to occur can be useful, providing a more detailed analysis of effects of certain stressors. The sensitivity of this method can be determined by comparing the reference data sets with matching test-sites of known impairment. Generally O/E models are applied to the entire set of community data; however, separate models can be developed for indicator groups of taxa based on their sensitivity to a particular response variable (e.g., water temperature, pH etc.).

Assessments based on predictive models have been shown to work well for interpretations of impairment in stream ecosystems (Reynoldson et al. 1995, Wright 1995, Hawkins et al. 2000, Simpson and Norris 2000) and for assessment of nonnative fish impacts to mountain lakes (Hawkins and Carlisle 2001, Knapp et al. 2005, Glesne NPS-NOCA, unpublished data). Predictive model data analysis methods are given in Moss et al. (1987), Barbour et al. (1999), Coysh et al. (2000), and Simpson and Norris (2000). A good summary of updated methods is presented by Flotemersch et al. (2006).

G. **Amphibians**

Amphibian data are collected by shoreline visual encounter surveys (VES) and optional snorkel surveys. At least one complete shoreline VES is completed at each lake during each year of sampling. Additional VES or combinations of VES and snorkel surveys are conducted at a subsample of lakes each year. A minimum of four nearshore and four offshore 25-m transects are surveyed at each lake for snorkel surveys. Information concerning the numbers of individual taxa observed and their life stage is recorded. Length is recorded for all captured specimens. Basic data summaries include the following:

1. Abundance: Mean or median abundance of amphibians by species and life stage (no./100 m surveyed, and reported separately for each of the two survey types).

2. Length: Mean or median lengths (mm) by species and life stage (*see* SOP 14: Aquatic Amphibian Sampling and Processing for the types of measurements to be made by taxon and life stage).

Frequency of occurrence of individual species among lakes will be used for park and network assessments of status.

H. **Fish**

Gill nets, visual observations, and/or angling are used during fish surveys at each lake. Fish abundance, length, and weight data are collected. All responses are used to assess changes and trends at individual sites.

1. Fish Abundance: Gill nets are the primary method used to collect fish for calculation of abundance data and are used at least once every 5 years at each sampling site. One or two multi-panel monofilament gillnets are set overnight at each lake. Recommended net length is 30 to 40 m with a depth of 1.5 to 2 m. Mean abundance values are reported for lakes sampled with more than one net; otherwise a single value is reported. Abundance is measured and reported as the total number of fish captured by the number of hours fished by the gill net (fish/gill net-hr). Abundance is reported as the total for all species, for individual species, and for species by size classes (*see* SOP 13: Fish Sampling and Processing, Table 13.2).
2. Fish Length: Both fork length (mm) and total length (mm) are measured for all fish collected by gill nets and are summarized by species and species length groups as the mean length (mm) for both total and fork length measurements.

Frequency of occurrence of individual species among lakes will be used for park and network assessments of status.

III. Criteria Development

A primary goal of the Mountain Lakes Monitoring project is to monitor the condition of lakes in the parks to protect against degradation. Well defined criteria based on characteristics of lakes in the target population and/or other established criteria provide a standard for assessments of degradation at individual sites. Criteria can be represented as: 1) an average value of a response for a single site or for a group of sites with similar environmental characteristics, 2) an index of condition that partitions responses among categories of impairment such as the benthic macroinvertebrate Index of Biological Integrity (B-IBI), observed/expected ratios (O/E), and Carlson Trophic Indices, 3) a statistically significant change of a certain amount over natural background levels at the site (for assessment of site-specific impairment), or 4) a change of some magnitude outside the range of values representing natural conditions for multiple sites.

A discussion of methods for developing biological criteria using multimetric indices and O/E predictive models is given in Section II.F of this SOP. A useful approach for developing lake reference conditions for nutrients (also applicable for other water quality parameters) is described in the USEPA (2000) document: Ambient Water Quality Criteria Recommendations, Lakes and Reservoirs in Nutrient Ecoregion II, Sections 4.5-7.5, http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/upload/2007_09_27_criteria_nutrient_ecoregions_lakes_lakes_2.pdf (accessed 20 March 2011). Reference conditions were selected based on the 25th or 75th percentiles of the distribution of median values for nutrient parameters from all lakes in a region or subregion.

The NCCN Mountain Lakes Monitoring Project will follow an adaptive approach for developing and refining criteria using empirical monitoring data collected through time, data collected from other short-term projects, historical data, and existing criteria following State, Federal, or other agency recommendations that apply to the same region and type of lakes being sampled (*see* examples of chemical and physical criteria in Appendix E, Table E-7.).

IV. Data Analysis Procedures

A. Background

This section describes a set of potential statistical analyses designed to satisfy important quantitative objectives of the NCCN Mountain Lakes Monitoring Project. They are designed to estimate the current or past value of a parameter, detect abrupt changes in a parameter, and to detect long-term steady trends and step trends, and to estimate the proportion of sites that meet, fall below, or exceed a certain threshold or criterion. While additional analyses beyond those described in this section will be considered, these proposed analyses will form the basis for detecting changes in the condition of mountain lakes in all three NCCN parks. Parametric and nonparametric methods are proposed to provide alternatives when specific test assumptions and other considerations (e.g., nondetects, missing data, and outliers) cannot be met or corrected. It is expected that consultation with a statistician will be required in the development of, at least, the first Five-year Summary Report to evaluate the applicability of chosen methods given the proposed survey design and to conduct some of the more complex analyses.

B. Target Population and Sample Selection Overview

Throughout, it is assumed that the NCCN Mountain Lakes Monitoring Project measures biological, physical, and chemical parameters at a sample of lakes that are selected with equal probability from lakes in some target population. A detailed description of the target population in each park, as well as sample selection, can be found in the protocol narrative, Section 2: Sampling Design and Elements. Here, a general overview of the target population and sample selection elements relevant to analysis is given.

Separate target populations of lakes were identified at MORA, NOCA, and OLYM. Following target population identification, separate samples were drawn from each population. At each park, a single set of criteria was used to identify lakes in the target population. A lake was considered in the target population if it met all of the following inclusion criteria (*see* protocol narrative, Section 2: Sampling Design and Elements, Table 3):

1. Entirely within the boundaries of the park.
2. Surface area between 0.4 ha and 6.0 ha.
3. Elevation between 1220 m (4000 ft) and an upper limit that varied by park. The upper elevation limit for inclusion in the target population varied with climatic and topographic factors influencing the extent of the subalpine zone at each park and ranged from 1790 m at OLYM to 2126 m at NOCA.
4. Not strongly influenced by glacial meltwater runoff.

5. Ice free and safely accessible by foot on or off trails from August through September.
6. Maximum Depth >2.5 m.
7. Not a high fish density lake. High fish densities generally occurred in lakes with spawning habitat.
8. Temporal sampling window of August and September.

The sample frames for each park are represented by a subset of target population lakes that are ice free and safely accessible on foot by trail or off trails in August and September.

A total of 67 lakes were included in the sampled portion of the target population at OLYM, 54 lakes were included at MORA, and 42 lakes were included at NOCA (protocol narrative, Section 2: Sampling Design and Elements, Table 4). Lakes were also included in the sample frames where information for accessibility, maximum depth, and fish density criteria were unknown. If these unknown attributes are verified in the future and not found to meet the inclusion criteria, then the lake will be removed from the sample frame. In this case, inclusion probabilities for analyses given in Section IV will be adjusted based on the reduced size of the sample frame.

At OLYM, the 67 target population lakes were partitioned into low, moderate, and high annual precipitation strata. Separate sampling frames for each of the precipitation strata at OLYM included a total of 42 lakes in the low precipitation strata, 12 in the moderate precipitation strata, and 13 in the high precipitation strata. The list of lakes in the sampled and unsampled portions of the target populations at each park is shown in Appendix D, Tables D-1 through D-3).

An additional objective of the unified design was to incorporate annual precipitation into the analysis of trends, particularly for responses that are indicators of atmospheric deposition. The unified design (Hoffman and Huff 2008) required that selected sample lakes would represent the precipitation gradient at each park. This was accomplished by stratification into precipitation categories at OLYM (as in the above paragraph) where separate simple random samples of three lakes were selected from the low and high precipitation strata and two lakes were selected from the moderate precipitation stratum. At MORA and NOCA, a fixed-size equi-probable general random tessellation stratified (GRTS) sample with reverse hierarchical ordering was drawn from lakes contained in these park's sampling frames. Size of the initial GRTS sample was set equal to the frame's size (i.e., census) so that a randomized list of all lakes in the sample frame was obtained. The first six lakes from each park's GRTS ordered list were selected for monitoring. The ability of the GRTS spatially balance sampling procedure provided an adequate representation of the annual precipitation gradients at MORA and NOCA.

Strictly speaking, statistical inference from the procedures outlined below are for the index period of August through September and apply to all lakes listed in the sampling frames at NOCA and MORA, and to all lakes listed in the low, moderate, and high

precipitation strata at OLYM. No statistical inference is possible to lakes that do not meet all the inclusion criteria listed above.

C. **Analysis Overview**

There are three basic groups of proposed analyses. One set of analyses is designed to determine status by estimation of a value for a parameter at a particular point in time. Examples of this type of analysis include estimating the current average acid neutralizing capacity (ANC) for a single lake sampled multiple times or for all lakes in a particular group of lakes. Another example would estimate the proportion of lakes (i.e. park-wide or network-wide, pending sample size limitations) with an ANC value < *x* µg/L. Another set of analyses are designed to detect abrupt changes in a parameter. An example analysis of this type is detection of an atypical increase (significant departure from the norm) in average water temperature at a particular site. The final group of analyses is designed to detect long-term steady changes. Examples of this type include detecting a decrease in lake water level for an individual lake or for all lakes in a park, or estimating the average annual change in zooplankton density in a specific lake or for all lakes in a park or the network. The final group of analyses is for detection of step trends, which compares two sets of data for a response variable from non-overlapping time periods at a site. An example of a step trend analysis would be comparing a time series of data for a change in zooplankton density before and after the introduction of a non-native fish species.

These groups of analyses can be further divided into three different inference scenarios. The first inference scenario utilizes data from a single site (lake) and makes inference to that site. For example, researchers may wish to estimate changes in an average or median value of water temperature at a particular lake, or estimate the trend in density of zooplankton in a lake. The second inference scenario assumes data from multiple sites within a park will be pooled to make inference about a parameter for all lakes in the sample frame for that park or, in the case for OLYM, in a single stratum (e.g., lakes in the High, Moderate or Low annual precipitation strata). These inferences will be called park-wide. An example of park-wide inference could address the question "Is the average concentration of total nitrogen increasing through time in lakes in a park?" The third inference scenario pools data from the three parks of the NCCN and makes inference to all lakes in the union of each park's sampled target population. These inferences will be called network-wide, and the union of target populations will be called the network population. For example, researchers may wish to detect and quantify average annual changes in water level of lakes in the network's population of mountain lakes.

The general statistical procedures proposed to accomplish each type of analysis under all three inference scenarios are listed in Table 21.5. Several methods are proposed for each inference scenario to provide alternatives when specific test assumptions cannot be met or corrected.

Table 21.5. Summary of analytical procedures to detect status, abrupt and steady change under three inference scenarios. (*see* discussions in following Sections D-G).

Statistical Test	Analysis Goal: Inference	Description
Mean and Median and Confidence Interval.	Status: Specific Site, Park, Network	Site: mean/median and CI summarized by replicated samples in a given year and samples over years. Park and Network: mean/median and CI summarized for samples from all sites and by years.
One-Sample Hypothesis Tests: t-Tests, Wilcoxon Signed Rank Test, Sign Test.	Status: Specific Site, Park, Network	One-sample tests for comparison of a mean (*t*-Test, Wilcoxon Signed Rank) or median (Wilcoxon Signed Rank, Sign Test) to a fixed threshold value.
Distribution Estimation: Histograms, Box Plots, Cumulative Frequency Distribution Plots, Cumulative Distribution Functions (CDF).	Status: Specific Site, Park, Network	Graphical representations of data distributions. Cumulative distribution function estimation methods provide an estimate of the proportion of samples that fall above or below a fixed threshold value and place a confidence interval around the estimate.
Prediction Intervals, Linear Regression on Time, Mixed Linear Model for temperature logger data.	Abrupt Change: Specific Site	Abrupt change represents a rapid shift or significant departure from the "norm". Abrupt change would be detected if the measured value at a site for the current year fell outside of prediction intervals established from the pattern of the previous years of data.
Mixed Linear Model	Abrupt Change: Park and Network	Separate trends from all individual sites from the park or network are included in the analysis. Prediction intervals for trends at each site are determined. Abrupt change for the park or network would be detected if one or more current year responses fell outside of their respective individual site prediction intervals.
Cumulative Sum (CUSUM)	Abrupt Change: Park and Network	CUSUM is a non-parametric technique for detecting abrupt change in a region when responses are not normally distributed. Fundamentally work by setting upper and lower "warning" and "action" limits (confidence intervals) for the sample mean. Randomization methods used to decide whether the CUSUM chart for time *t* indicates a significant departure from the long term mean.
Mixed or Fixed Effect Linear Regression on Time, Mann-Kendall and Seasonal Kendall with slope estimators.	Steady Trend Detection: Specific Site	For steady trend detection all years including the current year are included in the analysis. Trend significance, direction, confidence intervals, and magnitude of rates of change are determined.
Mixed Linear Model, Regional Kendall and Regional Seasonal Kendall with slope estimators.	Steady Trend Detection: Park and Network	Separate trends for all individual sites from the park or network are included in the analysis, which is conducted in a way that cancels inherent differences between sites. Trends are assumed when change in the same direction occurs at many of the individual sites.
Two-Sample t-Test, Mann-Whitney-Wilcoxon Rank Sum Test and the Associated Hodges-Lehmann Estimator Of Trend Magnitude	Step Trend Detection: Specific Site	Comparison of two sets of data for a response variable from non-overlapping time periods at a site.

It must be noted that running several tests on the same data set can affect the interpretation of the Type I error rate. McDonald et al. (2009) provide the following recommendations if multiple trend analysis tests are used on the same data set:

> "When possible, we recommend deciding *a priori* which trend analysis to apply and sticking to it. If assumptions of the analysis selected *a priori* turn out to be violated, and another analysis is chosen, authors are duty bound to report this fact and reasons for the switch. When multiple tests are desired or unavoidable, perhaps due to questionable assumptions in all candidate analyses, we recommend correcting (reducing) the level at which individual tests are performed in order to control the experiment's overall Type I error rate. This is a well known problem in statistical hypothesis testing, and the standard Bonferroni correction in which individual tests are conducted at $\alpha B = \alpha / k$, where k is the number of tests, is one relatively simple solution."

Many of the procedures making inference to a specific site are time series analyses because they analyze a single number per lake, and repeated measurements through time are required to assess variation. That is, some responses are unreplicated within a site while other responses are measured at multiple locations within a lake. An example of a replicated response is shoreline disturbance which is measured at multiple systematically placed shoreline plot locations. Variation of shoreline disturbance across plots may in some cases be used in an analysis to judge the degree of variation in disturbance across the entire site. Most park-wide and network-wide inferences, on the other hand, utilize or incorporate site-to-site variation to quantify inferences. For example, the CUSUM function utilizes variation through time at a site as well as variation across sites to determine whether the underlying system's mean has recently shifted.

Software Applications

To assist with and facilitate application of some of these analyses in Table 21.5, Dr. Trent McDonald and Michelle Bourassa Stahl of WEST, Inc. have developed a set of menu-driven 'R' routines to summarize continuous temperature data for parameters shown in Table 21.4 of this SOP, and to run linear regressions, mixed linear models, CUSUM, and their associated analytical procedures (e.g., bootstrapping, handling covariates, accounting for serial correlation, etc.). These routines and documentation are maintained by the Project Lead and Data Manager. The programs are designed to work with 'R' statistical software which can be freely downloaded from the following website: http://www.r-project.org/ (accessed 2 January 2011).

There are numerous statistical software packages, including the 'R' program, that can be used for calculating measures of central tendency, dispersion, parametric and nonparametric one- and two-sample hypothesis tests, and for generating basic graphical representations of the data. Nonparametric trend procedures described in Table 21.5 can also be calculated using 'R' Software. In addition, the USGS provides documentation (Helsel et al. 2006) and a computer program (Kendall.exe) for the Kendall family of trend tests, including LOWESS procedures and the Regional Kendall test. Software documentation for this program is located at

http://pubs.usgs.gov/sir/2005/5275/pdf/sir2005-5275.pdf, and the program can be downloaded from the following website: http://pubs.usgs.gov/sir/2005/5275/downloads/ (accessed 24 March 2011). Cumulative distribution functions can be estimated following methods developed specifically for probability surveys by Diaz-Ramos et al. (1996). User's guides and S-Plus and 'R' Software statistical routines for these methods are available at the following USEPA website: http://www.epa.gov/nheerl/arm/analysispages/techinfoanalysis.htm, (accessed 27 March 2011).

Incorporation of Covariates/Explanatory Variables into Analyses

The basic analysis to detect both long-term trend and abrupt change of a lake parameter is regression. These regressions will include time as one factor and will account for any potential auto-correlation in residuals through time using mixed models such as restricted maximum likelihood (REML) (Lahiri 2003). Trend or abrupt change will be detected if the coefficient of time in these models is significantly different from zero. To increase the statistical power of these analyses to detect trend or change, it is advisable to include other important explanatory covariates in the regression model. Examples of such covariates include elevation of the lake, annual or seasonal precipitation at the lake, lake levels at time of the measurement, annual or seasonal summaries of temperature at the lake, lake size, lake catchment area, basin azimuth, etc. The only requirement for these covariates is that they be consistently measured and applicable to individual lakes. Large scale discrete factors, such as precipitation or elevation stratum, can also be used as covariates.

Precipitation and temperature (air and water) influence many lake parameters and should be considered as covariates in many of the regression models that attempt to detect trend or change. Continuous temperature data are collected year-long, using data loggers, at each of the selected monitoring lakes. Precipitation data are not currently measured at each lake. However, predicted precipitation values, such as those from the PRISM model (http://www.prism.oregonstate.edu, accessed 27 March 2011), are acceptable for use as covariates provided the predictions are highly correlated with actual values. It is not necessary that predicted or modeled precipitation exactly matches actual precipitation. To increase correlation of predicted precipitation values with actual values, predicted annual precipitation values from the PRISM model can be calibrated using actual precipitation data. The NCCN Climate Monitoring Protocol (Lofgren et al. 2010) lists sites where precipitation data are being collected at MORA, NOCA, and OLYM as well as recently installed and proposed future site locations. Calibration entails regressing predicted values onto actual values using a small number of locations where actual precipitation values are known. This regression is then used to predict precipitation at all lakes.

It must be noted that six to eight lakes per park are barely enough to fit a model testing for differences among parks in slopes and intercepts of the effects covariates. Adding terms to test slopes and intercepts for covariates such as mean annual precipitation, surface area, maximum depth, and other attributes plus their interactions would require substantially larger sample sizes. Further, covariation among the monitored response variables across lakes, and correlated changes over time, contain substantial information

that might be useful for understanding the changes and adapting or mitigating effects; such analyses also require a larger sample size (Tom Philippi, Ph.D, NPS I&M Program Quantitative Ecologist, personal communication, February 2010). Limitations of the sample size regarding inference to the target populations of lakes at each park were previously discussed in the Objectives Section (1.4.2.1). To address the sample size issue, a proposal to expand the sampling effort at each of the three parks has been developed (Appendix J).

D. **Status Estimation Procedures:**
In every annual report, it is recommended that the current status of the responses discussed in Section II be estimated for the smallest useful reporting units (*see* Appendix E, Tables E-1 through E-4). This section describes, in general, analyses designed to estimate a parameter's value at a particular point in time. These analyses, with slight modifications, can be used to estimate status for a specific site and for all sites in a region.

1. Mean, Median, and Measures of Dispersion
Single-Site Inference: For responses that are replicated within a site, the simplest estimates of current status involve calculating the mean or median value of the response with appropriate measures of dispersion (e.g., standard deviation, standard error, confidence intervals, interquartile range, etc.). For example, water clarity as measured by the depth that a Secchi disk disappears from view will be measured three times at one location within a lake. An estimate of the current average Secchi depth is simply the average of the three depth measurements taken. An estimate of the variation in Secchi depth is the standard deviation or standard error of these three numbers. A 95% confidence interval for the true mean response is $\bar{X} \pm 1.96 se(\bar{X})$ if individual measurements are approximately normally distributed. If a particular response is not approximately normal, bootstrap methods (Manly 1997) should be employed to construct appropriate confidence intervals. Bootstrap methods are recommended over "normalizing" transformation for two reasons. First, bootstrap methods utilize original measurement units that do not need to be back-transformed for interpretation, and second, confidence intervals based on transformations only approximate confidence intervals produced by bootstrapping. In other words, bootstrap methods are preferred because they do not rely on normality, and while transformations may be successful in improving the distribution of the response, they cannot make distributions perfect. Alternatively, distribution-free methods could be applied such as calculating the median value and interquartile range of the data or by calculating the confidence interval for the median as described by Helsel and Hirsch (2002, Chapter 3), available at the following website: http://water.usgs.gov/pubs/twri/twri4a3/ (accessed 3 April 2011).

For responses that produce one number per site, (such as unreplicated chemistry parameters and zooplankton samples), the current estimate of status is the observed number. In some cases it may be possible to compute a standard error for this number based on a model or past data, but in general, variation of these responses will be assessed through time.

Park and Network-wide Inference: The primary method of estimating status in a region containing multiple lakes will be to estimate the parameter's mean or median and an associated confidence interval. In these analyses, it is anticipated that within site variation will generally be minimal compared to variation between sites.

Assuming one measurement of a response is taken at each lake, an estimate of the current average of a parameter is simply the average of that parameter's value (or median value) over all sampled lakes in a sub-region or region. For mean response values, variation of the average parameter estimate can be estimated by the usual standard deviation, or with the neighborhood variance estimator of Stevens and Olsen (2003). The neighborhood estimator should be used when possible because it takes into account spatial location of sampled site and any potential spatial correlation induced by close proximity. The neighborhood estimator, however, involves complex calculations. Standard or bootstrap 95% confidence intervals for the true mean can be constructed for current status estimates, depending on approximate normality of the underlying responses. Block bootstrap methods (Lahiri 2003) can be used if spatial correlation of responses is high.

2. One-Sample Hypothesis Tests
Single-Site Inference: Application of these tests is proposed for comparing a mean or median with a fixed threshold or criterion value and can be applied to responses derived from either multiple observations or a single observation taken at a site during each annual sampling visit. However, at least five or more years of data may be required for evaluating responses represented by a single observation for each year.

The proposed one-sample nonparametric tests for comparing a median value to a threshold include the Sign test and the Wilcoxon Signed Rank test (also used for mean values). The *t*-Test provides a parametric alternative one-sample test for comparing a mean value with a threshold. Test assumptions, limitations (e.g., outliers, nondetects, sample size, etc.), and example calculations are given in Chapter 3 of USEPA (2006).

Park and Network-wide Inference: The same procedures described for single-site inference (above) can be applied to park-wide and network-wide assessments of status. Response values are summarized for all years and sites in order to expand interpretation to the larger spatial scales. For *t*-Tests, if spatial correlation is a concern, then methods described above (D.1) for estimating variance (neighborhood variance estimator) and confidence intervals (block bootstrap) should be considered.

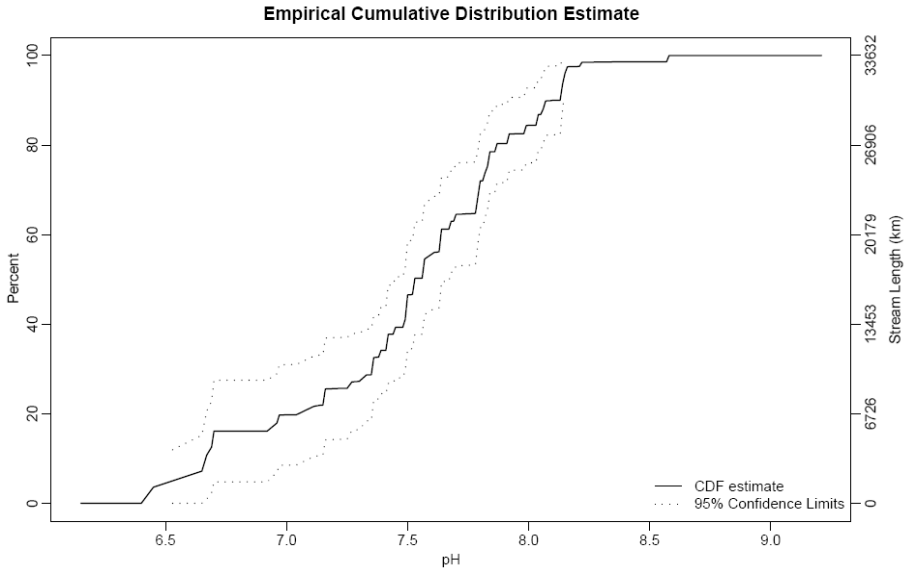
Analyses of network-wide data, where park strata are combined (including combining precipitation strata at OLYM for a park-wide estimate), requires that differences in the inclusion probabilities are accounted for in each analysis strata. An example application for a one-sample *t*-Test from a stratified sample is given in Chapter 3 of USEPA (2006).

3. Distribution Estimation

Single-Site Inference: For responses that are measured many times within a single lake (e.g., continuous temperature data) it may be possible to construct plots that depict the response's entire distribution. These plots include histograms, box and whisker plots, and cumulative frequency distribution plots (*see* Section B.1 of this SOP, and Helsel and Hirsch 2002, Chapter 2). Standard histograms divide the range of a response into a number of bins and plot the number of measurements in each bin. Box and whisker plots show outliers and the 25th, 50th, and 75th quartiles of the distribution of a response. Cumulative distribution functions (CDF) plot the proportion of measurements below all observed levels of a response and can be constructed from smoothed or non-smoothed histograms. Cumulative distribution functions can also be estimated using the methods of Diaz-Ramos et al. (1996; *see* following discussion on CDFs, below).

Initially, it is anticipated that few responses will be replicated enough times within lakes to make distributional estimates useful. These types of status estimates will be more useful when region-wide data from multiple lake sites are combined. Methods for constructing these plots are the same for site specific and regional inference scenarios and the reader is referred to the next section for specific examples.

Park and Network-wide Inference: When the region of inference contains a large number of lakes, it will be useful to estimate the statistical distribution of lake-level measurements across the region. Histograms and associated smoothed density estimates can be estimated using the methods of Wand and Jones (1995) from data collected in the current year. Cumulative distribution functions can be estimated following methods of Diaz-Ramos et al. (1996). Using these analyses, we can estimate the current proportion of lakes in the region that meet a specified condition. For example, it will be possible to estimate the proportion of lakes in a region with a $pH < x$, and place a confidence interval around the estimate (Figure 21.9). S-Plus and R Software statistical routines for these methods are available at the following USEPA website: http://www.epa.gov/nheerl/arm/analysispages/techinfoanalysis.htm (accessed 27 March 2011) and were developed specifically for probability surveys. It must be noted that at the network and park level, given the current sample size, the sampling precision of estimates of status based on the proportion of sites in the target population meeting or exceeding a criterion may be less than desired without a periodic infusion of samples from additional target population lakes (*see* Appendix J: Proposal to expand mountain lake sampling).



Summary Statistics

Statistic	Est	LCB	UCB
5Pct	6.53	6.15	6.68
10Pct	6.67	6.43	6.96
25Pct	7.16	6.69	7.42
50Pct	7.53	7.44	7.67
75Pct	7.83	7.78	8.03
90Pct	8.13	7.92	8.21
95Pct	8.15	8.07	9.02
Mean	7.49	7.37	7.62
Std Dev	0.49	0.40	0.58

Figure 21.9. Example of a cumulative distribution estimate with confidence limits and summary statistics for reporting status/condition for pH in Washington streams. An example interpretation of results follows: 25% of the streams sampled (summarized by total km) in the Washington target population had a pH ≤7.16 (95% CI of 6.69-7.42). From USEPA EMAP website: http://www.epa.gov/nheerl/arm/documents/r10_exam/chemistry_plots.pdf (accessed 29 March 2011).

A discussion on the sample size requirements for estimation of a proportion at various levels of precision is given at the following USEPA website: http://www.epa.gov/nheerl/arm/designpages/monitdesign/sample_size.htm (accessed 27 March 2011).

In most cases, distributional estimates will be expressed in terms of number of lakes rather than by surface area. Histograms, smoothed density estimates, and CDF's should be expressed as the proportion of the total number of lakes in the region meeting some criterion (Figure 21.9). Generally, region-wide estimates of status will be reported at five-yr intervals.

E. **Abrupt Change Detection Procedures**

Abrupt change represents a rapid shift or significant departure from the "norm" and would be detected if the measured value at a site for the current year fell outside of prediction intervals established from the pattern of the previous years of data. Abrupt change can be applied for responses measured at a single site, for all sites in a park, or all sites in the network. The discussions on park-wide and network-wide abrupt change detection require some interpretation related to the stratified sampling design of the monitoring project. The only difficulty is combining data from the design strata. This is not a concern for park-wide detection of abrupt change at MORA and NOCA. However at OLYM, assessment of abrupt change would require combining the data from the three precipitation-based strata in a park-wide analysis. Interpretation of abrupt change at the network level combines the three strata at OLYM with the strata for MORA and NOCA. Description of methods and calculation of inclusion probabilities for observations from these strata are given in the network-wide discussion of abrupt change, below.

1. Parametric and Nonparametric Prediction Intervals

Single-Site Inference: Prediction intervals represent a statement of the likelihood that a single data point with a specified magnitude comes from the population under study (Helsel and Hirsch 2002). These methods provide a simple way to evaluate if a current year response value from a lake is likely to have come from the distribution of data collected from previous years. Prediction intervals are developed from the individual data values rather than a summary statistic (e.g., mean) and, as a result, are wider than a corresponding confidence interval. For interpretation, a new value is considered to be different if found to be outside of the prediction interval calculated from the previously collected data. The likelihood of a current value being different is dependent on the choice of α.

These procedures work better if the data from previous years does not exhibit a trend. The width of the prediction interval would be greater if a significant trend is present and not accounted for, possibly increasing the chance of a Type II Error in the interpretation of current values. For this reason, results from graphical procedures and tests for trends should be examined prior to calculation of the prediction intervals. If a trend is present, then the methods described in Section E.2 (below) should be applied. Methods for calculation of parametric and nonparametric prediction intervals are described by Helsel and Hirsch (2002) and are found at the following website: http://water.usgs.gov/pubs/twri/twri4a3/ (accessed 3 April 2011).

2. Regression on Time

Single-Site Inference: The following single-site abrupt change analyses are applicable to the time series of data collected at a lake. The methods listed in this section are applicable to lakes sampled annually and to lakes with randomly missing data. Missing data are "randomly missing" if the response of interest (e.g., ANC, water level, etc.) cannot be predicted in years when the response was not measured. For example, if a sample was lost in shipping to a contractor, it is unlikely that the distribution of the response that year could depend on the probability of failing to measure the response.

Assume a response can be summarized into a single number every year it is sampled. Typically this single number will be the estimated mean or total for that year. In this section, the single summarizing number associated with a lake will be called "the response," even though in some cases "the response" will be a mean or composite of several measures. The methods of this section also assume that an estimated standard error of the response is available. If a standard error is not available, the methods are still applicable because standard error estimates are primarily used as weights in the analysis, and it is always possible to give equal weight to all years when standard errors are unavailable.

Assuming the response of interest is approximately normally distributed and that statistical errors are uncorrelated, abrupt change can be detected by fitting a weighted regression to past data, constructing a 95% prediction interval for the current value, and observing whether the measured value is outside this interval (Figure 21.10). If serial (through time) correlation in response values is appreciable, it will be necessary to apply mixed linear model methods such as REML (Littell et al. 1996) to correctly compute prediction intervals. Alternatively, blocked bootstrapping (Lahiri 2003) can be used if serial correlation is high. To illustrate the method, we assume serial correlation in residuals of the model is low. A statistical synopsis of the regression method using the matrix formulation of the problem is given in Appendix E., Attachment 1. This synopsis illustrates some of the necessary calculations and lays a foundation for later analyses.

While the following regression approach assumes that the long term trend at a site is linear, linearity is not necessary because curvilinear or polynomial trends can be fit in the regression. If auxiliary variables, such as temperature, are known to effect responses, they can also be incorporated into the model to explain variation and improve precision. If the residuals from the regression analysis are not normally distributed, bootstrapping (Manly 1997) should be used to construct the final prediction confidence interval. In this case, past residual values (and weights) should be randomly sampled with replacement, added back to the original predicted value for each year, and the regression re-fitted. This yields new (bootstrap) predicted values for the past and current years. For the current year, a single residual from past data should be selected at random and added to the new (bootstrap) predicted value for the current year. This value should be stored and the entire procedure repeated 1000 times to yield 1000 typical values for the current year. Finally, the 2.5 and 97.5 percentiles of the 1000 typical values for the current years should be computed and used for the current year's prediction interval.

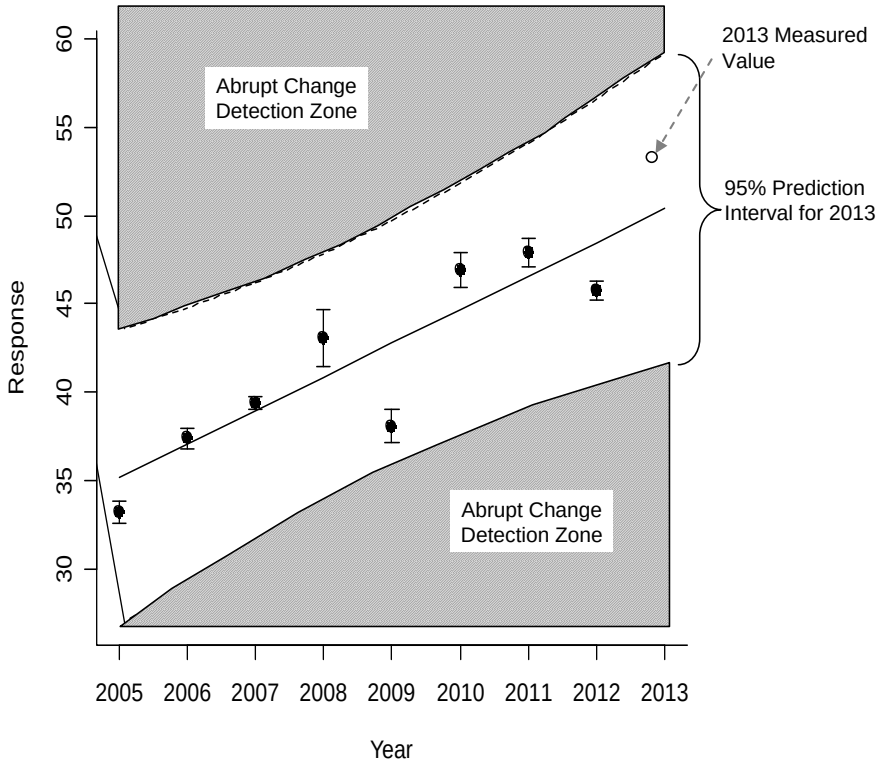


Figure 21.10. Illustration of the regression method for detecting abrupt change. Filled circles are previous estimates of the response. Bars are ±1 standard error. Assuming uncorrelated errors, weighted regression can be used to fit a linear regression to data from 2005 through 2012, and a prediction interval for 2013 can be constructed. Abrupt change would be detected if the measured value for 2013 fell outside this interval (i.e., in one of the 'Abrupt Change Detection Zones').

3. Mixed Linear Model

Single-Site inference (Continuous Temperature Data): While relatively simple regression analyses can be applied to most responses, continuous water and air temperature data require special attention because they are recorded several times per day throughout a season. Most other responses are recorded once during a season. When analyzing water temperature for abrupt change, it will likely be necessary to model patterns of natural change within a season. Modeling intra-seasonal natural variation can be accomplished by fitting polynomials or smoothing splines (Hastie 1992) effects in a least-squares regression. These effects will estimate the natural pattern of changes in water temperature within a single season; and abrupt change in the current year, if present, would cause the pattern of changes in the current season to be different from the pattern in previous years, or a shift in the mean of the pattern. In addition to fitting curvilinear effects, temperature is measured so often that the correlation in individual measurements must be accounted for when deciding whether change has occurred.

Estimation proceeds as above (E.1) except that mixed linear model procedures (e.g., REML) should be used to estimate the coefficients in β. In this process an appropriate

model for the correlation of observations has to be estimated and used. A statistical synopsis of the regression method for continuous temperature data is also given in Appendix E.5.

Park-wide Inference: If responses are normally distributed, a linear model analysis similar to the single-site models described above can be used to detect abrupt change among all lakes in a stratum (e.g., OLYM) or the entire target population of a park (e.g., NOCA and MORA). The only difference is that site effects are necessary and this slightly complicates the modeling process. When multiple sites from the same region are included in the analysis, the model must include terms for each site, and in general separate trends should be estimated for each site. Separate trends at each site are estimated by including site and site-by-year interaction terms. An example of the model is shown in Figure 21.11. A statistical synopsis of the method is given in Appendix E., Attachment 1.

When the model is fit, possibly using REML methods to account for serial correlation, *k* simultaneous prediction intervals are constructed for all values in the current year, where *k* is the number of sites in the analysis. If abrupt changes have not taken place, all responses in the current year will be within their respective prediction intervals. If one or more responses are outside their prediction interval, abrupt change has been detected in the region at the experiment-wide α level of 5%. Certain attributes will be assessed at an experiment-wide α level of 10%, rather than 5%.

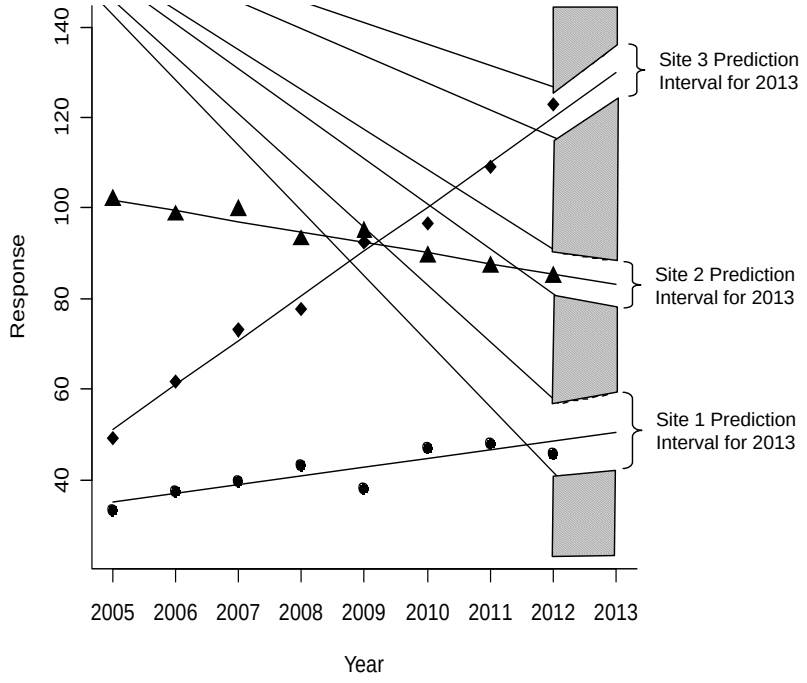


Figure 21.11. Illustration of the regression method for detecting abrupt change at multiple sites. The model is similar to that displayed in Figure 21.1 except that separate trends have been fit to data from each site and multiple simultaneous prediction intervals have been constructed for responses in 2013. If a single observed value in 2013 is outside its prediction interval, abrupt change has been detected.

OLYM and Network-wide Inference: The same basic procedures for detecting abrupt change at the park-level can be used to detect abrupt change at the network-level. The only difficulty is in combining data from the three strata at OLYM with the GRTS sample collected at the other parks, but this difficulty is easily overcome.

To estimate abrupt change at the network-wide level, the network target population (all lakes in the MORA and NOCA frames plus lakes in the low, moderate and high precipitation strata from OLYM) is viewed as being partitioned into five strata for the purposes of analysis. These five strata are: Stratum 1 = MORA, Stratum 2 = NOCA, Stratum 3 = low precipitation stratum at OLYM, and Stratum 4 = moderate precipitation stratum at OLYM, and Stratum 5 = high precipitation stratum at OLYM. These are *analysis* strata. The abrupt change analyses outlined for a single target population can be used to detect abrupt change in the network population by including an additional weighting factor for each observation that is equal to the inverse of its *inclusion probability.* Because sampling from all analysis strata was equi-probable, a lake's inclusion probability is its analysis stratum sample size divided by analysis stratum size. Inclusion probabilities and weights for observations in each of the analysis stratum will be as follows:

- Stratum 1 (MORA): Pr(incl.) = 6 /54 = 0.1111, weight = 9.0009
- Stratum 2 (NOCA): Pr(incl.) = 6/42 = 0.1429, weight = 6.9979
- Stratum 3 (OLYM low precip.): Pr(incl.) = 3/42 = 0.0714, weight = 14.0056
- Stratum 4 (OLYM mod precip.): Pr(incl.) = 2/12 = 0.1667, weight = 5.9988
- Stratum 5 (OLYM high precip.): Pr(incl.) = 3/13 = 0.2308, weight = 4.3328

In a mixed linear model analysis for abrupt change, observations would actually receive two weights. Weight #1 is the inverse of the observation's standard error. Weight #2 is the inverse of the observation's inclusion probability. To actually run the analysis, these two weights are multiplied together and this product is supplied as the observation's weight.

4. CUSUM Procedure

Park-wide Inference: CUSUM is an acronym for the cumulative sums of differences between the mean for specific time intervals and the grand mean of each data set. The CUSUM procedure is a non-parametric technique for detecting abrupt change in a region for the case when responses are not normally distributed. Manly (2001, Sections 5.7 and 5.8) and Manly and MacKenzie (2000) discuss use of control charts and CUSUM charts for detecting abrupt changes in a mean. These charts have a long history in industrial process monitoring (Montgomery 1991) and fundamentally work by setting upper and lower "warning" and "action" limits for the sample mean. An example of ecological application of the CUSUM procedure is given by Nicholls (2001) where breakpoints in CUSUM functions for chlorophyll-a and phytoplankton were found to reinforce the anecdotal information available on the invasion history and spatial distribution of *Dreissena* spp. (zebra and quagga mussels) in Lake Ontario. A statistical synopsis of the CUSUM procedure is given in Appendix E, Attachment 1.

An example of a CUSUM chart is given in Figure 21.12. A positive slope in the CUSUM line indicates that responses during time period t were, on average, higher than their historical averages. A negative CUSUM slope indicates the opposite. Positive, then negative, slope in the CUSUM chart indicates that responses on units with low means were higher than their respective means, while responses on units with large means were lower than their respective means.

Manly and MacKenzie (2000) propose randomization methods to decide whether the CUSUM chart for time *t* indicates a significant departure from the long-term mean. The randomization method computes an envelope of expected CUSUMs under the null hypothesis of no departure from the long-term mean at time *t*. Missing values or non-sampled occasions are acceptable. If missing values are present, the means from each unit are calculated from the available data, and the randomization scheme permutes the available data among the occasions that were observed. The CUSUM method is affected by serial correlation in the measurements at a given site; however, the randomization test can be adjusted to account for this.

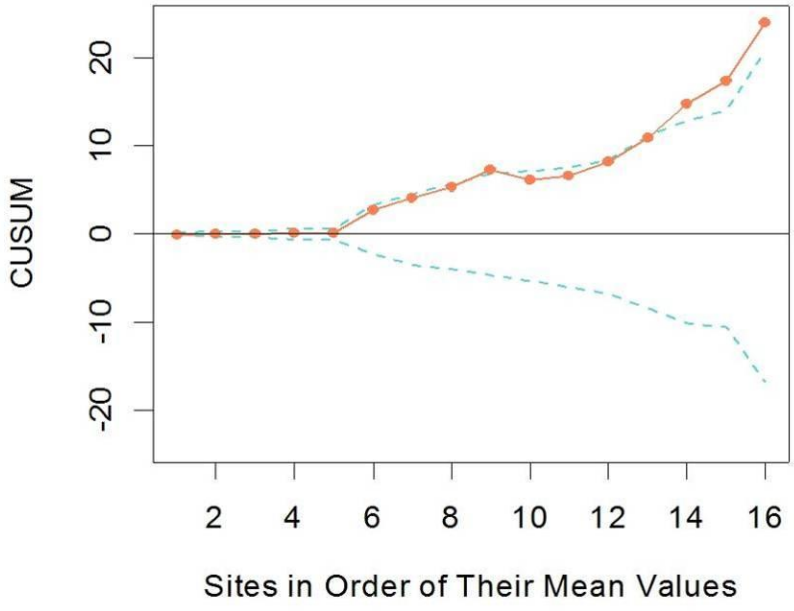


Figure 21.12. Illustration of the CUSUM method for detecting abrupt change at multiple sites in a region. In this plot, 16 sites were measured and their partial sums (S_{it}) are plotted against ***i*** for the current year (– • –). If the CUSUM line crosses the 95% confidence interval established by randomization (– – –) as here, abrupt change would be detected.

OLYM and Network-wide Inference: For the CUSUM procedure, a weighted grand mean is taken, where weights are the inverse of inclusion probabilities. Deviations from the grand mean are also weighted by the inverse of their inclusion probability when computing the cumulative sums displayed in the chart. Inclusion probability weights stay with the observation during permutation.

F. **Long-Term Steady Trend Analyses**

1. Regression on Time

Single-Site Inference: Long-term steady trend in a response collected at a single site can be detected using a mixed or fixed effect linear model that is similar to the linear model for abrupt change. The primary differences between this and the abrupt change model are that all responses, including those from the current year, are included in the response vector, and interest is in inference toward the slope parameter. The coefficient vector is estimated using an appropriate technique (either least-square, the REML method for correlated data), and inference about the single slope parameter is made. If the slope parameter β_1 is significantly different from zero, significant trend has been detected. If residuals of the model are not normally distributed, bootstrapping or permutation methods (Manly 1997, 2001) should be used. Multiple explanatory variables can be included in the model. For example, elevation can be included in the linear model, in addition to time, to account for differences in the response at different elevations.

Variables, either the response or predictors, can be transformed to improve linearity or normalize a distribution without ill effects on the procedure; however, it must be kept in mind that transformations often change the nature of what coefficients measure and the functional form of trend. For example, fitting a linear model to logarithmically transformed response variables means that the "slope" coefficient is a multiplier of time in the exponent, i.e., trend is exponential. Transformations are not necessary if non-parametric techniques such as bootstrapping or permutation are used.

Some responses can be "below detection limits" and thus constitute censored values. Analysis of data containing censored values is difficult and for most cases data handling and transformation (censoring) recommendations found in Helsel (2005) will be followed. Consultation with a professional statistician may be required in cases regarding some of the more complex procedures.

2. Mann-Kendall and Sen's Slope Estimator Procedures

Single-Site Inference: As an alternative to ordinary least squares regression, responses with single and multiple observations per time period from a single site can be analyzed for steady trend detection using the nonparametric Mann-Kendall (MK) test (Mann 1945, Kendall 1975). This test is based on the Kendall's tau value (Kendall 1975) which is a rank correlation measure of the strength of linear dependence between the ranks of data. The MK test estimates a robust trend line that is the median slope for the set of lines joining all possible pairs of points in a time series. For samples with multiple observations per time period, a summary statistic (e.g., median) can be computed and applied in the Mann-Kendall test (*see* Section 4.3.4.2 in USEPA 2006).

The MK test is paired with the Sen's slope estimator (Sen 1968), where the MK test is used to determine the average direction of yearly changes and the Sen's slope

estimator is applied to determine the magnitude of trend (unit change per year) and confidence limits. A response is reported as statistically significant only when significant upward or downward trends are found for both the MK and Sen's procedures.

The MK test is rank-based, which doesn't assume normality, is resistant to outliers, and admits censored data because only ranks are used. Data can also be adjusted to remove the effects of an ancillary variable before testing for trend. A LOWESS smooth (Locally Weighted Scatterplot Smooth, Cleveland and Devlin 1988) is used to describe the relation between the Y variable (response) and the ancillary variable. Residuals from the smooth therefore have the relation between Y and the ancillary variable subtracted, removing the effect of the ancillary variable from the Y variable data. The Kendall test is then computed on the residuals from the LOWESS smooth, to test for trend after removing the effect of the ancillary variable. This procedure is available for use with the Seasonal Kendall and Mann-Kendall tests and is discussed, among other options, by Helsel and Hirsch (2002).

The assumption of independence for MK test is violated if serial correlation is present. Alternatives for handling serial correlation in Kendall tests are discussed by Hirsch and Slack (1984) and Yue and Wang (2004).

3. Seasonal Kendall and Sen's Slope Estimator Procedures
Single-Site Inference: Temporal data collected over extended periods of time may often show cyclic patterns that repeat over time. For example, temperature data will show cyclic patterns at several temporal scales within a year (e.g., day, month, and season). These patterns may affect the interpretation of trends for a particular response variable of interest if they are unaccounted for in the trend analysis. The Seasonal Kendall (SK) test for trends is proposed as an alternative to the Mixed Linear Model approach described for application with temperature data (Section E.3), and it replaces the MK test when temporal cyclic patterns are found in the data.

The SK test was initially developed by the USGS (Hirsch et al. 1982) and later modified by Hirsch and Slack (1984) to account for serial correlation. The SK test performs separate MK tests for individual seasons of the year and then combines the individual results into one overall test for whether the response (Y) variable changes in a consistent direction (monotonic trend) over time. As with the MK test, the Sen's slope estimator is applied to determine the magnitude of trend (unit change per year) and confidence limits. The SK test can analyze responses with single and multiple observations per time period from a single site and can handle ancillary variables (Figure 21.13) as described for the MK procedure, above. Additional information on application of SK and MK test procedures are given in Helsel and Hirsch (2002), Helsel et al. (2006), and USEPA (2006).

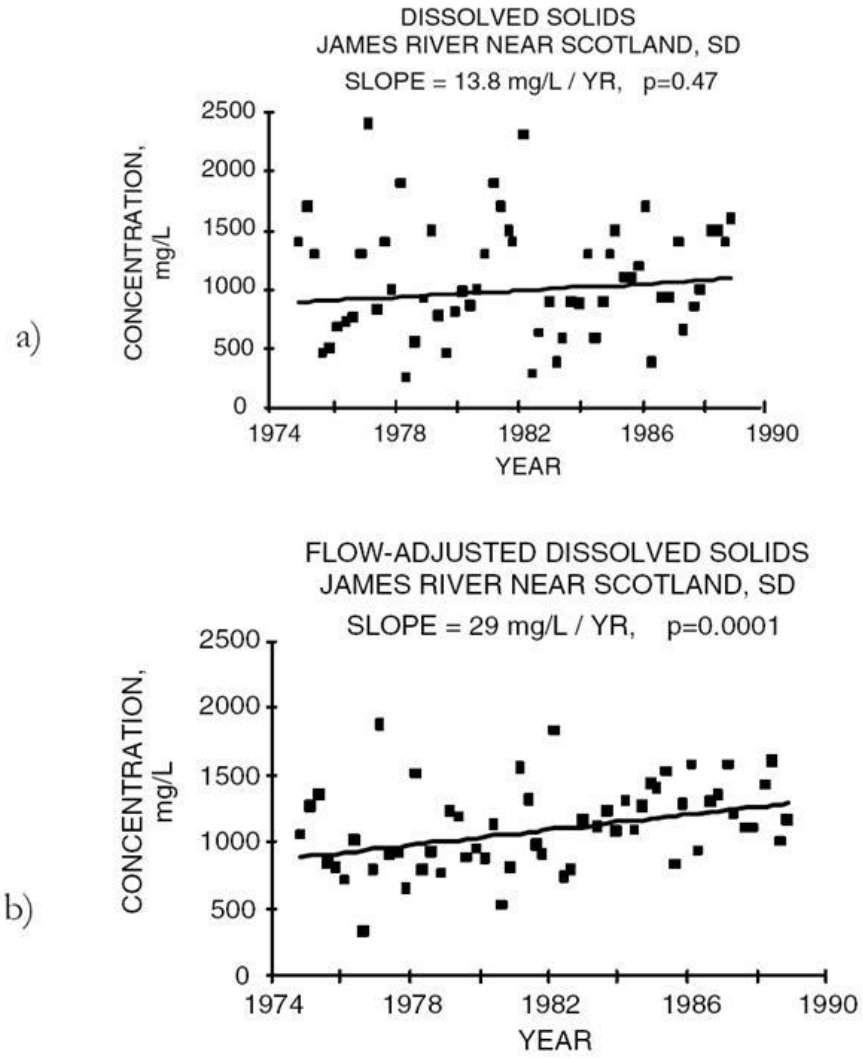


Figure 21.13. Comparison of Seasonal Kendall tests for trends in dissolved solids concentrations, before (a) and after (b) removing the effects of flow. The Sen estimate of linear trend associated with the Seasonal Kendall test is shown by the solid line The trend in unadjusted data (a) is not statistically significant (p=0.47). Using the same data, the trend following the removal of flow-related variability in dissolved solids concentrations is highly significant (p=0.0001). The estimate of the magnitude of trend in flow-adjusted concentrations is about twice the estimate of the trend magnitude in raw concentrations. From Hirsch et al. 1991.

4. Mixed Linear Model

Park-wide Inference: When multiple lakes are involved in a trend analysis, it is important to conduct the analysis in a way that cancels inherent differences between lakes. As such, it is only possible to include a lake in the analysis if it has been visited at least twice. Randomly varying revisit intervals, or non-informative missing values, do not matter provided at least two visits have occurred.

The analysis discussed in this section is un-weighted by inclusion probabilities. It is assumed that all lakes in the analysis are selected with equal probability. This

confines the inference at OLYM from these un-weighted analyses to the low, moderate, or high precipitation strata. To make truly park-wide inferences at OLYM, the weighted analyses discussed in the next section must be used.

Assuming approximately normal response values, the trend analysis proposed by Piepho and Ugutu (2002) views responses as repeated measures and estimates a mixed linear model. The mixed linear model assumes:

$$y_{ij} = \mu + w_j\beta + b_j + a_i + w_j t_i + c_{ij}$$

Where y_{ij} is the response on the ith site during the jth year, w_j is the year covariate equal to the year that y_{ij} was recorded, μ is the fixed intercept parameter, β is the fixed overall slope parameter that we wish to make inference about, b_j is the random effect of the jth year, a_i and t_i are random effects of the ith site, and c_{ij} is the random effect of site and year combined (i.e., interaction). Using REML, it is possible to obtain an estimate of the fixed overall slope parameter β accounting for correlation in the random effects, and to test whether or not β is significantly different from zero. If β is significantly different from zero, significant trend has been detected.

If responses are grossly non-normal in distribution, a permutation method can be used to assess the significance of β. To perform the permutation method, a reduced model without trend should be fitted, and residuals from the reduced model should be obtained. The reduced model without trend is:

$$y_{ij} = \mu + b_j + a_i + c_{ij}$$

Where residuals from this model are the c_{ij}. Once obtained, residuals should be randomly permuted within-site and added back to the other effects to obtain a new pseudo response. During permutation, residuals from one site should not become associated with effects from other sites (i.e., only the j index should be permuted). The full mixed model with time trends should then be fitted to the pseudo-responses and the obtained value of β should be stored. Repeating the permutation and fitting 1000 or more times builds a distribution of β under the null hypothesis of no trend. If the percentage of β's in this distribution is more extreme than the original β is less than the established significance level (e.g., 5%), it can be concluded that the original trend was unlikely to have occurred if there were no trend in the population. If the original trend (β) is unlikely to have occurred, assuming no trend, the null hypothesis can be rejected and significant trend has been detected.

Network-wide Inference: The mixed linear model proposed for park-wide trend detection is also proposed for network-wide trend detection, with one change. When detecting network-wide trend, differing inclusion probabilities must be accounted for by including weights in the mixed linear model. Inclusion probability weights are inversely proportional to the fraction of sampled lakes in each park/strata, and are

listed in the Abrupt Change section above. These weights must be included in both the normal and permutation based procedures.

5. Regional Kendall and Regional Seasonal Kendall Procedures

The Regional Kendall (RK) extends the concept to spatial locations rather than seasons as used in the Mann-Kendall (MK) and Seasonal Kendall (SK) tests. The RK test, developed by Helsel and Frans (2006), is a nonparametric test that provides an increased power of trend detection by grouping data from multiple sites within a given geographic region (Clow 2010). Calculation or the RK test uses the MK procedure which is computed for individual locations and results are combined into one overall test for consistent regional trend (Helsel and Frans 2006).

The Regional Seasonal Kendall (RSK) test is a modification of the RK test that accounts for seasonality. Computations for the RSK test, including spatial correlation and incorporation of ancillary variables (e.g., flow adjusted), are given by Sprague and Lorenz (2009). Examples of the application of the RSK tests include detection of regional nutrient trends in streams and rivers (Sprague and Lorenz 2009) and trends in pesticide concentrations in Corn-Belt streams (Sullivan et al. 2009).

For park-wide inference at OLYM and for network-wide inference it is necessary to include strata weights as previously described in Sections E.3 and F.4, above. To accommodate this requirement the individual Mann-Kendall tests can be weighted by strata inclusion probabilities to obtain a weighted, overall Regional Kendall test (D. Helsel, Practical Stats, Highland CO, pers. comm., 1 April 2011).

