National Park Service
U.S. Department of the Interior

Natural Resource Program Center

North Coast and Cascades Network Vital Signs Monitoring Report

Natural Resource Report NPS/NCCN/NRR—2009/098

ON THE COVER
Little Tahoma, Mount Rainier National Park
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Contents

Page

Contents (continued)

Page

Contents (continued)

Page

Contents (continued)

Page

Contents (continued)

Page

Figures

Page

Figures (continued)

Page

Tables

Page

Tables (continued)

Page

Appendices

Page

Executive Summary

Knowing the condition of natural resources in national parks is fundamental to the National Park Service's ability to manage park resources "unimpaired for the enjoyment of future generations." The challenge of protecting and managing a park's natural resources requires a broad-based knowledge of the status and trends of park resources and takes an ecosystem approach. Most parks are open systems, vulnerable to threats such as air and water pollution and invasive species, which originate outside the park's boundaries. Understanding the dynamic nature of park ecosystems and the consequences of human activities is essential for management decision making aimed to maintain, enhance, or restore the ecological integrity of park ecosystems and to avoid, minimize, or mitigate ecological threats to these systems.

Parks with significant natural resources have been grouped into 32 monitoring networks linked by geography and shared natural resource characteristics. The network organization will facilitate collaboration, information sharing, and economies of scale in natural resource monitoring. Parks within each of the 32 networks work together and share funding and professional staff to plan, design and implement an integrated long-term monitoring program. This program will assure the full and proper utilization of the results of scientific studies for park management decisions. The North Coast and Cascades Network is composed of seven park units including three, large, predominantly natural areas (Olympic National Park, Mount Rainier National Park, and North Cascades National Park Complex) and four, smaller, predominantly historic areas (Fort Vancouver National Historical Site, San Juan Island National Historical Park, Ebey's Landing National Historical Reserve, and Lewis and Clark National and State Historical Parks (Figure 1). Olympic National Park is a World Heritage Site and a UNESCO International Biosphere Reserve.

The NCCN parks are in the mountains and lowlands of the Pacific Northwest, from the east slope of the Cascade Range to the Pacific Ocean, an area that is also rapidly urbanizing. Tall mountains and a maritime climate produce a tremendous environmental gradient, varying in elevation from sea level to glaciers, and in annual precipitation from almost 200-inches to less than 20-inches per year. These environmental patterns shape the variety and distribution of plant and animal communities and ecosystems encompassed within the seven parks. The four historic parks preserve snapshots of significant cultural milestones in the development of the Pacific Northwest. The three larger parks showcase the variety of terrestrial and aquatic ecosystems native to this region. All the parks share ecological systems and associated anthropogenic influences including invasions of exotic species, altered fire regimes, degraded air and water quality, heavy recreational pressure, habitat loss outside NPS boundaries, and climate change with associated sea level rise.

Program Goals

The broad goals of the NPS and NCCN Vital Signs monitoring program are to:

1) Determine status and trends in selected indicators of the condition of park ecosystems to allow managers to make better-informed decisions;
2) Provide early warning of abnormal conditions and impairment of selected resources to help develop effective mitigation measures and reduce costs of management;

3) Support better understanding of the dynamic nature and condition of park ecosystems and to provide reference points for comparisons with other, altered environments;
4) Help meet certain legal and Congressional mandates related to natural resource protection and visitor enjoyment; and;
5) Serve in measuring progress towards performance goals.

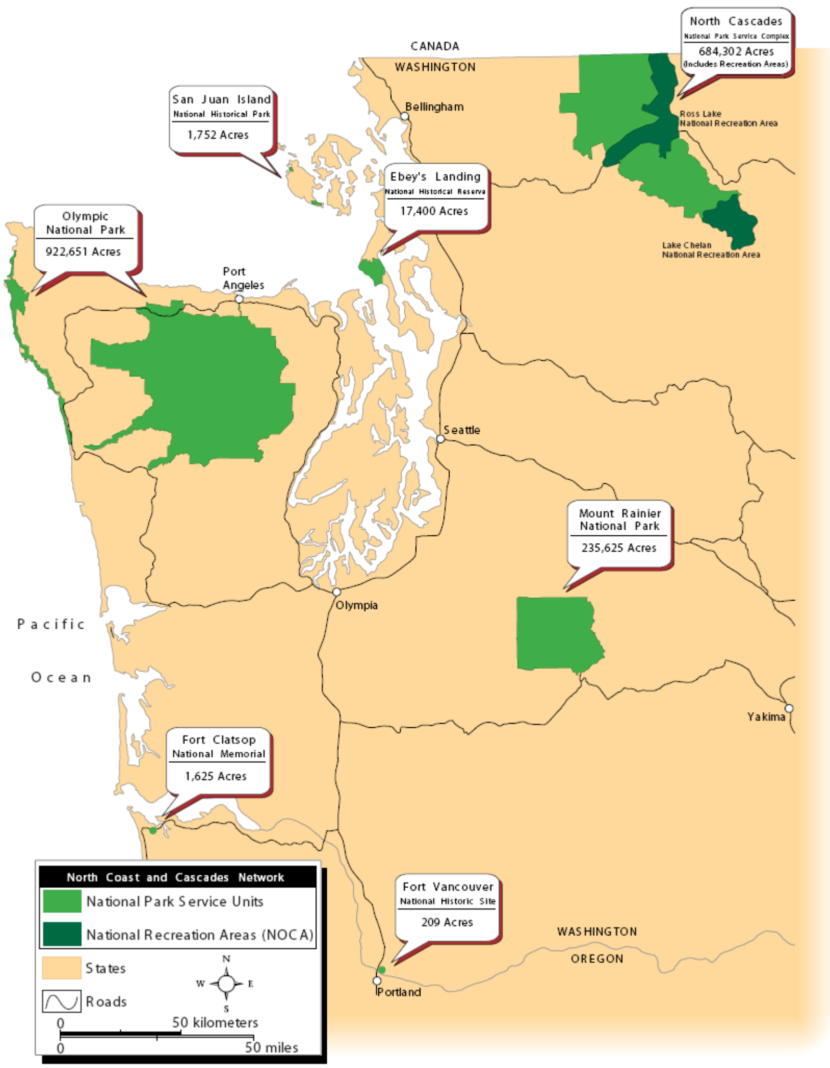

Figure 1. Units of the North Coast and Cascades Network.

Vital Signs

"Vital Signs" are a subset of physical, chemical, and biological elements and processes of ecosystems, selected to represent the condition of natural resources, effects of stressors, or elements that have important management values. NCCN staff identified and prioritized potential Vital Signs in an iterative process. Beginning with expert workgroups and proceeding through both subjective and quantitative ranking processes, Network technical staff and other subject matter experts produced a list of approximately 30 Vital Signs. Finally, a scientific review panel of five scientists reviewed the selected suite of Vital Signs, further refined the list, suggested budgets, and helped the parks balance their monitoring efforts (Table 1).

Table 1. Summary of Vital Signs for NCCN in the context of the national framework. Those in white cells will be supported at least partially by the network monitoring program; light gray cells will be supported by other agencies or NPS programs; dark gray cells have no support at this time.

Level 1 Category	Level 2 Category	Level 3 Category	Network Vital Sign
Air & Climate	Weather & Climate	Weather & Climate	Weather & Climate
			Snow cover
Geology & Soils	Geomorphology	Glaciers	Glaciers
		Stream/River Channels	Channel Characteristics
		Lake Features	Lake Features & Processes
Water	Hydrology	Surface Water Dynamics	Surface Water Levels
	Water Quality	Water Temperature	Water temperature
		Water chemistry – WRD requirements	Water chemistry
		WQ Nutrients	WQ Nutrients
	WQ & Biological Integrity	Aquatic Invertebrates & Algae	Benthic macroinvertebrates
			Zooplankton
Biological Integrity	Focal Species or Communities	Intertidal Communities	Intertidal Communities
		Grassland Vegetation	Prairie & Coastal Vegetation
		Forest Vegetation	Forest Vegetation
		Vegetation Communities	Subalpine Vegetation
			Riparian Vegetation
		Fishes	Fishes –
		Birds	Landbirds
		Mammals	Elk
		Amphibians & Reptiles	Amphibians – Mtn./Small Lakes
	Invasive Plants	Invasive Plants	Invasive Plants
	At Risk Biota	T&E Species & Communities	Salmonids
Ecosystem Pattern & Processes	Landscape Dynamics	Land Cover & Use	Landscape Dynamics
	Extreme Disturbance Events	Extreme Disturbance Events	Disturbance
	Fire	Fire & Fuel Dynamics	Fire & Fuel Dynamics
Biological Integrity	At Risk Biota	T&E Species & Communities	Northern Spotted Owl
	Focal Species or Communities	Mammals	Mountain Goats
Air & Climate	Air Quality	Ozone	Ozone
		Wet & Dry Deposition	Wet & Dry Deposition
		Visibility & Particulate Matter	Visibility

Table 1. Summary of Vital Signs for NCCN in the context of the national framework. Those in white cells will be supported at least partially by the network monitoring program; light gray cells will be supported by other agencies or NPS programs; dark gray cells have no support at this time (continued).

Level 1 Category	Level 2 Category	Level 3 Category	Network Vital Sign
Water	Hydrology	Surface Water Dynamics	River & Stream flow
Air & Climate	Air Quality	Air contaminants	Air contaminants
Biological Integrity	Focal Species or Communities	Rare Plants	Rare Plants
		Amphibians & Reptiles	Amphibians – Wadeable Streams
Human Use	Visitor & Recreational Use	Visitor usage	Recreational Impacts- Vegetation & Soils

Implementation

Continuity of quality monitoring is ensured by describing detailed methods for one or several Vital Signs in detailed protocols. Protocols describe the objectives, standard operating procedures, quality assurance/quality control standards, and a data management plan. Each protocol also specifies a spatial and temporal sample frame. Whenever possible, vital sign monitoring efforts are collocated to enable integration of results across Vital Signs. For example, the wadeable streams protocol calls for collocated measurements of channel characteristics, water chemistry, benthic macroinvertebrates, fish, and amphibians in selected stream segments to assess the overall condition or "health" of streams.

Recognizing that the initial funding for each network is only enough to implement a 'bare-bones' program, the long-term strategy of the NCCN is to start modestly, demonstrate the value of scientific monitoring data in protecting park resources and saving money, and use results and successes to argue for additional funding. Special emphasis has been placed on sharing monitoring with available agency or academic partners. Because each protocol must begin modestly, care is being taken to employ statistical designs that permit additional sampling (greater spatial area, more replicates, or additional strata) should more funding become available. Such designs, based on carefully planned randomized probabilistic sampling, lay a firm foundation for future development.

NCCN monitoring is oriented towards trend detection of Vital Signs indicating ecosystem status, having immediate management concern, or both. Trends must be detectable in time to be of use to managers. Our trend detection is aimed at providing park managers with timely information by concentrating on the most rapid possible detection of change. While it takes longer to detect a change in tree growth patterns than in the amount of algae in a lake, our goal for each case is to provide trend information as quickly as possible, thereby sampling with management concern foremost.

Budget

Annual funding for NCCN is $1,145,100 with an additional $82,000 coming from the National Park Service Water Resources Division for water quality monitoring. In the implementation budget, very roughly 50% will be spent on personnel, 30% on information/data management, and 20% on operations and equipment.

Integration with Management

As part of the Service's efforts to improve park management through greater reliance on scientific knowledge, a primary purpose of the monitoring program is to develop, organize, and make available natural resource data by transforming data into useful information through analysis, synthesis, modeling, and reporting. Vital Signs monitoring will be and integral part of the adaptive management cycle by providing critical information about trends in natural resource conditions. The information will be available to identify desired conditions and evaluate management effectiveness. It will also provide early warning of unforeseen changes in ecosystem status. To help deliver the information needed at the park, network, regional, and national levels, the Vital Signs networks are designing a system for scientific data collection, analysis, and reporting that is unprecedented in the National Park Service.

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Chapter 1. Introduction and Background

1.1 Introduction

The North Coast and Cascades Network includes eight parks in western Washington and the northwestern corner of Oregon. They include three large, mountainous parks that are coastal, continental or both (Mount Rainier and Olympic National Parks and North Cascades National Park Complex) and five small, historically based parks (Ebey's Landing National Historic Reserve, Fort Clatsop National Memorial, Fort Vancouver National Historic Site, Klondike Goldrush National Historical Park – Seattle Unit, and San Juan Island National Historical Park). Seven of these parks (Klondike Goldrush excepted) are considered to have significant natural resources, and thus are the subject of this monitoring plan (See map in the Executive Summary and Table 1.1).

Table 1.1. North Coast and Cascades Network Parks Sizes.

Park	Code	Size (acres)	Size (ha)
Ebey's Landing National Historical Reserve	EBLA	17,400	7,042
Fort Vancouver National Historic Site	FOVA	209	85
Lewis & Clark National & State Historical Parks	LEWI	7,000	2,834
San Juan Island National Historical Park	SAJH	1,752	709
Mount Rainier National Park	MORA	235,625	95,395
North Cascades National Park Complex	NOCA	684,302	277,045
Olympic National Park	OLYM	922,652	373,543

1.2 Purpose and Importance of Monitoring

Fundamental to the National Park Service's ability to manage park resources "unimpaired for the enjoyment of future generations" is the need to understand the condition of park natural resources. As National Park managers everywhere are confronted with increasingly complex and challenging issues, they require a broad understanding of the status and trends of park resources as a basis for making decisions. With this understanding the National Park Service can most effectively partner with other agencies and the public to manage and preserve park resources. Goals include characterizing trends, assessing the efficacy of management practices and restoration efforts, and to providing early warning of impending threats.

Vital Signs, as defined by the National Park Service, are a subset of the physical, chemical, and biological elements and processes of park ecosystems that represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements with important human values (http://science.nature.nps.gov/im/monitor/glossary.htm). Vital Signs monitoring data will help define the normal limits of natural variation in park resources, providing a basis for understanding future changes. Monitoring results may also be used to define impairment and to identify the need to initiate or change management practices. The information obtained through a well-designed natural resource monitoring program will have multiple applications for management decision-making, research, education, and promoting public understanding of park resources.

1.2.1 Service-wide goals for vital sign monitoring

The five national goals for Vital Signs monitoring are to:

- Determine the status and trends in selected indicators of the condition of park ecosystems to allow managers to make better-informed decisions and to work more effectively with other agencies and individuals for the benefit of park resources.
- Provide early warning of abnormal conditions of selected resources to help develop effective mitigation measures and reduce costs of management.
- Provide data to better understand the dynamic nature and condition of park ecosystems and to provide reference points for comparisons with other, altered environments.
- Provide data to meet certain legal and Congressional mandates related to natural resource protection and visitor enjoyment.
- Provide a means of measuring progress towards performance goals.

These five goals provide the fundamental guidance for our monitoring program. Several of these goals were explicitly incorporated into ranking criteria used by this network to select the most important Vital Sign monitoring questions, ensuring that critical objectives for monitoring are met (see Chapter 3).

1.3 Overview of NCCN I&M Parks and Their Natural Resources

In this section we briefly describe the physical, biological and cultural characteristics of NCCN I&M parks, collectively and by park. Detailed descriptions for each park can be found in the, Appendices 1.1-1.7 of the NCCN Phase 2 Plan (http://www1.nature.nps.gov/im/units/nccn/Reports/NCCN_Phase2_Appendices_v1.doc) where we describe each park's natural resource goals and desired future conditions, the national and regional significance of natural resources, the specific natural resource management and scientific issues each park faces, a summary of the monitoring that has occurred, along with water quality issues.

1.3.1 Geography and Climate

The dynamic geologic and cultural processes that have shaped the Pacific Northwest are on display in the seven units of the NCCN I&M Network, located in western Washington and northwest Oregon. Collectively, these seven parks span an elevation gradient from just below sea level to over 4300 m (14,000 ft), with topographic relief as much as 4,300 m (14,000 ft) on Mount Rainier, typically 2000 m (6500 ft) in the Cascades and Olympics, and less than 100 m (320 ft) in the historic parks. The Cascade and Olympic ranges are major barriers to the eastern flow of storms from the Pacific Ocean. As a result, western slopes receive heavy precipitation, exceeding 5 m (200 in) annually in places, and rain shadow areas have annual precipitation as low as 50 cm (20 in; Phillips and Donaldson 1972). Most precipitation in the region falls during winter, with snowfall exceeding 15 m (50 ft) on high elevation western slopes of mountain ranges (Reiner 1992). These environmental gradients result in an ecologic gradient of intertidal to alpine including eight major ecosystems (i.e., 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 Washington; Washington Department of Natural Resources 2003). These environmental patterns have shaped the variety and distribution of plant and animal communities and ecosystems included in the parks. The three larger parks, comprising 99% of NCCN area, showcase the diversity of terrestrial and aquatic ecosystems native to this region, while the four historic parks preserve snapshots of significant cultural milestones in the development of the Pacific Northwest.

1.3.2 Geology

The seven NCCN I&M parks fall within three physiographic provinces, including the Cascade and Olympic Mountains, and the Puget-Willamette Lowlands (McKee, 1972), all resulting from different geologic processes. The Olympic Mountains were formed when sea floor was scraped onto the continental plate as an oceanic plate subducted under it (Tabor 1987); the Cascades Mountains were formed by folding and volcanism; the Puget-Willamette Lowlands were formed by the Wisconsin Ice Sheet as it moved south from Canada (Armstrong et al. 1965, Tabor 1987). Geologic processes still active in the Network include volcanism, glaciation, landslides, tectonics (earthquakes and tsunamis), and intense flooding. Mount Rainier is an active volcano that was named a Decade Volcano by the United Nations because of its immense size, history of catastrophic debris flows, and location near a large urban center.

1.3.3 Water resources and aquatic ecosystems

Washington State is second only to Alaska in glacier cover among the United States (Spicer 1986). Many of these glaciers and permanent snowfields originate within the three big parks, and their watersheds contribute substantial freshwater inflows to tributary rivers that power hydroelectric utilities before emptying into Puget Sound, the Columbia River and the Pacific Ocean. These relatively pristine rivers provide increasingly threatened habitat for native sea-run and resident salmon and trout, and a wide variety of wildlife associated with the river corridors. Among these are grizzly bears, coastal cutthroat and west slope cutthroat trout and several species on the federal T&E species list, including bull trout and chinook salmon. In addition to many large river systems, the network parks include hundreds of alpine lakes and several large lowland lakes and reservoirs, some with distinctive native fish communities. Finally, these parks include over 117 km (73 mi) of marine shoreline and the associated vertebrate and invertebrate intertidal species.

There are few sites designated as having impaired water quality in NCCN. Two sites listed on the Washington State 303(d) list occur in OLYM and are considered to have impaired pH. In both cases, park management believes the conditions are natural. New acreage added to LEWI in 2005 includes impaired water in Washington (part of the Columbia River) and two 303(d) waters in Oregon (Lewis & Clark River and Skippanon River). An overview of the NCCN water quality resource status, including past studies, can be found in Appendix 1.1. Specific information on the water bodies within NCCN which are listed on State 303(d) lists can be found in Appendix 1.2.

1.3.4 Air resources

Three parks within NCCN are designated Class I areas (MORA, NOCA and OLYM) in recognition of their relatively clean air. While the air quality of the Pacific Northwest is generally considered better than other areas of the United States, there is potential for both long-term and short-term degradation that could affect human health, vegetation, aquatic resources, and biogeochemical processes. Parks with the NCCN are subject to regional long-distance transport of air pollutants (sulfur and nitrogen oxides, ozone, particulates, toxic pollutants) from a large area, but especially from the metropolitan areas of Seattle-Tacoma and Portland. Trans-Pacific transport of persistent organic pollutants is also occurring (Jaffe et al. 1999). Persistent organic pollutants (POPs) include pesticides (e.g., DDT, chlordane, dieldrin, etc.) and compounds used in or produced by industry (e.g., PCBs, dioxins, furans, etc.). Toxic metals, also produced by industry, include mercury, lead, zinc, and cadmium. All of these chemicals are easily vaporized into the atmosphere (Simonich and Hites 1995). In addition, there are new chemicals whose behavior is not yet understood, including brominated compounds, flame retardant coatings and substitutes for CFCs. Contaminants can reside and move in the air and water, but because most NCCN parks are remote and mountainous, atmospheric deposition is the most important source of contamination (Biddleman 1999).

Potential effects on park resources include:

- Tropospheric ozone, which is highest during the summer and at higher elevations, may damage vegetation and reduce respiratory function in humans (US EPA 1996);
- Acidic deposition, which could increase the acidity of poorly buffered aquatic systems and soils over the long term, may affect fish, amphibians, and soil dependent organisms (Allan 2001);
- Particulate pollutants, which reduce visibility of scenic views, may cause respiratory distress in some visitors (Wilson 1996);
- Little is known about the presence, amounts or distribution of POPs and other toxics in NCCN parks but potential effects on park resources may be significant (Bailey et al. 2000, Blais et al. 1998).

An overview of air quality monitoring being conducted in NCCN is in Appendix 1.3. NCCN will depend on other agencies for air quality monitoring for the foreseeable future.

1.3.5 Terrestrial resources

As one might imagine, this group of diverse parks provides habitat for a wide range of terrestrial plant and animal communities. Plant communities vary from intertidal marine algae and eel-grass to lowland prairies and old-growth coniferous forest, to high-mountain subalpine and alpine vegetation. Similarly, complex vertebrate and invertebrate marine and terrestrial animal communities can be found in these parks, including a number of federally listed threatened and endangered species. Northern spotted owls and marbled murrelets are among these species found in the old-growth forests of Olympic, North Cascades, and Mount Rainier National Parks.

1.3.6 NCCN I&M Park Summaries

Mount Rainier National Park (MORA), established in 1899, includes 95,395 ha (235,625 acres) on the west side of the Cascade Range, surrounding an active volcano and covering a 3901 m (12,800 ft) elevation gradient (Figure 1.3.1). Approximately 58 percent of the Park is forested, 23 percent is subalpine parkland, and the remainder is alpine, half of which is vegetated and the other half consists of permanent snowfields. The Park includes 26 named glaciers in nine major watersheds, 382 lakes plus rivers, streams and wetlands. The Park houses four threatened or endangered vertebrate species in its diversity of plant and animal species. (See http://www.nps.gov/mora).

Enabling Legislation: The Mount Rainier National Park Act (1899) established the Park in order 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."

Threats/Concerns:
- Air pollution from Puget Trough, especially Seattle-Tacoma and Portland
- Visitor impacts on day use areas and climbing routes
- Land-use change around boundaries of Park (e.g., Crystal Mountain Ski area)
- Global climate change impacts
- Regional and global air quality and precipitation chemistry
- Geologic disturbance (e.g., volcanic activity, lahars, glacial out-wash floods)

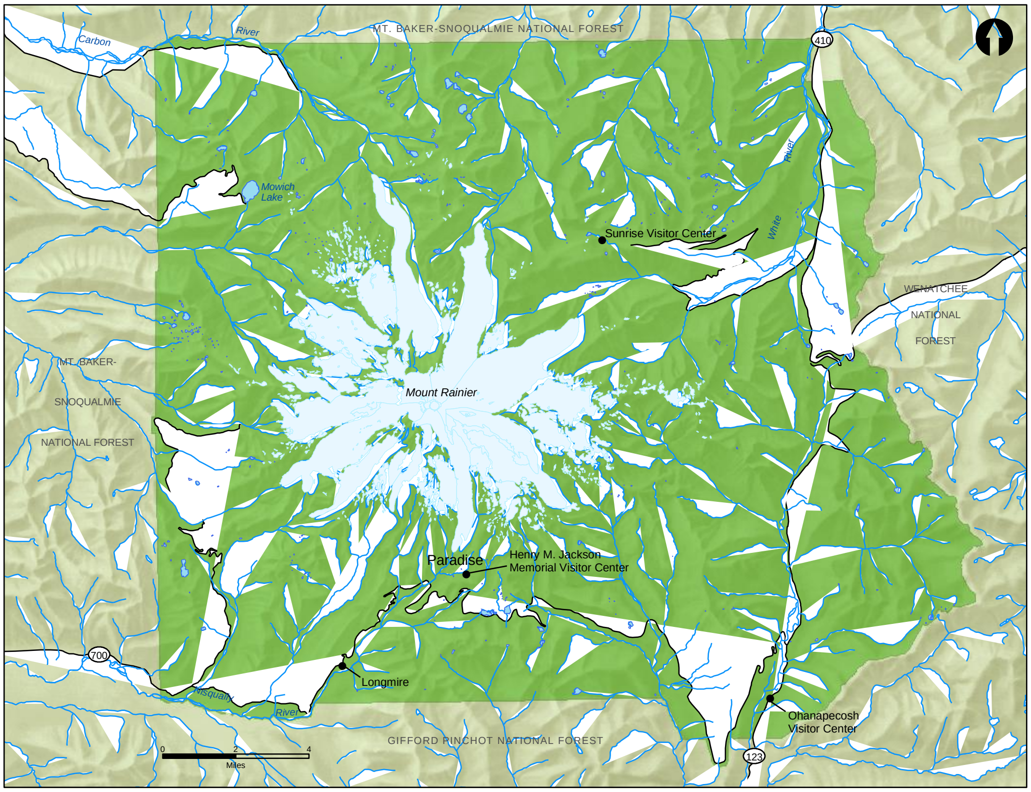

Figure 1.3.1. Mount Rainier National Park (MORA).

North Cascades National Park Complex (NOCA) consists of North Cascades National Park, and Lake Chelan and Ross Lake National Recreation Areas (Figure 1.3.2). The Complex covers 277,045 ha (684,302 acres) at the northern end of the Washington Cascade Range, bordering Canada. It was established in 1968 to preserve the scenery and natural features of the area while allowing for recreational use and hydroelectric operations. Ecologically, NOCA contains a diverse set of habitats because it spans several transition zones including maritime to continental climate, and Cascade granite to Cascade volcanic geology. The Complex contains the largest collection of glaciers in the lower 48 States, 4184 km (2600 mi) of perennial streams, 180 lakes and ponds, and 233 bird species, more than 1600 vascular plant species, and 500 mushroom species. (See http://www.nps.gov/noca).

Enabling Legislation: Public Law 90-544 states that the purpose of North Cascades National Park is "... to preserve for the benefit, use and inspiration of present and future generations certain majestic mountain scenery, snow fields, glaciers, alpine meadows, and other unique natural features ...." [16 U.S.C. §90] Further, the purpose of the Lake Chelan and Ross Lake National Recreation Areas is "... to provide for the public outdoor recreation use ... and for the conservation of the scenic, scientific, historic and other values contributing to the public enjoyment ...." [16 U.S.C. §90a & 90a-l].

Threats/Concerns:

- Air and precipitation quality
- Stocking of fish in high-elevation lakes
- Hydroelectric reservoirs and run-of-the-river projects
- Extraction of mineral deposits
- Restoration of fire

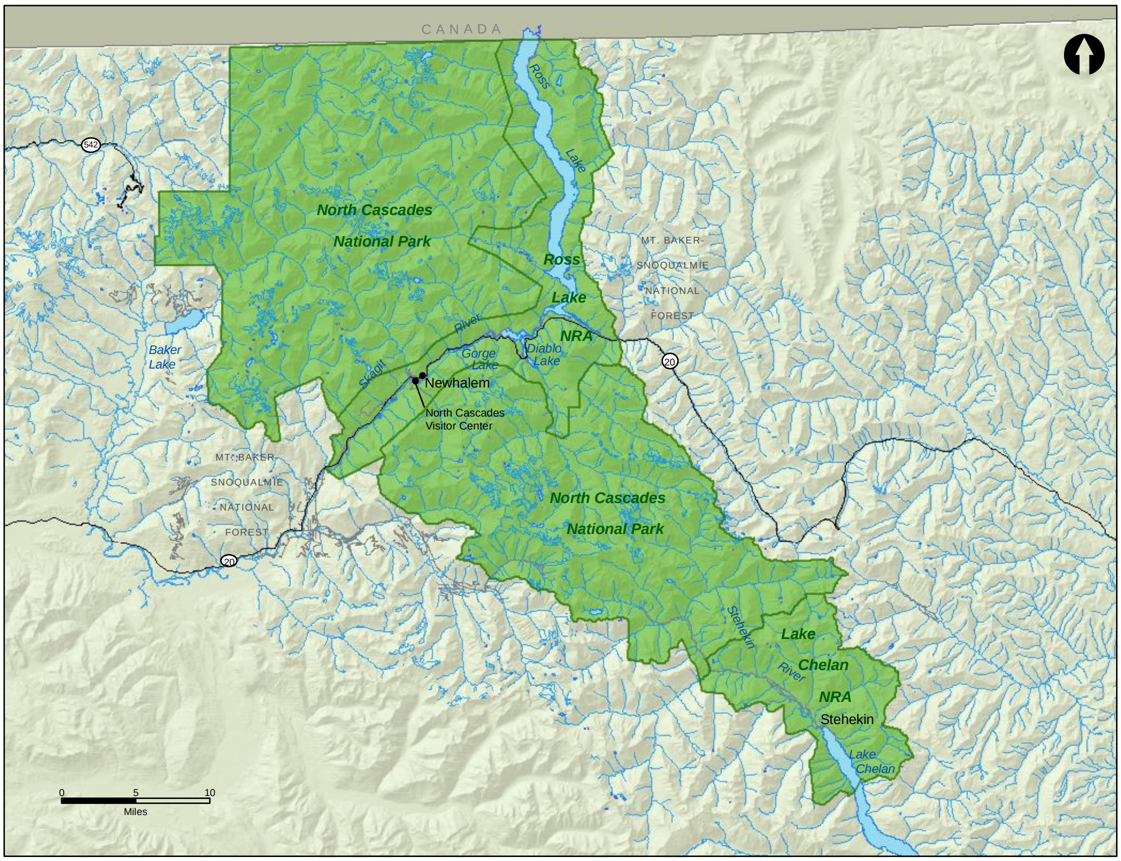

Figure 1.3.2. North Cascades National Park Complex (NOCA).

Olympic National Park (OLYM), established in 1938, covers 373,384 ha (922,652 acres) on the Olympic Peninsula of Washington, and is said to be three parks in one: rugged, glacier capped mountains, over 96 km (60 mi) of wilderness coastline, and stands of old-growth temperate rain forest (Figure 1.3.3). Habitats and communities of the park include intertidal areas, coastal bogs, temperate rainforests, riparian zones, montane and subalpine forests, alpine fellfields, and glaciers. In addition to the biological diversity found in these communities, the Park includes all five species of Pacific salmon, among other important fish species, 24 endemic plant and animal species, and 46 plants and animals that are federally listed under the Endangered Species Act (species of concern, endangered, or threatened). (See http://www.nps.gov/olym).

Enabling Legislation: Olympic National Park was established to protect specific natural resources including: "[T]he finest sample of primeval forests of Sitka spruce, western hemlock, Douglas fir, and western red cedar in the entire United States…herds of native Roosevelt elk and other wildlife indigenous to the area… outstanding mountainous country, containing numerous glaciers and perpetual snow fields, and a portion of the surrounding verdant forests together with a narrow strip along the beautiful Washington coast." (*H.R. 2247* accompanying the park's enabling legislation).

Threats/Concerns:
- Air pollution and contaminants (from Asia or circumpolar)
- Global climate change impacts
- Habitat loss and fragmentation around boundaries
- Anadromous fish harvest and habitat alteration outside Park
- Harvest of coastal resources
- Elk hunting outside of the Park
- Visitor use impacts
- Exotic plants and animals

Figure 1.3.3. Olympic National Park (OLYM).

Ebey's Landing National Historical Reserve (EBLA) is a 7,042 ha (17,400 acre) reserve established in 1978 to preserve and protect a rural community on Whidbey Island (Figure 1.3.4). The historical landscape looks much like it did a century ago – a mosaic of farms, forests and century-old buildings and homes. Outstanding resources include miles of marine shoreline, Penn Cove, three large native prairies, multiple glacial kettles, the island's best farmland, high seaside bluffs, low rolling hills, shallow brackish lakes, and a long, narrow, rugged beach along

Admiralty Inlet. This diversity of features provides habitat for a large number and diversity of plants-including one threatened species, marine animals, and large numbers of migratory birds along the coastal strip. (See http://www.nps.gov/ebla).

Enabling Legislation: Ebey's Landing National Historical Preserve was created by Congress in 1978 "to preserve and protect a rural community which provides an unbroken historic record from...19th century exploration and settlement in Puget Sound to the present time." Among the stipulations in the enabling legislation (Public Law number 95-625) was to "formulate a comprehensive plan for the protection, preservation, and interpretation of the reserve," including "…those areas or zones within the reserve which would most appropriately be devoted to … historic and natural preservation…"

Threats/Concerns:

- Land-use changes in parts of the Reserve not owned by NPS
- Endangered plants
- Prairie restoration
- Changes in visibility due to airborne particulate matter
- Exotic plants

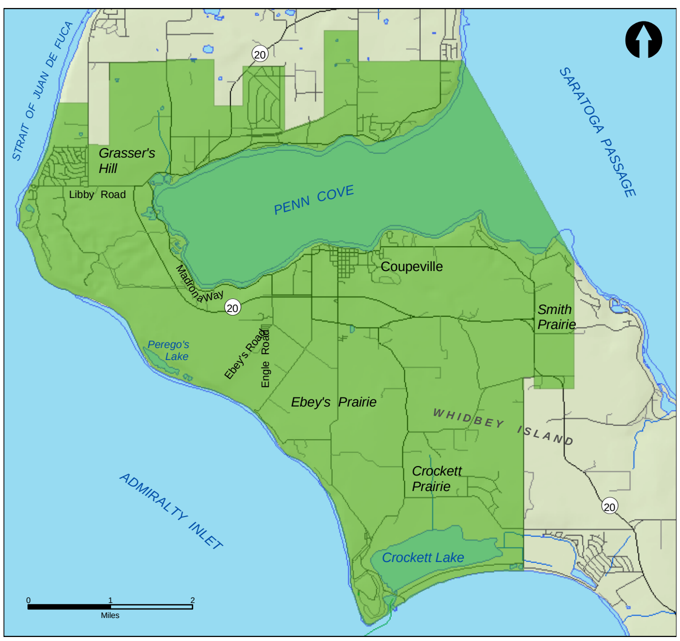

Figure 1.3.4. Ebey's Landing National Historical Reserve (EBLA).

Fort Vancouver National Historic Site (FOVA) is located on the Columbia River, across from Portland. Its 85 ha (209 acres) were protected in 1948, as well as in subsequent legislation to preserve and interpret the Hudson's Bay Company fort, the settlement of Oregon Country, and the establishment of Fort Vancouver, the first US military post in the Pacific Northwest (Figure 1.3.5). The natural environment of the site has been heavily impacted over time by the Hudson's Bay Company beginning in 1929, US Army development beginning in 1849, and by urbanization of the Portland/Vancouver metropolitan area. As a result, only vestiges of the pre-contact prairie and Columbia River habitat remain. (See http://www.nps.gov/fova).

Enabling Legislation: Congress has enacted legislation four times with regard to Fort Vancouver National Historic Site. Originally established as Fort Vancouver National Monument on June 19, 1948, the Park was established "...to preserve as a national monument the site of the original Hudson's Bay Company stockade (of Fort Vancouver) and sufficient surrounding land to preserve the historical features of the area" for "the benefit of the people of the United States" (62 Stat.352).

Threats/Concerns:

- Maintain and restore natural environment
- Preservation of heritage natural resources
- Exotic plants
- Urbanized environment

Figure 1.3.5. Fort Vancouver National Historic Site (FOVA).

Lewis and Clark National and State Historical Parks (LEWI) is an approximately 7,000 acre multi-state collaborative historical park that rings the mouth of the Columbia river with several separate units (Figure 1.3.6). It was established in 1958 to commemorate the winter encampment of the Lewis and Clark expedition at Fort Clatsop during the winter of 1805-1806. The Park includes pacific coast headlands, estuarine mudflats, tidal marshes, shrub and forested swamps and upland coniferous rainforest. Flora and fauna diversity within the Park are high, reflecting the Park's diversity of habitats, moderate climate, location along the Pacific flyway, and proximity to the Pacific Ocean. In 2004, this park expanded from 125 acres to 3,246 directly managed lands plus an additional roughly 4,000 acres of partnership lands, joining a confederation of state and national parks extending along a 40 mile stretch of Pacific coast, from Long Beach, WA, to Cannon Beach, OR. (See http://www.nps.gov/lewi).

Enabling Legislation: Public Law 108-387 states that the purpose of LEWI is "to preserve for the benefit of the people of the United States the historic, cultural, scenic, and natural resources associated with the arrival of the Lewis and Clark Expedition in the lower Columbia River area, and for the purpose of commemorating the culmination and the winter encampment of the Lewis and Clark Expedition in the winter of 1805-1806 following its successful crossing of the North American Continent…"

Threats/Concerns:

- Inventory of newly acquired lands
- Restoration of natural resources and processes
- Impacts of land-use practices outside of park boundaries and in Columbia River estuary
- Elk population status and future trends
- Spread of terrestrial and aquatic non-native species

Figure 1.3.6. Lewis and Clark National and State Historical Parks (LEWI).

San Juan Island National Historical Park (SAJH), established in 1966, covers 709 ha (1752 acres) in two disjunct areas on San Juan Island along Haro Strait (Figure 1.3.7). These areas preserve and commemorate the sites of American and British military emplacements meant to protect their interests prior to the final settlement in 1871 of the Oregon Territory boundary dispute. Natural habitats include six miles (10 km) of shoreline and intertidal habitat, wetlands, grasslands and second growth forest. These habitat areas host a diversity of plant and animal species, including a unique suite of butterfly species. (See http://www.nps.gov/sajh).

Enabling Legislation: San Juan Island National Historical Park was established "for the purpose of interpreting and preserving the sites of the American and English camps on the island, and of commemorating the historic events that occurred from 1853 to 1871 on the island in connection with the final settlement of the Oregon Territory boundary dispute, including the so-called Pig War of 1859."

Threats/Concerns:

- Effects of European rabbits on vegetation and soil properties
- Restoration of prairies
- Exotic plants
- Visitor use impacts
- Development around Park
- Global climate change
- Oil spills and other catastrophic anthropogenic events

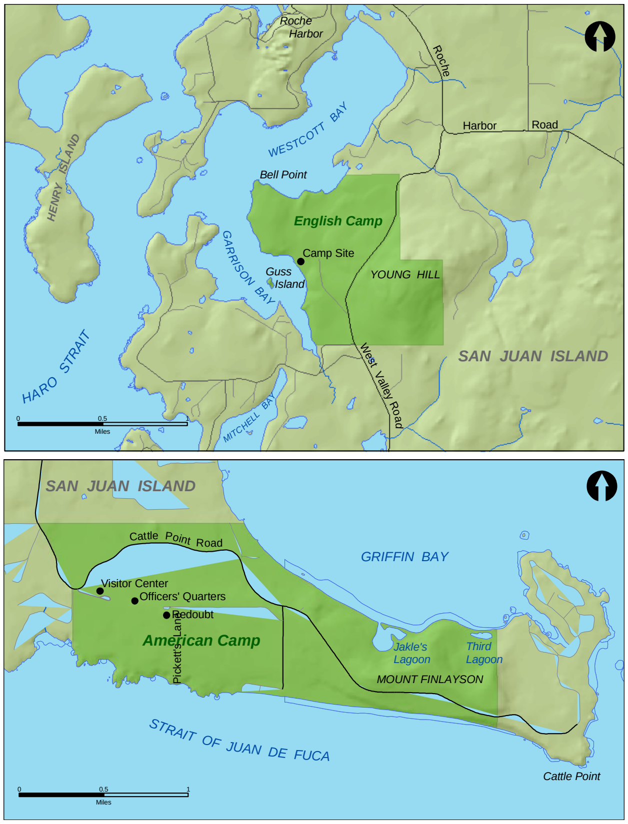

Figure 1.3.7. San Juan Island National Historical Park.

1.4 Legislative and Policy Basis for Monitoring

In addition to addressing individual park enabling legislation, National Park managers are directed by federal law and National Park Service policies and guidance to know the status and trends in the condition of natural resources under their stewardship in order to fulfill the NPS mission of conserving parks unimpaired (see Summary of Laws, Policies, and Guidance, URL: http://www1.nrintra.nps.gov/im/monitor/officialmemos.htm; Table 1.4.1).

Table 1.4.1. Excerpts from federal legislations requiring monitoring in National Parks.