G. **Step Trend Procedures**

Step trends compare two sets of data for a response variable from non-overlapping time periods at a site. These analyses are more limited in application to this protocol when compared to steady long-term trend procedures. However, they can be useful in interpreting short-term changes occurring over longer records of time and for documenting changes occurring to a response variable following a known event that occurred at a specific time during the record. Example events could include improved access to lake by construction of a new trail resulting in more visitor use, the introduction of a non-native species to a lake, or a natural disturbance such as a mass-wasting event that entered a lake.

The basic parametric test for step trends is the two-sample *t*-test with estimates of change magnitude based on the difference in sample means. The nonparametric alternatives are the Mann-Whitney-Wilcoxon Rank Sum test (Bradley 1968) and the associated Hodges-Lehmann (H-L) estimator of trend magnitude (Hodges and Lehmann 1963). The H-L estimator is the median of all possible differences between data in the "before" and "after" periods. Procedures for adjusting for seasonality and ancillary variables are available for both parametric and nonparametric tests (Helsel and Hirsch 2002). An example plot of the Mann-Whitney-Wilcoxon Rank Sum test is shown in Figure 21.14.

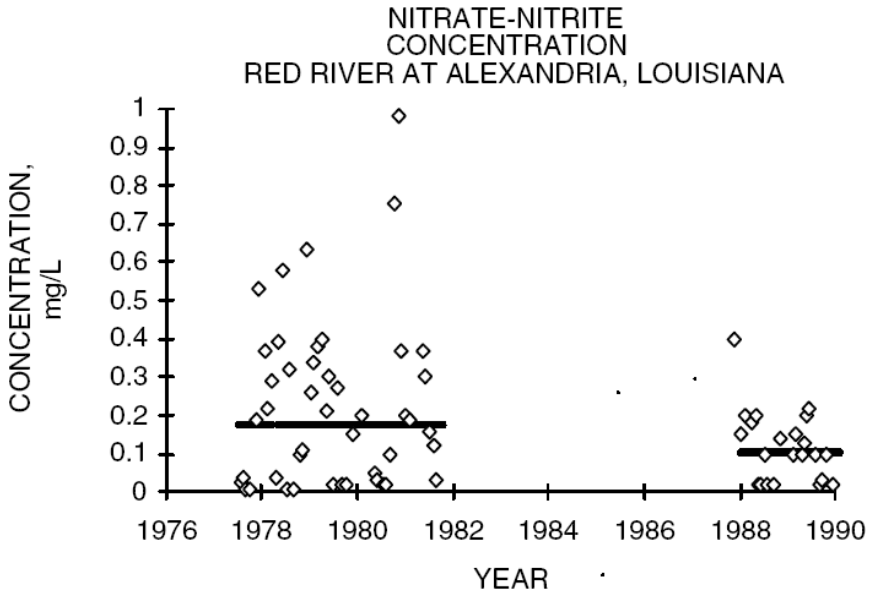


Figure 21.14. Significant step trend (p=0.085) as measured by the rank sum test. Solid lines are group medians. From Hirsch et al. 1991.

Step trend procedures should only be used in two situations. The first is when the records being analyzed are naturally broken into two distinct time periods with a relatively long gap between them. In general, if the within-period trends are small in comparison to the between-period differences (*see* Figure 21.14), then step-trend procedures should be used. In the second situation, a step-trend is used when a known event has occurred at a specific time during the record which is likely to have changed a response variable. The record is first divided into "before" and "after" periods at the time of this known event. It is imperative that the decision to use step trend procedures not be based on examination of the data, or on a computation of the time which maximizes the difference between periods (Helsel and Hirsch 2002).

V. Reporting

The reporting schedule includes production of annual reports and Five-year Summary Reports. Annual Reports will be issued every year after field data collection and sample processing is completed. The Five-year Summary Reports will be completed in the year following each cycle. These reports will contain summaries of information presented in annual reports, as well as results of analyses designed to detect park-wide and network-wide abrupt change, long-term trends, and step trends. The first Five-year Summary Report will include the development of park-specific reference conditions and identification of criteria thresholds for assessments of site-specific and park-wide condition (Section III of this SOP). Criteria and thresholds will be evaluated and revised, if necessary in following Summary Reports. Examples of statistical data summaries and figures that may be included in the reports are found throughout this SOP. A description of the report contents follows:

A. **Annual Reports:**

- Description of the background and objectives.
- List project personnel and their roles.
- List of lakes sampled including location and dates of sampling.
- Provide overview of data collected with references to filenames and data storage locations.
- Description of methods used.
- Routine data summaries and statistics for all response variables (Section I.B and Section II of this SOP).
- Graphical representations of the data and initial exploratory analyses for patterns in the data (Section I.B of this SOP).
- Documentation of any unexpected results or anomalies in the data.
- Describe current status of resource at each site using descriptive statistics and graphical representations of the data (Section IV.D of this SOP).
- Provide park and network-wide summaries of status for key response variables.
- Annually updated graphical depictions of site-specific trend data (Section IV.F and G of this SOP) will be added to the Annual Report following the 5th year of data collection.
- QA/QC compliance and concerns will be documented (*see* SOP 19: Quality Assurance and Control Plan).
- Changes in the protocol will be noted in the annual report and documented in SOP 25: Revising the Protocol.
- Monitoring results and summaries of activities will be communicated with other park and NCCN staff.

B. **Five-year Summary Reports**

- Routine data summary statistics and statistical analyses that normally appear in an Annual Report with the addition of park-wide and network-wide analysis of abrupt change, long-term trends, and step trends (Sections IV.D-G of this SOP).
- Selection of statistical tests following detailed exploratory analysis focused on evaluations of test assumptions and other concerns (missing data, nondetects, seasonality, etc.).
- Examination of relationships between monitoring project response variables and their covariates/explanatory/ancillary variables (Section IV.C, E-G of this SOP).
- Development and revision of reference site groups and criteria thresholds (Section III of this SOP).
- Summary evaluation of QA/QC compliance results (measurement precision, sensitivity, systematic error/bias, cumulative bias, completeness, etc.) and concerns will be documented (SOP 19: Quality Assurance and Control Plan).
- Evaluation of sampling precision (natural and measurement variability) for all response variables and make recommendations concerning future utility of response variables with poor sampling precision.
- Re-evaluation of sample size requirements for detection of trends and estimations of status.
- Changes in the protocol will be summarized in the Five-year Report.

- Acquire project peer review and make necessary changes as needed.
- Develop management and research recommendations.
- Interpret data for public and upper level managers at Park, Network, and National levels.

Reports will be organized and formatted according to NPS Natural Resource Publications Management guidelines (NPS 2010).

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SOP 22: Data Quality Review and Certification

February 28, 2012

Prepared by: John Boetsch NPS NCCN-OLYM.

Revision History Log

Revision Date	Author	Changes Made	Reason for Change

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Data Quality Review and Certification

This SOP describes the procedures for validation and certification of data in the project database. Refer also to protocol narrative Section 4.3, Overview of Database Design, Section 4.5, Quality Review, and Section 4.7, Data Certification and Delivery for related guidance.

A critical part of project quality assurance is the year-end data quality review and certification. After the season's field data have been entered and processed, they need to be reviewed and certified by the Project Lead before they can be used for analysis and reporting. Data validation is the process of rigorously testing data for completeness, structural integrity, and logical consistency. Although the front-end data entry forms have built-in quality assurance measures – such as domain lookup pick lists, defined range limits for numeric data, and checks for missing values – not all errors can be caught during the data entry step. The following are a few of the general sources of data problems that might be identified during the validation:

1. The response design is ambiguous or insufficiently documented to prevent data gaps and logical inconsistencies.
2. There were logistics problems or a change of plans that prevented a complete sample (e.g., weather conditions, staffing changes).
3. Field crew members did not collect or properly record one or more data elements in the field.
4. Data were entered incorrectly or incompletely.
5. Database records were edited incorrectly or deleted after entry.
6. There is a design flaw in the front-end application that causes data errors during or after data entry.

Given the varied sources of data problems, there is a need for a thorough check of data quality on a regular basis as a means of ensuring continued data quality throughout the span of the project. The front-end database application includes a Quality Review Tool to facilitate the review process by showing the results of pre-built queries that check for data integrity, data outliers, missing values, and illogical values. The user may then fix these problems and document the fixes. Not all errors and inconsistencies can be fixed (e.g., missing response variable values), in which case documentation of the resulting errors and why records were not fixed is included in the metadata and certification report.

Once the data have been through the validation process and metadata have been developed for them, the Project Lead should certify the data by completing the NCCN Project Data Certification Form, available on the NCCN website.

Data Quality Review

Validation Queries

The database application has a set of validation checks that are performed on the data set. Each pre-built database query checks for potential problems in the data set, including data outliers, missing values, and illogical values. The set of queries is customized to match project requirements and the structure of the underlying data model. Each query is classified in one of three categories:

1. Critical – These queries check for structural integrity problems or gaps in critical information. This category might include queries that check for missing primary key values, mismatches between data values and lookup domain values, duplicate records, or illogical data combinations. Records returned by these queries fail to meet basic project requirements or structural requirements of the data model, and must be fixed so that they do not return any records before the data can be certified.

2. Warning – These queries represent problems that range in importance, but in any case have the potential to compromise data usability or representativeness if they are not addressed or at least made known to the end user. This category might include queries that check for missing response variables (e.g., substrate or cover class) or values that are beyond a reasonable range; alternatively, it may include queries that require follow-up on data records that can only be done after the field season (e.g., changing status of a monitoring location from "Proposed" to "Active"). The person performing the quality review should make efforts to fix as many of these records as possible by reviewing hard-copy data forms or otherwise following up. However, it may frequently be the case that records in this category cannot be fixed because the reviewer does not have the information needed to fix the record. In such cases the reviewer should provide documentation about which records were not fixed and why using the space provided in the quality review tool (see below). If there are numerous records that cannot be fixed, a general description such as "80 records" or "all lake sites, 43 records", along with a statement of why these were not fixed, will suffice. Documentation will help future data users to know that reasonable efforts were made to address the problems.

3. Information – These queries provide information that can be used to evaluate the completeness and logical consistency of the data set – for example, the number of plots visited per park in a given season, the range of dates for sampling visits, or the number of species recorded during a sampling event. This category may also include checks for missing values in less-vital or optional fields, where a large number of missing values may be anticipated on a regular basis (i.e., as an alternative to making these Warning queries that require follow-through and documentation).

The queries are named and numbered hierarchically so that high-order information – for example, from tables on the parent side of a parent-child relationship such as sample locations – is addressed before low-order information (e.g., individual species observation records). The rationale for this is that one change in a high-order table affects many downstream records, and so proceeding in this fashion is the most efficient way to isolate and treat errors.

The set of queries may need to be augmented or changed as project requirements shift. The Data Manager is also available to revise queries or construct new database queries as needed. Throughout the quality review, the person performing the review should remain vigilant for problems that may not be caught by the validation queries. One task that cannot be automated is the process of making sure that all of the data for the current season are in fact entered into the database. This will often involve manual comparisons between field forms or other lists of the sites visited against the results of queries showing the sites for which data exist.

Using the Quality Review Tool

Open the front-end database application and hit the button labeled "QA checks" to open the quality review form. Upon opening, the quality review form automatically runs the validation queries and stores the results in a back-end database table (tbl_QA_Results). Each time the query results are refreshed, the number of records returned and the run times are updated so that the most recent result set is always available. Reviewer name and remedy descriptions are retained between query runs. Together, these results form the basis of documentation in the certification report output as shown below.

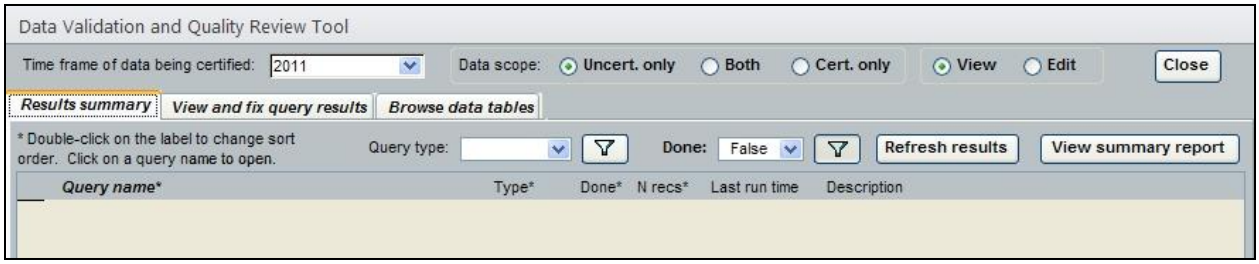
Across the very top of the form are indicators of the time frame (i.e., sample year) and scope of the data being validated. Data scope has three options:

- Uncertified data only (default) – Only uncertified events (i.e., those from the current sampling year) will be considered in validation queries. Note that by design, certain queries will evaluate for problems in records are associated with certified data anyway – for example, all location records are evaluated for duplicate location codes, even those associated only with certified sampling events.
- Both uncertified and certified data – All database records will be included, including certified event data from previous years.
- Certified data only – Only certified events from previous seasons will be considered in the validation queries.

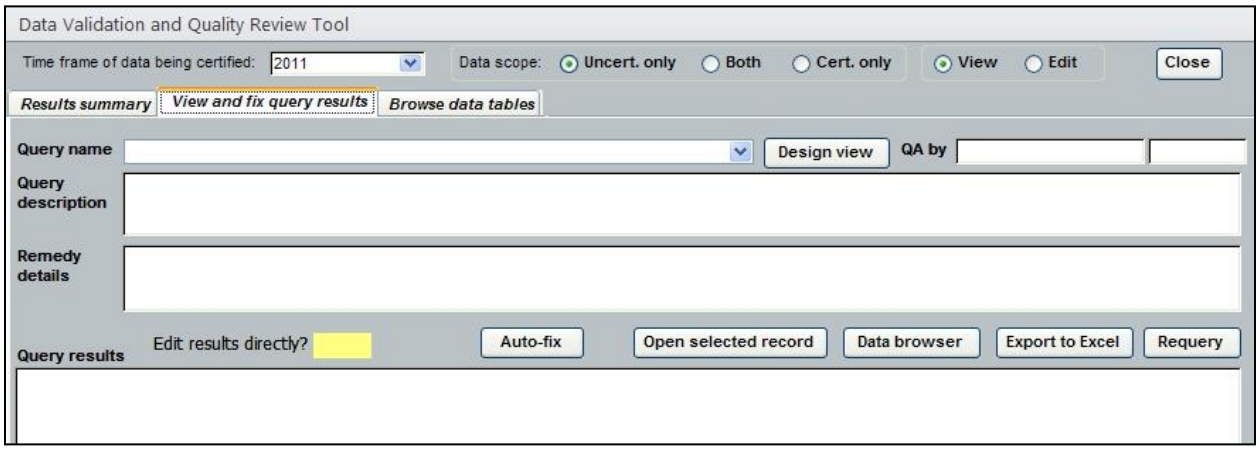
Changing the data scope will show only results for that scope – in other words, results and fixes associated with one scope will be retained even if the scope is changed and the results are refreshed.

The first tab of the quality review form contains a results summary showing each validation query, the type of query (i.e., Critical, Warning or Information), the number of records returned by the query, the most recent query run time, and the description. At the top of the page, there is a button for refreshing the full set of results, which may need to be done periodically as changes in one part of the data structure may change the number of records returned by other queries. Records default to sort by query name, but can be sorted by double-clicking on any of the column headings indicated with an asterisk.

There is also a "Done" checkbox that the reviewer can use as an indicator that they are finished looking at that particular query. Critical and Warning queries that return zero records from the start are automatically set to "Done". The results records may be filtered by query type and/or by whether or not the query has been marked as "Done". Note that updating records in one query may change the number of records returned by another query; if the number of records returned by a query changes, the "Done" indicator will be switched off automatically.



Upon double-clicking a particular query name, the second page will open up to show the results from that query. The "Query description" field will indicate the kind of records returned, and may also include a suggested remedy.



In the upper-right is a switch that allows the user to put the form in either view mode (default) or edit mode. Upon changing to edit mode, the form changes color to provide a visual reminder that edits are possible. At this point the query results may be modified and any documentation may be entered in the "Remedy details" section. If certain records in a query result set are not to be fixed for whatever reason, this is also the place to document that. Reviewer name is automatically filled in (if it was blank) once the user updates the documentation. If the reviewer does not have sufficient information to fix one or more records returned by a query, s/he should describe which records were not fixed and why. If there are numerous records that cannot be fixed, a general description such as "80 records" or "All reconnaissance sites, 43 records", along with a statement of why these were not fixed, will suffice. Documentation will help future data users to know that reasonable efforts were made to address the problems.

Some of the other functions of this second page of the Quality Review Tool:

- Edit results directly? – A flag to indicate whether the results for the selected query can be edited directly inside the query results subform. Queries that contain complex joins, subqueries, or grouping functions cannot be edited directly, and instead must be edited in the original data entry form.
- Auto-fix – A button that runs an action query for bulk updates if such a solution is appropriate and available (e.g., replacing all missing values with a code for "Unknown"). Not all validation queries contain references to a bulk update query.

- Open selected record – Opens the selected record returned by the query in the appropriate form. This is useful for quickly moving to the place where the fix can be made most efficiently and taking advantage of existing quality assurance functionality.
- Data browser – Opens the Data Browser form, which provides comprehensive access to data arranged by sampling location.
- Export to Excel – Exports the validation query results to Excel. This can be helpful when there is a need to follow up on complex problems or to verify that all data have been entered.
- Requery – Reruns the validation query and updates the results set.

On this page is also a button labeled "Design view", which will open the currently selected query in the design interface in Access. In this manner, the user can verify that the query is in fact filtering records appropriately. Note: Please contact the Data Manager before making any changes to query structure or names.

Finally, the third page of the Quality Review Tool is for viewing and editing data tables directly if needed. This page is only available for those with power user or administrator privileges to the database. Important: As with all edits performed during the quality review, these types of direct edits in the data tables should be made with extreme care as many of the quality assurance measures built into the data entry forms are not present in the tables themselves. It is possible, therefore, to make edits to the tables that may result in a loss of data integrity and quality.

Quality Review with NPSTORET Tools

NPSTORET has a number of reporting functions that can be used to facilitate the completion of data quality review.

A random report consisting of 10% of the delineated data can be created using the "Reports and Statistics" tool in NPSTORET. On the "Reports" tab (Figure 22.1), choose "Results" and then choose "Random Sample" of 10% under "Data To Include". Under "Filter Options," select the "Date Ranges" of interest. Finally, click on "View Report" to produce the results. All activities and all characteristics can be included in a single report. The report will identify records requiring the attention of the Project Lead, and the results generated can be used as an aid to producing the NCCN Project Data Certification Form. The Project Lead will make all possible effort to recover missing data and/or information and to correct existing incomplete or inaccurate information which is identified in this report.

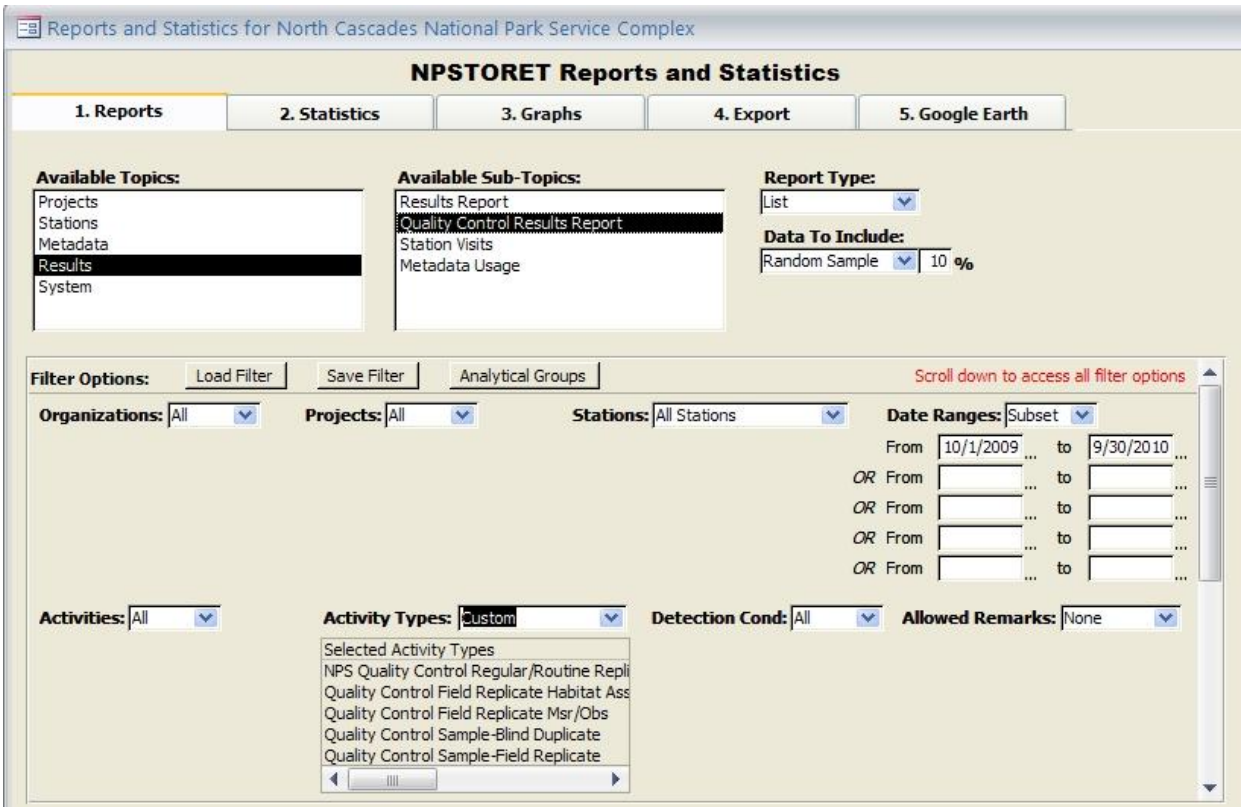


Figure 22.1. Example of how to generate a random report that consists of 10% of data in NPSTORET.

Graphic Data Output

Datasets can be graphed in NPSTORET using the "Reports and Statistics" tool. From the “Graphs” tab, specify the project, station, and date range as shown in Figure 22.2. Once all desired selections are made, click on “Generate Graphs” at the page bottom to bring up a MS Excel worksheet containing the data range and specified graph (Figure 22.3).

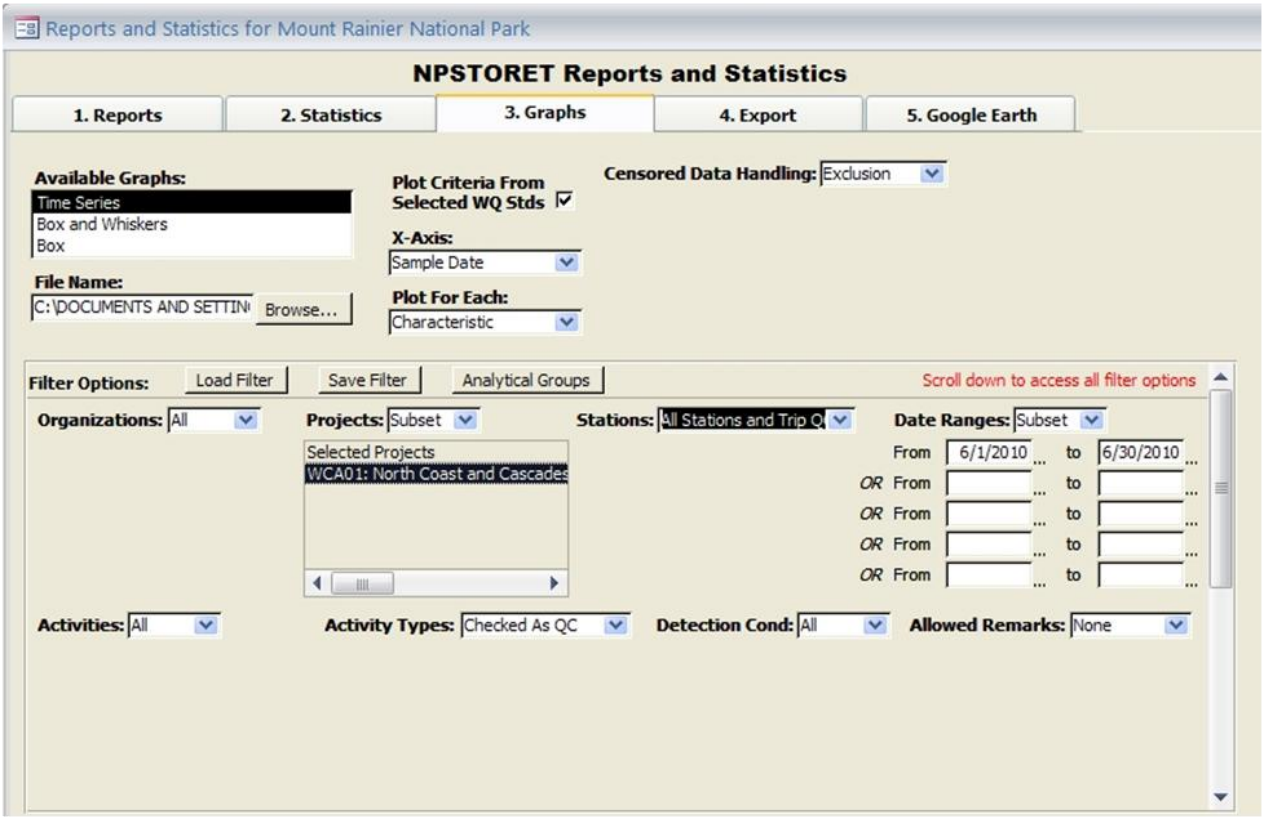
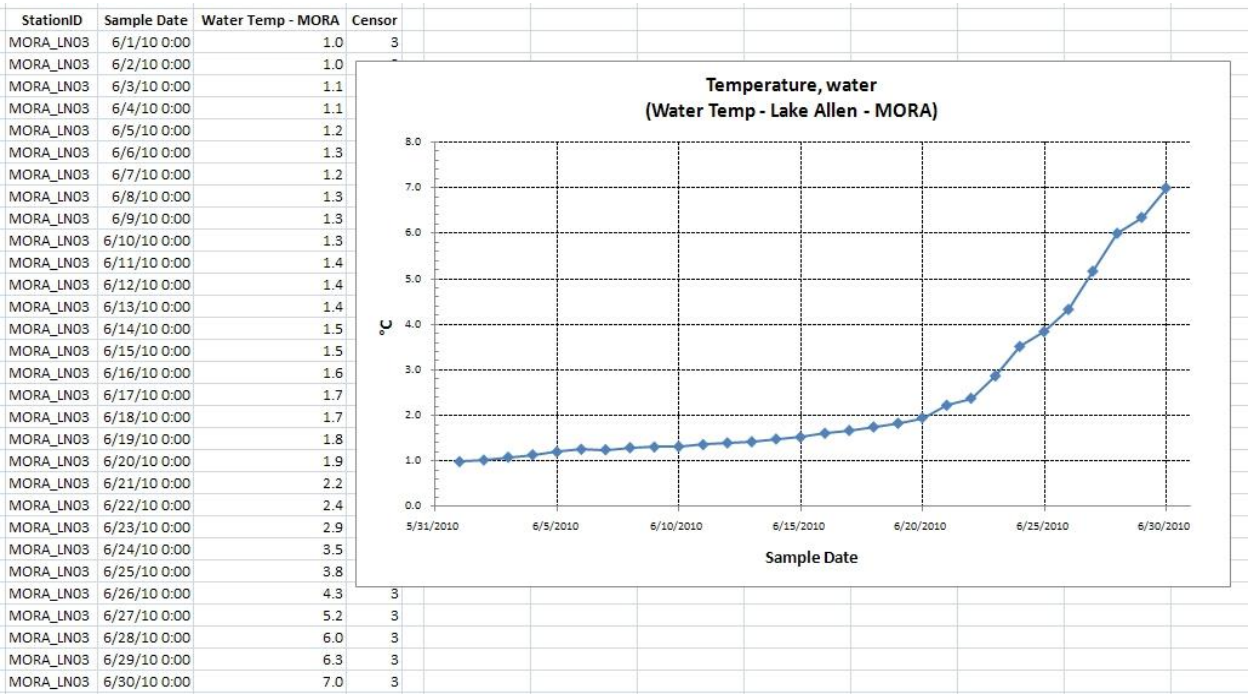


Figure 22.2. Graphing options in the Reports and Statistics tool.



StationID	Sample Date	Water Temp - MORA	Censor
MORA_LN03	6/1/10 0:00	1.0	3
MORA_LN03	6/2/10 0:00	1.0	
MORA_LN03	6/3/10 0:00	1.1	
MORA_LN03	6/4/10 0:00	1.1	
MORA_LN03	6/5/10 0:00	1.2	
MORA_LN03	6/6/10 0:00	1.3	
MORA_LN03	6/7/10 0:00	1.2	
MORA_LN03	6/8/10 0:00	1.3	
MORA_LN03	6/9/10 0:00	1.3	
MORA_LN03	6/10/10 0:00	1.3	
MORA_LN03	6/11/10 0:00	1.4	
MORA_LN03	6/12/10 0:00	1.4	
MORA_LN03	6/13/10 0:00	1.4	
MORA_LN03	6/14/10 0:00	1.5	
MORA_LN03	6/15/10 0:00	1.5	
MORA_LN03	6/16/10 0:00	1.6	
MORA_LN03	6/17/10 0:00	1.7	
MORA_LN03	6/18/10 0:00	1.7	
MORA_LN03	6/19/10 0:00	1.8	
MORA_LN03	6/20/10 0:00	1.9	
MORA_LN03	6/21/10 0:00	2.2	
MORA_LN03	6/22/10 0:00	2.4	
MORA_LN03	6/23/10 0:00	2.9	
MORA_LN03	6/24/10 0:00	3.5	
MORA_LN03	6/25/10 0:00	3.8	
MORA_LN03	6/26/10 0:00	4.3	3
MORA_LN03	6/27/10 0:00	5.2	3
MORA_LN03	6/28/10 0:00	6.0	3
MORA_LN03	6/29/10 0:00	6.3	3
MORA_LN03	6/30/10 0:00	7.0	3

Figure 22.3. North Coast and Cascades Network water temperature graph generated from NPSTORET.

Spatial Data Review

NPSTORET contains a tool for reviewing geospatial records on stations using the Google Earth® application. From the "Station Entry" form, the user can load station coordinate data into Google Earth® to display station plots on a satellite image. The image (Figure 22.4) can be zoomed and multiple stations can be saved and displayed if desired. The shape of the icon used to mark the station location is determined by the Station Primary Type as follows:

- Circle = Well or Spring or Cave or Land
- Square = Lake or Great Lake or Ocean or Reservoir
- Triangle = River/Stream or any other type



Figure 22.4. North Coast and Cascades Network lake site in Google Earth.

Completing Data Certification

Data certification is a benchmark in the project information management process that indicates that the data 1) are complete for the period of record, 2) have undergone and passed the quality assurance checks (protocol Section 4.5), and 3) are appropriately documented and in a condition for archiving, posting, and distribution as appropriate. Certification is not intended to imply that the data are completely free of errors or inconsistencies that may or may not have been detected during quality assurance reviews.

To ensure that only quality data are included in reports and other project deliverables, the data certification step is an annual requirement for all tabular and spatial data. The Project Lead is the primary person responsible for completing an NCCN Project Data Certification Form available

on the NCCN website at: http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm. This brief form and the certified data should be submitted according to the timeline in the annual project task list (Appendix B). Refer to SOP 23: Product Delivery, Posting and Distribution for delivery instructions.

Generating Output for the Certification Report

The first page of the Quality Review Tool in the project database application has a button labeled "View summary report". This button opens the formatted information for each query, the last run time, the number of records returned at last run time, a description and any remedy details that were typed in by the user. This report can be exported from the project database application and included as an attachment to the certification report.

SOP 23. Product Delivery, Posting and Distribution

February 28, 2012

Prepared by: John Boetsch NPS NCCN-OLYM.

Revision History Log

Revision Date	Author	Changes Made	Reason for Change

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Overview

This SOP provides a schedule, product specifications, and instructions for delivering completed data sets, reports, and other project deliverables for long-term storage (see Table 23.1 of this SOP). Details are also provided on posting products to websites and clearinghouses, and on responding to data requests.

Table 23.1. Product Delivery Schedule and Specifications.

Deliverable Product	Primary Responsibility	Target Date	Instructions
Field season report	Lead Technician	November 15 of the same year	Upload digital file in Microsoft Word format to the NCCN Digital Library.
Raw GPS data files	Lead Technician	October 15 of the same year	Store in appropriate sections of the project workspace
Processed GPS data files	GIS Specialist	November 30 of the same year	
Scanned field forms	Lead Technician	November 30 of the same year	Scan original, marked-up field forms as PDF files and store in the project workspace.
Digital photographs	Project Lead	November 30 of the same year	Organize, name and maintain photographic images in the project workspace according to SOP 18: Acquiring and Mananging Photographic Images
Certified back-end database	Project Lead	March 1 of the following year; data are not published until two years after the certification date	Refer to the following sections (of this SOP) on delivering certified data and related materials.
Certified NPSTORET .zip archive	Project Lead		
Certified geospatial data	Project Lead with GIS Specialist		
Data certification report	Project Lead		
Metadata interview form	Project Lead		
Full metadata (parsed XML)	Data Manager and GIS Specialist	July 15 of the following year	Upload the parsed XML record to the NPS Data Store[1].
Annual I&M report	Project Lead	June 30 of the following year	Refer to the following section on reports and publications.
5-year analysis report	Project Lead	Every 5 years by June 30 of the following year	
Other publications	Project Lead	As completed	
Field data forms	Project Lead	Every 6 years by May 31 of the following year	Verify scanned digital copy in project workspace. Hard copy originals go to the Park Curator for archiving 6 years after data collection.
Specimens and collections	Project Lead	November 30 of following year	Label, package and send to Park Curator for archiving. See the section in this SOP on Park Collections.

Table 23.1. Product Delivery Schedule and Specifications (continued).

Deliverable Product	Primary Responsibility	Target Date	Instructions
Other records	Project Lead	Review for retention every January	Retain or dispose of records following NPS Director's Order #19 [2]. Organize and send analog files to Park Curator for archiving. Digital files that are slated for permanent retention should be uploaded to the NCCN Digital Library.

[1] The NPS Data Store is an internet clearinghouse for documents, data and metadata on natural and cultural resources in parks. It is a primary component of the NPS Integrated Resource Information Management Applications (IRMA) portal (http://irma.nps.gov).

[2] NPS Director's Order 19 provides a schedule indicating the amount of time that the various kinds of records should be retained. Available at: http://home.nps.gov/applications/npspolicy/DOrders.cfm.

NCCN Digital Library

The NCCN Digital Library is a document management system maintained in a Microsoft SharePoint environment at: http://imnetsharepoint/nccn/default.aspx. The primary purpose of this system is to maintain important digital files – such as reports, protocol documents, and select project images – within a content management system, and to make them available to NCCN and NPS users. NCCN users may view, post and edit documents within this system; other NPS users have read-only access to these files, except where information sensitivity may preclude general access.

To enable discovery and long-term usability of key documents, certain information about each file needs to be filled in as files are uploaded, for example:

- Document title
- Project code (e.g., "ACa02" for Mountain Lakes Monitoring)
- Park(s) to which the file(s) apply; multiple parks may be selected for each upload
- Document type (e.g., formal report, database, protocol, etc.)
- Date of publication or last revision
- Author name(s)
- Sensitivity: Sensitive, NPS Only, or Public. Sensitive files will not be viewable without permission. For a definition of sensitive information, see Section 4.10, Identifying and Handling Sensitive Information.
- Description - Document abstract, additional authors and credits, special use instructions, etc.

For project staff without access to the NPS intranet, files may be sent by email or CD/DVD to the Project Lead or Data Manager for upload, along with the above information in a text file or accompanying email.

Park Collections

The collections at NOCA will serve as the park of record for the NCCN Water Quality Monitoring Project. Voucher specimens, hardcopy field forms, and printouts of annual reports, technical reports, and other publications will be filed there. In addition, other hard copy project records should be reviewed and organized on an annual basis (or at the conclusion of a project), and sent to park collections for long-term storage.

The Project Lead should contact the Park Curator during the project planning if voucher specimens will be collected. All specimens must be labeled with NPS accession and catalog numbers, and with advance notice the Park Curator can help to provide these numbers ahead of time so they can be included in label printouts. Specimen label information will be entered by the Park Curator into the ANCS+ database. The Park Curator will help to decide which and how many specimens can be maintained at the park versus sent to another institution or collection. Collected materials remain NPS property even if they later reside in a non-NPS collection (e.g., university herbarium).

Delivering Certified Data and Related Materials

Data certification is a benchmark in the project information management process that indicates that the data a) are complete for the period of record, 2) have undergone and passed the quality assurance checks, and 3) are appropriately documented and in a condition for archiving, posting and distribution as appropriate. To ensure that only quality data are included in reports and other project deliverables, the data certification step is an annual requirement for all tabular and spatial data.

The following deliverables should be delivered as a package:

- *Certified back-end database* – Database containing data for the current season that has been through the quality assurance checks documented in SOP 22: Data Quality Review and Certification. Delivery of this item is only applicable in cases where the back-end database is implemented in Microsoft Access and/or is deployed outside the NPS firewall during the quality review. In all other cases, the Data Manager will already have access to the certified data.
- *Certified geospatial data* – GIS themes in ESRI shapefile or geodatabase format. Refer to NCCN GIS Development Guidelines (NCCN 2009) and NCCN GIS Product Specifications (NCCN 2007a) for more information (available at on the NCCN website at: http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm).
- *Data certification report* – A brief questionnaire in MS Word that describes the certified data product(s) being submitted. A template form is available on the NCCN website at: http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm.
- *Metadata interview form* – The metadata interview form is an MS Word questionnaire that greatly facilitates metadata creation. It is available on the NCCN website at: http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm. For more details, refer to Section 4.6, Metadata Procedures.

Packaging Certification Materials for Delivery

After the quality review is completed, the Project Lead should package the certification materials for delivery as follows:

1. Create a compression file (using WinZip® or similar software, or by right-clicking in Windows Explorer). This file should be named in accordance with general file naming standards, and the name should include the project code (ACa02), park code if applicable, and the year or span of years for the data being certified. For example: ACa02_2012_certification_pkg.zip.
2. Add the back-end database file to the compression file. Note: NPSTORET automatically creates a .zip format backup file every time a user closes the application (**Note**: this is an option that needs to be set from the 'set defaults' utility). This file includes a copy of the back-end, including any associated images and documents, and is placed in the network 'backups' subfolder of the NPSTORET application. The front-end application does not contain project data and as such should not be included in the delivery file.
3. Add the completed metadata interview and data certification forms to the compressed file. Both files should be named in a manner consistent with the naming conventions described elsewhere in this document.
4. Add any geospatial data files that aren't already in the possession of the GIS Specialist. Geospatial data files should be developed and named according to NCCN GIS Naming Conventions (NCCN 2007b).
5. Deliver the compressed file containing all certification materials to the \Data\Archive folder of the project workspace and notify the Data Manager by email. If the Project Lead does not have network access, then certification materials should be delivered as follows:
   a. If the compressed file is under 9 mb in size, it may be delivered directly to the Data Manager by email.
   b. If the compressed file is larger than 9 mb, it should be copied to a CD or DVD and delivered in this manner. Under no circumstances should products containing sensitive information be posted to an FTP site or other unsecured web portal. For more information refer to Sensitive Information Procedures at http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm).

Upon receiving the certification materials, the Data Manager will:

1. Review them for completeness and work with the Project Lead if there are any questions.
2. Check in the delivered products using the NCCN project tracking application.
3. Notify the GIS Specialist if any geospatial data are submitted. The GIS Specialist will then review the data, update any project GIS data sets and metadata accordingly, and file those products in the project workspace.
4. Work with the GIS Specialist to finalize coordinate data and any GIS-derived fields therein (e.g., elevation, slope, aspect).
5. Archive the certified products in the project workspace.
6. Notify the Project Lead that the year's data have been successfully reviewed and processed. The Project Lead may then proceed with data summarization, analysis and reporting.
7. Develop, parse and post the XML metadata record to the NPS Data Store.

8. After a holding period of two years, the Data Manager will upload the certified data to the NPS Data Store. This holding period is to protect professional authorship priority and to provide sufficient time to catch any undetected quality assurance problems.

No sensitive information (e.g., information about the specific nature or location of protected resources) may be posted to the NPS Data Store or any other publicly-accessible website, or otherwise shared or distributed outside NPS without a confidentiality agreement between NPS and the agency, organization, or person(s) with whom the sensitive information is to be shared. Only products that are intended for public/general-use may be posted to public websites and clearinghouses – these may not contain sensitive information.

Instructions for Reports and Publications

Annual reports and trend analysis reports will use the NPS Natural Resource Publications template, a pre-formatted Microsoft Word template document based on current NPS formatting standards. Annual reports will use the Natural Resource Technical Report (NRTR) template, and trend analysis and other peer-reviewed technical reports will use the Natural Resource Report (NRR) template. These templates and documentation of the NPS publication standards are available at: http://www.nature.nps.gov/publications/NRPM/index.cfm.

The procedures for annual reports, technical reports, and publications are as follows. (Note: This is optional for field season reports, which are intended to be internal communications only.)

1. The Project Lead or Data Analyst formats the document according to the NPS Natural Resource Publications standards.
   a. Formatting according to NPS standards is easiest when using the report template from the very beginning, as opposed to reformatting an existing document.
   b. When creating the file, use appropriate naming standards (described in this document). If creating the document in SharePoint (e.g., the NCCN Digital Library), attribute the file as a draft; otherwise add "DRAFT" to the file name.
   c. Open the document and add "DRAFT" to the header or document watermark as appropriate.
2. The document should be peer reviewed at the appropriate level. For example, I&M Annual Reports should be reviewed by other members of the project work group. The Network Program Manager will also review all annual reports for completeness and compliance with I&M standards and expectations. Before sending the document for review, rename the document by adding a date stamp to the end of the file name using the YYYYMMDD format.
3. Upon completing the peer review, the Project Lead should acquire a publication series number from the appropriate regional or national key official. Instructions for acquiring a series number are available at: http://www.nature.nps.gov/publications/NRPM/index.cfm.
4. The Project Lead should finalize the document:
   a. Ensure that the publication/version date (last saved date field code in the document header, if used) and file name (field code in the document footer, if used) are updated properly throughout the document.
   b. Remove the word "DRAFT" from watermarks, document headers, and file name.
   c. Remove any previous date stamp from the file name.

d. If the document has been developed and maintained in SharePoint (e.g., the NCCN Digital Library), update the document attribute to "Final".
e. To avoid unplanned edits to the document, reset the document to read-only by right-clicking on the document in Windows Explorer and checking the appropriate box in the Properties popup.
f. Create a PDF version of the document and upload the final file and PDF copy to the NCCN Digital Library for long-term storage.
g. Store both the Word document and PDF copy in the appropriate section of the project workspace (see SOP 2).

5. Notify the Park Curator and Data Manager that the report is available, and send a printout to the Park Curator to add to the host park collections.
6. The Data Manager (or a designee) will create a bibliographic record and upload the PDF copy to the NPS Data Store according to document sensitivity.

File Naming Standards

Prior to delivering or uploading digital products, files should be named according to the naming conventions appropriate to each product type.

Reports and Publications

- No spaces or special characters in the file name.
- Use the underbar ("_") character to separate file name components.
- Try to limit file names to 30 characters or fewer, up to a maximum of 50 characters.
- Dates should be formatted as YYYYMMDD.
- As appropriate, include the project code (e.g., "ACa02"), network code ("NCCN"), and year in the file name.

Examples:

- NCCN_ACa02_2012_Annual_report.pdf
- NCCN_ACa02_2012_Field_season_report.doc
- NCCN_ACa02_2012_Certification_report.doc

Other Files

General naming standards as described in SOP 2 apply to all deliverables. When delivering files to the NCCN Digital Library, file names should be modified as needed to include the project code (e.g., "ACa02"), network code ("NCCN") or park code, and year as appropriate (e.g., NCCN_ACa02_2012_cert_package.zip). Specific standards for images are described in SOP 18: Acquiring and Managing Photographic Images, and in SOP 25: Revising the Protocol for protocol documents.

Product Posting

Once digital products have been delivered and processed, the Data Manager or a designee will post them to or otherwise update the following applications to make them generally available:

1. The NPS Data Store is an internet clearinghouse for documents, data and metadata on natural and cultural resources in parks. It is a primary component of the NPS Integrated Resource Management Applications (IRMA) portal (http://irma.nps.gov). Refer to the section on sensitive information in Section 4.10, Identifying and Handling Sensitive Information for information on options for flagging products containing sensitive information within the system, or for modifying products prior to posting so that they no longer contain sensitive information and can therefore be shared broadly. Full metadata records will be posted to the NPS Data Store as they are created; data sets will be posted after a two-year hold to protect professional authorship priority and to provide sufficient time to catch any undetected quality assurance problems. For reports and other publications, an online record is created after first verifying that one does not already exist. The digital report file in PDF format is then uploaded.

2. The EPA STORET Data Warehouse (http://www.epa.gov/storet/dw_home.html) is an online system for nation-wide water quality data collected by states, federal agencies, volunteer monitoring groups, and other entities. Under the Clean Water Act, states are responsible for ensuring that waters within their boundaries (including waters in National Park units) meet or exceed their designated beneficial uses. On an annual basis, after data certification, the NCCN NPSTORET database file(s) will be sent to the NPS Water Resources (WRD) staff contact who will quality check the data and, in consultation with the Project Lead, make any edits/modifications necessary to upload the data into the WRD copy of STORET. If necessary – due to data revisions or back-end version upgrades – WRD will return a revised version of the data in NPSTORET to NCCN. On a monthly basis, WRD will transmit data to the EPA for inclusion in the STORET Data Warehouse, where the data will be accessible to the states, other entities, and the public via the internet.

3. NPSpecies is the NPS database and application for maintaining park-specific species lists and observation data, and is also a component of the IRMA portal (http://irma.nps.gov). Species observations will be extracted from project data sets and uploaded into NPSpecies.

4. NCCN Web Site is maintained by NCCN staff as part of the NPS Inventory and Monitoring web site (http://science.nature.nps.gov/im/units/nccn) to describe our program, the vital signs selected for monitoring, and to highlight certain products and information derived from inventory and monitoring work at NCCN. The site has both internet and intranet components. Select products such as annual reports and technical reports will be posted to the web site.

These applications serve as the primary mechanisms for sharing reports, data, and other project deliverables with other agencies, organizations, and the general public.

Holding Period for Project Data

To protect professional authorship priority and to provide sufficient time to complete quality assurance measures, there is a two-year holding period before posting or otherwise distributing certified project data. This means that certified data sets are first posted to publicly-accessible

websites (i.e., the NPS Data Store and EPA STORET) approximately 24 months after they are certified (e.g., data collected in June 2012 and certified in January 2013 becomes generally available through the NPS Data Store in January 2015). In certain circumstances, and at the discretion of the Project Lead and Park Biologists, data may be shared before a full two years have elapsed. (**Note**: This hold only applies to raw data, and not to metadata, reports or other products which are to be posted to NPS clearinghouses in a timely manner as they are received and processed.)

Responding to Data Requests

Occasionally, a park or project staff member may be contacted directly regarding a specific data request from another agency, organization, scientist, or from a member of the general public. The following points should be considered when responding to data requests:

- For all Inventory and Monitoring projects in NCCN, NPS is the originator and steward of the data, and the NPS Inventory and Monitoring Program should be acknowledged in any professional publication using the data.
- NPS retains distribution rights; copies of the data should not be redistributed by anyone but NPS.
- The data that project staff members and cooperators collect using public funds are public records and as such cannot be considered personal or professional intellectual property.
- No sensitive information (e.g., information about the specific nature or location of protected resources) may be posted to the NPS Data Store or any other publicly-accessible website, or otherwise shared or distributed outside NPS without a confidentiality agreement between NPS and the agency, organization, or person(s) with whom the sensitive information is to be shared. Refer to the section in this document about sensitive information and also to http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm.
- For quality assurance, only the certified, finalized versions of data sets should be shared with others. In exceptional cases where a provisional data set needs to be shared with others prior to certification:
    - Any accompanying communications should clearly indicate that the data set is provisional and subject to change according to our quality review process.
    - File names and the media it is sent on should be clearly labeled as containing provisional data not for distribution.

The Project Lead will handle all data requests as follows.

1. Discuss the request with other network and park staff members (e.g., Park Biologists) as necessary to decide on an appropriate response to the request.
2. Notify the Data Manager if s/he is needed to facilitate fulfilling the request in some manner.
3. Respond to the request in an official email or memo.
4. In the response, refer the requestor to the NPS Data Store and the IRMA Portal (http://irma.nps.gov), so they may download the necessary data and/or metadata. If the request cannot be fulfilled in that manner – either because the data products have not been posted yet or because the requested data include sensitive information – work with

the Data Manager to discuss options for fulfilling the request directly (e.g., writing data to CD or DVD). Ordinarily, only certified data sets should be shared outside NPS.

5. It is recommended that documents be converted to PDF format prior to distribution. This is to maximize portability and to reduce the ability for others to alter and redistribute files.
6. If the request is for data that may reveal the location of protected resources, refer to Section 4 (below) and the Sensitive Information Procedures at: http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm.
7. After responding, provide the following information to the Data Manager, who will maintain a log of all requests in the NCCN project tracking database
    - Name and affiliation of requestor
    - Request date
    - Nature of request
    - Responder
    - Response date
    - Nature of response
    - List of specific data sets and products sent (if any)

Freedom of Information (FOIA) Requests

All official Freedom of Information Act (FOIA) requests will be handled according to NPS policy. The Project Lead will work with the Data Manager and the park FOIA representative(s) of the park(s) for which the request applies.

Special Procedures for Sensitive Information

Products that have been identified upon delivery by the Project Lead as containing sensitive information will normally be revised into a form that does not disclose the locations of protected resources, most often by removing specific coordinates and only providing coordinates that include a random offset to indicate the general locality of the occurrence. If this kind of measure is not a sufficient safeguard given the nature of the product or the protected resource in question, the product(s) will be withheld from posting and distribution.

If requests for distribution of the unedited version of products are initiated by the NPS, by another federal agency, or by another partner organization (e.g., a research scientist at a university), the unedited product (e.g., the full data set that includes sensitive information) may be shared only after a confidentiality agreement is established between NPS and the agency, organization, or person(s) with whom the sensitive information is to be shared. Refer to Section 4.10, Identifying and Handling Sensitive Information for additional details.

Documenting Sample Transfer

1. Lead Technicians fill out the chain-of-custody (COC) forms that include the following from Appendix C: Field and Laboratory Data Forms. The COC form is used to document the taking, shipment, and receipt of samples. The laboratory will use the COC forms to check samples into the analytical process.

a. Chlorophyll-a Sample Shipping Log
b. Water Chemistry Sample Shipping Log
c. Zooplankton Sample Shipping Log
d. Lake BMI Sample Processing Bench Sheet

2. The contracted laboratory will maintain custody logs sufficient to track each sample submitted.

3. COC documentation will be maintained by the Project Lead. The COC will include not only the form, but all references to the sample in any form, document, or log book that allow tracing the sample back to its collection, and documents the possession of the samples from the time they were collected until the sample analytical results are received.

Annual Data Transfer to WRD STORET

Overview

Annual transfer of the NPSTORET park master versions and associated files to NPS WRD satisfies the Natural Resource Challenge-Water Quality STORET reporting requirement. Public distribution as well as long-term archival of water quality data, is provided by the NPS WRD STORET database and the National EPA STORET Data Warehouse and their associated online interfaces.

Upon completing data certification, the Project Lead will work with the Data Manager to submit a copy of the certified NPSTORET data file to NPS WRD. The submission will include the necessary information resources that are not stored within the NPSTORET database, such as images and reference documents. A copy of the submitted master data file at each park will be archived in the project workspace. NPS WRD staff will normally return the park's validated master WQ data file between one and three weeks after submission. During this period they will communicate as required with project staff and the Data Manager to address errors and/or issues, and they will upload the validated data to WRD STORET (an NPS database instance of STORET). Once the data is in WRD STORET, it is harvested every month to populate and/or update the EPA STORET Data Warehouse.

Data Transfer to WRD

The following steps are recommended to accomplish the annual submission and return process:

1. Perform validation and data flagging procedures on preliminary data
2. Complete data certification.
3. Retrieve the backup file from the NPSTORET ‘backup’ folder
4. Rename the archived file ‘NCCN_NPSTORET_yyyy_WRD_submitted<mm_dd_yyyy>.zip’ where ‘yyyy’ is the sampling year
5. Forward a copy of the archived file to WRD
6. Set read-only permission for the archived data file in the NPSTORET folder; this file serves as a record of what has been submitted to WRD
7. Set read-only permission for the master back-end data file in the NPSTORET folder

8. Upon return of the validated data file from WRD, replace the master file with the validated file
9. Update any analysis and reporting based on corrections made by WRD

References

North Coast and Cascades Network (NCCN). 2007a. GIS Product Specifications. USDI National Park Service. Available at: http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm.

North Coast and Cascades Network (NCCN). 2007b. GIS Naming Conventions. USDI National Park Service. Available at: http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm.

North Coast and Cascades Network (NCCN). 2009. GIS Development Guidelines. USDI National Park Service. Available at: http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm.

SOP 24: Field and Laboratory Safety

April 19, 2011

Prepared by: Barbara Samora, NPS NCCN-MORA, and Reed Glesne, Hugh Anthony, and Ashley Rawhouser, NPS-NCCN NOCA.

Revision History Log

Revision Date	Author	Changes Made	Reason for Change

Suggested citation:
Samora, B. A., R. S. Glesne, H. Anthony, and A. K. Rawhouser. 2011. Standard Operating Procedure 24: Field and Laboratory Safety. *In* Glesne, R. S., S. C. Fradkin, B. A. Samora, J. R. Boetsch, R. E. Holmes and B. Christoe. 2012. Protocol for long-term monitoring of mountain lakes in the North Coast and Cascades Network: Version July 9, 2012. Natural Resource Report NPS/NCCN/NRR—2012/549. National Park Service, Fort Collins, Colorado.

Field and Laboratory Safety

A. **Overview**

Assembling a field crew of safe and responsible individuals is a top priority of the Project Leads and Field Leads. Field Leads should be experienced field technicians. Crew members should be capable of living and working cooperatively with others under often stressful and challenging conditions in rugged and isolated areas for extended periods. Under these conditions, risk of personal injury increases and crews are often hours or days removed from emergency medical help. Although the field crew's primary objective is to gather data at mountain lakes, individuals are responsible for personal safety and the safety of other crew members while maintaining positive work relationships. In addition to field safety, laboratory procedures have been developed to ensure sample analyses are conducted in a safe manner.

Field and laboratory procedures will be conducted in accordance with park and NPS safety requirements including the following topics found in Appendix G:

- Job Hazard Analysis
- Helicopter Operations and Safety (NOCA)
- Backcountry Travel and Radio Communication Procedures (MORA, NOCA, OLYM)
- Backcountry Situational Awareness and Risk Management.

In addition, Hazard Communication and Chemical Hygiene Plans for MORA, NOCA, and OLYM are maintained at Park Headquarters. Comprehensive project pre-season safety training will be conducted and documented and safety tailgate sessions will be held during the field season.

B. **Access to Sampling Sites**

Management regulations of National Parks and Wilderness Areas exclude the use of off-road mechanized transportation (e.g., motorcycles and bicycles), so hiking is the primary method used for accessing backcountry montane lakes. Potential obstacles to safe and easy access to backcountry lakes include: 1) ruggedness of terrain, 2) vagaries of summer weather in montane areas (especially, early and late summer snowstorms and thunderstorms), and 3) time of lake ice-out. Safety related information pertinent to backcountry travel is found in Appendixes G, Table G-1, and Attachments 3-6.

Hiking several miles with heavy packs is necessary to reach most lakes. At NOCA, helicopter use is accepted and is used to reach some sites (*see* Appendix G, Attachments 1-2). Field personnel must be competent in basic wilderness survival skills in order to be fully prepared to handle all conditions and situations that may arise. Safety tailgate sessions are presented at the beginning of and during the field season, covering topics such as prevention of overuse injuries, safe stream crossing, thermoregulation, physical response to cold, hypothermia, frostbite, insulation qualities of clothing types, and bear and mountain lion safety.

Field personnel must be competent at map reading, compass and GPS use, and orienteering because cross-country hiking is frequently required to reach field sites. Field personnel must determine and mark on a topographic map the exact location at which unmapped lakes were

sampled; use maps, landmarks and compasses to locate and travel to field sites where no trails exist; and determine the orientation of field sites. Personnel must also be prepared to navigate in poor weather conditions, and so must be proficient in the use of a compass. Competency in these skills is essential for safe wilderness travel. Field personnel will also be trained in proper radio communication procedures.

C. **Sampling Crew Safety**

A three- or four-person crew is generally adequate for safe and efficient sampling of most mountain lakes. However, a five or six-person crew is preferable for transporting necessary field equipment and personal gear to backcountry sampling sites. Additional crew members may be needed periodically if the amount or weight of equipment increases due to additional sampling needs or extended periods in the field.

All crew members working in inflatable boats will wear a life vest while working on the lake. Snorkelers will always work with one or two other crew members and will take care to continually assess their personal safety and protection from hypothermia and other hazards. Samplers will exercise extreme caution in selecting foot placements and in movement when conducting field sampling at night or in poor light. A headlamp will be used to allow freedom of hand movement for balance and for handling instruments.

Safety training increases the safety awareness of crew members and prepares them for responding to potential medical emergencies. Each crew member should be trained, skilled, and/or certified in:

- Basic first aid and cardiopulmonary resuscitation (CPR);
- Swimming;
- Backpacking skills, wilderness survival, and orienteering;
- Use of handheld communication devices;
- Aircraft safety awareness;
- Boat safety as related to the use of inflatable boats, and occasionally other types of hand-propelled boats;
- Bear safety and food handling.

Crew members also will be oriented to and trained in the safe and proper use of sampling equipment and chemicals to be used for water-quality analysis or organism preservation.

D. **Crew Safety Training**

Crew training will include development and completion of a Job Hazard Analysis (JHA) for each task performed including packing equipment, transporting equipment to a field site, work at a field site, return trip, and processing samples in the park laboratory (*see* Appendix G, Table G-1). Each field crew member is responsible for completing and documenting monthly "safety tailgate" sessions during the field season. Crews will be required to have a park safety orientation, training in use of radios, safe river crossing, vehicles, accident and injury prevention, accident reporting, map, compass, GPS use, and laboratory safety including safe handling of chemicals and use of Material Safety Data Sheets (MSDS) information.

E. **Laboratory Safety**

Analysis of lake samples will be conducted in accordance with park safety plans and guidelines (Chemical Hygiene Plan, Hazard Communication). Material Safety Data Sheets (MSDS) are detailed informational documents which describe the physical and chemical properties of hazardous chemicals. These documents are prepared by the manufacturer of the chemicals. The Hazard Communication Standard (Federal Standard 29 CFR 1910.1200 or for Washington State WAC 296-62-054) also known as the "Right -to-Know" law enacted in 1985 sets forth the following requirements,

1. It is the responsibility of the *manufacturer* of a material to determine what hazards are associated with the material, to prepare an MSDS for the material, and to provide the MSDS to any recipients of the material.

2. It is the responsibility of an *employer* to provide MSDS and training in their interpretation to the employees. MSDS for hazardous materials must be readily available in the workplace.

3. It is the responsibility of the *employees* to read and understand the MSDS's of any chemicals used on the job.

Chemical Hygiene Plans with MSDS for every chemical used as a part of this monitoring project will be kept on file in the park laboratories for all crew members to review at the beginning of and during the sampling season.

SOP 25: Revising the Protocol

April 19, 2011

Prepared by: John Boetsch NPS NCCN-OLYM, Ronald Holmes, NPS NCCN-NOCA, and Bret Christoe, NPS NCCN-MORA.

Revision History Log

Revision Date	Author	Changes Made	Reason for Change

Suggested citation:
Boetsch, J. R, R. E. Holmes, and B. Christoe. 2011. Standard Operating Procedure 25: Revising the Protocol. *In* Glesne, R. S., S. C. Fradkin, B. A. Samora, J. R. Boetsch, R. E. Holmes and B. Christoe. 2012. Protocol for long-term monitoring of mountain lakes in the North Coast and Cascades Network: Version July 9, 2012. Natural Resource Report NPS/NCCN/NRR—2012/549. National Park Service, Fort Collins, Colorado.

Revising the Protocol

Overview

This document explains how to make and track changes to the NCCN Mountain Lakes Monitoring Protocol, including its accompanying SOPs. Project staff should refer to this SOP whenever edits are necessary, and should be familiar with the protocol versioning conventions in order to identify and use the most current versions of the protocol documents. Required revisions should be made in a timely manner to minimize disruptions to project operations.

Peer Review

This protocol attempts to incorporate the best and most cost-effective methods for monitoring and information management. As new technologies, methods, and equipment become available, this protocol will be updated as appropriate, by balancing current best practices against the continuity of protocol information.

All edits require review for clarity and technical soundness. Small changes to existing documents – e.g., formatting, simple clarification of existing content, minor changes to the task schedule or project budget, or general updates to information management SOPs – may be reviewed in-house by project and NCCN staff. However, changes to data collection or analysis techniques, sampling design, or response design are usually more significant in scope and impact and will typically trigger an outside review to be coordinated by the Pacific West Regional Office of the National Park Service.

Document Life Cycle

Protocol documents may be maintained as separate files for each component (e.g., narrative, SOPs, appendices in separate document files) or unified into a single document file. During its life cycle, each document file can be classified in one of six life cycle stages:

1. Draft documents – Documents that have been drafted or revised but have not been reviewed and approved yet.
2. Review documents – Draft documents that have been sent out for peer review or administrative review.
3. Active documents – The current, reviewed and accepted version of each protocol component in Microsoft Word format. These documents have been reviewed and approved at the appropriate level, and are currently implemented for active monitoring projects.
4. Inactive documents – Older versions of approved protocol components that are no longer in active implementation.
5. Archived documents – Comprehensive set of active protocol components plus older, inactive versions of approved protocol components in Microsoft Word format. These are stored as read-only and have a date stamp to identify their approval date. The history of the protocol versions through time should be entirely traceable from within the document archive.

6. Distribution copies – PDF versions of approved, date-stamped protocol components, used to post to websites or otherwise share outside NPS.

Protocol documents are stored in the project workspace in separate subfolders named for each life cycle stage, except for inactive documents which are filed together with date-stamped copies of active documents in the archive folder. See SOP 2: Project Workspace and Records Management, for additional details about the project workspace.

Document Versioning Conventions

Rather than using a sequential numeric versioning convention, we use date stamps to distinguish document versions because they are more intuitive and informative than version numbers. Date stamps are embedded within the document header and are also included in the document name.

Document Header

Within each document, the upper right section of the document header should show the date that the document was last saved. By using save date instead of current date, printouts and document previews will show the correct version number. The following is the field code to be used within the header to indicate the version number:

SAVEDATE } \@ "MMMM d, yyyy"

File Naming Conventions

All documents *except for active documents and draft documents* should include the last edit date as a suffix, using the YYYYMMDD format so that documents will sort by date rather than month or day (e.g., NCCN_Mountain_Lakesy_Protocol_DRAFT_20100923.doc for the review draft on 9/23/2010).

Active documents and draft documents that have not been shared with others (as review documents) should not include the date because – unlike documents in other life cycle stages – they are not "point in time" document snapshots. By omitting the date stamp from these documents, they can more easily be distinguished from review drafts and archive or distribution copies. Draft documents should clearly contain the word "DRAFT" in the file name.

Revision Procedures

Proposed changes to protocol components should be discussed among project staff prior to making modifications. It is especially important to consult with the Data Manager prior to making changes because certain types of changes may jeopardize data set integrity unless they are planned and executed with the continuity of the data set in mind. Because certain changes may require altering the database structure or functionality, advance notice of changes is important to minimize disruptions to project operations. Consensus should be reached on who will be making the agreed-upon changes and in what timeframe.

The protocol narrative contains a Revision History Log, located just before the narrative ‘Introduction,’ that will be filled out each time the narrative or any SOP is revised to document when and why the change was made, who authored the change, and to assign a new Version

Date to the revised protocol or SOP. Each SOP also has its own Revision History Log with the same fields to be populated. The new version of the protocol narrative and/or SOP will then be archived in the project workspace in the appropriate folder as well as in NCCN Digital Library.

Note: A change in one document may also necessitate other changes elsewhere in the protocol. For example, a change in the narrative may require changes to several SOPs; similarly renumbering an SOP may mean changing document references in several other sections of the protocol. The project task list and other appendices also may need to be updated to reflect changes in timing or responsibilities for the various project tasks.

The Project Lead is the primarily responsible for making edits and ensuring document review at the appropriate level. The process for creating and revising protocol documents is shown in Figure 25.1, and outlined below:

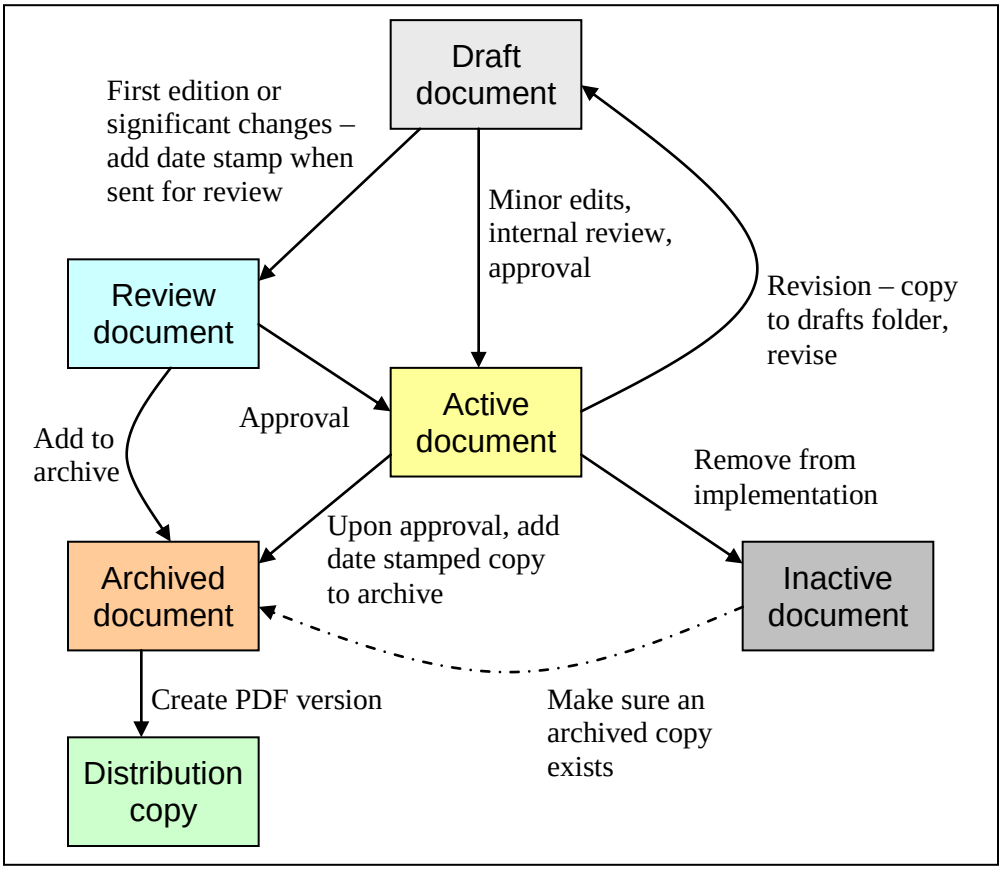


Figure 25.1. Process for creating and revising protocol documents. Boxes represent document life cycle stages, and connecting arrows indicate procedures.

1. Create the draft document in Microsoft Word format. If modifying an existing document (usually an active document), copy the document to the draft document folder, remove any date stamp from the name. Add "DRAFT" to the file name. Open the document and add "DRAFT" to the header or document watermark as appropriate.

2. Track revision history. If modifying an existing document, document all edits in the Revision History Log embedded in the protocol narrative and each SOP. Log changes only for the section of the document being edited (i.e., if there is a change to an SOP, log those changes only in the revision history log for that SOP). Record the date of the changes (i.e., the date on which all changes were finalized), author of the revision, describe the change and cite the paragraph(s) and page(s) where changes are made, and briefly indicate the reason for making the changes.

3. Document review. Circulate the changed document for internal review among project staff and cooperators. If the changes are significant enough to trigger peer review (as defined above), create a review document by adding a date stamp to the end of the file name using the YYYYMMDD format, copy the file to the archive folder, and submit the document for peer review according to current instructions.

4. Finalize and archive. Upon approval and final changes:
    a. Ensure that the version date (last saved date field code in the document header) and file name (field code in the document footer, if used) are updated properly throughout the document.
    b. Move the approved document to the active folder. Remove the word "DRAFT" from watermarks, document headers, and file name. Remove any previous date stamp. This is now an active, implemented document.
    c. To avoid unplanned edits to the document, reset the document to read-only by right-clicking on the document in Windows Explorer and checking the appropriate box in the Properties popup.
    d. Create a copy of the file and add the revision date to the end of the file name using the YYYYMMDD format. Move this copy to the archive folder.
    e. Inform the Data Manager so the new version number can be incorporated into the project metadata.

5. Create distribution copies. As needed, create a PDF version of the archived document to post to the internet and share with others. These PDF versions should have the same date-stamped name as the archived Microsoft Word file. Post the distribution copy to the NCCN Digital Library and forward copies to all individuals who had been using a previous version of the affected document.

6. Remove from implementation. If it is decided that a document needs to be removed from implementation – either because it is no longer necessary (e.g., an unneeded SOP), or because it has been superseded by a more recent version – this can be easily done by removing the document from the active document folder, after first checking that a copy of that version already exists in the archive folder.

Appendices

Appendix A. Roles and Responsibilities.

Table A-1. Roles and responsibilities for Mountain Lakes Monitoring Project.

Role	Responsibilities	Name / Position
Project Lead	• Project oversight and administration • Project operations and implementation • Track project objectives, budget, requirements, and progress toward meeting objectives • Coordinate and ratify changes to protocol • Train and ensure safety of field crew members • Certify each season's data for quality and completeness • Perform data summaries and analyses, interpretation and report preparation • Complete reports, metadata, and other products according to schedule • Maintain and archive project records	Reed Glesne, Aquatic Ecologist, NOCA; Barbara Samora, Aquatic Biologist, MORA; Steven Fradkin, Aquatic Ecologist, OLYM
Data Analyst	• Perform data summaries and analyses, interpretation and report preparation	Reed Glesne and Ashley Rawhouser, NOCA; Steve Fradkin, OLYM
Field Lead	• Facilitate logistics planning and coordination • Train and ensure safety of field crew • Oversee all preseason preparation and season close-out tasks • Plan and execute field visits • Acquire and maintain field equipment • Oversee data collection and entry, verify accurate data transcription into database • Assist with preparation of data for analysis and conduct basic statistical summaries and tests. • Assist in preparation of reports • Review reports, data and other project deliverables • Complete a field season report	Carmen Welch, Aquatic Ecologist NOCA; Rebecca Lofgren, Biological Technician, MORA; Bill Baccus, Biological Technician, OLYM
Technicians	• Collect, record, enter and verify data	NPS Technicians and interns
Data Manager	• Consultant on data management activities • Facilitate check-in, review and posting of data, metadata, reports, and other products to national databases and clearinghouses according to schedule • Maintain and update database application • Provide database training as needed	NCCN Data Manager *
GIS Specialist	• Consultant on spatial data collection, GPS use, and spatial analysis techniques • Facilitate spatial data development and map output generation • Work with Project Lead and Data Analyst to analyze spatial data and develop metadata for spatial data products • Primary steward of GIS data and products	NCCN GIS Specialist *

Table A-1. Roles and responsibilities for Mountain Lakes Monitoring Project (continued).

Role	Responsibilities	Name / Position
Network Program Manager	• Review annual reports for completeness and compliance with I&M standards and expectations	Mark Huff, NCCN Program Manager
Park Curator	• Receive and catalogue voucher specimens • Receive and archive copies of annual reports, 5-year analysis report, and other publications • Facilitate archival of other project records (e.g., original field forms, etc.)	Brooke Childrey, MORA; Kelly Cahill, NOCA; Gay Hunter, OLYM
USGS Liaison	• Consultant on technical issues related to project sampling design, statistical analyses, or other issues related to changes in protocol and SOPs	Bob Hoffman, Ecologist, USGS-FRESC Mike Adams, Ecologist, USGS-FRESC
Statistical Consultant	• Consultant on technical issues related to project sampling design, statistical analyses, or other issues related to changes in protocol and SOPs	Trent McDonald, WEST, Inc., Laramie, WY

* These individuals act as coordinators and primary points of contact related to data management activities for this project. Their responsibility is to facilitate communication among network and park staff and to coordinate the work which may be shared among various staff to balance work load and to enhance the efficiency of information management activities.

Appendix B. Yearly Task List.

Table B-1. Yearly Project Task List.

Task Description	Responsibility	Timing
Preparation Stage		
Initiate announcements for seasonal technician positions, begin hiring.	Project Lead	Jan-Feb
Notify Data Manager and GIS Specialist of needs for the coming season (field maps, GPS support, training).	Project Lead	Jan-Feb
Meet (or conference call) to recap past field season, discuss the upcoming field season, and document any needed changes to field sampling protocols or the project database structure or front-end application.	Project Lead, Field Lead, Data Manager, GIS Specialist	Feb
Ensure all project compliance needs are completed for the coming season.	Field Lead	Feb-Mar
Inform GIS Specialist and Data Manager of specific needs for upcoming field season.	Project Lead, Field Lead	By May 1
Plan schedule and logistics, including ordering any needed equipment and supplies (SOP 1).	Project Lead, Field Lead	By May 30
Complete contracts for water quality analysis, chlorophyll-a analysis, zooplankton and macroinvertebrate identification.	Project Lead	By May 30
Generate field navigation reports, roster of lakes and coordinates from the sample frame (SOP 1).	Project Lead, Field Lead	May 15 –June 15
Gather aerial photos of lakes designated for sampling and prepare and print field maps (SOP 4.).	Project Lead, Field Lead	May 15 –June 15
Gather historical sampling data and other information useful during field sampling. For revisit sites, make copies of previous survey bathymetric data, water level forms, continuous temperature data form, and photos helpful in relocating benchmarks.	Field Lead, Technician	May 15 –June 15
Update and load data dictionary, background maps, and target coordinates into GPS units.	GIS Specialist	By May 15
Ensure that project workspace is ready for use and GPS download software is loaded at each park (SOP 2).	Project Lead, Field Lead, Data Manager and GIS Specialist	By May 30
Implement working database copy.	Data Manager	By May 30

Table B-1. Yearly Project Task List (continued).

Task Description	Responsibility	Timing
Initiate computer access and key requests (may need park-specific dates).	Field Lead	By May 30
Provide staff email addresses and user logins to Data Manager. Grant modify access to project workspace once crew user logins are known.	Field Lead	June
Provide data management, database use, and GPS training.	Data Manager and GIS Specialist	June
Check all equipment (i.e. gillnets, boats, zooplankton and macroinvertebrate nets, measuring lines, etc.) to make sure that it is in workable condition. If not, replace or make needed repairs. (*see* SOPs 4 through 15).	Field Lead, Technician	June
Complete final inventory all equipment and supplies to ensure everything needed for field sampling is available, update inventory database.	Field Lead, Technician	June
Test all water quality monitoring probes and equipment, calibrate depth measurement lines, check batteries and probe membranes, calibrate temperature data loggers and other thermistors (SOP 8).	Field Lead, Technician	June
Prepare water filtering apparatus, filters and water sample bottles for water chemistry sampling (SOP 9).	Field Lead, Technician	June
Train field crew in species identification, equipment use, sampling protocols, and safety (SOP 1). Certification of field observer qualifications.	Field Lead	June
Develop field sampling schedule.	Project Lead, Field Lead	June
Data Acquisition		
Collect field observations and position data during field trips.	Technician	Jul-Sep
Review data forms for completeness and accuracy.	Technician	Daily
Check in with Project Lead.	Field Lead	After each tour
Debrief crew on operations, field methods, gear needs.	Field Lead	After each tour

Table B-1. Yearly Project Task List (continued).

Task Description	Responsibility	Timing
Data Entry & Processing		
Download GPS data and provide to GIS Specialist for processing (SOP 3).	Technician	After each tour
Download and process digital images (SOP 18).	Technician	After each tour
Enter data into the database (SOP 20).	Technician	After each tour
Review database records to verify accurate transcription from field forms.	Technician and Field Lead	After each tour
Correct GPS data and relate any problems to Field Lead and Project Lead for review.	GIS Specialist	After each tour
Review GPS location data and database entries for completeness and accuracy.	Field Lead	Bi-weekly
Scan all field forms and file in the project workspace.	Field Lead	By October
Confirm that data entry and data verification is complete, and notify the Project Lead and Data Manager.	Field Lead	By October
Complete field season report, send to Project Lead, Park Aquatic Resource Representatives; submit to the NCCN Digital Library [1] when finalized.	Field Lead	By October
Merge, correct, and export GPS data. Upload processed and verified coordinates to database.	GIS Specialist	October
Sample/Specimen Processing		
Organize samples and specimens, log, and mail to contractors for analyses.	Field Lead	Oct - Mar
Quality Review		
Complete quality review and data validation using database tools (SOP 22).	Project Lead and Field Lead	Nov - Jan
Prepare coordinate summaries and/or GIS layers and data sets as needed for spatial data review.	GIS Specialist	by Jan 15
Joint quality review of GIS data, determine best coordinates for subsequent mapping and field work.	Project Lead and GIS Specialist	By Jan 31
Metadata		
Identify any sensitive information contained in the data set (Section 4.10).	Project Lead	Nov - Jan
Update project metadata records (Section 4.6).	Project Lead and Field Lead	Nov - Jan
Data Certification and Delivery		
Certify the season's data and complete the certification report (SOP 22).	Project Lead	By Mar 1
Deliver certification report, certified data, and updated metadata to Data Manager (SOP 23).	Project Lead	By Mar 1

Table B-1. Yearly Project Task List (continued).

Task Description	Responsibility	Timing
Store certified data files in the project workspace.	Data Manager	Upon delivery
Notify Project Lead that data are ready for analysis and reporting.	Data Manager	March
Update project GIS data sets, layers and associated metadata records.	GIS Specialist	March
Finalize and parse metadata records, store in the project workspace.	Data Manager and GIS Specialist	by Apr 15
Data Analysis		
Preliminary review and preparation of data (SOP 21, Section I).	Data Analyst and Field Lead	Apr - May
Develop *Statistics* input file and export from database.	Data Analyst	Apr - June
Import data into *Statistics* program and run analyses (SOP 21, Section IV.C).	Data Analyst	Apr - June
Export and reformat *Statistics* output for import into database and other analytical tools.	Data Analyst	Apr – June
Export park-specific statistical outputs for each response variable, abrupt change and trends. Import into database.	Data Analyst	Apr - June
Reporting and Product Development		
Export automated summary queries and reports from database.	Data Analyst	Apr - June
Produce park-wide and lake-specific map outputs for archives.	GIS Specialist	Apr - June
Generate report-quality map output for reports.	GIS Specialist	Apr - June
Acquire the proper report template from the NPS Natural Resource Publications Management website, create annual report.	Data Analyst and Project Lead	Apr - June
Screen all reports and data products for sensitive information.	Project Lead	Apr - June
Prepare draft report for preliminary review.	Project Lead and Field Lead	By June 15

Table B-1. Yearly Project Task List (continued).

Task Description	Responsibility	Timing
Product Delivery		
Submit draft report to Network Program Manager for review.	Project Lead	By June 30
Review report for formatting and completeness, notify Project Lead of approval or need for changes.	Network Program Manager	July
Upload completed report to NCCN Digital Library[1], notify network publications manager (SOP 23).	Project Lead	Upon approval
Deliver other products according to the delivery schedule and instructions (SOP 23).	Project Lead	Upon completion
Product check-in.	Data Manager	Upon receipt
Posting and Distribution		
Submit metadata to the NPS Data Store[2] (SOP 23).	Data Manager	By Jul 15
Create an online reference record and upload PDF document to the NPS Data Store.[2]	Data Manager	Upon receipt
Update NPSpecies[3] records according to data observations.	Data Manager	Aug
Submit certified tabular and geospatial data sets to the NPS Data Store[2] (SOP 23).	Data Manager	March (hold for 2 years after certification)
Submit certified NPSTORET data to WRD for upload to EPA's STORET Data Warehouse.	Data Manager	March (hold for 2 years after certification)
Archiving and Records Management		
Store finished products slated for permanent retention in NCCN Digital Library[1].	Project Lead	January
Review, clean up and store and/or dispose of project files according to NPS Director's Order 19[4].	Project Lead	January
Move hard-copy data forms and voucher specimens to park collections after making sure that all forms have been scanned and all species records are entered into NPSpecies.	Project Lead	January
Season Close-out		
Inventory equipment and supplies.	Field Lead	October
De-brief field crew concerning safety, logistics, and data concerns.	Project Lead and Field Lead	October
Meet to discuss the recent field season and to document any needed changes to field methods, quality assurance methods, or data management practices.	Project Lead, Park-based Aquatic Leads, Field Lead, Data Manager, GIS Specialist	October-November

[1] The NCCN Digital Library is a document management system implemented in Microsoft SharePoint for maintaining important digital files (reports, protocol documents, and selected project images) within a content management system, and to make them available to NCCN and NPS users.
[2] The NPS Data Store is an internet clearinghouse for documents, data and metadata on natural and cultural resources in parks. It is a primary component of the NPS Integrated Resource Management Applications (IRMA) portal (http://irma.nps.gov).
[3] NPSpecies is the NPS database and application for maintaining park-specific species lists and observation data, and is also a component of the IRMA portal (http://irma.nps.gov).
[4] NPS Director's Order 19 provides a schedule indicating the amount of time that the various kinds of records should be retained. Available at: http://home.nps.gov/applications/npspolicy/DOrders.cfm.

Appendix C. Field and Laboratory Data Forms.

Mountain Lake Daily Sampling Checklist

Park Unit: _____ **Lake Name:** _____ **Lake Code:** _____

Date: ___/___/___ **Samplers:** _____

General Weather Conditions (Describe the general conditions over the course of the sampling activities).

Precipitation		% Cloud Cover		Waves	
___ Dry	___ Fog/Mist	___ 0	___ 51-75	___ None	___ Mod.
___ Light Rain	___ Sleet/Hail	___ 1-25	___ 76-100	___ Slight	___ Heavy
___ Heavy Rain	___ Snow	___ 26-50			

		Replicate?	Notes/Comments
Onsite Safety Briefing	☐		_____
Site Map / GPS Features	☐		_____
Panorama Photos	☐		_____
Air Temperature Logger	☐		_____
Water Clarity (Secchi Disk)	☐	☐	_____
Zooplankton	☐	☐	_____
Water Column Profile	☐	☐	_____
Water Collection	☐	☐	_____
Water Temperature Array	☐		_____
Lake Level Measurement	☐	☐	_____
Amphibian Survey	☐	☐	_____
Macroinvertebrates	☐	☐	_____
Riparian Disturbance	☐	☐	_____
Fish Angling / Observation	☐	☐	_____
Gill Netting (≤ 5 years)	☐	☐	_____
Bathymetry (Every 20 years)	☐		_____
Data Forms Reviewed	☐		_____

Comments / Other Information:

Figure C-1. Mountain Lake Daily Checklist.

Trip Photo Log

Park Unit: _____ Lake Name:_____ Lake Code:_____

Observers: _____ Sampling Dates:_____

Photo Codes: PAN - panoramic, PANRP - reference point location for panoramic photos, WLBM - water level benchmark MRP - bathymetric mapping reference point, RD - riparian disturbance, SP - specimen photos, OT - other

Photo #	Code	Date	Time	Description (include plot numbers for RD codes, benchmark numbers for WLBM, reference point numbers for PANRP and MRP codes)

Figure C-2. Trip Photo Log.

Lake Bathymetry Data Form

Park Unit: _____ **Lake Name:** _____ **Lake Code:** _____

Date: ____/____/_____ **Mappers:** _____ Page ____ of ____

MBM location descriptions:

Sonar Calibration Check (m ___ ft ___)
Cal. Depth: ____ Ave. Diff.(+/- ; 3reps.): ____

Depth Transect # ____ MRP# ____				Depth Transect # ____ MRP# ____				Depth Transect # ____ MRP# ____				Additional shoreline mapping points (SLMP)			
Transect Start: (check one) Opposite shore ____ At MRP____				Transect Start: (check one) Opposite shore ____ At MRP____				Transect Start: (check one) Opposite shore ____ At MRP____							
Point #	Azimuth	Dist. (m)	m __ ft __	Point #	Azimuth	Dist. (m)	m __ ft __	Point #	Azimuth	Dist. (m)	m __ ft __	MRP#	SLMP#	Azimuth	Dist. (m)
Shore				Shore				Shore							
1				1				1							
2				2				2							
3				3				3							
4				4				4							
5				5				5							
6				6				6							
7				7				7							
8				8				8							
9				9				9							
10				10				10							
11				11				11							
12				12				12							
13				13				13							
14				14				14							
15				15				15				Comments/Notes			
16				16				16							
17				17				17							
18				18				18							
19				19				19							
20				20				20							
21				21				21							
22				22				22							
23				23				23							
24				24				24							
25				25				25							
26				26				26							
27				27				27							
28				28				28							
Shore				Shore				Shore							

Max. Depth Information: MRP#: _____ Azimuth: _____ Dist. (m): _____ Depth (m __ ft __): _____ **Lake Perimeter (m)** _____

Figure C-3. Lake Bathymetry Data Form.

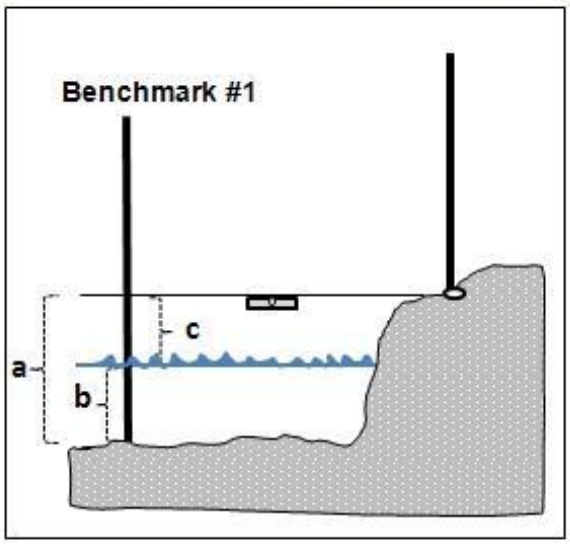
Water Level Form (String Level Version)

Park Unit: _____ Lake Name: _____ Lake Code: _____

Date: ____/____/___ Time: _____ Observers: _____

Water Level

Line Level Method: measure the distance from the lake bottom to the line level and record it as (**a**). Measure the distance from the lake bottom to the lake level and record it as (**b**). Subtract (**b**) from (**a**) to determine Relative Lake Level (**c**). Subtract the Relative Lake Level from Previous Level to determine the difference between years. The difference values between Benchmark #1 and Benchmark #2 should compare well, otherwise, repeat measurements.



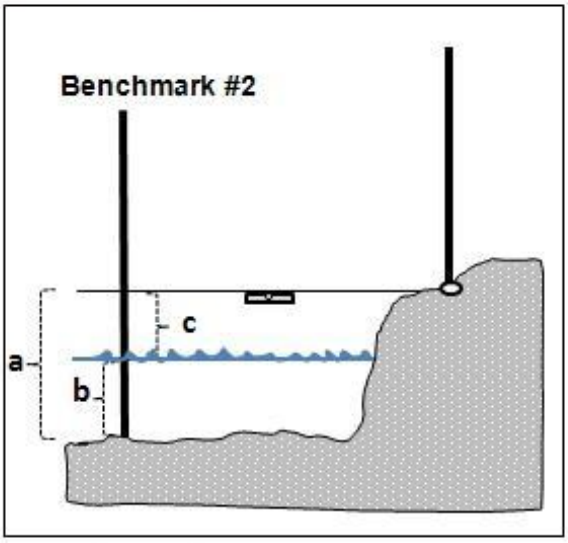
a = ☐

b = ☐

Previous Year Lake Level: ☐

Relative Lake Level: a-b = c: ☐

Difference:



a = ☐

b = ☐

Previous Year Lake Level: ☐

Relative Lake Level: a-b = c: ☐

Difference:

Notes

Figure C-4. Lake Water Level Form – String level method.

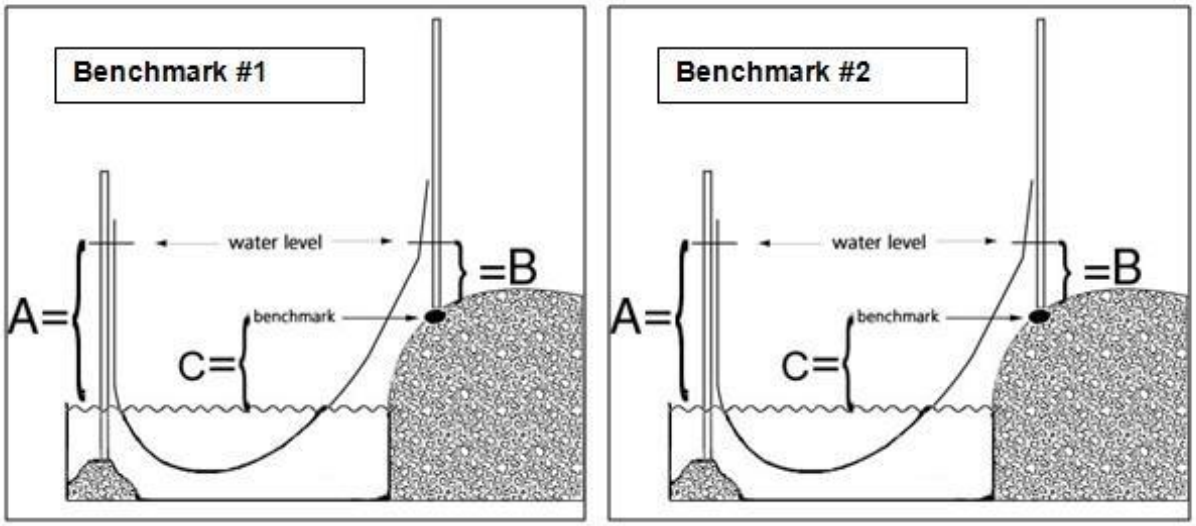
Water Level Form (Tygon Tube Version)

Park Unit: _____ Lake Name: _____ Lake Code: _____

Date: ____/____/___ Time: _____ Observers: _____

Water Level

Tygon Tube Method: Measure the height of meniscus above lake level and record as (A). Measure the height of meniscus above Water Level Benchmark and record as (B). Subtract B from A to determine Relative Lake Level (C). Subtract the Relative Lake Level from the Previous Level to determine the difference between years. The difference values between Benchmark #1 and Benchmark #2 should compare well, otherwise, repeat measurements.



A = B = Previous Year Lake Level:

Relative Lake Level: A-B = C

Difference:

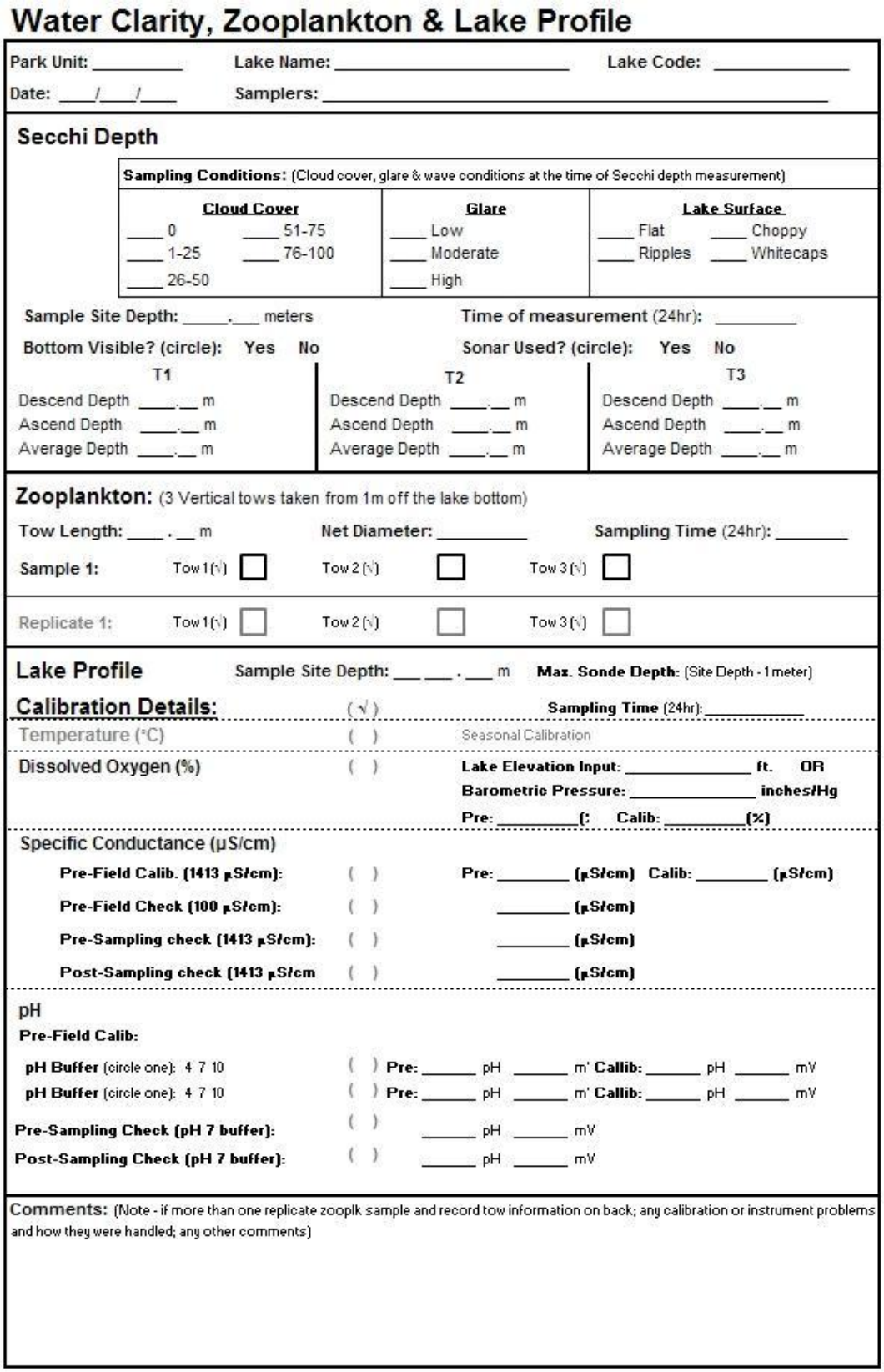
A = B = Previous Year

Relative Lake Level: A-B = C

Difference:

Notes

Figure C-5. Lake Water Level Form – Tygon tube method



Water Clarity, Zooplankton & Lake Profile

Park Unit: _____ Lake Name: _____ Lake Code: _____

Date: ___/___/___ Samplers: _____

Secchi Depth

Sampling Conditions: (Cloud cover, glare & wave conditions at the time of Secchi depth measurement)

Cloud Cover		Glare	Lake Surface	
____ 0	____ 51-75	____ Low	____ Flat	____ Choppy
____ 1-25	____ 76-100	____ Moderate	____ Ripples	____ Whitecaps
____ 26-50		____ High		

Sample Site Depth: ____.__ meters Time of measurement (24hr): _____

Bottom Visible? (circle): Yes No Sonar Used? (circle): Yes No

T1	T2	T3
Descend Depth ____.__ m	Descend Depth ____.__ m	Descend Depth ____.__ m
Ascend Depth ____.__ m	Ascend Depth ____.__ m	Ascend Depth ____.__ m
Average Depth ____.__ m	Average Depth ____.__ m	Average Depth ____.__ m

Zooplankton: (3 Vertical tows taken from 1m off the lake bottom)

Tow Length: ____ . __ m Net Diameter: _____ Sampling Time (24hr): _____

Sample 1: Tow 1 (√) ☐ Tow 2 (√) ☐ Tow 3 (√) ☐

Replicate 1: Tow 1 (√) ☐ Tow 2 (√) ☐ Tow 3 (√) ☐

Lake Profile

Sample Site Depth: ___ ___ . ___ m **Max. Sonde Depth:** (Site Depth - 1 meter)

Calibration Details: (√) **Sampling Time** (24hr): _____

Temperature (°C) ( ) Seasonal Calibration

Dissolved Oxygen (%) ( ) **Lake Elevation Input:** _____ **ft. OR**

Barometric Pressure: _____ **inches/Hg**

Pre: _____ **(: Calib:** _____ **(%)**

Specific Conductance (µS/cm)

Pre-Field Calib. (1413 µS/cm): ( ) **Pre:** _____ **(µS/cm) Calib:** _____ **(µS/cm)**

Pre-Field Check (100 µS/cm): ( ) _____ **(µS/cm)**

Pre-Sampling check (1413 µS/cm): ( ) _____ **(µS/cm)**

Post-Sampling check (1413 µS/cm ( ) _____ **(µS/cm)**

pH

Pre-Field Calib:

pH Buffer (circle one): 4 7 10 ( ) **Pre:** _____ pH _____ m' **Callib:** _____ pH _____ mV

pH Buffer (circle one): 4 7 10 ( ) **Pre:** _____ pH _____ m' **Callib:** _____ pH _____ mV

Pre-Sampling Check (pH 7 buffer): ( ) _____ pH _____ mV

Post-Sampling Check (pH 7 buffer): ( ) _____ pH _____ mV

Comments: (Note - if more than one replicate zooplk sample and record tow information on back; any calibration or instrument problems and how they were handled; any other comments)

Figure C-6. Water Clarity, Zooplankton, and Lake Profile Form.

Temperature Sensor Calibration Form

NIST Ref. SN: _____

Temp Logger SN: _____ or **Instrument Model No:**_____

Test # (Second test required if Test 1 fails): **1 / 2**

Pre-Calibration				**Post-Calibration**			
Low Range Water Bath (approx. 0•C)				Low Range Water Bath (approx. 0•C)			
Date:		Start Time:		Date:		Start Time:	
Time	**NIST Ref. •C**	**Logger •C**	**Abs. Diff.**	**Time**	**NIST Ref. •C**	**Logger •C**	**Abs. Diff.**
1 min.				1 min.			
2 min.				2 min.			
3 min.				3 min.			
4 min.				4 min.			
5 min.				5 min.			
6 min.				6 min.			
7 min.				7 min.			
8 min.				8 min.			
9 min.				9 min.			
10 min.				10 min.			
High Range Water Bath (approx. 20•C)				High Range Water Bath (approx. 20•C)			
Date:		Start Time:		Date:		Start Time:	
Time	**NIST Ref. •C**	**Logger •C**	**Abs. Diff.**	**Time**	**NIST Ref. •C**	**Logger •C**	**Abs. Diff.**
1 min.				1 min.			
2 min.				2 min.			
3 min.				3 min.			
4 min.				4 min.			
5 min.				5 min.			
6 min.				6 min.			
7 min.				7 min.			
8 min.				8 min.			
9 min.				9 min.			
10 min.				10 min.			
		Mean Difference:				**Mean Difference:**	
		Required Accuracy:	0.2			**Required Accuracy:**	0.2
		Suspect ? (Do Not Deploy)	☐			**Suspect ? (Flag Data)**	☐

Comments: (Provide manufacturer post-calibration results for loggers with dead batteries and other comments)

Figure C-7. Temperature Sensor Calibration Form.

YSI 600 XLM Sonde - Lab Calibration Log (Olympic NP - Lake pH range 7-10)

Unit #:								
Date	Who		Sp. Cond.	pH		pHmV		Comments
			µS/cm	7	10	7	10	
		Pre						
		Calib						
		Post						
		Pre						
		Calib						
		Post						
		Pre						
		Calib						
		Post						
		Pre						
		Calib						
		Post						
		Pre						
		Calib						
		Post						
		Pre						
		Calib						
		Post						
		Pre						
		Calib						
		Post						
		Pre						
		Calib						
		Post						
		Pre						
		Calib						
		Post						
		Pre						
		Calib						
		Post						

Figure C-8. YSI 600 XLM Calibration Log for OLYM.

YSI 600 XLM and Other Instruments - Lab Calibration Log (MORA & NOCA)

Instrument: _____ **Model No:** _____

Date	Who		Sp. Cond.	pH		pHmV		Comments
			µS/cm	4	7	4	7	
		Pre						
		Calib						
		Post						
		Pre						
		Calib						
		Post						
		Pre						
		Calib						
		Post						
		Pre						
		Calib						
		Post						
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		Pre						
		Calib						
		Post						
		Pre						
		Calib						
		Post						
		Pre						
		Calib						
		Post						
		Pre						
		Calib						
		Post						

Figure C-9. YSI 600 XLM Calibration Log for NOCA and MORA.

Continuous Temperature Data Field Form

Park Unit: _____ Lake Name: _____ Lake Code: _____

Site Depth: _____ Observers: _____

Deployment Information Year:_____	Retrieval Information Year: _____
Surface Logger Logger SN: Programmed Deployment Start: Date: ____/____/____ Time (24hr): _____ **Field Deployment Start:** Date: ____/____/____ Time (24hr): _____	Downloaded? **Yes / No** (Circle One) Malfunction? **Yes / No** (Circle One) Replaced with New? **Yes / No** (Circle One) **Data/Logger Retrieval Date and Time:** Date: ____/____/____ Time (24hr): _____
Mid-Depth Logger Logger SN: Programmed Deployment Start: Date: ____/____/____ Time (24hr): _____ **Field Deployment Start:** Date: ____/____/____ Time (24hr): _____	Downloaded? **Yes / No** (Circle One) Malfunction? **Yes / No** (Circle One) Replaced with New? **Yes / No** (Circle One) **Data/Logger Retrieval Date and Time:** Date: ____/____/____ Time (24hr): _____
Bottom Logger (1 meter above lake bottom) Logger SN: Programmed Deployment Start: Date: ____/____/____ Time (24hr): _____ **Field Deployment Start:** Date: ____/____/____ Time (24hr): _____	Downloaded? **Yes / No** (Circle One) Malfunction? **Yes / No** (Circle One) Replaced with New? **Yes / No** (Circle One) **Data/Logger Retrieval Date and Time:** Date: ____/____/____ Time (24hr): _____
Air Temp Logger Logger SN: Programmed Deployment Start: Date: ____/____/____ Time (24hr): _____ **Field Deployment Start:** Date: ____/____/____ Time (24hr): _____	Downloaded? **Yes / No** (Circle One) Malfunction? **Yes / No** (Circle One) Replaced with New? **Yes / No** (Circle One) **Data/Logger Retrieval Date and Time:** Date: ____/____/____ Time (24hr): _____

Retrieval Observations and Comments (Note new logger SN# if deployed, location and depth if the logger assembly has been moved):

Figure C-10. Continuous Temperature Data Field Form.

Temperature Logger Pre/Post Deployment Record Sheet

Lake Name	Lake Code	Position	Serial #	Launch Date	Launch Time	Launch Location	Deploy Date	Deploy Time	Removal Date	Post-deploy Calibration Result
		Top, Mid Bottom, Air, Extra			(24hr)	Lab or Field		(24hr)		Suspect? Y/N

Figure C-11. Temperature Logger Pre/Post Deployment Record Sheet.

Water Sample Collection Field Form

Park Unit: _____ **Lake Name:** _____ **Lake Code:** _____

Date: ____/____/___ **Samplers:** _____ **Replicate?** ☐

Lake Stratified?: Y / N **Collection Time (24hr)** _____

Filtered water - Nutrients and TDS (500 mL, 0.7 µm glass fiber filter, amber Nalgene bottle) ☐

Mid-Depth _____ **(xx.x m)** Surface (Strat.) _____ (xx.x m) Bottom (Strat.) _____ (xx.x m)

Filtered water - Dissolved Organic Carbon (125 mL, 0.7 µm glass fiber filter, amber Nalgene bottle)

Depth (1.0 m) _____ ☐

Filtered water - Anions/Cations (250 mL, 0.7 µm membrane filter, amber Nalgene bottle) ☐

Mid-Depth _____ **(xx.x m)** Surface (Strat.) _____ (xx.x m) Bottom (Strat.) _____ (xx.x m)

Unfiltered water - ANC (250 mL amber Nalgene bottle) ☐

Mid-Depth _____ **(xx.x m)** Surface (Strat.) _____ (xx.x m) Bottom (Strat.) _____ (xx.x m)

Chlorophyll (500 mL, 0.45 µm membrane filter, aluminum wrapped microcentrifuge tube) ☐

Unstratified: **Mid-Depth** _____ **(xx.x m)**

Stratified: Mid-Depth _____ (xx.x m)

Lower Epilimnion Boundary _____ (xx.x m)

Field Blank

Nutrients and TDS (500 mL, 0.7 µm glass fiber filter, amber Nalgene bottle) ☐

Dissolved Organic Carbon (60 mL, 0.7 µm glass fiber filter, amber Nalgene bottle) ☐

Anions and Cations (250 mL, 0.7 µm membrane filter, amber Nalgene bottle) ☐

ANC, Specific Conductance, and pH (250 mL, unfiltered, amber Nalgene bottle) ☐

Chlorophyll (500 mL, 0.45 µm membrane filter, aluminum wrapped microcentrifuge tube) ☐

Labeling instructions: 1) sample number (sample 1= primary sample and sample 2 = replicate); 2) lake code; 3) sample type (anion/cation, nutrients, DOC, unfiltered); 4) date.

Comments / Other Information:

Figure C-12. Water Sample Collection Form.

Water Chemistry Sample Shipping Log

Park:	**Park Contact:**
Phone:	Email:
Lab Contact:	
Phone:	Email:
Sample Type:	**Lab Address:**
Shipping Date:	
Date Received:	

Lake Code	Lake Name	Collect Date	Sample #	Depth (m)	Filter (µ)	Vol. (mL)

Figure C-13. Water Chemistry Shipping Log.

Acid Neutralizing Capacity Lab Sheet

Park Unit: _____ **Lake Name:** _____ **Lake Code:** _____

Analysis Date: ____/____/____ **Analyst (initials):** _____

Sample Type: Check appropriate box. Calculate RPD for replicate from a separate aliquot of the same sample or RPD(+) for replicate from different sample.

Primary Sample? ☐

Replicate - Separate Aliquot? ☐ **RPD :** _____

Replicate - Separate Sample? ☐ **RPD (+):** _____

		pH	Titrat. Digits	Time (minutes)
Collection Date:				
Collection Time (24hr):				
Sample Temp (°C):				
Sample Sp.Cond. (µS/cm):				
Analysis Date:				
Analysis Time (24hr):				
Sample Volume (mL):				
Filtered?:				
Acid Concentration (N):				
Acid Lot Number:				
Acid Correction Factor:				
Acid Expiration Date:				
Stirring Method:				
Titration Type:				
pH Meter Used: Calibration Date ____/ ____ / _____ Pre: _____ _____ Post: _____ _____ 4 and 7 7 and 10 Buffer Used: Circle One				
Results				
Gran Method				
F1 ANC (Bicarb - µeq/L)				
F3 ANC (Bicarb - µeq/L)				
F2 ANC (Carbonate - µeq/L)				
F4 ANC (Carbonate - µeq/L)				
Inflection Point Method				
Carbonate Endpoint:				
Bicarbonate Endpoint:				
ANC:				
Notes:				

Figure C-14. Acid Neutralizing Capacity Lab Sheet.

Chlorophyll-a Sample Storage Log

Lake ID	Sample ID	Date Sampled	Date Stored	(Storage) Initials	Date Analyzed	Analyst Initials	Comments

Figure C-15. Chlorophyll-a Sample Storage Log.

Chlorophyll-a Sample Analysis Log (OLYM)

Vial #	Sample ID	Date Sampled	Date Analyzed	Analysis ID	Replicate Number	(Analyzer) Initials	Comments

Figure C-16. Chlorophyll-a Sample Analysis Log (OLYM).

Chlorophyll-a Shipping Log

Park: _____
Park Contact: _____
Phone: _____
Email: _____
Sample Type: *Chlorophyll-Lake*

Lab: John Salinas
2601 Sand Creek Rd
Grants Pass, OR 97527

Shipping Date: ___ /___ / _____

Filter size: 0.45 micron
Lab Contact: John Salinas
johnsalinas@charter.net
(541) 479-7351

Date Received: ____ / ____ / ____

Lake Code	Lake Name	Collect Date	Sample #	Depth (m)	Sample Vol. (mL)

Figure C-17. Chlorophyll-a Sample Shipping Log.

Benthic Macroinvertebrate Field Form

Lake Name: _____ **Lake Code:** _____ **Date:** ___/___/_____

Samplers: _____

Benthic Macroinvertebrates

Linear Dist. Interval (m): _____ **Sample (S):** **Time: Start** _____ **Finish** _____ #Containers _____

Time Constraint (min): _____ **Replicate (R):** **Time: Start** _____ **Finish** _____ #Containers _____

Habitat (evaluated at all BMI sub-sample sites, 5 for primary sample with additional 5 if replicate is taken)

Sub-Sample Site #	Dominant Substrate Type (List the top 4 dominant substrate types in order of dominance) (Record % CWD even when not a dominant substrate. Mark with a check next to CPOM if any is present in plot.)	Aquat. Veg. (in 5% increments)
Sub-S1	1._____ 2._____ 3._____ 4._____ %CWD_____ CPOM present _____	Emerg____ Float____ Submerg____
Sub-S2	1._____ 2._____ 3._____ 4._____ %CWD_____ CPOM present _____	Emerg____ Float____ Submerg____
Sub-S3	1._____ 2._____ 3._____ 4._____ %CWD_____ CPOM present _____	Emerg____ Float____ Submerg____
Sub-S4	1._____ 2._____ 3._____ 4._____ %CWD_____ CPOM present _____	Emerg____ Float____ Submerg____
Sub-S5	1._____ 2._____ 3._____ 4._____ %CWD_____ CPOM present _____	Emerg____ Float____ Submerg____
Sub-R1	1._____ 2._____ 3._____ 4._____ %CWD_____ CPOM present _____	Emerg____ Float____ Submerg____
Sub-R2	1._____ 2._____ 3._____ 4._____ %CWD_____ CPOM present _____	Emerg____ Float____ Submerg____
Sub-R3	1._____ 2._____ 3._____ 4._____ %CWD_____ CPOM present _____	Emerg____ Float____ Submerg____
Sub-R4	1._____ 2._____ 3._____ 4._____ %CWD_____ CPOM present _____	Emerg____ Float____ Submerg____
Sub-R5	1._____ 2._____ 3._____ 4._____ %CWD_____ CPOM present _____	Emerg____ Float____ Submerg____

Substrate Type: St = Silt (smooth between fingers <0.06 mm), Sd = sand (<2 mm), G = gravel (2-64 mm), C = Cobble (65-256 mm), Bd = Boulder (257-4096 mm), Br = Bedrock (>4096 mm), FPOM = Fine particulate org. matter (<1 mm dia.), CPOM = Coarse particulate organic matter (leaves, needles, twigs, small branches up to small logs 1-100 mm), CWD = Coarse woody debris (branches, rootwads, logs >100 mm dia.).

Notes: 1) Mark all subsample locations on Lake Map Form. 2) Replicate samples collected at a randomly selected subset of lakes. 3) Subsamples are pooled (by primary sample and replicate sample) and number of sample containers for the entire sample is noted above.

Comments and miscellaneous information: (record field sample split sizes)

Figure C-18. Benthic Macroinvertebrate (BMI) Field Form.

Lake BMI Sample Processing Bench Sheet

Park Code: **Sample Year:**

Lake Name	Sample ID	Number of Vials	% of Samples Sorted	Total No. of Organisms Sorted	Sorted by (initials)	Sort Date	Notes

Sorting Efficiency QC Checks:

Sorter Name	Lake/Sample ID	QC Invest. No. Remain	Total No.	% of Org. Missed	QC Invest. Name/Check Date

QC Process: During each year, three samples from each sorter are checked by QC person. Following the initial sort the QC person will examine the subsample fraction for additional organisms that were missed. If none of the three samples, for each sorter, exceed 10%, then QC checks are no longer required for that sorter. Sorters that exceed 10% missed organisms and any new employees will be required to have QC checks on all samples until the QC investigator decides that they are not needed (based on consistent sorts with <10% missed).

Figure C-19. Benthic Macroinvertebrate (BMI) Sample Processing Bench Sheet.

Lake BMI Sample Log Form

Park Code	Lake Code	Lake Name	Collection Date	Subsample #	# of Containers	% of Sample Collected	Notes

Figure C-20. Benthic Macroinvertebrate (BMI) Sample Log Form.

Lake BMI/Zooplankton Identification QC Summary Form

Park Code: **Sample Year:** **QC Investigator:**

Contractor Name: **QC1 Contr. Name:** **QC2 Contr. Name:**
Address: **Address:** **Address:**

Lake/Sample ID Code	Specimen ITIS Code	Specimen Identification			Final ID Code	Systematic Name Change* Specimen ID	Action Code	Correction Date
		Primary Contractor	QC-1 Contractor	QC-2 Contractor				

Comments:

Systematic Name Change: Record new scientific name and apply Action Code 4

Final ID Code:
1) Accept primary contractor ID
2) Accept QC-1 ID
3) Accept QC-2 ID
4) List at higher taxa level (i.e. *Genus* instead o *Genus species*)
5) List Unident. - early instar
6) List Unident. - damaged specimen
7) List Unident. - other (explain in comments)

Action Code:
1) Primary Contractor ID accepted - no change in data.
2) Edit changes in current year bench sheet and spreadsheet for specific lake.
3) Edit changes in bench and spreadsheets for all current year lake locations where specific taxa is found.
4) Document changes in spreadsheets and edit corresponding output variables (for those affected) for all years.
5) Other actions (explain in comments)

Correction Date: Record completion date for follow up of required action.

Figure C-21. Benthic Macroinvertebrate (BMI)/Zooplankton Identification QC Form.

Zooplankton Sample Shipping Log

Park:	**Park Contact:**
Phone:	Email:
Lab Contact:	
Phone:	Email:
Sample Type:	**Lab Address:**
Shipping Date:	
Date Received:	

Lake Code	Lake Name	Collect Date	Sample #	Net Dia. (cm)	Depth of Tow (m)

Figure C-22. Zooplankton Sample Shipping Log.