	Legislation	Excerpt
SERVICE-WIDE LEGISLATION	NPS Organic Act 1916	"...to promote and regulate the use of the Federal areas known as national parks, monuments, and reservations … which purpose is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations."
	NPS Omnibus Management Act 1998	"continually improve the ability of the NPS to provide state-of-the-art management, protection, and interpretation of and research on the resources of the NPS", and develop "inventory and monitoring of NPS resources to establish baseline information and to provide information on the long-term trends in the condition of NPS resources."
	FY2000 Appropriations Bill	"… preservation of the diverse natural elements and … scenic beauty of America's national parks…should be as high a priority in the Service as providing visitor services…(T)he leadership of the National Park Service … (must) carry out a systematic, consistent, professional inventory and monitoring program, … that is regularly updated to ensure that the Service makes sound resource decisions based on sound scientific data."
	NPS Management Policies 2001	"Natural systems in the national park system, and the human influences upon them, will be monitored to detect change. The Service will use the results of monitoring and research to understand the detected change and to develop appropriate management actions."
LEGISLATION FOR NCCN PARKS	Clean Air Act 1977	Mount Rainier and Olympic National Parks, and North Cascades National Park Service Complex were designated Class I areas where air quality standards are stricter than those required by the National Ambient Air Quality Standards, and very little deterioration of air quality and related values is allowed. Parks must monitor air quality and related values to determine whether they are in compliance with the Clear Air Act.
	Washington Park Wilderness Act 1988 (P.L. 100-688	Significant portions of Mount Rainier National Park (97%), North Cascades National Park Complex (93%), and Olympic National Park (95%) were designated as Wilderness to be managed according to the Wilderness Act of 1964 (P.L. 88-577).
	Geothermal Steam Act Amendment 1988	Mount Rainier National Park and other NPS sites were designated as having significant thermal features and are called to develop a monitoring program for significant thermal features.

Additional statutes provide legal direction for expending funds to determine the condition of natural resources in parks and to guide the natural resource management of network parks, including:

- Taylor Grazing Act 1934;
- Fish and Wildlife Coordination Acts, 1958 and 1980;
- Wilderness Act 1964;
- National Historic Preservation Act 1966;
- National Environmental Policy Act of 1969;
- Clean Water Act 1972, amended 1977, 1987;

- Endangered Species Act 1973, amended 1982;
- Migratory Bird Treaty Act, 1974;
- Forest and Rangeland Renewable Resources Planning Acts of 1974 and 1976;
- Mining in the Parks Act 1976;
- American Indian Religious Freedom Act 1978;
- Archaeological Resources Protection Act 1979;
- Federal Cave Resources Protection Act 1988;
- Clean Air Act, amended 1990.

1.5 Network History

The National Park Service began developing a comprehensive long-term ecological monitoring program in 1993 by soliciting proposals for eleven prototype parks with the goal of developing "a better understanding of national park ecosystem dynamics and ecological integration" (NPS 1995). Prototype programs were to be phased in over time and OLYM and NOCA, which were chosen to represent the coniferous forest and the lakes and streams biomes respectively, were scheduled to be funded in the last group. Before all prototype programs were established, the NPS augmented the prototype park program by grouping geographically related parks into 32 monitoring networks. NOCA and OLYM were both incorporated into NCCN, making it the only network with two prototypes.

The NCCN was formed, and first received funding, in the year 2000. Funding was granted in three budgets, one for each prototype program and one for the Network as a whole. The NOCA and OLYM prototype programs were funded at approximately half the level that had been proposed and approved. Meanwhile, prior to receiving NPS I&M funding and starting in 1993, the two Prototypes began developing natural resource monitoring programs and protocols using other funding sources: OLYM with base funds, special project funds, and help from USGS; NOCA with base funds and special project funds. Consequently NCCN was formed from a complex mix of players including two more advanced, staffed programs, many partnerships and funding sources, and several completely new programs.

Since that time, the I&M network concept has been expanded in the Pacific West Region far beyond its original scope. Parks in networks are encouraged to work together to pursue mutually beneficial goals on subjects ranging from concessions to information technology. For these broader purposes, Klondike Gold Rush National Historical Park – Seattle Unit, was added to the Network and a new charter was written. However, when the Board of Directors discusses I&M issues, the original charter is in effect.

NCCN has unique circumstances compared with other networks. The two prototype parks made the Network a priority for protocol development by the USGS I&M program. Normally USGS funding for protocol development is meant to precede NPS funding for implementation, but the two funding sources coincided for NCCN. Recognizing these particular financial circumstances, USGS and NPS entered a Memorandum of Understanding (MOU) to define their relationship. The MOU specifies that both agencies will be involved with protocol development, whereas implementation will still be the responsibility of the NPS. USGS is required to maintain a close working relationship with designated NPS leads for each protocol project to ensure that protocols developed meet Park Service needs. At the same time, it is expected that NPS will take the lead on other protocols, with or without USGS involvement. Also, the USGS work plan must be evaluated in the context of network needs, even when it does not address them directly. USGS funding is expected to be available from FY02 through FY06.

1.6 Network Administrative Structure

The administrative structure of NCCN includes a Board of Directors, a Network Monitoring Coordinator, a Steering Committee, and a Technical Committee which is divided into subject-matter work groups (Figure 1.6.1). Staff from USGS are involved in some of these entities. The roles of the players and groups are described in more detail in Chapter 8.

North Coast & Cascades Network I&M Organizational Chart

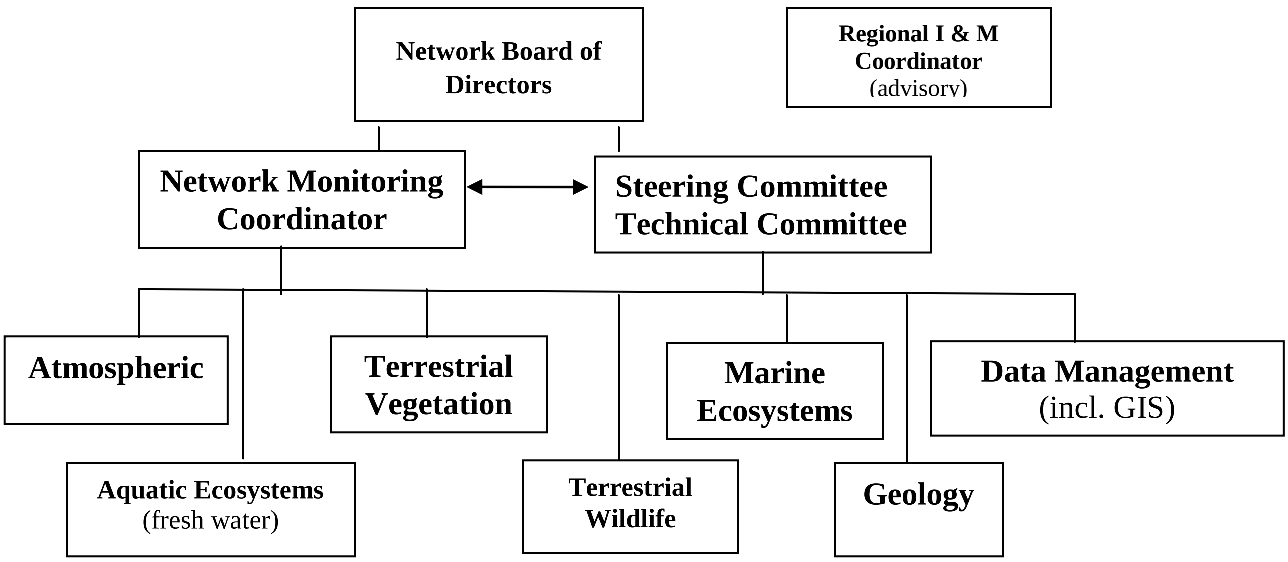

Figure 1.6.1. Organizational chart for the North Coast and Cascades Network.

Board of Directors: The Board of Directors of NCCN is comprised of the Superintendents of the eight network parks, although only the seven representing I&M parks are involved in monitoring decisions.

Network Coordinator: The Network Monitoring Coordinator is housed at one of the parks and reports directly to the Board.

Technical Committee: The Technical Committee (TC) is composed of the Chiefs of Natural Resources of each park, selected natural resource program leads, the Network Coordinator, and a USGS scientist. The Regional Network Coordinator attends meetings in an advisory capacity.

Steering Committee: The steering committee is a subset of the Technical Committee, including The Chiefs of Natural Resources, the Network Coordinator, the Science Advisor and the USGS Representative.

NCCN Workgroups. Workgroup members include resource management specialists from throughout the Network, whether on not they regularly attend the TC meetings. There is wealth of technical expertise within these groups, and the members regularly consult a wide array of other experts from universities, agencies, private landowners, and private contractors. The NCCN currently has workgroups in: Aquatic Ecosystems, Air and Climate, Geology, Wildlife, Vegetation, Marine Ecosystems and Data Management.

Network staff. The Network has three full-time data managers – one network data manager stationed at MORA, and two prototype data managers stationed at OLYM and NOCA. Park specialists engaged in Geographic Information System (GIS) and information technology, at OLYM and NOCA are also partially funded. Other technical staff members are engaged with the ongoing monitoring development work, with part or all of their salaries paid through I&M funds.

Park Staff. The level or participation of NCCN park staff is unusually high compared to many other networks for several reasons. First, there is a very high degree of scientific expertise and experience in this network, due largely to the Prototype programs. Second, some inventory and monitoring programs were under development by network parks for many years before NCCN became a network. Third, the Network lacked a Coordinator for many months after receiving funding, requiring the Division Chiefs to begin planning and hold all seven park Vital Sign meetings before the first Network Coordinator arrived (FY01). Together these factors make NCCN a particularly grassroots, bottom-up organization, with a great deal of participation by personnel not paid for by the I&M program. Additional park-level personnel contribute to the effort as circumstances allow.

USGS. The program coordinator for the USGS I&M project for NCCN is also a member of the Technical Committee. Many other USGS employees from a variety of USGS Disciplines and Science Centers collaborate with NPS staff to develop particular protocols.

Other Integral Partners. The Network is fortunate to have nearly a dozen universities, colleges and community colleges located near its member parks. Faculty and staff will be actively engaged in research and monitoring, during and after plan development with coordination from the University of Washington CESU. University staff have helped with the monitoring plan through links to workgroups, active participation in the Vital Signs workshops, and peer-review. Personnel from the USGS Water Resources Discipline, adjacent National Forests, and the Natural Resource Conservation Service (NRCS) have helped NOCA develop protocols for fluvial aquatic systems, primarily focused on glaciers, stream habitat, geologic disturbance, and fish and macroinvertebrate community characterization (Appendix 1.12 of the Phase 2 Report and http://www.nps.gov/noca). These relationships will be strengthened by a network-defined agenda of monitoring and research needs, and by bringing financial and other incentives to the program to attract qualified faculty and students.

1.7 Network Approach to Planning

Although each network and park in the NPS develops a monitoring program to meet its particular needs, there are national guidance and reporting requirements for developing the monitoring program (Table 1.7.1). The first three steps are incorporated in the following summary. The remaining steps are described in subsequent chapters of this plan.

Table 1.7.1. Planning and design schedule for the NCCN Vital Signs Monitoring Program. Grey cells mean that row's activity occurs in that column's fiscal year. The last row shows the planning schedule.

Phase	Task	FY01		FY02		FY03		FY04		FY05	
		Oct-Mar	Apr-Sep	Oct-Mar	Apr-Sep	Oct-Mar	Apr-Sep	Oct-Mar	Apr-Sep	Oct-Mar	Apr-Sep
1	Data gathering										
	Inventories										
	Scoping workshops										
	Conceptual modeling										
2	Vital Sign prioritization										
3	Protocol development										
	Due Dates: Phases 1-3 & Final Monitoring Plan					Ph1		Ph2		Ph3	Final

1.7.1 Data gathering

In preparation for park-specific scoping workshops, NCCN staff located (mined), organized, assessed, and summarized existing data and current levels of understanding of park resources. Network staff accumulated this wealth of information for workshop participants so they would understand park resources, issues, threats, existing monitoring needs, existing monitoring efforts, goals, desired future conditions, and potential partners (See Phase 2, Appendices 1.1 – 1.7: http://www1.nature.nps.gov/im/units/nccn/Reports/NCCN_Phase2_Appendices_v1.doc). All NCCN parks have a history of conducting monitoring to address specific needs (Table 1.6.2). A brief description of the focus of these efforts for the two prototype parks, OLYM and NOCA, can be found in the Phase 2 Report Appendices 1.11 and 1.12 (http://www1.nature.nps.gov/im/units/nccn/Reports/NCCN_Phase2_Appendices_v1.doc). MORA staff have invested considerable time and effort into monitoring biotic and abiotic ecosystem components over several decades (Phase 2, Appendix 1.13, http://www1.nature.nps.gov/im/units/nccn/Reports/NCCN_Phase2_Appendices_v1.doc).

1.7.2 Inventory Efforts

The national I&M program specifies that networks perform specific inventories of natural resources in each discipline (embracing physical science, vascular plants, and vertebrate animals). Inventories give a "snapshot in time" telling managers which species were confirmed as present in the parks at a fixed point in time. Both data gathering and field inventory work for NCCN parks are summarized in Table 1.7.2.

Table 1.7.2. Summary of current NCCN inventory efforts. All data have been collected excepting for rare plants, which will end in 2006. Notations indicate whether the report is final (Final), a draft report is in preparation (Draft), a checklist is complete (Chklist), or progress has been made (Progress).

	Inventory Project Type	EBLA	FOVA	LEWI	SAJH	MORA	NOCA	OLYM
Vascular Plants	Vascular Plants	Draft	Draft		Draft		Draft	
	Coastal bogs & wetland vascular plants							Draft
	Rare plant Inventory					Draft		
	Invasive Plant Distribution					Draft	Draft	Draft
Vertebrates	Birds- Inventory	ChkList	ChkList	Final	Final			
	Birds - Distribution					Final	Final	Final
	Amphibian - Inventory	Draft	Draft	Draft	Draft			
	Amphibian - Distribution					Draft	Draft	
	Intertidal Fish - Inventory	Draft			Draft			Draft
	Freshwater Fish – Inventory			Final*				
	Freshwater Fish – Distribution					Draft	Draft	Final
	Small Mammals - Inventory		Draft	Final				
	Forest Carnivores - Distribution					Draft	Final	Final
	Bats - Inventory				Draft			
Data Mining	NPSpecies certification	Draft	Draft	Draft	Draft	Draft	Draft	Draft
	Wildlife observation database							Progress
	Vascular plant herbarium database						Final	

*The inventory of final for the Fort Clatsop unit; it is underway for the expanded.

1.7.3 Monitoring Efforts

Due to the longstanding nature of NCCN park interest in natural resource monitoring, particularly the Prototype parks, there are already monitoring efforts underway (Table 1.7.3). Additional detail can be reviewed in the NCCN Phase 2 Report, located at http://www1.nature.nps.gov/im/units/nccn/Reports.

Table 1.7.3. Summary of current monitoring efforts - NCCN parks (X = monitoring).

	Ecosystem Component	SAJH	EBLA	FOCL	FOVA	MORA	NOCA	OLYM
Weather/Climate Resources	Particulates/Visibility					X	X	X
	Meteorology (temp., precipitation, etc.)	X	X	X	X	X	X	X
	Snow/Glaciers					X	X	X
	Air quality					X	X	X
	Ozone					X		X
	UV radiation							X
	Wet & dry deposition					X	X	X
	Stream processes						X	
Aquatic Resources	Freshwater Aquatic Habitats							
	Channel & In-stream characteristics						X	
	Riparian characteristics						X	
	Lakes and wetlands					X	X	X
	Marine Aquatic Habitats							
	Near-shore tidal and subtidal	X	X	X				X
	Estuary / river delta	X		X				X
	Aquatic Biotic Communities							
	Salmonids - resident or anadromous fish						X	X
	Native and non-native fish communities						X	X
	Amphibians					X	X	X
	Freshwater macroinvertebrates/plankton					X	X	
	Freshwater and/or marine algae							X
	Marine vertebrates (fish, birds, mammals)							X
	Marine invertebrates							X
	Water Quality Constituents							
	Physical: temperature, conductivity, pH			X		X	X	X
	Nutrients/chemical constituents			X		X	X	X
	Organic pollutants							X
	Water Quantity Measures							
	Gage sites & spot measurements			X			X	X
	Hydrology?						X	X
Geology and Landscape Processes	Geothermal features						X	X
	Terrain features and processes						X	
	River channel geomorphology						X	X
	Volcanic and tectonic processes					X		
Terrestrial Resources - Plants	Selected Plant Communities	X	X	X		X	X	X
	Exotic Plants	X	X	X	X	X	X	X
	Sensitive, rare and threatened plants	X	X			X	X	X
Terrestrial Resources - Wildlife	Northern spotted owls							X
	Mountain goats							X
	Elk and deer population dynamics							X
	Marbled murrelets	X				X		X
	Amphibians	X	X				X	X

Table 1.7.3. Summary of current monitoring efforts - NCCN parks (X = monitoring) (continued).

	Ecosystem Component	SAJH	EBLA	FOCL	FOVA	MORA	NOCA	OLYM
	Native cats						X	
	Mustelids						X	
	Bald eagles	X					X	X
	Sea otters							X
	Dead seabirds							X
	Others				X			
Human Uses	Number of park visitors	X	X	X	X	X	X	X
	Human impacts	X	X	X	X	X	X	X

1.7.4 Workshops

NCCN organized park-specific scoping workshops as well as one network-wide workshop (Table 1.7.4). These workshops were held to identify resource issues, park objectives, and monitoring needs. Scientists from academic institutions, state, tribal, non-governmental organizations, federal agencies, resource management specialists, and interested citizens participated in the workshops. OLYM also held an I&M scoping workshop exclusively for park personnel to have input from a wide representation of park employees. Each of the park-based workshops resulted in a list of perceived natural resource issues and monitoring questions (see Appendix 3.1 of the Phase 2 Report for lists).

Table 1.7.4. NCCN I&M Parks and "Vital Signs" Workshop Dates.

NCCN Park	Workshop Held
North Cascades National Park Service Complex (NOCA)	March, 1998
Olympic National Park (OLYM) - Monitoring Workshop	January 26-28, 1999
San Juan Island National Historical Park (SAJH)	March 20 - 22, 2001
Fort Clatsop National Memorial (FOCL)	May 8 – 10, 2001
Mount. Rainier National Park (MORA)	May 22 - 24, 2001
Ebey's Landing National Historical Reserve (EBLA)	June 5 - 7, 2001
Fort Vancouver National Historic Site (FOVA)	June 19 - 20, 2001
Network-wide VS Workshop	Feb. 26-27, 2002

NCCN staff held a network-wide workshop in February 2002 to apply a network perspective to the park-based lists. The workshop objectives were to: discuss and refine a list of key natural resource questions as the basis for network-wide monitoring; illustrate how these questions can be reassembled and linked into an integrated program that builds upon relationships between key ecosystem components to yield useful information; translate these questions into more explicit components and measurable objectives; provide an opportunity for feedback from participants.

In addition to the workshops targeted to Vital Sign identification, the Network held several workshops to focus on specific subject areas or methodological questions (Table 1.7.5). Examples include a workshop on geo-indicators for OLYM sponsored by the NPS Geologic Resources Division, and a workshop on ultraviolet radiation exposure to learn how increased exposure might influence park visitors and biotic communities. In addition, workshops examining bio-geo-chemical cycles, glacier monitoring, sampling design and trend detection, habitat sampling frameworks for large rivers, persistent organic pollutants (POPs), remote sensing tools, climate monitoring, and terrestrial community diversity indices, to name a few. Others will be held as needed. Subsequent steps in developing our monitoring program include conceptual modeling (Chapter 2), Vital Sign prioritization (Chapter 3) and development of monitoring design (Chapter 4) and protocols (Chapter 5).

Table 1.7.5. Focused Workshops for specific issues within the NCCN.

TOPIC of Workshop	DATE HELD
Indicator selection for ecological monitoring (USGS sponsored)	May 6-7, 1997
Bio-geo-chemical processes	January 16-17,2001
Persistent Organic Pollutants	June 26-27, 2001
Ozone depletion & ultraviolet radiation	July 16-17, 2001
Statistics and sampling design for monitoring (USGS sponsored)	April 2001
Geo-indicators (GRD sponsored workshop)	August 14-15, 2001
Marine intertidal monitoring	February 2002
Network-wide workshop to develop conceptual ecosystem models and prioritize questions	February 27-28, 2002
Soils inventory scoping at EBLA	April 2002
Glacier monitoring symposium	October 2002
Recreational impacts workshop	September 2002
Remote sensing of natural resources (USGS sponsored)	September 2002
Geological resources for network member parks (GRD sponsored)	September 2002
Soils inventory scoping SAJH	February 2003
Weather workshop (NPS and USGS sponsored)	June 2003
Stream workshop	October 2003
Temporal sampling workshop (USGS sponsored)	November 2003

Chapter 2. Conceptual Ecosystem Models

2.1 Conceptual Framework for Monitoring (from Jenkins et al. 2003)

The service-wide monitoring goals of the NPS recognize that ecosystems are fundamentally dynamic and that the challenge of monitoring is to separate ‘natural’ variation from undesirable anthropogenic sources of change to park resources. Although the distinction between natural and anthropogenic change is somewhat artificial, and sometimes difficult to distinguish, we define ‘natural’ change as the normal consequence of often cyclical ecosystem processes that are in a state of dynamic equilibrium in the absence of modern human pressures. By comparison, ‘anthropogenic’ changes result mainly from industrial activities of humans. Anthropogenic changes tend to be directional, rather than cyclical, and may be accompanied by losses in biodiversity and functional integrity. One of the primary intents of monitoring in National Parks, therefore, is to document natural variation in key components of park ecosystems as context for recognizing unacceptable impairment to park resources, identifying the goals of resource restoration projects, and comparing to more altered landscapes outside parks.

How best to meet these goals – whether to focus monitoring efforts on known threats to park resources or on general properties of ecosystem status—was the topic of considerable discussion at a monitoring workshop held at OLYM (Woodward et al. 1999). There are many considerations, including political, inherent in choosing among a strictly threats-based monitoring program, or alternate taxonomic, integrative, or reductionist designs (Woodley et al. 1993, Woodward et al. 1999). To best meet NPS needs, NCCN adopted a multi-faceted approach to monitoring park resources, building upon concepts presented originally for the Canadian national parks (Woodley 1993, Figure 2.1.1). Specifically we chose indicators in each of the following broad categories:

- **Ecosystem drivers** that fundamentally affect park ecosystems,
- **Effects of currently known threats** to the condition of park ecosystems,
- **Basic indicators of ecosystem integrity**, and
- **Focal resources** of parks.

Ecosystem drivers, both natural and anthropogenic, are the primary factors influencing change in park ecosystems. These may be related to global or regional changes in climate, nutrient inputs, or human pressures. At some point it is possible (even likely) that these drivers will exceed their range of natural variation (natural drivers, e.g., climate) or that the ecosystem will lose the capacity to absorb their effects (anthropogenic drivers, e.g., pollutants). Trends in ecosystem drivers will suggest what kind of changes to expect and may provide an early warning of presently unforeseen changes to the ecosystem.

Monitoring **effects of known threats** will provide information useful to management on current issues and ensure short-term relevance of monitoring.

Indicators of ecosystem integrity will provide the long-term baseline needed to judge what constitutes unnatural variation in park resources and provide the earliest possible warning of unacceptable change. NCCN embraced Karr and Dudley's (1981) definition of biological integrity as the capability of supporting and maintaining a balanced, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitats within a region. Ecological integrity includes the summation of chemical, physical, and ecological integrity, and it implies that ecosystem structures and functions are unimpaired by human-caused stresses. Indicators of basic ecosystem integrity are aimed at early-warning detection of presently unforeseeable detriments to the sustainability or resilience of ecosystems.

Focal resources are flagship resources of parks. By virtue of their special protection, public appeal, or other management significance, these resources have paramount importance for monitoring regardless of current threats or whether they would be monitored as an indication of ecosystem integrity.

Collectively, these basic strategies for choosing monitoring indicators achieve the diverse monitoring goals of the NPS. They include many of the criteria that have been suggested previously for selection of monitoring attributes (Davis 1989, Silsbee and Peterson 1991) and used in the NCCN prioritization of Vital Signs (Chapter 3).

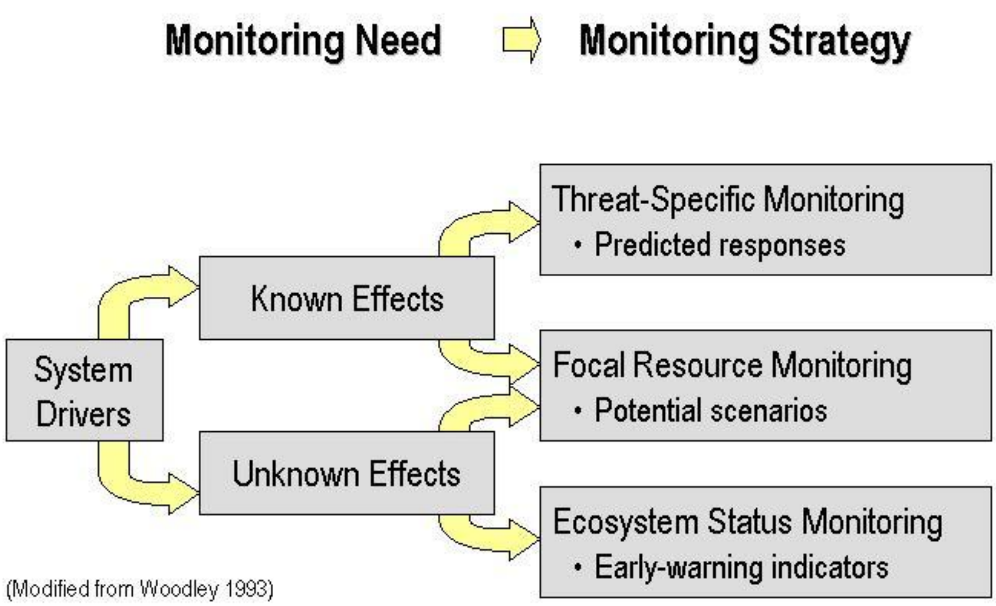

Figure 2.1.1. A multi-faceted approach for monitoring known and unknown effects of system drivers on ecosystem integrity and health in national parks (from Jenkins et al. 2003).

2.2 Purpose of Conceptual Models (excerpted from Jenkins et al. 2003)

Environmental conceptual modeling is the process of articulating relationships among ecosystem components, processes, and environmental effects to help select monitoring indicators. Models can also be tools to communicate why specific indicators were selected. Conceptual models are necessary because different people can have distinct views of a system based on their interests, background and experience. For example, a botanist may see vegetation in terms of individual species and their adaptations, while a wildlife biologist may see vegetation in terms of nutritional value and accessibility for herbivores, and as cover or shelter for carnivores. Conceptual models help create a common perspective, operating hypotheses, and experimental design. We hope to avoid the situation of the fabled blind men who individually insisted they were touching a rope, a tree and a snake instead of the elephant they explored in common. It is also important to recognize that conceptual models are always works in progress, representing state-of-the-art syntheses of understanding. As our perspective responds to new information, either from the monitoring program or from other sources, we must update the conceptual model to reflect new understanding.

There is no single model that adequately describes an entire system because the effort is hampered by the impossibility of achieving both model generality and model realism. Model generality is needed to characterize large-scale influences and relationships among park resources and parks; model realism is needed to identify specific potential expressions of change that could be effective monitoring indicators. Consequently both integrative general models and realistic specific models are needed to represent systems having the spatial scale of National Park networks, and we will present both for NCCN.

2.3 Network-Wide Conceptual Models

Models general enough to describe entire parks or networks will include few details about individual ecosystem components. Instead, they provide a broad vision of how those components interact within and among parks. We present two network-wide models to describe: a) the landscape relationship of park ecosystems, which ones occur in which parks, and how management may respond to changes (Figure 2.3.1), and b) a more detailed holistic model of how categories of park resources interact with one another (Figure 2.3.2).

The seven NCCN parks vary widely in size, composition, and purpose, yet they collectively represent an environmental landscape extending from the coastal intertidal zone to mountain-top glaciers, and they include five ecoregions (Figure 2.3.1). Some resources (e.g., anadromous fish, migratory birds) use more than one ecosystem, creating linkages among parks, while others are park-specific. When resources are threatened, individual parks can respond most directly, but the Network also has some management options. The development of a network monitoring program must recognize that some needs are park-specific, while some have regional components.

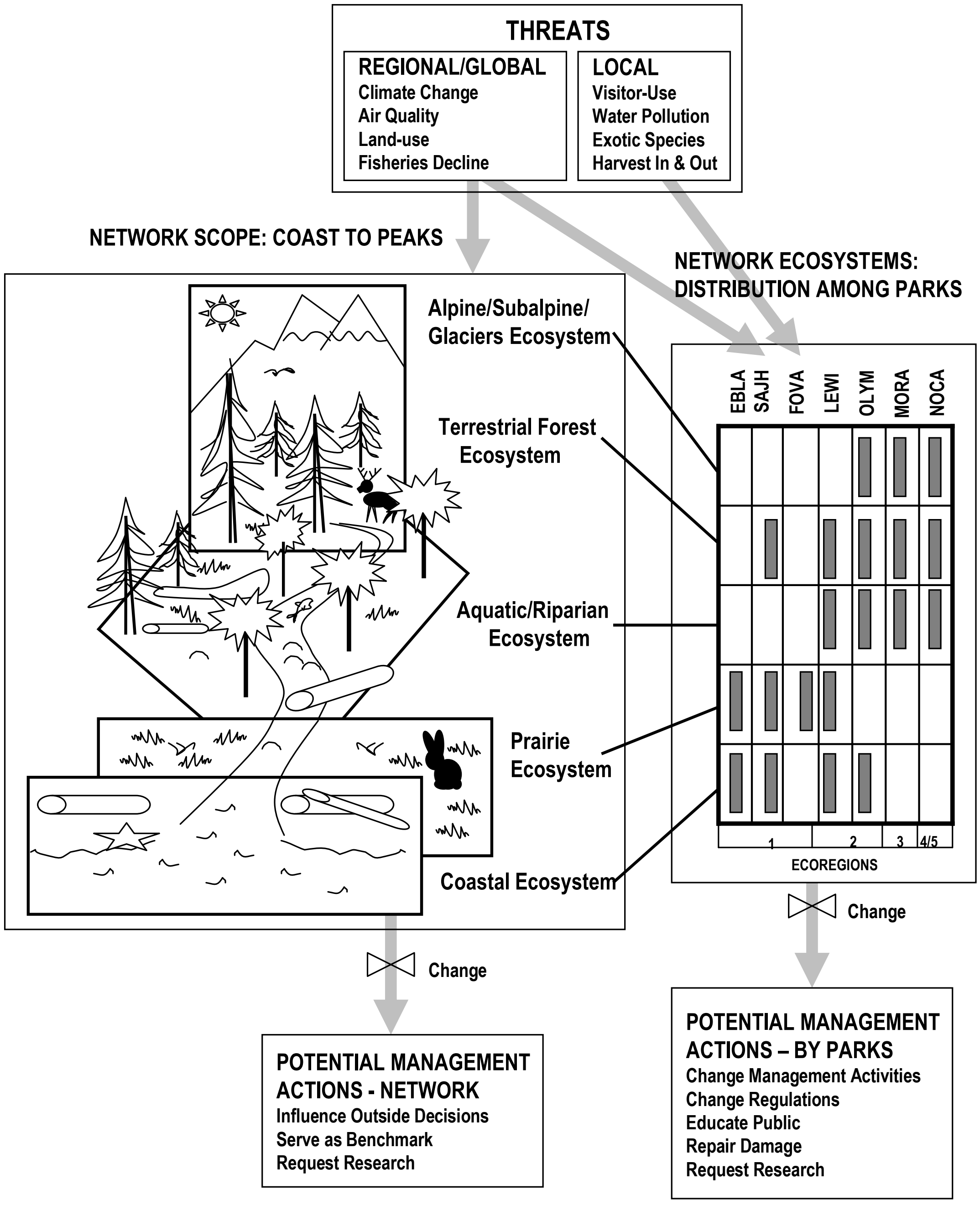

Figure 2.3.1. Conceptual model of the landscape context of ecosystems in the NCCN and their distribution among parks. Regional and local threats are identified as well as possible management responses to changes in park resources.

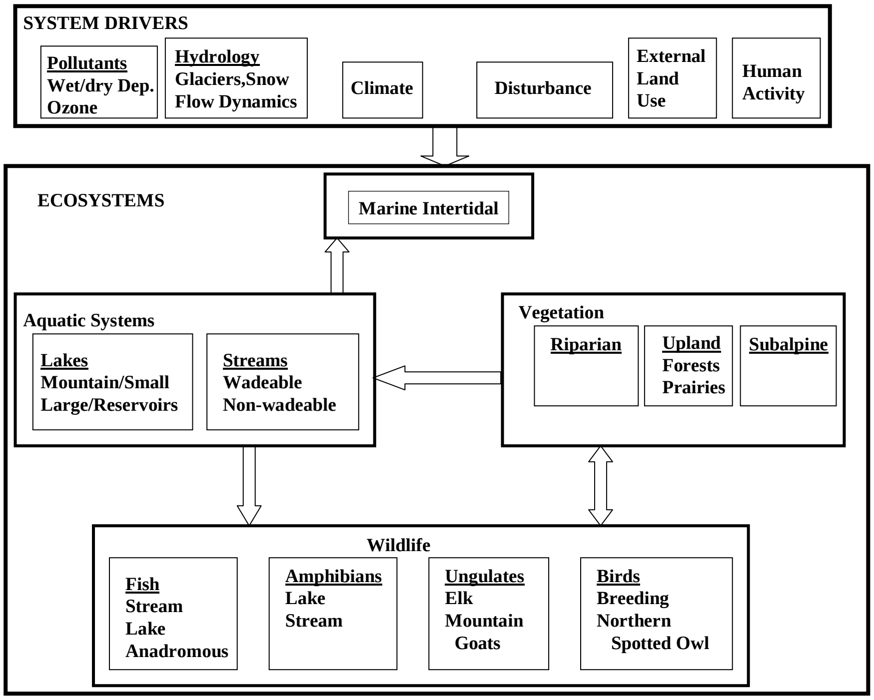

Figure 2.3.2. Holistic model of NCCN ecosystems and components to be monitored, system drivers and their primary interrelationships.

The system drivers important to NCCN include:

- Meteorology/Climate – operating at multiple scales of time and space, and global climate change
- Pollutants transported through the atmosphere – both organic and inorganic
- Hydrology/Geology/Landscape Processes – coupled with climate information; a major driver in aquatic and riparian ecosystems, and including glaciation
- Natural disturbances – nature, magnitude, frequency, duration and persistence
- Human activities – both within and outside park boundaries
- External land and water use – consumptive and extractive use, and conversion to other land uses.

Stressors relevant to different ecosystems, which result when system drivers leave their range of natural variation, are shown in the conceptual models of ecosystems (below). Understanding system drivers and stressors will help build a larger context for analysis and interpretation of monitoring results by describing variability and background levels of important system components and their signals. Many of these drivers are closely interrelated and reflect the interaction of natural processes and human influences. These factors are included in the conceptual ecosystem models that follow.

2.4 Ecosystem Models

The Technical Committee divided the North Coast & Cascades Network into the following ecosystems or components for the purpose of conceptual modeling. The Committee recognizes that these divisions are somewhat arbitrary because all categories are interrelated (Figure 2.3.2):

Aquati cResources
- Lentic systems (e.g., lakes, ponds/wetlands)
- Lotic systems (e.g., streams, rivers)
- Marine coastal/estuary and nearshore
- Glaciers

Terrestrial Resources
- Vegetation (forested, riparian, wetlands, subalpine, alpine, prairies)
- Terrestrial wildlife

The Pacific Northwest, home of NCCN, is characterized by certain features that are implicit in the conceptual models that follow. Large-scale and dynamic geologic processes have created the Cascade (MORA and NOCA) and Olympic (OLYM) Mountains with their steep elevational range from sea level to the top of Mount Rainier (4390 m, 14,411 ft). Bedrock substrates include sedimentary in the western Olympic Peninsula, volcanic near Mount Rainier, and granitic in the northern Cascades. In addition, these substrates have been mixed and moved by continental and montane glaciations. The four small parks are in the Puget Trough which was carved by the Wisconsin ice sheet during the last ice age. At the local scale, bedrock geology, glaciers, running water, climate and vegetation have created a diverse array of landforms with varied soil properties and microclimates.

Mountainous areas are characterized by steep precipitation and temperature gradients. In the Pacific Northwest, mountains intercept moisture-laden maritime air from the Pacific Ocean, causing precipitation to fall heavily on the windward side. The precipitation in NCCN includes extremely moist maritime areas on the coast to semi-arid conditions in the rain shadow of the Olympic and Cascade Mountains. Climate is fundamental in determining the availability of solar energy, ambient temperature, water, and to a lesser degree, soil nutrients, and interacts with geology to create the physical template for vegetation, wildlife habitat and aquatic systems. Climate and geology also strongly influence natural processes and disturbances, most of which have stochastic frequencies, magnitudes and durations. Commonly occurring natural disturbances in MORA, NOCA and OLYM include fire, wind throw, insects, pathogens, disease, parasitism, flooding, glacial activity, and geologic disturbances (e.g., volcanism, slope failures, snow avalanches, earthquakes).

The Water Resources Division (WRD) of NPS has a mandate to distinguish differences in the effects of human-induced disturbance versus natural processes on aquatic communities and habitats. WRD support and oversight is part of the Network's effort to quantify human-induced disturbances to water quality and quantity, habitat destruction or modification, and biological alterations (e.g. non-native species introductions, fish harvest and stocking, logging, etc.).
In addition, parks in NCCN are subject to regional long-distance transport of air pollutants (sulfur and nitrogen oxides, ozone, particulates, toxic pollutants) from various mobile and

stationary sources, from as far north as Vancouver BC and south to Portland Oregon. Canadian sources from the Lower Frasier Valley also affect air quality in NOCA and possibly SAJH. Most stationary and mobile sources are in metropolitan Seattle-Tacoma and Portland regions. Trans-Pacific transport of persistent organic pollutants (POPs) is also occurring (Bailey et al. 2000).

NCCN conceptual ecosystem models are in the form of box and arrow diagrams illustrating interactions among ecosystem components. NCCN staff members are also aware of other factors that are important for describing ecosystems (Pickett and Cardenasso 2002). Because some of them are difficult to illustrate, they are expressed separately from the models (Table 2.4.1). Each model includes all or a subset of the important system drivers listed above along with relevant stressors (top row of each model) and the ecosystem responses. In some models, the width of arrows indicates the strength of relationships.

Our conceptual model for choosing indicators (Figure 2.1.1) stresses the need to consider both known and unknown effects of ecosystem drivers in order to understand their effects on focal species and status indicators. The following more specific conceptual models of individual ecosystems relate to the general model by showing system drivers and the foreseen stressors that may result from each. These models also identify indicators of ecosystem status. Some of these integrative indicators include invertebrate and algae communities (lentic, lotic and coastal models), mass balance (glacier model) and community structure and compositions (vegetation and wildlife models). Focal species chosen for monitoring through our prioritization process (Chapter 3) are also indicated in the models.

Table 2.4.1. Key attributes of North Coast & Cascades Network conceptual ecosystem models (inspired by text in Picket and Cadenasso, 2002).

Conceptual Model of Ecosystem	Biotic/Abiotic elements	Temporal Scales (yr.)	Spatial Scales	Direct Linkages	Indirect Linkages	System boundaries & constraints
Aquatic- Lentic systems (lakes, ponds, etc.)	Organic and inorganic nutrient inputs; water	$10^0 – 10^5$ yr	10^{-1} m– 10^2 (km^2)	Climate, geology, hydrology	Soils, nutrient cycling, atmos. deposition; climate	Hydrologic divides; input & output paths; limits to productivity
Aquatic- Lotic systems (streams, rivers, etc.)	Water, nutrients, organic debris, sediment, vertebrate & invertebrate biota	$10^0 – 10^5$ yr	10– 10^4m; 10^{-1} m^2 - 10^4 (km^2); Watershed, stream, segment, reach, pool/riffle	Upland and riparian processes, nutrient inputs and uptakes; hyporrheic zone; beavers	Climate cycles and extremes; geologic processes; disturbance legacies; hydrologic cycles	Valley form and channel constraints; upstream barriers to migration; declines in salmon runs
Aquatic- Coastal marine ecosystems	Water, nutrients, organic debris, sediment, vertebrate & invertebrate biota, algae	$10^0 – 10^6$ yr	$10^{-1} – 10^5$ m	Upstream inputs/ river transport processes, long and x-shore; upwelling -nutrient inputs and uptakes	El Nino, up welling; watershed processes w/ water & sediment	Salinity & temp grad., currents, magnitude of inputs from tributaries
Glaciers	Precipitation, Deposition Temperature, Topography, Invertebr.	Seasonal Annual Decadal	Watershed local	Climate, Hydrology (flow amt & timing, clarity, temp)	Aquatic biota, habitat, stream channel morph.	Weather (Climate), geomorphology

Table 2.4.1. Key attributes of North Coast & Cascades Network conceptual ecosystem models (inspired by text in Picket and Cadenasso, 2002) (continued).