Fish Gill Net Survey Form

Park Unit: _____ Lake Name: _____ Lake Code: _____

Gill Net #1

Start Date: ____/____/____ Start Time (24h): _____

Finish Date: ____/____/____ Finish Time (24h): _____

Total Hours: _____

Samplers: _____

Species Code	Tot./Fork Lgth. (mm)	Weight (g)	Species Code	Tot./Fork Lgth. (mm)	Weight (g)	Species Code	Tot./Fork Lgth. (mm)	Weight (g)

Gill Net #2

Start Date: ____/____/____ Start Time (24h): _____

Finish Date: ____/____/____ Finish Time (24h): _____

Total Hours: _____

Samplers: _____

Species Code	Tot./Fork Lgth. (mm)	Weight (g)	Species Code	Tot./Fork Lgth. (mm)	Weight (g)	Species Code	Tot./Fork Lgth. (mm)	Weight (g)

Comments / Photos:

Species Codes: WCT - Westslope Cutthroat, CCT - Coastal Cutthroat, YCT - Yellowstone Cutthroat, RBT - Rainbow Trout, GOT - Golden Trout, BUL - Bull Trout, BRK - Brook Trout. Note: Mark gill net locations on map. Sex: M or F. Maturity: Immature (IM), Adult (AD), Adult-ripe (AD-r)

Figure C-23. Fish Gill Net Survey Form.

Fish Angling and Visual Observation Form

Park Unit: _____ Lake Name: _____ Lake Code: _____

Date: ____/____/____ Anglers: _____

Angling Data Total Hrs Fished: _____

Species Code	Life Stage (check box)			Number Caught	Species Code	Life Stage (check box)			Number Caught
	Fry	Fgl.	Adult			Fry	Fgl.	Adult	

Species Codes: WCT - Westslope Cutthroat, CCT - Coastal Cutthroat, YCT - Yellowstone Cutthroat, RBT - Rainbow Trout, GOT - Golden Trout, BUL - Bull Trout, BRK - Brook Trout. Life Stage: Fry (<50 mm), Fingerling (50-150 mm), Adult (>150 mm).

Comments:

Visual Observations Total Hrs Observed: _____

Species Code	Life Stage (check box)			Number Caught	Observer Initials	Comments
	Fry	Fgl.	Adult			

Figure C-24. Fish Angling and Visual Observation Form.

Amphibian Visual Encounter Survey (VES) Form

Park Unit: _____ **Lake Name:** _____ **Lake Code:** _____

Date: ___/___/___ **Day or Night Survey** (circle one)

VES #1 or VES #2 (circle one)

Start Time (24hr): _____ **Stop Time (24hr):** _____ **Total Time (hrs:min.):** ___:___

No. of Observers: _____ **Observer Names:** _____

Survey Perimeter Distance (m): _____ **No. of Intensive Search Sites:** _____

Sp. Code/ Life Stage	in between sites (note site	Total Number	Count Method (Actual or Estimate)	Sample Method (Hand net, Visual only)	Comments (note voucher specimens, photographs, etc.)
			A____ E____	H____ V____	
			A____ E____	H____ V____	
			A____ E____	H____ V____	
			A____ E____	H____ V____	
			A____ E____	H____ V____	
			A____ E____	H____ V____	
			A____ E____	H____ V____	
			A____ E____	H____ V____	
			A____ E____	H____ V____	
			A____ E____	H____ V____	
			A____ E____	H____ V____	
			A____ E____	H____ V____	
			A____ E____	H____ V____	
			A____ E____	H____ V____	
			A____ E____	H____ V____	
			A____ E____	H____ V____	
			A____ E____	H____ V____	
			A____ E____	H____ V____	
			A____ E____	H____ V____	
			A____ E____	H____ V____	
			A____ E____	H____ V____	

Species Codes: *Ambystoma gracile* = **AMGR**, *Ambystoma macrodactylum* = **AMMA**, Unidentified Ambystoma = **AMSP**, *Ascaphus truei* = **ASTR**, *Bufo boreas* (*Anaxyrus boreas*) = **BUBO**, *Dicamptodon tenebrosus* = **DITE**, *Dicamptodon copei* = **DICO**, *Plethodon larselli* = **PLLA**, *Plethodon vehiculum* = **PLVE**, *Plethodon vandykei* = **PLVA**, *Ensatina eschscholtzii* = **ENES**, *Rana aurora* = **RAAU**, *Rana cascadae* = **RACAS**, Rana luteiventris = **RALU**, *Pseudacris regilla* = **PSRE**, *Taricha granulosa* = **TAGR**

Specimen Length and Life Stage Data (measure up to 10 for each species/life stage)

Sp. Code/Stage	TL (mm)	SVL (mm)	Sp. Code/Stage	TL (mm)	SVL (mm)

Length Measurement: Total Length **(TL)** and Snout-vent Length **(SVL)** used for salamander larvae. **SVL** used for all other.

Life Stage: **E** = egg, **EM** = egg mass, **L** = larval, **J** = juvenile, **A** = adult, **P** = paedomorph, **U** = unknown.

Figure C-25. Amphibian Visual Encounter Survey (VES) Form.

Amphibian Visual Encounter Survey Habitat Form

Park Unit: _____ **Lake Name:** _____ **Lake Code:** _____

Date: ___ /___ /___ **Day or Night Survey** (circle one) **Observers:** _____

Habitat: Evaluated at intensive search sites spaced at 50 m intervals, counter clockwise around lake perimeter from a random start point (7 intensive search sites required for lakes<1 ha). **Note:** Habitat not evaluated for replicate survey (VES 2).

Site No.	Dominant Substrate Types (List the top 4 dominant substrate types in order of dominance) (Record %CWD even when not a dominant substrate. Mark a check next to CPOM if any is present in plot)	Aquat. Veg. (check all present within plot)
	1._____ 2._____ 3._____ 4._____ %CWD_____ CPOM present_____	Emerg___ Float___ Submerg___
	1._____ 2._____ 3._____ 4._____ %CWD_____ CPOM present_____	Emerg___ Float___ Submerg___
	1._____ 2._____ 3._____ 4._____ %CWD_____ CPOM present_____	Emerg___ Float___ Submerg___
	1._____ 2._____ 3._____ 4._____ %CWD_____ CPOM present_____	Emerg___ Float___ Submerg___
	1._____ 2._____ 3._____ 4._____ %CWD_____ CPOM present_____	Emerg___ Float___ Submerg___
	1._____ 2._____ 3._____ 4._____ %CWD_____ CPOM present_____	Emerg___ Float___ Submerg___
	1._____ 2._____ 3._____ 4._____ %CWD_____ CPOM present_____	Emerg___ Float___ Submerg___
	1._____ 2._____ 3._____ 4._____ %CWD_____ CPOM present_____	Emerg___ Float___ Submerg___
	1._____ 2._____ 3._____ 4._____ %CWD_____ CPOM present_____	Emerg___ Float___ Submerg___
	1._____ 2._____ 3._____ 4._____ %CWD_____ CPOM present_____	Emerg___ Float___ Submerg___
	1._____ 2._____ 3._____ 4._____ %CWD_____ CPOM present_____	Emerg___ Float___ Submerg___
	1._____ 2._____ 3._____ 4._____ %CWD_____ CPOM present_____	Emerg___ Float___ Submerg___
	1._____ 2._____ 3._____ 4._____ %CWD_____ CPOM present_____	Emerg___ Float___ Submerg___
	1._____ 2._____ 3._____ 4._____ %CWD_____ CPOM present_____	Emerg___ Float___ Submerg___
	1._____ 2._____ 3._____ 4._____ %CWD_____ CPOM present_____	Emerg___ Float___ Submerg___
	1._____ 2._____ 3._____ 4._____ %CWD_____ CPOM present_____	Emerg___ Float___ Submerg___
	1._____ 2._____ 3._____ 4._____ %CWD_____ CPOM present_____	Emerg___ Float___ Submerg___
	1._____ 2._____ 3._____ 4._____ %CWD_____ CPOM present_____	Emerg___ Float___ Submerg___
	1._____ 2._____ 3._____ 4._____ %CWD_____ CPOM present_____	Emerg___ Float___ Submerg___
	1._____ 2._____ 3._____ 4._____ %CWD_____ CPOM present_____	Emerg___ Float___ Submerg___
	1._____ 2._____ 3._____ 4._____ %CWD_____ CPOM present_____	Emerg___ Float___ Submerg___
	1._____ 2._____ 3._____ 4._____ %CWD_____ CPOM present_____	Emerg___ Float___ Submerg___
	1._____ 2._____ 3._____ 4._____ %CWD_____ CPOM present_____	Emerg___ Float___ Submerg___
	1._____ 2._____ 3._____ 4._____ %CWD_____ CPOM present_____	Emerg___ Float___ Submerg___

Substrate Type: St = Silt (smooth between fingers <0.06 mm), **Sd** = sand (<2 mm), **G** = gravel (2-64 mm), **C** = Cobble (65-256 mm), **Bd** = Boulder (257-4096 mm), **Br** = Bedrock (>4096 mm), **FPOM** = Fine particulate org. matter (<1mm dia.), **CPOM** = Coarse particulate organic matter (leaves, needles, twigs, small branches up to small logs 1-100 mm), **CWD** = Coarse woody debris (branches, rootwads, logs >100 mm dia.).

Comments / Other Information:

Figure C-26. Amphibian Visual Encounter Survey (VES) Habitat Form.

Amphibian Snorkel Survey Form (Optional)

Park Unit: _____ Lake Name: _____ Lake Code: _____

Date: ____/____/____ Observers: _____

Time (24 hr.): _____

Transect No.	Time Start	Time End	Tran. Dist. (m)	UTM_East	UTM_North	Dominant Habitat of Transect
Nearshore 1						
Offshore 1						
Nearshore 2						
Offshore 2						
Nearshore 3						
Offshore 3						
Nearshore 4						
Offshore 4						

Survey Type (near shore / offshore)	Transect Number	Species Code	Life History Stage	Count	Microhabitat of Observed Individuals	Specimen Length (mm)

Substrate Type: St = Silt (smooth between fingers <0.06 mm), **Sd** = sand (<2 mm), **G** = gravel (2-64 mm), **C** = Cobble (65-256 mm), **Bd** = Boulder (257-4096 mm), **Br** = Bedrock (>4096 mm), **FPOM** = Fine particulate organic matter (<1 mm dia.), **CPOM** = Coarse particulate organic matter (leaves, needles, twigs, small branches up to small logs 1-100 mm), **CWD** = Coarse woody debris (branches, rootwads, logs >100 mm dia.); Observations of individuals in the water column = WC. **Note:** Habitat evaluated only for Sample #1 and not required for replicate amphibian survey.

Species Codes: *Ambystoma gracile* = **AMGR**, *Ambystoma macrodactylum* = **AMMA**, Unidentified *Ambystoma* = **AMSP**, *Ascaphus truei* = **ASTR**, *Bufo boreas (Anaxyrus boreas)* = **BUBO**, *Dicamptodon* tenebrosus = **DITE**, *Dicamptodon copei* = **DICO**, *Plethodon larselli* = **PLLA**, *Plethodon vehiculum* = **PLVE**, *Plethodon vandykei* = **PLVA**, *Ensatina eschscholtzii* = **ENES**, *Rana aurora* = **RAAU**, *Rana cascadae* = **RACAS**, *Rana luteiventris* = **RALU**, *Pseudacris regilla* = **PSRE**, *Taricha granulosa* = **TAGR**

Life Stage: **E** = egg, **EM** = Egg Mass, **L** = larval, **J** = juvenile, **A** = adult, **P** = Paedomorph, **U** = unknown

Figure C-27. Amphibian Snorkel Survey Form.

Lake Riparian Disturbance Form

Park Unit: _____ Lake Name: _____ Lake Code: _____

Date: ____/____/____ Personnel: _____

Starting Sample Point Location Description (bearing and distance to landmarks and/or GPS, other descriptive information):

- First plot starts at randomly selected point followed by successive plot center points located at 50 m intervals. Intermediate plots at 25 m can be used to obtain a minimum sample of 5 plots.
- Plots numbered counter-clockwise around lake from start.

Plot No.	Distance (m)	Human Influence		Land Cover Type		Cover Type
		Shore Zone (0 - 3 m)	Near Shore (>3 - 10 m)	Shore Zone (0 - 3 m)	Near Shore (>3 - 10 m)	
Start-1	0					MD - Meadow
2						SH - Shrub
3						SH/MD - Shrub-Meadow
4						CF - Conifer Forest
5						DF - Deciduous Forest
6						MXF - Mixed Conif./Decid.
7						BR - Bedrock
8						BD - Boulder
9						AL - Alluvium
10						TA - Talus
11						SN/I - Snow/Ice
12						
13						**Human Influence**
14						(see details on back of form)
15						
16						0 - Pristine, no visible use
17						1 - Minimal human use
18						2 - Mod. use and disturbance
19						3 - Significant disturbance
20						4 - Severe disturbance
21						
22						
23						
24						
25						
26						
27						
28						
29						
30						
31						
32						
33						**Distance from last plot center point to start point (m)**
34						
35						_____

Figure C-28. Lake Riparian Disturbance Form

Lake Riparian Disturbance Form

(back side of form)

Human Use Condition Class Descriptions

Code	Description
0 – Pristine, no visible use.	No signs of human use of the area.
1 – Minimal human use.	Small and temporary indications of use caused by people or animals, such as litter, trampled vegetation, scuffed soil, footprints but no lasting damage such as plant loss (bare ground), erosion, or broken stems.
2 – Moderate use and disturbance	Human impacts are easily recognizable but limited in severity or distribution; examples include uprooted plants, clearing of forest litter, clearing of pebbles or rocks in fell fields or compacted soils, but not erosion; area of individual impacts should be small (<0.8 sq. ft. or 1ft. in diameter) and covering less than 15 % of the sub-plot area (shore zone 0-3m, near shore 3.1-10m, and far 10.1-20m).
3 – Significant disturbance	Few severe or many moderate impacts. Severe impact examples include walled campsites in an alpine area, eroded social trails (>1in. deep), large compacted sites (>0.8 sq.ft.); extensive moderate use impacts. Combined severe and moderate impacts covering 15 to 50% of the sub-plot areas.
4 – Severe disturbance	Greater than 50% of the sub-plot areas covered by combined severe and moderate use impacts.

Figure C-29. Lake Riparian Disturbance Form (backside).

Appendix D. Sampling Design.

Table D-1. North Cascades National Park Complex (NOCA) target population, sample frame, and selected sample (bold).

Lake Code	GRTS Order	Sample Frame	Lake Name	Surface Area (ha)	Elevation (m)	UTM X_Coordinate	UTM Y_Coordinate	Precip. (cm/yr)	Max. Depth (m)	Fish Density	Access on Foot
MR-12-01	**1**	**yes**	**Bowan**	**0.59**	**1980**	**669402.24**	**5364000.7**	**184**	**4**	**low**	**yes**
MA-03-01	**4**	**yes**	**Lower Silent**	**1.24**	**2042**	**659945.92**	**5379095.4**	**188**	**10**	**none**	**yes**
MC-14-02	**8**	**yes**	**Lower East**	**3.25**	**1664**	**622445.75**	**5416396.6**	**325**	**16.2**	**none**	**yes**
SM-02-02	**10**	**yes**	**Upper Triplet**	**0.96**	**1997**	**681649.31**	**5351346.4**	**167**	**4.3**	**low**	**yes**
MC-03-01	**11**	**yes**	**Easy Ridge**	**1.01**	**1679**	**615104.3**	**5412559.8**	**308**	**3.9**	**none**	**yes**
LS-07-01	**12**	**yes**	**Lower Blum**	**2.58**	**1506**	**610279.17**	**5400323.3**	**322**	**7.9**	**low**	**yes**
MC-17-02	13	yes	Tapto #2 (Middle)	0.5	1747	619647.05	5415485.6	328	5.5	none	yes
M-19-01	17	yes	Middle Thornton	4.82	1433	622593.44	5394102.6	301	24.0	low	yes
MC-06-01	18	yes	Copper	5.14	1604	613588.15	5419302.7	314	22.6	low	yes
MR-05-01	19	yes	Kettling	4.01	1638	667806.12	5368438.5	157	7	low	yes
MC-16-01	21	yes	Upper Middle	1.82	1737	620731.04	5416006.7	329	7.9	none	yes
MC-02-01	22	yes	Blum #1 (Vista)	1.03	1798	610359.76	5401599.6	310	10.7	none	yes
LS-03-01	24	yes	Middle Diobsud	1.57	1347	607406.18	5389244.5	379	5.2	low	yes
M-11-01	25	yes	Middle Blum	5.22	1533	610671.85	5400557.5	339	15.4	low	yes
LS-02-01	26	yes	Lower Diobsud	1.26	1286	607807.55	5388938.8	352	5.3	low	yes
MR-06-01	27	yes	Upper Kettling	0.78	1692	667915.17	5367949	157	3	none	yes
PM-04-01	28	yes	Upper Skymo	1.02	1611	639074.35	5410452.7	246	4.6	low	yes
MR-13-02	30	yes	Upper South Rainbow	1.45	1788	666808.9	5363128.3	182	7.4	low	yes
MM-11-01	32	yes	Upper West Rainbow	1.43	1973	666396.34	5363466.8	185	8.4	low	yes
M-10-01	43	yes	Mt Blum Lake	3.75	1750	611236.16	5400039.6	339	unk.	none	yes
MC-21-02	44	yes	Lower Reveille	1.64	1522	619725.39	5417201	318	3	none	yes
EP-14-01	45	yes	Hidden Lake Tarn	2	1777	634047.05	5373548.6	311	13	low	yes
MR-10-01	46	yes	Mcalester	5.36	1679	672027.02	5366339.5	167	7	moderate	yes
MC-21-01	47	yes	Upper Reveille	1.37	1522	619559.45	5417057.5	317	5	none	yes
LS-01-01	48	yes	Diobsud #1	0.41	1286	607863.84	5388785.9	352	3.4	low	yes
MR-01-01	49	yes	Stiletto	4	2071	673274.89	5372330.4	161	25.6	low	yes
MC-17-04	53	yes	Tapto #4 (West)	0.94	1725	619304.72	5415635.1	323	4.3	none	yes
PM-03-01	54	yes	Skymo	4.38	1608	639273.42	5410792.9	246	6.1	low	yes
DD-01-01	56	yes	Jeanita	0.56	1495	636845.34	5400632.9	252	3	low	yes
MM-08-01	58	yes	Upper Sandalee	0.59	1859	661764.81	5365792.1	203	3	none	yes
MC-14-01	59	yes	Upper East	2.51	1705	621992.43	5416675	325	4	none	yes

Table D-1. North Cascades National Park Complex (NOCA) target population, sample frame, and selected sample (bold) (continued).

Lake Code	GRTS Order	Sample Frame	Lake Name	Surface Area (ha)	Elevation (m)	UTM X_Coordinate	UTM Y_Coordinate	Precip. (cm/yr)	Max. Depth (m)	Fish Density	Access on Foot
MR-11-01	63	yes	Unnamed	1.15	1863	671236.91	5364764.4	167	8.8	low	yes
MC-04-01	64	yes	Egg	0.49	1579	611158.22	5417126.9	305	5	none	yes
MC-16-02	67	yes	Lower Middle	1.18	1705	620978.09	5415831.1	321	3	none	yes
MM-07-01	68	yes	Middle Sandalee	0.7	1641	661756.72	5366345.6	199	11.9	none	yes
MR-15-01	70	yes	Dee Dee	4.93	1921	674034.95	5363623.7	177	27	low	yes
MA-02-01	71	yes	Upper Silent	1.51	2126	659603.55	5379167.2	198	9.6	none	yes
MR-04-01	72	yes	Dagger	3.31	1679	673419.05	5370790	160	4.8	low	yes
MC-13-01	73	yes	Pass	2.53	1987	624466.92	5420033	304	unk.	unk.	yes
MP-08-01	75	yes	Torrent	0.64	1565	632060.06	5405090.1	295	3.7	none	yes
FP-09-01	79	yes	Skagit Queen #2	0.48	1661	647441.99	5375804.9	184	3.4	none	yes
MC-17-01	82	yes	Tapto #1 (Upper)	4.14	1753	619631.67	5415699.3	328	13.1	none	yes
ML-02-01	2	no	Sweet Pea	4.17	1689	651666.69	5384936.4	188	28.1	low	no
LS-12-01	3	no	Unnamed	0.55	1652	608673.95	5389648.5	391	5.6	none	no
M-14-01	5	no	Despair Lake Lower	0.7	1469	620042.55	5398225	316	5.9	none	no
LS-06-01	6	no	Ipsoot	3.61	1359	607506.74	5396243.2	328	17.1	low	no
MC-10-01	7	no	Ruta	0.44	1556	620279.36	5422892	247	5.2	none	no
MR-09-01	9	no	Unnamed	1.89	1812	668975.09	5366745.3	173	4.9	low	no
ML-07-01	14	no	Unnamed	0.53	1765	648560.1	5380407.9	177	5.1	none	no
M-15-01	15	no	Unnamed	0.57	1716	619354.61	5396518.7	304	unk.	unk.	no
DD-05-01	16	no	Upper Bouck	2.22	1533	635004.26	5393472.8	264	8.9	low	no
M-22-01	20	no	Unnamed	0.75	1567	613867.41	5397483.6	325	unk.	none	no
M-06-01	23	no	Talus Tarn	0.61	1692	610713.21	5396502.8	352	3.6	unk.	no
M-13-01	29	no	Upper Despair	0.85	1554	619679.35	5398257	316	unk.	none	no
EP-01-01	31	no	Unnamed	0.9	1664	635534.15	5386984.5	299	unk.	unk.	no
MSH-04-01	33	no	Ruth Mountain	1	1615	608742.73	5412633.6	316	8.9	none	no
FP-01-01	34	no	Unnamed	5.47	1567	638328.9	5382921.2	314	unk.	none	no
LS-04-01	35	no	Green Bench	1.59	1484	609974.29	5393122.8	374	6.5	low	no

Table D-1. North Cascades National Park Complex (NOCA) target population, sample frame, and selected sample (bold) (continued).

Lake Code	GRTS Order	Sample Frame	Lake Name	Surface Area (ha)	Elevation (m)	UTM X_Coordinate	UTM Y_Coordinate	Precip. (cm/yr)	Max. Depth (m)	Fish Density	Access on Foot
ML-03-01	36	no	Torment	1.45	1969	651475.39	5384096.7	191	15.2	low	no
EP-04-01	37	no	Unnamed	0.47	1623	633487.78	5384871.2	300	unk.	none	no
M-05-01	38	no	Nert	1.44	1389	610339.46	5395542	351	9	low	no
EP-02-01	39	no	Isolation	1.23	1743	636208.55	5385972.6	307	unk.	none	no
EP-06-01	40	no	Upper Wilcox	4.26	1565	634880.72	5384522.1	302	19.8	high	no
LS-05-01	41	no	Unnamed	1.43	1536	609827.75	5389717.7	394	4.0	none	no
MSH-02-01	42	no	Phantom Pass	0.51	1250	609513.83	5408971.7	305	4.7	none	no
MC-27-01	50	no	Wild	5.15	1487	619976.6	5405393.1	310	8.8	none	no
ML-04-01	51	no	Vulcan	3.33	1579	650632.83	5380703.3	187	7.7	none	no
MS-02-01	52	no	Mist	0.51	1399	633040.08	5416247.7	283	unk.	none	no
MLY-02-01	55	no	Battalion	2.55	1628	663983.37	5356901	121	4.8	mod	no
MP-02-01	57	no	Firn	2.29	1668	635561.17	5410367.3	303	12	mod	no
EP-16-01	60	no	Unnamed	0.42	1664	634437.02	5375966.3	276	unk.	unk.	no
FP-06-01	61	no	Klawatti Pot #2	0.62	1689	641985.52	5378355.2	246	3.4	none	no
M-07-01	62	no	Lower Berdeen	3.02	1359	612089.53	5395796.3	337	11	mod	no
MM-06-01	65	no	Waddell	4.1	1503	661545.26	5367233.8	196	11.9	none	no
LS-13-01	66	no	Unnamed	0.49	1530	605990.5	5390093	370	unk.	unk.	no
M-09-01	69	no	Upper Berdeen	3.91	1539	612593.37	5397888.5	360	unk.	none	no
M-02-01	74	no	Unnamed	0.58	1576	611126.52	5392803.3	373	unk.	unk.	no
EP-13-01	76	no	Sky Lake	0.79	1640	632819.8	5381593.4	316	unk.	none	no
EP-05-01	77	no	Lower Wilcox	2.19	1561	634607.82	5384550.3	305	6	low	no
EP-10-01	78	no	Pegasus	4.41	1713	637877.15	5383104.4	288	unk.	none	no
EP-03-01	80	no	Unnamed	0.85	1603	634247.09	5385322.9	297	3.7	none	no
MC-19-01	81	no	Unnamed	0.47	1445	621127.24	5412738.4	343	unk.	unk.	no

Table D-2. Mount Rainier National Park (MORA) target population, sample frame, and selected sample (bold).

Lake Code	GRTS Order	Sample Frame	Lake Name	Surface Area (ha)	Elevation (m)	UTM X_Coordinate	UTM Y_Coordinate	Precip. (cm/yr)	Max. Depth (m)	Fish Density	Access on Foot
ln03	**1**	**yes**	**Lake Allen**	**1.72**	**1397**	**584631.52**	**5179450.87**	**228**	**7.2**	**none**	**yes**
lh14	**2**	**yes**	**Upper Palisades Lake**	**0.78**	**1785**	**607152.01**	**5200464.19**	**190**	**15.3**	**none**	**yes**
lp19	**3**	**yes**	**Unnamed Lake**	**1.76**	**1372**	**584373.48**	**5185868.53**	**242**	**12.0**	**low**	**yes**
lh15	**4**	**yes**	**Unnamed Lake**	**2.95**	**1659**	**605176.85**	**5200714.75**	**185**	**10.0**	**low**	**yes**
lw32	**5**	**yes**	**Deadwood Lakes**	**2.70**	**1600**	**612691.18**	**5193418.07**	**203**	**3.5**	**low**	**yes**
lz35	**6**	**yes**	**Blue Lake**	**5.74**	**1352**	**601092.42**	**5176691.80**	**279**	**10.5**	**low**	**yes**
lw09	7	yes	Hidden Lake	2.12	1806	606711.34	5199433.68	191	7.0	none	yes
lw26	8	yes	Sunrise Lake	1.50	1750	607552.04	5197020.67	194	7.0	none	yes
lp22	9	yes	Kenworthy Lake	1.08	1445	582945.19	5183121.75	245	5.6	none	yes
lf05	10	yes	Lake James	4.98	1349	596329.12	5201989.67	203	23.0	low	yes
lw11	11	yes	Unnamed Lake	0.50	1730	607207.73	5199447.57	191	4.2	none	yes
lz31	12	yes	Cliff Lake	1.04	1592	595616.03	5178448.62	293	8.3	low	yes
lo12	13	yes	Shriner Lake	1.68	1490	613424.66	5184756.85	177	3.5	none	yes
lw38	14	yes	Shadow Lake	0.89	1896	602352.94	5195994.14	198	5.0	none	yes
lz29	15	yes	Snow Lake	2.39	1426	599542.83	5178840.24	304	10.7	low	yes
ln21	16	yes	Reflection Lakes	0.70	1487	597447.91	5180146.88	303	3.5	none	yes
lo11	17	yes	Unnamed Lake	3.08	1414	615214.18	5185531.63	173	3.9	none	yes
lw03	18	yes	Unnamed Lake	0.87	1526	609393.49	5203460.92	162	6.4	low	yes
lc25	19	yes	Unnamed Lake	0.73	1474	592961.16	5204128.78	217	unk.	unk.	yes
lo09	20	yes	Unnamed Lake	1.19	1591	614551.67	5187790.92	170	5.7	none	yes
lo15	21	yes	Unnamed Lake	0.49	1563	617705.18	5180463.14	183	unk.	unk.	yes
lw29	22	yes	Crystal Lake	3.20	1780	613790.89	5195513.66	222	10.7	none	yes
lz10	23	yes	Fan Lake	1.29	1654	601201.72	5183244.67	302	4.3	none	yes
lz27	24	yes	Bench Lake	2.88	1384	599474.41	5179432.29	289	11.0	low	yes
lw20	25	yes	Clover Lake	2.90	1753	607131.24	5198018.01	192	14.2	none	yes
lw27	26	yes	Lower Crystal Lake	0.63	1664	613285.15	5196118.44	191	4.0	none	yes
lm18	27	yes	Unnamed Lake	0.78	1327	582921.47	5193161.00	200	unk.	none	yes
lc28	28	yes	Chenuis Lakes	1.40	1549	592498.31	5203088.97	210	14.2	none	yes
lm26	29	yes	Unnamed Lake	0.60	1430	584169.58	5192875.57	202	4.7	none	yes
lf12	30	yes	Mystic Lake	1.93	1741	594952.85	5196093.46	238	3.5	none	yes
lh09	31	yes	Unnamed Lake	0.81	1743	606163.86	5201322.64	183	2.9	none	yes

Table D-2. Mount Rainier National Park (MORA) target population, sample frame, and selected sample (bold) (continued).

Lake Code	GRTS Order	Sample Frame	Lake Name	Surface Area (ha)	Elevation (m)	UTM X_Coordinate	UTM Y_Coordinate	Precip. (cm/yr)	Max. Depth (m)	Fish Density	Access on Foot
lm01	32	yes	Eunice Lake	5.32	1635	585462.97	5200618.35	223	20.0	none	yes
lf01	33	yes	Adelaide Lake	2.60	1383	595795.95	5203879.49	209	4.0	low	yes
lf03	34	yes	Marjorie Lake	3.99	1390	595762.97	5203331.43	209	8.0	low	yes
lc32	35	yes	Unnamed Lake	0.87	1751	594795.78	5201376.90	226	3.9	unk.	yes
lm15	36	yes	Unnamed Lake	0.79	1407	583724.34	5193714.82	199	unk.	unk.	yes
lh12	37	yes	Lower Palisades Lake	1.57	1678	607369.57	5200838.66	190	5.9	low	yes
lw05	38	yes	Unnamed Lake	0.79	1649	608810.55	5201068.12	174	3.5	none	yes
lc08	39	yes	Unnamed Lake	1.19	1552	588013.18	5199305.64	222	unk.	unk.	yes
lw31	40	yes	Deadwood Lakes	3.03	1600	612482.25	5193681.85	197	3.5	low	yes
lw35	41	yes	Unnamed Lake	0.58	1778	607247.10	5192135.76	192	unk.	unk.	yes
lc10	42	yes	Unnamed Lake	1.96	1605	588999.88	5200057.18	213	unk.	unk.	yes
lm30	43	yes	Unnamed Lake	0.83	1496	583892.15	5192559.00	202	9.0	none	yes
lh07	44	yes	Unnamed Lake	1.73	1675	605450.52	5202311.94	177	2.8	none	yes
lm32	45	yes	Unnamed Lake	0.75	1502	584128.62	5192590.71	202	9.0	low	yes
lc31	46	yes	Chenuis Lakes	1.13	1516	592949.13	5202516.90	211	5.0	none	yes
lw02	47	yes	Unnamed Lake	0.60	1474	609593.40	5203649.63	162	5.7	low	yes
lm23	48	yes	Golden Lakes	2.41	1371	583360.90	5192809.53	204	6.0	none	yes
lh18	49	yes	Unnamed Lake	2.62	1686	602224.04	5199489.65	176	8.9	low	yes
lm11	50	yes	Unnamed Lake	0.94	2007	590254.09	5195699.95	235	11.6	none	yes
lo19	51	yes	Three Lakes	1.68	1425	616627.69	5179910.89	193	4.0	none	yes
lw46	52	yes	Unnamed Lake	0.74	1938	602876.21	5189990.64	247	3.0	none	yes
lp04	53	yes	Unnamed Lake	0.66	1620	584774.39	5191409.31	213	unk.	unk.	yes
lw40	54	yes	Ghost Lake	1.20	1333	611245.40	5191882.92	191	5.2	none	yes

Table D-3.a. Olympic National Park (OLYM) low precipitation stratum: target population, sample frame, and selected sample (bold).

Lake Code	Sample Frame	Lake Name	Surface Area (ha)	Elevation (m)	UTM X_Coordinate	UTM Y_Coordinate	Precip. (cm/yr)	Max. Depth (m)	Fish Density	Access on Foot
Low Precipitation Stratum										
14	yes	Happy	0.95	1487	448774.37	5317547.85	196	unk.	unk.	yes
21	yes	Boulder	3.72	1319	444031.04	5313958.93	204	unk.	unk.	yes
24	yes	Three Horse	1.55	1261	444781.45	5313199.97	214	unk.	unk.	yes
26	yes	Unnamed	1.45	1335	444113.26	5313127.27	211	unk.	unk.	yes
29	yes	Unnamed	2.73	1241	442776.93	5312207.14	221	unk.	unk.	yes
30	yes	Unnamed	1.42	1259	442134.72	5312122.45	222	unk.	unk.	yes
31	yes	Blue	0.92	1426	445025.50	5312124.85	224	unk.	unk.	yes
33	yes	Unnamed	0.62	1338	468002.45	5311997.28	210	unk.	unk.	yes
40	yes	Unnamed	0.66	1384	468981.66	5310413.43	217	unk.	unk.	yes
60	yes	Haigs	2.04	1425	446829.24	5307924.90	291	unk.	unk.	yes
61	yes	Clear	2.30	1290	441697.54	5307650.48	303	unk.	unk.	yes
63	yes	Morgenroth	4.14	1257	442890.73	5307547.70	293	unk.	unk.	yes
64	yes	Y Lake	0.50	1330	443234.05	5307558.11	290	unk.	unk.	yes
70	yes	Round	1.10	1303	441034.84	5307241.07	305	unk.	unk.	yes
72	yes	Lunch	1.14	1365	441484.87	5307194.88	305	unk.	unk.	yes
76	yes	Number 8	1.48	1411	443979.91	5306909.03	296	unk.	unk.	yes
79	yes	Heart	0.50	1456	445136.10	5306534.18	301	unk.	unk.	yes
84	yes	Unnamed	0.56	1663	472901.62	5305870.68	229	unk.	unk.	yes
90	yes	Unnamed	0.70	1765	475616.01	5305069.63	223	unk.	unk.	yes
95	yes	Grand	5.15	1446	474199.36	5304183.51	229	unk.	unk.	yes
98	yes	Unnamed	3.29	1540	473792.23	5303297.57	237	unk.	unk.	yes
106	**yes**	**Gladys**	**0.49**	**1642**	**473243.45**	**5302663.36**	**242**	**4.5**	**low**	**yes**
123	yes	Unnamed	0.45	1480	476398.49	5301094.06	226	unk.	unk.	yes
169	yes	Unnamed	0.84	1558	476150.68	5298597.49	237	unk.	unk.	yes
182	yes	Unnamed	0.82	1558	484224.18	5297650.99	196	unk.	unk.	yes
206	yes	Unnamed	0.44	1742	483555.29	5296576.06	201	unk.	unk.	yes
256	yes	Unnamed	0.50	1753	475931.95	5292730.25	286	unk.	unk.	yes
263	**yes**	**Heather**	**0.42**	**1590**	**486670.14**	**5292448.14**	**200**	**6.7**	**low**	**yes**
269	yes	Unnamed	0.45	1790	485843.24	5291825.31	204	unk.	unk.	yes
271	yes	Unnamed	0.48	1776	486426.40	5291731.84	202	unk.	unk.	yes
272	yes	Unnamed	0.48	1445	481970.12	5291698.19	227	unk.	unk.	yes
280	yes	Unnamed	0.73	1618	487704.66	5290944.16	200	unk.	unk.	yes
292	yes	Unnamed	4.42	1421	489312.16	5288664.59	203	unk.	unk.	yes

Table D-3.a. Olympic National Park (OLYM) low precipitation stratum: target population, sample frame, and selected sample (bold) (continued).

Lake Code	Sample Frame	Lake Name	Surface Area (ha)	Elevation (m)	UTM X_Coordinate	UTM Y_Coordinate	Precip. (cm/yr)	Max. Depth (m)	Fish Density	Access on Foot
Low Precipitation Stratum (cont.)										
375	yes	Unnamed	0.64	1642	482000.22	5282950.46	284	unk.	unk.	yes
397	yes	Unnamed	2.00	1690	481190.00	5281913.66	296	unk.	unk.	yes
485	yes	Unnamed	0.43	1459	483763.83	5275363.32	292	unk.	unk.	yes
489	yes	Unnamed	0.41	1518	482676.32	5274865.48	298	unk.	unk.	yes
491	yes	Unnamed	1.35	1435	484527.32	5274713.47	287	unk.	unk.	yes
497	yes	Unnamed	1.24	1298	481656.95	5274579.45	304	unk.	unk.	yes
498	**yes**	**Milk**	**1.14**	**1435**	**484442.80**	**5274562.96**	**287**	**13.7**	**none**	**yes**
514	yes	Unnamed	0.64	1507	482137.49	5274399.68	300	unk.	unk.	yes
549	yes	Unnamed	0.69	1434	480868.82	5273110.84	315	unk.	unk.	yes
49	no	Unnamed	0.43	1442	454607.90	5308850.91	315	unk.	unk.	no
74	no	No Name	2.66	1273	443071.79	5307142.22	296	unk.	unk.	no
104	no	Unnamed	0.41	1642	468238.77	5302911.44	252	unk.	unk.	no
112	no	Unnamed	0.45	1607	478039.31	5302090.84	215	unk.	unk.	no
121	no	Unnamed	0.97	1752	470494.29	5301084.21	254	unk.	unk.	no
129	no	Lillian	2.85	1764	470617.40	5300753.10	254	unk.	unk.	no
238	no	Unnamed	3.64	1777	483482.77	5294569.40	207	unk.	unk.	no
268	no	Unnamed	1.00	1629	490677.02	5291836.90	193	unk.	unk.	no
343	no	Wildcat	1.70	1274	488256.91	5284867.71	224	unk.	unk.	no

Table D-3.b. Olympic National Park (OLYM) moderate precipitation stratum: target population, sample frame, and selected sample (bold).

Lake Code	Sample Frame	Lake Name	Surface Area (ha)	Elevation (m)	UTM X_Coordinate	UTM Y_Coordinate	Precip. (cm/yr)	Max. Depth (m)	Fish Density	Access on Foot
Moderate Precipitation Stratum										
382	yes	Unnamed	5.11	1516	479196.22	5282548.34	325	unk.	unk.	yes
421	yes	Unnamed	1.13	1529	474038.84	5279341.26	398	unk.	unk.	yes
426	**yes**	**Crazy Lake**	**2.84**	**1447**	**472944.86**	**5279102.45**	**413**	**7.7**	**none**	**yes**
463	yes	Unnamed	1.36	1335	472613.64	5277384.68	418	unk.	unk.	yes
520	**yes**	**La Crosse**	**0.96**	**1457**	**478933.51**	**5274073.87**	**336**	**8.0**	**none**	**yes**
525	yes	Unnamed	1.46	1422	479526.03	5273915.43	330	unk.	unk.	yes
533	yes	Unnamed	0.74	1447	479704.04	5273614.18	327	unk.	unk.	yes
543	yes	Unnamed	0.62	1487	479524.36	5273197.32	330	unk.	unk.	yes
560	yes	Unnamed	0.78	1506	479410.23	5271490.88	333	unk.	unk.	yes
574	yes	Unnamed	0.96	1373	474209.43	5269003.28	386	unk.	unk.	yes
599	yes	Unnamed	1.28	1352	476607.57	5265949.25	353	unk.	unk.	yes
622	yes	Unnamed	1.07	1229	477432.80	5264384.72	341	unk.	unk.	yes
77	no	Unnamed	1.18	1716	453056.06	5306626.43	370	unk.	unk.	no
91	no	Unnamed	0.53	1560	453517.24	5304991.41	394	unk.	unk.	no
101	no	Unnamed	1.36	1411	455765.74	5303260.77	430	unk.	unk.	no
105	no	Unnamed	5.17	1523	454472.26	5302610.58	446	unk.	unk.	no
262	no	Unnamed	0.45	1544	463083.92	5292460.44	402	unk.	unk.	no
293	no	Unnamed	0.93	1641	469162.17	5288647.04	393	unk.	unk.	no
304	no	Unnamed	3.48	1703	478212.26	5287387.10	318	unk.	unk.	no
316	no	Unnamed	0.58	1656	478385.21	5286585.98	317	unk.	unk.	no
337	no	Unnamed	0.49	1607	476030.98	5285392.11	396	unk.	unk.	no
358	no	Unnamed	0.42	1511	475718.60	5283808.40	391	unk.	unk.	no
440	no	Unnamed	0.45	1420	479764.04	5278065.44	328	unk.	unk.	no
454	no	Unnamed	0.83	1388	479846.39	5277773.10	329	unk.	unk.	no
511	no	Unnamed	0.48	1401	472083.59	5274442.22	419	unk.	unk.	no

Table D-3.c. Olympic National Park (OLYM**)** high precipitation stratum: target population, sample frame, and selected sample (bold).

Lake Code	Sample Frame	Lake Name	Surface Area (ha)	Elevation (m)	UTM X_Coordinate	UTM Y_Coordinate	Precip. (cm/yr)	Max. Depth (m)	Fish Density	Access on Foot
High Precipitation Stratum										
125	yes	Unnamed	1.73	1226	453720.04	5300952.57	504	unk.	unk.	yes
138	**yes**	**Ferry basin**	**1.31**	**1434**	**455307.09**	**5300225.34**	**522**	**9.5**	**none**	**yes**
142	yes	Unnamed	1.00	1457	456007.43	5299956.88	521	unk.	unk.	yes
156	yes	Unnamed	1.49	1642	456800.75	5299143.37	534	unk.	unk.	yes
158	yes	Unnamed	0.62	1643	456635.63	5299072.63	534	unk.	unk.	yes
163	yes	Unnamed	2.29	1688	456891.14	5298663.55	548	unk.	unk.	yes
341	yes	Unnamed	1.00	1434	452039.85	5284957.66	537	unk.	unk.	yes
349	yes	Unnamed	0.91	1421	460061.64	5284542.95	559	unk.	unk.	yes
354	yes	Unnamed	0.43	1426	460123.93	5284304.74	559	unk.	unk.	yes
385	yes	Unnamed	1.61	1690	459706.52	5282478.91	558	unk.	unk.	yes
609	yes	Unnamed	0.51	1263	458624.94	5265542.05	557	unk.	unk.	yes
623	**yes**	**Sunup**	**0.98**	**1224**	**463405.78**	**5264336.26**	**480**	**6.6**	**low**	**yes**
627	**yes**	**Connie**	**2.11**	**1300**	**455346.81**	**5263487.01**	**559**	**9.2**	**none**	**yes**
191	no	Unnamed	1.36	1508	451428.88	5297300.91	610	unk.	unk.	no
203	no	Unnamed	4.48	1580	443905.67	5296508.82	559	unk.	unk.	no
205	no	Unnamed	1.64	1567	443642.96	5296585.79	559	unk.	unk.	no
221	no	Unnamed	0.51	1519	443858.87	5295768.53	559	unk.	unk.	no
225	no	Unnamed	0.42	1529	444009.16	5295530.06	559	unk.	unk.	no
237	no	Unnamed	0.59	1482	453781.08	5294668.76	602	unk.	unk.	no
259	no	Unnamed	0.92	1483	455317.32	5292484.28	559	unk.	unk.	no
274	no	Unnamed	1.94	1519	449842.56	5291596.08	540	unk.	unk.	no
290	no	Unnamed	0.42	1408	446694.18	5289234.32	519	unk.	unk.	no
321	no	Unnamed	1.18	1287	437869.69	5286179.75	473	unk.	unk.	no
348	no	Unnamed	0.69	1712	470293.28	5284597.17	468	unk.	unk.	no
420	no	Unnamed	0.53	1413	464692.49	5279461.71	522	unk.	unk.	no
432	no	Unnamed	1.99	1328	463224.14	5278525.70	521	unk.	unk.	no
458	no	Unnamed	2.83	1506	465235.59	5277501.78	508	unk.	unk.	no

Table D-4. Mean coefficient of variation (CV) values for a subset of proposed NCCN lake monitoring response variables. Historical lake data collected at Mount Rainier and North Cascades National Parks (R. Glesne, Mar. 2007 NOCA files).

Response Variables[1]	No. of Lakes	No. of Data Sets	Replicates/Data Set	Mean[2] CV	Evaluation Method[3]
Water Temperature	4	5	9	0.075	3
Secchi Depth	17	36	3-9	0.018	1
Dissolved Oxygen	16	53	3-21	0.136	2
Conductivity	15	47	3-21	0.200	2
Alkalinity	16	52	3-21	0.173	2
pH	15	50	3-21	0.033	2
Chlorophyll a	7	32	3-7	0.398	2
Total Nitrogen	13	26	3-11	0.340	4
Total Phosphorus[4]	13	26	3-11	0.454	4
Ammonia[4]	13	26	3-11	0.610	4
Sodium	13	26	3-11	0.099	4
Potassium	13	26	3-11	0.168	4
Calcium	13	26	3-11	0.085	4
Magnesium	13	26	3-11	0.167	4
Sulfate	13	26	3-11	0.293	4
Chloride	13	26	3-11	0.265	4
Crustacean Zooplk (no./L)	12	15	3-6	0.400	3
Crustacean Zooplk (no.of taxa)	12	15	3-6	0.271	3

[1]Mount Rainier NP historical lake data used for all variables except zooplankton. Zooplankton data from North Cascades NP Complex.

[2]Mean CV values for water temperature were calculated by combining data sets from measurements recorded at 3 depths (near surface, mid-depth, and near bottom). Mean CV values for all chemistry variables were calculated by combining data sets from measurements recorded at 2 depths (near surface and near bottom).

[3]Evaluation Method: 1) Replicates from same sampling occasion used; 2) Replicates were from same season (mid July -Sept.) and same year; 3) Replicates were from same month (July or Aug.), but from different years; 4) Replicates were from same season (mid July-Sept.), but from different years.

[4]Total phosphorus and ammonia data near detection limits. Natural log transformation of data resulted in CVs of 0.141 and 0.171 for total phosphorus and ammonia, respectively.

Appendix D, Attachment 1. Power analysis methods for detection of trends (Trent McDonald).

This appendix contains methods for power analyses designed to estimate number of lakes needed to achieve 80% power. Sample size (number of lakes) required to detect a 2 to 5% annual trend with 80% power is based on testing the hypothesis H_0: $\beta_1 = 0$ versus the one-sided alternative H_1: $\beta_1 < 0$ in the following linear regression: $y_i = \beta_0 + \beta_1 x_i$, where y_i is the response of interest and x_i is year. Errors in this regression model were assumed to be correlated through time if they occurred on the same lake. Sample sizes were the same if we had tested H_1: $\beta_1 > 0$ because responses were assumed to follow the normal distribution. Trend is detected if the null hypothesis of no trend is rejected in favor of H_1. Assuming σ^2 is known, the null hypothesis H_0: $\beta_1 = 0$ will be rejected if the statistic $t = \hat{\beta}_1 / \sigma_{\beta,n}$ is less than the $(1\text{-}\alpha)^{th}$ quantile of a T distribution with $m = (n_{yrs}n\text{-}2)$ degrees of freedom, where n_{yrs} is number of years and n is number of lakes. The standard deviation of trend, $\sigma_{\beta,n}$, is the square root of the second diagonal element in the variance-covariance matrix,

$$\sigma_{\beta,n} = \sqrt{\sigma^2 (\underset{\sim}{X}' \underset{\sim}{R}^{-1} \underset{\sim}{X})^{-1}}$$

where R is the (block diagonal) correlation matrix for observations measured on the same lake through time. Lakes were assumed independent. The correlation between observations made in consecutive years was arbitrarily set at 0.5. (In addition, correlations were estimated as the lag 1 autocorrelation in values observed for several chemical parameters from 11 lakes at Mount Rainier National Park, with 5 to 10 year datasets. Ave correlation ranged from -0.01 to 0.12 for the five chemical parameters tested.). Assuming this lag 1 autocorrelation was ρ, the correlation of observations separated by k ($k \geq 1$) years was assumed to be ρ^k.

Assuming the random variable $\hat{\beta}_1$ follows a non-central T distribution with mean $\Delta = (0.05)\,\bar{Y}$ (= observed annual change of 5% of the original mean value) and variance $\sigma^2_{\beta,n}$, we calculate sample size as the smallest n such that

$$\Pr\left(\frac{\hat{\beta}_1}{\sigma_{\beta,n}} < t_{m,0.1}\right) = \Pr\left(\frac{\hat{\beta}_1}{\sigma_{\beta,n}} - \frac{\Delta}{\sigma_{\beta,n}} < t_{m,0.1} - \frac{\Delta}{\sigma_{\beta,n}}\right) = \Pr\left(T_m < t_{m,0.1} - \frac{\Delta}{\sigma_{\beta,n}}\right) = 0.8$$

where T_m follows a central T distribution with m degrees of freedom and $t_{m,0.1}$ denotes the critical value in a central T distribution corresponding to a test of size alpha = 10%. Letting $t_{m,0.8}$ denote the value of the central T distribution such that 80% of its area is to the left, sample size to obtain 80% power is calculated as the smallest value of n satisfying

$$t_{m,0.1} - \frac{\Delta}{\sigma_{\beta,n}} = t_{m,0.8}$$

Note that n denotes the number of lakes and the total number of points in the regression is $n_{yrs}n$.

Appendix D, Attachment 2. Power analysis script (for S+ statistical software) for detection of trends (Trent McDonald).

```
F.trend.eff.power _ function( slope=seq(0,0.075,by=.01), var.obs, corr.obs, n.range=seq(5,15,by=5), xbar,
nyears=10, alpha=0.05, one.sided=F ){
#
#               Compute the sample size needed to achieve 1-beta power to detect a slope of 'slope'
#               using linear regression with correlated errors after nyears years.  Var-Covar of observations
#               involves var.obs and corr.obs.
#
#
#               Input:
#               slope = slope coefficient desired to detect THESE ARE PERCENTAGES OF XBAR!!
#               var.obs = variance of an individual observation in the regression
#               corr.obs = correlation year-to-year of observations measured on the same sampling unit
#               n = number of sample sites/units to assess power for
#               xbar = overall average level of density
#               alpha = Type I error rate
#               nyears = number of consecutive years of measurements at each site.
#               one.sided = T or F depending on whether one or two sided test desired
#
#               output:
#               number of sample units to use.
#
#               tlm - 22jul04
#

n.all _s.all _ p.all _ NULL
slope _ slope / 100
slope.real _ xbar * slope
print(slope.real)
for(slp in slope.real){
  print( slp )
  for( n in n.range ){
                p.all_c(p.all, F.trnd.power( slp, var.obs, corr.obs, n, nyears, alpha, one.sided ))
                n.all _ c(n.all, n)
                s.all _ c(s.all, 100*slp/xbar)
  }
}

ans _ data.frame(s.all, n.all, p.all)
names(ans) _ c("beta", "n", "power")

ans
}
```

Appendix D, Attachment 2. Power analysis script (for S+ statistical software) for detection of trends (Trent McDonald) (continued).

```
# ------------------------------------------------------------------------------

F.trnd.power _ function(  slope, var.obs, corr.obs, n, nyears, alpha, one.sided ){
#
#               compute power of linear model to detect slope for one value of n
#
#

# correlation matrix, exponential form
r _ diag(nyears)   # identity matrix
for( i in 1:(nyears-1)){
               r[ abs(row(r) - col(r)) == i ] _ corr.obs^i
}


# Big correlation matrix
big.r _ kronecker( diag(n), r )

# The design matrix
big.n _ nrow(big.r)
#print(big.n)
x _ cbind( rep(1, big.n), rep( 1:nyears, n ) )

# compute std error of slope
sig.beta _ t(x) %*% solve(big.r) %*% x
sig.beta _ solve( sig.beta ) * var.obs
#print( sig.beta )
sig.beta _ sqrt( sig.beta[2,2] )

# Compute t stat and power
if( one.sided ){
               # assume lower tail is of interest, but everything symmetric, so doesn't matter.
               t.alpha _ qt( 1-alpha, big.n - 2 )

               t.stat _ - t.alpha - (slope / sig.beta)
               pow2 _ pt( t.stat, big.n - 2 )   # lower tail probability

               pow _ pow2

} else {
               t.alpha _ qt( 1-(alpha/2), big.n - 2 )

               t.stat _ t.alpha - (slope / sig.beta)
               pow1 _ 1 - pt( t.stat, big.n - 2 )   # upper tail probability

               t.stat _ - t.alpha - (slope / sig.beta)
               pow2 _ pt( t.stat, big.n - 2 )   # lower tail probability

               pow _ pow1 + pow2
}
```

Appendix D, Attachment 2. Power analysis script (for S+ statistical software) for detection of trends (Trent McDonald) (continued).

```
pow
}

# ------------------------------------------------------------
F.plot.power _ function( power1, main.title, lab.x ){
#
#               Plot the results of a call to F.trend.eff.power
#

# plot negative slopes as positive declines
power1$beta _ -power1$beta

plot( range(power1$beta), range(power1$power), type="n", xlab="Annual decline in average response (%)",
ylab="", ylim=c(0,1),
                cex=2 )
mtext( "Power", side=2, line=3, cex=2 )
title( main=main.title, cex=2)
for( n in sort(unique(power1$n)) ){
                tmp.ind _ power1$n == n
                lines(power1$beta[ tmp.ind ], power1$power[ tmp.ind ] )
                tmp.y _ approx( power1$beta[ tmp.ind ], power1$power[ tmp.ind ], xout=lab.x )$y
                if( n != max(power1$n) ){
                                text( lab.x - .02, tmp.y+.02, n, adj=1)
                                #text( -6.3, tmp.y+.02, n, adj=1)
                } else {
                                text( lab.x - .02, tmp.y+.02, paste("n=",n), adj=1)
                }

}

#text(lab.x - .02, tmp.y + 0.06, "n=", adj=1 )
#lines(c(lab.x-.1, lab.x-.25), c(tmp.y+.04, tmp.y+.04))
abline( h=.8, lty=2)
abline( v=5, lty=2)
#abline( v=-5, lty=2 )

invisible()
}

# --- Change the next line using values for your situation.  I.e., residual variance = var.obs, year-to-year
#               correlation = corr.obs, overall mean level = xbar, etc.   Then execute "source(trend_samp_size.s)" in S-
plus.

power1 _ F.trend.eff.power( slope=seq(-5,0,by=.5), var.obs=0.01, corr.obs=0.5, n.range=c(5, 10, 20, 30, 40, 50),
xbar=1.0, nyears=10, alpha=0.10, one.sided=T )
F.plot.power( power1, "NOCA Example", lab.x=3.8 )
```

Appendix E. Data Analysis.

Table E-1. Water temperature routine data summaries and analyses for responses measured from each lake at NOCA, MORA, and OLYM National Parks, NCCN Mountain Lake Protocol.

Monitoring Component	Measures	Measurements Per Lake	Calculation/Response Variables	Reported By:	Data Analyses
Continuous Water Temp.	Daily Max.	1[a] location, multiple measurements.	Max. value of daily max. temps. (MDMT)	Month and season (with occur. dates)	1) Site status and trend 2) Park and Network trends 3) Abrupt change (site, park, network)
	Daily Min.	1[a] location, multiple measurements.	Average of daily maximum temps. (ADMT).	Month	
	Daily Min.	1[a] location, multiple measurements	Max. weekly max. temp (MWMT) derived from 7-day moving average of daily maximum temperatures	Year (with occur. dates)	Same as above
	Daily Min.	1[a] location, multiple measurements	Average of daily minimum temps. (ADMinT).	Month	Same as above
	Daily Min. and Max.	1[a] location, multiple measurements	Max. diurnal fluctuation – max. value of daily max. minus daily min. temperatures (MAXDIURN)	Month and season (with occur. dates)	Same as above
	Daily Average	1[a] location, multiple measurements	Average of daily average temp. (ADAT)	Month	Same as above
	Daily Average	1[a] location, multiple measurements	Maximum value of daily avg. temp. (MDAT)	Month and season (with occur. dates)	Same as above
	Daily Average	1[a] location, multiple measurements	Max. weekly avg. temp. (MWAT) derived from 7-day moving average of daily average temperatures	Year (with occur. dates)	Same as above
	Daily Average	1[a] location, multiple measurements	Degree-days (DEGDAY) derived as sum of differences between daily avg. temps. and base temperature of 0°C.	Year (starting Jan 1) and seasons	Same as above
	Date of ice-out	1[a] location, multiple measurements	Date corresponding to the initiation of surface temperature rising above 0°C.	Year	Same as above
Temperature Profile	Depth and temperature values	1 location with measurements at 1 m intervals from surface to bottom	1) Mean or median temperature for profile, and if stratified, then separate means or medians for epilimnion, hypolimnion, and metalimnion, 2) Metalimnion depth interval and limits.	Lake by sampling occasion	1) Site status and trend

[a] Temperature is recorded year-round at 0.5 to 1.0 hour intervals. Total of three loggers used, set near surface, mid-depth, and near the bottom

Table E-2. Lake morphology, riparian zone characteristics, and water clarity routine data summaries and analyses for responses measured from each lake at NOCA, MORA, and OLYM National Parks, NCCN Mountain Lake Protocol.

Monitoring Component	Measures	Measurements Per Lake	Calculation/Response Variables	Reported By:	Data Analyses
Lake Morphology	Lake water level	2 to 3 locations - 3 measurements at each location	Mean relative water surface elevation for each location.	Lake by sampling occasion	1) Site status and trend 2) Park and Network trends 3) Abrupt change (site, park, network)
	Basin aspect	1 measurement	Compass heading in the direction of the downslope axis of the basin or GIS.	Lake (first sampling occasion)	1) Site status
	Surface area	1 measurement (entire lake)	Surface area value	Lake (once every 20 yrs)	1) Site status
	Shore line length	1 measurement (entire shoreline)	1) Shore line perimeter value, 2) Shore line Development Ratio	Lake (once every 20 yrs)	1) Site status
	Max. depth	1 location	Max depth value	Lake by sampling occasion	1) Site status
	Mean depth	Multiple depth measurements	Mean depth value (estimated from lake depth contours)	Lake (once every 20 yrs)	1) Site status
	Lake volume	Multiple depth measurements	Lake volume (estimated from lake depth contours)	Lake (once every 20 yrs)	1) Site status
	Littoral zone substrate	Multiple random locations around lake perimeter.	Median % coverage for each substrate type.	Lake by sampling occasion	1) Site status
Lake Riparian Zone Characteristics	Land cover type	Multiple locations and from 2 shoreline proximity classes	Frequency for each dominant cover type class by each shoreline proximity class	Lake (once every three years)	1) Site status
	Disturbance class	Multiple locations and from 2 shoreline proximity classes	Frequency for each condition class by each shoreline proximity class	Lake (once every three years)	1) Site status and trend 2) Park and Network trends 3) Abrupt change (site, park, network)
Water Clarity	Secchi depth	1 location - 3 measurements	1) Mean Secchi depth, 2) Trophic State Indicator (TSI-SD, Carlson 1977)	Lake (once every three years)	1) Site status and trend 2) Park and Network trends 3) Abrupt change (site, park, network)

Table. E-3. Water chemistry routine data summaries and analyses for responses measured from each lake at NOCA, MORA, and OLYM National Parks, NCCN Mountain Lake Protocol.

Monitoring Component	Measures	Measurements Per Lake	Calculation/Response Variables	Reported By:	Data Analyses
Water Chemistry	Dissolved oxygen	1 location – multiple measurements from surface to bottom of the lake	1) Mean or median concentration (mg/L) by depth location or entire profile.	Lake by sampling occasion	1) Site status and trend 2) Abrupt change (site)
	pH	1 location, multiple measurements from surface to bottom of the lake	Mean or median pH	Lake by sampling occasion	1) Site status and trend 2) Park and Network trends 3) Abrupt change (site, park, network)
	Acid neutralizing capacity (ANC)	1 location, 1-2 measurements [a]	Mean ANC concentration (meq/L)	Lake by sampling occasion	Same as shown for pH
	Specific conductance	1 location, multiple measurements from surface to bottom of the lake	Mean or median specific conductance (µS/cm)	Lake by sampling occasion	Same as shown for pH
	Nutrients	1 location, 1-2 measurements [a]	1) Mean concentration (mg/L) - total nitrogen, ammonia, total phosphorus, orthophosphate, 2) Trophic State Indicators for total phosphorus (TSI-TP, Carlson 1977) and total nitrogen (TSI-TN, Kratzer and Brezonik 1981, and Carlson 1992)	Lake by sampling occasion	Same as shown for pH
	Total dissolved solids (TDS)	1 location, 1-2 measurements [a]	Mean TDS concentration (mg/L)	Lake by sampling occasion	Same as shown for pH
	Anions and cations	1 location, 1-2 measurements [a]	Mean concentration (meq/L) - (chloride, nitrate, sulfate, sodium, ammonium, potassium, magnesium, and calcium)	Lake by sampling occasion	Same as shown for pH
	Dissolved organic carbon	1 location, 1-2 measurements [b]	Mean DOC concentration (mg/L)	Lake by sampling occasion	Same as shown for pH

[a] Two samples for thermally stratified lakes (near surface and bottom) and one for unstratified lakes (mid-depth). Replicates taken at some lakes each year during the same sampling occasion.
[b] Dissolved organic carbon – one sample collected near surface. Replicates taken at some randomly chosen lakes each year during the same sampling occasion.

Table E-4. Biological routine data summaries and analyses for responses measured from each lake at NOCA, MORA, and OLYM National Parks, NCCN Mountain Lake Protocol.

Monitoring Component	Measures	Measurements Per Lake	Calculation/Response Variables	Reported By:	Data Analyses
Algal Biomass	Chlorophyll-a	1 location, 1 measurement at mid-depth	1) Mean chlorophyll-a (µg/L). 2) Trophic State Indicator for chlorophyll-a (TSI-Chl, Carlson 1977).	Lake by sampling occasion	1) Site status and trend 2) Park and Network trends 3) Abrupt change (site, park, network)
Zooplankton	Number of individuals in observed taxa	1 location, 1 pooled sample from 3 tows [a]	1) Mean total no./L. 2) Mean no./L by taxa. 3) Composition metrics by: indicator taxa groups, dominant taxa, functional feeding groups, tolerance or other indicators.	Lake by sampling occasion	Same as above
	Number of taxa	1 location, 1 pooled sample from 3 tows [a]	1) Mean total no. of taxa 2) Mean no. of taxa by broader taxonomic groups, functional feeding groups, tolerance or other indicators.	Lake by sampling occasion	Same as above
Littoral Benthic Macroinvertebrates	Number of individuals in observed taxa	1 pooled sample from 5 subsamples collected at 5 separate random locations around the lake [a]	Fixed count subsample of 500 specimens: 1) Composition metrics by: indicator taxa groups, dominant taxa, functional feeding groups, tolerance or other indicators.	Lake by sampling occasion	Same as above
	Number of taxa	1 pooled sample from 5 subsamples collected at 5 separate random locations around the lake [a].	Fixed Count Subsample of 500 specimens: 1) Mean total no. of taxa 2) Mean no. of taxa by broader taxonomic groups, functional feeding groups, tolerance or other indicators.	Lake by sampling occasion	Same as above
Amphibians	No. of individ. by species	1-2 complete shoreline VES surveys [a, b]	Presence/absence and relative abundance by species/life stage (mean no./100 m shoreline)	Lake by sampling occasion	1) Site status and trend
Fish	No. of individ. by species and by total catch	1-2 gill net locations depending on lake size [c]	Presence/absence and gill net catch/hr. by species/life stage (size class).	Lake by sampling occasion	1) Site status and trend
	Specimen length and weight	All individuals captured	Mean length (total and fork length-mm) and weight by species.	Lake by sampling occasion	1) Site status and trend

[a] Replicates taken at some randomly chosen lakes each year during the same sampling occasion.
[b] Amphibian snorkel transect surveys (optional) can be used for replication.
[c] Gill nets must be used every 5 years and is optional during other years.

Table E-5. Potential zooplankton metrics for assessment of impairment in NCCN mountain lakes. Listed metrics represent those used in development of other lake monitoring protocols or those that may be representative of results found in other publications (predicted response of most metrics is variable depending on lake typology, chemical characteristics, and stressors).

Metrics	Calculation	References[1]
	Abundance Measures	
Total Abundance	Number/L of all taxa.	6, 7, 16
Crustacean Abundance	Number/L of all crustacean zooplankton taxa	7, 11,16, 17
Cladoceran Abundance	Number/L of Cladoceran taxa.	6, 7, 8, 14, 16, 17
Daphnia species	Number/L of *Daphnia* taxa	1, 5, 6, 8, 10, 16
Copepod Abundance	Number/L of Copepoda taxa. (also grouped by calanoid and cyclopoid, e.g., Stemberger and Lazorchak 1994.)	7, 8, 10, 11, 12, 13, 16
Rotifer	Number/L of Rotifer taxa	3, 7, 8, 11, 16
Large-bodied crustaceans	Number/L of large-bodied crustaceans (≥1 mm)[2].	1, 2, 5, 6, 8, 9, 10, 11, 12, 13, 16
	Composition Measures	
% Crustaceans	% of total abundance represented by crustacean zooplk.	1
% Rotifers	% of total abundance represented by Rotifers.	3, 8
% Large-bodied crustaceans	% of total abundance represented by large-bodied (≥1 mm)[2] crustacean zooplankton.	1, 5, 6, 8, 9, 10, 11, 12, 13, 18
% Small-bodied crustaceans	% of total abundance represented by small-bodied (<1 mm)[2] crustacean zooplankton.	6, 5, 8, 9, 11, 12, 13
	Taxa Richness[3] Measures	
Total taxa	Count of all distinct taxa in the sample.	4, 5, 6, 7, 16, 18
Crustacean taxa	Number of crustacean zooplankton taxa.	1, 4, 15, 16
Rotifer taxa	Number of rotifer taxa.	1, 3, 16
Large-bodied crust. taxa	Number of large-bodied (≥1 mm)[2] crust. zooplk. taxa.	1, 6, 8, 9, 11, 12, 13, 16
Daphnia species	Number of Daphnia species.	1, 6, 12, 16
	Dominance	
% Dominant taxa	% of total abundance represented by top 1, 3, or 5 taxa.	6, 12, 18
	Functional Feeding Groups	
% Predators/omnivores	% of total abundance represented by predators and omnivores.	9, 12
% Herbivores	% of total abundance represented by herbivores	9, 12
Predator taxa	Number of predator taxa.	9, 18

[1]*See* Table E-5. References

[2]Criterion of 1 mm body size (e.g., Knapp et al. 2001) may be subject to change for NCCN lakes.

Table E-5 References.

1. Bradford, D. F., S. D. Cooper, T. M. Jenkins, K. Kratz, O. Sarnelle, and A. D. Brown. 1998. Influences of natural acidity and introduced fish on faunal assemblages in California alpine lakes. Canadian Journal of Fisheries and Aquatic Sciences 55:2478-2491.

2. Carlisle, D. M., and C. P. Hawkins. 1998. Relationships between invertebrate assemblage structure, 2 trout species, and habitat structure in Utah mountain lakes. Journal of North American Benthological Society 17(3):286-300.

3. Deimling, E. A., W. J. Liss, G. L. Larson, R. L. Hoffman, and G. Lomnicky. 1997. Rotifer abundance and distribution in the northern Cascade mountains, Washington, USA. Archiv für Hydrobiologie 138(3):345-363.

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Table E-6. Potential benthic macroinvertebrate metrics for assessment of impairment in NCCN mountain lakes. Listed metrics represent those used in development of other lake monitoring protocols or those that may be representative of results found in other publications.

Metric (Predicted Response with Increasing Stress)	Calculation	References[1]
	Composition	
% EPT (-)	% of total count represented by Ephemeroptera, Plecoptera, and Trichoptera.	5, 6, 7, 8, 10
% ETO (-)	% of total count represented by Ephemeroptera, Trichoptera, and Odonata.	4, 11
% Ephemeroptea (-)	% of total count represented by Ephemeroptera.	5, 6, 7, 8, 10
% Trichoptera (-)	% of total count represented by Trichoptera.	3, 5, 6, 7, 8, 10
% Limnephilidae (-)	% of total count represented by Limniphilids	3, 5, 6, 7, 8, 10, 11
% Oligochaeta (+)	% of total count represented by Oligochaetes.	2, 3, 6, 7, 8, 9
% Diptera (+/-)	% of total count represented by Dipterans.	2, 3, 4, 7, 8
% Chironomids (+/-)	% of total count represented by Chironomids.	1, 2, 3, 9
% Hemiptera + Coleoptera (-)	% of total count represented by Hemiptera and Coleoptera.	3, 7, 8
% Non-Insects (+/-)	% of total count represented by non-insects.	9, 11
% Amphipoda (-)	% of total count represented by Amphipods.	2, 3, 6, 7, 8
	Taxa Richness	
Total taxa (-)	Count of all distinct taxa in a sample.	1, 3, 4, 5, 6, 7, 8, 9, 10, 11
EPT taxa (-)	Number of Ephemeroptera, Plecoptera, and Trichoptera taxa.	5, 6, 7, 8, 10
ETO taxa (-)	Number of Ephemeroptera, Trichoptera and Odonata taxa.	2, 4, 11
POET taxa (-)	Number of Plecoptera, Odonata, Ephemeroptera, and Trichoptera taxa in sample.	1
Ephemeroptera taxa (-)	Number of Ephemeroptera taxa in sample.	5, 6, 7, 8, 10
Trichoptera taxa (-)	Number of Trichopetera taxa in sample.	3, 5, 6, 7, 8, 10
Diptera taxa (+/-)	Number of Diptera taxa in sample.	2, 3, 8
Chironomidae taxa (+/-)	Number of Chironomid taxa in sample.	1, 2, 3, 6
	Dominance	
% Dominant taxa (+)	% of total count represented by top 1,3,or 5 taxa.	1, 7, 8, 9
	Functional Feeding Group	
% Predators (-)	% of total count represented by predators.	3, 6, 7, 8
Predator taxa (-)	Number of Predator taxa in sample	3, 6, 7, 8
% Collectors and Gatherers (-)	% of total count represented by collector-gatherers.	3, 5, 6, 7, 8
Collector-Gatherer. taxa (-)	Number of collector-gatherer taxa in a sample.	3, 5, 6, 7, 8
% Shredders (-)	% of total count represented by shredders	11
	Habitat Group	
% Clingers + Swimmers (-)	% of total count represented by clingers and swimmers.	5, 6, 7, 8
% Burrowing taxa (+)	% of total count represented by burrowing taxa.	7, 8
	Tolerance/Intolerance	
HBI	A published tolerance value is given to each taxa, summed for the assemblage as a whole using the following equation. Values range from 0 to 10. HBI = xi ti / n where: xi = number of individuals within genera i, ti = tolerance value for genera i, n = total number of organisms in the sample.	2, 9, 11
% Tolerant (+)	% of total count represented by all taxa that are insensitive to perturbance (based on published Tolerance Values).	2
Intolerant taxa (-)	Number of taxa considered to be sensitive to perturbance (based on published Tolerance Values).	2, 9,

[1]*See* Table E-6 References.

Table E-6 References.

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Table E-7. Miscellaneous recommendations for chemical and physical criteria for protecting freshwater aquatic life in lakes of the Cascades Region.

Parameter	Suggested Criteria	Region	Citation
Nitrate (NO_3)	≤40 mg/L as Nitrogen [1]	British Columbia	Nordin and Pommen (2001)
Ammonia (NH_3)	≤1.80 mg/L as Nitrogen [2]	British Columbia	Nordin and Pommen (2001)
Total Phosphorus	0.005 to 0.015 mg/L [3]	British Columbia	Nordin (2001)
Dissolved Oxygen	≥8.0 mg/L[1] or ≥5.0 mg/L[4]	British Columbia	B.C. Ministry Water, Land and Air (1997)
Total Nitrogen (Summer: June-Aug.)	≤0.02 mg/L [5]	USEPA Level III Nutrient Ecoregion 4 (Cascades)	USEPA (2000), Appendix B
Total Phosphorus (Summer: June-Aug.)	≤0.0075 mg/L [5]	USEPA Level III Nutrient Ecoregion 4 (Cascades)	USEPA (2000), Appendix B
Dissolved Oxygen (Summer: June-Aug.)	≥9.10 mg/L [5]	USEPA Level III Nutrient Ecoregion 4 (Cascades)	USEPA (2000), Appendix B
pH (Summer: June-Aug.)	≥6.4 [5]	USEPA Level III Nutrient Ecoregion 4 (Cascades)	USEPA (2000), Appendix B
Secchi Depth (Summer: June-Aug.)	≥5.98 [5]	USEPA Level III Nutrient Ecoregion 4 (Cascades)	USEPA (2000), Appendix B
Chlorophyll-a (Summer: June-Aug.)	≤0.80 µg/L [5]	USEPA Level III Nutrient Ecoregion 4 (Cascades)	USEPA (2000), Appendix B
7-Day Avg. Daily Max Temp.	No increase >0.3^{0}C over natural conditions	Washington lakes	WADOE (2006) State Water Quality Standard
Dissolved Oxygen	No decrease >0.2 mg/L below natural conditions	Washington lakes	WADOE (2006) State Water Quality Standard
Total Phosphorus	≤004 mg/L	Washington ultra-oligotrophic lakes	WADOE (2006) State Water Quality Standard
Total Phosphorus	≤010 mg/L	Washington oligotrophic lakes	WADOE (2006) State Water Quality Standard

[1] The average value calculated from a period of 30 days.

[2] The average value calculated from a period of 30 days. Ammonia criteria based on a temperature of 10°C and pH of 6.5.

[3] Total phosphorous in lakes is either the spring overturn concentration, if the residence time of the epilimnetic water is greater than 6 months, or the mean epilimnetic growing season concentration, if the residence time of the epilimnetic water is less than 6 months.

[4] Instantaneous measurement.

[5] Reference condition established by the 25th percentile of median values (75th percentile for pH, dissolved oxygen and Secchi depth) summarized for all lakes within the ecoregion.

Table E-7 References.

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Appendix E, Attachment 1. Abrupt change analysis statistical synopses (McDonald 2005).

Single Site – Regression on Time:
In what follows, we assume that no auxiliary covariates are included in the model. If they were, additional columns would be included in the **X** matrix.

Let y_i be the response of interest at time i on a particular stream segment. To formulate the regression method, we collect all responses prior to the current year in vector **Y.** Assume **Y** has n elements. Then, we assume,

$$\mathbf{Y} = \mathbf{X}\boldsymbol{\beta} + \mathbf{E}$$

where

$$\mathbf{X} = \begin{bmatrix} 1 & year_1 \\ 1 & year_2 \\ 1 & year_3 \\ \vdots & \vdots \\ 1 & year_n \end{bmatrix},$$

and

$$\boldsymbol{\beta} = \begin{bmatrix} \beta_0 \\ \beta_1 \end{bmatrix},$$

is a vector of unknown coefficients to be estimated, and **E** is a vector of unknown random errors. The $year_i$ values in **X** are the actual years that each response was measured (e.g., 2006, 2007, 2010, etc.). If responses were not measured in a particular year, that year would not appear in **X**. Consequently, n is the number of data points, not the number of years that the overall monitoring project has been collecting data when analyzing data from a single site.

In addition to the above linear model assumption, we also assume that individual errors in **E** are normally distributed with a mean of 0 and individual variance v_i, i.e.,

$$\mathbf{E} = MVN(\mathbf{0}, \boldsymbol{\Sigma})$$

where

$$\boldsymbol{\Sigma} = \begin{bmatrix} v_1 & 0 & \cdots & 0 \\ 0 & v_2 & & \vdots \\ \vdots & & \ddots & \\ 0 & \cdots & & v_n \end{bmatrix}.$$

Under these linearity and distributional assumptions, the least squares estimate of $\boldsymbol{\beta}$ is,

$$\hat{\boldsymbol{\beta}} = (\mathbf{X}'\hat{\boldsymbol{\Sigma}}^{-1}\mathbf{X})^{-1}\mathbf{X}'\hat{\boldsymbol{\Sigma}}^{-1}\mathbf{Y}$$

where $\hat{\boldsymbol{\Sigma}}^{-1}$ is the inverse of the estimated variance-covariance matrix, i.e.,

Appendix E, Attachment 1. Abrupt change analysis statistical synopses (McDonald 2005) (continued).

$$\hat{\boldsymbol{\Sigma}}^{-1} = \begin{bmatrix} 1/\hat{v}_1 & 0 & \cdots & 0 \\ 0 & 1/\hat{v}_2 & & \vdots \\ \vdots & & \ddots & \\ 0 & \cdots & & 1/\hat{v}_n \end{bmatrix}.$$

If a separate estimate of $\boldsymbol{\Sigma}$ is available, say based on a spatial variogram (Isaaks and Srivastava 1989), that estimate can be used in place of $\hat{\boldsymbol{\Sigma}}$. A 95% prediction interval for the response in year n+1 is

$$\mathbf{x}'\hat{\boldsymbol{\beta}} \pm t_{0.025,n-2}\hat{\sigma}(1+\mathbf{x}'(\mathbf{X}'\hat{\boldsymbol{\Sigma}}^{-1}\mathbf{X})^{-1}\mathbf{x}),$$

where

$$\mathbf{x} = \begin{bmatrix} 1 \\ year_{n+1} \end{bmatrix},$$

$$\hat{\sigma} = \sqrt{(\mathbf{Y} - \mathbf{X}\hat{\boldsymbol{\beta}})'(\mathbf{Y} - \mathbf{X}\hat{\boldsymbol{\beta}})/(n-2)},$$

and $t_{0.025,n-2}$ is the 2.5% -th quantile from Student's T distribution with n-2 degrees of freedom. If additional covariates other than year are included in **X,** the denominator of $\hat{\sigma}$ and the degrees of freedom of the T distribution are n – (*number of columns in* **X**).

Single Site -Temperature Model:
Keeping the same notation as above, let temperature readings from all years at a single site be included in the **Y** vector together. That is, let

$$\mathbf{Y} = \begin{bmatrix} t_{11} & \cdots & t_{1,m_1} & t_{21} & \cdots & t_{2,m_2} & \cdots & t_{n,1} & \cdots & t_{n,m_n} \end{bmatrix}'$$

where t_{ij} is the j-th temperature measurement during year i. Note that all temperature measurements included in **Y** are from similar seasons. The appropriate **X** matrix to use in this situation includes an intercept, several columns for the polynomial or regression splines, a year column, a 0-1 indicator column equal for the current year, and interaction effects between the indicator and curvilinear effects. Assuming two regression splines adequately fit past within season trends (in reality, more columns may be needed), the **X** matrix has the form,

$$\mathbf{X} = \begin{bmatrix} 1 & s_{11} & s_{12} & 0 & 0 & 0 \\ 1 & s_{21} & s_{12} & 0 & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 1 & s_{k1} & s_{k2} & 1 & s_{k1} & s_{k2} \end{bmatrix}$$

where s_{ij} is the value of the j-th curvilinear effect covariate for the i-th observation. The fourth column of **X** is the 0-1 indicator column equal to 1 for all observations from the current year and

Appendix E, Attachment 1. Abrupt change analysis statistical synopses (McDonald 2005) (continued).

0 for all other years. The last two columns are for the interaction between the curvilinear effects (columns 2 and 3) and current year (column 4). Interaction columns are simply the curvilinear effect columns times the indicator column. The coefficient matrix in this linear model is

$$\boldsymbol{\beta} = \begin{matrix} \beta_0 & \beta_1 & \beta_2 & \beta_3 & \beta_4 & \beta_5 \end{matrix}'.$$

Abrupt change in the current year, if present, would cause the pattern of changes in the current season to be different from the pattern in previous years, or a shift in the mean of the pattern.

These changes from previous years will be quantified by β_3, β_4, and β_5. If β_3, β_4, and β_5 are all 0, no change from previous years has occurred. If one or more of β_3, β_4, and β_5 are non-zero, some type of change has occurred.

Estimation proceeds as before except that mixed linear model procedures (e.g., REML, Littell et al. 1996) should be used to estimate the coefficients in **β.** In this process, an appropriate model for the correlation of observations has to be estimated and used. Abrupt change is then tested with the null hypothesis H_0: β_3=0, β_4=0 and β_5=0. If this hypothesis is rejected at the experiment-wide α level of 5%, a change in the pattern of water temperature has been detected during the current year. Note that the test for H_0 has three degrees of freedom. H_0 can be tested a number of ways, the best of which is to drop the last three columns of **X,** refit the model, and compute a drop-in-sum-of-squares F test.

Region-wide – Mixed Linear Model:
A linear model analysis similar to the single-site models described above can be used to detect abrupt change among all lakes in a region. The only difference is that site effects are necessary and this complicates the modeling process slightly. When multiple sites from the same region are included in the analysis, the model must include terms for each site, and in general separate trends should be estimated for each site. Separate trends at each site are estimated by including site and site by year interaction terms. When the model is fit, possibly using REML methods to account for serial correlation, *k* simultaneous prediction intervals are constructed for all values in the current year, where *k* is the number of sites in the region. Using Scheffé's method (Neter et al. 1989, p. 247) and assuming $\hat{\boldsymbol{\beta}}$ has been estimated, *k* simultaneous 95% prediction intervals can be constructed as,

$$\mathbf{x}_h'\hat{\boldsymbol{\beta}} \pm kF_{0.05,k,n-p}\hat{\sigma}(1+\mathbf{x}_h'(\mathbf{X}'\hat{\boldsymbol{\Sigma}}^{-1}\mathbf{X})^{-1}\mathbf{x}_h)$$

where $\mathbf{x}_h$ is the appropriate predictor vector for one site during the current year (h = 1, 2, …, k), $F_{0.05,k,n-p}$ is the 5%-th quantile from an F distribution with k and n-p degrees of freedom (p = number of columns in **X**), and the rest of the quantities are the same as in the previous section. If abrupt changes have not taken place, all responses in the current year will be within their respective prediction intervals. If one or more responses are outside their prediction interval, abrupt change has been detected in the region at the experiment-wide α level of 5%.

Appendix E, Attachment 1. Abrupt change analysis statistical synopses (McDonald 2005) (continued).

Certain attributes will be assessed at an experiment-wide α level of 10%, rather than 5%.

Region-wide – CUSUM Procedure:
Assuming *n* successive measurements have been made on each of *k* segments, let y_{ut} be the measurement on segment *u* at time *t*. Let $\bar{y}_u$ be the average of all measurements on segment *u* including the current year. Sort segments based on their $\bar{y}_u$ and label them such that $\bar{y}_1 \le \bar{y}_2 \le \ldots \le \bar{y}_k$. The CUSUM is a series of *k* successive sums of the form,

$$S_{it} = (y_{1t} - \bar{y}_1) + (y_{2t} - \bar{y}_2) + \ldots + (y_{it} - \bar{y}_i).$$

When S_{it} are plotted against *i* for *t* the resulting graphs are called CUSUM charts. An example of a CUSUM chart is given in SOP 21, Figure 21.7. A positive slope in the CUSUM line indicates that responses during time period *t* were, on average, higher than their historical averages. A negative CUSUM slope indicates the opposite. Positive, then negative, slope in the CUSUM chart indicates that units with low means were higher than their respective means, while units with large means were lower than their respective means.

Manly and MacKenzie (2000) propose randomization methods to decide whether the CUSUM chart for time *t* indicates a significant departure from the long-term mean, The randomization method computes an envelope of expected CUSUMs under the null hypothesis of no departure from the long-term mean at time *t*. Missing values, or non-sampled occasions, are acceptable. If missing values are present, the means from each unit are calculated from the available data, and the randomization scheme permutes the available data among the occasions that were observed. The CUSUM method is affected by serial correlation in the measurements at a given site; however, the randomization test can be adjusted to account for this.

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Appendix F. Lake and Pond Monitoring History.

Table F-1. Mount Rainer National Park (MORA) lake and pond monitoring history.

Waterbody	Investigators	Study Focus	Description	Date Collected
Mowich Lake	Larson 1973	Limnology	Nine month limnology study of a high mountain lake: physical & chemical features, primary production, phytoplankton, zooplankton. concentrations were examined as well as oxygen levels and zooplankton. Includes bathymetric map of lake.	1966
Shadow Lake	Hall 1973	Limnology	Limnology of Shadow Lake: physical, chemical, and biological parameters were considered. Includes bathymetric charts of Shadow, Clover, Hidden, and Sunrise	1970-72
Fan Lake	Perry 1980	Limnology	Study in which nitrogen, phosphate, sulfate, and silicate concentrations were examined as well as oxygen levels and zooplankton. Includes bathymetric map of lake.	1979
Parkwide	Welch and Chamberlain 1981	Limnology	water chemistry analyses	1981
Parkwide (16 lakes)	Nelson and Baumgartner 1986	Acid deposition	total aluminum, major anions, major cations, dissolved silica, dissolved organic carbon, and pH	1983
Parkwide (5 lakes)	Eilers et al. 1987	Air pollution effects	EPA Western Lakes Survey -Water chemistry	1985
Reflection Lake	Funk et al. 1985	Recreational Impacts	Study of the basic physiochemical and biological structures and initial assessment of increased human activity in drainage area.	1985
Parkwide	Turney et al. 1986	Air pollution effects	Evaluated 13 lakes for general chemical characteristics, sensitivity to acidification, and existing degree of acidification.	1986
Parkwide	NPS – MORA files	Limnology, baseline inventory	Lake water quality & bathymetric characterization; one time sampling	1988 to 1999
Parkwide	Larson et al. 1992, 1994	Limnology, baseline inventory	27 lakes (including Mowich Lake) – Limnology - plankton, DO, temperature, conductivity, ANC, pH, nutrients, cations.	1988-1989
Parkwide	Larson 2000	Chlorophyll	Analysis of chlorophyll samples taken from park-wide selected lakes.	1989-1999
Parkwide	Larson et al. 1999a	Plankton	Temporal variations of water quality and plankton at 6 lakes	1990-93

Table F-1. Mount Rainer National Park (MORA) lake and pond monitoring history (continued).

Waterbody	Investigators	Study Focus	Description	Date Collected
Parkwide	Charles 1995	Atmospheric Deposition Effects	Diatoms collected in MORA lake sediment cores. Used to develop diatom calibration set for the Cascade Mountain Ecoregion	1991
Parkwide	Eilers et al. 1998	Atmospheric Deposition Effects	Diatoms collected in MORA lake sediment cores. Used to develop diatom calibration set for the Cascade Mountain Ecoregion	1991,1996
Parkwide	NPS – MORA files	Amphibians	Qualitative surveys of non-randomly selected sites throughout the park. 12 species documented	1991-92
Mazama Ridge Ponds	Girdner 1994	Plankton	Studied zooplankton communities in several Mazama Ridge ponds	1991-92
Mazama Ridge Ponds	NPS – MORA files	Plankton	Water chemistry, zooplankton for subset of Mazama Ridge ponds	1993-96
Lakes- in White and Huckleberry R. watersheds	NPS - MORA files	Amphibians	Snorkel and Visual encounter surveys of lakes with and without fish. Focus was on Ambystoma salamander species.	1993-1995
Parkwide	Jetton et al. 1995	Recreational use impacts	Lakes and ponds near backcountry camps. Human wastes effects (from toilets) on adjacent lakes and ponds (and streams)	1993-1994
Parkwide Lakes	NPS – MORA files	Fish	Fish presence was determined using gill nets for 47 lakes. Fish present in 32 lakes.	1994-1999
Parkwide	Tyler et al. 2003, Galvan et al. 2006	Amphibians	Survey of aquatic breeding amphibians in each of the nine park watersheds. Standardized inventories were conducted using visual encounter and snorkel surveys for lentic ecosystems. 114 lotic and 205 lentic sites were inventoried using a stratified random sample design.	1994-1999
Parkwide (5 lakes)	NPS 1995a	Air pollution effects	Repeated EPA Western Lakes Survey for water chemistry	1996
Huckleberry and White R. Watersheds – 20 lakes/ponds	Brokes 2000	Amphibians	Alkalinity, conductivity, pH, water temperature and dissolved oxygen profiles	1996
Parkwide Lakes	NPS – MORA files	Limnology	Water quality (transparency, temperature, pH, specific conductance, dissolved oxygen, ANC) for all sites; nutrients for approximately 35 selected sites	1996-1999

Table F-1. Mount Rainer National Park (MORA) lake and pond monitoring history (continued).

Waterbody	Investigators	Study Focus	Description	Date Collected
Parkwide	NPS – MORA files	Wetland inventory	Lacustrine and Palustrine wetland inventory - classification of wetlands, water quality, soil descriptors.	1996-1997
Lakes- in White and Huckleberry R. watersheds	Hoffman 1999, Hoffman and Larson 1999, Hoffman et al. 2004	Fish, Amphibians	Passive techniques for removing fish and response of salamanders after fish removal. Quantitative snorkel surveys conducted to document Ambystoma species presence.	1996-present
Parkwide- 8 lakes	Drake 1998	Fish Stocking effects	M.S. Thesis to assess the effects of fish stocking on lakes in the park.	1997
Parkwide lakes, ponds, wetlands	NPS – MORA files	Benthic macroinvertebrates	Invertebrates collected at 72 wetland sites	1997
Eunice Lake	Cosby and Sullivan 2001	Atmospheric Deposition Effects	Soil chemistry, water chemistry	1998
Mowich Lake	NPS – MORA files	Limnology	Limnology monitoring three times between July and September. (transparency, temperature, pH, specific conductance, dissolved oxygen, ANC, nutrients, cations, SO4 and Cl. 2001 sampling includes full cation-anions, cation-anion balance, and Si.	1998-2003
Louise, Bench, Snow, Green, Eunice, George, Shriner, Clover, Reflection	NPS – MORA files	Limnology	Limnology monitoring three times between July and September. (transparency, temperature, pH, specific conductance, dissolved oxygen, ANC, nutrients, cations, SO4 and Cl. 2001 sampling includes full cation-anions, cation-anion balance, and Si.	1999-2003
Parkwide	NPS – MORA files	Benthic macroinvertebrates	Macroinvertebrates were collected from 17 lakes and ponds.	2000
Parkwide	Frest and Johannes 2005	Mollusks	Baseline Mollusk Survey of MORA	2000-2003
Eunice Lake	Clow and Samora 2003	Atmospheric Deposition Effects	Snowpack sampling, daily outlet stream chemistry. Samples analyzed for pH, ANC, major dissolved constituents including major anions, cations, dissolved organic carbon and silica.	2000
Parkwide	Kondratieff and Lechleitner 2002, Stark and Kondratieff 2004	Aquatic Invertebrates	Parkwide survey of aquatic invertebrates with a focus on Stoneflies.	2001

Table F-1. Mount Rainer National Park (MORA) lake and pond monitoring history (continued).

Waterbody	Investigators	Study Focus	Description	Date Collected
4 Lakes	Moran et al. 2007	Mercury and organochlorine, Effects on fish	USGS study of mercury and organochlorine contaminant levels in northwest parks. Lakes in NOCA (5), OLYM (5), and MORA (4) were studied. Genetic and physiological effects of mercury contamination in trout was studied for 2 NOCA lakes.	2002-2003
Parkwide	Ruiter et al. 2005	Aquatic Invertebrates	Parkwide survey of aquatic invertebrates with a focus on caddisflies.	2002-2004
Parkwide	Larson et al. 2008	Zooplankton	Zooplankton, water chemistry (pH, DO, ANC, specific conductance)	2003-2005
Parkwide	Rawhouser and Glesne (in prep)	Littoral benthic macroinvertebrates	Benthic macroinvertebrates collected from 77 MORA lakes and ponds	2003-2005
Parkwide	NPS – MORA files	Integrated limnology, fish, amphibians as Vital Signs	Protocol Testing for Mountain Lakes and Ponds Vital Signs Monitoring	2004-2007
Eunice and Louise Lakes	Clow and Campbell 2008	Atmospheric Deposition Effects	Outlet stream chemistry. Samples analyzed for pH, ANC, major dissolved constituents including major anions, cations, dissolved organic carbon and silica	2005-2006

Table F-2. North Cascades National Park Service Complex lake and pond monitoring history.

Waterbody	Investigators	Study Focus	Description	Date Collected
Parkwide	NPS - NOCA files (Lake and pond investigations by R. Wasem)	Water quality, fish, amphibians, physical characteristics.	An assortment of stocking records, angling surveys, water quality measurements, biological and physical data. This data provides good baseline information on many park waterbodies though no final report was filed.	1971 - 1986
Parkwide (30 lakes)	Brakke, D. F. 1984	Water Quality	A survey of 30 Cascade Lakes in North western Washington were surveyed in late summer - early fall to characterize the chemistry of the lakes. The Cascade lakes ranged in elevation from 853 - 1676 m. The lakes selected were low color, oligotrophic, and predominantly granitic or gneissic bedrock.	1983
6 Lakes	Eilers et al. 1987	Water Chemistry, physical characteristics	Data compendium from the EPA Western Lakes Survey. A total of 6 lakes at NOCA were sampled.	1985
approx. 10 lakes	NPS 1995b	Water Chemistry	Baseline water quality data inventory and analysis for lakes and streams. NPS Water Resource program database in Fort Collins, CO.	1985
Parkwide (70 lakes)	Liss et al. 1995	Fish stocking effects: Lake physical and chemical characteristics, fish, zooplankton, phytoplankton, amphibians, macroinvertebrates.	Phase I of the OSU research initiated in response to a directive from the Director of the National Park Service which related to the stocking of fish into lakes of the North Cascades National Park Service Complex. This initial phase of the research focused on lake classification and collection of baseline biotic and abiotic data for future analysis of the effects of stocked fish on communities of native species in naturally fishless high-mountain lakes.	1989 - 1993
Park wide	Liss et al. 1998	Fish stocking effects: Lake physical and chemical characteristics, fish, zooplankton, phytoplankton, amphibians.	Phase II of the OSU research. 1) Additional analyses of physical/chemical data from 58 lakes sampled from 1989 to 1993. 2) Analysis of phytoplankton data from 51 lakes sampled in 1989. 3) Analysis of Diaptomid copepods from 27 lakes sampled from 1989 to 1993. 4) Evaluation of fish effects on salamanders from 45 lakes sampled between 1990 and 1994. 5) Lab studies of salamander behavioral difference with and without fish.	1989 - 1994

Table F-2. North Cascades National Park Service Complex lake and pond monitoring history (continued).

Waterbody	Investigators	Study Focus	Description	Date Collected
Parkwide (7 Lakes)	Tyler et al.1998	Fish effects on salamanders	Publication of interactions of salamanders and fish from 7 lakes sampled during the OSU research study (Liss et al. 1995 and 1998).	1989-1994
Parkwide (41 lakes)	Hoffman et al. 1996	Nearshore Macroinvertebrates	Publication on nearshore macroinvertebrates collected during the OSU research study (Liss et al. 1995). Community structure, classification and habitat relationships are reported.	1989-1993
Parkwide (66 lakes)	Deimling 1997	Rotifers	Publication on rotifers collected during the OSU research study (Liss et al. 1995). Community structure, density, classification and habitat relationships are reported.	1989-1993
Parkwide (51 lakes)	Larson et al. 1998	Phytoplankton	Publication on phytoplankton collected during the OSU research study (Liss et al. 1995). Community structure, species composition, and habitat relationships are reported.	1989
Parkwide (58 lakes)	Larson et al. 1999b	Physical and chemical	Publication characterizing NOCA lakes by physical and chemical data collected during the OSU research study (Liss et al. 1995).	1989-1993
Parkwide	Liss et al. 2002	Fish effects on salamanders and large copepods	Part three of the OSU Phase III report. Summary analysis of fish effects on distribution and abundance of salamanders and large zooplankters. Analysis of data from 63 lakes for salamanders and 70 lakes for zooplankton.	1989-1994; 1998-1999
Parkwide (9 Lakes)	Gresswell et al. 1997	Fish density	Publication on fish densities from 9 lakes sampled during the OSU research study (Liss et al. 1995).	1990-1993
7 Lakes	Hospodarsky and Brown 1992	Lakeshore vegetation impacts.	Evaluated impacts of angling vs. non-angling visitors on riparian vegetation and soils at 7 lakes.	1990
Parkwide (8 lakes)	Shields and Liss 2003	Fish effects on salamanders	Report on genetic diversity of Long-toed salamanders in NOCA high lakes and relationship to fish stocking (i.e. genetic diversity and genetic isolation).	1993-1999
2 Adjacent lakes	Liss et al. 2002	Fish effects on salamanders	Part two of the OSU Phase III report. Further analysis of behavioral interactions between salamanders and fish from two adjacent lakes (with and without fish).	1994-1999

Table F-2. North Cascades National Park Service Complex lake and pond monitoring history (continued).

Waterbody	Investigators	Study Focus	Description	Date Collected
Wetlands in Baker, N. Fork Cascade, Chilliwack, and Upper Stehekin Watersheds	Holmes and Kuntz 1994	Wetland classification and inventory	Wetland classification and inventory.	1994
Wetlands in Lower Big Beaver Creek	Glesne et al. 2000	Riparian terrestrial arthropods	Terrestrial riparian arthropod community structure, diversity, and environmental factors influencing community structure.	1995-1996
Parkwide	Bury and Adams 2000	Amphibians	Summarizes stream and pond amphibian data collected by Holmes and Glesne (reported in 1997, 1998, and 1999). Also includes amphibian surveys at OLYM National Park.	1995-1998
Lakes and ponds in the Big Beaver Creek Watershed	Holmes and Glesne 1997	Amphibians, water temp., pH and conductivity, and lake physical characteristics.	Study objectives were to establish a baseline inventory, evaluate environmental conditions affecting distribution of amphibians. 21 lakes and ponds were surveyed (additional 30 seeps and 21 stream reaches were also surveyed). Eight species of amphibians were found in lakes and ponds.	1996
Parkwide	Galvan et al. 2006	Amphibians	Survey of aquatic breeding amphibians in OLYM, NOCA, and MORA. Standardized inventories were conducted using visual encounter and snorkel surveys for lotic and lentic ecosystems.	1996-1999
Lakes and ponds in the Bridge Creek Watershed	Holmes and Glesne 1998	Amphibians, water temp., pH and conductivity, and lake physical characteristics.	Study objectives were to establish a baseline inventory, evaluate environmental conditions affecting distribution of amphibians within the Bridge Creek watershed. 15 lakes and ponds were surveyed (additional 28 stream reaches and 7 seeps were surveyed). Five species of amphibians were found in lakes and ponds.	1997
Parkwide lakes and ponds	Holmes and Glesne 1999	Amphibians, water temp., pH, turbidity, and conductivity, and lake physical characteristics.	Study objectives were to establish a baseline inventory, evaluate environmental conditions affecting distribution of amphibians within the Bridge Creek watershed. 72 lakes and ponds were surveyed (additional 19 stream reaches were surveyed). Nine species of amphibians found in lakes and ponds.	1998

Table F-2. North Cascades National Park Service Complex lake and pond monitoring history (continued).

Waterbody	Investigators	Study Focus	Description	Date Collected
Parkwide (159 lakes and ponds of which 89 are also reported in Holmes and Glesne 1998, 1999)	Glesne (report in progress, NPS-NOCA, Sedro-Woolley WA)	Amphibians, fish, macroinvertebrates, water chemistry, lake physical characteristics	Expand lake and pond inventory to previously unsurveyed waters, Update survey information from previously surveyed lakes, Providing fundamental background data on benthic macroinvertebrate assemblages and associated environmental attributes to develop predictive models for the assessment of water quality and biological integrity in NOCA lakes and ponds.	1997-2000
Parkwide (31 lakes)	Liss et al. 2002	Fish effects on salamanders	Part one of the OSU Phase III report. Further analysis of interactions between salamanders and fish following Tyler et al. 1998. A random sample of 31 lakes were selected. Analysis focused on larval salamander density related to nitrogen concentrations and fish density.	1998-1999
5 Lakes	Moran et al. 2007	Mercury and organochlorine, Effects on fish	USGS study of mercury and organochlorine contaminant levels in northwest parks. Lakes in NOCA (5), OLYM (5), and MORA (4) were studied. Genetic and physiological effects of mercury contamination in trout was studied for 2 NOCA lakes.	2002-2003
Parkwide (17 lakes)	NPS - NOCA files	Integrated limnology, fish, amphibians as Vital Signs	Protocol Testing for Mountain Lakes and Ponds Vital Signs Monitoring	2006-2007

Table F-3. Olympic National Park mountain lake monitoring history.

Waterbody	Investigators	Study Focus	Description	Date Collected
Parkwide (44 lakes)	Hagen 1961	Fish	inventory of exotic fish presence	1951-1960
Parkwide (3 lakes)	Landers et al. 1987	Limnology	Regional Lake chemistry characterization, Western Lake Survey	1985
Parkwide (7 lakes)	Larson et al. 1995	Limnology	Baseline physical/chemical/productivity characterization in July and Augusts	1987
Parkwide (20 lakes)	Olson and Meyer 1994	Fish	re-inventory of exotic fish presence	1992-1994
Parkwide (77 ponds)	Galvan et al. 2003	Amphibians	Amphibian survey for pond-breeding amphibians	1999-2001
Parkwide (5 lakes)	Moran et al. 2007	Contaminants	Assessment of mercury and persistent organic pollutants	2002
PJ and Hoh lakes	Landers et al. 2008	Contaminants	Western Airborne Contaminants Assessment Project	2002-2007
Parkwide (10 lakes)	NPS - OLYM	Limnology	Protocol testing for Mountain Lakes Vital Signs monitoring.	2005-2008

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Appendix G. Safety Considerations.

Table G-1. Job hazard analysis, NCCN Mountain Lakes Monitoring Project.

MT. RAINIER, OLYMPIC and NORTH CASCADES NATIONAL PARKS **JOB SAFETY ANALYSIS**	JOB TITLE Lake Monitoring		DATE: 11/12/2007	NEW
	TITLE OF PERSON WHO DOES JOB: Ecologist Biological Technician	SUPERVISORS: Barbara Samora, Steve Fradkin, and Reed Glesne	ANALYSIS BY: Ashley Rawhouser Rebecca Lofgren	
	LOCATION: MORA, OLYM and NOCA	DIVISION: Resource Management	REVIEWED BY:	
REQUIRED AND/OR RECOMMENDED **PPE: See Recommended Action or Procedures**			APPROVED BY:	

SEQUENCE OF JOB STEPS	POTENTIAL HAZARDS	RECOMMENDED ACTION OR PROCEDURE
Office Work - Computer use for email and data entry, report writing.	Muscle and eye strain, repetitive stress injury	Proper posture and use of ergonomic furniture Take breaks every hour
Field Work Preparation - Packing and loading gear/equipment.	Unpreparedness, straining muscles/back	Use check lists, check radio batteries, pack carefully, prepare itinerary and pack appropriate food, clothing and shelter.
Vehicle Travel - Driving to/from site	Break-downs/vehicle failure	Be licensed to operate vehicle and be familiar with controls before driving. Pre-operational checks of lights, tires, windows, mirrors, body damage, fluids on ground, vehicle fluid levels, vehicle belts and general vehicle condition. Make sure you have clear vision from windows and mirrors are clean and adjusted. Make sure safety equipment is available and in good condition (first aid kit, fire extinguisher, flares, wheel chocks, tire changing equipment). Make sure seat belts are working and adjusted properly. Make sure engine is operating properly. Do not use a vehicle that is unsafe to operate.

Table G-1. Job hazard analysis, NCCN Mountain Lakes Monitoring Project (continued).

Vehicle Travel - Driving to/from site (continued)	Driving on highway and unpaved roads to job site	Use Defensive Driving Techniques. Do not drive aggressively. Avoid driving fatigue. Switch drivers when possible or pull off road and rest for a while. Do not drive if not feeling well or on medication or in any condition which could affect judgment. Always drive with headlights on. Stay alert to the type and pattern of traffic around you. Follow all traffic regulations-do not exceed speed limit or tailgate. Watch ahead to anticipate traffic or object hazards and adjust speed accordingly. Make sure you are seen by large trucks and allow them plenty of room for their turning radius. Drive at a safe speed for road, traffic and terrain type. Drive at a safe speed for the type of roadway and its surface conditions. Be alert to changing road conditions and adjust speed and driving techniques accordingly. Be aware of the capabilities, power and clearance of the vehicle you are operating. If the road ahead is too narrow, rough, muddy, brushy or snow is too deep, do not push vehicle capabilities. Park and walk to destination or use another means of transportation or another route. Watch out for animals, anticipate their actions and slow down or stop. Drive at a speed that is safe for weather and visibility conditions. Carry tire chains for snow and ice conditions and use them.

Table G-1. Job hazard analysis, NCCN Mountain Lakes Monitoring Project (continued).

Vehicle Travel - Driving to/from site (continued)	Driving on highway and unpaved roads to job site	Use visor and sun glasses to shield glare. Keep windshield clean and ensure wipers work properly. Take proper clothing with you in case your vehicle breaks down and you are stranded for a while. Keep window cracked if idling engine for any length of time. Move away from and avoid large trees during windstorms.
	Backing and parking vehicles	Get out of vehicle and walk behind it to look for objects and hazards. Have a passenger be a spotter and guide you. Always face danger with front of vehicle when turning around. Ensure adequate sight distance while turning around i.e., don't turn around on blind corners. Avoid backing down steep grades-especially on loose gravel, snow and ice. Park vehicle in a safe location. Back vehicle in to park. Ensure there is adequate clearance for passing traffic. Put vehicle in park or lowest gear in direction of roll, set parking brake turn front wheels into curb or cutbank, place chock blocks in front of, or behind tires. Do not park in a truck turn-around.
Foot Travel – Hiking to and from job site	Sprains, strains, broken bones (injuries from slipping/falling)	Always travel in teams of two or more. Wear sturdy laced boots which support the ankles for support. Boots should have slip resistant soles and heels (Vibram) and be comfortable. Wear cuffless pants with narrow bottoms to prevent catching on sticks etc.

Table G-1. Job hazard analysis, NCCN Mountain Lakes Monitoring Project (continued).

Foot Travel – Hiking to and from job site (continued)	Sprains, strains, broken bones (continued)	Watch footing-especially under wet conditions. Avoid stepping on downed logs and branches, especially when they point downhill. Do not run and avoid jumping. Be aware of slippery leaves and loose rocks. Do not lean into the hill when contouring steep slopes. Be aware of your surroundings. Look ahead and check your footing before shifting weight and avoid stepping where the ground cannot be seen. Check for upslope and downslope hazards (rolling rocks, logs, leaning trees, cliffs etc.) avoid potentially unsafe routes. Watch for hazards at eye level (limbs, branches etc.) and keep your distance when following co-workers. Be sure to keep your body aligned and footing stable and avoid twisting motions. Use your hands to catch yourself if you fall-review proper falling techniques. Do not travel directly up or down slope if the potential for dislodging rocks or other debris exists.
	Stream crossings – drowning, sprains, strains, broken bones, hypothermia	Cross during periods of low flow (morning/evening) if necessary. Follow safe crossing techniques: unhook your pack, link arms, use a brace such as a stick, travel diagonally upstream against flow, watch for debris and other hazards. Take your time and be aware of cold exposure.

Table G-1. Job hazard analysis, NCCN Mountain Lakes Monitoring Project (continued).

Foot Travel – Hiking to and from job site (continued)	Stream crossings – drowning, sprains, strains, broken bones, hypothermia (continued)	Waterproof items in pack, especially the bottom. Be careful on slippery logs. Use personal judgment when crossing streams. Choose areas with less depth and flow such as shallow low gradient riffles or tailouts of pools. Make sure there is a way out if you do fall, check downstream before crossing. Do not cross if you cannot see bottom. Use a pole for stability but do not rely on it. Avoid crossing in areas where you might be swept under a log jam if footing is lost. Use care when navigating log jams. Be aware of areas of loose rock and avoid them or use caution in going through them. Avoid working in flooding conditions, be aware of forecast.
	Scratches, bruises, cuts, punctures, abrasions, sunburn, insect bites	Wear long sleeved shirts and pants of sturdy materials. Wear gloves to protect hands. West Nile Virus is in the PNW. Use insect repellant. Alert crew members to possible problems with allergens. Be alert for toxic plants and alert to common bee and wasp nesting habitat and activity-especially the person in front. Carry Benadryl, epi-pen or other anti-histamine Use sunscreen and wear brimmed hat and sun glasses to limit exposure to sun. Prevent blisters and have blister treatments (moleskin, tape etc) accessible

Table G-1. Job hazard analysis, NCCN Mountain Lakes Monitoring Project (continued).

Foot Travel – Hiking to and from job site (continued)	Carrying equipment in the field	Keep objects where they will not hinder your mobility. Store especially sharp objects to avoid injury when falling. Carry tools and equipment in down slope hand when crossing side slopes. Maintain a safe walking distance (10 feet minimum) between each person. Carry heavy objects in properly fit backpack if possible. Keep pack weights as light as possible to limit falling and prevent long-term overuse injuries. Pay attention to how you put your pack on (avoid twisting motions- get help or place pack on surface or against tree) Make sure your pack is properly fitted and balanced. Use trekking poles to maintain balance and reduce overuse injuries.
General Field Hazards	No emergency contact	Carry and use radios. Do radio checks at new jobsites. Check radio contact on daily bases. Carry extra batteries. Know dead zones.
	Getting lost	Have map and compass and other navigational aids and know how to use them. Travel together when off-trail. Make sure members of the team are aware of location, and can find route out if they are separated. When trail hiking, plan stops at trail junctions to regroup. Arrange meeting places and times -all crew members must wear a watch.

Table G-1. Job hazard analysis, NCCN Mountain Lakes Monitoring Project (continued).

General Field Hazards (continued)	Getting lost (continued)	Have a travel plan for each day and make sure it is understood by all crew members. Stay in communication via radio, voice or stay in sight. If lost, follow prearranged procedures (most likely to stay put). Have emergency equipment (food, shelter, heat, clothing) to survive spending time on your own. If lost for a long period, consider moving to an area where you can be seen by helicopter (gravel bar or ridge top). Do not leave your gear if you travel. Do not panic. Have a mental plan for what to do if lost.
	Dehydration/heat exhaustion	Always carry plenty of water (minimum 1 liter). Replace bodily fluids and salts regularly (every 15 minutes). Rest in cool, shady places during periods of high temperatures.
	Hypothermia	Wear proper equipment- and have extra layers for cold conditions in waterproof bags. Do not rely on cotton clothing for warmth. Remove wet clothing immediately after hiking, carry spare layers in accessible part of pack. Recognize the signs of hypothermia in yourself and others. Have shelter such as tent, sleeping bag or emergency shelter. Have the means to create heat such as matches or a stove. Carry and eat high-calorie foods, stay well-hydrated.
	Wind	Never work in a forested area during high winds when blow down is likely. Never work near burned trees or snags during high winds; watch for falling trees, bark branches. Be aware that standing dead trees become more hazardous through time. Anchor tents and inflatable boats using large rocks and stakes to avoid loss.

Table G-1. Job hazard analysis, NCCN Mountain Lakes Monitoring Project (continued).

General Field Hazards (continued)	Lightning	Do not stand under trees or next to rock outcrops. Get off ridges and other high points. Get/stay out of water and away from other conductors. If you are in a vehicle, stay completely inside, don't touch metal parts of vehicles. Turn off electronic devices. Get rid of any metal on your person. If on horses dismount. If caught in the open or in a tent squat on sleeping pad.
	Illness from Giardia, E. coli or other bacteria	Do not drink any water unless it has been filtered, boiled or treated in some fashion. Do not create more contaminated areas- urinate away from streams and water, dig a cat hole for solid waste and bury toilet paper. Wash hands when possible and carry hand cleaner. Clean cooking implements during and between tours with hot water. Use soap between tours.
	Hazardous animals and plants	Keep updated on specific hazards in your area. Be able to identify hazardous plants. Advise supervisor/co-workers of allergies. Apply proper first aid methods and wash thoroughly following exposure. Be aware of the presence of potentially hazardous animals in your working environment. Be familiar with signs implicating their presence. Keep your distance from animals especially if they act unusual (rabies).

Table G-1. Job hazard analysis, NCCN Mountain Lakes Monitoring Project (continued).

General Field Hazards (continued)	Hazardous animals and plants (continued).	Don't touch wild animals. Make noise (radio squelch etc.) if you cannot stay out of the way of bears or other large animals. Store food in bear safe containers or hang from trees 15 ft. high and 4 ft. from tree and branches. Do not store food near sleeping areas.
	Public contact where personal safety is uncertain due to: hostile people, domestic disputes, apparent intoxication or impaired judgment or presence of weapons.	Do not make contact. Seek law enforcement assistance. Contact communications center. Position vehicle for easy departure. Leave personal escape routes. Do not get boxed in. Establish personal space.
Communications		Establish check-in and check-out procedure prior to field work. Set up procedure with a contact person at communications center Establish overdue procedures. Contact person calls head ranger if overdue. Tailgate safety session before beginning work to reemphasize the hazards and control factors particular to the day's work.
Working from inflatable boats	Drowning and hypothermia.	Know the boat's maximum weight capacity and do not exceed this threshold. Be aware of hypothermia. Ensure watercraft is in good condition. Wear a personal flotation device. Ensure at least one other person knows your location or is making visual contact with you at all times. Make sure you have access to dry clothing and a heat source.
Working from helicopters	Injury of propellers and blades.	All personnel with helicopters should have completed at a minimum the Basic Aviation Safety Course. All flight planning and contracting will be completed by a fully trained Helicopter Manager.

Table G-1. Job hazard analysis, NCCN Mountain Lakes Monitoring Project (continued).

Working from helicopters (continued)	Injury of propellers and blades (continued).	All staff flying in or working adjacent to aircraft are required to wear appropriate personal protective equipment. Refer to Park's Aviation Safety Plan for more specific details regarding flight safety and personnel requirements.
Working in Laboratory	Exposure to hazardous chemicals.	Review and follow the Lab Hygiene Plan and MSDS sheets before working in the laboratory. Work with another person or notify co-workers if you will be working in the lab alone. Use appropriate personal protective equipment at all times. Keep counter-tops clean and uncluttered.
	Muscle and eye strain, repetitive stress injury	Proper posture and use of ergonomic furniture Take breaks every hour

Appendix G, Attachment 1. Helicopter operations, safety and training, North Cascades National Park Complex.

Helicopter Operations, Safety and Training, North Cascades National Park Complex.

Overview

The use of helicopters for resource management within the North Cascades National Park Service Complex allows researchers to safely, efficiently and effectively accomplish research goals. Conversely the use of helicopters in a National Park setting has the potential to create undesirable impacts on park personnel, visitors and wildlife. With this in mind it becomes essential that helicopter operations are carried out in such a way as to maximize the benefits and minimize negative impacts.