Conceptual Model of Ecosystem	Biotic/Abiotic elements	Temporal Scales (yr.)	Spatial Scales	Direct Linkages	Indirect Linkages	System boundaries & constraints
Terrestrial Vegetation	Geology/soil microclimate	Seasonal, $<1 - 10^3$ yr	$1 m^2 – 10^4 km^2$	Wildlife, soils, lithology, topography	Nutrient cycling; radiation; atmos. deposition	Vertical limits to distrib. imposed by climate/soils
Terrestrial Wildlife	Structural diversity of habitats; link to trophic relations.	Seasonal, $<1 - 10^2$ yr	$10 m^2 – 10^3 km^2$	Vegetation community structure, water, climate	Climate/weather, soils	Vertical & horizontal limits to distribut.

2.5 NCCN Ecosystem-Scale Conceptual Models

2.5.1 Conceptual Model for Lentic (non-flowing) Aquatic Ecosystems

The NCCN contains over 1300 glacial montane lakes and ponds in MORA, NOCA and OLYM, and several large lowland lakes and reservoirs in OLYM, NOCA and EBLA. These diverse systems differ in geologic and climatic setting, geological age, geomorphic origin, elevation, aspect, and extent of glacial influence, vegetation, morphology, and trophic status. The conceptual model is necessarily general (Figure 2.5.1) and operates on a seasonal to decadal temporal scale depending upon the specific component. Stressor effects on ecosystem processes are considered below.

Over the long-term, climate and geomorphic processes such as tectonics and glaciation form a geologic template that determines lake evolution and development. Geologic and climatic processes influence lake physical and chemical regimes through their impacts upon watershed structure (Aber and Mellilo, 1991), lake morphometry (Rawson, 1955), rate of soil maturation (Buol et al., 1973), and vegetation (Mosello et al., 1990). Developmental processes that are constrained or enhanced by climate include drainage network development, organic material accumulation, and sedimentation. These processes affect the rate and path of water movement through watersheds which affects nutrient concentrations in lakes.

In the shorter-term, climate affects both upslope 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, temporal patterns in thermal regimes, productivity, and distributions and abundance of aquatic biota (Schindler 1997).

Land use includes stressors that exist both within and adjacent to the parks. Some examples include activities such as logging and road management. These activities may result in increased erosion and sedimentation in lentic systems (Eilers et al. 1996). Point source pollution from residential development and park utilities (e.g., septic systems, fuel tanks) located in lake watersheds can affect nutrient cycles by altering productivity levels, and distribution and abundance of aquatic biota (Carpenter and Cottingham 1997, Harper 1992, National Research Council 1992).

Activities associated with park recreational activities such as camping and hiking within lake watersheds, can alter physical, chemical and biological processes, such as nutrient cycling and sedimentation. Trampling in the littoral areas may result in direct habitat disturbance, altering food web structure.

Non-native fish stocking in naturally fish-free lakes has been a controversial issue since the 1960s because over 90 percent of the mountain lakes west of the Rocky Mountains were naturally fish-free (Bahls 1992). Numerous mountain lakes in the NOCA Complex, OLYM, and MORA were stocked for fishermen with non-native fish, and contain extant fish populations. Non-native fish create direct and indirect impacts through alteration of the natural aquatic food chain by consuming preferred prey species such as zooplankton, benthic macroinvertebrates, and amphibians (Markle 1992). Amphibians are displaced as top predators to become primary prey.

Non-native fish may also disperse from lakes and hybridize with native fish species. Indirect impacts such as trampling of native vegetation by recreational fishermen and introduction of pathogens by fish stocking may also impact native communities (Beauchamp 1995).

Airborne pollutants of interest, including nitrates, sulfates, mercury and pesticides, are chemicals that can cause changes in surface water chemistry and aquatic biota populations when deposited in rain, snow, cloudwater or as dry deposition. Sulfur and nitrogen deposition in MORA and NOCA is believed to be exceeding acceptable levels based on modeling and field studies (Vimont 1996, Clow and Samora 2001). Eighty to 99% of sulfur emissions and 83%-95% of nitrogen oxides (N) emissions are anthropogenic in origin (NAPAP 1991b).

High priority indicators of lentic habitat include *chemical and physical water column properties* (e.g., Secchi disk, pH, dissolved oxygen, contaminants), lake *morphometry* (area and perimeter) and distribution of *large woody debris*. These are the fundamental determinants of habitat quality for aquatic biota. *Zooplankton* and *macroinvertebrates* are important integrative indicators of lentic ecosystem status. *Fish* and *amphibians* are the subjects of important management concerns as well as representing important

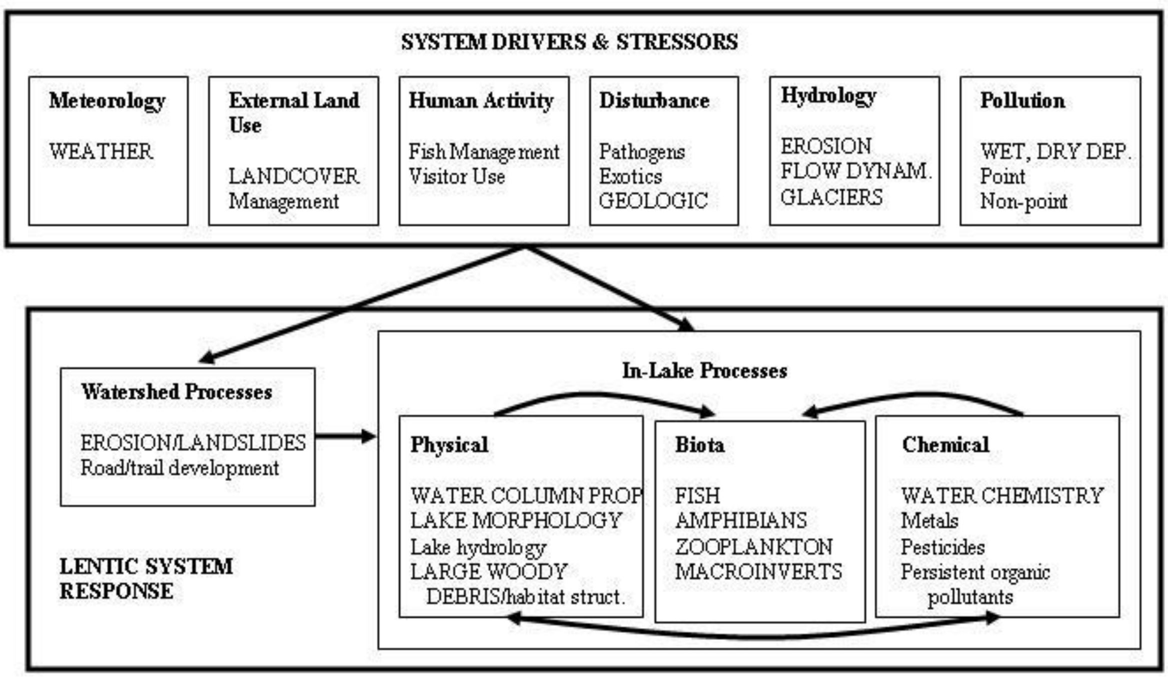

Figure 2.5.1. Conceptual model for the lentic (lake and pond) component of aquatic ecosystems in NCCN. Indicators for stressors and ecosystem components funded for monitoring by NPS monitoring or other programs are shown in capital letters.

2.5.2 Conceptual Model for Lotic (flowing) Aquatic Ecosystems

Although lotic ecosystems include all running waters, we have chosen to focus specifically on perennial rivers and streams which are present in at least five of the seven NCCN parks. Other

lotic systems, such as seeps and riverine wetlands, are recognized as important habitat for many endemic species, but are not addressed here.
The conceptual model (Figure 2.5.2) describes our understanding of the interaction and integration of hill-slope, riparian and in-channel processes, and the ecological functions provided by these features. We recognize that these factors can drive the expression and interaction of physical, chemical and biological components of ecosystems.

Stream dwelling plant and animal communities will colonize and persist in a given stream by virtue of their ability to thrive under the physical and chemical conditions imposed by the dynamics of the stream system. Several paradigms have been developed to describe and explain spatial patterns of biota in rivers and streams (Vannote et al.1980, Elwood et al. 1983, Naiman et al 1988). Our model recognizes the interactions among habitat features, relative stream position, and biotic components by incorporating living communities as well as physical instream and riparian characteristics.

Natural factors that help determine the form and functions of both fresh and marine aquatic ecosystems in NCCN parks include climate, geology, and processes influenced by both natural and human disturbances. Specifically, watershed characteristics and valley form determine in large part the pattern and profile of rivers and streams, as they adjust to valley gradient and varying supplies of water and sediment inputs. Stream channel dimensions are also affected by the input of sediment and flow regimes as constrained (or not) by valley-wall features and riparian conditions (Montgomery and Buffington 1997, Leopold et al. 1964, Dunn and Leopold 1978). The spatial distribution of reach types within a drainage basin influences the distribution of potential input sources for wood, water and sediment, and channel responses to disturbance (Montgomery and Buffington 1998).

In general, rivers and streams in this network, experience seasonal patterns of precipitation which create an annual hydrologic regime having one peak of runoff with timing depending on elevation (Naiman and Anderson 1996). In the lower gradient fluvial systems (<4% gradient), flood-level flows recur at approximately two-year intervals and can significantly reshape local channel dimensions and pool/riffle characteristics.

Frequency and size of flood events also affect the supply and delivery of water, sediment and large woody debris to stream channels (Ziemer and Lisle, 1998). Originating primarily in the upslope zone of forested watersheds, heavy precipitation associated with seasonal “rain on snow events” trigger slope failures and floods from breaking of in-channel debris-dams, which can contribute large volumes of sediment and organic debris into stream channels. Debris and sediment are then transported downstream at rates that vary with inherent channel transport capacity. The frequency, magnitude, spatial extent and duration of sediment, organic debris and flow fluxes through the system determine the rate and characteristics of changes to the physical, chemical and biotic features of streams (Bilby and Bisson 1998). These changes occur at multiple spatial scales and persist for varying periods of time.

Water temperature, habitat, fish, water quality and biologic integrity (based on macroinvertebrates) were chosen as our highest priorities for monitoring lotic systems (Figure 2.5.2). *Water temperature* greatly influences a number of biotic processes (McClain et al. 1998) leading to changes in distributions of biota, which are greatly influenced by small changes in water temperature. Shifts in species distribution can affect a number of important community processes including competition, reproduction, growth rates, and productivity. Global climate change and land management activities on adjacent lands may alter temperature regimes in NCCN aquatic systems (Oswood et al. 1992, USDA Forest Service 1994).

Evaluation of *aquatic habitat* is critical to understanding natural processes and the interpretation of impairment. Aquatic habitat complexity is a primary factor influencing the diversity of fish, amphibian, and macroinvertebrate communities (Evans and Noble 1979, Angermeier 1987). Attributes of aquatic habitats include the variety and range of hydraulic conditions (e.g. width, depth, and water velocities), numbers of pieces and size of wood, types and frequency of habitat units, and variety of bed substrate, water temperature, and water chemistry parameters (O'Neill and Abrams 1987).

Fish occur in at least four of the seven NCCN parks and are ecologically, culturally and economically important. Often the most stringent constraints on water quality stem from the need to protect coldwater fisheries. Ecologically, fish are important because they represent the higher trophic levels in streams and lakes and also provide a food source for terrestrial fauna. The presence or absence of particular species can be a quick and important indicator of serious impairment. Fish can be a useful integrator of a variety of physical and biological factors including streamflow, sediment, temperature, turbidity, pH, dissolved oxygen, stream habitat structural components, productivity, and food availability (Schoener 1987). All species of Pacific salmon are found in NCCN waters. Several salmonid species are either listed as threatened or endangered under the Endangered Species Act, or are considered as candidate species for listing including: chinook salmon, bull trout, and cutthroat trout. Stocking of nonnative fish species and strains, fish harvest and habitat impairment has seriously affected fish populations (Ki et al. 1987, Hicks et al. 1991, Bisson et al. 1982), including those in OLYM, NOCA and MORA).

Biological integrity and *water quality* are also components of the monitoring program. The assessment of water quality has historically focused on chemical parameters and comparing concentrations to state or federal criteria or standards, which we will continue to do. Recently there has been an increase in the use of biological indicators for the assessment and monitoring of surface waters (Karr 1991, Davis and Simon 1995, US EPA 1996b,c). Among the variety of reasons for the increased use of bio-indicators is the time-integrated assessment of both physical and chemical alterations they provide. Within a given habitat certain expectations for community composition and abundance can be defined. Deviation in these biological attributes from a presumably unimpacted "reference condition" provides the framework for impairment diagnosis (Karr 1998). The multivariate nature of complex biological systems requires that we interpret changes based on a number of biological attributes, including a variety of organisms, trophic classes and functional groups. Assessments of biological integrity will use the community and indicator species metrics that have already been developed for assessment of environmental impairment, primarily benthic macroinvertebrates (BMI) and fish (Fore et al. 1996). However, it is important to evaluate these assessment tools for their applicability to NCCN streams and rivers.

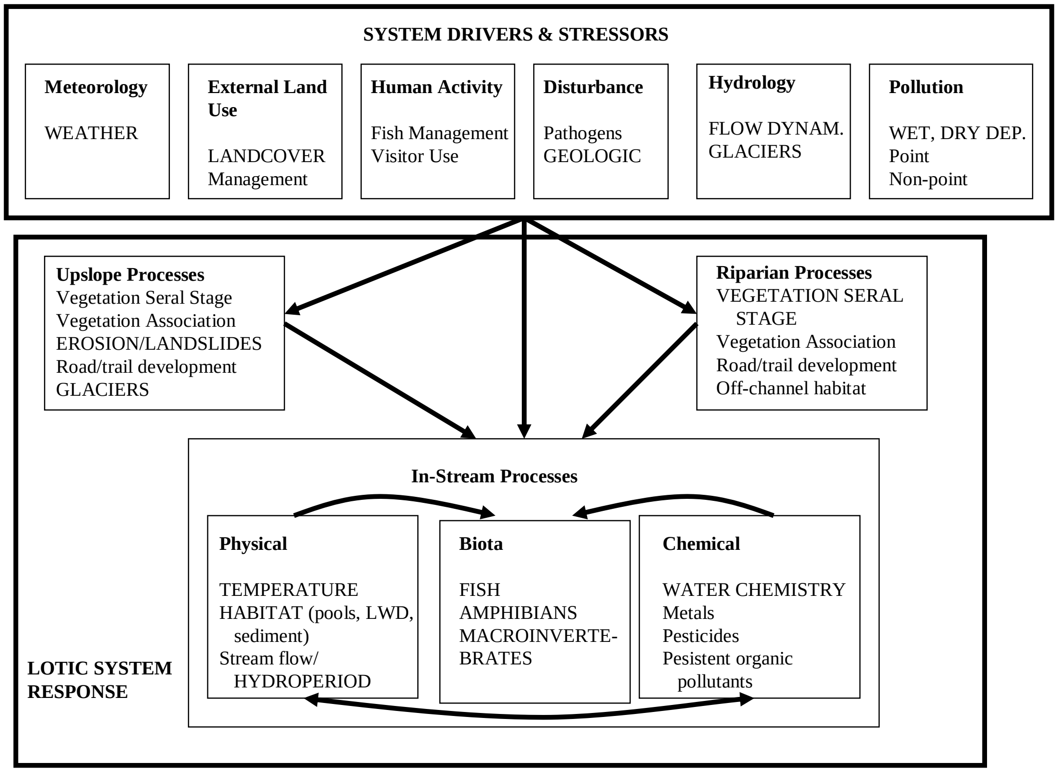

Figure 2.5.2. Conceptual model for the lotic (flowing freshwater) component of aquatic ecosystems in NCCN. Indicators of stressors and ecosystem components funded for monitoring by NPS monitoring or other programs are shown in capital letters.

2.5.3 Coastal Marine Ecosystem Model

Four out of the seven parks within the Network (OLYM, LEWI, EBLA, SAJH) have direct connections to marine ecosystems whereas the other three are connected indirectly (FOVA, NOCA, MORA). EBLA on Whidbey Island, and SAJH, on San Juan Island, have marine shorelines and/or tidally influenced estuarine habitats within their jurisdictional boundaries; the 65-mile coastal strip of OLYM contains both coastal riparian and marine inter-tidal habitats. LEWI has both estuarine, tidally influenced river habitat and marine shores and the shoreline of FOVA is on the tidally influenced portion of the lower Columbia River. NOCA and MORA are linked to the marine environment by anadromous native salmon returning to spawn in their natal rivers, returning marine-derived nutrients to these parks and benefiting a host of aquatic and terrestrial organisms (Cederholm et al. 1989, Larkin and Slaney 1997). The remote wilderness Pacific coast (OLYM), Puget Sound areas (EBLA, SAJH), and the Columbia River marine region (LEWI) in NCCN encompass unique coastal ecosystems of the contiguous United States (Menge and Branch 2001).

Network marine areas host a diverse array of protected and exposed habitats, including sandy beaches, cobble beaches, boulder fields, rocky platforms, cliffs and estuaries. These habitats support assemblages of macroalgae, invertebrates, and fish that represent the most bio-diverse marine region on the west coast of North America (Ricketts 1985). The intertidal zone is tightly linked to adjacent nearshore zones through physical processes and influences, and by the complex life-histories of most marine organisms that utilize both intertidal and nearshore zones during their life-cycle These biotic and abiotic processes operate across a range of spatial and temporal scales. Vertical limits of zones are set by tide height, physical disturbance regime, accumulation of sediments, and biotic interactions. The horizontal limits of community distribution are set by shoreline geomorphology, along-shore currents, and temperature and salinity gradients. (see for example, Downing 1983, Menge and Branch 2001).

Coastal habitats are not closed systems, and are affected by changes in oceanic processes operating at nearly global scales (e.g. El Nino cycles, sea-surface temperature changes) as well as near-shore processes (e.g. sediment fluxes and transport shift, current oscillations; Menge et al. 2003, Menge 2004). Consideration of linkages between the intertidal and subtidal/near-shore zones is necessary for adequate treatment of intertidal monitoring needs (Gaines and Roughgarden 1987). Ecologically there are substantial physical and biological linkages between these zones that are critical in determining zonal community structure (Possingham and Roughgarden 1987, Underwood and Chapman 1996). Accounting for and understanding the mechanisms for effects associated with system drivers are key to understanding, interpreting and anticipating possible outcomes from the interplay of these factors in the marine/terrestrial ecotone. We will also need to understand the influence of stressors associated with increasing human use of the near-shore marine environment in order to craft appropriate management plans to address unacceptable change. Changes to the various trophic webs of marine life (plants and animals, vertebrates and invertebrates) in these coastal areas will be the key focus for the intertidal monitoring program.

The conceptual model of coastal ecosystems (Figure 2.5.3) is a stressor-based model (*sensu* Cloern 2001) that illustrates the linkages between system drivers (major external forces), stressors (perturbations) they produce, and emergent ecosystem responses caused by stressors. Ecosystem responses are partitioned into top-ranked Vital Signs and other ecosystem responses.

The type and magnitude of drivers and stressors vary among NCCN marine parks, so this model is general, representing features common to all. The model emphasizes the intertidal zone because it is directly relevant to all NCCN marine parks; subtidal, nearshore and terrestrial components are included only where they directly influence the intertidal zone. The modeled stressors and responses are expected to operate on a seasonal to decadal scale, depending upon the specific process under consideration.

Six drivers are identified in the model: pollution, human activity, external land use, disturbance, hydrology and meteorology. These drivers produce ten stressor categories (Table 2.5.3) that ultimately affect intertidal biota and/or habitat. Alteration of intertidal habitat (e.g., shoreline change) can directly affect intertidal biota. Biota are affected through alteration of competitive and/or predator-prey interactions, and mortality associated with intoxication and direct removal.

Table 2.5.3. Specific examples of types of stressors that may occur in NCCN marine parks.

Stressor	Examples
Marine Deposition	Toxic spills, marine debris, Nutrient inputs from ships
Terrestrial Runoff	Toxic spills, nutrient inputs from Septic/waste systems
Visitor use/harvest	Trampling, Harvest
Exotic Introduction	Alien species introduction
Management Activities	Shoreline modification,
Sediments & Water temp	Terrestrial runoff of sediments &/or surface water
Shoreline modification	Breakwater, shoreline stabilization, etc.
Geologic activity	Earthquakes, etc.
Near-shore water movement	Shoreline modification effects on circulation patterns
Precipitation, temp, sea level	Global climate change

High-priority indicators for intertidal habitat include *shoreline morphology* and *water temperature*. Shoreline morphology determines the available substrates for biota and may be affected by changing sea level; water temperature is a fundamental property of intertidal habitat and may respond to global warming and changing sea surface temperature patterns. The metric chosen for monitoring biota is *community composition of macroalgae and invertebrates* due to its complexity and potential response to the variety of stressors.

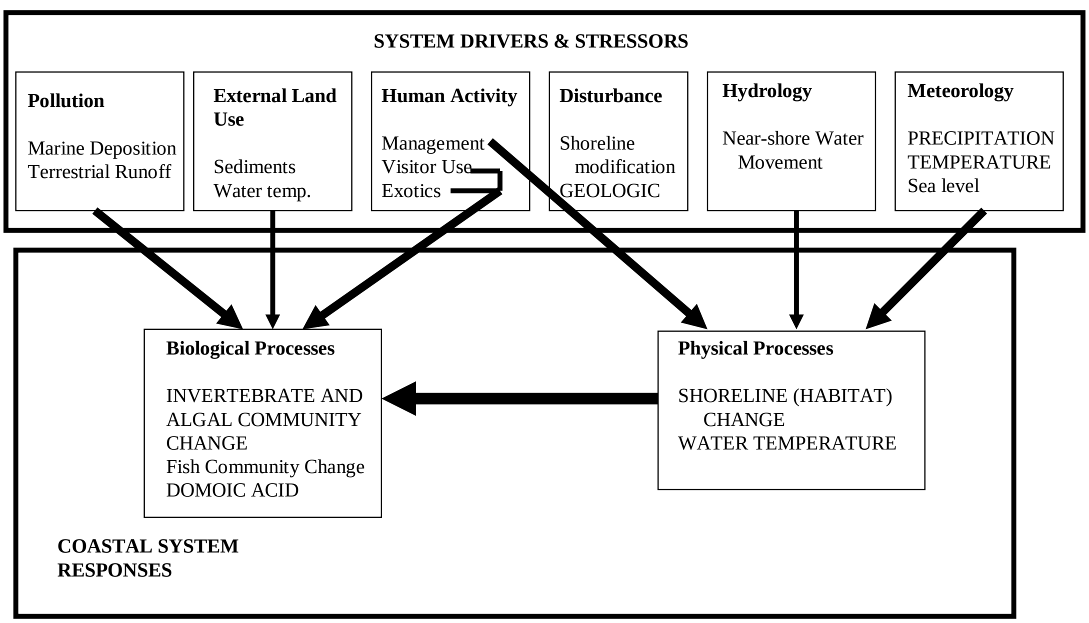

Figure 2.5.3. Conceptual model of the coastal component of aquatic ecosystems in NCCN. Indicators of stressors and ecosystem components funded by NPS monitoring or other programs for monitoring are shown in capital letters.

2.5.4 Conceptual Model for Glaciers

Glaciers are a significant resource of many mountainous areas of the world including the three large parks in this network, where glaciers collectively cover 235km^2. Glaciers are integral components of the region's hydrologic, ecologic, and geologic systems, and they are melting rapidly. At NOCA, geologic mapping data and a 1998 inventory (Granshaw, 2001) indicate that glacier area has declined 44% in the last 150 years.

The role of glaciers in Pacific Northwest ecosystems is illustrated in a glacier-ecosystem conceptual model (Figure 2.5.4). Glacier changes are driven primarily by climate, and in special cases, tectonic processes such as geothermal ablation and debris cover from landslides. Topographical factors interact with weather, climate, and glacier movement to influence glacier change. Glaciers integrate these factors and export landforms (soils and terrestrial habitat) and meltwater (aquatic habitat, nutrient cycling, and water supply: Post et al. 1971, Hartzel 2003, Riedel and Burrows 2005). Further, glaciers are habitat to a number of species, and are the sole habitat for ice worms (*Mesenchytraeus solifugus*) and certain species of springtails (Collembola; Hartzell 2003). Glaciers significantly change the distribution of aquatic and terrestrial habitat through their advance and retreat. They directly influence aquatic habitat by the amount of cold, turbid meltwater and fine-grained sediment they release. Glaciers also indirectly influence habitat through their effect on nutrient cycling and microclimate. Many of the subalpine and alpine plant communities in NCCN flourish on landforms and soils created by glaciers during the last century.

The influence of glaciers on regional hydrology is immense in both the quantity and timing of discharge of glacial meltwater. Post and others (1971) estimate that glaciers contribute 800 million cubic meters to streamflow annually in the North Cascades alone. In the Thunder Creek watershed (250 km^2 area; NOCA), glaciers contribute as much as 45% of the total summer runoff. More importantly, glacial meltwater delivery peaks during the hot, dry summers in the Pacific Northwest, buffering the region's aquatic ecosystems from seasonal and interannual droughts Meier 1969, Meier and Roots 1982). Aquatic ecosystems, endangered species such as salmon, bull trout and western cutthroat trout, and the hydroelectric and agricultural industries benefit from the stability glaciers impart to the region's hydrologic systems.

The sensitive and dynamic response of glaciers to variations in both temperature and precipitation makes them excellent indicators of regional and global climate change at multiple time scales Bitz and Battisti 1999, Pelto and Riedel 2001). This feature of glaciers is particularly valuable at remote high elevation sites in the NCCN, where meteorological data are not available. Glaciers also provide valuable insight to climate change over longer time periods than most other climate measures (Paterson, 1981).

We have chosen *mass balance* as our indicator of glacier change because it gives an annual assessment of glacier response to particular weather conditions. It is easier to relate to climate than the lagged response of the glacier terminus.

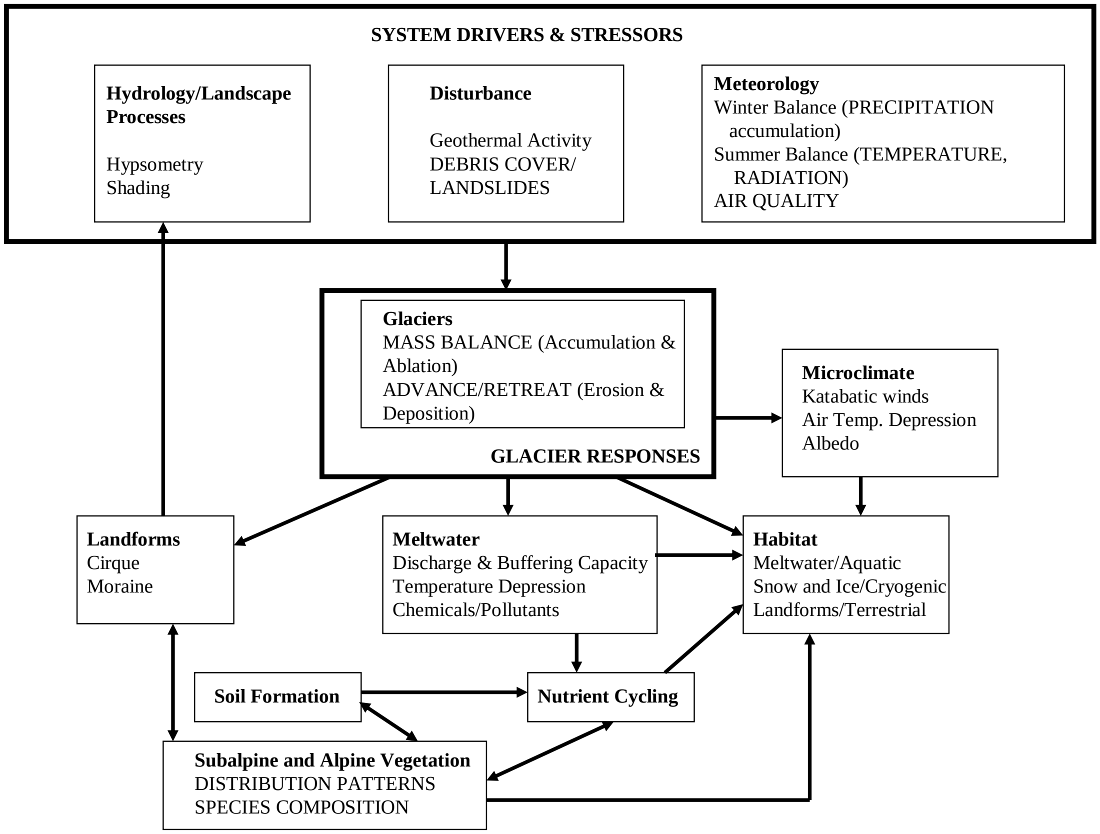

Figure 2.5.4. Conceptual model for processes and functions of the glacier component of aquatic ecosystems in NCCN. Indicators of stressors and resource responses funded for monitoring by NPS monitoring or other programs are shown in capital letters.

2.5.5 Terrestrial Vegetation Model

Vegetation is the great integrator of the biological and physical environment, and is the foundation for trophic food webs and animal habitat (Gates 1993, Pastor and Post 1986, 1988). Consequently, results from monitoring vegetation and associated ecological processes are an essential tool for detecting changes occurring in park ecosystems (Figure 2.5.5).

Natural forces shaping vegetation in the Pacific Northwest include climate, geology, and local-to landscape-level processes that are associated with disturbance (Henderson et al. 1989, Franklin and Dyrness 1988). Climate is fundamental in determining the availability of energy, water, and soil nutrients. Geology interacts with climate to create the template for vegetation growth and establishment. The diversity of vegetation types resulting from the mosaic of environments in NCCN includes alpine areas, subalpine parklands, montane and low-elevation forests dominated by hemlock, Douglas-fir, or Ponderosa pine, coastal rainforests dominated by Sitka spruce, wetlands, prairies and coastal grasslands, and numerous types of riparian zones. These various vegetation types will respond to environmental changes in different ways (Barnosky 1984, Davis 1981). Consequently, patterns of vegetation change in relation to environmental gradients offer a superb opportunity to detect a variety of natural and anthropogenic mechanisms.

Human-caused disturbances also affect vegetation composition. Locally, park visitors and the park management necessary to accommodate them can affect vegetation (OLYM 1999, NPS 1997). Trampling from hiking and camping, run-off from roads and hardened trails, and legal or illegal plant collection, are among the various mechanisms. At the landscape scale, changes in land use surrounding parks (e.g., timber harvest, development) can disrupt corridors of dispersal for some native plants and encourage the spread of unwanted exotic plants, and increase the susceptibility of park edges to wind throw (Souies 1997, ONP 1999). Regionally and globally, air pollution can alter vegetation by affecting nutrient cycles and compromising plant health. Natural and anthropogenic forces can also interact with plants by affecting their associated soil and soil organisms.

Vegetation is the base of terrestrial food chains, and therefore has many important interactions with wildlife. As well as providing nutrition and structural resources for animals, vegetation structure and composition is in turn, shaped by animals that occupy these habitats. For example, herbivory by animals (from insects to ungulates), can have a profound effect upon vegetation community structure and subsequent function. Integration of vegetation and wildlife monitoring efforts will increase our understanding of both communities.

Both riparian and upland vegetation play important roles in aquatic ecosystems. Vegetation can shade stream channels and influence water temperature, contribute leaf-litter and other energy sources to aquatic food webs, provide large wood to affect in-stream habitat, and influence the rate of delivery of sediment to streams. Thus we need to integrate aquatic and vegetation monitoring.

Priorities for vegetation-related monitoring encompass landscape, ecosystem, community, and species scales. Both *disturbance* and *vegetation patterns* at the landscape scale are high priorities. *Riparian vegetation* will be monitored using aerial photos to indicate community types and ages. Priorities for community-level monitoring include structure and composition of *forests*, *subalpine vegetation*, and *prairies*. At the species level, tracking abundance and distribution of *invasive species* is the highest priority.

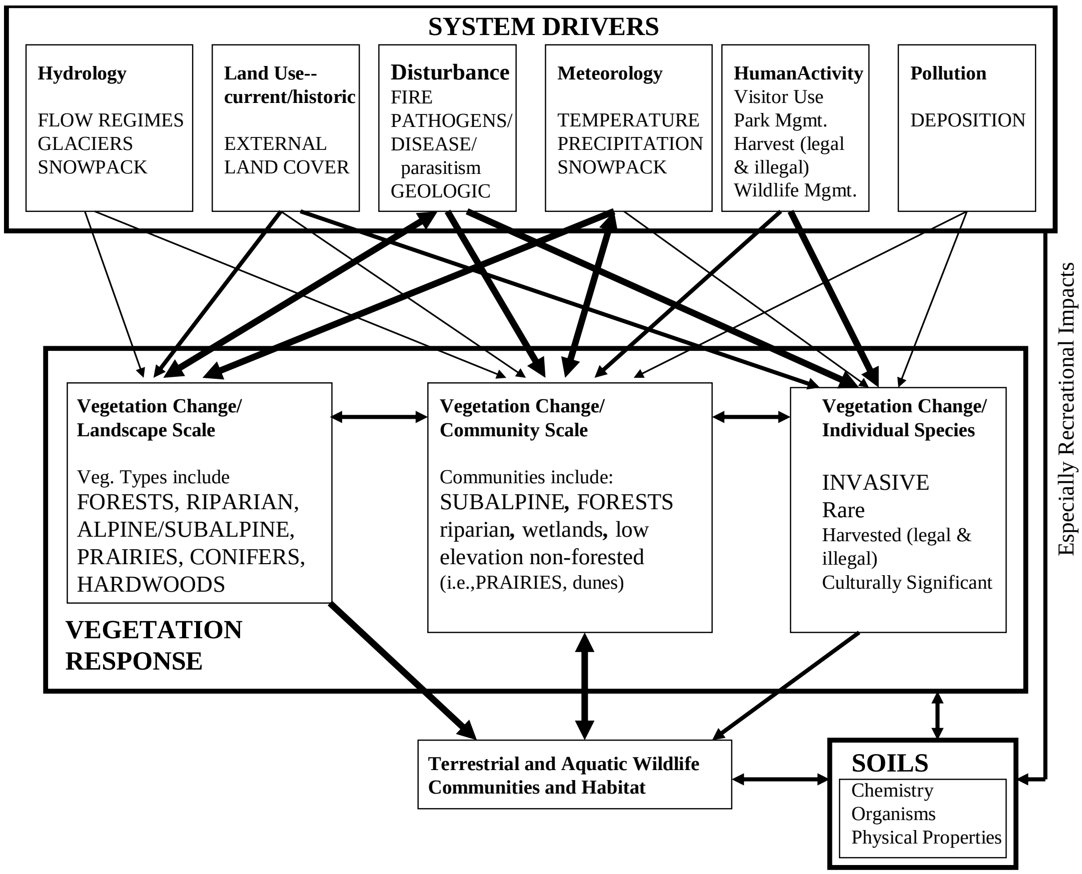

Figure 2.5.5. Conceptual model of vegetation component of terrestrial ecosystems in the NCCN. Arrow width indicates strength of interaction. Indicators for stressors and ecosystem responses funded for monitoring by NPS monitoring or other programs are shown in capital letters.

2.5.6 Terrestrial Wildlife Conceptual Model

Acting as bio-monitoring indicators, animal populations can provide excellent evidence of environmental change. Selected to complement physical monitoring, they can help us understand cause and effect relationships in community dynamics. Animals that are high on the food chain can act as suitable monitors of signals that accumulate in their environment (e.g., DDT can cause eggshell thinning). Long-lived species are capable of integrating the effects of environmental stresses over time. Animals also have widespread public interest.

In the terrestrial wildlife conceptual model (Figure 2.5.6), system drivers identified as key forces shaping wildlife communities in NCCN parks include climate and weather, landscape use patterns, natural disturbances, and human induced disturbances. These system drivers shape wildlife communities by influencing wildlife species presence/absence, abundance, fitness, and viability, in several ways and at different scales. The single most important way system drivers shape wildlife communities is through wildlife habitat creation and change within and outside park boundaries. We define wildlife habitat as the suite of environmental attributes species must have in order to survive and reproduce. In our conceptual model, habitat at the community level is comprised of attributes like cover type, structural condition, and plant species composition. At the landscape level, heterogeneity of vegetation communities, patch size, and fragmentation represent influences shaping wildlife communities. Though direct linkages are not shown in the model between system drivers and vegetation (wildlife habitats), they exist at the strongest levels of interaction. Linkages between all the system drivers and habitats occur, but are not shown, to simplify the figure. The boxes between system drivers and vegetation are examples of ecosystem responders, some of which have been selected for long-term monitoring.

It is important to note that interactions between wildlife communities and their environment are not unidirectional. Wildlife communities can influence their own environment though direct manipulation (e.g., changing vegetation structure and volume through deer and elk browsing and trampling). Component species of animal communities interact with each other (e.g. predator – prey relationships, colonization and displacement by exotic species). The interactions shown in this model are dynamic and fluid.

Climate and weather not only shape wildlife communities by their influences on habitat, but also by direct effects upon the individual and populations. For example, scientists have identified strong relationships among climate, weather, and avian population dynamics (e.g., birth and death rates; Nott et. al. 2002). Wildlife harvest, internal and external barriers to migration and dispersal, disease, parasitism, intake of contaminants, and geologic events, such as landslides and avalanches, all identified in the model, can regulate animal populations through direct mortality of individuals or through reproductive failure.

Wildlife species represented in the model have varied life histories and a significant number spend portions of every year living outside parks where they are subject to habitat loss and manipulation at important stop-over and wintering sites. Influences from other regions can have dramatic effects on species abundance, fitness, and viability. Consequently, monitoring migratory species can shed light upon distant phenomena which nevertheless affect park resources.

Two indicators for terrestrial wildlife have both ecological. *Elk* shape the structure of old-growth forests through elk population fluctuations and corresponding herbivory rates and patterns (Happe 1993, Schreiner et al. 1996, Woodward et al. 1994). Because legal hunting of elk outside of park boundaries seems to be changing the demographic structure and/or abundance of populations, elk have management importance across jurisdictional boundaries. MORA and FOCL have experienced dramatic fluctuations in elk abundance since the 1980's and fewer elk have been counted near park boundaries of OLYM (P. Happe, OLYM, unpublished data).

Monitoring of breeding *landbirds* will provide a community-level monitoring component to the NCCN wildlife monitoring program. Species of both migrant and resident landbirds are declining globally (Terborgh 1989) while National Parks include remaining habitat and reference sites for more heavily managed lands. Landbird monitoring is likely the most cost effective method of assessing a broad based element of terrestrial ecosystem integrity, and standard methodologies exist (Buckland et al. 1993, Nichols et al. 2000) to compare monitoring results at network, regional national and global scales.

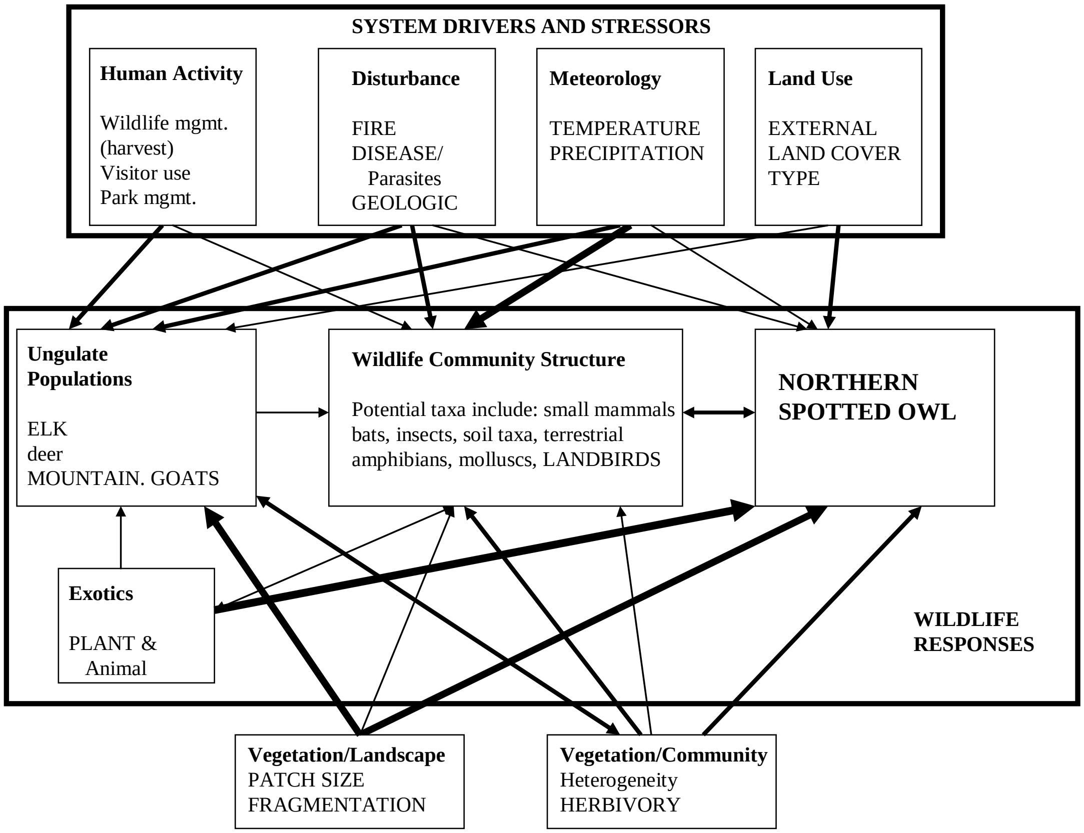

Figure 2.5.6. Conceptual model of the wildlife component of terrestrial ecosystems in the NCCN. The width of arrows indicates the strength of interactions. Indicators of stressors and wildlife responses chosen for monitoring are shown in capital letters.