The United States Department of the Interior has adopted the Interagency Helicopter Operations Guide (IHOG) as policy for helicopter operations within national parks (*Interagency Helicopter Operations Guide* 2006, NFES #1885. www.nifc.gov/policies/ihog.htm). This comprehensive manual outlines all aspects of DOI helicopter operations including but not limited to: contracting procedures, maintenance and power-check intervals, fuel truck and helicopter safety equipment, necessary personal protective equipment and required training of personnel. The IHOG acts as a standard protocol for operations within DOI but individual agencies and parks can create more stringent regulations as they see fit.

North Cascades National Park Service Complex has a general aviation management plan in place and specific departments within the park have their own project aviation plans (Bush, Kelly. *North Cascades National Park Service Complex Aviation Management Plan.* March 2006. On file at NOCA). The Aquatic Ecology division has a specific aviation plan prepared to address standard operating procedures for helicopter use during the high lakes long-term ecological monitoring project (Attachment 1, *NOCA High Lakes Helicopter Operations Aviation Safety Plan Form.*). This is updated prior to each field season. These three documents direct the use of helicopters for field research conducted by the Aquatic Ecology Division of the North Cascades National Park Service Complex.

Justification

Helicopter operations can be expensive and dangerous when risk mitigation is not completed. When compared, however, to the risk and expense involved in the backpacking or horse-packing of gear to high lakes, the use of helicopters can become highly cost effective and safer for park personnel. The following factors are useful in determining whether to access a site via helicopter or over land:

- The weight of scientific survey equipment needed for successful ecological monitoring of mountain lakes, in addition to camping supplies and food for survey participants, will be quite heavy. A large number of people would be needed to transport this gear safely, which would add to the impact of sensitive areas such as lake shores.
- Access to these mountain lakes can be quite difficult. Several of the selected lakes are not on or near a maintained trail, and can be many miles from a trailhead or road. Terrain in NOCA is extremely rugged, with a vertical relief of thousands of feet in a short distance. Trails are typically steep, and off- trail travel can be quite dangerous.

Appendix G, Attachment 1. Helicopter operations, safety and training, North Cascades National Park Complex (continued).

Wilderness Issues

To ensure that wilderness values within the park are minimally affected by proposed aircraft operations a flight approval process must be carried out. This begins with the Field Lead filling out a Flight Request Form. The Field Lead then attends a Wilderness and Aviation Committee meeting where the request is reviewed. This committee decides whether to proceed with the project based on the following set of criteria:

- The activity complies with safety requirements of the Aviation Management Plan.
- Administrative aircraft use is confined to Monday through Thursday, and as much as possible to before July 4 and after Labor Day. In addition, flights over the National Recreation Areas are avoided during fall hunting seasons.
- Cost effectiveness and/or efficiency will not be the determining factors in whether or not to grant approval for any non-emergency aircraft use in wilderness.
- The activity is necessary to protect the park/ wilderness resource and/ or manage use.
- It is the minimum action required to accomplish the stated objective.
- It protects wilderness values.
- It is reasonable, and of common sense.

Flight Operations Requirements and Training

Flight operations begin with filling out a Flight Request Form and filing this with the Park Aviation Manager. If the project is to occur within a wilderness area then the Wilderness and Aviation Committee will review the project proposal. This Wilderness and Aviation Committee will notify each flight requestor of their decision and may recommend alterations to the proposed aviation activity.

Department of the Interior non incident (project) helicopter flights require individuals trained as Helicopter Manager and Helicopter Crew member. The S-372 certified Helicopter Manager has responsibilities to assure the efficacy and safety of aircraft operations. These specific responsibilities are myriad and are outlined in section 2-6 of the Interagency Helicopter Operations Guide (IHOG). The S-271 certified Helicopter Crew member serves as a trained member of the helicopter crew, assisting the Helicopter manager in the operation of helicopter missions. The Helicopter Crew member serves to load and unload personnel and cargo, provide mission and safety briefing to passengers, prepare loads and perform daily inventory and equipment checks. A complete list of Helicopter Crew member duties is listed in section 2-9 of the IHOG.

Safety Precautions

It is essential that all aviation operations are planned with utmost regard for the safety of those involved. Working in and around aircraft there are numerous hazards that need to be mitigated through risk management. The proper steps for risk management are as follows:

Appendix G, Attachment 1. Helicopter operations, safety and training, North Cascades National Park Complex (continued).

- Identify hazards
- Assess hazards
- Analyze risk control measures
- Make risk decisions
- Implement controls
- Supervise

Information needed to achieve acceptable risk management include an aviation hazards map, a map of repeaters and their frequencies, helicopter pre-use inspection and checklist, load calculations, weather related contingency plans and mission and safety briefing for crew members.

Personal protective equipment must be worn when flying in or working around helicopters. This equipment as outlined in the IHOG part 9-2 is as follows:

- Nomex Clothing (long-sleeved shirt & pants, or flight suit)
- Nomex and/or Leather Gloves
- Approved Aviator Flight Helmet
- All-leather Boots
- Hearing Protection

Appendix G, Attachment 2. NOCA high lakes helicopter operations aviation safety plan form.

NOCA High Lakes Helicopter Operations Aviation Safety Plan Form

Flight Dates (list individual dates of each flight):

Project Aviation Manager – Hugh Anthony (Helispot manager)
Project Name – North Cascades High Lakes Long-term Ecological Monitoring
Estimated Hrs. **Flying Time -**
Justification – This project proposes to use helicopters to insert two separate crews (A and B) of field technicians and equipment into high mountain lakes located in the North Cascades National Park Service Complex in order to conduct water quality, hydrologic and biological surveys. The flight patterns will follow terrain providing the most direct and safe flight paths to preselected locations. Helicopter use is required due to the remote and inaccessible locations of the lakes to be surveyed.

Project Date(s) –

Location -

Radio Frequencies –

Projected Costs –

Aircraft –

Pilot –

Fuel Truck –

Participants –

Flight Following and Emergency Search and Rescue – Helicopter will use standard 15-minute flight following with OLYM dispatch by radio and will also inform dispatch when helicopter travels from one drainage (survey area) to the next. SAR will use park Aviation, Crash/Rescue plan in the event of an incident or accident.

Aerial Hazard Analysis – Power lines follow roadways, but most are below tree line height within survey areas. Occasional private aircraft fly through the area at approximately 1,000 ft. AGL. Military Aircraft may fly area above 500’ AGL. Startled or flying eagles may also pose potential aerial hazards. Passengers and pilot will be briefed about maintaining aerial hazard awareness. Personnel are aware that if weather deteriorates, mission will be aborted or postponed.

Risk Analysis – The IHOG risk assessment was completed and a determination of moderate risk was made for this flight. The flight is completed almost exclusively in a low level environment, with potential impact from flying eagles. Risk is minimal from other aircraft or aerial hazards.

Appendix G, Attachment 2. NOCA high lakes helicopter operations aviation safety plan form (continued).

All personnel are trained in this type of mission and have performed past eagle aerial survey missions.

The two most significant risk elements of these flights concern weather/visibility and continuous low level flight. An analysis of risk factors ("effects") and mitigations are given below.

1. Weather/visibility effect: Poor visibility (< ½ mile) conditions develop prior to or during operations.

   Probability: occasional
   Effect: moderate
   Outcome: medium
   Mitigation: Initial preflight go/no-go decision by manager and pilot based on weather forecasts, satellite imagery and visual observation. During flights appropriate in-flight communications will occur and flights will be cancelled if weather conditions deteriorate.

2. Terrain effect: Helicopter rotor strike of trees.

   Probability: unlikely
   Effect: catastrophic
   Outcome: medium
   Mitigation: Thorough pre-flight briefing, appropriate in-flight communications. Pilot instructed to maintain concentration on surrounding terrain and flight, rather than eagle observation.

3. Mission focus effect: Pilot and navigator distracted by census count during low level operations.

   Probability: unlikely
   Effect: critical or catastrophic
   Outcome: medium
   Mitigation: Thorough pre-flight briefing, appropriate in-flight communications. Pilot instructed to maintain concentration on surrounding terrain and flight, rather than eagle observation.

4. Personnel effect: Helicopter rotor strike of crew member boarding or leaving aircraft.

   Probability: unlikely
   Effect: catastrophic
   Outcome: medium
   Mitigation: Thorough passenger safety briefing, helicopter is shut down before passengers exit helicopter.

Appendix G, Attachment 3. NOCA backcountry travel and radio communications.

NOCA Backcountry Travel and Radio Communications

I. Purpose and Scope

The purpose of this Standard Operating Procedures (SOP) is to establish policy for NPS-NOCA employees and volunteers who are involved in backcountry travel while accomplishing their duties. This policy is intended to promote safe work practices and procedures that will enhance employee and visitor safety in the backcountry. It also directs procedures for utilizing the park Communications Center (Comm. Center) for tracking employees engaged in backcountry duties.

The scope of this SOP includes all employees and volunteers who travel in the backcountry regardless of division, discipline, grade, or job title. It is incumbent among all employees and volunteers to support and abide by this policy. It is incumbent among supervisors to always know the general working area of each employee.

NOTE: When the Comm. Center is not operational (off season) or unstaffed (after hours) direct contact with a supervisor is required anytime this SOP mandates contact the Comm. Center. Supervisors should relay any necessary information when the Comm. Center is operational.

II. Authority

The NPS Director has directed the development of Backcountry Travel Procedures for all backcountry operations (July 2006). The Superintendent has directed the development and implementation of this SOP specific to NOCA projects and backcountry operations.

All employees assigned duties in backcountry locations in will be tracked through the Comm. Center as outlined in the following procedures. Exceptions to this SOP may granted by the Chief Ranger during emergencies or special LE operations.

III. Backcountry Defined

For the purpose of this plan, and what the SOP is trying to accomplish in the name of an increased safety net for employees without becoming cumbersome, backcountry refers to areas in the park or park complex that are:

- Over one mile of designated trail beyond any given trailhead.
- Over ½ mile into a crosscountry zone, or non-trailed area
- Anywhere if the immediate terrain beyond the road/parking area is “technical terrain” in nature (exposed ground, requires protection gear, etc.)

Appendix G, Attachment 3. NOCA backcountry travel and radio communications (continued).

IV. Tracking and Accountability of Employees

The purpose of tracking and accountability procedures ensures that employees traveling and working in the backcountry return safely and that if an accident or unplanned event occurs, awareness of a situation will occur as early as possible. Earliest possible medical intervention and/or rescue will increase the chances of a positive outcome for any unplanned event or accident.

Employees should become familiar with radio coverage and radio dead zones in the areas they will be working. Employees should also be aware of other NPS staff in the backcountry in order to help transmit radio communications to mitigate dead zones.

A. Communications Equipment
Employees are required to carry a functioning park radio with battery resources to last well through the expected trip and to carry a minimum of two radios per group. While cell phones can be useful and do work in some areas of the park, they should not be considered reliable. Cell coverage in NCCN parks is quite variable depending on cell carrier, calling location and elevation. It is advised to carry visual aids such as brightly colored material, smoke or a camera with a flash to help make you more visible if needed.

B. Reporting In and Out of Service
All park employees, volunteers or a member of a group must notify the Comm. Center when entering and leaving the backcountry. For day trips, notification of the Comm. Center when entering with your intended route and again when ‘clear’ of the backcountry is required.

For the duration of any multi-day trip, checking in and out of the backcountry is required as well as daily check-ins with the Comm. Center. Daily check-in is required twice a day (am and pm) and should confirm your location and/or intended route for the current and following day. Plan your radio check in where you know there is good radio communications. Backcountry permits will serve as a “Backcountry Travel Plan”. The permittee is responsible for getting a copy of the permit to the Comm. Center along with your intended route. This will trigger the Comm. Center to initiate tracking.

Upon completion of a backcountry trip, it is essential that employees close out their travel plan with the Comm. Center as soon as possible. For groups, the permittee is responsible to contact the Comm. Center when all members have exited the backcountry. Failing to do so will prompt the initiation of a search. Likewise, it is important that changes made to the plan while in the backcountry, such as extending the trip by a day or splitting the group up is communicated by radio to the Comm. Center.

Appendix G, Attachment 3. NOCA backcountry travel and radio communications (continued).

C. Status Checks
Status checks are encouraged anytime you encounter high risk activities such as: swift water crossings, crossing a suspected avalanche prone slope, hazardous chainsaw use, bridge crossings with stock, and encounters with suspicious people, etc. When requesting a status check with Comm. Center, indicate how often you want the Comm. Center to check on you, which may vary depending on the activity. When the status check is no longer necessary, the employee will notify the Comm. Center that they are 'clear' and no longer need "status checks".

D. Loss of Contact with Employee
If an employee fails to call 'out of service' or answer a status check, Comm. Center will continue to make contact for a reasonable period of time. If no contact is made, the dispatcher will follow notification procedures similar to standard overdue persons calls and notify the appropriate on-duty ranger. Actions will vary depending on circumstances, but the approach will be consistent with the manner in which all backcountry overdue persons are addressed. This approach quickly shifts decision-making from a dispatcher to a park ranger.

E. Radio Battery Failure
In the event of radio or battery failure, the employee has the responsibility to recognize and know when a first missed check-in occurs and that search efforts may follow. The employee should take action to avert a search and make contact with other employees in the area, or hike out, depending on the circumstances.

V. Equipment Requirements and Expectations

For backcountry travel and work, supervisors will ensure that a hazard assessment has been completed and reviewed with employees, and personal protective equipment (PPE) needs have been identified and addressed. OSHA standards 1910.132(a) and 1926.28(a) address the responsibility to provide employees with PPE, to the extent possible. It must be noted that not all specialized equipment can be provided by the park, and much of the gear that keeps one safe in the backcountry such as effective types and materials of clothing and boots are a personal responsibility.

Employees who utilize their own equipment or PPE must receive supervisory approval. This complies with OSHA standard 1910.132(b) that requires an employer to ensure the adequacy and proper maintenance of PPE not provided. Such equipment must comply with general industry standards. The supervisor is required to review equipment items, determine suitability for work and then monitor equipment to ensure ongoing serviceability.

Adequate preparedness in the backcountry is highly dependent on the particular work duties and assignments of each employee. Factors such as time of year, weather conditions, location and elevation of trip and type of terrain traveled, purpose and length of trip will dictate what is appropriate for each backcountry traveler. This is shared responsibility of employees and supervisors to meet such preparedness and to follow the backcountry travel procedures outlined in this plan.

Appendix G, Attachment 4. NOCA backcountry travel procedures check list.

NOCA Backcountry Travel Procedures Check List.

Day Use

1. Check in with Comm. Center and state route
2. Advise Comm. Center when you have exited the backcountry

Overnight Use

1. Submit a backcountry permit to the Comm. Center (include route).
2. Check in twice daily with Comm. Center.
3. Employees are responsible for alerting Comm. Center of any travel deviations
4. Advise the Comm. Center when you have exited the backcountry

Note:

1. A minimum of two radios are required for all groups
2. Request status checks when engaged in potentially high risk activities
3. Supervisors are required to complete a hazard assessment with employees

Appendix G, Attachment 5. MORA backcountry travel procedures.

MORA Backcountry Travel Procedures

DAY HIKES

BEFORE going in the field for the day, field crew leads record your destination and route on the NCR Aquatics calendar (http://inpmoralo1/TeamCalendars/Lists/Events/Aquatics.aspx). Send a copy of your itinerary to your Supervisor. If the WIC is open when you leave, check in "in person" or by phone with the WIC staff. Provide them with a written copy of your itinerary including where you are heading and any unusual aspects to your route. **Also, leave a written copy of your itinerary posted on your office wall**. Check in with Comm. Center 637, via radio, when you are out of the backcountry.

OVERNIGHT

BEFORE going in the field for the day, field crew leads record your destination and route on the NCR Aquatics calendar (http://inpmoralo1/TeamCalendars/Lists/Events/Aquatics.aspx). Send a copy of your itinerary to your Supervisor and to the Wilderness Information Center WIC), or check in with them in person and provide them with a written copy of your itinerary including where you are heading and any unusual aspects to your route. **Also, leave a written copy of your itinerary posted on your office wall**.

Example (lake numbers are made up):
7/8 Summerland trail to Panhandle Gap area (Lake LW 22), and Sarvent Glacier (LW31)
7/9 Sarvent/Panhandle to Ohanapecosh Park to Lake LO52
7/10 Lake LO52 to Nickel Creek near Trailside Camp
7/11 Nickel Creek to Box Canyon

All overnight personnel are required to call in and out of service. A travel itinerary must be filed with your supervisor/work unit, ***and*** with a Wilderness Information Center at either Longmire or White River (email address using Lotus Notes NPS Catalog addresses: MORA Longmire WIC, MORA White River WIC).

An employee roundup will be performed each morning at 0900 hours immediately following the morning report. The round-up will begin with the Longmire WIC calling each employee in the field originating from the west side of the park for a status check, the day's itinerary, and any pertinent messages. This will be followed by White River WIC doing the same for employees originating from the east side of the park. Log books will be maintained by the WICs.

Upon completion of the day's work, check-in with the Communications Center providing your general camp location to close out the day. Overnight employees beginning backcountry travel before 0900 hours must check-in with the Communications Center at the beginning of their shift. The 0900 round-up will still occur for detailed itinerary information.

Appendix G, Attachment 5. MORA backcountry travel procedures (continued).

Loss of contact with employee
If an employee fails to answer the 0900 round-up status check, the immediate supervisor will be notified. The supervisor will check with the Communications Center to verify whether the employee called out of service the previous evening. If there is no record of a previous evening check-in, dispatch will notify a Supervisory Park Ranger. Supervisory Ranger staff will be responsible for initiating appropriate action that is intended to locate and ensure the safety of any employee who is unaccounted for. The supervisor will gather all available information regarding the employee, their travel route, plan, weather conditions, area hazards, and other known information that will assist in determining an appropriate reaction or response (i.e., search urgency). Efforts to contact the employee will continue. Keep in mind that the inability to contact an employee does not necessarily prompt an immediate response. However, it is likely that missing two consecutive check-ins (24 hrs) will initiate a search and rescue response.

It must be recognized that actions will vary dependent upon totality of circumstances. What may be a reasonable course of action/response in one situation may differ in another. Good judgment, experience, and available information will guide decisions. This approach is consistent with the manner in which all backcountry overdue persons or parties are addressed in the Park.

Missed Check-in
In the event an employee misses the round-up because of poor radio reception or any other reason, the employee must find a location to call in *as soon as possible* and before the evening check-in. The employee's supervisor will be notified each time efforts are initiated to follow up on employees who fail to respond to status checks or fail to check out of service.

Communications Equipment Failure
In the event of known communication equipment failure while in the backcountry, the employee has the responsibility to recognize that search efforts may soon follow. The employee must exit the backcountry as soon as possible or locate another unit with good communication equipment. Immediately exiting the backcountry is preferred unless the exact location of the other unit is known and can be reached in a timely manner.

Deviation from Travel Plan
Employees are empowered to change their travel plan when deemed necessary. Significant deviations from filed travel itineraries must be reported to Barbara Samora, Rebecca Doyle (when she is not in the field), or the Communications Center for day trips, and the Wilderness Information Center, or the Communications Center for overnight trips.

High risk areas & activities
Status checks should be requested any time an employee is entering a suspected high risk area, undertaking high risk activities, or conducting unusual visitor contacts. The Communications Center should be contacted and given information specific to the area, the hazard, and the frequency of status check requested. Re-contact the Communications Center once the hazard has been cleared.

Appendix G, Attachment 5. MORA backcountry travel procedures (continued).

You will be contacted by White River WIC each day just after 0900 hours. When contacted, give your current location and your plans for the day, e.g., "637, Lake James, I'll be hiking to the Northern Lakes today." If you do not hear White River call in the "ranger roundup," you'll need to initiate the contact with White River. White River will record your check in by marking your itinerary with their initials and the time on the appropriate date. (Rangers beginning backcountry travel before 0900 hours must check-in with the Comm. Center at the beginning of the shift. The 0900 roundup will still occur.)

At the end of your day, after you have completed travel, camp checks, etc., and are basically ready to crawl in your tent, you need to call Comm. Center and tell them that you are "out of service". Keep in mind, you must call in before Comm. Center shuts down for the day!

If you fail to respond to the morning ranger roundup AND you did not call "out of service" the night before (the WIC will call Comm. Center to check on this), we WILL initiate a SAR response. If you fail to respond to the ranger roundup but you DID call out of service the night before, an appropriate amount of time may be afforded for you to hike out before a SAR response is initiated. In either case, efforts to contact the employee will continue on a regular basis. The extent of the SAR response (search urgency) will be determined from all available information.

If you miss a check-in because of bad radio position *or any other reason,* you must find a spot to call in from or immediately hike out of the backcountry. If you can *hear* the roundup but cannot reach White River directly, try relaying through any available station or individual.

When the WIC person sees that a ranger has missed two consecutive check-ins, they will notify, in order: 1.Wilderness District Personnel, 2. Your Supervisor, 3. NCR Division Chief. If none are available, they will call Comm. Center and have them notify the Chief Ranger.

If you find yourself in a strange or confrontational contact at any point during the day, call Comm. Center and tell them that you are making the contact. They will put you on a 5 minute "status check." **ASSUMING ALL IS WELL, <u>THE ONLY APPROPRIATE RESPONSE</u> TO A STATUS CHECK IS: "637, CODE FOUR." IF YOU HAVE RADIO FAILURE BECAUSE OF MALFUNCTION OR DEAD BATTERIES/ETC… YOU NEED TO IMMEDIATELY HIKE OUT BY THE SAFEST AND MOST DIRECT ROUTE!!!!**

Appendix G, Attachment 6. Tracking of backcountry personnel NPS Olympic National Park.

Tracking of Backcountry Personnel NPS Olympic National Park (OLYM Office Order No. 54, August 2, 2006)

I. PURPOSE:

To establish a call-in and call-out procedure (backcountry tracking) for employees and volunteers traveling in the wilderness of Olympic National Park (OLYM).

II. POLICY:

When on duty, all employees and volunteers of OLYM must adhere to the backcountry tracking procedure when traveling in the wilderness of OLYM. This policy will also apply to off duty employees that utilize the backcountry cabins and caches in OLYM.

III. GENERAL:

Accounting for employees traveling in the wilderness is imperative. Just as private backcountry travelers are encouraged to leave their itinerary with a responsible party, employees of OLYM should do the same. To that end, the employer, the National Park Service, is the responsible party. While backcountry tracking cannot replace good judgment on the part of the backcountry traveler, implementation of backcountry tracking procedures will provide a degree of safety for both the backcountry traveler and the potential rescuers.

This office order applies to all employees traveling in parties of two or fewer during backcountry travel, but is available for all parties. It will also apply immediately if a larger party separates forming a group or groups of two or fewer.

Temporary backcountry tracking may be warranted for all parties, regardless of size, during certain times. These may include approaching an animal carcass, negotiating a steep snow field or difficult stream crossing, scrambling on exposed rock, etc.

The employee should keep the following in mind. “If the worst were to happen right now, how difficult would it be for a rescuer to find me and how long would it take?” Think about those who care for you and those who will come looking for you.

IV. PROCEDURE:

1) **Responsibilities:**
   The responsibility for tracking employees is shared by the employee, supervisors, and Dispatch.
   a. Employees will follow the procedures outlined in #2 Trip pre-planning, #3 Check-in, #4 Monitoring, and #5 Check-out.
   b. Supervisors are responsible for ensuring that their employees understand and adhere to the backcountry tracking SOPs.

Appendix G, Attachment 6. Tracking of backcountry personnel NPS Olympic National Park (continued).

2) **Trip pre-planning:**
   a. Overnight travel:
      All employees planning overnight wilderness travel will provide dispatch with a written travel itinerary using the Wilderness Travel Itinerary form. The form can be found on the Olympic National Park intranet site under "Forms", or on the I-drive (I:\All\Wilderness Travel Itinerary Form.doc.). This form may be faxed to 360-565-3119, e-mailed to OLYM Communication Center, or hand delivered to OLYM Communication Center. The employee must confirm that the Communication Center has the written itinerary before starting into the wilderness.
   b. Single day travel:
      Employees may, but are not required to, file a written travel itinerary for scheduled single day wilderness patrols. However, intended deviations from the scheduled patrol must be communicated to the Communication Center at the time of check-in. If while on patrol, the employee deviates from what is scheduled, the employee will communicate this to the Communication Center at that time.

3) **Check-in procedure:**
   A check-in at the beginning of each travel period must be made with the Communication Center. Check-in by radio should occur just prior to entering the wilderness on a day patrol or when the overnight traveler begins their work day. **Important: The Communication Center will not begin tracking employees in the wilderness until the EMPLOYEE initiates the tracking procedure**.

4) **Monitoring and mid-patrol check-in procedure:**
   a. The employee will check-in with the Communication Center twice daily.
      - Morning check-in between 0700 and 0900.
      - Evening check-in between 1700 and 1900.
   b. If an employee anticipates that he/she will be in an area where no radio coverage exists, or otherwise out of radio contact for the check-in, the employee may check-in with the Communication Center outside of the times listed above. The Communication Center will document the check-in on the employee's trip planner and note the reason.
   c. Any employee may request a status check at any time, if they are embarking on a short term activity that is high risk (e.g., a river crossing or snow field crossing).

5) **Check-out procedure:**
   A check-out when the employee exits the wilderness must be made with the Communication Center. A check-out by radio is preferred. The employee should confirm that they are terminating wilderness tracking at that time.

Appendix G, Attachment 6. Tracking of backcountry personnel NPS Olympic National Park (continued).

6) <u>Communications</u>:

a. The check-in and check-out of service with the Communication Center should be done whenever possible by radio. Phone service may be available and used in areas where radio coverage is not available.

b. Radios may fail, batteries can run down, and consideration should be given to this when traveling in the wilderness for an extended period of time. It is also recommended that extra batteries should be taken into the wilderness. The wilderness traveler should use good judgment in deciding when it is appropriate to monitor radio traffic and when it is appropriate to turn off the radio to conserve the battery.

c. Examples of communications with Olympic Communication Center:

Dispatch – 690, (Reply: 690)
690 - In service, from Deer Park Ranger Station to Falls Camp as reflected on my written itinerary.
(Reply: Copy, have a good day at [time])

_____

Dispatch – 120, (Reply: 120)
120 - In service as scheduled, Low Divide. I plan to hike the Skyline Trail today.
(Reply: Copy, have a good day at [time])

_____

Dispatch – 120, (Reply: 120)
120 – I will be crossing the snowfield at the top of the Skyline Trail near Lake Beauty. I would like a status check in 15 minutes if you have not heard from me.
(Reply: Copy, status check in 15 at [time])

7) <u>Failure to check-in or check-out</u>:

In the event of a missed check-in, the Communication Center will attempt to contact the employee as outlined below.

* In the event of a missed check-in, the Communication Center will note the miss on the Trip Plan.
* Dispatch will attempt to contact employee hourly and note each attempt on the Trip Planner.
* In the event of a second missed check-in the Communication Center will notify the employee's supervisor. If the supervisor cannot be contacted, the Division Chief for that employee will be contacted. The supervisor will evaluate the terrain and initiate some level of search and rescue effort.

Appendix G, Attachment 6. Tracking of backcountry personnel NPS Olympic National Park (continued).

* In the event of a known communications equipment failure while in the Wilderness, the employee has the responsibility to recognize that search efforts will follow and attempt to intervene by exiting the wilderness as soon as possible.
* Employees working in the wilderness should routinely carry visual aids such as orange smoke or brightly colored garments to assist aerial searchers. The uniform alone is sometimes difficult to detect in dense forest.
* The employee's supervisor, division chief, and superintendent will be notified each time search and rescue efforts are initiated on employees that fail to respond to status checks.

8) Alternative tracking options:

Employees may conduct backcountry tracking with a fellow employee and not with the Communication Center for brief visits to the backcountry. For example, if an employee is going to use an hour of PT time to hike the Pyramid Trail, he/she may use a fellow employee to track his/her progress for that brief period. The fellow employee is then responsible for knowing the planned route and reporting to the Communication Center if the employee is overdue. **This alternative is the exception and not the rule and is only to be used for brief excursions into the backcountry.**

9) Complex Patrols:

Even though a written itinerary may exist, if the employee will be on a complex patrol such as climbing an obscure route or traveling cross country, the employee should discuss their plan with their supervisor or the Communication Center. The supervisor, or the Communication Center, should know exactly what the employee plans to do in the event that a search must be initiated.

Approved: _____*/s/ Susan K. McGill*_____ Date: ___August 2, 2006____
for Superintendent

Appendix G, Attachment 7. OLYM wilderness tracking itinerary form.

WILDERNESS TRACKING ITINERARY
OLYM Dispatch Fax 360-565-3119
E-MAIL: OLYM Communication Center

NAME (S)

DATE (S) OF TRAVEL

SUPERVISOR **CONTACT NUMBER**

ITINERARY:
(sample: 6/1/06- Third Beach to Oil City. Spend the night at Toleak Point. 6/2/06- Toleak Point to Oil City.

VEHICLE DESCRIPTION:

Make/Model	Color	License Plate & State	Location Parked

WHO ELSE KNOWS THE SPECIFICS OF YOUR ITINERARY:

Name	Phone Number

ANY OTHER PERTINENT INFORMATION:

Appendix G, Attachment 7. OLYM wilderness tracking itinerary form (continued).

****REMEMBER TO CHECK IN BETWEEN 7 & 9 AM DAILY!****

Appendix G, Attachment 8. Backcountry situational awareness & risk management, NCCN Mountain Lakes Monitoring Project.

Backcountry Situational Awareness & Risk Management, NCCN Mountain Lakes Monitoring Project *(rev. 11/19/08).*

An important element of work in a backcountry, wilderness setting is self reliance and personal preparedness. Accordingly, park personnel are expected to assume a high degree of responsibility for their own safety, commensurate with the nature of activities they undertake. While safe practices and procedures will be emphasized in all aspects of the backcountry/wilderness program, employees are ultimately responsible for their own safety. A safe and successful backcountry trip is dependent upon good situational awareness and the ability to anticipate, detect and act upon problems encountered (risk management.) Discretion and judgment are key elements of this process.

1. Situational Awareness
   Situational Awareness is the ability to identify, process, and comprehend the critical elements of information about what is happening around you. It is dependent upon the degree of accuracy by which one's perception of the current environment mirrors reality. When we lose situational awareness we increase the potential for human error mishaps.

   a. Perception vs. Reality

      - View of the situation
      - Incoming information
      - Expectations & biases
      - Incoming information vs. expectations

   b. Factors that reduce situational awareness (loss of situational awareness usually occurs over a period of time and will leave a trail of clues.) Be alert for the following:

      - Confusion or gut feeling (listen to your inner voice!)
      - Lack of attention to surroundings
      - Departure from established policy or procedure
      - Failure to meet objectives or plans
      - Ambiguity
      - Fixation or preoccupation
      - Insufficient communication
      - Fatigue or stress
      - Task overload
      - Task underload
      - Group mindset
      - “Press on regardless” philosophy
      - Degrading conditions, such as weather

Appendix G, Attachment 7. OLYM wilderness tracking itinerary form (continued).

Pay attention to current and changing conditions. What is your physical and mental status? Are you properly clothed and equipped for your trip? Observe your surroundings. Watch your footing. Evaluate current and changing weather. Regularly communicate your status. Good situational awareness requires constant attention and processing of all the objective and subjective information that surrounds you. Situational awareness is an essential element to managing risk.

2. Risk Management

Risk management is a process that begins with effective situational awareness. Risk management helps ensure that critical factors and risks associated with backcountry travel and activities are considered during the decision making process. This proactive process must precede action and should include the following five steps:

a. Identify hazards (Steep snow slope ahead!)

b. Assess hazards (Is snow hard or soft? Does slope exceed my skill and ability? Is my footwear adequate? Is an ice axe necessary and available? Is there a safe run-out zone? Could an uncontrolled fall result in serious injury?)

c. Make decisions (Do benefits outweigh potential costs? Do the benefits of going down the slope outweigh those of finding an alternative route? Should I turn around?)

d. Implement controls (Are controls in place for identified hazards? Has the best route down the slope been identified? Do other reasonable routes exist? Is my safety equipment ready? Have I contacted dispatch and advised of my plan to cross a hazardous area? Have I asked for status checks until I've cleared the hazard?)

e. Evaluate (Revaluate your decision. Still a good decision? Are conditions different than anticipated? Reassess. Change the plan if necessary!)

Appendix H. Database Documentation.

The database for this project consists of three types of tables: core tables describing the "who, where and when" of data collection, project-specific tables, and lookup tables that contain domain constraints for other tables. Although core tables are based on NCCN standards, they may contain fields, domains or descriptions that have been added or altered to meet project objectives.

The database includes the following standard tables:

tbl_Locations	Sample locations - survey units within which aerial counts are conducted
tbl_Strata	Stratification classes used during design and analysis
tbl_Schedule	Schedule for monitoring sites
tbl_Events	Data collection events (flights)
tbl_Coordinates	Coordinate data collected during sampling events
tbl_GPS_Info	GPS information associated with flight paths and group observations
tbl_Observers	Observers for each sampling event
tbl_QA_Results	Quality assurance query results for the working data set
tbl_Edit_Log	Edit log for changes made to data after certification
tbl_Images	Images associated with flights or individual observations

The following are project-specific data tables:

List of data tables in the data model:

tbl_Amphibian_VES	User entered Amphibian Field Data
tbl_Amphibian_VES_Habitat	User entered amphibian habitat survey results
tbl_Amphibian_VES_Species	User entered amphibian VES observation results
tbl_Amph_Snorkel	Amphibian snorkel survey data table
tbl_Amph_Snorkel_Species	Amphibian snorkel transect observations
tbl_Amph_VES_Specimens	Amphibian VES specimen length and life stage results
tbl_Analysis_Notes	Sample location-specific comments related to data analysis
tbl_BMI	User entered Benthic Macroinvertebrate field data.
tbl_BMI_Habitat	User entered BMI habitat survey results
tbl_BMI_Lab	Benthic Macroinvertebrate lab data
tbl_Cation_Anion_Lab	Cation/anion lab results
tbl_Chlorophyll_Lab	Chlorophyll lab results
tbl_Continuous_Temp_Logger	User entered continous temperature logger field data
tbl_Field_Log	Checklist of sampling methods and activities performed during a sampling event
tbl_Fish_Angling	Fish angling and visual catch results
tbl_Fish_Gillnet	Gillnet field data form
tbl_Fish_Survey	Fish survey data form
tbl_Lake_Profile	Field data for water clarity, zooplankton and lake profile field information
tbl_Lake_Profile_Sonde	Sonde temperature, DO and pH profile data

tbl_Riparian_Disturbance	Lake riparian disturbance field data
tbl_Riparian_Dist_Plots	Human influence shore disturbance plots
tbl_Sample_Periods	The span of dates during which data collection occurs
tbl_Secchi	Secchi measurements from field collection
tbl_Target_Coords	Target coordinates for sample locations
tbl_Task_List	Checklist of tasks to be completed at sampling locations
tbl_Water_Chem_Lab	Water chemistry results from CCAL
tbl_Water_Level	Lake features mapping and water level and panoramic photos
tbl_Water_Sample	Water sample collection information
tbl_Zooplankton_Lab	Zooplankton lab species results

The following are a few of the more prominent, standard lookup tables:

tlu_Project_Crew	List of personnel associated with a project
tlu_Project_Taxa	List of species associated with project observations
tlu_Park_Taxa	Park-specific attributes for taxa

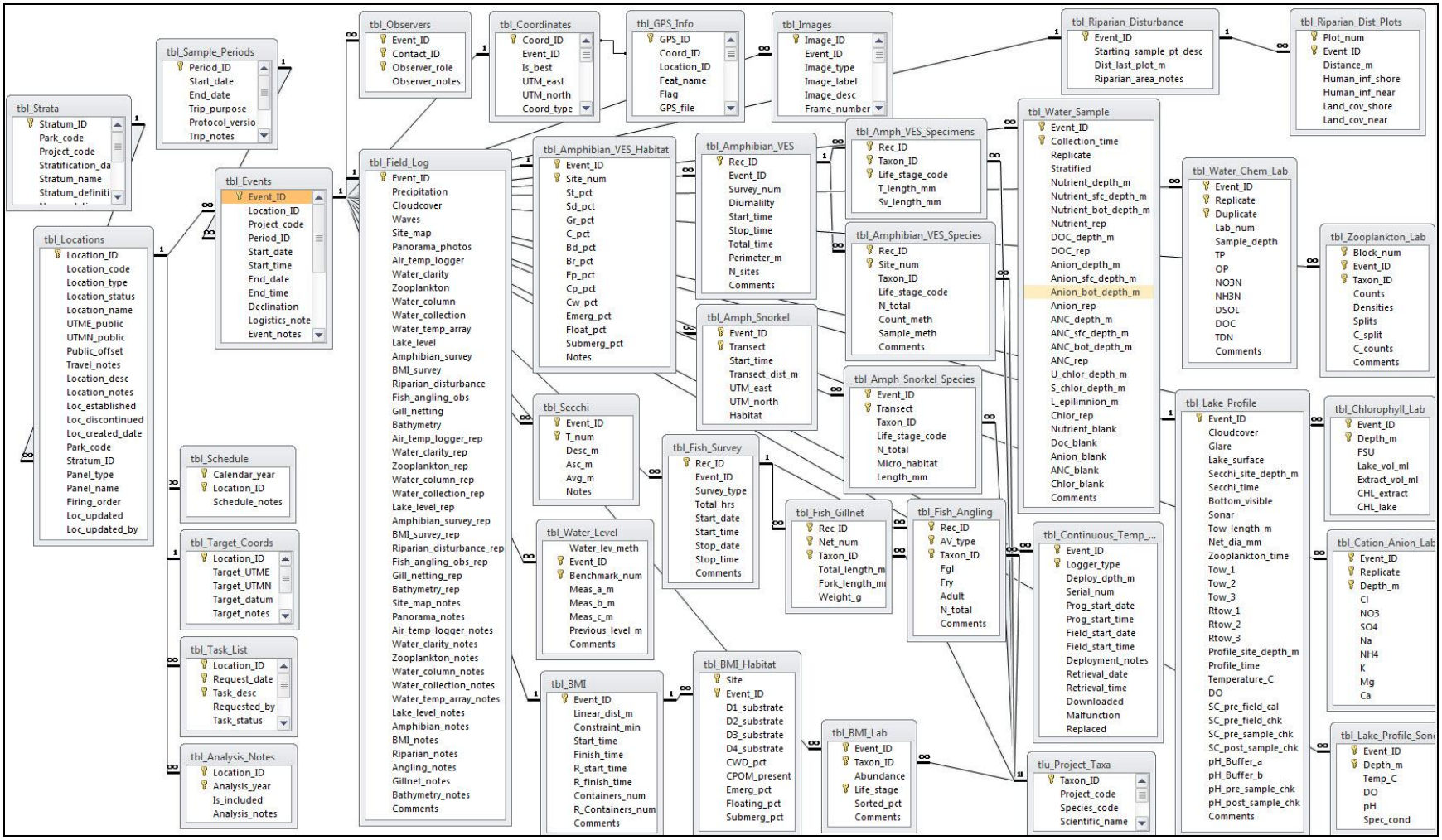


Figure H.1. Entity relationship diagram for the project database. Relationships between tables are represented by lines. Dark green tables represent core standard tables; light green represents extended standard tables; light brown are standard lookup tables. Project-specific tables are unshaded.

Data Dictionary

File name: Mountain Lakes Monitoring Database (ACa02)
Report date: 2/28/2012 10:21:02 AM

Required fields are denoted with an asterisk (*).

tbl_Amphibian_VES - User entered Amphibian Field Data

Index	*Index columns*
Event_ID	Event_ID
PrimaryKey (primary)	Rec_ID
Rec_ID (unique)	Rec_ID

Field name	*Index/key*	*Data type*	*Description*
Rec_ID	primary *	text (50)	Field data table row identifier (Rec_ID) Default: =Format(Now(),"yyyymmddhhnnss") & '-' & 1000000000*Rnd(Now())
Event_ID	indexed (FK)*	text (50)	Link to tbl_Events
Survey_num		text (1)	Indicated survey number (VES 1 or VES 2)
Diurnalilty		text (1)	Indicates whether this was a day or night survey
Start_time		datetime	Start time of VES survey
Stop_time		datetime	Stop time of VES survey
Total_time		text (5)	Total time of VES survey
Perimeter_m		double	Survey perimeter distance in meters
N_sites		smallint	Number of intensive search sites
Comments		text (100)	Comments regarding the survey

tbl_Amphibian_VES_Habitat - User entered amphibian habitat survey results

Index	*Index columns*
Event_ID (unique)	Event_ID
PrimaryKey (primary)	Event_ID, Site_num
Site_num (unique)	Site_num

Field name	*Index/key*	*Data type*	*Description*
Event_ID	unique (FK)*	text (50)	Sampling event
Site_num	primary *	text (8)	Site number assigned to intensive search site
St_pct		smallint	Substrate type; Percentage of silt Constraint: Is Null Or Between 0 And 100
Sd_pct		smallint	Substrate type; Percentage of sand Constraint: Is Null Or Between 0 And 100
Gr_pct		smallint	Substrate type; Percentage of gravel Constraint: Is Null Or Between 0 And 100
C_pct		smallint	Substrate type; Percentage of cobble Constraint: Is Null Or Between 0 And 100
Bd_pct		smallint	Substrate type; Percentage of boulder Constraint: Is Null Or Between 0 And 100
Br_pct		smallint	Substrate type; Percentage of bedrock Constraint: Is Null Or Between 0 And 100
Fp_pct		smallint	Substrate type; Percentage of fine particulate organic matter Constraint: Is Null Or Between 0 And 100
Cp_pct		smallint	Substrate type; Percentage of silt Constraint: Is Null Or Between 0 And 100
Cw_pct		smallint	Substrate type; Percentage of silt Constraint: Is Null Or Between 0 And 100
Emerg_pct		smallint	Vegetation; Percent emergent Constraint: Is Null Or Between 0 And 100
Float_pct		smallint	Vegetation; Percent floating

			Constraint: Is Null Or Between 0 And 100
Submerg_pct		smallint	Vegetation; Percent submerged
			Constraint: Is Null Or Between 0 And 100
Notes		memo	Notes regarding habitat collection including field sample split sizes

tbl_Amphibian_VES_Species - User entered amphibian VES observation results

Index	*Index columns*
PrimaryKey (primary)	Rec_ID, Site_num
Rec_ID	Rec_ID
Site_num	Site_num
Taxon_ID	Taxon_ID

Field name	*Index/key*	*Data type*	*Description*
Rec_ID	primary (FK)*	text (50)	Link to tbl_Ampibian_VES_Species
Site_num	primary *	text (8)	Site number or in-between sites (note site numbers)
Taxon_ID	indexed (FK)*	text (50)	Taxon observed
Life_stage_code	*	text (2)	Amphibian species life stage code
N_total		int	Total number of this species observed
Count_meth		text (1)	Count method used (actual or estimated)
Sample_meth		text (1)	Sample method used (hand net or visual only)
Comments		text (100)	Comments including voucher specimens, photographs, etc.)

tbl_Amph_Snorkel - Amphibian snorkel survey data table

Index	*Index columns*
Event_ID	Event_ID
PrimaryKey (primary)	Event_ID, Transect
Transect	Transect

Field name	*Index/key*	*Data type*	*Description*
Event_ID	primary (FK)*	text (50)	Link to tbl_Events (Event_ID)
Transect	primary *	text (2)	Nearshore or offshore transect number
Start_time		datetime	Transect start time
Transect_dist_m		int	Transect distance in meters
UTM_east		double	Final UTM easting (zone 10N, meters), including any offsets and corrections
UTM_north		double	Final UTM northing (zone 10N, meters), including any offsets and corrections
Habitat		text (4)	Dominant habitat classification

tbl_Amph_Snorkel_Species - Amphibian snorkel transect observations

Index	*Index columns*
Event_ID1	Event_ID
PrimaryKey (primary)	Event_ID, Transect
Taxon_ID	Taxon_ID
Transect	Transect

Field name	*Index/key*	*Data type*	*Description*
Event_ID	primary (FK)*	text (50)	Link to tbl_Events (Event_ID)
Transect	primary *	text (2)	Nearshore or offshore transect number
Taxon_ID	indexed (FK)*	text (50)	Taxon observed
Life_stage_code		text (2)	Amphinian species life stage code
N_total		int	Total count for this species at this transect
Micro_habitat		text (4)	Amphibian substrate habitat classification
Length_mm		single	Specimen length in millimeters

tbl_Amph_VES_Specimens - Amphibian VES specimen length and life stage results

Index	*Index columns*
Event_ID	Rec_ID
Life_stage_code1	Life_stage_code
PrimaryKey (primary)	Rec_ID, Taxon_ID, Life_stage_code
Taxon_ID	Taxon_ID

Field name	*Index/key*	*Data type*	*Description*
Rec_ID	primary (FK)*	text (50)	Unique identifier for field data form
Taxon_ID	primary (FK)*	text (50)	Taxon observed
Life_stage_code	primary *	text (2)	Amphinian species life stage code
T_length_mm		smallint	Specimen total length in millimeters
Sv_length_mm		smallint	Snout vent length in millimeters

tbl_Analysis_Notes - Sample location-specific comments related to data analysis

Index	*Index columns*
Location_ID	Location_ID
pk_tbl_Analysis_Notes (primary)	Location_ID, Analysis_year

Field name	*Index/key*	*Data type*	*Description*
Analysis_notes		memo	Comments about this sample location related to the specified analysis year
Location_ID	primary (FK)*	text (50)	Sampling location
Analysis_year	primary *	text (4)	Analysis year (e.g., 2010)

tbl_BMI - User entered Benthic Macroinvertebrate field data.

Index	*Index columns*
Event_ID	Event_ID
PrimaryKey (primary)	Event_ID

Field name	*Index/key*	*Data type*	*Description*
Event_ID	primary (FK)*	text (50)	Link to tbl_Events (Event_ID)
Linear_dist_m		single	Linear distance interval in meters
Constraint_min		double	Time constraint in minutes
Start_time		datetime	Start time
Finish_time		datetime	Finish time
R_start_time		datetime	Replicate start time
R_finish_time		datetime	Replicate finish time
Containers_num		int	Number of containers for regular sample
R_Containers_num		smallint	Number of containers for replicate
Comments		text (100)	Notes regarding habitat collection including field sample split sizes

tbl_BMI_Habitat - User entered BMI habitat survey results

Index	*Index columns*
Event_ID	Event_ID
PrimaryKey (primary)	Site, Event_ID
Site	Site

Field name	*Index/key*	*Data type*	*Description*
Site	primary *	text (2)	Sub-sample site assigned to intensive search site (prefix is "S" for sample, "R" for replicate)
Event_ID	primary (FK)*	text (50)	Link to tbl_Events
D1_substrate		text (4)	Most dominant substrate type
D2_substrate		text (4)	2nd most dominant substrate type
D3_substrate		text (4)	3rd most dominant substrate type
D4_substrate		text (4)	4th most dominant substrate type

CWD_pct	smallint	Percentage of course woody debris Constraint: Is Null Or Between 0 And 100
CPOM_present	text (1)	Indicated whether course particulate organic matter (CPOM) is present
Emerg_pct	smallint	Percent emergent aquatic vegetation to nearest 5% Constraint: Is Null Or In (5,10,15,20,25,30,35,40,45,50,55,60,65,70,75,80,85,90,95,100)
Floating_pct	smallint	Percent floating aquatic vegetation to nearest 5% Constraint: Is Null Or In (5,10,15,20,25,30,35,40,45,50,55,60,65,70,75,80,85,90,95,100)
Submerg_pct	smallint	Percent submerged aquatic vegetation to nearest 5% Constraint: Is Null Or In (5,10,15,20,25,30,35,40,45,50,55,60,65,70,75,80,85,90,95,100)

tbl_BMI_Lab - Benthic Macroinvertebrate lab data

Index	*Index columns*	
Event_ID	Event_ID	
Life_stage	Life_stage	
PrimaryKey (primary)		Event_ID, Taxon_ID, Life_stage
Species	Taxon_ID	

Field name	*Index/key*	*Data type*	*Description*
Event_ID	primary (FK)*	text (50)	Link to tbl_Events (Event_ID)
Taxon_ID	primary (FK)*	text (50)	Species taxon for benthic macroinvertebrate
Abundance		smallint Default: 0	Species abundance
Life_stage	primary *	text (1)	Species life stage code
Sorted_pct		double Default: 0 Constraint: Is Null Or Between 0 And 100	Percent sample sorted
Comments		text (100)	Comments from the lab report

tbl_Cation_Anion_Lab - Cation/anion lab results

Index	*Index columns*	
Depth_m	Depth_m	
Event_ID	Event_ID	
PrimaryKey (primary)		Event_ID, Replicate, Depth_m
Replicate	Replicate	

Field name	*Index/key*	*Data type*	*Description*
Event_ID	primary (FK)*	text (50)	Link to tbl_Events
Replicate	primary *	text (1) Default: "N"	Indicates whether sample was a replicate
Depth_m	primary *	single	Depth in meters from lab
Cl		double	Chloride ueq/L
NO3		double	Nitrate ueq/L
SO4		double	Sulfate ueq/L
Na		double	Soduim ueq/L
NH4		double	Ammonium ueq/L
K		double	Potassium ueq/L
Mg		double	Magnesium ueq/L
Ca		double	Calcium ueq/L

tbl_Chlorophyll_Lab - Chlorophyll lab results

Index	*Index columns*
Depth_m	Depth_m

Index	*Index columns*
Event_ID	Event_ID
PrimaryKey (primary)	Event_ID, Depth_m

Field name	*Index/key*	*Data type*	*Description*
Event_ID	primary (FK)*	text (50)	Link to tbl_Events (Event_ID)
Depth_m	primary *	single	Depth value in meters from lab sheet
FSU		single	Raw flourometric signal value from lab sheet
Lake_vol_ml		single	Lake sample volume in millilters
Extract_vol_ml		single	Extract volume in milliliters
CHL_extract		single	Chlorophyll extract ug/l from lab sheet
CHL_lake		single	Chlorophyll lake sample ug/l from lab sheet

tbl_Continuous_Temp_Logger - User entered continous temperature logger field data

Index	*Index columns*
Event_ID	Event_ID
PrimaryKey (primary)	Event_ID, Logger_type

Field name	*Index/key*	*Data type*	*Description*
Event_ID	primary (FK)*	text (50)	Event identifier for this record
Logger_type	primary *	text (7)	Indicates whether and air or water temperature logger was used
Deploy_dpth_m		single Default: 0	Logger deployment depth in meters
Serial_num		text (7)	Logger serial number
Prog_start_date		datetime	Programmed deployment start date
Prog_start_time		datetime	Programmed deployment start time
Field_start_date		datetime	Field deployment start date
Field_start_time		datetime	Field deployment start time
Deployment_notes		memo	Logger deployment remarks including logger assembly and placement
Retrieval_date		datetime	Field retrieval date
Retrieval_time		datetime	Field retrieval date
Downloaded		text (1)	Indicates whether temperature logger data was downloaded
Malfunction		text (1)	Indicates whether a temperature logger malfunction was detected
Replaced		text (1)	Indicates whether the temperature logger was replaced during the visit

tbl_Coordinates - Coordinate data collected during sampling events

Index	*Index columns*
Coord_label	Coord_label
Coord_type	Coord_type
Coord_updated	Coord_updated
Datum	Datum
Event_ID (unique)	Event_ID
Field_coord_source	Field_coord_source
pk_tbl_Coordinates (primary)	Coord_ID

Field name	*Index/key*	*Data type*	*Description*
Coord_ID	primary *	text (50) Default: =Format(Now(),"yyyymmddhhnnss") & '-' & 1000000000*Rnd(Now())	Unique identifier for each coordinate record
Event_ID	unique (FK)*	text (50)	Sampling event of coordinate data collection
Is_best		bit	Indicates whether this set of coordinates is the best available for this location
UTM_east		double	Final UTM easting (zone 10N, meters), including any offsets and corrections
UTM_north		double	Final UTM northing (zone 10N, meters), including any offsets and corrections
Coord_type	indexed	text (20)	Coordinate type stored in UTM_east and UTM_north: target, field, post-processed

Datum	indexed	text (5)	Datum of UTM_east and UTM_north Default: "NAD83"
Est_horiz_error		double	Estimated horizontal error (meters) of UTM_east and UTM_north
Elevation_m		single	Elevation in meters, derived from GIS using final UTMs
Slope_deg		single	Slope steepness in degrees, derived from GIS using final UTMs
Aspect_deg		single	Slope aspect in degrees, derived from GIS using final UTMs
Coord_label	indexed	text (25)	Name of the coordinate feature (e.g., plot center, NW corner)
Field_UTME		double	UTM easting (zone 10N) as recorded in the field
Field_UTMN		double	UTM northing (zone 10N) as recorded in the field
Field_datum		text (5)	Datum of field coordinates
Field_horiz_error		double	Field coordinate horizontal error (m)
Field_offset_m		double	Distance (meters) from the field coordinates to the target Constraint: Is Null Or >=0
Field_offset_azimuth		smallint	Azimuth (degrees, declination corrected) from the coordinates to the target Constraint: Is Null Or (>=0 And <=360)
Field_coord_source		indexed	text (12) Field coordinate data source
GPS_file_name		text (50)	GPS rover file used for data downloads
GPS_model		text (25)	Make and model of GPS unit used to collect field coordinates
Source_citation		text (250)	Name, date and scale of the source map
Coordinate_notes		memo	Notes about this set of coordinates
Coord_created_date		datetime	Time stamp for record creation Default: Now()
Coord_updated	indexed	datetime	Date of the last update to this record
Coord_updated_by		text (50)	Person who made the most recent edits

tbl_Edit_Log - Edit log for changes made to data after certification

Index	*Index columns*
Edit_date	Edit_date
Edit_type	Edit_type
pk_tbl_Edit_Log (primary)	Data_edit_ID
Project_code	Project_code
Table_affected	Table_affected
User_name	User_name

Field name	*Index/key*	*Data type*	*Description*
Data_edit_ID	primary *	text (50)	Unique identifier for each data edit record Default: =Format(Now(),"yyyymmddhhnnss") & '-' & 1000000000*Rnd(Now())
Project_code	indexed *	text (10)	Project code, for linking information with other data sets and applications Default: "ACa02"
Edit_date	indexed *	datetime	Date on which the edits took place Default: Now()
Edit_type	indexed *	text (12)	Type of edits made: deletion, update, append, reformat, tbl design
Edit_reason	*	text (100)	Brief description of the reason for edits
User_name	indexed *	text (50)	Name of the person making data edits
Table_affected	indexed	text (50)	Table affected by edits
Fields_affected		text (200)	Description of the fields affected
Records_affected		text (200)	Description of the records affected
Data_edit_notes		memo	Comments about the data edits

tbl_Events - Data collection event for a given location

Index	*Index columns*
Certified_date	Certified_date
Location_ID	Location_ID
pk_tbl_Events (primary)	Event_ID

Start_date	Start_date
udx_tbl_Events (unique)	Location_ID, Start_date
Verified_date	Verified_date
Period_ID	Period_ID
Updated_date	Updated_date

Field name	*Index/key*	*Data type*	*Description*
Event_ID	primary *	text (50)	Unique identifier for each sampling event
		Default: =Format(Now(),"yyyymmddhhnnss") & '-' & 1000000000*Rnd(Now())	
Location_ID	unique (FK)*	text (50)	Sampling location for this event
Project_code	*	text (10)	Project code, for linking information with other data sets and applications
		Default: "ACa02"	
Period_ID	indexed (FK)	text (50)	Sample period during which this event occurred
Start_date	unique *	datetime	Start date of the sampling event
Start_time		datetime	Start time of the sampling event
End_date		datetime	End date of the sampling event (optional)
End_time		datetime	End time of the sampling event (optional)
Declination		text (25)	Declination correction factor for measurement of compass bearings
Logistics_notes		memo	Comments about logistics for reaching and sampling this location
Event_notes		memo	Comments about the sampling event
Entered_by		text (50)	Person who entered the data for this event
Entered_date		datetime	Date on which data entry occurred
		Default: Now()	
Updated_by		text (50)	Person who made the most recent updates
Updated_date	indexed	datetime	Date of the most recent edits
Verified_by		text (50)	Person who verified accurate data transcription
Verified_date	indexed	datetime	Date on which data were verified
Certified_by		text (50)	Person who certified data for accuracy and completeness
Certified_date	indexed	datetime	Date on which data were certified
QA_notes		memo	Quality assurance comments for the selected sampling event
Is_excluded		bit	Flag to exclude the sampling event from data summary output
		Default: False	
Precipitation		text (10)	Observed precipitation conditions
Cloud_cover		text (10)	Observed cloud cover conditions
Waves		text (10)	Observed wave conditions
Field_notes		memo	Event comments made on the event cover sheet

tbl_Field_Log - Checklist of sampling methods and activities performed during a sampling event

Index	*Index columns*
pk_tbl_Field_Log (primary)	Event_ID, Checklist_task
Checklist_task	Checklist_task
Completed	Completed
Event_ID	Event_ID
Replicate	Replicate
Sort_order	Sort_order

Field name	*Index/key*	*Data type*	*Description*
Event_ID	primary (FK)*	text (50)	Sampling event
Checklist_task	primary *	text (30)	Sampling checklist task item
Completed	indexed	text (1)	Whether the checklist task was completed during the sampling event
Replicate	indexed	text (2)	Whether the checklist task was completed during the sampling event
Task_comments		text (100)	Comments about the task item
Sort_order	indexed *	int	Sort order for displaying records in the order they were entered

tbl_Field_Log_orig - General information collected during site visits

Field name	*Index/key*	*Data type*	*Description*
Event_ID	primary *	text (50)	Sampling event
Precipitation		text (10)	Observed precipitation conditions
Cloud_cover		text (6)	Observed cloud cover conditions
Waves		text (10)	Observed wave conditions
Site_map	*	bit	Indicates whether site maps or gps features were recorded during the visit
Panorama_photos	*	bit	Indicates whether panoramic site photos were taken during the visit
Air_temp_logger	*	bit	Indicates whether air temperature logger data was downloaded during the visit
Water_clarity	*	bit	Indicates whether water clarity or secchi disk measurements were recorded during the visit
Zooplankton	*	bit	Indicates whether zooplankton surveys were performed during the visit
Water_column	*	bit	Indicates whether water column profile data were collected during the visit
Water_collection	*	bit	Indicates whether water samples were collected during the visit
Water_temp_array	*	bit	Indicates whether water temperature array data were collected during the visit
Lake_level	*	bit	Indicates whether lake water level data were recorded during the visit
Amphibian_survey	*	bit	Indicates whether amphibians were surveyed during the visit
BMI_survey	*	bit	Indicates whether benthic macroinvertebrates were surveyed during the visit
Riparian_disturbance	*	bit	Indicates whether riparian disturbance data were collected during the visit
Fish_angling_obs	*	bit	Indicates whether fish angling or observations were conducted during the visit
Gill_netting	*	bit	Indicates whether gill nets were deployed during the visit
Bathymetry	*	bit	Indicates whether lake bathymetry data were recorded during the visit
Air_temp_logger_rep	*	bit	Indicates whether replicate air temperature logger data was downloaded during the visit
Water_clarity_rep	*	bit	Indicates whether replicate water clarity or secchi disk measurements were recorded during the visit
Zooplankton_rep	*	bit	Indicates whether replicate zooplankton were surveyed during the visit
Water_column_rep	*	bit	Indicates whether replicate water column profile data were collected during the visit
Water_collection_rep	*	bit	Indicates whether replicate water samples were collected during the visit
Lake_level_rep	*	bit	Indicates whether replicate lake water level data were recorded during the visit
Amphibian_survey_rep	*	bit	Indicates whether replicate amphibian surveys were made during the visit
BMI_survey_rep	*	bit	Indicates whether replicate benthic macroinvertebrates surveys were made during the visit
Riparian_disturbance_rep	*	bit	Indicates whether replicate riparian disturbance data were collected during the visit
Fish_angling_obs_rep	*	bit	Indicates whether replicate fish angling or observations were conducted during the visit
Gill_netting_rep	*	bit	Indicates whether replicate gill nets were deployed during the visit
Bathymetry_rep	*	bit	Indicates whether replicate lake bathymetry data were recorded during the visit
Site_map_notes		text (100)	Notes regarding site maps or GPS features were recorded during the visit
Panorama_notes		text (100)	Notes regarding panoramic site photos taken during the visit
Air_temp_logger_notes		text (100)	Notes regarding the downloading of temperature logger data

Water_clarity_notes	text (100)	Notes regarding water clarity or secchi measurements conducted during the visit
Zooplankton_notes	text (100)	Notes regarding zooplankton samples taken during the visit
Water_column_notes	text (100)	Notes regarding water column profile survey conducted during the visit
Water_collection_notes	text (100)	Notes regarding water samples taken during the visit
Water_temp_array_notes	text (100)	Notes regarding water temperature array data collected during the visit
Lake_level_notes	text (100)	Notes regarding lake or water level measurements taken during the visit
Amphibian_notes	text (100)	Notes regarding amphibian surveys conducted during the visit
BMI_notes	text (100)	Notes regarding BMI surveys conducted during the visit
Riparian_notes	text (100)	Notes regarding riparian surveys conducted during the visit
Angling_notes	text (100)	Notes regarding fish angling or observations conducted during the visit
Gillnet_notes	text (100)	Notes regarding gillnet surveys conducted during the visit
Bathymetry_notes	text (100)	Notes regarding bathymetry surveys conducted during the visit
Comments	memo	General site visit comments

tbl_Fish_Angling - Fish angling and visual catch results

Index	*Index columns*
PrimaryKey (primary)	Rec_ID, AV_type, Taxon_ID
Rec_ID	Rec_ID
Species_code	Taxon_ID
Survey_type	AV_type

Field name	*Index/key*	*Data type*	*Description*
Rec_ID	primary (FK)*	text (50)	Field data table row identifier (Rec_ID)
AV_type	primary *	text (1)	Angling or visual survey type
Taxon_ID	primary (FK)*	text (50)	Fish species code
Fgl		text (1) Default: "N"	Indicates whether fingerling species were present
Fry		text (1) Default: "N"	Indicates whether fry species were present
Adult		text (1) Default: "N"	Indicates whether adult species were present
N_total		int	Total caught for this species
Comments		text (100)	Comments regarding this fish species catch or observation

tbl_Fish_Gillnet - Gillnet field data form

Index	*Index columns*
Net_num	Net_num
PrimaryKey (primary)	Rec_ID, Net_num, Taxon_ID
Rec_ID	Rec_ID
Species_code	Taxon_ID

Field name	*Index/key*	*Data type*	*Description*
Rec_ID	primary (FK)*	text (50)	Field data table row identifier (Rec_ID)
Net_num	primary *	text (1)	Gillnet number
Taxon_ID	primary (FK)*	text (50)	Fish species code
Total_length_mm		smallint	Fish total length in millimeters
Fork_length_mm		smallint	Fork length in millimeters
Weight_g		smallint	Gillnet - catch weight in grams

tbl_Fish_Survey - Fish survey data form

Index	*Index columns*
Event_ID	Event_ID
PrimaryKey (primary)	Rec_ID
Rec_ID (unique)	Rec_ID

Survey_type	Survey_type

Field name	*Index/key*	*Data type*	*Description*
Rec_ID	primary *	text (50)	Field data table row identifier (Rec_ID) Default: =Format(Now(),"yyyymmddhhnnss") & '-' & 1000000000*Rnd(Now())
Event_ID	indexed (FK)*	text (50)	Link to tbl_Events (Event_ID)
Survey_type	indexed *	text (2)	Indicates Angling/Visual or Gillnet survey type
Total_hrs		single	Total hours surveyed
Start_date		datetime	Start date of gill net survey
Start_time		datetime	Start time ofgill net survey
Stop_date		datetime	Stop date of gill net survey
Stop_time		datetime	Stop time of gill net survey
Comments		text (100)	Comments regarding the fish survey

tbl_GPS_Info - GPS information associated with sampling event coordinates

Index	*Index columns*
Coord_ID	Coord_ID
Corr_type	Corr_type
Datum	GPS_datum
Feat_name	Feat_name
Feat_type	Feat_type
GPS_date	GPS_date
GPS_file	GPS_file
Location_ID	Location_ID
pk_tbl_GPS_Info (primary)	GPS_ID

Field name	*Index/key*	*Data type*	*Description*
GPS_ID	primary *	text (50)	Unique identifier for the GPS record Default: =Format(Now(),"yyyymmddhhnnss") & '-' & 1000000000*Rnd(Now())
Location_ID	indexed	text (50)	Sample location, used for temporary links
Feat_name	indexed	text (50)	Feature name in data dictionary
Flag	*	bit	Internal flag used to identify records while matching with tbl_Coordinates during post-season processing Default: False
GPS_file	indexed	text (50)	GPS file name
GPS_date	indexed	datetime	Date GPS file was collected
GPS_time		datetime	Time GPS file was collected
Corr_type	indexed	text (50)	GPS file correction type
GPS_UTME		double	UTM easting in GPS unit
GPS_UTMN		double	UTM northing in GPS unit
UTM_zone		text (5)	UTM projection system zone Default: "10N"
GPS_datum	indexed	text (5)	Datum of GPS coordinates
Feat_type	indexed	text (20)	Feature type (point, line, or polygon) collected with GPS
Data_dict_name		text (50)	Data dictionary name used to collect feature
Elev_m		double	Elevation (meters) in GPS unit
Num_sat		smallint	Number of satellites tracked by GPS unit during data collection
GPS_duration		text (25)	Length of time GPS file was open
Filt_pos		smallint	Number of GPS positions exported from GPS file
PDOP		double	Position dilution of precision scale
HDOP		double	Horizontal dilution of precision scale
H_err_m		double	Horizontal error (meters)
V_err_m		double	Vertical error (meters)
Std_dev_m		double	Standard deviation (meters)
GPS_process_notes		text (255)	GPS file processing notes

Is_better	*	bit	Indicates that the field crew thought this coordinate record to be an improvement over the current Is_best coordinate
		Default: False	
Coord_ID	indexed (FK)	text (50)	Coordinate identifier

tbl_Images - Images associated with sampling events

Index	*Index columns*
Event_ID	Event_ID
Image_label	Image_label
Image_quality	Image_quality
Image_type	Image_type
pk_tbl_Images (primary)	Image_ID
Sort_order	Sort_order

Field name	*Index/key*	*Data type*	*Description*
Image_ID	primary *	text (50)	Unique identifier for each image record
		Default: =Format(Now(),"yyyymmddhhnnss") & '-' & 1000000000*Rnd(Now())	
Event_ID	indexed (FK)*	text (50)	Sampling event
Image_type	indexed	text (20)	Type of image
		Default: "Ground photo"	
Image_label	indexed	text (25)	Image caption or label
Image_desc		text (255)	Brief description of the image bearing, perspective, etc.
Frame_number		text (10)	Frame number for photographic images
Image_date		datetime	Date on which the image was created, if different from the sampling event date
Image_source		text (50)	Name of the person or organization that created the image
Image_quality	indexed	tinyint	Quality of the image
Is_edited_version		bit	Indicates whether this version of the image is the edited (originals = False)
Object_format		text (20)	Format of the image
Orig_format		text (20)	Format of the original image
Image_edit_notes		text (200)	Comments about the editing or processing performed on the image
Image_is_active		bit	Indicates whether the image is still being used for navigation or interpretation
		Default: True	
Image_root_path		text (100)	Drive space location of the main project folder or image library
Image_project_path		text (100)	Location of the image from the main project folder or image library
		Default: "Images\"	
Image_filename		text (100)	Name of the image including extension (.jpg) but without the image path
Image_notes		memo	Comments about the image
Sort_order	indexed *	int	Sort order for displaying records in the order they were entered
Image_time		datetime	Timestamp for image acquisition

tbl_Lake_Profile - Field data for water clarity, zooplankton and lake profile field information

Index	*Index columns*
Event_ID	Event_ID
PrimaryKey (primary)	Event_ID

Field name	*Index/key*	*Data type*	*Description*
Secchi_time		datetime	Secchi measurement start time
Bottom_visible		text (1)	Indicates whether lake bottom was visible during secchi survey
		Default: "N"	
Sonar		text (1)	Indicates whether sonar was used to determine depth
		Default: "N"	

Tow_length_m		single	Zooplankton tow length in meters
Net_dia_mm		single	Diameter of net used for zooplankton sampling in millimeters
Zooplankton_time		datetime	Start time of zooplankton survey
Tow_1		text (1)	Indicates whether sample tow 1 was completed during the visit
Tow_2		text (1)	Indicates whether sample tow 2 was completed during the visit
Tow_3		text (1)	Indicates whether sample tow 3 was completed during the visit
Rtow_1		text (1)	Indicates whether replicate tow 1 was completed during the visit
Rtow_2		text (1)	Indicates whether replicate tow 2 was completed during the visit
Rtow_3		text (1)	Indicates whether replicate tow 3 was completed during the visit
Profile_site_depth_m		single	Maximum depth minus 1 meter
Profile_time		datetime	Time that lake profile was conducted
Temperature_C		text (1)	Indicates whether Temperature calibration was completed for the sonde
DO		text (1)	Indicates whether dissolved oxygen calibration was completed for the sonde
SC_pre_field_cal		text (1)	Indicates whether specific conductivity pre field calibration was completed for the sonde
SC_pre_field_chk		text (1)	Indicates whether specific conductivity pre field check was completed for the sonde
SC_pre_sample_chk		text (1)	Indicates whether specific conductivity pre sample check was completed for the sonde
SC_post_sample_chk		text (1)	Indicates whether specific conductivity sample check was completed for the sonde
pH_Buffer_a		text (1)	Indicates whether pH pre field calibration was completed for the sonde
pH_Buffer_b		text (1)	Indicates whether pH pre field calibration was completed for the sonde
pH_pre_sample_chk		text (1)	Indicates whether specific conductivity pre sample check was completed for the sonde
pH_post_sample_chk		text (1)	Indicates whether specific conductivity sample check was completed for the sonde
Comments		text (100)	Comments regarding this survey
Event_ID	primary (FK)*	text (50)	Link to tbl_Events (Event_ID)
Cloudcover		text (6)	Cloud cover percentage category
Glare		text (4)	Water surface glare recorded during secchi
Lake_surface		text (9)	Water surface character determined during secchi
Secchi_site_depth_m		single	Secchi sample site depth in meters

tbl_Lake_Profile_Sonde - Sonde temperature, DO and pH profile data

Index	*Index columns*
Depth_m	Depth_m
Event_ID	Event_ID
PrimaryKey (primary)	Event_ID, Depth_m

Field name	*Index/key*	*Data type*	*Description*
Event_ID	primary (FK)*	text (50)	Link to tbl_Events (Event_ID)
Depth_m	primary *	single	Depth value in meters
Temp_C		single	Water temperature in degrees C
DO		single	Dissolved oxygen in mg/L
pH		single	ph in pH units
Spec_cond		single	Specific conductance in µS/cm

tbl_Locations - Sample locations - places where data collection occurs

Index	*Index columns*
Firing_order	Firing_order
Loc_updated	Loc_updated
Location_code	Location_code
Location_status	Location_status

Location_type	Location_type
Panel_name	Panel_name
Panel_type	Panel_type
Park_region	Park_region
pk_tbl_Locations (primary)	Location_ID
Public_offset	Public_offset
Stratum_ID	Stratum_ID
Evaluation_code	Evaluation_code
Park_code	Park_code
udx_tbl_Locations (unique)	Location_code

Field name	*Index/key*	*Data type*	*Description*
Location_ID	primary *	text (50)	Unique identifier for each sample location Default: =Format(Now(),"yyyymmddhhnnss") & '-' & 1000000000*Rnd(Now())
Location_code	unique *	text (10)	Alphanumeric code for the sample location
Location_type	indexed *	text (20)	Indicates the type of sample location
Location_status	indexed *	text (10)	Status of the sample location Default: "active"
Location_name		text (50)	Brief colloquial name of the sample location (optional)
UTME_public		double	UTM easting (zone 10N, meters). Note: in addition to any measurement error, these coordinates may have been offset up to 2 km from their actual position.
UTMN_public		double	UTM northing (zone 10N, meters). Note: in addition to any measurement error, these coordinates may have been offset up to 2 km from their actual position.
Public_offset	indexed	text (50)	Type of processing performed to make coordinates publishable
Travel_notes		memo	Directions for relocating the sample location
Location_desc		memo	Environmental description of the sampling location
Location_notes		memo	Other notes about the sample location
Loc_established		datetime	Date the sample location was established
Loc_discontinued		datetime	Date the sample location was discontinued
Loc_created_date		datetime	Time stamp for record creation Default: Now()
Park_code	indexed *	text (25)	Park in which the site is located
Stratum_ID	indexed (FK)*	text (50)	Stratum of the sampling location
Panel_type	indexed	text (20)	Sampling panel for the site
Panel_name	indexed	text (10)	Name of the sampling panel, used to group data for analysis
Firing_order	indexed	int	Site selection and evaluation order
Loc_updated	indexed	datetime	Date of the last update to this record
Loc_updated_by		text (50)	Person who made the most recent edits
Park_region	indexed	text (25)	Region of the park in which the lake is located
Evaluation_code	indexed	text (2)	Site evaluation status code
Evaluation_notes		text (100)	Brief comment about the site evaluation, rationale for not sampling, etc.
Depth_m		single	Maximum lake depth, in meters

tbl_Observers - Observers for each sampling event

Index	*Index columns*
Contact_ID	Contact_ID
Event_ID	Event_ID
Observer_role	Observer_role
pk_tbl_Observers (primary)	Event_ID, Contact_ID, Observer_role

Field name	*Index/key*	*Data type*	*Description*
Event_ID	primary (FK)*	text (50)	Sampling event identifier
Contact_ID	primary (FK)*	text (50)	Observer identifier

Observer_role	primary *	text (25)	Role of the observer during data collection (optional)
Observer_notes		text (200)	Comments about the observer specific to this sampling event

tbl_QA_Results - Quality assurance query results for the working data set

Index	*Index columns*
Data_scope	Data_scope
pk_tbl_QA_Results (primary)	Query_name, Time_frame, Data_scope
Query_name	Query_name
Query_result	Query_result
Query_type	Query_type
Time_frame	Time_frame

Field name	*Index/key*	*Data type*	*Description*
Query_name	primary *	text (100)	Name of the quality assurance query
Data_scope	primary *	tinyint	Scope of the data included in queries: 0=uncertified events only, 1=both certified and uncertified, 2=certified events only
Time_frame	primary *	text (30)	Field season year or range of dates for the data being passed through quality assurance checks
Query_type	indexed	text (20)	Severity of data errors being trapped: 1=critical, 2=warning, 3=information
Query_result	indexed	text (50)	Query result as the number of records returned the last time the query was run
Query_run_time		datetime	Run time of the query results
Query_description		memo	Description of the query
Query_expression		memo	Evaluation expression built into the query
Remedy_desc		memo	Details about actions taken and/or not taken to resolve errors
Remedy_date		datetime	When the remedy description was last edited
QA_user		text (50)	Name of the person doing quality assurance
Is_done	*	bit	Temporary flag to indicate that the user is done reviewing this query even if some records remain

tbl_Riparian_Disturbance - Lake riparian disturbance field data

Index	*Index columns*
Event_ID (unique)	Event_ID
PrimaryKey (primary)	Event_ID

Field name	*Index/key*	*Data type*	*Description*
Event_ID	unique (FK)*	text (50)	From tbl_Events (Event_ID)
Starting_sample_pt_desc		text (255)	Description of starting sample point location
Dist_last_plot_m		single	Distance from last plot center point to start point in meters
Riparian_area_notes		text (100)	Notes regarding impacts observed outside of plots

tbl_Riparian_Dist_Plots - Human influence shore disturbance plots

Index	*Index columns*
Event_ID	Event_ID
Plot_num	Plot_num
PrimaryKey (primary)	Plot_num, Event_ID

Field name	*Index/key*	*Data type*	*Description*
Plot_num	primary *	smallint Constraint: >0	Plot number (1-35) from datasheet
Event_ID	primary (FK)*	text (50)	From tbl_Events (Event_ID)
Distance_m		int Default: 0	Distance in meters of the plot
Human_inf_shore		text (1)	Shoreline human influence condition class code (1-4)
Human_inf_near		text (1)	Nearshore human influence condition class code (1-4)

Land_cov_shore	text (5)	Shore land cover type
Land_cov_near	text (5)	Near-shore land cover type

tbl_Sample_Periods - The span of dates during which data collection occurs

Index	*Index columns*
Period_updated	Period_updated
pk_tbl_Sample_Periods (primary)	Period_ID
Protocol_version	Protocol_version
Start_date	Start_date

Field name	*Index/key*	*Data type*	*Description*
Period_ID	primary *	text (50)	Unique identifier for each sample period Default: =Format(Now(),"yyyymmddhhnnss") & '-' & 1000000000*Rnd(Now())
Start_date	indexed *	datetime	Start date of the sample period
End_date	*	datetime	End date of the sample period
Trip_purpose		text (200)	Brief description of the purpose of the trip
Protocol_version	indexed	text (100)	Version of the protocol used for sampling
Trip_notes		memo	Details about the trip
Period_created		datetime	Time stamp for record creation Default: Now()
Period_updated	indexed	datetime	Date of the last update to this record
Period_updated_by		text (50)	Person who made the most recent edits

tbl_Schedule - Schedule for monitoring sites

Index	*Index columns*
Calendar_year	Calendar_year
pk_tbl_Schedule (primary)	Calendar_year, Location_ID
Location_ID	Location_ID

Field name	*Index/key*	*Data type*	*Description*
Calendar_year	primary *	text (10)	Calendar year for scheduled sampling (not necessarily actually sampled)
Location_ID	primary (FK)*	text (50)	Sampling location
Schedule_notes		text (255)	Comments about this schedule item (especially for out-of-rotation sites)

tbl_Secchi - Secchi measurements from field collection

Index	*Index columns*
Event_ID	Event_ID
PrimaryKey (primary)	Event_ID, T_num
T_num	T_num

Field name	*Index/key*	*Data type*	*Description*
Event_ID	primary (FK)*	text (50)	From tbl_Events (Event_ID)
T_num	primary *	text (2)	Indicates secchil test number t1, t2 or t3
Desc_m		single	Descending depth in meters
Asc_m		single	Ascending depth in meters
Avg_m		single	Average depth in meters from field form
Notes		text (100)	Notes regarding this secchi measurement

tbl_Strata - Stratification classes used during design and analysis

Index	*Index columns*
pk_tbl_Strata (primary)	Stratum_ID
Stratum_updated	Stratum_updated
udx_tbl_Strata (unique)	Park_code, Project_code, Stratification_date, Stratum_name

Field name	*Index/key*	*Data type*	*Description*
Stratum_ID	primary *	text (50)	Unique identifier for each stratum record Default: =Format(Now(),"yyyymmddhhnnss") & '-' & 1000000000*Rnd(Now())
Park_code	unique *	text (4)	4-letter park code of the stratification
Project_code	unique *	text (10)	Project code, for linking information with other data sets and applications
Stratification_date	unique *	datetime	Date on which the stratification occurred, used for grouping strata
Stratum_name	unique *	text (25)	Name of the stratification class (e.g., low, medium, high)
Stratum_definition		text (250)	Brief text definition of the stratum (e.g., elevations below 1000 meters)
N_population		int	Total population in the stratum
Weight_factor		double	Weight factor to be used in analyses; inverse of inclusion probability
Stratum_notes		memo	Comments about the stratum
Stratum_created		datetime	Time stamp for record creation Default: Now()
Stratum_updated	indexed	datetime	Date of the last update to this record
Stratum_updated_by		text (50)	Person who made the most recent edits

tbl_Target_Coords - Target coordinates for sample locations

Index	*Index columns*
pk_tbl_Target_Coords (primary)	Location_ID
Target_updated	Target_updated

Field name	*Index/key*	*Data type*	*Description*
Location_ID	primary (FK)*	text (50)	Sample location
Target_UTME		double	Target UTM easting (zone 10N)
Target_UTMN		double	Target UTM northing (zone 10N)
Target_datum		text (5)	Target coordinate datum Default: "NAD83"
Target_notes		memo	Notes about the target coordinates
Target_created_date		datetime	Time stamp for record creation Default: Now()
Target_updated	indexed	datetime	Date of the last update to this record
Target_updated_by		text (50)	Person who made the most recent edits

tbl_Task_List - Checklist of tasks to be completed at sampling locations

Index	*Index columns*
Date_completed	Date_completed
pk_tbl_Task_List (primary)	Location_ID, Request_date, Task_desc
Task_status	Task_status
Location_ID	Location_ID
Request_date	Request_date
Task_desc	Task_desc

Field name	*Index/key*	*Data type*	*Description*
Location_ID	primary (FK)*	text (50)	Sampling location
Request_date	primary *	datetime	Date of the task request Default: Now()
Task_desc	primary *	text (100)	Brief description of the task
Requested_by		text (50)	Name of the person making the initial request
Task_status	indexed *	text (50)	Status of the task Default: "active"
Date_completed	indexed	datetime	Date the task was completed
Followup_by		text (50)	Name of the person following up on or completing the task
Task_notes		memo	Notes about the task
Followup_notes		memo	Comments regarding what was done to follow-up on or complete this task

tbl_Water_Chem_Lab - Water chemistry results from CCAL

Index	*Index columns*
Duplicate	Duplicate
Event_ID	Event_ID
PrimaryKey (primary)	Event_ID, Replicate, Duplicate
Replicate	Replicate
Sample_depth	Sample_depth

Field name	*Index/key*	*Data type*	*Description*
Event_ID	primary (FK)*	text (50)	Link to tbl_Events
Replicate	primary *	text (1) Default: "N"	Indicates whether this collection was a replicate
Duplicate	primary *	text (1) Default: "N"	Indicates whether this is a duplicate
Lab_num		text (3)	Lab number from lab results
Sample_depth	indexed	single	Depth recorded from lab results in meters
TP		double	Dissolved total phosphorus in mg/l
OP		double	Dissolved orthophosphorus in mg/l
NO3N		double	Ammonia nitrogen in mg/l
NH3N		double	Nitrates in mg/l
DSOL		double	Dissolved solids in mg/l
DOC		double	Dissolved organic carbon in mg/l
TDN		double	Dissolved total nitrogen in mg/l
Comments		double	Comments from lab results including sample arrival details

tbl_Water_Level - Lake features mapping and water level and panoramic photos

Index	*Index columns*
Benchmark_num	Benchmark_num
Event_ID	Event_ID
pk_tbl_Water_Level (primary)	Event_ID, Benchmark_num
Method	Method

Field name	*Index/key*	*Data type*	*Description*
Event_ID	primary (FK)*	text (50)	Sampling event
Benchmark_num	primary *	tinyint Constraint: 1 Or 2	Water level benchmark number (1 or 2)
Meas_a_m		single	Measurement a: distance from lake level to line level; or for the tygon tube method, the height of the meniscus above lake level
Meas_b_m		single	Measurement b: distance from lake bottom to lake level for benchmark; or for the tygon tube method, the height of meniscus above benchmark
Meas_c_m		single	Relative lake level for benchmark, as a-b=c (storing a and b for comparison only); negative values mean that the lake water level is above the benchmark
Previous_c_m		single	Previous value for measurement c, water level at benchmark (written down by field crew prior to field work)
Comments		text (100)	General comments or notes regarding data for this benchmark
Method	indexed *	text (1)	Method used to measure water level

tbl_Water_Sample - Water sample collection information

Index	*Index columns*
Event_ID	Event_ID
PrimaryKey (primary)	Event_ID, Collection_time

Field name	*Index/key*	*Data type*	*Description*
Event_ID	primary (FK)*	text (50)	Event identifier for this record
Collection_time	primary *	datetime	Water sample collection time
Replicate	*	text (1) Default: "N"	Indicates whether this collection was a replicate
Stratified		text (1) Default: "N"	Indicates whether lake is stratified
Nutrient_depth_m		single	Surface depth in meters for nutrients
Nutrient_sfc_depth_m		single	Mid depth in meters for nutrients
Nutrient_bot_depth_m		single	Bottom depth in meters for nutrients
Nutrient_rep		text (1)	Indicates whether nutrient blanks were included
DOC_depth_m		single	Mid depth in meters for DOC
DOC_rep		text (1) Default: "N"	Indicates whether dissolved organic carbon replicate
Anion_depth_m		single	Mid depth in meters for anions/cations
Anion_sfc_depth_m		single	Surface depth in meters for anions/cations
Anion_bot_depth_m		single	Bottom depth in meters for anions/cations
Anion_rep		text (1) Default: "N"	Indicates whether anion replicate
ANC_depth_m		single	Mid depth in meters for ANC
ANC_sfc_depth_m		single	Surface depth in meters for ANC
ANC_bot_depth_m		single	Bottom depth in meters for ANC
ANC_rep		text (1) Default: "N"	Indicates whether ANC replicate
U_chlor_depth_m		single	Unstratified chlorophyll mid depth in meters
S_chlor_depth_m		single	Stratified chlorophyll mid depth in meters
L_epilimnion_m		single	Depth of lower epilimnion in meters
Chlor_rep		text (1) Default: "N"	Indicates whether chlorophyll replicate
Nutrient_blank		text (1) Default: "N"	Indicates whether nutrient blanks were included
Doc_blank		text (1) Default: "N"	Indicates whether dissolved organic carbon blanks were included
Anion_blank		text (1) Default: "N"	Indicates whether anion blanks were included
ANC_blank		text (1) Default: "N"	Indicates whether ANC blanks were included
Chlor_blank		text (1) Default: "N"	Indicates whether chlorophyll blanks were included
Comments		text (50)	General comments on water sample collection

tbl_Zooplankton_Lab - Zooplankton lab species results

Index	*Index columns*
Block_num	Block_num
Event_ID	Event_ID
PrimaryKey (primary)	Block_num, Event_ID, Taxon_ID
Species	Taxon_ID

Field name	*Index/key*	*Data type*	*Description*
Block_num	primary *	text (3)	Block number from lab results
Event_ID	primary (FK)*	text (50)	Link to tbl_Events (Event_ID)
Taxon_ID	primary *	smallint	Species code from lab results
Counts		single	Species abundance (counts) from lab results
Densities		single Default: 0	Densites (sp/m-3) from lab results
Splits		single	Splits from lab results

C_split	single	C Split from lab results
C_counts	single	Species abundance (c counts) from lab results
Comments	text (100)	Comments from the lab report

tlu_Amph_Life_Stage - Amphibian species life stage lookup table

Index	*Index columns*
PrimaryKey (primary)	Life_stage_code
Sort_Order	Sort_order
Substrate_code	Life_stage_code

Field name	*Index/key*	*Data type*	*Description*
Life_stage_code	primary *	text (2)	Code, abbreviation used to identify BMI life stage
Life_stage_desc		memo	Description of BMI life stage
Sort_order	indexed	smallint	Order in which to sort lookup values

tlu_BMI_Substrate - BMI substrate lookup table

Index	*Index columns*
PrimaryKey (primary)	Substrate_code
Sort_Order	Sort_order
Substrate_code	Substrate_code

Field name	*Index/key*	*Data type*	*Description*
Substrate_code	primary *	text (4)	Code, abbreviation used to identify substrate
Substrate_desc		memo	Description of substrate type
Sort_order	indexed	smallint	Order in which to sort lookup values

tlu_Checklist_Tasks - Checklist tasks performed during sampling events

Field name	*Index/key*	*Data type*	*Description*
Task_code	primary *	text (30)	
Task_desc		text (100)	
Is_active		bit Default: True	Indicates whether the record is active for data entry; those with TRUE will be auto-appended to the checklist table
Has_replicates		bit Default: False	Indicates whether replicates apply to the checklist item; those with FALSE will be auto-appended with "NA" for Replicate to the checklist table
Table_ref		text (64)	Database table that the checklist item relates to, used to check for illogical data combinations during quality assurance checks
Tab_ref		text (50)	Front-end application form tab that the checklist item relates to, used to highlight/enable controls for the user during data viewing and entering
Sort_order		tinyint	

tlu_Cloud_Cover_Code - List of cloud cover codes for general weather conditions

Field name	*Index/key*	*Data type*	*Description*
Cloud_cover_code	primary *	text (10)	
Cloud_cover_desc		text (100)	
Sort_order		tinyint	

tlu_Coord_Source - List of coordinate data sources (standard)

Field name	*Index/key*	*Data type*	*Description*
Coord_source	primary *	text (12)	
Coord_source_desc		text (100)	
Sort_order		tinyint	

tlu_Coord_Type - List of coordinate types (standard)

Field name	*Index/key*	*Data type*	*Description*
Coord_type	primary *	text (20)	
Coord_type_desc		text (100)	
Sort_order		tinyint	

tlu_Datum - List of coordinate datum codes (standard)

Field name	*Index/key*	*Data type*	*Description*
Datum	primary *	text (5)	
Datum_desc		text (50)	
Sort_order		tinyint	

tlu_Edit_Type - List of the types of post-certification edits made to data (standard)

Field name	*Index/key*	*Data type*	*Description*
Edit_type	primary *	text (12)	
Edit_type_desc		text (100)	
Sort_order		tinyint	

tlu_Evaluation_Status - List of evaluation codes for sample sites (template)

Field name	*Index/key*	*Data type*	*Description*
Eval_code	primary *	text (2)	
Eval_status	*	text (20)	
Eval_status_desc		text (100)	
Sort_order		tinyint	

tlu_GPS_Model - List of GPS devices used to collect coordinate data (template)

Field name	*Index/key*	*Data type*	*Description*
GPS_model	primary *	text (25)	
Sort_order		tinyint	

tlu_Habitat_Substrate - BMI substrate lookup table

Index	*Index columns*
PrimaryKey (primary)	Substrate_code
Sort_Order	Sort_order
Substrate_code	Substrate_code

Field name	*Index/key*	*Data type*	*Description*
Substrate_code	primary *	text (4)	Code, abbreviation used to identify substrate
Substrate_desc		memo	Description of substrate type
Sort_order	indexed	smallint	Order in which to sort lookup values

tlu_Image_Format - List of image, map, and photographic formats (template)

Field name	*Index/key*	*Data type*	*Description*
Image_format	primary *	text (12)	
Image_format_desc		text (100)	
Sort_order		tinyint	

tlu_Image_Label - List of image label codes

Field name	*Index/key*	*Data type*	*Description*
Image_label	primary *	text (5)	
Image_desc		text (100)	
Sort_order		tinyint	

tlu_Image_Quality - List of quality ranks for images (template)

Field name	*Index/key*	*Data type*	*Description*
Quality_code	primary *	tinyint	

Image_quality	*	text (20)
Image_quality_desc		text (100)

tlu_Image_Type - List of image types (template)

Field name	*Index/key*	*Data type*	*Description*
Image_type	primary *	text (12)	
Image_type_desc		text (100)	
Sort_order		tinyint	

tlu_Location_Type - List of location type codes (template)

Field name	*Index/key*	*Data type*	*Description*
Location_type	primary *	text (20)	
Loc_type_desc		text (200)	
Sort_order		tinyint	

tlu_Observer_Role - List of observer role assignments (template)

Field name	*Index/key*	*Data type*	*Description*
Observer_role	primary *	text (25)	
Role_desc		text (100)	
Sort_order		tinyint	

tlu_Origin_Code - List of origin codes for park taxa (standard)

Index	*Index columns*	
NPSpp_ID	NPSpp_ID	
pk_tlu_Origin_Code (primary)		Origin_code

Field name	*Index/key*	*Data type*	*Description*
Origin_code	primary *	text (16)	
Origin_desc		text (100)	
NPSpp_ID	indexed	smallint	
Sort_order		tinyint	

tlu_Panel_Type - List of sampling panel types (template)

Field name	*Index/key*	*Data type*	*Description*
Panel_type	primary *	text (20)	
Panel_type_desc		text (200)	
Sort_order		tinyint	

tlu_Parks - List of NCCN parks and park codes (standard)

Field name	*Index/key*	*Data type*	*Description*
Park_code	primary *	text (4)	
Park_name		text (50)	

tlu_Park_Taxa - Park-specific attributes for taxa (template)

Index	*Index columns*	
Park_origin	Park_origin	
Park_status	Park_status	
pk_tlu_Park_Taxa (primary)		Taxon_ID, Park_code
Record_status	Record_status	

Field name	*Index/key*	*Data type*	*Description*
Taxon_ID	primary (FK)*	text (50)	Taxon identifier
Park_code	primary *	text (4)	Park code
Park_status	indexed	text (16)	Status of the taxon in this park (from NPSpecies) Default: "unknown"
Park_origin	indexed	text (16)	Origin of the taxon in this park (from NPSpecies)

		Default: "unspecified"	
Local_list		bit	Indicates that the taxon is the preferred one for use at the park (from NPSpecies)
Local_accepted_TSN		int	Taxonomic serial number of the local preferred taxon (from NPSpecies)
Preferred_sci_name		text (255)	Preferred scientific name of the taxon at the park (from NPSpecies)
Park_taxon_notes		memo	Comments about the taxon specific to this park
Record_status	indexed	text (16)	Indicates the status of the record in terms of synchrony with master databases
		Default: "new record"	
Created_date		datetime	Time stamp for record creation
		Default: Now()	
Updated_date		datetime	Date of the last update to this record
Updated_by		text (50)	Person who made the most recent edits

tlu_Park_Taxon_Status - List of codes for park species occurrence (standard)

Index	*Index columns*
NPSpp_ID	NPSpp_ID
pk_tlu_Park_Taxon_Status (primary)	Taxon_status_code

Field name	*Index/key*	*Data type*	*Description*
Taxon_status_code	primary *	text (16)	
Taxon_status_desc		text (250)	
NPSpp_ID	indexed	smallint	
Sort_order		tinyint	

tlu_Precipitation_Code - List of precipitation codes for general weather conditions

Field name	*Index/key*	*Data type*	*Description*
Precip_code	primary *	text (10)	
Precip_desc		text (100)	
Sort_order		tinyint	

tlu_Project_Crew - List of personnel associated with a project (template)

Index	*Index columns*
Contact_location	Contact_location
Contact_updated	Contact_updated
First_name	First_name
Last_name	Last_name
Organization	Organization
pk_tlu_Project_Crew (primary)	Contact_ID
Project_code	Project_code

Field name	*Index/key*	*Data type*	*Description*
Contact_ID	primary *	text (50)	Unique identifier for the individual (Lastname_Firstname_MI)
Project_code	indexed *	text (10)	Project code, for linking information with other data sets and applications
		Default: "ACa02"	
Last_name	indexed *	text (24)	Last name
First_name	indexed	text (20)	First name
Middle_init		text (4)	Middle initials
Organization	indexed	text (50)	Employer (e.g., NPS-MORA)
Position_title		text (50)	Position title held by the individual
Contact_is_active		bit	Indicates that the contact record is currently available for data entry pick lists
		Default: True	
Email		text (50)	Email address

Work_voice		text (25)	Work phone number
Work_ext		text (5)	Work extension number
Mobile_voice		text (25)	Mobile phone number
Home_voice		text (25)	Home phone number
Fax		text (25)	Fax number
Contact_location	indexed	text (255)	Where the individual is located
Contact_notes		memo	Notes about the contact
Contact_created		datetime	Time stamp for record creation
		Default: Now()	
Contact_updated	indexed	datetime	Date of the last update to this record
Contact_updated_by		text (50)	Person who made the most recent edits

tlu_Project_Taxa - List of species associated with project observations (template)
Constraints: : ([Taxon_is_active] And [Refers_to] Is Null) Or ([Taxon_is_active]=False And [Refers_to] Is Not Null)

Index	*Index columns*
Accepted_TSN	Accepted_TSN
Category	Category
pk_tlu_Project_Taxa (primary)	Taxon_ID
Project_code	Project_code
Record_status	Record_status
Scientific_name (unique)	Scientific_name
Species_code (unique)	Species_code
Subcategory	Subcategory
Taxon_type	Taxon_type
TSN	TSN

Field name	*Index/key*	*Data type*	*Description*
Taxon_ID	primary *	text (50)	Unique identifier for each taxon
		Default: =Format(Now(),"yyyymmddhhnnss") & '-' & 1000000000*Rnd(Now())	
Project_code	indexed *	text (10)	Project code, for linking information with other data sets and applications
		Default: "ACa02"	
Species_code	unique *	text (20)	Unique field code for each project taxon
Scientific_name	unique *	text (100)	Scientific name of the taxon (from ITIS/NPSpecies)
Common_name		text (100)	Common name for the taxon (from ITIS/NPSpecies)
Pref_com_name		text (100)	Preferred common name for this project
TSN	indexed	int	ITIS taxonomic serial number or a provisional number (from NPSpecies)
Accepted_TSN	indexed	int	ITIS taxonomic serial number of the accepted name for this taxon (from NPSpecies)
Category	indexed *	text (20)	General category of the taxon (from NPSpecies)
		Default: "Unspecified"	
Subcategory	indexed	text (20)	Subcategory specific to the needs of each taxonomic discipline (from NPSpecies)
Authority		text (60)	Taxonomic authority (from ITIS)
Authority_subsp		text (60)	Taxonomic authority for subspecific taxa (from ITIS)
Family		text (60)	Taxonomic family (from ITIS)
Taxon_type	indexed *	text (12)	Indicates the taxonomic resolution and certainty represented by this record
		Default: "specific"	
Taxon_notes		memo	General notes about the taxon
Created_date		datetime	Time stamp for record creation
		Default: Now()	
Updated_date		datetime	Date of the last update to this record
Updated_by		text (50)	Person who made the most recent edits

Taxon_is_active		bit Default: True	Indicates that the record is currently available for data entry pick lists
Refers_to		text (50)	Valid taxon the record should refer to for analysis and summaries
Record_status	indexed	text (16) Default: "new record"	Indicates the status of the record in terms of synchrony with master databases
Rec_status_notes		text (255)	Notes about the disposition of the record
Project_taxon_notes		memo	Project-specific comments about the taxon

tlu_Riparian_Cover_Type - Riparian disturbance survey cover types

Index	*Index columns*
Enum_Code	Cover_type_code
PrimaryKey (primary)	Cover_type_code
Sort_Order	Sort_order

Field name	*Index/key*	*Data type*	*Description*
Cover_type_code	primary *	text (5)	Riparian cover type code, abbreviation
Cover_type_desc		memo	Riparian cover type description
Sort_order	indexed	smallint	Order in which to sort lookup values

tlu_Riparian_Human_Influence - Riparian human influence classifications

Index	*Index columns*
Enum_Code	Human_Inf_code
PrimaryKey (primary)	Human_Inf_code
Sort_Order	Sort_order

Field name	*Index/key*	*Data type*	*Description*
Human_Inf_code	primary *	text (1)	Human influence code, abbreviation
Human_Inf_desc		memo	Riparian human influence description
Sort_order	indexed	smallint	Order in which to sort lookup values

tlu_Site_Status - List of status codes for sampling stations (standard)

Field name	*Index/key*	*Data type*	*Description*
Site_status	primary *	text (10)	
Site_status_desc		text (200)	
Sort_order		tinyint	

tlu_Taxon_Category - List of taxonomic categories (standard)

Index	*Index columns*
NPSpp_ID	NPSpp_ID
pk_tlu_Taxon_Category (primary)	Category

Field name	*Index/key*	*Data type*	*Description*
Category	primary *	text (20)	
Category_desc		text (100)	
NPSpp_ID	indexed	smallint	
Sort_order		tinyint	

tlu_Taxon_Rec_Status - List of status codes for taxon records (standard)

Field name	*Index/key*	*Data type*	*Description*
Record_status_code	primary *	text (16)	
Record_status_desc		text (200)	
Sort_order		tinyint	

tlu_Taxon_Type - List of taxon resolution codes (standard)

Field name	*Index/key*	*Data type*	*Description*

Taxon_type	primary *	text (12)
Taxon_type_desc		text (200)
Sort_order		tinyint

tlu_Wave_Code - List of precipitation codes for general weather conditions

Field name	*Index/key*	*Data type*	*Description*
Wave_code	primary *	text (10)	
Wave_desc		text (100)	
Sort_order		tinyint	

tlu_Zooplankton_Species - Zooplankton species codes developed from lab documentation

Field name	*Index/key*	*Data type*	*Description*
Species_code	primary *	smallint	Species code from zooplankton lab results
Division		text (30)	Three character division code
Scientific_name		text (40)	Scientific name of this species

tsys_App_Releases - Application table - Application release history

Index	*Index columns*
pk_tsys_App_Releases (primary)	Release_ID
udx_tsys_App_Releases (unique)	Release_date, Database_title, Version_number

Field name	*Index/key*	*Data type*	*Description*
Release_ID	primary *	text (50)	Unique identifier for the release Default: =Format(Now(),"yyyymmddhhnnss") & '-' & 1000000000*Rnd(Now())
Release_date	unique *	datetime	Date of the release
Database_title	unique *	text (100)	Title of the database
Version_number	unique *	text (20)	Version control number
File_name		text (50)	Filename, used to identify older versions of the database
Release_by		text (50)	Person who issued the release
Release_notes		memo	Release notes, which may include a summary of revisions
Is_supported	*	tinyint	Indicates the support level of this release: 0=user must use a newer version; 1=supported but newer available; 2=full support, current version Default: 2

tsys_Bug_Reports - Application table - Application bugs and development history

Index	*Index columns*
Fix_date	Fix_date
pk_tsys_Bug_Reports (primary)	Bug_ID
Release_ID	Release_ID
Report_date	Report_date

Field name	*Index/key*	*Data type*	*Description*
Fix_details		memo	Notes on fix
Bug_ID	primary *	text (50)	Unique identifier for each bug record Default: =Format(Now(),"yyyymmddhhnnss") & '-' & 1000000000*Rnd(Now())
Release_ID	indexed (FK)*	text (50)	Database release version of the report
Report_date	indexed *	datetime	Date the bug was reported Default: =Date()
Found_by		text (50)	Person who found the bug
Reported_by		text (50)	Person who filled out this bug report
Report_details		memo	Nature of the bug report
Fix_date	indexed	datetime	Date the bug was fixed
Fixed_by		text (50)	Person who fixed the bug

tsys_Logins - Application table - Log of user access to the database through the front-end

Field name	*Index/key*	*Data type*	*Description*
Time_stamp	primary *	datetime Default: Now()	Time stamp of activity record
User_name	primary *	text (50)	Login name of the user
Action_taken		text (50)	Action taken by the user

tsys_User_Roles - Application table - Determines user access privileges through the front-end

Field name	*Index/key*	*Data type*	*Description*
User_name	primary *	text (50)	Network login
User_role	*	text (50)	Database application role, used to determine the access level

Appendix I. Administrative History for NCCN Mountain Lakes Monitoring Protocol Development.

The following administrative history briefly summarizes the process used to develop the NCCN Mountain Lakes monitoring protocol and associated set of standard operating procedures (SOPs). This history also identifies the documents used to develop the protocol and SOPs, and provides a list of these documents. A summary is presented in Table I-1.

Table I-1. Summary of Administrative History for development of NCCN Mountain Lakes Protocol.

Task	Date Initiated	Date Completed	Results
NOCA Proposal for Lakes and Rivers Monitoring in response to the NPS Long Term Ecological Monitoring (LTEM) Program	1992	1992	PNWRO submitted as one of two Regional proposals to go forward to NPS-WASO
NOCA and OLYM selected as two of the eleven Service-wide "prototype" parks in NPS LTEM program. NOCA was selected to represent lakes and rivers and OLYM was selected to represent the coniferous forest biome.	1993	1993	Although selected to represent an ecosystem “type”, no funding was provided to implement the LTEM program at NOCA
NOCA LTEM Conceptual Plan	1998	1998	In preparation for obtaining necessary funding for the NOCA LTEM program, park staff prioritized monitoring components, described specific parameters to be measured, and identified linkages among resources.
OLYM Vital Signs Plan	1999	1999	The Vital Signs workshop and resultant plan identified monitoring of mountain lakes identified as a high priority.
NCCN Vital Signs funded	2001	To present	Funding received to initiate the NCCN vital signs monitoring to include 7 parks.
NCCN Water Quality Planning	2001	2004	NCCN plan developed and submitted to NPS-WRD. Plan approved to identify impaired, potentially impaired and pristine surface waters. A large portion of the $82,000/yr received from NPS-WRD during this period was included in the development cost of the NCCN Mountain Lakes protocol, as this protocol was seen to address pristine waters at the time and water quality monitoring was to be incorporated into Mountain Lakes, Wadeable Streams, and Large Rivers protocols. Water quality has since been more thoroughly addressed in a separate NCCN protocol. Additional funding was obtained through NPS-WRD and other sources to use benthic macroinvertebrates as indicators of water quality, including mountain lakes.

Table I-1. Summary of Administrative History for development of NCCN Mountain Lakes Protocols (continued).

Task	Date Initiated	Date Completed	Results
NPS Vital Signs planning process, NOCA	2001	2001	NOCA identified mountain lakes and ponds among their highest priorities for monitoring vital signs (components include water chemistry, BMI, fish, amphibians, water level, bathymetry, lake basin disturbance).
USGS-BRD (FRESC) convened expert scientific panel to advise on mountain lakes and ponds protocols	2001	2002	Panel reviewed "Protocols used to sample abiotic and biotic characteristics of mountain lakes and ponds in two Pacific Northwest National Parks" –Tyler, T. J., R. L. Hoffman, and G. L. Larson, June 2002. Made recommendations for MORA, NOCA, OLYM.
MORA Vital Signs Plan (based on workshop results and additional prioritizing by park and USGS staff)	2002	2002	The park identified mountain lakes and ponds among their highest priorities for monitoring vital signs (components include water chemistry, BMI, fish, amphibians, water level, bathymetry, lake basin disturbance).
NCCN Vital Signs Prioritization (Feb 2002)	2002	2002	Narrowed list of NCCN vital signs and concluded with an outline of conceptual ecosystem models and a selection of key questions to be further refined. Included mountain lakes and ponds among the highest priorities.
Multiple Mountain Lakes and Ponds Protocol Sampling Design Proposed	2003	2005	Temporal Sampling Design Workshop held in Port Angeles in November 2003. Presentations by Trent MacDonald (statistician from WEST, Inc.) and Robert Hoffman (USGS) discussed split panel (GRTS) sample designs and reference based designs. Based on different goals and limitations, NOCA/MORA pursued a split panel (GRTS) design for Mountain Lakes and ponds, while OLYM pursued a reference design. First drafts are completed in 2005.
Water Quality Planning continued with funding supplemented by NPS-WRD and MORA funding for using lake benthic macroinvertebrates (BMI) as indicator of recreational use on lake water quality	2003	2006	The objective was to sample BMI at 70 to 80 MORA lakes divided between unimpaired (reference) and potentially impaired based on existing site and catchment disturbance information. A total of 71 lakes were sampled between FY03 and FY05 and included documentation of site disturbance attribute data for all lakes sampled.
Draft prepared for Sampling Protocols for Abiotic and Biotic Characteristics of Mountain Ponds and Lakes	2004	2004	Hoffman and Adams, USGS-BRD, FRESC with field testing at MORA beginning in 2004.

Table I-1. Summary of Administrative History for development of NCCN Mountain Lakes Protocols (continued).

Task	Date Initiated	Date Completed	Results
Field testing of draft protocols at MORA	2004	2006	Field methods for amphibians was revised to include snorkeling protocols and to clarify visual survey protocols. Field methods for various water chemistry variables were revised to meet accepted water quality standards for field and lab sample collection, storage and preservation, and analysis. Field methods for bathymetry mapping were revised. Field methods for benthic macroinvertebrate sampling were developed by Glesne.
Water Quality Planning continued	2004	2005	WRD supported NCCN's efforts to incorporate water quality monitoring goals and objectives into the Vital Signs monitoring planning for mountain lakes and ponds, wadeable streams, large rivers, and large lowland lakes) rather than prepare a separate Water Quality Plan. NCCN decision was to integrate water quality into Vital Signs protocols. Wadeable streams and large rivers were subsequently dropped from the high priority NCCN vital signs.
Aquatic Technical Group/NCCN Technical Committee/USGS-BRD-FRESC Meetings	2004	2005	Decision made and approved to move forward to implement 2 sample frames at MORA and NOCA and 1 sample frame at OLYM which will still provide regional inference (amphibians) as well as status and trends. Recommended that mountain lakes and ponds SOPs could also be used to address EBLA and LEWI lakes and ponds (This was subsequently dropped, however, Mountain Lakes SOPs have been incorporated into NCCN Water Quality Plan to address these small lowland lakes).
Completed USGS-BRD recommended protocols based on initial field testing	2005	2005	USGS published Hoffman, Robert L., Torrey J. Tyler, and Gary L. Larson. 2005. Sampling Protocols for Abiotic and Biotic Characteristics of Mountain Ponds and Lakes.
Phase III NCCN Vital Signs Monitoring Plan	2005	2005	Completed protocol development summary for Mountain lakes and Ponds. Completed conceptual model for mountain lakes and ponds. Incorporated water quality requirements. See Weber et al. 2005.

Table I-1. Summary of Administrative History for development of NCCN Mountain Lakes Protocols (continued).

Task	Date Initiated	Date Completed	Results
Scientific/Budget Review Panel	2005	2005	Panel recommended cutting budget and reducing number of sites in Mountain Lakes and Ponds sample design, with focus on trend rather than status. Aquatic Technical Committee reduced protocol budget, and reduced lakes to 11 at NOCA and 12 at MORA. OLYM remained at 5 lakes. After panel, NCCN Steering Committee, BOD, and Steve Fancy agreed to continue with two separate sampling designs (MORA/NOCA vs. OLYM) to meet park specific objectives.
OLYM begins field testing of protocol SOPs and establishing target monitoring lakes	2005	2010	Beginning in 2005, Hoffman et al. SOPs were tested and modified to meet field constraints at OLYM. A multi-year process to establish target lakes continued through 2010, taking into consideration protocol changes required after 2005, and logistical challenges of setting up sites at OLYM due to access difficulties and lack of a priori lake knowledge.
Continue field testing at MORA; initiate field testing at NOCA	2006	2007	Slightly revised Hoffman et al. SOPs to meet NPS Water Resources Division requirements for water quality monitoring and to correct/clarify some water chemistry procedures.
MORA/NOCA Mountain Lakes and Ponds Protocols draft prepared	2006	2007	Draft protocol prepared according to Oakley et al. 2003.
OLYM Mountain Lake Protocol draft prepared	2006	2006	Draft protocol included protocol narrative, sample design and data dictionary.
NCCN 3-Year Review Panel	2007	2007	Review panel reversed prior (2005) decision to allow separate NOCA/MORA and OLYM sampling designs and mandated a unified sampling/analytical design to be mediated by the Steering Committee and Robert Hoffman (USGS).
USGS Resolution for a Unified NCCN Mountain Lakes Protocol design	2007	2008	In November 2007 the USGS and the NCCN Program Manager convened a meeting to mediate a unified NCCN Mountain Lakes Monitoring Design. A unified design and SOPs resulted and was published as Hoffman and Huff 2008.
Unified NCCN Mountain Lakes Protocol draft prepared	2009	2009	A draft protocol following Oakley et al (2003) was prepared for peer review.

Table I-1. Summary of Administrative History for development of NCCN Mountain Lakes Protocols (continued).

NCCN Pre-review of Mountain Lakes Protocol	2009	2009	Prior to submission of for peer-review, the draft protocol was reviewed by the Regional I&M Coordinator and Dr. Jim Agee, the Regional Peer-Review coordinator. This review found the draft inadequately unified and called for further review by the NPS I&M Quantitative Ecologist, Dr. Tom Philippi.
NPS I&M Quantitative Ecologist review of draft protocol	2009	2010	With some modifications entailed, Dr. Philippi found the design proposed in the draft protocol adequate. The primary modification required the addition of 2 “mid” precipitation strata lakes at OLYM, leading to a total of 6 lakes at NOCA, 6 lakes at MORA, and 8 lakes at OLYM as the core lakes to be sampled in the protocol.
NCCN Protocol revision prior to peer-review	2010	2010	The NCCN mountain lakes team revised the protocol and submitted it for peer-review.
Peer-review comments received and protocol revisions made	2010	2011	This document represented the response to the NCCN Peer-Review.
Revised protocol peer-review comments received and protocol revisions made	2011	2012	This present document represents the response to additional comments regarding the 2011 revised protocol and additional comments regarding the sampling design by Tom Philippi, NPS I&M Program Quantitative Ecologist.

Appendix J. Proposal to expand mountain lake sampling to enhance interpretations of status and trend information collected from the NCCN Mountain Lake Monitoring Protocol annual sampling sites.

Parks: Mount Rainier (MORA), North Cascades (NOCA), Olympic (OLYM)

Total Request: $186,770

Principal Investigators/Contacts:
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NCCN I&M Program Contact: Mark Huff, NCCN I&M Program Manager (MORA; Mark_Huff@nps.gov, 253-306-4473

PMIS: (leave blank)

Introduction

Mountain lakes and ponds are culturally and ecologically essential park ecosystems in the NPS North Coast and Cascades Network (NCCN). The NCCN contains over 1,200 mountain lakes and ponds. These waters are enormously popular visitor destinations due to their aesthetic and natural characteristics. Mountain lakes are tightly linked to their neighboring terrestrial environments, as critical breeding sites for many amphibian and insect species, and as both watering holes and feeding grounds for park wildlife. These highly sensitive ecosystems have in-lake physical, chemical, and biological processes that respond to and integrate a suite of key environmental stressors. Mountain lakes function as "Petri dishes in the sky," integrating the effects of climate change, atmospheric pollutant deposition, visitor impacts, amphibian declines, and exotic species introductions.

Because of the significance of this resource and its sensitivity to perturbations, the NCCN has developed a Mountain Lake Monitoring Protocol (Glesne et al. 2012) and implemented the monitoring program at Mount Rainier National Park (MORA), North Cascades National Park Service Complex (NOCA), and Olympic National Park (OLYM). The monitoring protocol describes the rationale, objectives, sampling design, field and laboratory methods, quality assurance and control, data management, analysis and reporting procedures. The overarching goal of this monitoring program is to determine the status and detect substantive trends in key ecosystem parameters, or Vital Signs, to assess whether mountain lakes are being negatively affected by anthropogenic stressors. The selected Vital Signs represent physical, chemical, and

biological components of lake ecosystems that characterize the quality and natural function of these ecosystems. This monitoring program is designed to detect changes in Vital Signs more as an early warning system, rather than one that identifies causal agents of trends. Given the suite of parameters to be measured, it is hoped that the monitoring program at least suggests possible root causes. The discovery of significant trends should serve as a trigger for further directed research to identify root causes and determine appropriate management actions.