2.6 WHAT IS NEXT?

Conceptual ecosystem models serve to place resources and stressors into an ecological context, as well as illustrate the relationships and links among model components within and across the other ecosystems under consideration. Models can also illuminate ecosystem components that otherwise might have been overlooked. Once parks and the Network have a robust list of natural resources and stressors that characterize network ecosystems, the next step is to determine which natural resources and stressors might serve as useful indicators of ecosystem health and status—that is, which would make good Vital Signs for monitoring. Then the Network must set priorities. Which of the potential NCCN Vital Signs would go the longest way toward helping us achieve our monitoring objective? An overview of this process, and the rationale behind it, is described in the following chapter, Vital Signs. The result is a prioritized list of NCCN Vital Signs which this network will monitor.

Chapter 3. Vital Signs

3.1 Introduction

Vital Signs can be defined as "a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values. The monitored elements and processes are a subset of the total suite of natural resources that park managers are directed to preserve 'unimpaired for future generations,' including water, air, geological resources, plants and animals, and the various ecological, biological, and physical processes that act on those resources. Vital Signs may occur at any level of organization including landscape, community, population, or the genetic level, and may be compositional (referring to the variety of elements in the system), structural (referring to the organization or pattern of the system), or functional (referring to ecological processes)." (The NPS view of Vital Signs monitoring may be found at: http://science.nature.nps.gov/im/monitor/index.htm)

The scoping meetings and conceptual modeling described in the first two chapters of this plan resulted in a list of network ecosystem resources and stressors and their interrelationships. This chapter presents an overview of the processes employed to identify high-priority Vital Signs from this list. The work was accomplished through an iterative series of workshops and formal prioritization exercises, all of which were designed to produce an unbiased list of monitoring projects supported by group consensus (Figure 3.1.1). A more detailed description of the process, methods, and products can be found in the NCCN Phase 2 Monitoring Plan (http://www1.nature.nps.gov/im/units/nccn/Reports/NCCN_Phase2_Appendices_v1.doc).

Identifying high-priority Vital Signs involved park staff and a wide range of experts from universities, government agencies, and the private sector. A group was assembled for each park to consider the natural resources, and the management and ecological objectives for monitoring. The result was a list of Vital Signs and related monitoring questions or objectives important to understanding and successfully managing the natural resources of that park (top two boxes of Figure 3.1.1).

Priorities for Vital Signs were set via two approaches, 1) by scientific discipline, across all parks and 2) within individual parks, by discipline (Figure 3.1.1).

1) Discipline-based priorities
The Network first set Vital Sign monitoring priorities at a network meeting in February 2002, where scientific discipline-based workgroups of the Technical Committee set priorities for questions across all parks by discipline (left side of Figure 3.1.1). Groups rated monitoring questions based on appropriate criteria, with each discipline-based group developing its own set of criteria. The outcome of the meeting was a set of Vital Sign priorities within scientific disciplines. Water quality monitoring topics for the Network were incorporated with other Vital Signs for this prioritization process (e.g., water quality of streams, water quality of montane lakes, intertidal communities).

2) Park-based priorities

Beginning in December 2002, Vital Sign-NCCN priorities were revisited on a park-by-park basis (right side of Figure 3.1.1) using the Analytical Hierarchy Process modified by Peterson et al. (1994, 1995) for use in natural resource management (for full description of process, details, and results, see Phase 2). This method is designed to prioritize multiple complex projects by obtaining a relatively objective group consensus through a numerical process. The process involves articulating the objectives of the monitoring program and choosing criteria to rate how well each monitoring question meets the objectives.

An important distinction was made between specific natural resources (e.g., vegetation, wildlife species) and those considered "system drivers." System (or ecosystem) drivers are major external driving forces such as climate, fire cycles, biological invasions, hydrologic cycles, and natural disturbance events (e.g., earthquakes, droughts, floods) that have large scale influences on natural systems. These phenomena have also been called "agents of change" or "stressors." Specific natural resources and system drivers differ in that natural resources also are evaluated for management significance, whereas system drivers are evaluated for their ability to explain results from monitoring natural resources. Both are evaluated for their ecological importance.

Objectives and criteria for each park were developed in work groups that included primarily park resource management staff. Next, another group of participants, which included superintendents, park resource specialists, network staff, and resource experts from other agencies, independently rated each selected topic applying approximately ten criteria. Although several outsiders participated, park and network resource management staff members predominated in the ranking exercise because the Technical Committee valued their first-hand knowledge of park resources and management issues. Park staff also were involved in reconciling any large discrepancies among independent ranks. Outside experts had much more influence during the Vital Signs meetings where the questions were generated, during peer review of monitoring plan drafts, and in protocol development and review.

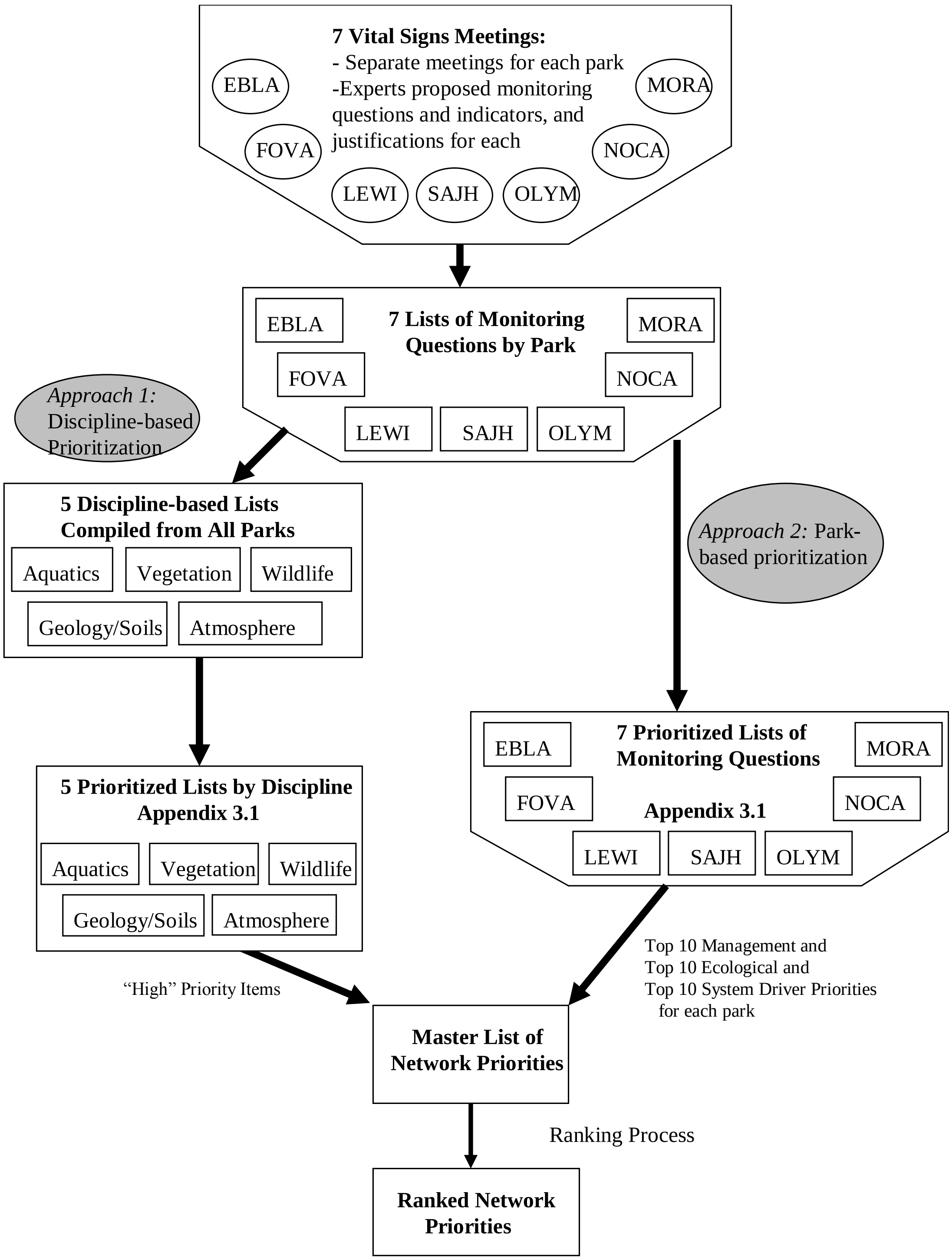

Figure 3.1.1. Flow chart describing the two independent prioritization processes used by NCCN that were combined to create the network monitoring list. Lists generated by a discipline–based approach and a park-based ranking approach were combined and ranked across the Network.

The outcome of the discipline-based prioritization process was a ranked list of monitoring questions (or Vital Signs) for each park (Figure 3.1.1, second box below "Approach 1"). These ranks contributed to the network prioritization process and determined, along with other factors, what is and is not to be included in the network monitoring program. These lists also serve as an important reference for parks as they seek resources beyond the Natural Resource Challenge to fulfill unmet park-specific monitoring needs.

Complete lists of park-based vital sign priorities and discipline-based priority lists can be found in Appendix 3.1 of the Phase 2 Report. These lists more fully describe the range and depth of Vital Signs important to understand park ecosystems. What is presented here is the shortened list of the very highest ranking Vital Signs for the Network. Many Vital Signs which are not listed in this chapter are still considered very important to parks, and may be pursued as time, opportunity, and funding allow.

3.2 Getting to Network Priorities for NCCN Vital Signs

The next step was to look for common ground among parks by developing a list of network priorities which combined the lists from the park-based and the discipline-based prioritization processes. The discipline-based list of Vital Signs-NCCN was initially developed with a network perspective but with only qualitative ranks (i.e., "high" "medium" or "low"). Park-based lists were ranked quantitatively but some lists were quite long (over 40 items), and did not have a network perspective. As a first step in assigning network-wide priorities among the park-based lists, the Technical Committee considered the top ten items from each park's priority list. Each proposed Vital Sign was judged for its importance to management, to ecosystem function, or as a system driver. The group felt that the top ten items from each park would indicate common interests across the Network.

The Network then assigned ranks to the final list of network priorities. Ranks were determined by averaging the highest park-based rank given to each Vital Sign in the top ten. The highest score given by each park (whether as a management concern, an ecosystem concern or a system driver) was used in the averages. Parks that did not list the Vital Sign-NCCN in its top 10 did not contribute to that Vital Sign's average. The final list of Vital Signs for the Network (Table 3.2.1) was further reduced by budget constraints, usually by reducing the number of parks sampled or the number of measurements taken.

In May 2005, a scientific review panel was asked to review the final list resulting from this process. The panel was asked to consider the balance of priorities, the completeness of the final monitoring scheme, and the adequacy of the proposed monitoring to achieve results. The panel's review resulted in some changes and realignments to budgets and priorities. Several Vital Signs were dropped (e.g., rare plants, recreational impacts, mountain goats), but some were picked up by other funding sources (e.g., northern spotted owls).

Table 3.2.1. Categories of funding sources for NCCN Vital Signs identified as a top-10 priority for all parks. Letters in park columns indicate funding source (A = NCCN Funds, B = other agency or NPS program, C = not funded at this time). Blank squares indicate parks not having the Vital Sign as a top 10 priority.

Level 1 Category	Level 2 Category	Level 3 Category	Network Vital Sign	Measures	EBLA	LEWI	FOVA	MORA	NOCA	OLYM	SAJH
Air & Climate	Air Quality	Ozone	Ozone	Concentration in air, foliar damage	C	C	C	B	B	B	B
		Wet & Dry Deposition	Wet & Dry Deposition	Wet: anions/cations in precipitation Dry: other undissolved compounds	C	C		B	B	B	C
		Visibility & Particulate Matter	Visibility & Particulate Matter	Light scatter by particles	C		C	B	B	B	C
Air & Climate	Air Quality	Air contaminants	Air contaminants	Concentrations of persistent organic pollutants, metals, mercury		C		C	C	C	
Air & Climate	Weather & Climate	Weather & Climate	Weather & Climate	Air & soil temperature, precipitation, relative humidity, windspeed & direction, radiation	B	B	B	A B	A B	A B	B
			Snow Cover	Annual cover & melt pattern				A	A	A	
Geology & Soils	Geomorphology	Glaciers	Glaciers - Metrics	Mass balance, surface elevation profile, runoff				A	A		
			Glaciers – Modeling	Modeled mass balance from photos						A	
		Stream/River Channels	Channel Characteristics – Wadeable streams	Width, depth, woody debris, habitat distribution	A	A		A	A	A	
			Channel Characteristics - Rivers			C		A	A	A	
		Lake Features	Lake Features & Processes – Mountain/small lakes	Bathymetry, woody debris, habitat distribution	A	A		A	A	A	
			Lake Features & Processes-Large Lakes							A	
Water	Hydrology	Surface Water Dynamics	Surface Water Levels – Mountain/Small Lakes	Depth	A	A		A	A	A	C
		Surface Water Dynamics	Surface Water Dyn.-River/Stream Flow	Flow rate	C	C		B	B	B	C

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Level 1 Category	Level 2 Category	Level 3 Category	Network Vital Sign	Measures	EBLA	LEWI	FOVA	MORA	NOCA	OLYM	SAJH
	Water Quality	Water Temperature	Water Temp.- Wadeable Streams	Temperature	A	A		A	A	A	A
			Water Temp.- Rivers					A	A	A	
			Water Temp.– Mtn./Small Lakes		A	A		A	A	A	C
			Water Temp. – Large Lakes							A	
		Water Chemistry – WRD req. parameters	Water chemistry – Wadeable Streams	Dissolved oxygen, pH, turbidity, anions/cations, conductivity	A	A		A	A	A	
			Water chemistry - Rivers					A	A	A	
		Water Chemistry	Water chemistry – Mtn./Small Lakes	Cations/anions, pH, dissolved organic C, chlorophyll, P, nitrate, ammonium	A	A		A	A	A	A
			Water chemistry – Large Lakes							A	
		WQ Nutrients	WQ Nutrients – Mtn./ Small Lakes	Ammonia, nitrate, Kjehldahl N, phosphorus, dissolved organic carbon	A	A		A	A	A	A
			WQ Nutrients – Large Lakes							A	
	WQ & Biological Integrity	Aquatic Invertebrates & Algae	Benthic Macroinvertebrates-Wadeable Streams	Community structure	A	A		A	A	A	
			Benthic Macroinvtebrates - Rivers					A	A	A	
			Benthic Macroinv. – Mtn./Sm. Lakes		A	A		A	A		
			Zooplankton – Mtn/Small Lakes	Community structure	A	A		A	A	A	
			Zooplankton – Large Lakes					C	A		
Biological Integrity	Focal Species or Communities	Intertidal Communities	Intertidal Communities	Species richness, abundance & distribution of invertebrates & macroalgae	A					A	A
		Grassland Vegetation	Prairie & Coastal Vegetation	Species composition and structure in native & restored areas, treeline	A		C				A
		Forest Vegetation	Forest Vegetation –Plots	Species composition & abundance; tree growth & mortality	C	C		A	A	A	
			Forest Vegetation - Remote	Conifer/deciduous distribution, structure	A	A		A	A	A	A

Table 3.2.1. Categories of funding sources for NCCN Vital Signs identified as a top-10 priority for all parks. Letters in park columns indicate funding source (A = NCCN Funds, B = other agency or NPS program, C = not funded at this time). Blank squares indicate parks not having the Vital Sign as a top 10 priority (continued).

Level 1 Category	Level 2 Category	Level 3 Category	Network Vital Sign	Measures	EBLA	LEWI	FOVA	MORA	NOCA	OLYM	SAJH
		Vegetation Communities	Subalpine Vegetation	Treeline position; tree island size; composition, richness, structure of vascular spp. communities; populations size of non-vascular spp.				A	A	A	
			Riparian Vegetation	Conifer/deciduous abundance, cover		A	C	A	A	A	
	Focal Species or Communities	Rare Plants	Rare Plants	Frequency & abundance of species	C			C	C		C
	Invasive Species	Invasive Plants	Invasive Plants	Distribution & abundance of extant & potentially threatening species	A	A	A	A	A	A	A
	Focal Species or Communities	Fishes	Fishes- Mountain/Small Lakes	Distribution, abundance, species composition	A	A		A	A	A	
			Fishes – Wadeable Streams	% stream miles occupied by native and non-native fishes	A	A		A	A	A	
			Fishes – Rivers	Species composition & relative abundance				A	A	A	
	Focal Spp. or Comm./At Risk Biota	Amphibians & Reptiles	Amphibians – Mountain/Small Lakes	Distribution and relative abundance	A	A		A	A	A	C
			Amphibians – Wadeable Streams	Distribution & relative abundance		C	C	C			
	Focal Species or Communities	Birds	Landbirds	Density & frequency of occurrence	C	A	C	A	A	A	A
		Mammals	Elk	Abundance in wither and/or summer range, herbivory		A		A B		A	
			Mountain Goats	Distribution & relative abundance				B	B		
	At Risk Biota	T&E Species & Communities	Salmonids – Wadeable Streams	Relative abundance, species composition, age structure	A	A		A	A	A	
			Salmonids – Rivers			C		A	B	A	
			Northern Spotted Owl	Population trend, distribution, fecundity, survival				B		B	

Table 3.2.1. Categories of funding sources for NCCN Vital Signs identified as a top-10 priority for all parks. Letters in park columns indicate funding source (A = NCCN Funds, B = other agency or NPS program, C = not funded at this time). Blank squares indicate parks not having the Vital Sign as a top 10 priority (continued).

Level 1 Category	Level 2 Category	Level 3 Category	Network Vital Sign	Measures	EBLA	LEWI	FOVA	MORA	NOCA	OLYM	SAJH
Ecosystem Pattern and Processes	Landscape Dynamics	Land Cover & Use	Landscape Dynamics	Size & distribution of land-use changes around parks	A	A	A	A	A	A	A
	Extreme Disturbance Events	Extreme Disturbance Events	Disturbance	Type, frequency, size, location				A	A	A	
	Fire	Fire & Fuel Dynamics	Fire & Fuel Dynamics	Frequency, size, location				A	A	A	
Human Use	Visitor & Recreational Use	Visitor usage	Recreational Impacts – Vegetation & Soils	Size, distribution of campsites & social trails; structure & composition of nearby vegetation	C			C	C		

3.3 Relationship between Vital Signs and Conceptual Models

Indicators and/or Vital Signs are emphasized on the ecosystem models (Figures 2.5.1-6) using capital letters. Sources of funds for the indicators include the NPS long-term ecological monitoring program, other NPS programs of base funds, and other agencies. In total they represent the system drivers, predicted threat responses, focal species and indicators of ecosystem health expected to meet the needs of NCCN parks to enable resource protection.

3.4 Ecological Integration

One of the most difficult aspects of designing a comprehensive monitoring program is integration of monitoring projects so that the interpretation of the whole monitoring program yields information more useful than that of individual parts (Jenkins et al. 2003). Integration has ecological, spatial, temporal and programmatic aspects. The next step in the development process is to evaluate the ecological integration of the chosen Vital Signs and measurable attributes.

Ecological integration involves considering the ecological linkages among system drivers and the components, processes, and functions of ecosystems when selecting monitoring indicators. The most effective ecosystem monitoring strategy will employ a suite of individual measurements that collectively monitor the integrity of the entire ecosystem or park. We can evaluate the NCCN program relative to a conceptual model describing the important linkages among ecosystem components with a detailed version of our holistic model (Figure 3.3.1). The linkages indicate information needed to interpret the monitoring of each Vital Sign that can be provided by monitoring another Vital Sign. It is important for ecological integration that the attributes measured by each monitoring project provide critical information to other projects.

Comparison of the desired linkages among Vital Signs (Figure 3.3.1) with proposed measurable attributes (Table 3.2.1; Chapter 5) shows that the desired linkages are accounted for. One of the remaining challenges is to provide information at useful temporal and spatial scales; this aspect of integration is discussed in the following chapter.

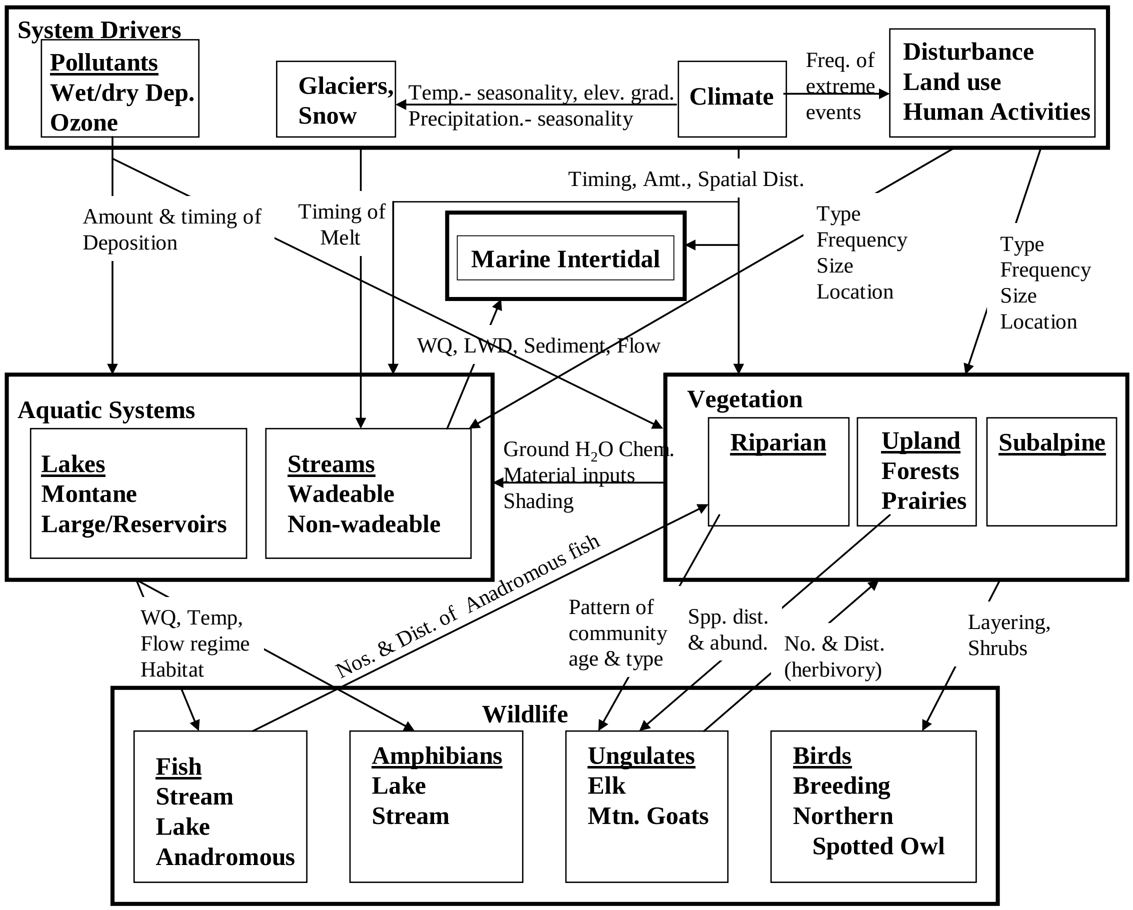

Figure 3.3.1. Conceptual model of desirable information flow among monitoring projects based on the holistic model presented in Figure 2.3.2.

Chapter 4. Sampling Design

4.1 Introduction

Developing a monitoring program requires a series of choices regarding *what*, *where*, and *how often* to monitor because it is not financially or logistically feasible to monitor everything everywhere. In Chapter 3 we addressed *what* by describing our process of choosing our highest priority items from the long list of potential Vital Signs. We made these decisions to promote understanding of interrelationships within ecological systems and the ability to explain possible causes of observed patterns of change, and to meet management needs. In this chapter we will describe the spatial and temporal sampling frames that result from our choices of *where* and *how often* to most efficiently locate samples on the landscape.

Recently, Hall (1999) described the challenge of designing a monitoring framework as a process of optimizing trade-offs among scale, scope, and statistical power of sampling.

- **Scale**, refers to both the smallest interval of space measured and the total area over which observations are made. The spatial scale defines the target population, which is area to which the monitoring can be inferred, and greatly influences the cost of monitoring.
- **Scope** refers to the amount of information that is gathered at each sampling site, or the depth of knowledge obtained.
- **Statistical power** refers to the ability of the sample measurements to reveal actual changes in the population being measured. Power depends primarily on the variability of the attribute measured and the number of independent measurements (sample plots) obtained.

In general, monitoring projects with the greatest scope and complexity are conducted at comparatively small spatial scales (e.g., atmospheric deposition) and the are rarely replicated sufficiently to allow inference beyond the study site. However, results from intensive monitoring may describe larger areas if they can be extrapolated using models (e.g., some climate models can interpolate between weather stations). At the other extreme, comparatively superficial information can be obtained across broader spatial scales and can be replicated more easily (e.g., satellite images are comprehensive samples where every pixel (plot) is measured).

Economics of the scaling issue are particularly acute in large wilderness-area parks where high costs of access to sampling sites greatly affects both the measurement and replication efforts possible under fixed funding constraints. Smaller parks are more likely to have the luxury of inference to larger proportions of their resources.

At a workshop held by USGS for NCCN, Tony Olsen (USEPA EMAP program) stated that the first steps in designing a monitoring framework include:
1) Clearly stating quantitative objectives
2) Explicitly defining the target population
3) Constructing a sample frame to represent the target population
4) Deciding on a survey design

As simple as they appear, deciding these points requires making the trade-offs described above. We will address these in order.

4.2 Objectives

Non-specific objectives are a weakness of many monitoring programs. Describing status and trends is much too vague an objective to address sampling design issues. Monitoring objectives must include precise definitions of the target population and the parameter to be measured. Objectives for monitoring of NCCN Vital Signs are given in Chapter 5.

4.3 Target Populations for NCCN

The target population is the group of items or area for which one hopes to have inference and follows directly from the monitoring objectives for each Vital Sign (see Chapter 5). Often the sampled population will not be a complete sample of the target population because some areas cannot be measured. For example, we consider slopes over 35^o to be unsafe to visit. With that caveat, the target populations in NCCN can be categorized into six classes based on range of inference:

Non-inferential samples (sample sites do not represent a population or they represent the entire population):

- Sentinel Sites – one or a few sensitive sites. Inference beyond the site is not possible so change indicates the need for more extensive monitoring.
- Representative Sites – sites are chosen to be representative of environmental, stressor impact or other gradients or conditions. Model-based inference may be possible, although design-based inference is encouraged by statisticians for use in monitoring
- Comprehensive Sample – the data describe an entire park with a complete sample of every sample unit (e.g., satellite-based remote sensing where pixels are the sample unit). No inference is needed because the entire population is sampled.

Inferential samples (samples are chosen with known probability from a larger population):

- Strata(um) within NCCN – samples are selected to describe strata across the Network. Sample size in any one park is insufficient to detect change within the desired time frame.
- Strata(um) within a park – samples are selected to describe strata within a park. The budget is usually not adequate to do all possible strata so one or a few of the most sensitive or important strata are chosen for monitoring.
- Entire park – Samples are selected probabilistically from a population across an entire park. The sample may be stratified, but all strata are included.

The necessary trade-off between scale and scope means that the depth of knowledge obtained varies among these sample classes. Usually more information can be gathered from samples of small target populations (e.g., biogeochemical monitoring is only feasible at a few easily accessible sites), but it has a small range of inference. The inference obtained from representative sites depends on the availability of a model to extrapolate data taken from only a few sites. For example, weather data may be extrapolated from a small number of meteorological stations to larger areas if there is a weather model that can be calibrated with a few points.

There are several ways of distributing samples within probabilistically sampled target populations (e.g., equal probability, stratified, unequal probability), but after considering the total budget, and the costs and logistical limitations of monitoring each Vital Sign, the NCCN determined that it could only afford to monitor no more than a few strata of any population (Table 4.3.1). The identity and justification for those strata are given below. Note that the recent expansion of LEWI requires sampling decisions to be revisited.

Table 4.3.1. Types of target populations for NCCN Vital Signs. See text for description of types, including sentinel (Sent), Reference (Ref), Stratified w/in park (StratP), Stratified within network (StratN), Entire park (Park) and comprehensive (Comp). Decisions yet to be made are indicated by TBD.

	Protocol	Network Vital Signs	EBLA	LEWI	FOVA	MORA	NOCA	OLYM	SAJH
Non-inferential	Climate	Weather and Climate	Sent	Sent	Sent	Sent	Sent	Sent	Sent
	Glaciers	Glaciers – Intensive, Glaciers--Extensive				Sent	Ref	Sent	
	Hydrology	Surface Water Dynamics-River/Stream Flow				Ref	Ref	Ref	
	Large Lakes	Water temperature, Water chemistry, Water quality nutrients, Zooplankton						Ref	
	Landscape Dynamics – R/S	Disturbance, Fire, Landscape dynamics, Forest - Extensive	Comp	Comp	Comp	Comp	Comp	Comp	Comp
Inferential in most parks	Landscape Dynamics - Aerial	Riparian vegetation, River Channel characteristics, Prairies – Extensive				StratP	StratP	StratP	Comp
	Wadeable Streams	Fishes, Salmonids, Benthic macroinvertebrates, Channel characteristics, Water temperature, Water chemistry	Park			StratP	StratP	TBD	
	Large Rivers	Fishes, Salmonids, Benthic macroinvertebrates, Channel characteristics, Water temperature, Water chemistry				Sent	Sent	StratP	
	Mountain/Small Lakes	Fishes, Surface water levels, Water temperature, Water chemistry, Water quality nutrients, Benthic macroinvertebrates, Zooplankton, Amphibians	Park			Park	Park	Ref	Park
	Intertidal Communities	Intertidal communities						StratP	
	Forest Vegetation – Intensive	Forest Vegetation -- Intensive				StratPN	StratPN	StratPN	
	Forest Vegetation - FIA	Forest vegetation - FIA				StratN	StratN	StratN	
	Subalpine Vegetation	Subalpine vegetation				StratPN	StratPN	StratPN	
	Prairie & Coastal Vegetation - Intensive	Prairie & Coastal Vegetation							StratP
	Invasive Plants	Invasive plants	TBD	TBD	TBD	TBD	TBD	TBD	TBD
	Landbirds	Birds		TBD		StratPN	StratPN	StratPN	Comp
	Elk	Elk				StratP		StratP	

4.4 Justification for Strata

There are several practical reasons for stratifying within and among network parks, 1) limiting the cost of the project, 2) ensuring the safety of field crews, 3) avoiding situations where monitoring is infeasible, and 4) using data collected by other agencies. It is important that strata be defined using stable parameters (e.g., elevation bands rather than plant associations for vegetation) for the strata to be viable over the long-term. The following list provides specific reasons for strata used in our sampling for Vital Signs with inferential sample designs:

- Invasive Plants. Sampling will be limited to the potential habitat of a few high-priority species to limit the cost of the monitoring project. These species and the detailed monitoring methods will be determined after the completion of a national project to develop a monitoring protocol for invasive species.
- Forest Vegetation – Plots (FIA). Samples are collected in parks by USDA Forest Service using a systematic grid. We predict that too few samples of any one vegetation type collected in any park will allow for parkwide inference. However, we expect that one common vegetation type will be sampled sufficiently across the Network. The relative weakness of this approach will be supplemented by a stronger effort using plot-based samples (below).
- Vegetation Communities (Forest - Plots, Subalpine, Prairies and Coastal). We define target populations for vegetation communities as domains of specific plant communities within strata defined by elevation bands. Each selected point within each stratum will be visited and characterized, but only those within the desired domain will be intensively sampled. This approach will provide a biologically interpretable sample (all intensive data coming from the same vegetation class) but with flexibility should species assemblages defining vegetation classes re-assort in response to future environmental change. Communities within strata for forest vegetation were chosen to characterize environmental extremes (subalpine = cold, dry; Sitka spruce = warm, wet) and one type common to all three large parks (western hemlock).
- Birds. Landbirds will be monitored with park-wide inference to three of the small parks, but inference will only apply to 1-km distances from trails in large parks, primarily for safety reasons. The protocol requires field crews to begin work before dawn, and it is not safe to navigate cross-country in difficult terrain in the dark.
- Wadeable Streams (including Benthic macroinvertebrates, Salmonids, Channel Characteristics, Water temperature, Water Chemistry, and Fishes). To limit the cost of the project, streams will be monitored by reach in areas with 0-8% gradient in NOCA and MORA. These areas are thought to be most likely to show change in response to stressors and are most likely to be logistically feasible. The sampling plan for OLYM is yet to be decided.
- Large Rivers (including Benthic macroinvertebrates, Salmonids, Channel Characteristics, Water temperature, Water Chemistry, and Fishes). Monitoring will occur in 5 km reference reaches located immediately upstream from the park boundary in OLYM and MORA. Monitoring at OLYM will occur at a sample of all rivers, but only at one or two sentinel rivers in MORA. Feasibility of access explains the restricted sample.

- Elk. Elk populations will be monitored in west-side drainages of OLYM because they are the largest segment of the population residing year-round in the Park. Elk populations will be monitored throughout MORA because the park is small enough for it to be financially feasible.
- Mountain Lakes (including Fishes, Surface water levels, Water temperature, Water chemistry, Water Quality Nutrients, Benthic macroinvertebrates, Amphibians, and Zooplankton). Mountain lakes will be monitored throughout MORA and NOCA but only at reference sites in OLYM due to different objectives among the parks. The highest priority for OLYM is to detect trends over time, which can be best determined with reference sites due to high variability among lakes. Trend detection requires detailed sampling that would be prohibitively costly unless only a few reference sites are sampled. These lakes will be chosen probabilistically so that further monitoring can be added as funds allow. The other parks are also critically interested in status of lakes throughout the parks because their lakes have been or are being stocked with fish. Status monitoring requires a larger sample of the park than is needed to detect trend.
- Intertidal Communities. Rocky platforms and sandy beaches stratified by tidal elevation will be monitored in OLYM. Cobble beaches will not be monitored because the most interesting organisms live under the cobble, and feasible methods for monitoring them have not been developed. Stratifying by tidal elevation focuses sampling in biologically interpretable areas. SAJH will be monitored by other agencies so we accept their sample frame.

It is often emphasized that funding for the NPS monitoring program is meant to be seed money that parks can use to leverage support from others for expanded monitoring. This is an important concept that must not be forgotten when designing the sampling frame for National Parks. Even though one stratum among many may be financially feasible to monitor at present, that stratum must be sampled probabilistically in the context of the entire resource. Consequently, sample sites must be chosen in a way that can be supplemented later without compromising the statistical validity of the entire sample. This should not be hard to do with the spatial sample frame: strata will be chosen based on sharp boundaries and the selection probability of the original sample will be known. Samples chosen in other strata later may have a different selection probability, but as long as it is a known probability, the data can be combined in the analysis. It may require a bit more care to incorporate new sites into a complicated temporal sampling design, so it is important to consider the potential for new sites from the beginning.

4.5 Survey Design

Largely for financial and safety reasons, most inferential sampling frames in NCCN are limited to one or a few strata within larger populations. Once the decision to stratify has been made, the next questions are how to choose the sample and how to sample through time.

4.5.1 Spatial Sample Distribution

There are many ways to distribute a sample in space. Some of the commonly used ways include:

- Simple random sample – does not result in an evenly distributed sample because random samples are often clumped.
- Systematic sample – either using a regular grid for regular spacing for a linear resource (e.g., streams). It provides domain elements in the proportion they naturally occur thereby over-sampling the common elements and under-sampling the rare ones.
- Cluster sample – sample several sites in clusters. This can decrease the cost of field operations; however, the independent sample size is only the number of clusters rather than the total number of plots.
- Spatially stratified random sample – an alternative way to spatially balance the sample (e.g., randomly sample within strata defined by elevation)
- Multiple stage sample – select larger units first and then smaller units within the larger units (e.g., randomly select counties within a state then randomly select cities within only those counties).

Generalized Random Tessellation Stratified (GRTS) sampling is a recently developed method of sample distribution combining a simple random sample and the systematic grid sample (Stevens 1997, Stevens and Olsen 2004). Points selected using GRTS are scattered throughout the target population ensuring that areas are neither over- nor under-sampled thereby strengthening inference. GRTS offers several additional benefits. For example, it is possible to use "unequal probability" when selecting samples so that some rarer areas will have a higher probability of being sampled than they would with a random or systematic sample. Also, the GRTS process is designed to work well when some of the points selected may not be suitable for monitoring, but it is difficult to determine that before they are visited. GRTS produces an ordered list of sampling locations and can select more locations than are actually needed for a given protocol. If a particular location cannot be sampled, then the next location on the list can be used instead, and the spatial balance of the sampling design will be maintained. Finally, as the GRTS points are all selected with a known probability, it will be simpler to combine data from the Vital Signs program with data collected by the individual parks or other agencies.

Besides providing a random, spatially balanced sample, the feature most important to the three large parks is that sites can be rejected without compromising the sample. It is not uncommon for a field crew to arrive at a site and determine that the slope is actually too steep to work on, or that the site is flat enough, but they can't get there safely, or there is some other unacceptable situation in the plot that does not show up on GIS maps. Most probability-based samples in NCCN whose sample frame have been finalized have used GRTS for site selection (i.e., Forest-Plots, Land Birds, Mountain/Small Lakes, Wadeable Streams, and Large Rivers protocols).

4.5.2 Temporal Sample Distribution

National Park Service monitoring goals include the understanding of both status and trends for park resources. These are difficult (expensive) to achieve concurrently because status requires spatially distributed samples and trend requires frequent visits. In general, 'panel' sampling designs are used to ensure adequate sampling efforts both spatially and temporally and to effectively manage the trade-off between status information and trend information (McDonald 2003).

A *panel* consists of a group of populations units that are always sampled during the same sampling occasion. They are defined spatially by the *membership design*, which is the plan by which populations become members of panels. They are sampled temporally according to the *revisit design*, which is the plan by which panels are sampled in time. The revisit design for each panel can be expressed with 2 numbers indicating how many years a site will be sampled, followed by how many it will be rested. For example, [1-4] would indicate that the panel would be sample in one year and rested for 4 then revisited for one, etc. (McDonald 2003). By having panels that are visited more frequently than others in the same design, one can optimize the trade-off between describing status (from panels visited infrequently) and detecting trend (from panels visited frequently). If panels are laid out appropriately, comparisons can be made between observations collected in any year with those in any other year, or covariates can be developed to minimize the error variance in observations.

Most protocols for NCCN have taken advantage of the powerful properties of panel designs. Chapter 5 contains brief descriptions of these protocols and hyperlinks to the more detailed Protocol Development Summaries online.

4.5.3 Sample Size

Most scientific experiments base significance of results on the probability of rejecting the hypothesis when it is correct. In monitoring, however, statistical power – that is, the probability of failing to reject the hypothesis when it is wrong – is needed to avoid negating the main purposes of monitoring by concluding that nothing is changing when in fact it is. Statistical power depends on sample size, and a power analysis is needed to determine the number of samples needed to achieve the desired amount of power.

Power analysis has been criticized because it is often done incorrectly or using ‘canned’ programs whose assumptions and analysis are not appropriate for the design being tested. All protocol development projects in NCCN have had or generated pilot data, determined the appropriate statistical analysis, and contracted with statisticians to run power analyses based on simulations based on the pilot data. While this analysis merely estimates the needed sample size, it is a useful way to determine whether the proposed sampling will come close to being adequate. The key is to a good power analysis is to use simulations rather than ‘canned’ programs. In practice, the chief constraint on sampling adequacy is nearly always a financial trade-off or judgement call.

4.6 Spatial Integration

The NPS national guidance for designing an integrated monitoring program (Fancy 2004 from Jenkins et al. 2003) states “(o)ne of the most difficult aspects of designing a comprehensive monitoring program is the integration of monitoring projects so that the interpretation of the whole monitoring program yields information more useful than that of the individual parts. Integration involves ecological, spatial, temporal and programmatic aspects.” Ecological integration was discussed in Chapter 3 and spatial integration will be discussed here. Specifically, spatial integration “involves establishing linkages of measurements made at different spatial scales within a park or network of parks, or between individual park programs”

(Fancy 2004 from Jenkins et al. 2003) and "requires understanding of scalar ecological processes, the collocation of measurements of comparably scaled monitoring indicators and the design of statistical sampling frameworks that permit the extrapolation and interpolation of scalar data (Fancy 2004 from Jenkins et al. 2003)." We believe spatial integration for monitoring of NCCN can be achieved in four ways: 1) collocating measurements at the same sample point or plot, 2) collocating measurements in the same strata, 3) linear integration of flowing aquatic systems, and 4) taking measurements at nested spatial scales. We will discuss each of these approaches in more detail and explain how they are used in NCCN.

- Collocating Data Collection at Points or Plots. Particularly when monitoring both biota and their habitat, it makes sense to collocate measurements of each to aid interpretation of change. Water chemistry, benthic macroinvertebrates, fish and their habitat will be monitored in streams at plots centered on selected points. These measurements are linked by species-habitat and trophic relationships and therefore may be causally connected.
- Collocating Data Collection in Strata. Large terrestrial wildlife and birds use their habitat over a greater breadth of spatial dimensions than aquatic biota, having more significant two- and/or three-dimensional components. Collocation of monitoring of these animals and their habitat must reflect their greater spatial range and the high costs and safety considerations of the monitoring projects. Consequently, habitat for terrestrial wildlife and birds will be monitored in a few significant vegetation communities (strata) for each. Specifically, elk and the Sitka spruce vegetation zone will both be monitored in OLYM, providing a linkage between elk populations and their winter and/or summer range. Subalpine vegetation communities should be chosen for monitoring to reflect use by mountain goats. Landbirds will be monitored in many vegetation communities, but the structure and composition of the most common community (i.e., western hemlock) will be monitored using data from FIA plots. We expect this sampling scheme should provide adequate information on the status of plant-animal interactions, including herbivory and habitat quality.
- Linear Integration of Flowing Aquatic Systems. Spatial integration of flowing aquatic systems can be achieved by linking site selection along the continuum of flow. While aquatic monitoring is divided into distinct Vital Signs (e.g., streams, rivers, hydrology), these elements are spatially linked by flow. In OLYM, the elements of the continuum climate-glaciers-hydrology-streams-rivers-intertidal will be monitored. Small OLYM streams will be sampled upstream of and linked to sampling sites in rivers.
- Collecting Data at Nested Spatial Scales. Spatial integration can also be accomplished by nesting samples so that smaller-scale and faster processes are measured in small areas nested within larger areas where larger-scale and slower processes are monitored. NCCN plans to take this approach to monitoring of vegetation. Composition of herbaceous species will be monitored in subplots within plots where structure and composition of shrubs and trees will be monitored. Plots will be allocated so that inference can be made from the plots to entire vegetation communities or zones. Satellite imagery will be used to monitor landscape scale changes in distributions of physiognomic types (e.g., grass, tree, shrub), coniferous and deciduous trees, and disturbance. With this plan, we expect to be able to scale up from short time scale changes in herbaceous vegetation to the longer time scale processes appearing at the landscape scale. A spatially nested approach is also

being used for streamflow monitoring based on a pilot project which will determine the appropriate spatial scales.

4.7 Water Resources

The Northwest is a water-driven ecosystem, its huge trees supported by copious rainfall arriving from the Pacific Ocean. Water quality was ranked second among all potential Vital Signs to monitor in the Network. The NCCN has an ambitious water monitoring plan embracing basic hydrology, water quality monitoring, and the complex biology of lakes, streams, and rivers. The NCCN approach to water resources embraces the goals of the NPS Water Resources Division (WRD) as well as other goals related to global climate change, biological impacts, and fisheries management. WRD's goals emphasize the attainment of the Service-wide water quality standards, improving the quality of impaired waters and maintaining the quality of pristine waters. The NCCN monitoring includes the WRD concerns and goes beyond them, capitalizing on the Network's strategic geographic situation as a study location for airborne pollutants and global changes and their effects on park resources.

Much of the NCCN is designated wilderness with few impaired waters (Table 4.7.1) although impacts due to forest practices may be found in surrounding areas. OLYM (and perhaps LEWI) are located west of industrial centers and have waters that are arguably pristine except for pollutants brought in by the prevailing west wind. Sources of these materials may be from Asia or may have been transported around the globe. The other network parks due to their locations may receive more or less direct airborne impacts from urbanized areas.

The health of northwestern forest ecosystems can be read in the physical, chemical, and biological parameters of rivers and lakes. In streams, macroinvertebrates are superb indicators because those streams concentrate and integrate the pulse of a watershed into a small area. Any ecological influence from substances in the rain, landslides, or chemical changes attributable to forest succession are concentrated and focused in streams. Streams unimpacted by human activities have diverse food webs resistant to ecological perturbation and capable of returning to a stable state when alterations do occur. Human impacts disrupt the species composition of stream organisms resulting in a distinctly discernible "signal" different from that of unimpacted waters.

An analogous situation applies to lakes. Whether affected by global influences (e.g. pollution from Asia) or local influences (e.g. recreationists in the park), lake flora and fauna are distinct monitors of ecosystem health. Montane lakes with their cold abiotic environment, low biodiversity, poor functional redundancy, and relative lack of local human perturbations can be viewed as Petri dishes, where whatever falls from the sky impacts otherwise relatively pristine lacustrine ecosystems (Vinebrooke and Leavitt 2004).

As part of the water quality planning process we prepared two products to aid selection of potentially impaired and pristine monitoring sites:

- Geo-referenced databases for MORA, NOCA, OLYM, FOCL, EBLA and SAJH summarizing available information on NCCN waters.

- Land-use maps and a rating system to assess disturbance within park watersheds (see Appendix 4.1 Watershed Scale Stream Disturbance and Function Evaluation)

We will ensure that sites with high disturbance ratings are included in sample selection for monitoring potentially impaired sites. Our sampling design for surface waters will include a large number of pristine waters; the sampling designs for monitoring lakes, ponds and streams will include both potentially impaired and potentially pristine sites. Water resource types and general overview of the NCCN water quality monitoring program are presented in Appendix 4.2

NCCN has integrated water quality monitoring with other aquatic monitoring, and has included seven categories of water resources in the monitoring plan (Table 4.7.1). Not all categories will be monitored in all parks (Figure 4.7.1). Detailed maps and descriptions of the monitoring sites chosen to date are found in Appendix 4.3.

The chosen sample designs and target populations are summarized in Chapter 5 and Table 4.3.1. Statistical power analysis will be conducted as part of the development of each protocol. With the exception of montane lakes and ponds, large lakes, and intertidal/marine sites, specific numbers and locations of sample sites have not yet been determined.

The different sampling approaches proposed by the three larger NCCN parks reflect different monitoring questions of interest. Detecting status and trends of water quality, stream flow, and fish communities throughout the park fell within the top 5 priorities of each park. In an ideal world, each park would obtain parkwide inference for all aquatic program components. In practice, budget limitations preclude an ideal program that will detect both status and trends in an inferential design. At OLYM, difficult access to its large number of lakes and streams prevent adequate sampling of either to ensure a robust inferential design. Detection of subtle, long-term, change related to anthropogenic activity and global climate is paramount to the OLYM program. Therefore OLYM will emphasize trend-related questions in montane lakes and wadeable streams.

NOCA's emphasis is on status-related questions in both systems, related to immediate management questions (e.g., non-native fish in montane lakes). The possibility of greater helicopter use in the NOCA wilderness provides relatively easier access such that NOCA staff feel an inferential design is feasible. Pilot data for streams and lakes in NOCA provide the opportunity for power analyses to determine whether an inferential design is indeed feasible.

MORA's emphasis is on both status and trends in montane lakes, and status in wadeable streams. MORA has a smaller relative area and access issues are even less of an impediment, thus both inferential (status) and reference (trends) designs are feasible. With respect to lakes, MORA intends to implement a hybrid sampling regime to create an inferential design. They suggest using a combination of a few fixed, annually repeated sites together with a small set if rotating panels. Again, power analysis will help determine whether this plan can accomplish estimation of both status and trends.

Table 4.7.1. Summary of funded aquatic monitoring in NCCN. For details see Appendix 4.

Category	No. Sites	Who	Frequency	Source	Parameters
303d sites	OLYM-1 LEWI-3	Park Staff	---	---	pH; need to test whether Sol Duc resort and/or hot springs are causing the aberrant pH levels
Montane Lakes & Ponds	MORA-48	Park Staff	5-yr rotation:1/yr, annual:2/yr, annual:1/yr	NCCN & USEPA 1998	Amphibians, fish, BMI. Zooplankton, macrophytes, water temp. (continuously), clarity, disturbance, substrate, DO, conductivity, Alkalinity/ANC, pH, total dissolved solids, DOC, nutrients, contaminants, basin characteristics (decadal)
	NOCA-64		5-yr rotation:1/yr, annual:1/yr		
	OLYM-5		Annual:2/yr		
Large Lowland Lakes	OLYM-2	Park Staff	Monthly	NCCN	Zooplankton, chlorophyll A, conductivity, temp. profile, clarity, DO, pH, turbidity, some nutrients
			Continuous		Lake level
			5-yr intervals		LWD
			Quarterly		Nutrients, anions, cations, DOC
Wadeable Streams	NOCA-48 OLYM-5 MORA-30	Park Staff	Annual: 1/yr	NCCN	Fish, BMI, temp., canopy cover, flow, gradient, substrate, large pools, LWD, channel characteristics, human disturbance, conductivity, alkalinity, DO, pH, turbidity, nutrients, anions, cations, amphibians (MORA)
	FOCL-1 SAJH-1 EBLA-1	Park & NCCN Staff	Annual:1/yr	NCCN	BMI, continuous water temperature, conductivity, DO, pH
Rivers	OLYM-12 MORA-7	Park Staff	Annual & 4-yr rotation	USFS Region 6 Level II, NCCN, (W)EMAP NCCN	Fish, temperature (continuous), canopy cover, flow, channel characteristics, substrate, large pools, LWD, human influence, conductivity, alkalinity, DO, pH, turbidity, DOC, nutrients, anions, cations
Hydrology	MORA-4 NOCA-7 OLYM-?	Park Staff	Continuous	NCCN	Flow at index sites
Marine/Intertidal	OLYM-9	Park staff	Continuous	NCCN	Water temperature
	OLYM-14		Annual & biennial	NCCN	Macroalgal & invertebrate community structure
	EBLA-1	WDOE	Annual	WDOE	Water quality

Chapter 5. Sampling Protocols

> *"Monitoring protocols are detailed study plans that explain how data are to be collected, managed, analyzed, and reported, and are a key component of quality assurance for natural resource monitoring programs. Protocols are necessary to be certain that changes detected by monitoring actually are occurring in nature and not simply a result of measurements being taken by different people or in slightly different ways".* (Oakley et al., 2003)

The I&M Program of the National Park Service and the Status and Trends Program of the U.S. Geological Survey have developed standards for the content and format of sampling protocols for long-term ecological monitoring. Experience has shown us that monitoring programs and protocols that incorporate a large up-front investment in defining the monitoring questions and objectives, optimizing sampling designs, and determining how monitoring data will be managed, analyzed, and used are more likely to succeed over the long term (Oakley et al. 2003). As part of the quality assurance of our monitoring program, and to document for future staff and other programs and agencies how and why we collected, managed, analyzed, and reported monitoring data, the North Coast and Cascades Network is developing a set of sampling protocols consistent with the Oakley et al. (2003) guidelines to address the highest-priority Vital Signs listed in Table 3.2.1.

As part of getting "more for our monitoring dollar" and increasing the scientific value of the results, most of the sampling protocols have been designed to address several Vital Signs. As described in Chapter 4, many of the Vital Signs will be sampled together in time or space for logistical expediency and to reduce costs, but also to allow comparisons and correlations across Vital Signs, which increases the overall scientific value of the results. The protocols currently being developed by the NCCN are listed in Table 5.1 below, with a brief summary of the Vital Signs and measurable objectives being addressed by each. The complete suite of Protocol Development Summaries is online at: http://www1.nature.nps.gov/im/units/nccn/index.htm. The website provides additional information for each protocol including: a justification statement; monitoring questions and specific, measurable objectives; the basic methodological approach and sampling design; the lead investigators for developing the protocol; and the schedule for protocol development. Clicking on the highlighted weblinks in Table 5.1 will take you to the most recently updated version of the Protocol Development Summary for each topic.

Wherever possible, we have adopted or modified existing protocols developed by other parks or agencies to promote consistency and data comparability. Before we accept our protocols for long-term monitoring, all protocols will be peer-reviewed and field tested for a number of years to ensure that they provide scientifically-sound results and address the monitoring questions and objectives as intended.

Table 5.1. Summary of long-term monitoring protocols being developed by the North Coast and Cascades Network for implementation with existing funding. Additional information for each protocol is provided at http://www1.nature.nps.gov/im/units/nccn/index.htm.

Name of Protocol	Vital Signs being Addressed	Parks	Monitoring Objectives
Climate	Weather and climate	EBLA, LEWI, FOVA, MORA, NOCA, OLYM, SAJH	1. Determine parkwide spatial (climate zone, elevation, aspect), and temporal (monthly, seasonal, annual, decadal) trends in air temperature, precipitation (including snow, snow depth, and snow water equivalent), wind speed, wind direction, soil moisture, relative humidity and solar radiation in each park. 2. Determine parkwide trends in the annual and decadal extent of snowpack in MORA, NOCA and OLYM. 3. Determine parkwide spatial, and annual and decadal trend in lake ice-out in MORA, NOCA and OLYM (index lakes are the sites selected by the aquatic technical working group for monitoring long-term trends in montane lakes.
Glaciers	Glaciers - Metrics Glaciers - Modeling	MORA, NOCA, OLYM	1. Determine summer, winter and net mass balance at index glaciers. 2. Determine glacial contribution to summer runoff for four NOCA, two MORA and one OLYM watersheds. 3. Assess surface features changes related to glacial hazards at MORA. 4. Determine glacier volume/area for index glaciers at 10-year intervals, and for all glaciers at 20 year intervals at all parks. 5. Track annual surface elevation changes, across 3 fixed lateral transects, at Nisqually Glacier, in order to track trends in kinematic waves. 6. Determine relationship among surface elevation data, mass balance data and glacier dynamics and movement.
Large Lakes	Water chemistry Water quality nutrients Zooplankton	OLYM	1. Determine seasonal and inter-annual changes in the horizontal and vertical distribution of physical/chemical characteristics of the lake water column. 2. Determine seasonal and inter-annual trends in zooplankton species composition, abundance, and distribution. 3. Obtain an accurate bathymetric map of a lake. 4. Determine changes in the distribution of littoral habitat types to determine extent of shoreline modification. 5. Determine distribution of Large Wood Debris on lake periphery.

Table 5.1. Summary of long-term monitoring protocols being developed by the North Coast and Cascades Network for implementation with existing funding. Additional information for each protocol is provided at http://www1.nature.nps.gov/im/units/nccn/index.htm (continued).

Name of Protocol	Vital Signs being Addressed	Parks	Monitoring Objectives
Mountain/Small Lakes	Surface water levels Water quality nutrients Benthic macroinvertebrates Zooplankton Fishes Amphibians Water chemistry Water temperature	EBLA, LEWI, MORA, NOCA, OLYM	For a randomly selected subset of mountain ponds and lakes in the parks, 1. Determine the natural variation and long term trends in selected physical, chemical and biological water quality parameters in reference lakes/ponds. 2. Determine the status and trend of amphibian assemblages in focal lakes. 3. Determine long-term trends in the abundance and condition of non-native fish assemblages in selected reference lakes. 4. Document trends in direct effects of visitor use on shoreline condition for the reference lakes.
Wadeable Streams	Water temperature Water chemistry Benthic macroinvertebrates Fishes Channel Characteristics	EBLA, LEWI, MORA, NOCA, OLYM	For a randomly selected subset of all wadeable streams in the parks, 1. Determine long-term trends in selected physical and hydrological characteristics, including changes in substrate size, channel bed stability, average width and depth, amount of dewatered channel, discharge, residual pool depth, amount of pool habitat, amount of off-channel habitat, stream gradient, channel sinuosity, number and volume of large woody debris, percent stream canopy cover, riparian canopy type and seral stage, frequency of human disturbance and type of disturbance and proximity to the channel. 2. Document trends in water temperature, dissolved oxygen, pH, turbidity, anions and cations, and specific conductivity. 3. Determine trends in measures of stream benthic macroinvertebrates, including frequency/abundance of indicator taxa, metric scores (compositional, functional, dominance, species richness and tolerance metrics), multi-metric index scores, and ratios of observed versus expected taxa. 4. Determine trends in measures of the condition of fish communities, including proportion of area occupied by species, relative abundance, distribution, and size composition (native, including at-risk bull trout and west slope cutthroat, and non-native species/strains).

Table 5.1. Summary of long-term monitoring protocols being developed by the North Coast and Cascades Network for implementation with existing funding. Additional information for each protocol is provided at http://www1.nature.nps.gov/im/units/nccn/index.htm (continued).

Name of Protocol	Vital Signs being Addressed	Parks	Monitoring Objectives
Rivers	Water chemistry Benthic Macroinvertebrates Water temperature Fishes Channel characteristics	MORA, NOCA, OLYM	1. Determine trends in frequency of occupancy, size and age distribution, relative abundance, and species composition of fish assemblages (native, non-native, and hatchery) in large rivers during summer low-flow conditions with sufficient precision to detect biologically significant changes. 2. Determine annual spawner escapement, recreational fishing effort, and extent of recreational and tribal harvest of Pacific salmonids in large rivers in MORA, NOCA, and OLYM. 3. Determine trends in the relative incidence and prevalence of fish pathogens in selected fish species and large rivers. 4. Determine changes in physical habitat characteristics and chemical components of selected reaches of large rivers. 5. Archive fish tissue samples for genetic analysis to determine extent of hatchery introgression and variability among selected Pacific salmonids.
Intertidal Communities	Intertidal communities	OLYM	1. Determine the range of natural variation in species richness, abundance and distribution (elevational and coast-wide) of intertidal invertebrates and macroalgae in rock platform and sand beach habitats. 2. Determine the temporal and spatial change in physical habitat types. 3. Determine long-term trends in intertidal water temperatures across the range of coastal nearshore oceanographic cells. 4. Determine long-term summer trends in nearshore marine water quality.
Invasive Plants	Invasive Plants	EBLA, LEWI, FOVA, MORA, NOCA, OLYM, SAJH	1. Document changes in distribution and abundance (at five-year intervals) of high-priority invasive plant species in areas identified as highly susceptible to establishment of those species (i.e., potential habitat). 2. Detect incipient populations (i.e., small and localized) and new introductions of selected invasive plant species in potential habitat and track changes in cover of these populations.

Table 5.1. Summary of long-term monitoring protocols being developed by the North Coast and Cascades Network for implementation with existing funding. Additional information for each protocol is provided at http://www1.nature.nps.gov/im/units/nccn/index.htm (continued).

Name of Protocol	Vital Signs being Addressed	Parks	Monitoring Objectives
Prairie and Coastal Vegetation	Prairie and Coastal Vegetation	EBLA, SAJH	1. Document the location of the forest/prairie interface at ten year intervals. 2. Track changes in the density of trees and shrubs in prairies of American Camp. 3. Determine long-term trends in distribution and abundance of native and exotic plant species across the prairies of EBLA and SAJH. 4. Determine long-term trends in species cover of native and exotic plant species in the native prairie remnants of EBLA and SAJH. 5. Determine short-term trends in germination, survival and cover of native species seeded into restored areas in EBLA and SAJH. 6. Determine short-term trends in survival and growth of transplanted native grasses in restored areas in EBLA and SAJH. 7. Determine long-term trends in plant species cover in restored areas to evaluate how similar restored areas are to native reference communities in EBLA and SAJH.
Forest Vegetation	Forest Vegetation - Plots	MORA, NOCA, OLYM, SAJH	1. Use data from the Forest Inventory and Analysis national program to the maximum degree possible to describe decadal changes in under- and over-story structure and composition. 2. Determine 5-yr changes in species composition and abundance of forest vegetation in three sets of intensively monitored permanent plots. Two sets will be established in an extreme environments in the Network (i.e., cold-dry and warm-wet) and one set will be established in a vegetation type common throughout the Network. 3. Determine changes in rates of nutrient cycling in the three sets of permanent vegetation plots.
Subalpine Vegetation	Subalpine Vegetation	MORA, NOCA, OLYM	1. Determine changes in species composition and abundance of subalpine vascular vegetation in permanent plots stratified by vegetation community. 2. Determine long-term trends in concentrations of pollutants in non-vascular plants living in high-elevation areas.

Table 5.1. Summary of long-term monitoring protocols being developed by the North Coast and Cascades Network for implementation with existing funding. Additional information for each protocol is provided at http://www1.nature.nps.gov/im/units/nccn/index.htm (continued).

Name of Protocol	Vital Signs being Addressed	Parks	Monitoring Objectives
Landbirds	Landbirds	LEWI, MORA, NOCA, OLYM, SAJH	1.Determine trends in density and frequency of occurrence of landbird species in accessible areas of NCCN parks during the breeding season.
Elk	Elk	LEWI, MORA, OLYM	1. Determine trends in abundance of elk populations inhabiting low-elevation winter ranges in Olympic National Park during spring, high-elevation summer ranges in MORA and OLYM, and using park and adjoining lands in LEWI.
Remote Sensing	Forest Vegetation - Remote Fire and fuel dynamics Landscape dynamics Disturbance Riparian Vegetation Prairie and Coastal Vegetation Channel Characteristics – Rivers Snow cover	EBLA, LEWI, FOVA, MORA, NOCA, OLYM, SAJH	Through the use of aerial and satellite imagery, determine long-term changes in the following: 1. Frequency, areal extent, and spatial patterns of large-scale disturbance events, including fire, disease pathogens, geologic processes, wind and storm events, flooding, and timber harvest. 2. Large-scale changes in forest composition (e.g., extent of coniferous vs. deciduous forests). 3. Species composition of overstory trees in riparian zones. 4. Elevational shifts at the interface between the subalpine and alpine vegetation zones. 5. Areal extent of glaciers and snowfields. 6. Areal extent and patterns of different land cover and land use categories. 7. Physiognomic pattern of prairie and coastal vegetation. 8. Channel characteristics of rivers.

Chapter 6. Data Management

The central mission of the NPS Inventory and Monitoring Program is to provide timely and usable scientific information about the status and trends of park resources to park managers. To meet this challenge, we need an information management system that can effectively produce, maintain and distribute the products of scientific work done in our parks.

Good data management is the means by which a thorough understanding of the scope, origin, and value of scientific information about our natural resources can become a part of our National Park Service heritage. Data management refers to the attitudes, habits, procedures, standards, and infrastructure related to the acquisition, maintenance and disposition of data and its resulting information. Data management is not an end unto itself, but instead is the means of maximizing the quality and utility of our natural resource information. This is particularly important for long-term programs where the lifespan of a data set will likely be longer than the careers of the scientists who developed it. Seen in this way, it becomes obvious that data management is vital to the success of any long-term monitoring initiative.

This chapter summarizes the NCCN data management strategy which is more fully addressed in the NCCN Data Management Plan in a file named "NCCN_DMP_Sep2005.pdf", available at: http://www1.nature.nps.gov/im/units/nccn/monitoringreports.htm .
The DMP documents the overarching strategy for ensuring that program data are documented, secure, and remain accessible and useful for decades into the future. The DMP, in turn, refers to other guidance documents and standard operating procedures which convey the specific standards and steps for achieving our data management goals.

6.1 Data Management Goals and Objectives

The goal of our data management system is to ensure the quality, interpretability, security, longevity and availability of ecological data and related information resulting from resource inventory and monitoring efforts.

- *Quality* – Awareness of the quality of information and its underlying data is fundamental to its proper use. Our objective is to ensure that appropriate quality assurance measures are taken during all phases of project development, data acquisition, data handling, summary and analysis, reporting, and archiving. These will reflect current best practices and meet rigorous scientific standards. Since standards and procedures can only accomplish so much, an important part of quality assurance is to continually encourage careful attitudes and good habits among all staff involved in creating, collecting, handling, and interpreting data.
- *Interpretability* – A data set is only useful if it can be readily understood and appropriately interpreted in the context of its original scope and intent. Data taken out of context can lead to misinterpretation, misunderstanding, and bad management decisions. Similarly, data sets that are obscure, complex or poorly documented can be easily misused. Sufficient documentation should accompany each data set, and any reports and

summaries derived from it, to ensure that users will have an informed appreciation of its applicability and limitations.

- *Security* – Our objective is to make certain that both digital and analog forms of source data are maintained and archived in an environment that provides appropriate levels of access to project managers, technicians, decision makers, and others. Our data management system will take advantage of existing systems for network security and systems backup, and augment these with specific measures aimed at ensuring the long-term security and integrity of our data.
- *Longevity* – Countless data sets have been lost over time simply because they were not sufficiently documented and organized when they were created. Too often data are left in a condition that renders them effectively irretrievable – either because the format is outdated (e.g., punch cards that can no longer be read in a cost-effective manner), or more often because there is not enough documentation to inform subsequent users of the scope and intended use of the data set. Without sufficient information about a data set we lose confidence in its quality and applicability, leaving it useless and unused. The longevity of a data set can be enhanced by thorough documentation, and by maintaining the data in an accessible and interpretable format. Although this requires an initial investment of time and effort upon creation of the data set, this investment almost certainly pays off over time because the data set is much more likely to be used. Furthermore, simply using a data set enhances its longevity because its value is being realized and enhanced through use. This begs us to apply an old adage to our natural resource data: use it or lose it.
- *Availability* – Natural resource information can only be useful for informing decisions if it is available to managers at the right time and in a usable form. Our objective is to expand the availability of natural resource information by ensuring that the products of inventory and monitoring efforts are created, documented and maintained in a manner that is transparent to the potential users of these products.

6.2 Data and Data Management – Providing Context

Collecting natural resource data is our first step toward understanding the ecosystems within our national parks. These ecosystems are evolving, as is our knowledge of them and how they function. We use these “raw” data to analyze, synthesize, and model aspects of ecosystems. In turn, we use our results and interpretations to make decisions about the Park’s vital natural resources. Thus, *data* collected and maintained by the North Coast and Cascades Network will become *information* through analysis, synthesis, and modeling. Information is the common currency among the people involved in stewardship projects throughout our National Park System.

But any good set of data – whether collected last week or 20 years ago – must tell us enough about itself so that we can reliably preserve and use it. Anyone using these data will need to know as much as possible about how and why these data were collected. Therefore, our network data management system cannot simply attend to the tables, fields, and values that make up a data set. It must also provide a process for developing, preserving, and integrating the context that makes data interpretable and valuable. Although this means more time will be spent documenting data sets, it will result in better preservation and presentation of data.

We sometimes use the term "data" in a way that also encompasses other products that are generated alongside primary tabular and spatial data. These products fall into five general categories: raw data, derived data, documentation, reports, and administrative records (Table 6.2.1).

To meet I&M Program goals, and to ensure adequate context for the primary data products, these categories of project deliverables all require some level of management to ensure their quality and availability. We intend to integrate the manner in which our network creates, manages, and makes available the products of our scientific efforts. Thus, we will take a holistic view of how natural resource data are generated, processed, finalized and provided to others. All phases of data and information processing are integrated, and information about each phase is shared through good documentation.

Table 6.2.1. Categories of data products and project deliverables.

Category	Examples
Raw data	GPS rover files, raw field forms and notebooks, photographs and sound/video recordings, telemetry or remote-sensed data files, biological voucher specimens
Compiled/derived data	Relational databases, tabular data files, GIS layers, maps, species checklists
Documentation	Data collection protocols, data processing/analysis protocols, record of protocol changes, data dictionary, FGDC/NBII metadata, data design documentation, quality assurance report, catalog of specimens/photographs
Reports	Annual progress report, final report (technical or general audience), periodic trend analysis report, publication
Administrative records	Contracts and agreements, study plans, research permits/applications, other critical administrative correspondence

6.3 Sources of Natural Resource Data

There are many potential sources of important data and information about the condition of natural resources in our parks. The types of work that may generate natural resource data about park resources include:

- Inventories
- Monitoring
- Protocol development pilot studies
- Special focus studies done by internal staff, contractors or cooperators
- External research projects
- Monitoring or research studies done by other agencies on park or adjacent lands
- Resource impact evaluations related to park planning and compliance with regulations
- Resource management and restoration work

> *Prioritizing data management efforts in a sea of unmanaged data*
> 1. Highest priority is to produce and curate high-quality, well-documented data originating from the Inventory and Monitoring Program
> 2. As time and resources permit, work toward raising the level of data management for current projects, legacy data, and data originating outside the Inventory and Monitoring Program
> 3. Place greatest emphasis on those projects that are just beginning to be developed and implemented, because inserting good data management practices into an existing project can be difficult and will generally meet with less success

Because the I&M Program focuses on long-term monitoring and natural resource inventories, our first priority should be toward the data and information that we derive from these primary efforts. However, we can easily apply the same standards, procedures, infrastructure and attitudes about data management to other natural resource data sources. One challenge will be to prioritize and manage workload and other resources. Naturally, high-profile data sets that provide crucial information to park management will be prioritized for data management regardless of funding source.

6.4 Data Stewardship Roles and Responsibilities

Data management is a complex process characterized as much by attitudes and habits as it is by infrastructure, standards and procedures. Although primary responsibility resides with the data managers, good data stewardship could not possibly be accomplished by data managers alone – it is truly a collaborative endeavor that involves many people with a broad range of tasks and responsibilities. As such, a valid data management system must be developed and continually modified to meet the needs of everyone with a role in coordinating, generating, maintaining, and using natural resource information in its many forms. This is a diverse group made up of park managers and scientists, GIS staff, IT specialists, project managers and technicians, and interpretive staff (Table 6.4.1). A successful data management system is maintained by reinforcing communication, awareness and acceptance among everybody with responsibilities related to the origin, quality, disposition, and use of the data.

Table 6.4.1. Roles and responsibilities for data stewardship.

Role	Data Stewardship Responsibilities
Project Crew Member	Collect, record, and verify data
Project Crew Leader	Supervise crew and organize data
GIS Specialist or Data Technician	Process and manage data
Information Technology Specialist	Provide IT support for hardware, software, networking
Project Leader	Oversee and direct project operations, including data management
Resource Specialist/Ecologist	Validate and make decisions about data. Integrate science in park and network activities.
GIS Coordinator	Support park management objectives with GIS and resource information management
Data Manager	Ensure inventory and monitoring data are organized, useful, compliant, safe, and available
Database Application Developer	Know and use database software and database applications
Curator	Oversee all aspects of specimen acquisition, documentation, and preservation, and manage the park collections
Statistician or Biometrician	Analyze data and/or consult on analysis
Network/Prototype Coordinator	Coordinate and oversee all network activities
Park Research Coordinator	Facilitate data acquisition by external researchers. Communicate NPS requirements to permit holders.
I&M Data Manager (National Level)	Provide Service-wide database availability and support
End Users (managers, scientists, interpreters, public)	Inform the scope and direction of science information needs and activities. Interpret information and apply to decisions.

Chief personnel involved with data management include the project leader and the data manager. The Network Coordinator interacts with project leaders to ensure that timelines for data entry, validation, verification, summarization/analysis and reporting are met. Figure 6.4.1 illustrates the core data management duties of the project leader and data manager and where they overlap.

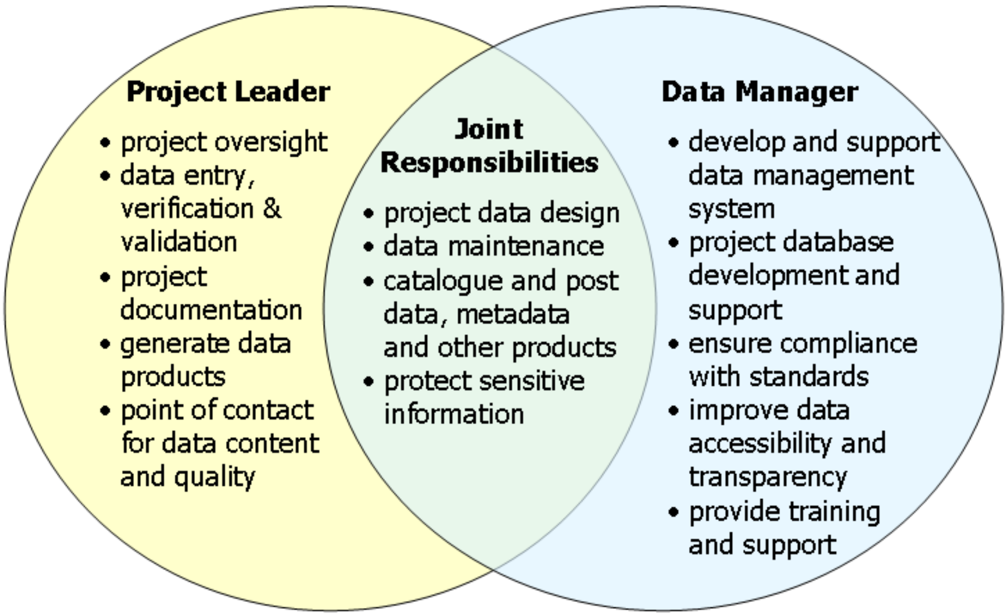

Figure 6.4.1. Core project data stewardship duties of project leaders and data managers.

6.5 Information Infrastructure

Our program relies heavily on park, regional, and national IT personnel and resources to maintain the computer resource infrastructure. This includes but is not limited to hardware replacement, software installation and support, security updates, virus-protection, telecommunications networking, and backups of servers. Therefore communication with park and regional IT specialists is essential to ensure adequate resources and service continuity for our system architecture.

An important element of a data management program is a reliable, secure network of computers and servers. Our digital infrastructure has three main components: park-based local area networks (LAN), network data servers, and servers maintained at the national level (Figure 6.5.1). This infrastructure is maintained by park, regional, and national IT specialists, who administer all aspects of system security and backups.

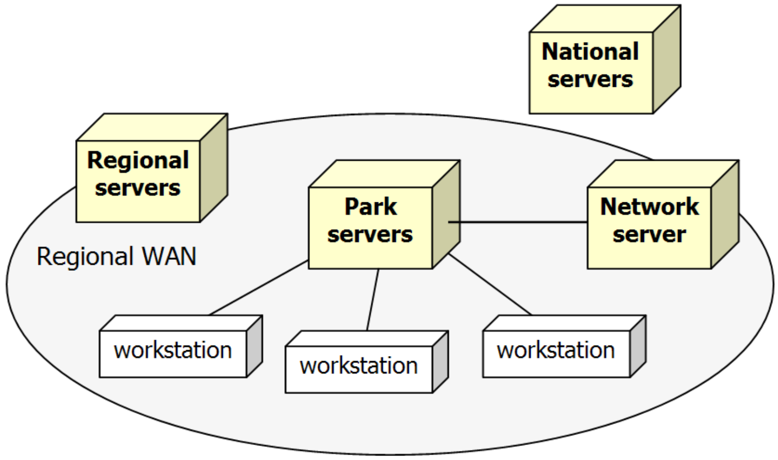

Figure 6.5.1. Schematic representing the logical layout and connectivity of computer resources within our regional wide-area network (WAN). These components each host different parts of our natural resource information system.

6.5.1 National-level Infrastructure

Data management support from the Washington office includes hosting and maintaining several databases for summarizing park data at the national level. These online applications provide a means for storing and making accessible the basic natural resource information and data for the parks:

- *NatureBib* – the master database for natural resource bibliographic references
- *NPSpecies* – a database application that lists the species that occur in or near each park, and the physical or written evidence for the occurrence of the species (i.e., references, vouchers, and observations)
- *NR-GIS Metadata Database* – a comprehensive database of metadata for all resource data sets. As of November, 2004, this application is not fully developed. A desktop counterpart, Dataset Catalog, is in use instead.
- *NR-GIS Data Store* – a centralized repository and graphical search interface that links data set metadata to a searchable data server on which data sets are organized by NPS units, offices and programs

6.5.2 Network-level Infrastructure

We are in the process of implementing a client-server database system for our network. Our strategy is to manage common tables and high-value, long-term project databases within this system as a means of maximizing performance in a distributed, multi-user environment. There are three data servers that comprise the Network infrastructure – one located at MORA, and one at each of the prototype parks (NOCA and OLYM). These three servers function as independent data nodes that can be accessed from any park location so long as it is within the wide area network maintained by the Pacific West Region. They are also integrated in that common tables are replicated regularly among data nodes, backups for one node are stored on a separate node, and network databases are distributed across the three nodes. The following types of materials are maintained on these network data servers:

- Master project databases – compiled data sets for monitoring projects and other multi-year efforts that have been certified for data quality
- Common lookup tables – e.g., parks, projects, personnel, species
- Project tracking application – used to track project status, contact information, product due dates
- Network digital library – network repository for finished versions of project deliverables for network projects (e.g., reports, methods documentation, data files, metadata, etc.)

Highlights of our information management infrastructure are as follows:

- Our system of replicated data servers will act as a repository for data and data products generated by our program. These data will be accessible via custom applications and open to authorized NPS personnel.
- Redundancy means that data are fully backed up on an off-site data node, which is crucial for information recovery in case of a local catastrophe at one of the host sites. Backups will be automated through scheduled services.
- Finalized data products and related information will be uploaded to the online national databases (NatureBib, NPSpecies, NR-GIS Metadata Database, and NR-GIS Data Store) for public access.

Given our collaboration with other agencies and organizations, certain NCCN data sets will be maintained by outside organizations. In such cases, we will maintain local copies of metadata for these data sets. In cases where information systems maintained by cooperators do not meet NPS needs, it may make sense to retain archival copies of data sets on our servers to ensure data availability.

6.5.3 Park-level Infrastructure

Because of the high degree of integration of our program with park operations, the primary distinction between park-based infrastructure and network infrastructure will be greater park emphasis on the use of local area networks (LAN) to serve as temporary storage of working copies of project materials, and local copies of national databases. The following materials are maintained on these local file servers:

- Local applications – desktop versions of national applications (e.g., NPSpecies, Dataset Catalog)
- Working files – working databases, draft geospatial themes, drafts of reports, administrative records
- Park digital library – base spatial data, imagery, and finished versions of park project deliverables
- Park GIS files – base spatial data, imagery, and project-specific themes

6.6 Database Design Strategies

Rather than developing a single, integrated database system, our strategy relies upon modular, standalone project databases that share design standards and links to centralized data tables. Individual project databases are developed, maintained, and archived separately. There are numerous advantages to this strategy:

- Data sets are modular, allowing greater flexibility in accommodating the needs of each project area. Individual project databases and protocols can be developed at different rates without a significant cost to data integration. In addition, one project database can be modified without affecting the functionality of other project databases.
- By working up from modular data sets, we avoid a large initial investment in a centralized database and the concomitant difficulties of integrating among project areas with very different – and often unforeseen – structural requirements. Furthermore, the payoff for this initial investment may not be realized down the road by greater efficiency for interdisciplinary use.

Project database standards are necessary for ensuring compatibility among data sets, which is vital given the often unpredictable ways in which data sets will be aggregated and summarized. When well thought out, standards also help to encourage sound database design and facilitate interpretability of data sets. As much as possible, NCCN standards for fields, tables and other database objects will mirror those conveyed through the Natural Resource Database Template. Where there are differences between local and national standards, documentation of the rationale for these differences will be developed. In addition, documentation and database tools (e.g., queries that rename or reformat data) will be developed to ensure that data exports for integration are in a format compatible with current national standards.

6.7 Project Work Flow

From the perspective of managing work flow, there are two main types of projects:

- *Short-term projects*, which may include individual park research projects, inventories, or pilot work done in preparation for long-term monitoring.
- *Long-term projects*, which will mainly be the implemented monitoring projects central to the I&M program, but which may also include multi-year research projects and monitoring performed by other agencies and cooperators. Long-term projects will often require a higher level of documentation, peer review and program support.