The sampling design for the NCCN Mountain Lakes Monitoring Program was developed to specifically monitor high forest/sub-alpine lakes in each of the three NCCN parks. Six lakes at MORA and NOCA and eight lakes at OLYM were selected randomly from a subset of lakes at each park. The subset of lakes at each park was determined using a set of criteria that standardized the type of lake monitored by size, elevation, depth, and access. After applying the criteria, the final representation of 20 annually sampled lakes would provide inference to 163 NCCN lakes that are accessible on foot, found in high forest and subalpine zones, range in surface area from 0.4 ha to 6.0 ha, and have maximum depths greater than 2.5 m.

Problem Statement

Initial mountain lake protocol development in the NCCN followed two separate paths (OLYM and combined NOCA/MORA) that used similar parameters and methods but with different sampling designs. The need for an expanded sampling program was recognized early on in the development of the NOCA/MORA sampling design. The design, developed by Trent McDonald, Ph.D. (Senior Biometrician, WEST Inc., Laramie WY), included an annual sampling panel of five sites and five rotating panels of six sites each, sampled every five years, for a total of 35 lakes sampled at each park in a five year period.

Given the competing priorities for NCCN monitoring and funding limitations, all three parks were combined into a unified program under a single protocol. The three park Mountain Lake Monitoring Program was initially designed to detect changes in multiple response variables in a small subset of annually monitored sites, 18 lakes in total from the three parks (six lakes at each park). Internal statistical review of the monitoring protocol was provided by Tom Philippi, Ph.D. (Quantitative Ecologist, NPS Inventory and Monitoring Program) in 2010. As result of the 2010 review, two additional annual sample sites were added to the program to provide a better representation of the strong precipitation gradient at OLYM, resulting in 20 total annual sampling sites among all three parks. Yet, even with a total of 20 lakes, the design was still considered to have marginal capability to provide statistical relevance concerning the condition and trends in condition of high elevation lakes in the target populations of these parks. With the small sample size, interpretation of the question “is change actually occurring in a park’s high elevation lakes” is problematic even when our annual sample sites exhibit a significant trend. For example, with only six lakes sampled at NOCA, the 95% confidence interval for the fraction of lakes, three affected out of six, is 14% to 86%, which would not provide any relevant information on how widespread the problem is. If all six of the sample lakes at NOCA show significant changes then the 95% confidence interval for the fraction of lakes in the park that are affected would range from 52% to 100%.

Philippi also concluded in his 2010 review that six to eight lakes per park are barely enough to fit a model testing for differences among parks in slopes and intercepts of the effects covariates.

Adding terms to test slopes and intercepts for individual lake attributes such as surface area, maximum depth, and other attributes plus their interactions would require substantially larger sample sizes. Further, covariation among the monitored response variables across lakes, and correlated changes over time, contain substantial information that might be useful for understanding the changes and adapting or mitigating effects; such analyses also require a larger sample size. Additionally, development and calibration of metrics and models used to assess biological condition, such as the IBI (Kerans and Karr 1994) and RIVPACS type predictive models (Moss et al. 1987, Wright 1995, 2000), will likely require at least a one-time survey with much larger sample sizes.

The 2011 revision of the Mountain Lakes Protocol acknowledged the need to expand the target population of lakes to include inaccessible lakes (requiring helicopter access) that met all of other selection criteria and to conduct additional, but less frequent sampling of a larger set of sites, if funding could be secured to do this. Based on Tom Philippi's recommendations, the goal of this proposal is to obtain funding to complete an initial one-time sample of 30 additional lakes at each of the three parks. Some cost savings can be obtained by sampling a reduced set of parameters. More significant cost saving can be obtained by utilizing recent data already collected from other target population lakes at NOCA and MORA. The first visit to the broader panel of sites will provide data for development of park specific chemical, physical, and biological criteria for the assessment of change, data for calibration of biological condition metrics and predictive models, and provide a baseline to quantify changes and characterize patterns in the predictors of change following future revisits to the broader panel of sites. Revisits could occur at 10 to 20 year intervals or at minimum once change is detected in the primary annual-revisit panel.

Management Questions and Objectives

Relevant management questions regarding status and trends in key indicators of the park lakes that characterize the quality and natural function of these ecosystems and their ecological condition include:

- How are lakes changing, and what is the rate of change?
- How many lakes are changing?
- Which lakes are affected, are changes occurring across the landscape or are they localized to regions of the parks or individual sites?
- Do lakes differ in their rates of change?
- What attributes can help in the prediction of lakes that are affected and be used to explain differences in rates of change among these lakes?
- What are the likely causes and consequences of these changes?

Data collected from the annual sample panel of lakes can answer the first question. A much larger sample of lakes is required to provide meaningful information regarding the rest of the questions above.

The objectives of this proposal are to provide ecologically relevant data from a sufficiently representative sample of lakes to: detect spatial patterns in temporal change; estimate the fraction

of lakes exceeding a management threshold; estimate the variation among lakes in magnitudes of change; identify covariates or risk factors that explain the variation among lakes in response; and to provide data for development and/or refinement of biological, chemical, and physical criteria for the future assessments of the ecological condition of mountain lakes in OLYM, MORA, and NOCA.

Project Implementation

Sample Design

Target Populations

Requested funds will be used to expand the overall representation of the NCCN mountain lake target populations by conducting a one-time sampling effort at 30 additional lakes in each park. With the large number of lakes and ponds in the three network parks and because of funding and logistical limitations, it was necessary to develop a workable subset of physically similar lakes to provide a spatially representative sample from which to draw inference. A common set of inclusion criteria (NCCN Mountain Lake Protocol, Narrative Section 2, Table 3) were applied to develop target populations for each park and are described as follows:

"The population of perennial mountain lakes of interest for monitoring at MORA, OLYM, and NOCA that is found entirely within park boundaries, has surface areas ranging from 0.4 to 6.0 ha, with maximum depths >2.5 m elevations ranging from 1,220 m extending to the upper limit of the subalpine zone at each park, does not include lakes that are heavily influenced by glacial runoff, does not include lakes that have high densities of fish, and with inference limited to the temporal sampling window of August and September."

Single target populations representing all lakes meeting the inclusion criteria were developed for NOCA and MORA. An additional step was taken at OLYM to provide contrast in the representation of the strong annual precipitation gradient in order to facilitate detection of potential differences in lake trends due to atmospheric deposition. Lakes meeting the inclusion criteria at OLYM were assigned to one of three strata based upon their mean annual precipitation. The three strata, considered as separate target populations, were derived by dividing the mean annual precipitation range experienced by lakes into three roughly equal groups: low (155 to 315 cm/yr), moderate (316 to 450 cm/yr) and high (451 to 610 cm/yr). A discussion on the background and rationale regarding the development of the NCCN Mountain Lake Protocol sampling design is given in the Protocol Narrative Section 2.1.

Sites selected for this proposed project and annual sampling sites selected for monitoring under the NCCN Protocol originate from the same target populations; however, the sample frames are different. The park sample frames for the NCCN Mountain Lake Protocol limited the target population lakes to only those that were accessible on foot. The proposed expanded sample frame includes all lakes regardless of accessibility (those that can be accessed by foot or by helicopter). A summary of the number of target population lakes and their accessibility are shown in Table J-1.

Table J-1. Number of lakes and accessibility of MORA, NOCA, and OLYM mountain lake target populations.

Park Unit	Accessible (on foot)	Inaccessible (helicopter access)	Target Population Total
MORA	54	0	54
NOCA	42	40	82
OLYM*			
Low precip. stratum	42	9	51
Moderate precip. stratum	12	13	25
High precip. stratum	13	14	27
Total	163	77	240

*OLYM strata were derived by dividing the mean annual precipitation range experienced by lakes into three roughly equal groups: low (155 to 315 cm/yr), moderate (316 to 450 cm/yr) and high (451 to 610 cm/yr). Verification of the maximum depth selection criteria is needed for almost all lakes other than the selected annual sampling sites.

Sample Site Selection

Olympic National Park

All of the OLYM target population lakes (Attachment 1), with the exception of the current annual sampling sites, lack maximum depth information needed to verify inclusion (>2.5 m) in the sample frame. Preliminary screening of all sites will be conducted prior to sample site selection in order to reduce helicopter reconnaissance costs.

Methods using GIS and remote sensing light intensity data will be used for the preliminary screening of lake maximum depth. Light intensity decreases exponentially with increasing depth, a process called "attenuation." Prior research on mapping underwater habitats using remote sensing techniques determined that light intensity (radiance) values, transformed using natural logarithms (ln), will decrease linearly with increasing depth (Mumby and Edwards 2000). We will use this relationship to model depth for lakes in Olympic National Park (OLYM) for which field bathymetry measurements do not exist. Lake depth estimates will be predicted using existing bathymetry data for eight OLYM lakes and 2009 National Agricultural Inventory Program (NAIP) aerial photography. Lake depth from existing bathymetry maps and values (digital numbers) of three visible bands of NAIP photography will be extracted for each 1x1 meter pixel of the lake surface using ArcGIS software. Only lakes without visible spectral anomalies will be used. Pixels corresponding to shadows from vegetation adjacent to shoreline will be removed prior to data extraction. Digital numbers of the aerial photography will be converted to absolute units of spectral radiance following established remote sensing methods (Lillesand and Kiefer 2003) and transformed using natural algorithms. Transformed values will be used as predictor variables in a linear regression model to estimate depth for other lakes at OLYM.

Alternatively, regression option of the Random Forest statistical technique can be tested to model lake depth using untransformed radiance values (Breiman 2001). Another approach would be to use the more commonly used classification option of the Random Forest technique to classify each lake pixel on the aerial photo as being above or below 2.5 m depth threshold.

A decision process will be developed to limit the possibility of excluding screened lakes from the OLYM sample frames that meet the maximum depth criterion. Following the screening process, the sampling frames will be updated and 30 new sampling sites will be proportionally allocated among the three precipitation strata sample frames. The allocation of sample sites for each sample frame and a 50% oversample will be selected at random.

Mount Rainier and North Cascades National Parks

In the NCCN Mountain Lakes Monitoring Protocol, a fixed sized equi-probable general random tessellation stratified (GRTS) (Stevens and Olsen 1999, 2003, 2004) sample with reverse hierarchical ordering was used to draw the annual sample sites for MORA and NOCA. Input files for the GRTS procedure included each lake's unique ID and 2-dimensional UTM coordinates (the lake's center point). The sample size parameter of the GRTS procedure was set high enough to provide a complete (census) GRTS ordered list of all target population lakes (including the inaccessible sites) at each park. The first six GRTS ordered annual sample frame lakes were selected for sampling at each park. The remaining ordered sites constituted the "over-sample" which was planned for the purpose of expanding the monitoring program in the future if funding became available. Selection of additional sites needed to meet the objectives of this proposal will use the same GRTS ordered lists (expanded to include the lakes requiring helicopter access) that were used for selection of annual sample lakes for NOCA and MORA.

In addition to the annual sampling lakes, a significant number of lakes belonging to the NOCA and MORA target populations have been sampled following the NCCN Mountain Lake Protocol methods since 2004 at MORA and 2006 at NOCA. GRTS ordered lists of all NOCA and MORA sample frame lakes, indicating annual sample sites and other lakes that have been previously sampled, are shown in Attachments 2 and 3. A total of 22 lakes in addition to the annual sample sites have been sampled at NOCA. Funds have been secured to sample an additional seven NOCA lakes by the end of 2013, to bring the total to 30 lakes (Attachment 2). At MORA, a total of 10 additional lakes have been sampled (Attachment 3). Unfortunately, not all of these additional sites follow the GRTS ordering of the sample frames. In order to fill in the gaps in the GRTS order we would need to sample 11 more lakes at NOCA and 22 lakes at MORA to meet our objective of sampling a total of 30 lakes at each park.

Field Logistics

All lakes will be sampled during August and September. Completion of sample collection will require three years at MORA and OLYM and two years at NOCA. All of the lakes at MORA are reasonably accessible on foot. Helicopters will be required for access to most of the lakes at OLYM and NOCA. Crew size varies depending on the method of access to the sites. Helicopter use is most efficient when using a crew of two people. Hiking requires more time to access a site and a crew of four people in order to accommodate all of the sampling gear. Three days are required on average to complete a sampling trip for lakes accessed by hiking. Most crewmembers work 10 hr day schedules, using the last day of their week to process samples and data and to prepare for the next sampling trip. Occasionally, two lakes may be sampled in a single four day workweek if the lakes are located in close proximity to each other.

Although access to lakes with helicopters requires fewer crewmembers and takes less time, the logistics are complicated by weather, availability of the helicopters, park restrictions on helicopter use in wilderness areas and NCCN Mountain Lake Protocol sampling window

requirements for Secchi depth, water column profiles, water chemistry, chlorophyll a, and zooplankton which only allows sample collection between 10:00 am to 2:00 pm. There are also other safety and operational considerations that require the use of a DOI certified Helicopter Manager and to have at least one person on each flight that is DOI certified as a Helicopter Crewmember. On average and given the best of conditions, a crew of two people in a helicopter could sample three lakes in a four day work week.

Sampling Parameters and Methods

Required and optional NCCN Mountain Lake Protocol parameters proposed for the expanded sampling project are shown in Table J-2. The required parameters represent essential physical, chemical, and biological data for interpreting changes in mountain lakes. Detailed bathymetry mapping, continuous air/water temperature and lake water level data collection were dropped in order to save time and some field costs. With the expected revisit pattern to these lakes of at least 10 or more years, temperature data loggers could not be retrieved and replaced and lake water level data with only few data points would be meaningless. Optional parameters or levels of sampling effort shown in Table J-2 can be applied if additional time is available during the sampling visit.

Further reduction of the recommended sampling parameters would not lead to significant cost savings given that most of the cost associated with collection of samples is attributed to accessing the lakes. In future revisits it may be possible to reduce the number of parameters pending the analysis of annual sampling panel results following the first ten years of monitoring.

Detailed sampling and sample processing methods for each of the parameters are given in SOPs #4-15, and 18 of the NCCN Mountain Lake Monitoring protocol. Data entry and management procedures are given in SOP #20 (Data Entry and Verification) and SOP #22 (Data Quality Review and Certification).

Data Analysis

While the small sample of visit-every-year lakes, of the NCCN Mountain Lake Protocol annual sample panel, should detect temporal change, those data cannot estimate the fraction of lakes exceeding a management threshold, estimate the variation among lakes in magnitudes of change, or identify covariates or risk factors that explain the variation among lakes in response. The focus of the following data analysis summary describes how integration of the annually sampled sites with a broader set of lakes, sampled much less frequently (every 10 or more years), can be used to address these objectives.

Routine data summaries for all response variables, including development of invertebrate multimetric indices and predictive models, are presented in SOP #21, Section II of the NCCN Mountain Lakes Protocol. Criteria development is discussed in SOP #21, Section III of the protocol. A number of analysis options for estimating status and trends are given in SOP #21, Section IV: Data Analysis Procedures.

Status

Assessments of status need to be supported by well defined criteria. The proposed expanded sample of lakes will greatly enhance our ability to develop and refine criteria specific to characteristics of lakes in the target populations for future assessments of status. Results from the

Table J-2. NCCN Mountain Lake Protocol sample parameters proposed for the expanded lake survey.

Parameters	Protocol SOP Number	Required
Physical Parameters		
Temperature depth profile	7	Yes
Continuous air and water temperature	8	No
Lake water level	5	No
Lake bathymetry mapping	4	No
Maximum depth location	4	Yes
Panoramic watershed photos	18	Yes
Riparian zone cover and disturbance classes	15	Optional
Water clarity (Secchi depth)	6	Yes
Chemical Parameters		
Dissolved oxygen depth profile	7	Yes
pH depth profile	7	Yes
Specific conductance depth profile	7	Yes
Acid neutralizing capacity (ANC)	9	Yes
Nutrients (e.g., TN, TP)	9	Yes
Total dissolved solids (TDS)	9	Yes
Anions and Cations	9	Yes
Dissolved organic carbon (DOC)	9	Yes
Biological Parameters		
Chlorophyll-a	10	Yes
Zooplankton	12	Yes
Littoral benthic macroinvertebrates	11	Yes
Amphibian VES survey	14	Yes (replicate optional)
Fish gill net (catch/hr; min 6 hrs)	13	Yes (overnight net set optional)

initial sampling of these lakes will be used to develop new criteria and/or improve existing ones represented as: 1) an average value of a response for a group of sites with similar environmental characteristics, 2) an index of condition that partitions responses among categories of impairment such as the benthic macroinvertebrate Index of Biological Integrity (B-IBI), Observed/Expected ratios (O/E), and Carlson Trophic Indices, or 3) a change of some magnitude outside the range of values representing natural conditions for multiple sites.

The simplest summary of status for park- or region-wide assessments is the percent of sites that are either ‘greater than’ or ‘less than’ an ecologically relevant threshold value (e.g., how many lakes have pH values <6.0). If the extensive panel of lakes is a single, equal-probability draw, this can be estimated from the percent of the lakes exceeding the standard, with confidence intervals about that estimate computed from binomial variances or bootstrapping. If the extensive sample is a combination of lakes from separate draws with different inclusion probabilities, percent exceedance can be estimated as a weighted mean of 1 for lakes above the threshold and 0 for lakes below the threshold, with weights from the inclusion probabilities. Confidence intervals can be generated via bootstrapping. A more complete summary of status is to estimate the distribution of the values of that metric across lakes. Again, if the extensive sample has unequal inclusion probabilities for lakes, the distribution of the metric values can be computed using those unequal weights.

Finally, lake-level covariates such as elevation, mean annual precipitation, and area to depth ratio can be tested as predictors of the among-lake variation in the response attributes. Depending on the response metric, this testing might use General Linear Models (pH, log Total Nitrogen, etc.) or Generalized Linear Models (Poisson counts or binomial presence or cover), with lakes weighted by inclusion probabilities if necessary.

Trends

The analyses of trends in the extensive sample should parallel those in the visit every year panel. The greatest difference is that the extensive sample will provide adequate sample size to test some of the covariates mentioned in the planned analyses for the visit every year panel. In terms of using a linear effect of year as a test for temporal trends, having only 2 visits at each of these lakes is not conceptually different from having samples every year, except that the effect is "change" instead of "trend". While the year to year variation can only be estimated from the annual revisit panel, the extensive sample lakes will only be revisited after substantial change is detected in at least some of the annual visit panel, so the magnitude of the change should exceed the year to year fluctuations. However, if necessary, individual year deviations can be estimated from the annual visit lakes to correct for the effect if the extensive lakes are resampled during a particularly high or low year.

Covariation among Measured Attributes

The above paragraphs outline metric by metric analyses, as in SOP #21 for the visit every year panel. The larger sample size of the extensive panel might support analyses of the patterns of temporal covariation among the various metrics. Such analyses have not yet been performed in this ecological context, but they have been developed in the context of longitudinal studies in medicine and sociology (e.g., Berridge and Crouchley 2011).

Quality Assurance and Quality Control

Monitoring parameters for this project are identical to those being conducted as part of the NCCN Mountain Lakes Monitoring Protocol. As such, the Quality Assurance and Control Plan (SOP #19) of the NCCN Mountain Lakes Monitoring Protocol will serve as the functional equivalent of a quality assurance project plan (QAPP) for this project. QA/QC procedures will be implemented during all aspects of the project as described in this SOP.

Data quality will be attained by maximizing and documenting the data quality indicators (DQIs) for the methods used. For the purposes of this project the principal DQIs are described in detail in SOP #19 of the NCCN Mountain Lake Monitoring Protocol and include precision, accuracy, representativeness, comparability, completeness, bias (systematic error), and sensitivity. DQIs, their methods of calculation, and specific measurement quality objectives are found in Tables 19.2 and 19.3 of SOP #19.

Project Evaluation

The current NCCN annual sampling panel of 6 to 8 lakes at each park is sufficient to determine if changes and trends are occurring, however insufficient in its ability to determine how much change and where it is occurring. The primary purpose of this expanded sampling project is to provide a baseline to quantify changes and characterize patterns in the predictors of change.

Given a change(s) detected in the annual monitoring lakes, the value of this broader sample will be realized following the analysis of data collected in future revisits.

This project must be capable of integrating data from the new sampling sites with existing annual sampling sites to provide a cohesive set of data that is representative of the target populations of mountain lakes in OLYM, MORA, and NOCA. To meet this objective, sampling designs and sampling methods for this project and the current NCCN monitoring program must be compatible. Additionally, data collection efforts must meet QA/QC data quality objectives for precision, accuracy, representativeness, comparability, completeness, bias (systematic error), and sensitivity given in SOP #19 of the NCCN Mountain Lake Monitoring Protocol.

Environmental Planning and Compliance

Compliance is not required for this project under the Categorical Exclusion for resources management "Non-destructive data collection, inventory (including field, aerial, and satellite surveying and mapping), study, research, and monitoring activities". However, actions such as mechanized use in wilderness need to be supported by a current Minimum Requirement/ Minimum Tool Analysis (MR/MT). This analysis would be required at OLYM and NOCA because of the planned use of helicopters. The MR/MT analysis needs to show that other options were considered but dismissed with a reasonable justification and then submitted for peer review by the park's wilderness compliance peer review team and approved by the superintendent.

Products and Information Dissemination

All data from this project will be entered into the NCCN Mountain Lake database and NPSTORET following data management procedures and guidance found in the NCCN Mountain Lakes Protocol (SOP 20: Data Entry and Verification and SOP 22: Data Quality Review and Certification). Data will be made available at several locations including; NPS Data Store, EPA STORET Data warehouse, NPSpecies database (*see* SOP 23: Product Delivery, Posting and Distribution). A final report will be prepared by the end of June in the year following the last year of data collection. This report will follow the Natural Resource Data Series (NRDS) template and will provide a lake by lake summary of the data by each park and will be posted at the following website: http://www.nature.nps.gov/publications/NRPM/. Development of criteria for assessment of the status of mountain lakes, using data from this project, will be completed as part of the Protocol Five-year Summary Report (*see* SOP 21: Data Analysis and Reporting, Section 5.B), or sooner as funds and time allows.

Project Staff and Assistance

Principal Investigators

Reed Glesne, MS, Aquatic Ecologist, North Cascades National Park Service Complex, 810 Hwy. 20, Sedro Woolley, WA 98284

Steven Fradkin, PhD, Coastal Ecologist, Olympic National Park, 600 Park Ave., Port Angeles, WA 98362

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Tom Philippi, PhD, Quantitative Ecologist, NPS Inventory and Monitoring Program, c/o Cabrillo National Monument, 1800 Cabrillo Memorial Dr, San Diego, CA 92106

Field Leads

Carmen Welch, Aquatic Ecologist, North Cascades National Park Service Complex, 810 Hwy. 20, Sedro Woolley, WA 98284

Bill Baccus, Physical Science Technician, Olympic National Park, 600 Park Ave., Port Angeles, WA 98362

Rebecca Lofgren, Biological Technician, Mount Rainier National Park, Tahoma Woods Star Rt., Ashford, WA 98304

GIS Support

Natalya (Natasha) Antonova, NCCN I&M GIS Specialist, North Cascades National Park Service Complex, 810 Hwy. 20, Sedro Woolley, WA 98284

Tasks and Schedule

The schedule and tasks for the proposed project are shown in Table J-3. Funding is requested for Fiscal Years (FY) 1-3. Data quality review of FY 3 field data, final data analyses and reporting will be completed by park/NCCN staff using park base and NCCN base program funds in FY 4.

Table J-3. Expanded mountain lake sampling project tasks by fiscal year.

Tasks	FY 1	FY 2	FY 3	FY 4
OLYM sample frame revision (GIS lake depth screening)	Oct - Dec			
Helicopter flight planning and compliance (NOCA and OLYM)	Apr – Jun	Apr – Jun	Apr – Jun	
Field preparations	May - Jul	May - Jul	May - Jul	
Data acquisition	Aug - Sept	Aug - Sept	Aug - Sept	
Data entry and verification	Sept	Sept	Sept	
Contracted sample/specimen processing and shipment	Sept	Sept	Sept	
Data quality review and certification		Oct - Nov	Oct - Nov	Oct - Nov
Metadata documentation		Oct - Nov	Oct - Nov	Oct - Nov
Data analysis and final reporting				Apr - Jun

The Yearly Task List of the NCCN Mountain Lakes Protocol (Appendix B) outlines specific activities, with SOP references, for each of the major tasks described above in Table J-3.

Budget

Requested funds for completion of the expanded mountain lake sampling project at NOCA, MORA, and OLYM is shown in Table J-4. All costs are based on FY 2012 dollars and are not adjusted for annual increases. The major difference in cost per lake between parks is related to how they are accessed (on foot at MORA, helicopters at NOCA and OLYM). Sampling effort will be spread out over two or three years to meet the objective sample size requirement and minimize the impact of this project on other park projects and monitoring activities. Total requested funds for project is $186,770. In addition, NCCN and ONPS park base cost share funds are estimated to be $145,144 (Table J-5) and include support for the monitoring program Field Leads, GIS support, and support for project oversight, data analysis and reporting activities conducted by Park Leads.

Table J-4. Requested funds for the expanded mountain lakes sampling project.

Description	MORA ($/lake)	NOCA ($/lake)	OLYM ($/lake)
Salaries and Benefits:			
MORA: 1- GS 6 and 1- GS 7 Bio. Tech; 1- Student Intern	$1880		
NOCA : 1- GS 7 Bio. Tech.		$800	$800
OLYM: 1- GS 7 Bio. Tech.			
Helicopter: (1.2 hrs/lake @ $1100/hr)		$1320	$1320
Field Per Diem-MORA: (6 person days/lake@$20/day)	$120		
Field Per Diem-NOCA/OLYM: (2.5 person days/lake@$20/day)		$50	$50
Vehicles-MORA: ($240 per week/ 2 lakes per week	$120		
Vehicles-NOCA/OLYM: ($240 per week/ 3 lakes per week		$80	$80
Contracted Laboratory Analyses:			
CCAL - Nutrients, TDS, DOC	$140	$140	$140
CWU – Anions and Cations	$80	$80	$80
Cascade Research - Chlorophyll	$40	$40	$40
Zooplankton	$110	$110	$110
Benthic Macroinvertebrates	$250	$250	$250
QC Bias: 1 blank sample out of 10 for CCAL, CWU, and Chlorophyll; prorated as cost per lake.	$25	$25	$25
QC Precision: 1 replicate sample out of 10 for all contracted analyses; prorated as cost per lake.	$55	$55	$55
Msc. Supplies:	$60	$60	$60
TOTAL COST/LAKE:	**$2880**	**$3010**	**$3010**
PROPOSED SAMPLE SIZE:	**22**	**11**	**30**
TOTAL REQUEST/PARK:	**$63,360**	**$33,110**	**$90,300**
GRAND TOTAL REQUEST:	**$186,770**		

Table J-5. NCCN and ONPS Park Base funding support for the expanded mountain lakes sampling project.

Description	NCCN $	ONPS $	Total Matching
Salaries- Field Leads: (preparation, sampling, and post-season tasks)			
Bill Baccus, OLYM, GS-8/9 Phys Sci Tech (12 pp over 3 yrs @ $2950/pp)	$35,400		$35,400
Rebecca Lofgren, MORA, GS-9/7 Bio Tech (11 pp over 3 yrs @ $3100/pp.)	$34,100		$34,100
Carmen Welch, NOCA, GS-9/1 Aquat Ecol (4 pp over 2 yrs @ $2591/pp)		$10,364	$10,364
Salaries – Project Leads: (oversight, data analysis, reporting)			
Reed Glesne, GS-12/10 (4 pp over 4 yrs @ $4385 pp)		$17,540	$17,540
Steve Fradkin, OLYM, GS-12/6 (6 pp over 4 yrs @ $4270 pp)		$25,620	$25,620
Barbara Samora, MORA, GS-12/9 (4 pp over 4yrs @ $4280 pp)		$17,120	$17,120
Salaries – GIS Support: (Managing GPS data, GIS OLYM lake depth analyses)			
Natasha Antonova, GS-9/GIS Specialist (2 pp total @ $2500/pp)	$5,000		
TOTAL MATCHING $:	**$74,500**	**$70,644**	**$145,144**

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Appendix J, Attachment 1. Olympic National Park (OLYM) mountain lake expanded sample frame showing annual monitoring sites (bold). No lakes, other than NCCN annual sample sites, have been previously sampled.

Lake Code	OLYM Precipitation Stratum	[1]MOLA Annual Sample Frame	[2]Sampled Lakes (Year sampled)	Lake Name	Surface Area (ha)	Elevation (m)	UTM X_Coordinate	UTM Y_Coordinate	Max. Depth (m)
14	Low	yes		Happy	0.95	1487	448774.37	5317547.85	unk.
21	Low	yes		Boulder	3.72	1319	444031.04	5313958.93	unk.
24	Low	yes		Three Horse	1.55	1261	444781.45	5313199.97	unk.
26	Low	yes		Unnamed	1.45	1335	444113.26	5313127.27	unk.
29	Low	yes		Unnamed	2.73	1241	442776.93	5312207.14	unk.
30	Low	yes		Unnamed	1.42	1259	442134.72	5312122.45	unk.
31	Low	yes		Blue	0.92	1426	445025.5	5312124.85	unk.
33	Low	yes		Unnamed	0.62	1338	468002.45	5311997.28	unk.
40	Low	yes		Unnamed	0.66	1384	468981.66	5310413.43	unk.
60	Low	yes		Haigs	2.04	1425	446829.24	5307924.9	unk.
61	Low	yes		Clear	2.3	1290	441697.54	5307650.48	unk.
63	Low	yes		Morgenroth	4.14	1257	442890.73	5307547.7	unk.
64	Low	yes		Y Lake	0.5	1330	443234.05	5307558.11	unk.
70	Low	yes		Round	1.1	1303	441034.84	5307241.07	unk.
72	Low	yes		Lunch	1.14	1365	441484.87	5307194.88	unk.
76	Low	yes		Number 8	1.48	1411	443979.91	5306909.03	unk.
79	Low	yes		Heart	0.5	1456	445136.1	5306534.18	unk.
84	Low	yes		Unnamed	0.56	1663	472901.62	5305870.68	unk.
90	Low	yes		Unnamed	0.7	1765	475616.01	5305069.63	unk.
95	Low	yes		Grand	5.15	1446	474199.36	5304183.51	unk.
98	Low	yes		Unnamed	3.29	1540	473792.23	5303297.57	unk.
106	Low	**yes**	**Annual**	**Gladys**	**0.49**	**1642**	**473243.45**	**5302663.36**	**4.5**
123	Low	yes		Unnamed	0.45	1480	476398.49	5301094.06	unk.
169	Low	yes		Unnamed	0.84	1558	476150.68	5298597.49	unk.
182	Low	yes		Unnamed	0.82	1558	484224.18	5297650.99	unk.
206	Low	yes		Unnamed	0.44	1742	483555.29	5296576.06	unk.
256	Low	yes		Unnamed	0.5	1753	475931.95	5292730.25	unk.
263	Low	**yes**	**Annual**	**Heather**	**0.42**	**1590**	**486670.14**	**5292448.14**	**6.7**

[1] Annual sample lakes in the NCCN Mountain Lake Monitoring Protocol (MOLA) were selected from a sample frame limited by accessibility (safely accessible on foot). Lakes not included in the MOLA annual sampling frame meet the same selection requirements of surface area, elevation, and depth but require the use of helicopters for access.

[2] At OLYM, no lakes other than the annual sampling sites have been sampled.

Appendix J, Attachment 1. Olympic National Park (OLYM) mountain lake expanded sample frame showing annual monitoring sites (bold). No lakes, other than NCCN annual sample sites, have been previously sampled (continued).

Lake Code	OLYM Precipitation Stratum	[1]MOLA Annual Sample Frame	[2]Sampled Lakes (Year sampled)	Lake Name	Surface Area (ha)	Elevation (m)	UTM X_Coordinate	UTM Y_Coordinate	Max. Depth (m)
269	Low	yes		Unnamed	0.45	1790	485843.24	5291825.31	unk.
271	Low	yes		Unnamed	0.48	1776	486426.4	5291731.84	unk.
272	Low	yes		Unnamed	0.48	1445	481970.12	5291698.19	unk.
280	Low	yes		Unnamed	0.73	1618	487704.66	5290944.16	unk.
292	Low	yes		Unnamed	4.42	1421	489312.16	5288664.59	unk.
375	Low	yes		Unnamed	0.64	1642	482000.22	5282950.46	unk.
397	Low	yes		Unnamed	2	1690	481190	5281913.66	unk.
485	Low	yes		Unnamed	0.43	1459	483763.83	5275363.32	unk.
489	Low	yes		Unnamed	0.41	1518	482676.32	5274865.48	unk.
491	Low	yes		Unnamed	1.35	1435	484527.32	5274713.47	unk.
497	Low	yes		Unnamed	1.24	1298	481656.95	5274579.45	unk.
498	Low	**yes**	**Annual**	**Milk**	**1.14**	**1435**	**484442.8**	**5274562.96**	**13.7**
514	Low	yes		Unnamed	0.64	1507	482137.49	5274399.68	unk.
549	Low	yes		Unnamed	0.69	1434	480868.82	5273110.84	unk.
49	Low	no		Unnamed	0.43	1442	454607.9	5308850.91	unk.
74	Low	no		No Name	2.66	1273	443071.79	5307142.22	unk.
104	Low	no		Unnamed	0.41	1642	468238.77	5302911.44	unk.
112	Low	no		Unnamed	0.45	1607	478039.31	5302090.84	unk.
121	Low	no		Unnamed	0.97	1752	470494.29	5301084.21	unk.
129	Low	no		Lillian	2.85	1764	470617.4	5300753.1	unk.
238	Low	no		Unnamed	3.64	1777	483482.77	5294569.4	unk.
268	Low	no		Unnamed	1	1629	490677.02	5291836.9	unk.
343	Low	no		Wildcat	1.7	1274	488256.91	5284867.71	unk.
382	Moderate	yes		Unnamed	5.11	1516	479196.22	5282548.34	unk.
421	Moderate	yes		Unnamed	1.13	1529	474038.84	5279341.26	unk.
426	Moderate	**yes**	**Annual**	**Crazy Lake**	**2.84**	**1447**	**472944.86**	**5279102.45**	**7.7**
463	Moderate	yes		Unnamed	1.36	1335	472613.64	5277384.68	unk.
520	Moderate	**yes**	**Annual**	**La Crosse**	**0.96**	**1457**	**478933.51**	**5274073.87**	**8**

[1] Annual sample lakes in the NCCN Mountain Lake Monitoring Protocol (MOLA) were selected from a sample frame limited by accessibility (safely accessible on foot). Lakes not included in the MOLA annual sampling frame meet the same selection requirements of surface area, elevation, and depth but require the use of helicopters for access.

[2] At OLYM, no lakes other than the annual sampling sites have been sampled.

Appendix J, Attachment 1. Olympic National Park (OLYM) mountain lake expanded sample frame showing annual monitoring sites (bold). No lakes, other than NCCN annual sample sites, have been previously sampled (continued).

Lake Code	OLYM Precipitation Stratum	[1]MOLA Annual Sample Frame	[2]Sampled Lakes (Year sampled)	Lake Name	Surface Area (ha)	Elevation (m)	UTM X_Coordinate	UTM Y_Coordinate	Max. Depth (m)
525	Moderate	yes		Unnamed	1.46	1422	479526.03	5273915.43	unk.
533	Moderate	yes		Unnamed	0.74	1447	479704.04	5273614.18	unk.
543	Moderate	yes		Unnamed	0.62	1487	479524.36	5273197.32	unk.
560	Moderate	yes		Unnamed	0.78	1506	479410.23	5271490.88	unk.
574	Moderate	yes		Unnamed	0.96	1373	474209.43	5269003.28	unk.
599	Moderate	yes		Unnamed	1.28	1352	476607.57	5265949.25	unk.
622	Moderate	yes		Unnamed	1.07	1229	477432.8	5264384.72	unk.
77	Moderate	no		Unnamed	1.18	1716	453056.06	5306626.43	unk.
91	Moderate	no		Unnamed	0.53	1560	453517.24	5304991.41	unk.
101	Moderate	no		Unnamed	1.36	1411	455765.74	5303260.77	unk.
105	Moderate	no		Unnamed	5.17	1523	454472.26	5302610.58	unk.
262	Moderate	no		Unnamed	0.45	1544	463083.92	5292460.44	unk.
293	Moderate	no		Unnamed	0.93	1641	469162.17	5288647.04	unk.
304	Moderate	no		Unnamed	3.48	1703	478212.26	5287387.1	unk.
316	Moderate	no		Unnamed	0.58	1656	478385.21	5286585.98	unk.
337	Moderate	no		Unnamed	0.49	1607	476030.98	5285392.11	unk.
358	Moderate	no		Unnamed	0.42	1511	475718.6	5283808.4	unk.
440	Moderate	no		Unnamed	0.45	1420	479764.04	5278065.44	unk.
454	Moderate	no		Unnamed	0.83	1388	479846.39	5277773.1	unk.
511	Moderate	no		Unnamed	0.48	1401	472083.59	5274442.22	unk.
125	High	yes		Unnamed	1.73	1226	453720.04	5300952.57	unk.
138	High	**yes**	**Annual**	**Ferry basin**	**1.31**	**1434**	**455307.09**	**5300225.34**	**9.5**
142	High	yes		Unnamed	1	1457	456007.43	5299956.88	unk.
156	High	yes		Unnamed	1.49	1642	456800.75	5299143.37	unk.
158	High	yes		Unnamed	0.62	1643	456635.63	5299072.63	unk.
163	High	yes		Unnamed	2.29	1688	456891.14	5298663.55	unk.
341	High	yes		Unnamed	1	1434	452039.85	5284957.66	unk.
349	High	yes		Unnamed	0.91	1421	460061.64	5284542.95	unk.

[1] Annual sample lakes in the NCCN Mountain Lake Monitoring Protocol (MOLA) were selected from a sample frame limited by accessibility (safely accessible on foot). Lakes not included in the MOLA annual sampling frame meet the same selection requirements of surface area, elevation, and depth but require the use of helicopters for access.

[2] At OLYM, no lakes other than the annual sampling sites have been sampled.

Appendix J, Attachment 1. Olympic National Park (OLYM) mountain lake expanded sample frame showing annual monitoring sites (bold). No lakes, other than NCCN annual sample sites, have been previously sampled (continued).

Lake Code	OLYM Precipitation Stratum	[1]MOLA Annual Sample Frame	[2]Sampled Lakes (Year sampled)	Lake Name	Surface Area (ha)	Elevation (m)	UTM X_Coordinate	UTM Y_Coordinate	Max. Depth (m)
354	High	yes		Unnamed	0.43	1426	460123.93	5284304.74	unk.
385	High	yes		Unnamed	1.61	1690	459706.52	5282478.91	unk.
609	High	yes		Unnamed	0.51	1263	458624.94	5265542.05	unk.
623	High	**yes**	**Annual**	**Sunup**	**0.98**	**1224**	**463405.78**	**5264336.26**	**6.6**
627	High	**yes**	**Annual**	**Connie**	**2.11**	**1300**	**455346.81**	**5263487.01**	**9.2**
191	High	no		Unnamed	1.36	1508	451428.88	5297300.91	unk.
203	High	no		Unnamed	4.48	1580	443905.67	5296508.82	unk.
205	High	no		Unnamed	1.64	1567	443642.96	5296585.79	unk.
221	High	no		Unnamed	0.51	1519	443858.87	5295768.53	unk.
225	High	no		Unnamed	0.42	1529	444009.16	5295530.06	unk.
237	High	no		Unnamed	0.59	1482	453781.08	5294668.76	unk.
259	High	no		Unnamed	0.92	1483	455317.32	5292484.28	unk.
274	High	no		Unnamed	1.94	1519	449842.56	5291596.08	unk.
290	High	no		Unnamed	0.42	1408	446694.18	5289234.32	unk.
321	High	no		Unnamed	1.18	1287	437869.69	5286179.75	unk.
348	High	no		Unnamed	0.69	1712	470293.28	5284597.17	unk.
420	High	no		Unnamed	0.53	1413	464692.49	5279461.71	unk.
432	High	no		Unnamed	1.99	1328	463224.14	5278525.7	unk.
458	High	no		Unnamed	2.83	1506	465235.59	5277501.78	unk.

[1] Annual sample lakes in the NCCN Mountain Lake Monitoring Protocol (MOLA) were selected from a sample frame limited by accessibility (safely accessible on foot). Lakes not included in the MOLA annual sampling frame meet the same selection requirements of surface area, elevation, and depth but require the use of helicopters for access.

[2] At OLYM, no lakes other than the annual sampling sites have been sampled.

Appendix J, Attachment 2. North Cascades National Park (NOCA) mountain lake expanded sample frame showing annual monitoring sites (bold) and lakes previously sampled (by year) using methods and parameters described in the NCCN mountain lake protocol.

Lake Code	GRTS Order	[1]MOLA Annual Sample Frame	[2]Sampled Lakes (Year sampled)	Lake Name	Surface Area (ha)	Elevation (m)	UTM X_Coordinate	UTM Y_Coordinate	Max. Depth (m)
MR-12-01	**1**	**yes**	**Annual**	**Bowan**	**0.59**	**1980**	**669402.24**	**5364000.7**	**4**
ML-02-01	2	no	2009	Sweet Pea	4.17	1689	651666.69	5384936.4	28.1
LS-12-01	3	no	2009	Unnamed	0.55	1652	608673.95	5389648.5	5.6
MA-03-01	**4**	**yes**	**Annual**	**Lower Silent**	**1.24**	**2042**	**659945.92**	**5379095.4**	**10**
M-14-01	5	no	2009	Despair Lake Lower	0.7	1469	620042.55	5398225	5.9
LS-06-01	6	no	2010	Ipsoot	3.61	1359	607506.74	5396243.2	17.1
MC-10-01	7	no	2010	Ruta	0.44	1556	620279.36	5422892	5.2
MC-14-02	8	**yes**	**Annual**	**Lower East**	**3.25**	**1664**	**622445.75**	**5416396.6**	**16.2**
MR-09-01	9	no	2010	Unnamed	1.89	1812	668975.09	5366745.3	4.9
SM-02-02	10	**yes**	**Annual**	**Upper Triplet**	**0.96**	**1997**	**681649.31**	**5351346.4**	**4.3**
MC-03-01	11	**yes**	**Annual**	**Easy Ridge**	**1.01**	**1679**	**615104.3**	**5412559.8**	**3.9**
LS-07-01	12	**yes**	**Annual**	**Lower Blum**	**2.58**	**1506**	**610279.17**	**5400323.3**	**7.9**
MC-17-02	13	yes	2006,2011	Tapto #2 (Middle)	0.5	1747	619647.05	5415485.6	5.5
ML-07-01	14	no	2011	Unnamed	0.53	1765	648560.1	5380407.9	5.1
M-15-01	15	no	2012*	Unnamed	0.57	1716	619354.61	5396518.7	unk.
DD-05-01	16	no	2012*	Upper Bouck	2.22	1533	635004.26	5393472.8	8.9
M-19-01	17	yes	2012*	Middle Thornton	4.82	1433	622593.44	5394102.6	24.0
MC-06-01	18	yes	2011	Copper	5.14	1604	613588.15	5419302.7	22.6
MR-05-01	19	yes	2010	Kettling	4.01	1638	667806.12	5368438.5	7
M-22-01	20	no	2013*	Unnamed	0.75	1567	613867.41	5397483.6	unk.
MC-16-01	21	yes	2013*	Upper Middle	1.82	1737	620731.04	5416006.7	7.9
MC-02-01	22	yes	2013*	Blum #1 (Vista)	1.03	1798	610359.76	5401599.6	10.7
M-06-01	23	no		Talus Tarn	0.61	1692	610713.21	5396502.8	3.6
LS-03-01	24	yes		Middle Diobsud	1.57	1347	607406.18	5389244.5	5.2
M-11-01	25	yes	2008,2009	Middle Blum	5.22	1533	610671.85	5400557.5	15.4
LS-02-01	26	yes	2008	Lower Diobsud	1.26	1286	607807.55	5388938.8	5.3

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[2] MOLA protocol annual sample lakes and other lakes in the expanded sample frame that were previously sampled (sample year) or are funded for sampling (*) following the MOLA protocol.

Appendix J, Attachment 2. North Cascades National Park (NOCA) mountain lake expanded sample frame showing annual monitoring sites (bold) and lakes previously sampled (by year) using methods and parameters described in the NCCN mountain lake protocol (continued).

Lake Code	GRTS Order	[1]MOLA Annual Sample Frame	[2]Sampled Lakes (Year sampled)	Lake Name	Surface Area (ha)	Elevation (m)	UTM X_Coordinate	UTM Y_Coordinate	Max. Depth (m)
MR-06-01	27	yes		Upper Kettling	0.78	1692	667915.17	5367949	3
PM-04-01	28	yes		Upper Skymo	1.02	1611	639074.35	5410452.7	4.6
M-13-01	29	no		Upper Despair	0.85	1554	619679.35	5398257	unk.
MR-13-02	30	yes		Upper South Rainbow	1.45	1788	666808.9	5363128.3	7.4
EP-01-01	31	no		Unnamed	0.9	1664	635534.15	5386984.5	unk.
MM-11-01	32	yes	2006	Upper West Rainbow	1.43	1973	666396.34	5363466.8	8.4
MSH-04-01	33	no		Ruth Mountain	1	1615	608742.73	5412633.6	8.9
FP-01-01	34	no		Unnamed	5.47	1567	638328.9	5382921.2	unk.
LS-04-01	35	no		Green Bench	1.59	1484	609974.29	5393122.8	6.5
ML-03-01	36	no		Torment	1.45	1969	651475.39	5384096.7	15.2
EP-04-01	37	no		Unnamed	0.47	1623	633487.78	5384871.2	unk.
M-05-01	38	no		Nert	1.44	1389	610339.46	5395542	9
EP-02-01	39	no		Isolation	1.23	1743	636208.55	5385972.6	unk.
EP-06-01	40	no	2008	Upper Wilcox	4.26	1565	634880.72	5384522.1	19.8
LS-05-01	41	no	2007	Unnamed	1.43	1536	609827.75	5389717.7	4.0
MSH-02-01	42	no	2006,2007	Phantom Pass	0.51	1250	609513.83	5408971.7	4.7
M-10-01	43	yes		Mt Blum Lake	3.75	1750	611236.16	5400039.6	unk.
MC-21-02	44	yes		Lower Reveille	1.64	1522	619725.39	5417201	3
EP-14-01	45	yes		Hidden Lake Tarn	2	1777	634047.05	5373548.6	13
MR-10-01	46	yes		Mcalester	5.36	1679	672027.02	5366339.5	7
MC-21-01	47	yes		Upper Reveille	1.37	1522	619559.45	5417057.5	5
LS-01-01	48	yes	2008	Diobsud #1	0.41	1286	607863.84	5388785.9	3.4
MR-01-01	49	yes	2006,2007	Stiletto	4	2071	673274.89	5372330.4	25.6
MC-27-01	50	no	2006,2007	Wild	5.15	1487	619976.6	5405393.1	8.8
ML-04-01	51	no		Vulcan	3.33	1579	650632.83	5380703.3	7.7
MS-02-01	52	no		Mist	0.51	1399	633040.08	5416247.7	unk.
MC-17-04	53	yes		Tapto #4 (West)	0.94	1725	619304.72	5415635.1	4.3
PM-03-01	54	yes	2010	Skymo	4.38	1608	639273.42	5410792.9	6.1

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[2] MOLA protocol annual sample lakes and other lakes in the expanded sample frame that were previously sampled (sample year) or are funded for sampling (*) following the MOLA protocol.

Appendix J, Attachment 2. North Cascades National Park (NOCA) mountain lake expanded sample frame showing annual monitoring sites (bold) and lakes previously sampled (by year) using methods and parameters described in the NCCN mountain lake protocol (continued).

Lake Code	GRTS Order	[1]MOLA Annual Sample Frame	[2]Sampled Lakes (Year sampled)	Lake Name	Surface Area (ha)	Elevation (m)	UTM X_Coordinate	UTM Y_Coordinate	Max. Depth (m)
MLY-02-01	55	no	2012*	Battalion	2.55	1628	663983.37	5356901	4.8
DD-01-01	56	yes	2006-2008	Jeanita	0.56	1495	636845.34	5400632.9	3
MP-02-01	57	no		Firn	2.29	1668	635561.17	5410367.3	12
MM-08-01	58	yes		Upper Sandalee	0.59	1859	661764.81	5365792.1	3
MC-14-01	59	yes		Upper East	2.51	1705	621992.43	5416675	4
EP-16-01	60	no		Unnamed	0.42	1664	634437.02	5375966.3	unk.
FP-06-01	61	no		Klawatti Pot #2	0.62	1689	641985.52	5378355.2	3.4
M-07-01	62	no	2006-2008	Lower Berdeen	3.02	1359	612089.53	5395796.3	11
MR-11-01	63	yes		Unnamed	1.15	1863	671236.91	5364764.4	8.8
MC-04-01	64	yes		Egg	0.49	1579	611158.22	5417126.9	5
MM-06-01	65	no		Waddell	4.1	1503	661545.26	5367233.8	11.9
LS-13-01	66	no		Unnamed	0.49	1530	605990.5	5390093	unk.
MC-16-02	67	yes		Lower Middle	1.18	1705	620978.09	5415831.1	3
MM-07-01	68	yes		Middle Sandalee	0.7	1641	661756.72	5366345.6	11.9
M-09-01	69	no		Upper Berdeen	3.91	1539	612593.37	5397888.5	unk.
MR-15-01	70	yes		Dee Dee	4.93	1921	674034.95	5363623.7	27
MA-02-01	71	yes		Upper Silent	1.51	2126	659603.55	5379167.2	9.6
MR-04-01	72	yes		Dagger	3.31	1679	673419.05	5370790	4.8
MC-13-01	73	yes		Pass	2.53	1987	624466.92	5420033	unk.
M-02-01	74	no		Unnamed	0.58	1576	611126.52	5392803.3	unk.
MP-08-01	75	yes		Torrent	0.64	1565	632060.06	5405090.1	3.7
EP-13-01	76	no		Sky Lake	0.79	1640	632819.8	5381593.4	unk.
EP-05-01	77	no		Lower Wilcox	2.19	1561	634607.82	5384550.3	6
EP-10-01	78	no		Pegasus	4.41	1713	637877.15	5383104.4	unk.
FP-09-01	79	yes	2006	Skagit Queen #2	0.48	1661	647441.99	5375804.9	3.4
EP-03-01	80	no		Unnamed	0.85	1603	634247.09	5385322.9	3.7
MC-19-01	81	no		Unnamed	0.47	1445	621127.24	5412738.4	unk.
MC-17-01	82	yes		Tapto #1 (Upper)	4.14	1753	619631.67	5415699.3	13.1

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[2] MOLA protocol annual sample lakes and other lakes in the expanded sample frame that were previously sampled (sample year) or are funded for sampling (*) following the MOLA protocol.

Appendix J, Attachment 3. Mount Rainier National Park (MORA) mountain lake expanded sample frame showing annual monitoring sites (bold) and lakes previously sampled (by year) using methods and parameters described in the NCCN mountain lake protocol.

Lake Code	GRTS Order	[1]MOLA Annual Sample Frame	[2]Sampled Lakes (Year sampled)	Lake Name	Surface Area (ha)	Elevation (m)	UTM X_Coordinate	UTM Y_Coordinate	Max. Depth (m)
ln03	**1**	**yes**	**Annual**	**Lake Allen**	**1.72**	**1397**	**584631.52**	**5179450.87**	**7.2**
lh14	**2**	**yes**	**Annual**	**Upper Palisades Lake**	**0.78**	**1785**	**607152.01**	**5200464.19**	**15.3**
lp19	**3**	**yes**	**Annual**	**Unnamed Lake**	**1.76**	**1372**	**584373.48**	**5185868.53**	**12.0**
lh15	**4**	**yes**	**Annual**	**Unnamed Lake**	**2.95**	**1659**	**605176.85**	**5200714.75**	**10.0**
lw32	**5**	**yes**	**Annual**	**Deadwood Lakes**	**2.70**	**1600**	**612691.18**	**5193418.07**	**3.5**
lz35	**6**	**yes**	**Annual**	**Blue Lake**	**5.74**	**1352**	**601092.42**	**5176691.80**	**10.5**
lw09	7	yes	2004	Hidden Lake	2.12	1806	606711.34	5199433.68	7.0
lw26	8	yes	2004-2006	Sunrise Lake	1.50	1750	607552.04	5197020.67	7.0
lp22	9	yes		Kenworthy Lake	1.08	1445	582945.19	5183121.75	5.6
lf05	10	yes		Lake James	4.98	1349	596329.12	5201989.67	23.0
lw11	11	yes		Unnamed Lake	0.50	1730	607207.73	5199447.57	4.2
lz31	12	yes		Cliff Lake	1.04	1592	595616.03	5178448.62	8.3
lo12	13	yes	2004	Shriner Lake	1.68	1490	613424.66	5184756.85	3.5
lw38	14	yes		Shadow Lake	0.89	1896	602352.94	5195994.14	5.0
lz29	15	yes	2004,2005	Snow Lake	2.39	1426	599542.83	5178840.24	10.7
ln21	16	yes		Reflection Lakes	0.70	1487	597447.91	5180146.88	3.5
lo11	17	yes		Unnamed Lake	3.08	1414	615214.18	5185531.63	3.9
lw03	18	yes		Unnamed Lake	0.87	1526	609393.49	5203460.92	6.4
lc25	19	yes		Unnamed Lake	0.73	1474	592961.16	5204128.78	unk.
lo09	20	yes		Unnamed Lake	1.19	1591	614551.67	5187790.92	5.7
lo15	21	yes		Unnamed Lake	0.49	1563	617705.18	5180463.14	unk.
lw29	22	yes	2006	Crystal Lake	3.20	1780	613790.89	5195513.66	10.7
lz10	23	yes		Fan Lake	1.29	1654	601201.72	5183244.67	4.3
lz27	24	yes		Bench Lake	2.88	1384	599474.41	5179432.29	11.0
lw20	25	yes		Clover Lake	2.90	1753	607131.24	5198018.01	14.2
lw27	26	yes		Lower Crystal Lake	0.63	1664	613285.15	5196118.44	4.0

[1] All lakes at MORA are accessible on foot, consequently the annual sampling frame from the NCCN Mountain Lake Monitoring Protocol (MOLA) and the proposed expanded sampling frame are the same.

[2] MOLA protocol annual sample lakes and other lakes in the sample frame that were previously sampled (sample year) following the MOLA protocol.

Appendix J, Attachment 3. Mount Rainier National Park (MORA) mountain lake expanded sample frame showing annual monitoring sites (bold) and lakes previously sampled (by year) using methods and parameters described in the NCCN mountain lake protocol (continued).

Lake Code	GRTS Order	[1]MOLA Annual Sample Frame	*Sampled Lakes (Year sampled)	Lake Name	Surface Area (ha)	Elevation (m)	UTM X_Coordinate	UTM Y_Coordinate	Max. Depth (m)
lm18	27	yes	2007	Unnamed Lake	0.78	1327	582921.47	5193161.00	unk.
lc28	28	yes		Chenuis Lakes	1.40	1549	592498.31	5203088.97	14.2
lm26	29	yes		Unnamed Lake	0.60	1430	584169.58	5192875.57	4.7
lf12	30	yes		Mystic Lake	1.93	1741	594952.85	5196093.46	3.5
lh09	31	yes		Unnamed Lake	0.81	1743	606163.86	5201322.64	2.9
lm01	32	yes	2005	Eunice Lake	5.32	1635	585462.97	5200618.35	20.0
lf01	33	yes	2007	Adelaide Lake	2.60	1383	595795.95	5203879.49	4.0
lf03	34	yes		Marjorie Lake	3.99	1390	595762.97	5203331.43	8.0
lc32	35	yes		Unnamed Lake	0.87	1751	594795.78	5201376.90	3.9
lm15	36	yes		Unnamed Lake	0.79	1407	583724.34	5193714.82	unk.
lh12	37	yes		Lower Palisades Lake	1.57	1678	607369.57	5200838.66	5.9
lw05	38	yes	2006	Unnamed Lake	0.79	1649	608810.55	5201068.12	3.5
lc08	39	yes		Unnamed Lake	1.19	1552	588013.18	5199305.64	unk.
lw31	40	yes		Deadwood Lakes	3.03	1600	612482.25	5193681.85	3.5
lw35	41	yes		Unnamed Lake	0.58	1778	607247.10	5192135.76	unk.
lc10	42	yes		Unnamed Lake	1.96	1605	588999.88	5200057.18	unk.
lm30	43	yes		Unnamed Lake	0.83	1496	583892.15	5192559.00	9.0
lh07	44	yes		Unnamed Lake	1.73	1675	605450.52	5202311.94	2.8
lm32	45	yes		Unnamed Lake	0.75	1502	584128.62	5192590.71	9.0
lc31	46	yes	2004-2005	Chenuis Lakes	1.13	1516	592949.13	5202516.90	5.0
lw02	47	yes		Unnamed Lake	0.60	1474	609593.40	5203649.63	5.7
lm23	48	yes		Golden Lakes	2.41	1371	583360.90	5192809.53	6.0
lh18	49	yes		Unnamed Lake	2.62	1686	602224.04	5199489.65	8.9
lm11	50	yes		Unnamed Lake	0.94	2007	590254.09	5195699.95	11.6
lo19	51	yes		Three Lakes	1.68	1425	616627.69	5179910.89	4.0
lw46	52	yes		Unnamed Lake	0.74	1938	602876.21	5189990.64	3.0
lp04	53	yes		Unnamed Lake	0.66	1620	584774.39	5191409.31	unk.
lw40	54	yes		Ghost Lake	1.20	1333	611245.40	5191882.92	5.2

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

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