From a data management standpoint, a primary difference between short- and long-term projects is an increased need to adhere to standards for long-term projects to ensure internal compatibility over time. While the need to follow standards is still present for short-term projects, sometimes the cost of compliance will outweigh the benefits due to the scope, budget, and level of NPS influence over the project details. Nevertheless, both short-term and long-term projects share many work flow characteristics, and both generate data products that must be managed and made available.

Projects can be divided into five primary stages, each of which is characterized by a set of activities carried out by staff involved in the project (Figure 6.7.1):

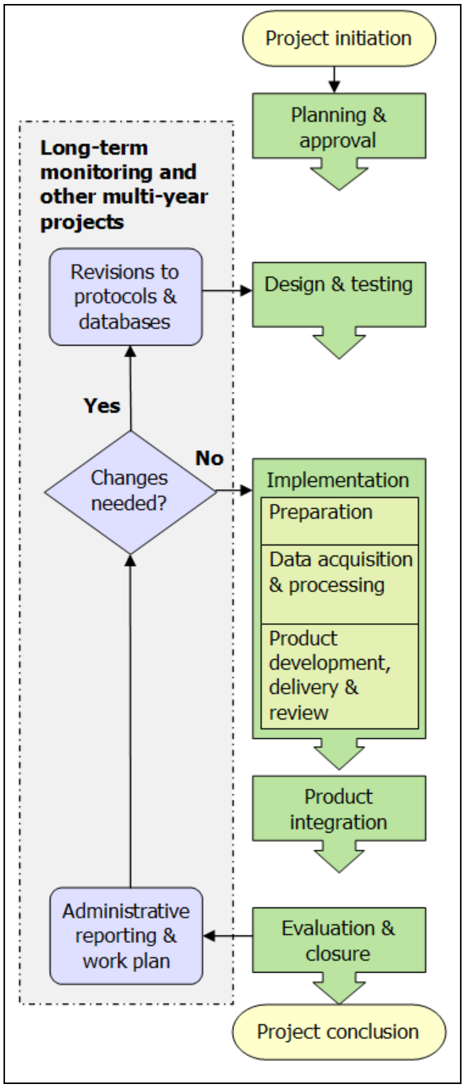

Figure 6.7.1. Project work flow.

- *Planning and approval* – This is when many of the preliminary decisions are made regarding project scope and objectives. In addition, funding sources, permits and compliance are all addressed in this phase. Primary responsibility rests with project leaders and program administrators. Although this phase lacks specific data management activities, it is important that data managers remain informed of projects in this phase. This is especially true as timelines for deliverables are finalized. All contracts, agreements and permits should include standard language that describes the formats, specifications, and timelines for project deliverables.
- *Design and testing* – During this phase, all of the details are worked out regarding how data will be acquired, processed, analyzed, reported and made available to others. The project

leader is responsible for development and testing of project methodology, or modifying existing methods to meet project objectives. It is critical that the project leader and the data manager work together throughout this phase. The dialog between these two will help to build and reinforce good data management throughout the project – especially during the crucial stages of data acquisition, processing, and retrieval. By beginning collaborative development as soon after project approval as possible, data integrity and quality can most easily be assured. An important part of this collaboration is the development of the data design and data dictionary, where the specifics of database implementation and parameters that will be collected are defined in detail. Devoting adequate attention to this aspect of the project is possibly the single most important part of assuring the quality, integrity and usability of the resulting data. Once the project methods, data design, and data dictionary have been developed and documented, a database can be constructed to meet project requirements.

- *Implementation* – During the implementation phase, data are acquired, processed, error-checked and documented. This is also when products such as reports, maps, GIS themes, and other products are developed and delivered. The project leader oversees all aspects of implementation – from logistics planning to data acquisition, report preparation and final delivery. Throughout this phase, data management staff function primarily as facilitators – providing training and support for database applications, GIS, GPS and other data processing applications; facilitation of data summarization, validation and analysis; and assistance with the technical aspects of documentation and product development.
- *Product integration* – During this phase, data products and other deliverables are integrated into national and network databases, metadata records are finalized and posted in clearinghouses, and products are distributed or otherwise made available to their intended audience. Another aspect of integration is merging data from a working database to a master database maintained on the network server. This occurs only after the annual working data set has been certified for quality by the project leader. Certain projects may also have additional integration needs, such as when working jointly with other agencies for a common database.
- *Evaluation and closure* – Upon project closure, records are updated to reflect the status of the project and its associated deliverables in a network project tracking application. For long-term monitoring and other cyclic projects, this phase occurs at the end of each field season, and leads to an annual review of the project. For non-cyclic projects, this phase represents the completion of the project. After products are catalogued and made available, program administrators, project leaders, and data managers should work together to assess how well the project met its objectives, and to determine what might be done to improve various aspects of the methodology, implementation, and formats of the resulting information. For monitoring protocols, careful documentation of all changes is required. Changes to methods, SOPs and other procedures are maintained in a tracking table associated with each document. Major revisions may require additional peer review.

6.8 Data Life Cycle

During various phases of a project, project data take different forms and are maintained in different places as they are acquired, processed, documented and archived (Figure 6.8.1, Table 6.8.1).

Key points of this life cycle are as follows:

- All raw data are archived intact.
- Working databases are the focal point of all modification, processing, and documentation of data collected for a given season (or other period that makes sense for a given project).
- Upon data certification – indicating that the data have passed all documentation and quality assurance requirements – the data are archived and posted or otherwise integrated with the national data applications.
- For long-term monitoring projects, data are then uploaded into a master database that includes multiple years of data.
- Certified data sets are used to develop reports and other data products (maps, checklists, etc.). These products are also archived and posted to appropriate national repositories.
- All subsequent changes to certified data sets are documented in an edit log, which is distributed with the data.

Table 6.8.1. Repositories for NCCN products.

Repository	Item
NCCN Digital Library	Project data, metadata, and other products •Raw and certified data sets •Metadata, protocols, SOPs •Reports and administrative records •Digital photographs, derived products
NCCN Project Databases	Comprehensive data for multi-year projects
Park Collections and/or National Archives	Administrative records, voucher specimens*, raw data forms, hard copy reports
National Databases - NPSTORET, NPSpecies, NatureBib	Compiled information about water quality, park species lists and taxonomic documentation, park resource bibliographies
NR Data Image Server	Copies of digital reports and other documents (catalogued in NatureBib)
NR-GIS Data Store	Copies of digital data sets (non-sensitive) and metadata

* Biological specimens can also be retained at other facilities (e.g., University of Washington Herbarium) with an appropriate agreement.

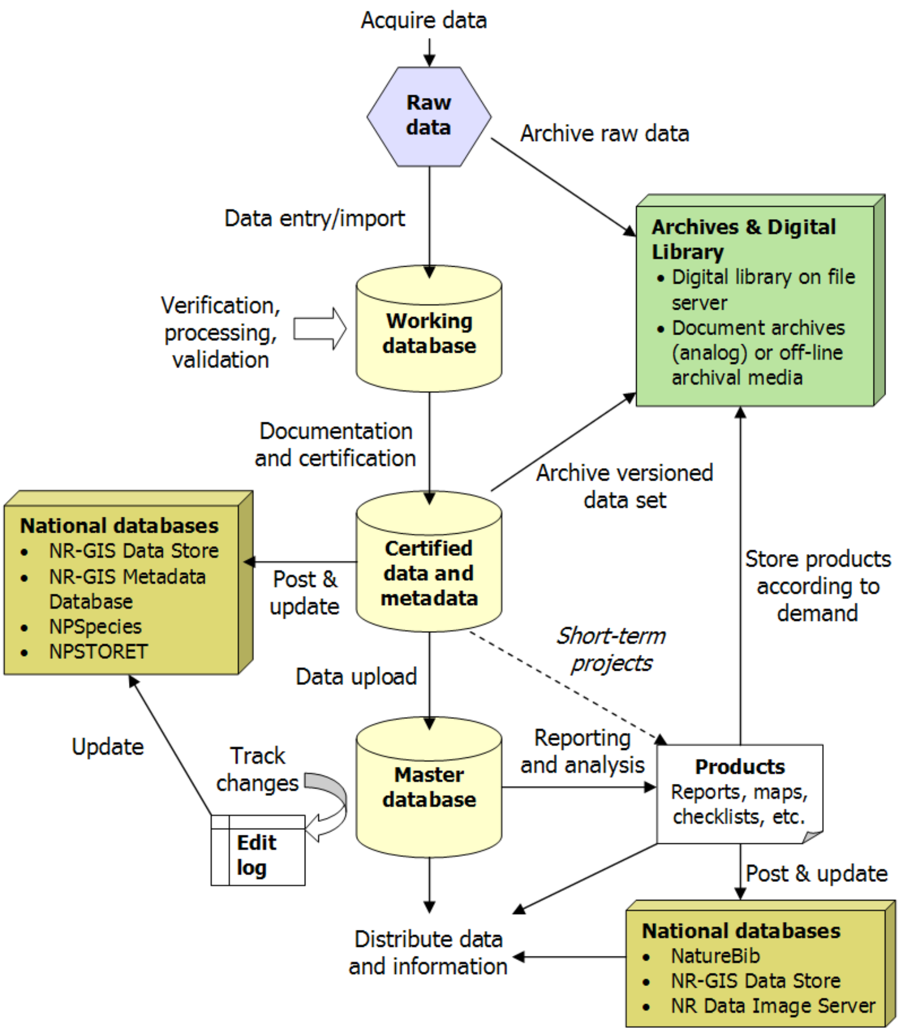

Figure 6.8.1. Diagram of project data life cycle.

6.9 Water Quality Data

All water quality data collected by our network will be managed according to guidelines from the NPS Water Resources Division. This includes using the NPSTORET desktop database application at the parks to help manage data entry, documentation, and transfer. We will implement and maintain a desktop copy of NPSTORET and transfer its contents at least annually to NPS Water Resource Division for upload to the STORET database (Figure 6.9.1). Because NPSTORET is constantly being updated, WRD uploads to STORET occur on a monthly basis.

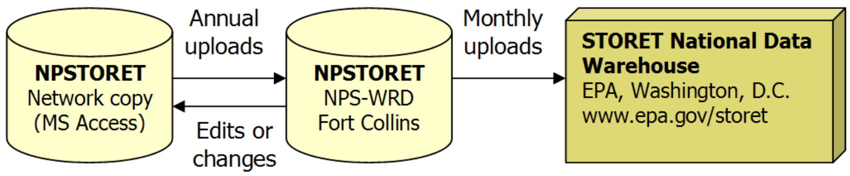

Figure 6.9.1. Data flow diagram for water quality data.

6.10 Data Summarization and Export for Analysis

Our project databases will store data in flexible, relational structures that may be reconfigured for a variety of output formats (e.g., delimited ASCII, etc.). Each monitoring protocol specifies the analyses to be conducted on the data, and data managers will work closely with project leaders and others to ensure that monitoring data is available in the formats required for analysis software. In addition, automated summary and export routines can be developed that prepare data for reporting or exporting to analysis software at the click of a button.

6.10.1 Quality Assurance

We must have confidence in the data we use. Our attempts to detect trends and patterns in ecosystem health require data of documented quality that minimize error and bias. Data of inconsistent or poor quality can result in loss of sensitivity and incorrect interpretations and conclusions.

To ensure that our projects produce and maintain data of the highest possible quality, we will establish procedures to identify and minimize both the frequency and significance of error at all stages in the data life cycle. Although many quality control procedures depend upon the nature of a specific project, some general concepts apply to all network projects. In addition, each monitoring protocol will include project-specific procedures to ensure data quality. Examples of quality assurance practices include:

- Field crew training
- Standardized field data sheets with descriptive data dictionaries
- Use of handheld computers and data loggers
- Equipment maintenance and calibration
- Procedures for handling data in the field
- Database features to minimize transcription errors, including range limit, pick lists, etc.
- Verification and validation, including automated error-checking database routines

Quality assurance methods should be in place at the inception of any project and continue through all project stages to final archiving of the data set. It is critical that each member of the data management group work to ensure data quality. Everyone plays a part in producing and maintaining high quality data.

The final step in project quality assurance is the preparation of summary documentation that assesses the overall data quality. A statement of data quality will be composed by the Project Leader and incorporated into formal metadata. Metadata for each data set will also provide information on the specific quality assurance procedures applied and the results of the review.

Additional information on our quality assurance program can be found in the DMP, which presents several options for carrying out data verification (ensuring data on field sheets match data entered into a database) and validation (ensuring that the data make sense).

6.10.2 Data Documentation – Metadata

Data documentation is a critical step toward ensuring that data sets are useable 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 data. Additionally, metadata provide the means to catalog data sets, within intranet and internet systems, thus making their respective data sets available to a broad range of potential data users. Without metadata, a potential data user is often left with little or no information regarding the quality, completeness, or manipulations performed on a particular copy of a data set. This ambiguity results in lost productivity as the user must invest time tracking information down, and can eventually render the data set useless because answers to these and other critical questions cannot be found. An upfront investment in planning and organization for documentation can preserve data from this type of degradation.

Metadata for all NCCN monitoring data will conform to FGDC guidelines and be parsed into three nesting levels of detail – each with a specific audience in mind. Level 1, or “Manager Level” will present an overview of the product crafted to quickly convey the essentials needed to understand the product. Level 2, or “Scientist Level” will present additional details that allow for rapid scientific evaluation of the product. Level 3, or “Full Metadata” will contain all components of supporting information such that the data may be confidently manipulated, analyzed and synthesized.

There are a variety of software tools available for creating and maintaining metadata. The data managers will provide training and support to project leaders to facilitate metadata development. Upon completion, metadata will be posted so that it is available and searchable in conjunction with related data and reports via the NCCN website, as well as the national NR-GIS Metadata Database.

6.10.3 Data and Information Dissemination

Access to NCCN data products will be facilitated via a variety of information systems that allow users to browse, search and acquire network data and supporting documents. These systems include the NCCN data server, the park and network digital libraries, the NCCN website, and national applications with internet interfaces (NatureBib, NPSpecies, NR-GIS Data Store, etc.; Table 6.10.3).

Table 6.10.3. Information systems that facilitate dissemination of NCCN information.

Web Application Name	Data types available at site
NPSpecies	Data on park biodiversity (species information)
NatureBib	Scientific citations related to park resources
NR-GIS Metadata and Data Store	Metadata, spatial and non-spatial data products
NCCN Website	Reports and metadata for all network projects

Because network data will reside in the repositories listed above, these data will automatically be searchable via the integrated metadata and image management system and search gateway called NPS Focus. This system is being built with Blue Angel Enterprise software for metadata management and the LizardTech Express Server for image management. Currently ten NPS and two non-NPS databases have been integrated into the NPS Focus prototype in either full or test bed form for one stop searching. NPS Focus has been released as an Intranet only version (http://focus.nps.gov/) – release of a public version is projected in the near future.

Network products will also be available via data requests that will be fulfilled using either electronic file transfer protocol (FTP), email attachments for small file sizes, or shipment of digital media such as DVDs, CD-ROMs, or diskettes.

6.11 Ownership, FOIA and Sensitive Data

NCCN products are considered property of the NPS. However the Freedom of Information Act (FOIA) establishes access by any person to federal agency records that are not protected from disclosure by any exemption or by special law enforcement record exclusions. We will comply with all FOIA strictures regarding sensitive data. If the NPS determines that disclosure of information would be harmful, information may be withheld concerning the nature and specific location of:

- Endangered, threatened, rare or commercially valuable National Park System Resources (species and habitats)
- Mineral or paleontological objects
- Objects of cultural patrimony
- Significant caves

Each project leader, as the primary data steward, will determine data sensitivity in light of federal law, and will stipulate the conditions for release of the data in the project protocol and metadata. Network staff will classify sensitive data on a case by case, project by project, basis. They will work closely with investigators for each project to ensure that potentially sensitive park resources are identified, and that information about these resources is tracked throughout the project. network staff is also responsible for identifying all potentially sensitive resources to principal investigator(s) working on each project. The investigators, whether network staff or partners, will develop procedures to flag all potentially sensitive resources in any products that come from the project, including documents, maps, databases, and metadata. When submitting any products or results, investigators should specifically identify all records and other references to potentially sensitive resources. Partners should not release any information in a public forum before consulting with network staff to ensure that the information is not classified as sensitive or protected.

The following guidance for determining whether information should be protected is suggested in the draft Director's Order #66 (the final guidance will be contained in the Reference Manual 66):

- Has harm, theft, or destruction occurred to a similar resource on federal, state, or private lands?
- Has harm, theft, or destruction occurred to other types of resources of similar commercial value, cultural importance, rarity, or threatened or endangered status on federal, state, or private lands?
- Is information about locations of the park resource in the park specific enough so that the park resource is likely to be found at these locations at predictable times now or in the future?
- Would information about the nature of the park resource that is otherwise not of concern permit determining locations of the resource if the information were available in conjunction with other specific types or classes of information?
- Even where relatively out-dated, is there information that would reveal locations or characteristics of the park resource such that the information could be used to find the park resource as it exists now or is likely to exist in the future?
- Does NPS have the capacity to protect the park resource if the public knows its specific location?

Natural Resource information that is sensitive or protected requires the following steps:

- Identification of potentially sensitive resources
- Compilation of all records relating to those resources
- Determination of what data must not be released to the public
- Management and archival of those records to avoid their unintentional release

6.12 Data Maintenance, Storage and Archiving

Our data maintenance, storage and archiving procedures ensure that data and related documents (digital and analogue) are:

- Kept up-to-date with regards to content and format such that the data are easily accessed and their heritage and quality easily learned
- Physically secure against environmental hazards, catastrophe, and human malice

Technological obsolescence is a significant cause of information loss, and data can quickly become inaccessible to users if they are stored in out-of-date software programs or on outmoded media. Effective maintenance of digital files depends on the proper management of a continuously changing infrastructure of hardware, software, file formats, and storage media. Major changes in hardware can be expected every 1-2 years and in software every 1-5 years. As software and hardware evolve, data sets must be consistently migrated to new platforms, or they must be saved in formats that are independent of specific platforms or software (e.g., ASCII delimited files). We will develop and keep track of data maintenance schedules, to ensure that data are migrated and kept up to date.

- Primary data maintenance will be performed on the NCCN data servers. The data and information content of files stored on this server will be kept current. Accompanying metadata files will reflect any data updates as well.

- A catalogue of the data and information on these servers will be maintained on the NCCN website and reflect changes and updates to data holdings. National repositories for NCCN data and information (see Table 6.8.1) will be updated to reflect current stores on the NCCN servers. Additionally, program archives will also be updated to mirror content on the data servers.
- Latest versions of primary data will be available in conventional formats reflecting common data usages in the resource management community.

Chapter 7. Data Analysis and Reporting

Vision Statement of the Board of Directors
North Coast and Cascades Network

In response to the Natural Resources Challenge, the seven National Park Service units in the North Coast and Cascades Network work collaboratively to design and implement a Network Monitoring Program to focus collective efforts on inventory, monitoring and research on natural ecosystems. This will result in a comprehensive body of knowledge that provides timely and relevant, scientifically credible information to Park managers and the public.

Through these efforts we will be better able to understand, and explain to others, the status and trends in key components and indicators of Park ecosystems, and how they have and will respond over time to natural and human induced changes both from within and outside of Park boundaries.

This comprehensive, integrated long-term ecological monitoring program provides for better protection, restoration and maintenance of the natural ecosystems under NPS management.

The Network Monitoring Program collaborates with complimentary monitoring efforts of all levels of government, in order to achieve the greatest level of protection to natural resources and to contribute a body of knowledge to address broader, regional natural resource issues.

The broad-based, scientifically sound information obtained through monitoring has many uses in management decision-making, research, education, and promoting public understanding of park resources. The primary audience for our monitoring results are park managers. These data will provide superintendents, park resource chiefs, and other managers with convincing evidence to support management decisions and will help others in their work to protect park resources. Other key audiences include park planners, interpreters, researchers and scientific collaborators, the general public, Congress, and the President's Office of Management and Budget (OMB). To be most effective, monitoring data must be analyzed, interpreted, and provided at regular intervals to each of these key audiences in a format they can use, which means that there must be several different scales of analysis, and the same information needs to be packaged and distributed in different formats to the different key audiences.

The scientific data needed to better understand how park systems work and to better manage the parks will come from many sources. In addition to new information collected through the I&M Program, status and trend data will come from other park projects and programs, other agencies, and from the general scientific community (Figure 7.1). To the extent that staffing and funding is available, the network monitoring program will collaborate and coordinate with these other efforts, and will promote the integration and synthesis of data across projects, programs, and disciplines.

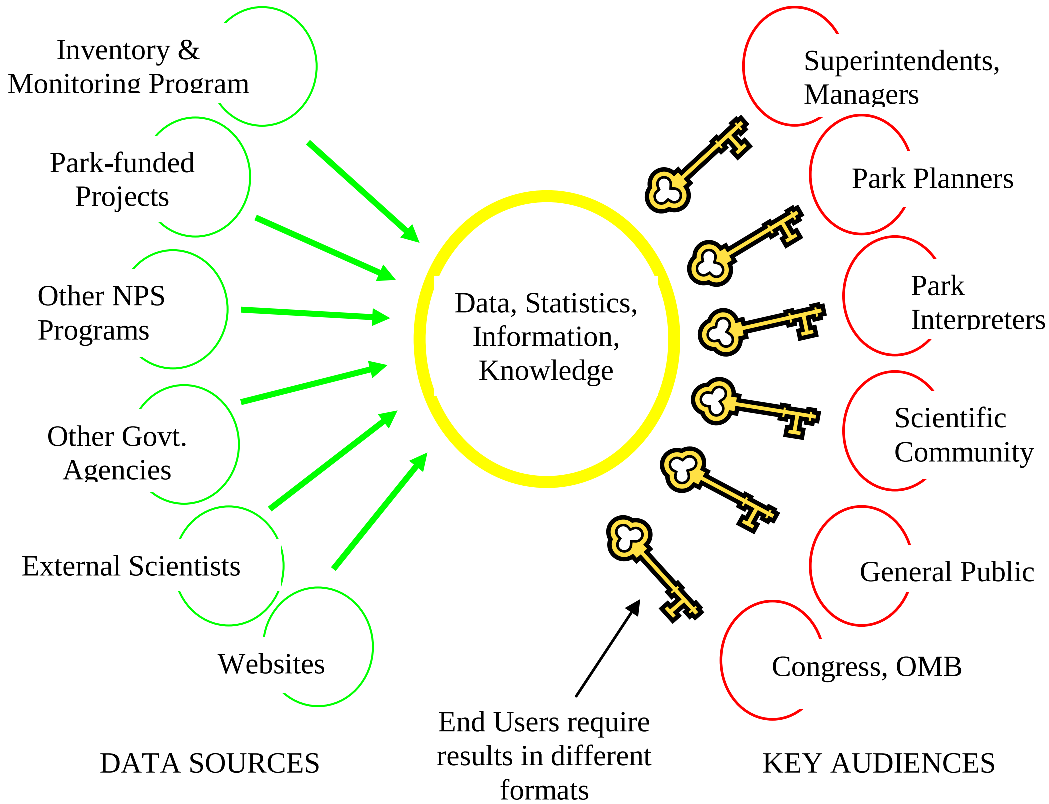

Figure 7.1. Scientific data for determining the status and trend in the condition of selected park natural resources will come from multiple sources, and will be managed, analyzed, and disseminated to multiple audiences in several different formats in order to make the results more available and useful.

Information is the common currency among the many different activities and people involved in the stewardship of a park's natural resources. The people involved with park planning, inventories, short- and long-term monitoring, research studies, restoration activities, control of invasive species, T&E species management, fire management, trail and road maintenance, law enforcement, and interpretation all require and/or provide natural resource information to others. As part of the Service's effort to "improve park management through greater reliance on scientific knowledge," a primary role of the Inventory and Monitoring Program is to develop, organize, and make available natural resource data and to contribute to the Service's institutional knowledge by facilitating the transformation of data into information through analysis, synthesis, and modeling.

This chapter presents an overview of how the Network proposes to analyze, synthesize, and disseminate monitoring results to the key audiences above.

7.1 Analysis of Monitoring Data

Appropriate analysis of monitoring data is directly linked to the monitoring objectives, the spatial and temporal aspects of the sampling design used, the intended audiences, and management uses of the data. Analysis methods need to be considered when the objectives are identified and the sampling design is selected, rather than after data are collected. Each monitoring protocol (Chapter 5) will contain detailed information on analytical tools and approaches for data analysis and interpretation, including the rationale for a particular approach, advantages and limitations of each procedure, and standard operating procedures (SOPs) for each prescribed analysis.

Table 7.1 summarizes four general categories of analysis for NCCN Vital Signs, and the lead analyst responsible for each. The lead analyst will ensure that data are analyzed and interpreted within the guidelines of the protocol and program, but they may not actually perform the analyses or interpret the results in some cases.

Table 7.1. Four levels of data analysis for NCCN Vital Signs.

Level of Analysis	Description	Lead Analyst
Data Summarization/ Characterization	Calculation of basic statistics of interest from monitoring data including measures of location and dispersion. Summarization encompasses measured and derived variables specified in the monitoring protocol. Data summarization and characterization forms the basis of more comprehensive analyses, and for communicating results in both graphical and tabular formats.	The Principal Investigator for each monitoring protocol, working with the data management staff, will produce routine data summaries. Parameters and procedures are specified in the monitoring protocols.
Status Determination	Analysis and interpretation of the ecological status (point in time) of a vital sign to address the following types of questions: •How do observed values for a vital sign compare with historical levels? •Do observed values exceed a regulatory standard, known or hypothesized ecological threshold? What is the level of confidence that the exceedance has actually occurred? •What is the spatial distribution (within park, network, ecoregion) of observed values for a given point in time? Do these patterns suggest directional relationships with other ecological factors? Status determination will involve both expert interpretation of the basic statistics and statistical analysis to address these monitoring questions. Assumptions about the target population and the level of confidence in the estimates will be ascertained during the analysis.	The Principal Investigator for each monitoring protocol is the lead analyst for status determination, although the Network Coordinator, cooperators, partners, interns or other network staff may conduct analyses and assist with interpreting results. Consultation with regulatory and subject matter experts will support status determination.

Table 7.1. Four levels of analysis for NCCN Vital Signs (continued).

Level of Analysis	Description	Lead Analyst
Trends Evaluation	Evaluations of trends in Vital Signs will address: •Is there directional change in a vital sign over the period of measurement? •What is the rate of change (sudden vs. gradual), and how does this pattern compare with trends over broader spatial scales and known ecological relationships? •What is the level of confidence that an actual change (or lack thereof) has occurred? Analysis of trends will employ parametric, nonparametric, or mixed models based on assumptions that can or cannot be reasonably made about the target population. Where appropriate, exogenous variables (natural, random phenomena that may influence the response variable) will be accounted for in the analysis.	The Principal Investigator for each monitoring protocol is the lead analyst for trend determination, although the Network Coordinator, cooperators, partners, interns or other network staff may conduct analyses and assist with interpreting results. Comparison with relevant long-term experimental results will aid interpretation.
Synthesis and Modeling	Examination of patterns across Vital Signs and ecological factors to gain broad insights on ecosystem processes and integrity. Analyses may include: •Qualitative and quantitative comparisons of Vital Signs with known or hypothesized relationships. •Data exploration and confirmation (e.g., correlation, ordination, classification, multiple regression, structural equation modeling). •Development of predictive models. Synthetic analysis has great potential to explain ecological relationships in the nonexperimental context of Vital Signs monitoring and will require close interaction with academic and agency researchers.	The Network Coordinator is responsible for ensuring thorough, peer reviewed data synthesis and modeling using expertise from agency scientists or academia. P.I.s for various protocols and cooperators, partners, interns or other network staff may conduct analyses and assist with interpreting results. Integration with researchers and experimental results is critical.

7.2 Communications and Reporting

The various approaches and products we plan to use to disseminate the results of the monitoring program and to make the data and information more available and useful to our key audiences are organized into the following seven categories and described in the following sections:

1. Annual Reports for Specific Protocols and Projects
2. Annual Briefings to Park Managers
3. Analysis and Synthesis Reports
4. Protocol and Program Reviews
5. Scientific Journal Articles, Book Chapters, and Presentations at Scientific Meetings
6. Internet and Intranet Websites
7. Interpretation and Outreach

7.2.1 Annual Reports for Specific Protocols and Projects

The primary purposes of annual reports for specific protocols and projects are to:

- summarize and archive annual data and document monitoring activities for the year;
- describe current condition of the resource;
- document changes in monitoring protocols; and,
- increase communication within the park and network.

The primary audiences for these reports are park superintendents and resource managers, network staff, park-based scientists, and collaborating scientists. Most annual reports will receive peer review at the network level, although a few may require review by subject matter experts with universities or other agencies. Many of our monitoring protocols involve data collection each year, and those protocols will generate an annual report each year (Table 7.2.1). However, some sampling regimes do not involve sampling every year - those projects will produce periodic reports only when there are significant monitoring activities to document. Wherever possible, annual reports will be based on automated data summarization routines built into the MS Access database for each protocol. The automation of data summaries and annual reports will facilitate the Network's ability to manage multiple projects and to produce reports with consistent content from year to year at timely intervals. For analyses beyond simple data summaries, data will first be exported to external statistical software.

Table 7.2.1. Overview of Vital Signs Monitoring Program and Annual Report production.

Protocols*	Who Initiates?	Analyses Performed	Due Date (month)
Weather and Climate	NPS-ARD & Atmospheric Program lead (MORA)	Summary statistics, others to be determined	June
Glaciers	Physical Science Program lead (NOCA)	Comparison of glacier data with high to low elevation weather station & SNOTEL data	May
Hydrology	Physical Science Program lead (NOCA)	Summary statistics, others to be determined	Mar
Large Lakes	OLYM Coastal Ecologist/ Limnologist & Fisheries Biologist (OLYM)	Summary statistics, others to be determined	Apr
Invasive Plants	OLYM, NOCA, and MORA Plant Ecologists	Routine data quality checks; confirmation that scheduled plots measured	Mar
Intertidal	OLYM Coastal Ecologist/Limnologist	Summary statistics, others to be determined	Feb
Wadeable Streams	MORA, OLYM, and NOCA Project Leads	Descriptive statistics for physical, chemical and biological components. Cumulative distribution frequencies representing % of sample sites where physical, chemical, and biological indicators of stream condition meet or exceed pre-established criteria.	Mar
Mountain/Small Lakes	Project leads for each park (MORA, OLYM, and NOCA)	Summary statistics and others to be determined	Mar
Rivers	OLYM Fisheries Biologist & Coastal Ecologist/Limnologist	Summary statistics	Feb

Table 7.2.1. Overview of Vital Signs Monitoring Program and Annual Report production (continued).

Protocols*	Who Initiates?	Analyses Performed	Due Date (month)
Prairie and Coastal Vegetation	Network staff – NOCA Science Advisor as lead	Descriptive statistics for vegetation patterns/trends in condition and species richness. Determine if exotic species have reached threshold levels for management action.	Feb
Forest Vegetation - Plots	OLYM Plant Ecologist, USGS - NPS liaison	Summary statistics	Feb
Subalpine Vegetation	Plant Ecologist at NOCA in consultation with MORA and OLYM and the science advisor & USGS staff.	Descriptive statistics for vegetation cover, species frequencies, density, phenology and distributions. Whitebark pine populations included.	May, in years 1-3
Landbirds	NOCA Wildlife Biologist	Descriptive statistics (mean and standard deviations) of estimated densities of birds by species; frequency of occurrence by species.	March
Elk	MORA, OLYM, NOCA Wildlife Biologists	Summary statistics	April
Remote Sensing	OLYM Plant Ecologist & OLYM GIS Specialist, USGS-NPS liaison	Annual changes in forest structure, coniferous versus deciduous trees, and trees versus meadows; identify areas experiencing catastrophic disturbance; annual changes in land use and land cover, especially in areas surrounding parks; changes in areas covered by snow and glaciers	May
NCCN Monitoring Program	NCCN Coordinator	Annual Administrative Report and Work Plan: accomplishments, products, budget, etc.	Nov & Jan

*Water Quality is monitored as part of Large Lakes, Mountain/Small Lakes, Wadeable Streams, and Rivers protocols

7.2.2 Annual Briefings to Park Managers

Each year, in an effort to increase the availability and usefulness of monitoring results for park managers, the Network Coordinator will take the lead in organizing a 1-day "Science briefing for park managers" (possibly in conjunction with a Board of Director's meeting) in which network staff, park scientists, USGS scientists, collaborators from academia, and others involved in monitoring the parks' natural resources will provide managers with a briefing on the highlights and potential management action items for each particular protocol or discipline. These briefings may include specialists from the air quality program, fire ecology program, Research Learning Center, and collaborators from other programs and agencies to provide managers with an overview of the status and trends in natural resources for their parks. Unlike the typical science presentation that is intended for the scientific community, someone representing each protocol, program, or project will be asked to identify key findings or "highlights" from the past year's work, and to identify potential management action items. The scientists will be encouraged to prepare a 1- or 2-page "briefing statement" that summarizes the key findings and recommendations for their protocol or project; these written briefing statements will then be compiled into an annual 'Status and Trends Report' for the Network. In the process of briefing the managers, the various scientists involved with the monitoring program will learn about other protocols and projects, and the process will facilitate better coordination and communication and will promote integration and synthesis across disciplines.

7.2.3 Analysis and Synthesis Reports

The role of analysis and synthesis reports is to:

- determine patterns/trends in condition of resources being monitored;
- discover new characteristics of resources and correlations among resources being monitored;
- analyze data to determine amount of change that can be detected by this type and level of sampling;
- provide context: interpret data for the park within a multi-park, regional or national context;
- recommend changes to management of resources (feedback for adaptive management).

The primary audiences for these reports are park superintendents and other resource managers, network staff, park-based scientists, and collaborating scientists. These reports will receive external peer review by at least 3 subject-matter experts, including a statistician. Analysis and synthesis reports can provide critical insights into resource status and trends, which can then be used to inform resource management efforts and regional resource analyses. This type of analysis, more in depth than that of the annual report, requires several seasons of sampling data. Therefore, these reports are usually written at intervals of every three to five years for resources sampled annually, unless there is a pressing need for the information to address a particular issue. For resources sampled less frequently, or which have a particularly low rate of change, intervals between reports may be longer. An overview of anticipated NCCN analysis and synthesis reports is presented in Table 7.2.3.

It is important that results from all monitoring projects within and across all parks be integrated across disciplines in order to interpret changes to park resources. This will be accomplished with a network synthesis report produced at no more than 10-year intervals.

7.2.4 Protocol and Program Reviews

Periodic formal reviews of individual protocols and the overall monitoring program are an important component of the overall quality assurance and peer review process. A review of each protocol will be conducted before the first 5-year Analysis and Synthesis Report and in conjunction with future Analysis and Synthesis Reports as needed, but at least at 10-year intervals. (Because protocols must be reviewed in light of the data they produce, it is most efficient to review protocols coincident with these synthesis reports). Features of these protocol reviews include:

- A USGS scientist, outside contractor or academic is enlisted to analyze data and evaluate results of the monitoring protocol (e.g., power analyses of the data) and report findings.
- Subject-matter experts/peers are invited to review the Analysis and Synthesis Report, power analysis, and protocol.
- Subject-matter experts/peers are invited to a workshop to discuss the protocol, results of the data analysis and evaluation, whether or not the protocol is meeting its specific objectives and is able to detect a level of change that is meaningful, and to recommend improvements to the protocol.
- The protocol P.I., Network Coordinator, or contractor writes a report summarizing the workshop. The report is reviewed and edited by the participants, and then the final report is posted on the network's website. Copies of the report are sent to NPS regional and WASO program offices.

The Network Coordinator will initiate the Network Monitoring Program review. The purpose of these reviews is to have the program evaluated by highly qualified professionals. Features include:

- Network staff and collaborators provide a summary of the program and activity to date including a summary of results and outcomes of any protocol reviews.
- Scientific review panel obtains input from Board of Directors, network staff, park scientists, and others. Panel holds a workshop to discuss the program and whether it is meeting its goals and expectations. Review Panel makes recommendations for improving the effectiveness and value of the monitoring program.
- Network Coordinator develops a strategy with the NCCN Technical Committee and Board of Directors as to which of the review panel's recommendations to implement, how, and when.

Topics to be addressed during the program review include program efficacy, accountability, scientific rigor, contribution to adaptive park management and larger scientific endeavors, outreach, partnerships, data management procedures, and products. These reviews cover monitoring results over a longer period of time, as well as program structure and function to determine whether the program is achieving its objectives, and also whether the list of objectives is still relevant, realistic, and sufficient.

Table 7.2.3. Overview of analysis and synthesis report production.

Protocol*	Who Initiates?	Peer-Review	Analyses Performed	Due (mo./yr.)	Frequency (yr)
Weather and Climate	Network staff – project leaders or network coordinator	Network	Trend detection; summary statistics; determine patterns/trends in climate change at local, park & network scales.	May	5
Glaciers	NOCA Geologist	Network & established peer-review team of selected scientists; coordinated by project leaders at MORA, OLYM, and NOCA.	Time series analysis/ cumulative glacier mass balance; Spatial patterns using GIS	May	10
Hydrology	NOCA Geologist	Network & by established peer-review team of selected scientists; coordinated by project leads from 3 large park	Trend detection; summary statistics	Mar	5
Large Lakes	OLYM Coastal Ecologist/Limnologist	Network, NPS-WRD & selected agency scientists	Trend detection; summary statistics	Apr	3-5
Invasive Plants	OLYM, NOCA & MORA Plant Ecologists	Network & established peer review team of agency scientists; coordinated by NPS leads.	Changes in distribution and abundance of high-priority exotic plant species in potential habitat at FOCL, MORA, NOCA, OLYM; list of other exotic plants emerging as threats	Mar	4
Intertidal	OLYM Coastal Ecologist/Limnologist	Network, NPS-WRD & selected scientists	Trend detection; summary statistics	Feb	5
Wadeable Streams	Project leads from 3 large parks	Network & established peer review team of selected scientists.	Time series analysis; spatial patterns in distribution using GIS; ordinations comparing community data among survey years; significance of change between years; others	Mar	5
Mountain/ Small Lakes	Network staff from 3 large parks	Network & established peer review team of selected scientists	Trend detection; summary statistics	Mar	5
Rivers	OLYM Fisheries Biologist	Network, selected scientists & NPS-WRD	Trend detection; summary statistics	Feb	5

Table 7.2.3. Overview of analysis and synthesis report production (continued).

Protocol*	Who Initiates?	Peer-Review	Analyses Performed	Due (mo./yr.)	Frequency (yr)
Prairie and Coastal Vegetation	NOCA Science Advisor in cooperation with SAJH Resource Specialist	Network & established peer review team of selected scientists	Ordination to track change through time, significance testing of cover & assessment of annual variation; identify "normal" levels of annual variation, identification of standards for unacceptable increases in exotic plants, & understanding of succession.	Feb	5
Forest Vegetation-Plots	OLYM, NOCA, & MORA Plant Ecologists, and USGS Liaison	Network & established peer-review team of selected scientists	Changes in species composition & abundance & nutrient cycling in 3 forest types across Network on 5-year time scale; changes in species composition & abundance in common forest types across Network on 10-year time scale (FIA data)	Feb	5
Subalpine Vegetation	NOCA Ecologist lead	Network & established peer-review team of selected scientists	Spatial patterns in distribution using GIS; ordinations showing similarities in community data among years; significance testing of change between years; others to be decided	May	5
Landbirds	NOCA Wildlife Biologist.	Network & established peer review team of selected scientists	Means and standard deviations of estimated densities by species or frequency of occurrence for less common species; mean level of change (i.e. difference or slope) of individual transects; cumulative distribution function of population changes; GIS analysis of changes in population density for key species. Results at park and network levels.	Mar	5
Elk	Wildlife program leads for MORA, NOCA and OLYM	Wildlife program leads at 3 large parks coordinate external peer review including federal, tribal, & state agencies, & universities.	Time series analysis; spatial patterns in distribution using GIS; comparative analyses with other study areas, including composition counts (sex and age ratios, etc.).	Apr	6
Remote Sensing	NPS and USGS project leads	Network level, and by established peer review team of selected agency scientists	Trends in forest structure, composition (coniferous versus deciduous), and extent (forest versus meadows); trends in occurrence of types of catastrophic disturbance; trends in land use & land cover, especially in areas around parks; trends in snow cover & glaciers	May	5

Table 7.2.3. Overview of analysis and synthesis report production (continued).

Protocol*	Who Initiates?	Peer-Review	Analyses Performed	Due (mo./yr.)	Frequency (yr)
NCCN Program Review	NCCN I&M Coordinator	NPS (PWR & WASO I&M, ARD and WRD), and peer-review team of selected scientists	Review program efficacy, accountability, scientific rigor, contribution to adaptive park management, feeding into larger scientific endeavors, outreach, partnerships	Nov 2006	3-5
Network Synthesis	NCCN I&M Coordinator	Network & selected scientists	Synthesis of results from all projects across Network; provide integrated description of observed changes.	Feb 2008	5-10

*Water Quality is monitored as part of Large Lakes, Mountain/Small Lakes, Wadeable Streams, and Rivers protocol

7.2.5 Scientific Journal Articles and Book Chapters, and Presentations at Scientific Meetings

The publication of scientific journal articles and book chapters is done primarily to communicate advances in knowledge, and is an important and widely-acknowledged means of quality assurance and quality control. Putting a program's methods, analyses, and conclusions under the scrutiny of a scientific journal's peer-review process is basic to science and one of the best ways to ensure scientific rigor. Network staff, park scientists, and collaborators will also periodically present their findings at professional symposia, conferences, and workshops as a means of communicating the latest findings with peers, identifying emerging issues, and generating new ideas.

All journal articles, book chapters, and other written reports will be listed in the Network's Annual Administrative Report and Work Plan that is provided to network staff, Technical Committee, Board of Directors, and regional and national offices each year. Additionally, all scientific journal articles, book chapters, and written reports will be entered into the NatureBib bibliographic database maintained by the Network.

7.2.6 Internet and Intranet Websites

Internet and (restricted) intranet websites are a key tool for promoting communication, coordination, and collaboration among the many people, programs, and agencies involved in the network monitoring program. All written products of the monitoring effort, unless they contain sensitive or commercially valuable information that needs to be restricted, will be posted to the main network website:http://www1.nature.nps.gov/im/units/nccn

Documents to be posted to the network website include this monitoring plan, all protocols, annual reports, analysis and synthesis reports, and other materials of interest to staff at the park, network, regional, and national levels, as well of being of interest to our collaborators.

In addition, to promote communication and coordination within the network, we will maintain a password-protected "team website" where draft products, works in progress, and anything that needs to have restricted access can be shared within the program.

7.2.7 Interpretation and Outreach

The National Park Advisory Board, in their July 2001 report, "Rethinking the National Parks for the 21st Century," wrote that, "A sophisticated knowledge of resources and their condition is essential. The Service must gain this knowledge through extensive collaboration with other agencies and academia, and its findings must be communicated to the public. For it is the broader public that will decide the fate of these resources." In keeping with this statement and the vision statement of the NCCN Board of Directors, the Network will make a concerted effort, working with park interpreters and others, to ensure that the results of natural resource monitoring are made available to the interested public. In addition to providing scientific reports and briefings to managers for their protocols, each scientist involved with the Network will be asked to contribute story ideas, photographs, and other materials to interpreters for use in newsletters, interpretive talks and exhibits, and other media for informing and entertaining the public. Park interpreters will be invited to participate in monitoring field efforts to increase communication and promote integration between the programs. The Network will collaborate with the annual event, “Science Days,” which is a program led by the North Cascades Science Advisor who invites network researchers to share their work and results with the interested public through a series of presentations. Network staff also speak at training sessions for seasonal employees and to special interest groups (e.g., Washington Native Plant Society, elder hostels, Olympic Park Institute, etc.).

Interpretation and outreach is a perfect place for the NCCN Vital Signs Monitoring program to team up with the NCCN Research Learning Network (RLN). The RLN promotes research in parks, as well as acting as a bridge between scientists and the public. The NCCN Network Coordinator and NCCN program leads are working with the RLN program to form connections with college students, partners, and the interested public to provide information from the Vital Signs monitoring program to the community in a digestible format.

Chapter 8. Program Administration & Implementation

This chapter provides more detail on the roles of the Board, Steering Committee, Technical Committee and Network Coordinator briefly mentioned in Chapter 1. Together, these organizational units comprise the oversight for and actual performance of the I&M program. This chapter describes each unit's role in program assignment, accountability, and tracking.

8.1 Role of Administrative Entities

8.1.1 The Board of Directors

The NCCN Board of Directors is comprised of the Superintendents of the seven natural area parks (I&M parks) and one purely cultural park in this network. The role of the Board of Directors is broader than the I&M Program, but the role and function of the NCCN Board of Directors *within* I&M is to:

- Promote accountability and effectiveness for the I&M Program by reviewing progress and quality control for the Network and oversee spending of network funds.
- Provide guidance to the Steering Committee, Technical Committee and natural resource staffs of the network parks in the design and implementation of Vital Signs monitoring and other management activities related to the Natural Resource Challenge.
- Decide on strategies and procedures for leveraging network funds and personnel to best accomplish the inventory and monitoring and other natural resource needs of network parks.
- Consult on hiring of new personnel using funding provided to the Network and from base funds and other sources.
- Seek additional funding from other sources to leverage the funds provided through the Servicewide program.
- Solicit professional guidance from and partnerships with other individuals and organizations.

The network Board originated through the I&M Program, and a Charter was written and signed in 2000 that focused on the I&M program. Within the Pacific West Region, the network concept now applies to other park activities, and a broader Network Charter was signed in 2004 to include all operations and functions in park units. In addition to having a Charter (Appendix 1.8 of the Phase 2 Report) and a Vision Statement (Appendix 1.9 of the Phase 2 Report) the Board has written and approved a Sense of the Board document (Appendix 1.10 of the Phase 2 Report) to describe Board expectations for working relationships among network I&M parks, including the role of prototype parks.

8.1.2 The Steering Committee

The Steering Committee is comprised of the Chiefs of Resource Management for each park and the Network I&M Coordinator. In addition, the Regional Science Advisor and a USGS/BRD liaison serve as advisors. The Steering Committee operates by consensus and has the power to direct the Technical Committee and to make recommendations to the Board of Directors. The

Network Coordinator chairs its meetings and coordinates its efforts. The Steering Committee is responsible for:

- Translating input from the Technical Committee and others into recommendations to the Board of Directors for the network I&M program
- Ensuring the proper implementation of the NCCN Vital Signs Monitoring Plan in the parks within the Network
- Developing in-park integration and support of the I&M program across all park programs.
- Serving as key advisors to the Network Coordinator at the park level

The products and recommendations of the Steering Committee are presented to the Board for discussion, approval, or modification.

8.1.3 The Technical Committee

The Technical Committee is the largest body doing the I&M work of the Network. It is composed of the Chiefs of Resource Management and Resource Management technical staff (scientists and technicians) from each park. A USGS/BRD scientist serves in advisory capacity, and the Regional Network Coordinator is a guest member. The Network I&M Coordinator chairs Technical Committee meetings and coordinates its efforts. The primary tasks of the Technical Committee are:

- Compiling and summarizing existing information about park resources.
- Developing materials for and summarizing the findings and recommendations of workshops held to develop a network monitoring strategy.
- Participating in the identification of monitoring objectives and development of the Network Strategic Plan.
- Assisting in the selection of indicator species, communities, and processes.
- Evaluating initial sampling designs, methods and protocols.
- Reviewing annual data reports and interpretation as well as participating in the preparation of the Annual Work Plan and Annual Report.
- Developing materials for and facilitating the Five Year Program Review.

As the implementation of the Vital Signs Monitoring Plan begins, the Technical Committee will continue to function as technical advisors for the monitoring program, and many specialists will be intimately involved with specific monitoring projects for the Network.

The Technical Committee is composed of members representing many disciplines. For expediency, sub-committees or working groups were established in the fields of: wildlife, vegetation, aquatics, air and climate, and data management. The working groups meet frequently to coordinate projects across the parks and to develop protocols, schedules and budgets for tasks within their subject area. Typically one or more representatives from each working group attends Technical Committee meetings to report the workgroup's activity.

Tasks are assigned to the Technical Committee by the Steering Committee or Board as needed. The products and recommendations of the Technical Committee are presented to the Steering Committee for discussion and approval, and forwarded to the Board as appropriate.

8.1.4 Network Staff

The NCCN currently supports portions of several positions. The organization diagram (Figure 8.1.1) shows positions fully or partially funded by I&M funds (gray boxes) and their supervisors (white boxes). Primary roles of each position are explained in Table 8.1.1. These positions fill gaps in network expertise that were deemed necessary for program success. There are more network positions duty stationed in the prototype parks than in the others and there are no network funded positions in small parks. This is largely due to greater capacity and infrastructure for personnel in the larger parks, greater access to natural resource professionals, and stronger programmatic obligations to conduct natural resource monitoring. All the positions listed in the staffing plan contribute importantly to the NCCN program, although most are not paid for with I&M funds (Figure 8.1.1, white boxes). Table 8.1.2 provides a more detailed accounting of the network parks' commitment of base-funded positions to the Vital Signs monitoring program, and shows the extensive commitment of network parks to this program.

The NCCN Network Coordinator and Data Managers are the only NCCN full time positions entirely funded by NCCN funds. Their duties are outlined below.

Network Coordinator: The Network Monitoring Coordinator reports directly to the Board, briefs them on I&M program progress, presents Steering and Technical Committee products for Board consideration, interprets the national I&M program guidance and activities, and makes recommendations. The NCCN Coordinator is supervised by the Superintendent of the park where the Coordinator is duty-stationed.

The Network Coordinator serves as the director of network planning activities and progress, as an interpreter of Washington and regional guidance, and as a liaison between the Board of Directors and the Steering and Technical Committees. The Network Coordinator is ultimately responsible for producing the Network Monitoring Plan. The Network Coordinator oversees budget formulation, account assignment, ensures funds are expended at year-end, writes and submits the annual report and work plan, and develops partnerships and other alliances to improve program efficiency, efficacy, and public support.

Data Managers: Data managers are responsible for the development, management, coordination, and implementation of natural resource information systems, including databases, data archives, and Geographic Information System (GIS). Responsibilities include creating new databases consistent with NPS standards, quality assurance/quality control (QA/QC) for new data, and generating Federal Geographic Data Committee (FGDC) compliant metadata. The data managers also provide training to park staff, organize the certification of inventory data sets, make data accessible to parks through summaries and reports, and share data through the internet or other media. Additional details of the responsibilities of the data manager are presented in the data management plan (see NCCN_DMP_Draft_Dec2004.pdf at http://www1.nature.nps.gov/im/units/nccn/Reports/).

Most network positions are funded for less than a full time position (Figure 8.1.1; Table 8.1.1). Having staff work part-time for the Network and part-time for individual parks is an efficient way to maximize access to dedicated, expert personnel, while minimizing costs and maximizing future budgetary flexibility. Network-paid staffs take leadership roles in network projects, and are expected to work with all network parks at times. Accomplishments and work plans for each staff member are addressed through the Annual Administrative Report and Work Plan, as well as individual work plans for each employee. Staff hired under this program are supervised and administratively supported by the park or office at which they are stationed. This includes safety and wellness training as well as project specific project training and orientation. Office and field equipment necessary to implement monitoring projects are located at the parks where project managers are duty stationed and/or at facilities near the sampling site. Many projects utilize professional laboratories to process samples. Specific parties involved and QA/QC standards they must adhere to are detailed in monitoring protocols.

Except for non-permanent technician positions, selection of an individual who will serve more than one park requires the concurrence of the parks to be served and approval by the Board of Directors. Any vacancies in permanent network positions are brought to the attention of the board, which then evaluates whether to refill the position or recruit other expertise. No position shall be converted from non-permanent to permanent status without the explicit written approval of the Board. NCCN does not presently plan to add any more positions to network staff positions. Any network positions that become vacant must be brought before the Board of Directors for re-evaluation.

When needed the Board, Steering Committee, Technical Committee, or Network I&M Coordinator may form groups of specialists to work on a particular task or program area. No such group are formed without a specific “sunset” provision.

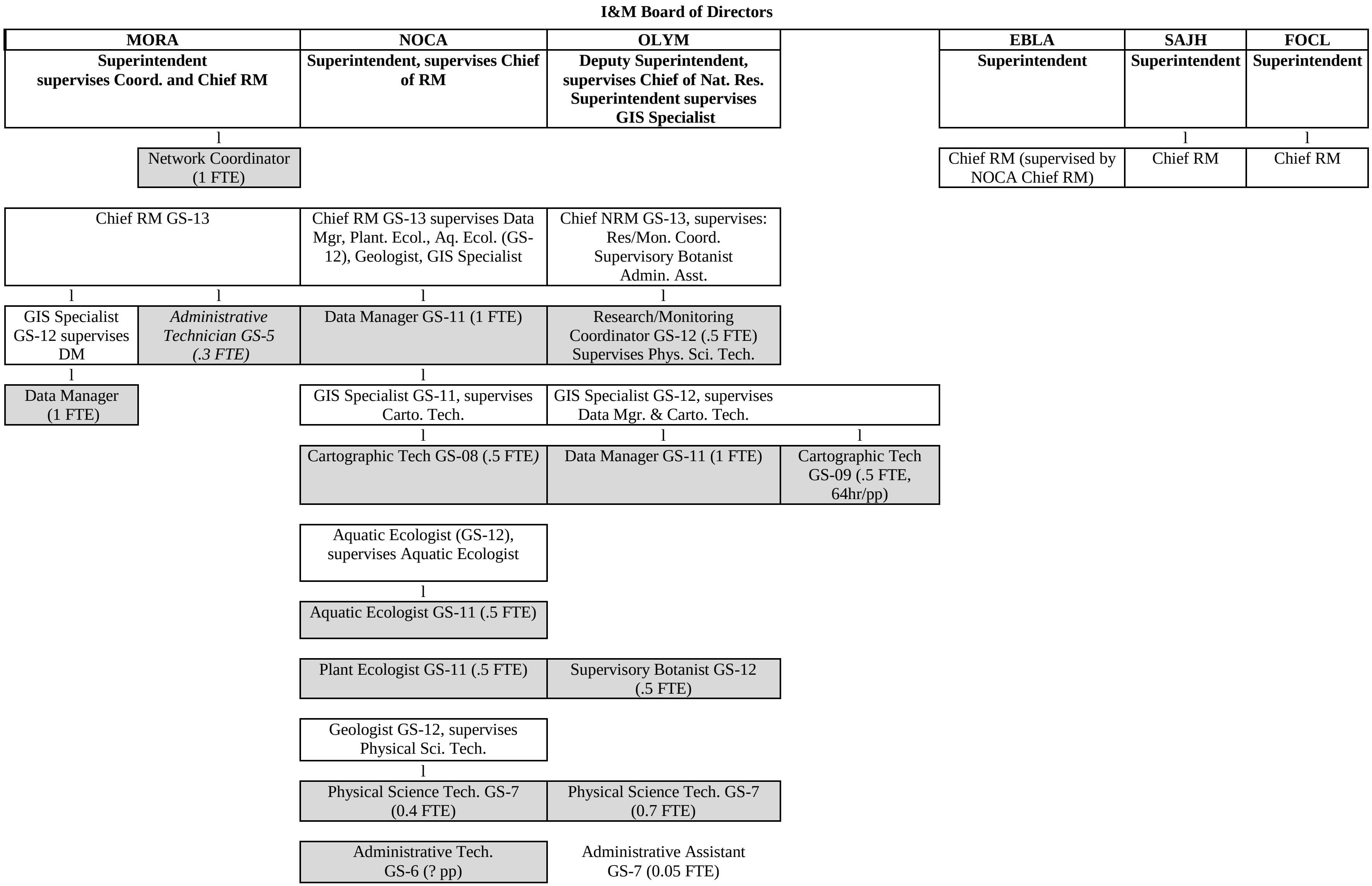

Figure 8.1.1. NCCN Staffing Plan. Grey boxes indicate positions supported by I&M funds.

Table 8.1.1. Network-funded positions for implementation of the NCCN Vital Signs Monitoring Program.

Position	GS Level	FTE funded by I&M	Primary Duties
Network Coordinator	12	1.0	Primary coordinator for all aspects of the monitoring program. Principal advisor to the Board and liaison between Board and Steering Committee. Works with the Steering Committee to formulate direction and administration of the program. Oversees network budget formulation, account assignment, ensures funds are expended at year-end, writes and submits the annual report and work plan, and develops partnerships and other alliances to improve program efficiency and public support.
Data Managers (one each at MORA, OLYM, NOCA)	11	1.0	Primary employees responsible for all aspects of data management. Responsible for development, management, coordination, and implementation of natural resource information systems, including databases, data archives, and GIS. Work with principal investigators to design appropriate databases for data collection and for integration of data, consistent with NPS standards, quality assurance/quality control, and in generating FGDC compliant metadata.
Research & Monitoring Coordinator (OLYM)	12	0.5	Primary backup for Network Coordinator during absences by that person. Helps integrate research and education activities with Research Learning Network. Pursues grant opportunities to increase Network Vital Signs monitoring program
Cartographic Technicians	8/9	0.5 0.5	GIS and GPS support for all I&M Vital Signs projects for Network. Direct the creation, maintenance, versioning, and archiving of I&M digital data libraries. Develop and incorporate I&M-related park datasets into national databases.
Aquatic Ecologist (NOCA)	11	0.5	Coordinator for NOCA and MORA Wadeable Streams protocol including field data collection/supervision, QA/QC, data analysis, reporting, for small park streams and ponds program, and for NOCA Rivers protocol.
Plant Ecologist (NOCA)	11	0.5	Primary responsibility for developing the Subalpine Vegetation protocol for the Network; shared responsibility for developing the Forest Plots, Prairie and Coastal protocols; NOCA-specific responsibility for assisting in implementing all vegetation protocols (Subalpine Vegetation, Invasive Species, Forest, Prairie and Coastal and Remote Sensing), which includes field crew supervision, training, QA/QC, hiring, data analysis, report writing.
Supervisory Botanist (OLYM)	12	0.5	Primary responsibility for developing and implementing the Invasive Species protocols for the Network; shared responsibility for developing the Forest protocols; OLYM-specific responsibility for implementing all vegetation protocols (Subalpine Vegetation, Invasive Species, Forest Plots, Prairie and Coastal, and Remote Sensing), which includes field crew supervision, training, QA/QC, hiring, data analysis, report writing
Physical Science Technician (NOCA)	7/9	0.4	Primary responsibility for field crew supervision of network glacier monitoring, data entry and analysis, QA/QC, and report writing
Physical Science Technician (OLYM)	7	0.6	Operates, maintains, downloads, and manages data for 13 OLYM weather stations and four snow survey stations. Field crew leader for implementing Mountain/Small Lakes protocol for OLYM, and crew member for Elk, Wadeable Streams, Rivers, Large Lakes, Intertidal, and Glacier protocols

Table 8.1.2. Base-funded staff support for implementation of the NCCN Vital Signs Monitoring Program.

Position	GS Level	Pay Periods committed to Network I&M program	Role
EBLA - Chief RM	11	2	Coordinate overall I&M program for park/Steering Committee.
SAJH – Chief RM	11	2	Coordinate overall I&M program for park/Steering Committee
LEWI – Chief RM	12	2	Coordinate overall I&M program for park/Steering Committee
NOCA – Chief RM	13	3	Coordinate overall I&M program for park/Steering Committee
MORA – Chief RM	13	3	Coordinate overall I&M program for park/Steering Committee
OLYM – Chief RM	13	3	Coordinate overall I&M program for park/Steering Committee
NOCA – Aquatic Ecologist	12	13	Primary responsibility for developing Wadeable Streams protocol; co-responsibility for developing Mountain Lakes protocol (MORA, NOCA). Provides assistance to small parks for aquatics protocols. NOCA lead for implementing Rivers and Large Lakes protocols.
NOCA – Biological Technician (Fisheries)	11	3	Physical habitat and fish data collection oversight, analysis, and reporting for the Wadeable Streams program for NOCA/MORA/small parks
NOCA – Geologist	12	6	Primary responsibility for developing Glacier protocol. Program oversight for Network for implementing Glacier protocols. NOCA lead for Climate and Air Quality protocols.
NOCA – Wildlife Biologist	11	9	Co-responsibility for developing Landbirds protocol. Program oversight for Network for implementing Landbirds protocol
NOCA – Science Advisor	13	9	Primary responsibility for developing and implementing Prairie and Coastal protocol. Shared network responsibility for developing Subalpine, Invasive Plants, Forest Plots, and Remote Sensing protocols.
NOCA – GIS Specialist	11	1	Provides GIS oversight/support for I&M project work.
NOCA – Administrative Tech	6	6	Provides administrative support for prototype and Vital Signs program and employees, including account tracking, procurement, and payroll and travel.
NOCA – Budget Analyst	11	1	Provides administrative oversight/support for park I&M program
MORA – Wildlife Ecologist	12	9	Primary responsibility for developing Air Quality and Climate protocols; co-responsibility for developing Mountain/Small Lakes protocol. MORA lead for implementing Wadeable Streams, Rivers protocols.
MORA – Botanist	12	11	Co-responsibility for developing Invasive Plants, Subalpine, Forest Plots, Prairie and Coastal, and Remote Sensing protocols.

Table 8.1.2. Base-funded staff support for implementation of the NCCN Vital Signs Monitoring Program (continued).

Position	GS Level	Pay Periods committed to Network I&M program	Role
MORA – GIS Specialist	12	2	Provides GIS oversight/support for I&M project work
MORA – Budget Technician	6	2	Provides administrative support for park I&M program
MORA – Budget Analyst	12	2	Provides administrative oversight/support for park I&M program
MORA – Budget Technician	7	3	Provides administrative support for park I&M program
MORA – Purchasing Agent	8	2	Provides administrative support for park I&M program
MORA – Financial Technician	5	2	Provides administrative support for park I&M program
OLYM – Research & Monitoring Coordinator	12	4	Provides coordinator support for Network and OLYM-specific I&M program. Integrates monitoring program with research of outside (e.g., academic) researchers, acting Network Coordinator in the coordinator's absence
OLYM – Wildlife Biologist	12	4	Primary responsibility for developing Elk protocol; OLYM lead for Landbirds protocol.
OLYM – Fisheries Biologist	12	7	Primary responsibility for developing Rivers protocol; co-responsibility for developing Wadeable Streams protocol (OLYM)
OLYM Fisheries Biologist	12	1	Assists implementation of Rivers and Wadeable Streams protocols in park.
OLYM Coastal Ecologist	12	11	Primary responsibility for Large Lakes and Intertidal protocols; co-responsibility for Mountain/Small Lakes protocol.
OLYM GIS Specialist	12	3	Provides GIS oversight/support for I&M project work
OLYM Physical Science Technician	7	1	Provides field support for several OLYM monitoring protocols
OLYM Administrative Asst.	7	5	Provides administrative support for prototype and Vital Signs program and employees, including account tracking, procurement, and payroll and travel.

8.1.5 Regional Staff

Cooperative Ecosystem Studies Unit (CESU) Coordinator: The coordinator acts as a liaison between I&M and CESU scientists. The position plays a critical role in identifying principal investigators, developing scopes of work, and implementing agreements.

Geographic Information Specialist: This is a regional position housed at the Columbia Cascades Support Office building in Seattle, WA. This position supports data management needs relating to geographic information data sets, including the storage and archiving of NCCN small park GIS data.

Regional I&M Coordinator: Provides direction, ensures the implementation of national guidelines, coordinates program review procedures including external peer review and coordinates with other I&M regions. Supervised by the Regional Natural Resources Program lead, the Regional I&M Coordinator also ensures that I&M networks are aware of relevant regional initiatives and resources. This position also develops long-term partnerships through Cooperative Agreements, Inter-Agency Agreements, and Contracts.

Regional Fluvial Geomorphologist (North Coast and Cascades Network and Klamath Basin Network): This position is duty stationed at MORA providing technical assistance to parks on issues of fluvial geomorphic processes, serves as the lead for implementing Glacier protocols (mass balance and surface elevation survey) at MORA.

8.1.6 USGS

The primary mission of the Inventory and Monitoring Program of the USGS Biological Resources Discipline is to help the National Park Service develop monitoring protocols. The USGS Forest and Rangeland Ecosystem Science Center hosts the monitoring development project for NCCN.

The NCCN has benefited greatly from its close ties to USGS scientists. Prior to network creation, USGS scientists developed a strategic plan for long-term ecological monitoring in OLYM, focused on terrestrial forests (Jenkins et al. 2003; (Appendix 1.11of the Phase 2 Report); http://www.nps.gov/olym). They also collected and analyzed pilot data sets for forest vegetation, breeding birds, small mammals and bats, some leading to protocols. USGS staff have also organized specific workshops to identify issues and information needs for: sampling design and trend detection statistics; vegetation and wildlife communities and populations; and remote sensing techniques. USGS staff have long worked with MORA to study lake ecosystems and have developed a monitoring protocol (Appendix 1.13 of the Phase 2 Report, http://www.nps.gov/mora). A scientist from the USGS Western Fisheries Research Center is working with OLYM to develop a protocol for monitoring fish populations in non-wadeable streams (i.e., “rivers”). In addition, the USGS Liaison to NCCN conducted the second prioritization exercise for the Network, regularly attends Technical Committee, Steering Committee, and workgroup meetings, and helps with network reports and plans.

In the future, USGS may play an important role in revising protocols, as well as analyzing, summarizing and synthesizing monitoring results.

8.1.7 Partnerships

The network I&M program may evolve to include other land and resource managers (federal, state, tribal) in the North Coast and Cascades Network area. In no case will Board membership be expanded without unanimous approval of the Board.

8.2 NCCN Program Accountability

8.2.1 Reporting

See Chapter 7, Data Analysis and Reporting, for details on monitoring protocol reporting requirements.

8.2.2 Steering and Technical Committee Meetings

Minutes of Steering and Technical Committee meetings are circulated by the Network I&M Coordinator to all members and the Regional I&M Coordinator. The Network I&M Coordinator is responsible for maintaining the NCCN I&M Administrative Record.

8.2.3 Annual Administrative Report

Working with appropriate subgroups and other partners, the Network I&M Coordinator presents an Annual Administrative Report to the Board for discussion, modification and approval. The Annual Administrative Report details specific accomplishments and products, lessons learned, coordination with others and a budget summary including a detailed accounting of all I&M program funds assigned to each park and office. This report is then forwarded to the PWR I&M Coordinator and WASO for review. The final, approved Annual Administrative Report is widely distributed and posted at appropriate websites no later than December 31 of each year.

8.2.4 Annual Work Plan

Working with appropriate subgroups and others partners, the Network I&M Coordinator presents a proposed Annual Work Plan to the Board for discussion, modification and approval no later than January 15 of each year. The Annual Work Plan identifies specific planned tasks, schedules and products, responsible individuals and deadlines, I&M program budget and to which park or office funds are assigned, and additional and potential funding sources (both NPS and others). This plan is forwarded to the PWR I&M Coordinator and WASO for review. The final, approved Annual Work Plan is widely distributed and posted at appropriate websites on the Internet.

8.2.5 Periodic Program Review - See Section 7.2.1 for schedules.

8.2.6 Funding

I&M program funds are distributed to network parks and offices as directed through the Annual Work Plan. As agreed by the Associate Director, Natural Resource Science and Stewardship, $200,000 of I&M program funds were added to each base budget for NOCA and OLYM in fiscal year 2001 (see Budget Chapter 10 for details). All I&M program funds must be strictly accounted for using a discrete PWE code and disclosed in the Appendix of the Annual Administrative Report and Work Plan. Using these funds for purposes other than the I&M program and/or in a manner contrary to direction by the Board constitutes cause for their reassignment to another network park or office. Additionally, other funds contributed by parks, other NPS programs and other sources will be carefully tracked and reported.

The Network Coordinator oversees network budget formulation, account establishment, ensures budgets are programmed, and directs year-end closing. For every funded monitoring project and account there is a named account manager, who is responsible for the efficient and timely expenditure of program funds, budget programming, and close-out. Monitoring funds cannot be spent beyond the amount allocated. If an account is overspent, the park which is the duty station of the project lead must cover the overage. Any monitoring funds remaining by the established year-end closing deadline are returned promptly to the Network via the Coordinator, and will be spent on a prioritized list of unmet needs generated by the Network Coordinator, with input from workgroups.

8.3 NCCN Monitoring Program Integration

Many network parks have strong staff and histories in resource management and monitoring. By design, the NCCN does not have a monitoring staff operating separately from the other functions of natural resource management. Instead, the network monitoring program is closely integrated with resource management and operations in each of the parks. Through the Steering Committee, the Resource Chiefs oversee the program as a whole to ensure smooth integration of the monitoring program in the duties of the resource management staff at each of the parks.

Three NCCN parks have large wilderness areas and helicopters or pack animals are needed for some of the work, and that requires project leaders from Natural Resource Divisions to collaborate with Ranger and Maintenance Divisions and Communication Centers to accomplish goals. Compliance procedures generally ensure that proposed projects (including I&M projects) are reviewed by key program leads in parks (Wilderness Coordinators, e.g.) as well as all division chiefs. Additionally in small parks, one resource chief has such diverse duties that their involvement in a project may represent the involvement of the chief of law enforcement, cultural resources, natural resources, the lead for wilderness issues, fire, air quality, water quality, threatened and endangered species management, compliance, and project management. Again, due largely the dual role most NCCN park staff have in the I&M program and in their parks, coordination with park operations occurs almost seamlessly.

8.4 Partnerships and Agreements

Before the advent of the Network, parks worked on their own or in teams to accomplish inventory and monitoring work. They formed many partnerships not only to make projects possible and broaden the impact and scope of projects, but also to join existing programs, raise awareness of park resources and their importance, and gain support for their work (Table 8.5.1). The organizations listed are very important partners for our network, because through them we have a very “deep bench” of scientists, managers, technicians, and students available to us.

Table 8.4.1. Key Partnerships and Agreements in NCCN.

Type of agreement	Objective	Parties involved	Parks involved
Cooperative Agreement	Monitoring elk at MORA	NPS and Washington Department of Fish and Wildlife	MORA
Interagency Agreement	Development of a protocol to measure total atmospheric deposition via the throughfall method.	NPS and USDA Forest Service	pilot study: MORA, NOCA, OLYM
Confidentiality Agreement	Gain access to Forest Inventory and Analysis location data for FIA plots in PWR parks	PWR I&M Coordinator and USDS Forest Service	Any PWR parks, but individuals must sign agreement to gain access to these data
Memorandum of Understanding	Developing protocols	USGS-BRD FRESC and NPS NCCN	EBLA, FOCL, FOVA, MORA, NOCA, OLYM, SAJH
Memorandum of Agreement	Establish Point of Contact for NPSpecies	EBLA, FOCL, FOVA, MORA, NOCA, OLYM, SAJH	EBLA, FOCL, FOVA, MORA, NOCA, OLYM, SAJH
Cooperative Agreement	NOCA Rare Plant & Habitat Monitoring	Botany Forays, University of Washington	NOCA
Cooperative Agreement	NCCN FOCL Landbird Inventory	Institute for Bird Populations	FOCL
Interagency Agreement	NCCN Whitebark Pine Protocol Development by NOCA	IA USFS Tree Nursery	NOCA
Cooperative Agreement	NCCN Develop Remote Sensing Protocols	Develop Remote Sensing Protocols-PNW Lab	NCCN
Cooperative Agreement	Landbird Monitoring Protocol Development	Develop Network Landbird Monitoring Protocols - Institute for Bird Populations	NCCN
Interagency Agreement	NCCN Soils Inventory	Natural Resource Conservation Service, NPS	SAJH, NOCA, EBLA, MORA, OLYM
Interagency Agreement	Network Field Support/Protocol Development-MORA	Atmospheric Protocol Development-IA with USGS/WRD, Don Campbell, Colorado	MORA
Interagency Agreement	SAJH Prairie Monitoring Protocol by NOCA	NOAA IA - Statistical Analysis	NOCA, SAJH
Cooperative Agreement	NCCN Regional Coordinator Support	1/8 cost of PWR Protocol Reviews via PNW CESU	all in PWR
Cooperative Agreement	Test Synthetic Hydrograph Model	Test Synthetic Hydrograph Model - CESU - University of Washington	MORA
Cooperative Agreement	Aquatic Protocol Development-MORA-ONPS, Analyze lake samples for cations and anions	MORA, Central Washington University	MORA
Cooperative Agreement	Bird inventory	MORA, Institute for Bird Populations	MORA
Interagency Agreement	WACAP Air Pollution Studies	WACAP Air Pollution Studies - USGS-WRD Colorado, Don Campbell	MORA, OLYM

Table 8.4.1. Key Partnerships and Agreements in NCCN (continued).

Type of agreement	Objective	Parties involved	Parks involved
Cooperative Agreement	Northern spotted owl monitoring	Student Conservation Association (2 volunteers)	OLYM
Cooperative Agreement	Prepare Landbird final report NOCA & NCCN	WWU professor John McLaughlin, author	NCCN
Cooperative Agreement	WACAP Air Pollution Studies	WACAP Air Pollution Studies Univ. Washington CESU (Dan Jaffee)	MORA
Interagency Agreement	NCCN USGS-NPS Lake Contaminants	USGS/WRD-NPS Lake Contaminants (Black Project)	MORA, NOCA, OLYM
Interagency Agreement	NCCN NPS-NRPP Snow Chemistry in MORA, NOCA, OLYM	NPS-NRPP Snow Chemistry in MORA, NOCA, OLYM (USGS-WRD-Colorado) Don Campbell	MORA, NOCA, OLYM
Cooperative Agreement	OLYM Exotic plant protocol development	Univ. Washington, Dr. Charles Halpern: exotic plant modeling and protocol development	OLYM
Cooperative Agreement	MORA Network Field Support/Protocol Development- MORA	Atmospheric Protocol Development - CA with CESU Staci Simonich	MORA
Cooperative Agreement	NCCN Atmospheric Protocol Development - USGS-BRD/WRD	Develop Snow Deposition Protocols (USGS BRD funding to USGS/WRD)	NCCN
Cooperative Agreement	MORA Test Network Montane Lakes/Ponds and Water Quality Planning	Sample Analysis - chemistry Central Washington Univ.	MORA
Cooperative Agreement	MORA Test Network Montane Lakes/Ponds and Water Quality Planning	Student Interns - Evergreen State (CA between E.S. and MORA-NPS)	MORA
Interagency Agreement	Development of Rivers protocols for NCCN	NPS and USGS, Western Fisheries Research Center, Cook	MORA, OLYM
Cooperative Agreement	NCCN Test Synthetic Hydrograph Model	Test Synthetic Hydrograph Model - CESU - University of Washington	NCCN
Cooperative Agreement	OLYM Physical environment monitoring: Small watershed studies	Water chemistry analysis. PI: Dr. Bob Edmonds, School of Forestry, Univ. Washington	OLYM
Interagency Agreement	MORA Atmospheric Protocol Development (Acct: Air Monitoring MORA)	MORA Weather Station Maintenance - Inter-agency Agreement with NW Avalanche Control Center USFS	MORA
Cooperative Agreement	MORA Atmospheric Protocol Development (Acct: Air Monitoring MORA)	High Elevation Wet Deposition Station -chemical analysis Cent. Wash. Univ.	MORA
Interagency Agreement	NCCN High Elevation Weather Station	NOAA Weather Station Maintenance MORA	NCCN
Interagency Agreement	NCCN Atmospheric Protocol Development - USGS-BRD	Develop Throughfall Protocols - IA with USFS Research Station, Riverside, Mark Fenn	NCCN

8.5 Peer Review and Approval Process

The National Park Service is committed to promoting the conduct of high quality projects in national parks as part of the Inventory and Monitoring Program. An essential element of any science or research program is peer-review. Peer-review of proposals, study plans, monitoring plans, sampling protocols, publications, reports, and other products improves the quality of scientific research by incorporating the knowledge of other expert scientists and by ensuring that studies conducted can withstand their rigorous scrutiny. The credibility of scientific research is enhanced by conveying to other scientists, policy-makers, managers, and the public that the work has met accepted standards of rigor and accountability thereby increasing the acceptance of management decisions based on that science. Peer-review of annual and synthesis reports, protocol reviews and program reviews is covered in Chapter 7.

There are two levels of peer-review for NCCN monitoring protocols when they are initially developed: network-level and national-level reviews. Network-level peer-review will be conducted one of two ways. Protocols designed by USGS staff will be peer-reviewed according to USGS policy. This involves at least three expert reviewers with coordination by the supervisor of the author. Each protocol will also require formal acceptance by the Network.

NPS-developed protocols will be subject to the NPS/ Cooperative Ecosystem Studies Unit (CESU) protocol review, coordinated by network and regional I&M staff. This process is currently being directed through an agreement between the PWR I&M program and the University of Washington CESU. In this process, a university scientist receives the draft protocol and a list of recommended reviewers, assembles a group of qualified reviewers, coordinates their efforts, and delivers the resulting review back to the Network. Following review, protocol developers address the review, and produce the final version of that protocol.

Once a protocol has gone through network-level peer-review, it must still be reviewed and approved by the NPS PWR and WASO Monitoring Program before it can be implemented. A protocol is not considered complete at this level until it is accompanied by a fully functioning monitoring database.

Fundamental to the successful function of a network monitoring program is its ability to forecast when protocols will be complete, when sampling will occur, and how often. This information is critical to program coordination, efficiency, and the ability to predict future workloads and program needs. This information is addressed in the following chapter, Schedule.

Chapter 9. Schedule

This chapter presents schedules for protocol development and implementation, as well as the projected sampling frequency and season for each protocol. Objectives of these monitoring protocols are discussed in Chapter 5.

9.1 Schedule for Monitoring Protocol Development

Development of monitoring protocols generally involves several participants. We partitioned protocol development into several tasks to enable better coordination between prototcol developers, data managers, park resource chiefs, the Network Coordinator, partners, and peer reviewers. Most protocols require at least 3 or 4 years to develop, including peer review. The Network's protocol tracking database lists each protocol, the principal investigators, NPS leads or contacts, current schedule of activities, and anticipated peer and completion dates.

Tasks for protocol development include:

0 = background and sample design4 = protocol writing/adaptation
1 = pilot field work5 = peer review
2 = data analysis methods6 = finished product
3 = data design/management

Table 9.1.1. Monitoring Protocol Development Schedule, NCCN.

Name of Protocol	Primary NPS Contacts	FY04	FY05	FY06	FY07	FY08
Climate	B. Samora	0-1	2-4	5-6		
Glaciers - mass balance	J. Riedel	3-4	3-6			
Glaciers - surface profile	P.Kennard	1-2	3-4	5-6		
Glaciers - sentinel site OLYM	J. Riedel	0	1-5	6		
Large Lakes	S. Fradkin	1-2	1-5	6		
Mountain/Small Lakes	R. Glesne, S. Fradkin	0-2	1-5	5-6		
Wadeable Streams	R. Glesne, S. Brenkman	0-2	2-4	5-6		
Rivers	S. Brenkman	0-1	2-4	5-6		
Intertidal Communities	S. Fradkin	2	2-4	3-6		
Invasive Plants	S. Acker	0	0	0	4-5	6
Prairie & Coastal Vegetation	R. Rochefort	0	1-3	1-4	5-6	
Forest Vegetation	S. Acker	0	1-3	3-4	5-6	
Subalpine Vegetation	M. Bivin		0-2	3-4	5	6
Landbirds	R. Kuntz	1-4	3-5	5-6		
Elk	J. Schaberl, P. Happe	0-2	0-4	0-4	4-5	6
Remote Sensing	R. Hoffman	1	2-4	4-6		

9.2 Sampling Season and Frequency

Attributes included in sampling protocols for the Network vary at temporal scales ranging from hours to decades. Sampling frequency is depicted in Table 9.2.1. Seasons of sampling vary according to site accessibility, the attribute being measured, sampling design constraints, etc. For some protocols, sampling of different elements covered by the protocol occur at different frequencies. Some aspects may be sampled annually, and others at longer intervals as described in the protocol development summaries. This schedule is subject to unforeseen changes based on budgets or other future constraints. Nonetheless, scheduling

Table 9.2.1. NCCN Protocol Sampling Frequency and Season.

Protocol Name	Measures	once	hourly	daily	weekly	monthly	X times/yr	Once each X yrs	spring	summer	fall	winter
									season			
Climate	Air/soil temp, precip., RH, wind, snow depth, radiation		√									
	Lake ice out						1					
	Snow cover (remote sensing)						1					
Glaciers	Mass balance (NOCA, MORA)						1					
	Modeled mass balance (OLYM)						1					
	Surface cover (NOCA, MORA) and profile (MORA)						1					
	Runoff (4NOCA, 2MORA, 1OLYM)						1					
	Volume/area (NOCA, MORA)							10				
Large Lakes	Bathymetry	√										
	Lake level				√							
	Zooplankton, chlorophyll a, conduc., temp, secchi, DO, pH, turbidity					√						
	Nutrients, anions, cations						4					
	Large woody debris distribution							5				
	Littoral habitat							10				
Mountain/Small Lakes	Water temperature			√								
	Water chem.., nutrients, phys charac, biota (amphib., fish, macroinv.)						1-2					
	Basin characteristics							10				
Wadeable Streams	Water temperature & chemistry						1	5				
	Macroinvertebrates, fish, channel characteristics						1	5				
Rivers	Water temperature & chemistry						3					
	Macroinvertebrates, fish, channel characteristics						3					
Intertidal Communities	Water temperature			√								
	Rocky platform habitat							2				
	Sandy beach habitat, invertebrates & macroalgae						1					
	Habitat type change surveys							10				

Table 9.2.1. NCCN Protocol Sampling Frequency and Season (continued).

Protocol Name	Measures	once	hourly	daily	weekly	monthly	X times/yr	Once each X yrs	spring	summer	fall	winter
									season			
Invasive Plants	Distribution/abundance							5				
Prairie & Coastal Vegetation	Spp composition & structure, treeline							10				
Forest Vegetation	Spp composition & abundance, growth/mortality						1	4				
Subalpine Vegetation	Treeline, tree island size, spp composition, richness							3-10				
Landbirds	Density and frequency of occurrence						1					
Elk	Abundance in winter and/or summer range, herbivory						2					
Remote Sensing	Landscape dynamics, disturbance, riparian veg., etc.						1	7				

Chapter 10. Budget

In this chapter we present the implementation budget for the NCCN monitoring program as agreed upon by the Technical Committee as the basis for protocol development. The program will begin implementation in FY06 and be completely implemented by FY08. Because NCCN is still receiving an unpredictable amount of funding from USGS for protocol development, we cannot present budgets for the final years of protocol development. We first show the network budget by the same expense categories networks use in preparing the Annual Administrative Report and work Plans that are submitted to Congress (Table 10.0). In Table 10.2 we show the same budget but with more detail, including our projections for network resources devoted to information management.

NCCN receives $1,145,100 from the NPS Servicewide Inventory ad Monitoring Vital Signs program and $82,000 from the NPS Water Resources Division annually. When the program is fully implemented, we plan to spend 71% ($873,724) on personnel, including permanent, term, and seasonal staff. These personnel will be supplemented by other resource management staff in the Parks. We believe that substantial involvement of park staff will promote consistency and longevity for the program.

The landbird monitoring protocol is the only protocol we intend to contract to others. Specifically, the contractor will be Institute for Bird Populations (IBP).

Because we plan to access our parks mainly on foot, our largest expenditure is for personnel, with the cost of operations and equipment constituting only 19% ($237,398) of the budget.

Table 10.1. Anticipated budget for the NCCN Vital Signs Monitoring Program at full implementation in FY04 dollars.

NCCN Vital Signs Monitoring Budget	2004 dollars	
Income		
Vital Signs Monitoring	$1,145,100	
Water Resources Division	$82,000	
Subtotal	$1,227,100	
Expenditures		% by budget category
Personnel	$873,724	71
Cooperative Agreements	0	0
Contracts	$61,600	5
Operations/Equipment	$261,098	19
Travel	$43,084	4
Other	$9,394	1
Subtotal	$1,227,100	

Guidelines for developing a monitoring program suggest that approximately 30% of the budget should be allocated to information/data management so that information is not lost, results are communicated, and adequate reporting takes place. In Table 10.2 we provide the percent of time that each network position devotes to information/data management. We also include anticipated costs for hardware and software to manage and make information available. Please note that these projections of time do not reflect the time spent on information/data management by park staff who are not paid by the Network. Therefore our estimate of 35% of the budget spent on information/data management is an underestimate and conservative in nature.

Table 10.2. Detailed budget for the NCCN Vital Signs Monitoring Program at full implementation.

Income		**2004**		
Vital Signs Monitoring	$1,145,100			
Water Resources Division	$82,000			
Subtotal	$1,227,100			
Expenditures				
Year Round Personnel	GS Level			Information Management
Network Coordinator	12	$81,999	20%	$16,400
Prototype Coordinator (50%)	12	$41,746	20%	$8,349
Data Manager	11	$84,744	100%	$84,744
Data Manager	11	$68,630	100%	$68,630
Data Manager	11	$67,543	100%	$67,543
Administration Support (35%)	7	$18,948		0
GIS Technician (40%)	9	$25,880	80%	$20,704
Cartographic Technician term (50%)	8	$19,633	80%	$15,706
Physical Science Technician (70%)	7	$37,718	30%	$11,315
Physical Science Technician (80%)	7	$15,500	30%	$4,650
Aquatic Ecologist (50%)	11	$34,000	40%	$13,600
Supervisory Botanist (50%)	12	$43,463	40%	$17,385
Plant Ecologist (50%)	11	$34,000	40%	$13,600
				Seasonal Personnel
Mountain/Small Lakes		$59,420	20%	$11,884
Wadeable Streams		$59,420	20%	$11,884
Rivers		$22,800	20%	$4,560
Intertidal		$14,480	20%	$2,896
Invasive Plants		$21,800	20%	$4,360
Prairie & Coastal Vegetation		$4,320	20%	$864
Forest Vegetation		$74,400	30%	$22,320
Subalpine Vegetation		$43,280	20%	$8,656
	Subtotal	**$873,724**		**$410,051**
Contracts				
Landbird Protocol		$61,600	30%	$18,480
	Subtotal	**$61,600**		**$18,480**

Table 10.2. Detailed budget for the NCCN Vital Signs Monitoring Program at full implementation (continued).

Operations/Equipment				
Weather & Climate		$36,960		
Glaciers		$24,640		
Water Quality – impaired & pristine		$12,320		
Mountain/Small Lakes		$9,500		
Wadeable Streams		$9,500		
Rivers		$3,000		
Large Lakes		$12,320		
Intertidal		$2,000		
Invasive Plants		$5,000		
Prairie & Coastal Vegetation		$6,000		
Forest Vegetation		$12,000		
Subalpine Vegetation		$2,000		
Elk		$36,960		
Remote Sensing		$49,280		
Network Hardware Replacement		$5,787		
Network Software		$2,880		
Network GIS Supplies		$936		
Network Coord Vehicle		$2,100		
Museum Curation Supplies – 3 parks		$4,215		
	Subtotal	**$237,398**		
Travel				
Network Coordinator		$1,873		
Other Network		$5,617		
Data Managers		$4,494		
Seasonal Crews		$33,000		
	Subtotal	**$44,984**		
Other				
Contingency		$9,394		
	Subtotal	**$9,394**		
	Total	**$1,227,100**	**35%**	**$428,531**

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Appendix A. Signature Pages.

North Coast and Cascades Network Inventory and Monitoring Plan

First submitted December 2004
(Approval signatures in Appendix A)

This revision September 2005
Approved by:

9/30/05
William F. Paleck, *Superintendent*, North Cascades National Park Service Complex — Date

9/16/05
Penelope Latham, *Inventory and Monitoring Coordinator*, Pacific West Region — Date

9-30-2005
Approved: Steven G. Fancy, Monitoring Program Leader — Date

9/30/05
Jerry Freilich, Acting Network Coordinator — Date

Appendix A. Signature Pages (continued).

Original Signature Page

SIGNATURE PAGE

APPENDIX A

North Coast and Cascades Network Vital Signs Monitoring Plan

North Coast &Cascade Network Approval Signatures

Gretchen Luxenberg, *Superintendent*, Ebey's Landing National Historical Reserve	12-2-04 Date
Chip Jenkins, *Superintendent*, Fort Clatsop National Memorial	12/2/04 Date
Acting Tracy Fortmann, *Superintendent*, Fort Vancouver National Historic Site	12-2-04 Date
Debby Conway, *Superintendent*, Klondike Gold Rush Seattle Unit National Historical Park	12/2/04 Date
Dave Uberuaga, *Superintendent*, Mount Rainier National Park	12/2/04 Date
William F. Paleck, *Superintendent*, North Cascades National Park Service Complex	12-2-04 Date
Bill Laitner, *Superintendent*, Olympic National Park	12/2/04 Date
Peter Dederich, *Superintendent*, San Juan Island National Historical Park	12/2/04 Date
Penelope Latham, *Inventory and Monitoring Coordinator*, Pacific West Region	12/6/04 Date

Submitted by

Samantha Weber, Network Inventory and Monitoring Coordinator, NCCN	12/2/04 Date

Appendix B. Acronyms.

AARWP	Annual Administrative Report and Work Plan
ASCII	American Standard Code for Information Interchange
ANC	Acid neutralizing capacity
BMI	Benthic Macroinvertebrates
CASTNET	Clean Air Status and Trends Network of the EPA
CESU	Cooperative Ecosystem Studies Units
CFC's	Chlorofluorocarbons
DDT	Dichlorodiphenyltrichloroethane
DMP	NCCN Data Management Plan
EBLA	Ebey's Landing National Historical Reserve
EPA	United States Environmental Protection Agency
ESA	Endangered Species Act 1973, amended 1982
FGDC	Federal Geographic Data Commission
FIA	Forest Inventory and Analysis program of the USFS
FOCL	Fort Clatsop National Memorial
FOIA	Freedom of Information Act
FOVA	Fort Vancouver National Historic Site
FTP	File Transfer Protocol
GPRA	Government Performance and Results Act
GPS	Global Positioning System
GRD	USGS Geologic Resources Discipline
GIS	Geographic Information System
I&M	Inventory & Monitoring Program of the National Park Service
LAN	Local Area Network
LEWI	Lewis and Clark National and State Historical Parks (formerly FOCL)
LWD	Large woody debris
MODIS	Moderate Resolution Imaging Spectroradiometer
MORA	Mount Rainier National Park
MOU	Memorandum of Understanding
NADP	National Atmospheric Deposition Program
NBII	National Biological Information Infrastructure
NCCN	North Coast and Cascades Network
NFMS	National Marine Fisheries Service
NOCA	North Cascades National Park Service Complex
NPS	National Park Service (Department of the Interior)
NPS -ARD	NPS - Air Resources Division
NPS-WRD	NPS - Water Resources Division
NRCS	Natural Resources Conservation Service
NRDT	Natural Resource Database Template
OLYM	Olympic National Park
PCB's	Polychlorinated biphenyls
PWR	NPS Pacific West Region
PNW	Pacific Northwest

Appendix B. Acronyms (continued).

POPs	Persistent Organic Pollutants
RLC	NCCN Research Learning Center
RS	Remote Sensing
SAJH	San Juan Island National Historical Park
SOP	Standard Operating Procedure
TC	NCCN Technical Committee
USDA	United Stated Department of Agriculture
USFS	United States Forest Service (Department of Agriculture)
USFWS	United States Fish and Wildlife Service (Department of Interior)
USGS	United States Geological Survey
UV	Ultraviolet radiation
WAN	Wide Area Network
WASO	Washington Servicing Office
USGS-BRD	USGS Biological Resources Discipline
USGS-WRD	USGS Water Resources Discipline

Appendix C. Glossary.

Ablation refers to the processes by which snow, ice, or water are removed from a glacier, including the processes of melting and evaporation.

Adaptive Management is a systematic process for continually improving management policies and practices by learning from the outcomes of operational programs. Its most effective form-"active" adaptive management-employs management programs that are designed to experimentally compare selected policies or practices, by implementing management actions explicitly designed to generate information useful for evaluating alternative hypotheses about the system being managed. (http://science.nature.nps.gov/im/monitor/glossary.htm)

Albedo refers to the ratio of incoming solar radiation to that which is reflected.

Attributes are any living or nonliving feature or process of the environment that can be measured or estimated and that provide insights into the state of the ecosystem. (http://science.nature.nps.gov/im/monitor/glossary.htm)

Benthic macroinvertebrates are insects, mollusks, crustaceans, worms, and other organisms lacking a backbone that live on, or in the vicinity of the bottom of lakes and streams.

Biological integrity NCCN has adopted Karr and Dudley's (1981) definition of biological integrity as the capability of supporting and maintaining a balanced, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitats within a region. Ecological integrity includes the summation of chemical, physical, and ecological integrity, and it implies that ecosystem structures and functions are unimpaired by human-caused stresses.

CASTNET provides atmospheric data on the dry deposition component of total acid deposition, ground-level ozone and other forms of atmospheric pollution.

Chlorophyll ą (concentration) refers to a general expression and estimator of phytoplankton biovolume and biomass. Chlorophyll ą is the most common type of chlorophyll.

Cirque is a bowl shaped recess in a mountain caused by glacial erosion.

Ecological integrity is a concept that expresses the degree to which the physical, chemical, and biological components (including composition, structure, and process) of an ecosystem and their relationships are present, functioning, and capable of self-renewal. Ecological integrity implies the presence of appropriate species, populations and communities and the occurrence of ecological processes at appropriate rates and scales as well as the environmental conditions that support these taxa and processes. (http://science.nature.nps.gov/im/monitor/glossary.htm)

Ecosystem is defined as, "a spatially explicit unit of the Earth that includes all of the organisms, along with all components of the abiotic environment within its boundaries" (Likens 1992). (http://science.nature.nps.gov/im/monitor/glossary.htm)

Appendix C. Glossary (continued).

Ecosystem drivers are major external driving forces such as climate, fire cycles, biological invasions, hydrologic cycles, and natural disturbance events (e.g., earthquakes, droughts, floods) that have large scale influences on natural systems. (http://science.nature.nps.gov/im/monitor/glossary.htm)

Ecosystem management is the process of land-use decision making and land-management practice that takes into account the full suite of organisms and processes that characterize and comprise the ecosystem. It is based on the best understanding currently available as to how the ecosystem works. Ecosystem management includes a primary goal to sustain ecosystem structure and function, a recognition that ecosystems are spatially and temporally dynamic, and acceptance of the dictum that ecosystem function depends on ecosystem structure and diversity. The whole-system focus of ecosystem management implies coordinated land-use decisions. (http://science.nature.nps.gov/im/monitor/glossary.htm)

Focal resources are park resources that, by virtue of their special protection, public appeal, or other management significance, have paramount importance for monitoring regardless of current threats or whether they would be monitored as an indication of ecosystem integrity. Focal resources might include ecological processes such as deposition rates of nitrates and sulfates in certain parks, or they may be a species that is harvested, endemic, alien, or has protected status. (http://science.nature.nps.gov/im/monitor/glossary.htm)

Hypsometry refers to the measure of height above sea level.

Ice-out refers to the initial date a body of water first becomes free of ice and snow.

Indicators are a subset of monitoring attributes that are particularly information-rich in the sense that their values are somehow indicative of the quality, health, or integrity of the larger ecological system to which they belong (Noon 2003). Indicators are a selected subset of the physical, chemical, and biological elements and processes of natural systems that are selected to represent the overall health or condition of the system. (http://science.nature.nps.gov/im/monitor/glossary.htm)

The term **Indicator** is reserved for a subset of attributes that is particularly information-rich in the sense that their values are somehow indicative of the quality, health, or integrity of the larger ecological system to which they belong (Noon 2002). See Indicator. (http://science.nature.nps.gov/im/monitor/glossary.htm)

Instream (v. riparian) the physical environment of streams. Changes occurring in adjacent riparian zones influence instream habitat.

Katabatic wind is a downslope wind that flows from a glacier.

Lentic refers to an ecosystem characterized by standing water as in a lake or pond.

Appendix C. Glossary (continued).

Lotic refers to an ecosystem characterized by running water as in a stream or river.

Macrophytes are vascular rooted plants growing in stream, not including mosses and algae.

Measures are the specific feature(s) used to quantify an indicator, as specified in a sampling protocol. (http://science.nature.nps.gov/im/monitor/glossary.htm)

Moraine (landform) refers to a mound or ridge composed of glacial till or drift

Particulates (airborne) solid or liquid particles suspended in the atmosphere.

Program (NCCN definition) the overall I&M program for NCCN encompassing the budget, organization, personnel, protocols, and reports.

Protocol is the written document describing a wide range of topics and procedures including sampling design, data acquisition, analysis, reporting and information management. Protocols are the subject of protocol development timelines and peer-review for scientific and statistical merit. Protocols may span several Vital Signs (e.g., the Remote Sensing-Satellite protocol includes Forest Vegetation and Extreme Disturbance Events among other things). Protocols may have some components that are implemented at some parks and not others (e.g., the atmospheric deposition in snow will be implemented only at MORA and NOCA, whereas other forms of deposition will be monitored at a larger number of parks). (NCCN definition)

Project is the implementation of monitoring to accomplish an objective. Projects generate information, are subject to reporting schedules and budgets, and are evaluated in terms of their effectiveness for meeting objectives. (NCCN definition)

Riparian (v. instream) are areas adjacent to rivers and streams with a high density, diversity, and productivity of plant and animal species relative to nearby uplands. Changes occurring in nearby riparian zones influence the physical environment of streams (instream habitat).

Scale refers to both the smallest interval of space measured and the total area over which observations are made. The spatial scale defines the target population, which is area to which the monitoring can be inferred, and greatly influences the cost of monitoring.

Scope refers to the amount of information that is gathered at each sampling site, or the depth of knowledge obtained.

Statistical power refers to the ability of the sample measurements to reveal actual changes in the population being measured. Power depends primarily on the variability of the attribute measured and the number of independent measurements (sample plots) obtained.

Stochastic refers to geological processes that exhibit random characteristics.

Appendix C. Glossary (continued).

Stressors are physical, chemical, or biological perturbations to a system that are either (a) foreign to that system or (b) natural to the system but applied at an excessive [or deficient] level (Barrett et al. 1976:192). Stressors cause significant changes in the ecological components, patterns and processes in natural systems. Examples include water withdrawal, pesticide use, timber harvesting, traffic emissions, stream acidification, trampling, poaching, land-use change, and air pollution. (http://science.nature.nps.gov/im/monitor/glossary.htm)

Thalweg refers to the lowest point in a stream channel or river bed.

Vital Signs, as used by the National Park Service, are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values. The elements and processes that are monitored are a subset of the total suite of natural resources that park managers are directed to preserve "unimpaired for future generations," including water, air, geological resources, plants and animals, and the various ecological, biological, and physical processes that act on those resources. Vital signs may occur at any level of organization including landscape, community, population, or genetic level, and may be compositional (referring to the variety of elements in the system), structural (referring to the organization or pattern of the system), or functional (referring to ecological processes). (http://science.nature.nps.gov/im/monitor/glossary.htm)

Vital Signs in NCCN (v. protocol v. project) refer specifically to the categories of resources that will be monitored.

Zooplankton are floating, or weakly swimming, aquatic animals.

Appendix 1. Introduction and Background.

Appendix 1.1 NCCN Water Quality Resource Status Overview.

1.1.1 Mount Rainier National Park

Mount Rainier National Park is part of a complex ecosystem. The park contains 26 named glaciers across 9 major watersheds, with 403 lakes and ponds, and 470 rivers and streams and over 3,000 acres of other wetland types. Several geothermal and mineral springs also occur in the park. The park contains the headwaters for four major river systems: Puyallup, White and Nisqually (Puget Sound), and the Cowlitz (Columbia River). Eighteen species of fish and 15 amphibian species, several of these listed as Federal and State threatened and species of concern, are dependent on park water resources. Most of the park's land base, 97% is designated Wilderness. The park is subject to pressures from near and in-park development, increasing recreational use, air pollution, presence of dams outside of the park which influence stream processes and fish migration, and past fish stocking actions including the stocking of non-native species.

Surface waters within MORA are thought to be mostly pristine throughout the park's lands designated Wilderness. Most park waters qualify for Outstanding Natural Waters designation under the State of Washington. External influences such as air pollution (acidic deposition, contaminants) and global climate change affect park water quality. Some waters immediately adjacent to the Wilderness boundary and near the park's developed areas (roads, facilities) are less pristine due to road and storm runoff, presence of roads through lake watersheds, and problems with facilities (sewage, oil spills) . Human-caused stressors and threats are described in more detail below. Long-term monitoring of surface waters has been limited to lakes and two streams, where park staff have been monitoring these for over a decade. Additional details are provided below.

Aquatic Habitat

Major natural disturbances affecting the mountainous regions in the Pacific Northwest include episodic floods, volcanic eruptions, earthquakes, geomorphic changes in stream channels and landforms, fire, wind, insect infestations and glacial activity. Human-induced disturbances include alterations of water quality and quantity, and habitat destruction or modification, and biological alterations (e.g. non-native species introductions, fish harvest and stocking, logging, etc.). It is important to track and understand how aquatic communities and habitats respond to natural processes, and to be able to distinguish differences between human-induced disturbance effects to aquatic ecosystems and those caused by natural processes.

Evaluation of aquatic habitat is critical to understanding natural processes and in the interpretation of impairment. Habitat assessment plays an important role in determining constraints of potential integrity or use of a site. The attainment of higher quality biological condition may be prohibited by the constraints of habitat quality. Aquatic habitat complexity is a primary factor influencing the diversity of fish, amphibian, and macroinvertebrate communities. Attributes of aquatic habitats include the variety and range of hydraulic conditions (e.g. width, depth, and water velocity), numbers of pieces and size of wood, types and frequency of habitat units, and variety of bed substrate, water temperature, and water chemistry parameters etc.

Achievement of goals and objectives requires a monitoring program that integrates various spatial scales through time to analyze or index natural processes and human-induced perturbations. The monitoring approach accommodates the various scales using extensive coarse level inventories, at the park-wide scale, and intensive sampling, at the local site scale. It follows a watershed approach that tracks upslope processes and conditions, but places emphasis and enhanced resolution on aquatic/riparian habitat and communities. In order to accomplish this it will be necessary to stratify the park complex by an integrated classification system. A classification system that incorporates various spatial scales and allows for the development of ecologically meaningful strata is required. This approach expands the scope of data interpretation to unsampled areas and simplifies comparisons between sampled areas. Construction of sampling strata will improve sampling efficiency and the sensitivity of statistical tests.

Many developed areas within the park are subject to frequent flooding. Late fall and early winter rain-on-snow events, spring snowmelt and glacial outburst floods can cause flood damage to park facilities. Precipitation -induced flooding and debris flows are extremes on a continuum of hydrologic/geologic hazards. In general, precipitation-induced flooding occurs more frequently, but is less destructive than debris flows. Precipitation-induced flooding occurs most often between early November and late February on the rivers draining Mount Rainier. Debris flows, in contrast, vary widely in size, timing and predictability. They may occur at any time of year. Flood events at Mount Rainier have undermined or buried roads, bridges, campgrounds and other facilities. Historically, developed areas at Mount Rainier were mostly limited to river valleys, many of which flooded frequently in recent years.
Riverine, lacustrine, and many palustrine wetlands are popular recreation areas for park visitors. Several developments are located in and adjacent to wetlands in the park. Wetland inventories were conducted from 1996-1999. Few studies have been completed on montane wetlands (Windell et al., 1986; Hansen et al. 1995). Detailed vegetation and soil surveys have been completed in subalpine wetlands located close to development zones or along trail corridors. These surveys revealed that many high-elevation wetlands do not contain soils with typical wetland characteristics (e.g., mottling). Additionally, many high-elevation plant species are not on the plant indicator status lists for the country or region. Wetland inventories conducted in 1996-1997 included collection of data on soils and vegetation to increase our understanding of the function of these wetlands. Without this additional data, many high-elevation wetlands within mountainous park areas may not be classified as wetlands.

Park facilities may pose threats to aquatic resources. Included are sewer line breaks, fuel storage tank leaks, storm water runoff, and other road runoff including sedimentation to adjacent lakes and streams. Routine park operations have affected park waters such as the occasional sewage "bypass" events that occur at the Paradise Sewage Treatment Plant, and hazardous material spills during routine servicing of fuel tanks. Oil spill effects on groundwater are also a concern where oil has been detected in the soils, such as the Longmire maintenance and residential areas.

Contamination from parking lot and road runoff may threaten water quality of adjacent waters. The cumulative impact of such constituents as heavy metals, petroleum derivatives, ammonia, suspended solids, rubber, etc., may result in a pronounced deterioration of water quality. Many sources of heavy metals have been identified in storm water runoff. Several park roads run adjacent to streams, rivers or lakes. Three large parking areas exist at Sunrise, Paradise and Longmire. These receive extensive use during summer months and year-round use in the case of Longmire and Paradise. During rainfall events a sheen of oil can be seen on water flowing into storm drains in these lots. The destination of outflow from all storm drains has not been determined. Although runoff may be a short-term event and dilution may make effects negligible, heavy rainfall could result in periodic shocks or "pulses" of contaminants to park surface waters. An assessment is needed to determine the severity, extent and effects of storm water runoff on park surface waters.

The effects of past mining activities on park waters is virtually unknown. Mining occurred in the park in the early part of the century and continued until the 1960’s when the last mine was purchased by the park. Little information has been collected to ascertain what effects these old mines have on park surface waters today.

Past Efforts
Stream habitat descriptions have been documented only in association with various fish and amphibian surveys. Physical and chemical characteristics of lakes, streams and wetlands have been documented as noted in the following table.

Appendix 1.1. NCCN Water Quality Resource Status Overview (continued).

Location	Monitoring Program or relevant Study/Stressors Addressed *projects listed in bold are ongoing monitoring programs*	Parameters/Frequency	Period of Record	Inventory (I) Monitoring (M) Research (R)
STREAMS				
Nisqually/ Ohanapecosh	**NPS Stressors Addressed: park and external land use; recreational impacts; atmospheric pollution**	**Sampled three times/year: temp, DO, pH, ANC, specific conductance, nutrients, cations, dissolved sediments, dissolved solids**	**1990 to present**	**I and M**
Parkwide (12 streams)	Turney, USGS 1981	Measurements of discharge, water chemistry, temperature	1981	I
Nisqually River	Publicover, D. A.	Study of the characteristics of the river basin and stream plus physical, chemical, and biological data. 2 maps included in appendices.	1986	I
White River	Smith, Stamford D.	Water samples from streams with heavy loads of 'glacial flour' (glacial streams) were examined for the presence of insects at different points along their course. Report describes the nature of the glacial streams and factors which may affect insect populations (temperature & current).	?	I
Parkwide	Bob Mariner, USGS	Chemical anomalies and constituent loads in streams draining Mount Rainier (sulfate concentrations, chloride or bicarbonate anomalies)	1997-2000	I
Tahoma glacier	Frank, D	Water chemistry to assess hydrothermal effects on seeps draining from Tahoma glacier	1995	I
Amphibian Surveys	NPS	Description of lotic survey sites (overstory, width, flow, instream cover, substrate). Description of lentic survey sites (substrate)	1996-1999 1993-1999	I
Ohanapecosh River, White River and Laughingwater Creek, and Meadow Creek	Hawkins and Ostermiller, Utah State University	Benthic macroinvertebrate samples and environmental characteristics were collected using a standard protocol (fixed area and fixed time qualitative procedures).	1998-1999	R
Fish Surveys	NPS	Habitat conditions were measured for each stream segment. Channel gradients, depth, overstory and stream width were measured at beginning, middle, and end of stream segments. substrate, recorded as %, dominant and subdominant substrate, and instream cover (Table 5), were recorded for stream segments.	1999 2000	I

Appendix 1.1. NCCN Water Quality Resource Status Overview (continued).

LAKE/WETLAND WATER QUALITY				
Mowich Lake	Larson 1966	Nine month limnology study of a high mountain lake: physical & chemical features, primary production, phytoplankton, zooplankton.	1966	I
Mowich Lake	**NPS Stressors addressed: park land use; recreational impacts; atmospheric pollutants; fish stocking effects;**	**Limnology monitoring three times between July and September. (transparency, temperature, pH, specific conductance, dissolved oxygen, ANC measured biweekly during season; nutrients, cations, SO4 and Cl measured once during season (generally August). 2001 sampling will include full cation-anions, cation-anion balance, and Si.**	**1998-present**	**M**
Parkwide-27 lakes (**including Mowich Lake)** Parkwide (6 lakes)	NPS (Larson, et al)	Limnology (plankton, DO, temp, cond, ANC, pH, nutrients, cations Temporal variations of water quality and plankton	1988-1989 1990-1993	I
Parkwide	NPS	Lake water quality & bathymetric characterization; one time sampling	1988 to 1999	I
Louise, Bench, Snow, Green, Eunice, George, Shriner, Clover, Reflection	**NPS Stressors addressed: park land use; recreational impacts; atmospheric pollutants; fish stocking effects**	**Limnology monitoring three times between July and September. (transparency, temperature, pH, specific conductance, dissolved oxygen, ANC measured three times during season; nutrients, cations, SO4 and Cl measured once during season (generally August). 2001 sampling will include full cation-anions, cation-anion balance, and Si.**	**1999-present**	**M**
Twenty lakes and ponds in the Huckleberry and White River Watersheds of the park	Brokes 2000	Alkalinity, conductivity, and pH samples were taken at a depth of 1 m below the surface, except in ponds less than 1 m deep, where samples were taken at one half the maximum depth. Water temperature and dissolved oxygen were recorded at 1 m intervals beginning at the surface to a depth of 1 m off the bottom using a YSI™ dissolved oxygen meter	1996	R
Parkwide	NPS	Water quality (transparency, temperature, pH, specific conductance, dissolved oxygen, ANC) for all sites; nutrients for approximately 35 selected sites	1996-1999	I
Parkwide	NPS	Classification of wetlands, water quality, soil descriptors.	1996-1997	I
Parkwide (5 lakes)	EPA in 1985 NPS /USFS Ft. Collins lab in 1996	Water chemistry pH, conductivity, Ca, Mg, Na, K, NH4, F, Cl, N03, S04, ANC, Si02, PO4, Al, sum anions/cations	1985 1996	I
Parkwide (16 lakes)	Nelson and Baumgartner 1986	total aluminum; major anions; major cations; dissolved silica; dissolved organic carbon; and pH	1983	I

Appendix 1.1. NCCN Water Quality Resource Status Overview (continued).

LAKE/WETLAND WATER QUALITY				
Parkwide	Welch, E. B.//Chamberlain, W. H.	water chemistry analyses	1981	I
Parkwide	Turney, G. L.//Dion, N. P.//Sumioka, S. S.(USGS)	Evaluated 13 lakes for general chemical characteristics, sensitivity to acidification, and existing degree of acidification.	1986	I
Reflection Lake	Funk, W. H.//Moore, B.//Johnstone, D.//Larsen, C.//McKarns, T.//Porter, J.//Juul, S.//Trout, C.//Becker, B.	Study of the basic physiochemical and biological structures and initial assessment of increased human activity in drainage area.	1985	I
Shadow Lake	Hall, T. J.	Limnology of Shadow Lake: physical, chemical, and biological parameters were considered. Includes bathymetric charts of Shadow, Clover, Hidden, and Sunrise	1970-72	I
Fan Lake	Perry, R.	Study in which nitrogen, phosphate, sulfate, and silicate concentrations were examined as well as oxygen levels and zooplankton. Includes bathymetric map of lake.	1979	I
Eunice Lake	Eilers and Sullivan Quantification of Dose Response Relationships and Critical Loads of Sulfur and Nitrogen	Soil chemistry, water chemistry	Data collected in 1998; document in prep	I
Eunice Lake	NPS/USGS	Snowpack sampling, daily outlet stream chemistry. Samples analyzed for pH, ANC, major dissolved constituents including major anions, cations, dissolved organic carbon and silica	2000	I
Parkwide lakes	Eilers/Charles/NPS	Diatoms collected in MORA lake sediment cores. Used to develop diatom calibration set for the Cascade Mountain Ecoregion	1999	I

Aquatic Biota

Assessment of biological integrity of lakes and streams is an important component of an aquatic monitoring program. Within a given habitat strata certain expectations for community composition and abundance can be defined. Deviation in these biological attributes, between what is observed and what is expected (reference conditions), provides the framework for diagnosis of impairment. The multivariate nature of complex biological systems requires that evaluations be based on a number of relevant biological attributes. In order to facilitate the interpretation of impacts and changes occurring at different temporal scales, we will incorporate information from a variety of organisms, trophic classes and functional groups. Primary assessments of Biological Integrity will be based on community and indicator species metrics that are known to respond to human disturbance using a variety of taxonomic groups including; amphibians, fish, benthic macroinvertebrates, zooplankton and phytoplankton.

Implementation of an aquatic biomonitoring program will incorporate surveys for the rapid assessment of biological integrity and document temporal changes in species distributions and community characteristics. Intensive studies will be also applied to address important fish and amphibian population attribute data for species of special management concern.

Recreational use, park facilities, and atmospheric pollution concerns in MRNP have been described in the Aquatic Habitat section of this plan. Park lakes, streams and wetlands are popular destination points for most park visitors. Trampling of lake and stream shorelines (habitat for benthic organisms and amphibians), sedimentation, and human waste effects are increasing in the park's Wilderness as recreational use increases. Benthic habitat has been altered by park trail development as in the shoreline area around Mowich Lake. Some park roads were constructed within the lake's watershed at Reflection, Louise, and Tipsoo Lakes. Frozen Lake was altered in the early 1930s when the Sunrise water supply system was developed. Oil and sewage spills have occurred at Paradise. Sewage treatment, water supplies, and storm water runoff also affect aquatic biota. The effects of atmospheric pollutants, including toxics, on aquatic biota in the park is unknown.

A conceptual plan for long-term monitoring of streams was prepared by Gregory, et al 1991. He recommended major components of aquatic ecosystems that should be characterized for park streams and rivers including water chemistry, geomorphology, aquatic plant communities, aquatic invertebrates, fish and critical biological processes.

Algae
Phytoplankton has been described for approximately 25 park lakes. One study documented algae in the Ohanapecosh hot springs.

Invertebrates
Most park lakes and wetlands contain plankton. These organisms provide an important food base for fish, and amphibians. Zooplankton usually feed on phytoplankton in the lake and are important second consumers. These organisms contribute significant amounts of biomass to aquatic environments in the park. They are also sensitive indicators of water quality. It is important to establish a baseline of what zooplankton are present in the park to assess future impacts from acid precipitation, runoff from roads, organic pollution from human use, or spills of hazardous materials (i.e. gasoline, oil, etc.) in to aquatic systems. The park has a small collection which contains both representative zooplankton and phytoplankton.

Most of the park's streams, rivers, lakes and ponds contain aquatic invertebrates. These organisms provide an important food base for fish, amphibians and birds. Aquatic invertebrates ingest a variety of organic material and can be divided into several broad groups. Shredders usually feed on large particulate organic material (deciduous leaves); Collectors feed on detritus and are termed either gathers (feed on large particles or filter feeders (feed on fine particles); Scrapers feed on periphyton growing on substrates in the water (e.g. rocks, logs); Macrophyte Piercers suck on tissues of vascular plants; Predators eat other animals; and Parasites feed on other live animals. The majority of aquatic invertebrates are insects. Many of them spend all or long periods of their life cycle in water, but some metamorphose in to terrestrial adult forms. Little is known about the distribution, abundance, or species identity of aquatic invertebrates that inhabit the park. These organisms contribute significant amounts of biomass to aquatic environments in the park. They are the major food source for many fish and amphibian species. They are also sensitive indicators of water quality. Little information is available on invertebrates inhabiting park springs. The Fender's soliperlan stonefly (*Soliperla fenderi)* is listed as a federal Sensitive species and has been documented in the park.

Freshwater mussels are now considered the most rapidly declining animal group in the United States and constitute the largest group of federally listed endangered or threatened invertebrates (Stein and Flack 1997). Recent studies show that more than 70 percent of mussel species in the U.S. are in need of protection. Ten freshwater species of bivalves occur west of the Rocky Mountains; only five species of them are known to occur in the state of Washington. Of the five, three are known to occur within the Mount Rainier N.P.: the Oregon floater, the western or Cascade floater, and the western pearlshell (Dr. Terry Frest, pers. comm). The remaining two, the western ridge mussel and the California floater potentially occur within the park. All five mussels are Washington State Watch species and the California floater is currently a federally listed Special Concern. Many of the gastropod mollusks also are declining, several of which likely occur within the park. Many new species and even genera remain to be discovered in this region, and many others lack recent records (Frest and Johannes 1993). It is probable that many undescribed regional endemics are nearing extinction or are already extinct. Accurate assessments of the presence (or absence) of species or genotypes in the park and the health of individual protected populations are essential to both maintaining natural diversity within the park, and the identification of potential new or expanded reserves encompassing biotic diversity that may not be currently protected within the park (Stohlgren and Quinn 1992). Mollusks are also valuable as indicators of the general health of aquatic ecosystems because most species are sensitive to disturbances and/or various forms of pollution (Frest and Johannes 1993).

Fish

The headwaters of several Puget Sound drainages (White, Puyallup, and Nisqually) and a Columbia River tributary (Ohanapecosh) originate in MORA. Those portions occurring in the park are primarily comprised of steep gradients and with the exception of the Ohanapecosh and Huckleberry drainages, are highly influenced by glacial turbidity. The present status of native fish populations in the park is not well understood due to previous stocking activities, construction of dams outside the park , and a general lack of knowledge as to current patterns of fish occurrence within the park.

Construction of Electron Dam on the Puyallup-Mowich drainage and Alder and LaGrande Dams on the Nisqually have blocked anadromous passage to these rivers and their upstream tributaries within the park. Mud Mountain Dam on the White River also blocks fish passage, but anadromous fish (chinook, coho, and steelhead) are transported around the dam, thereby conceivably allowing access to the White River, West Fork of the White River, and Huckleberry Creek basins. Chinook salmon have been observed in the White River drainage adjacent to the park boundary. Salmon migration in the Cowlitz and Ohanapecosh Rivers are blocked by dams at Riffe Lake and Mayfield Lake. However, coho salmon are still transported around the dams. The Carbon River is the only major drainage without man-made dams blocking fish

Appendix 1.1. NCCN Water Quality Resource Status Overview (continued).

Native fish species in streams include rainbow trout (*Oncorhynchus mykiss*), coastal cutthroat trout (*Oncorhynchus clarki clarki*), Dolly Varden (*Salvelinus malma*) and/or bull trout (*Salvelinus confluentus*), mountain whitefish (*Prosopium williamsoni*), and possibly anadromous rainbow trout or steelhead (*Onchorhynchus mykiss*). Several hatchery strains of rainbow and cutthroat trout were widely stocked throughout the park and may have hybridized or replaced native stocks within their historic ranges. Historically, Chinook (*Oncorhynchus tshawytscha*), Coho (*Oncorhynchus kisutch*), and Steelhead (*Oncorhynchus mykiss*) occupied streams within the park. in the past.

Bull trout and Chinook Salmon are federally listed threatened species. Coho and cutthroat have been proposed for listing

Amphibians
The status of certain amphibian populations is also of interest. Amphibians are an important component of the northwestern fauna. Thirteen species have been documented in the park; two additional species potentially occur here. Twenty two species inhabit forests of the northwest, with 14 of these species endemic to the region. Many of the habitats that they are associated with are increasingly affected by human activities. Fish stocking, alteration of streams, wetlands, and riparian areas, and logging practices have created widespread impacts to amphibian communities. Several species of frogs have considerably contracted distributions as a result of human disturbances. The Cascades frog, red-legged frog, western toad, Van Dyke’s salamander and Larch Mountain salamander all occur in MORA and are listed by the State of Washington as threatened species, and on federal lists as Species of Concern. Widespread stocking of fish into previously fishless lakes has affected the distribution of certain salamander species in park lakes and ponds.

Past Efforts
Baseline inventories are lacking for most invertebrate aquatic biota. Information on plankton is available for approximately 25 lakes. Qualitative information on macroinvertebrates is available for many wetlands and some streams. The park has a small insect collection which contains some aquatic insects. A freshwater mollusk survey is presently being conducted. Baseline inventories have been conducted for aquatic breeding amphibians. Presence/absence surveys have been conducted for some terrestrial breeding amphibians. General surveys, and surveys conducted for NEPA compliance purposes, have been conducted for fish in many streams. Information on fish in park lakes is available for most lakes that were previously stocked.

Park staff has conducted some sampling of fish in these drainages, directed primarily toward ESA and NEPA compliance. These surveys have revealed trout, sculpins, and bull trout or Dolly Varden. The US Fish and Wildlife Service listed bull trout as a threatened species on November 1, 1999. Distinguishing between bull trout and Dolly Varden requires DNA analysis, which has not been done, and sculpins have not been keyed out to species. Some anadromous salmonids (spring chinook and coho salmon and steelhead trout and possibly cutthroat trout) also utilize park rivers.

Appendix 1.1. NCCN Water Quality Resource Status Overview (continued).

Surveys pertaining to fish stocking efforts were conducted from 1937 to 1967. Creel census forms were gathered from anglers on a voluntary basis in the past years (Buttery 1983, NPS 1956, 1957, 1959, 1970, 1971, 1976, 1977, 1984-87). Cursory fish surveys were conducted in park streams in 1984 (Carbon and Huckleberry watersheds) and 1993 (Carbon, Huckleberry, Nisqually, Ohanapecosh, Cowlitz, Puyallup, White River watersheds). The 1993 survey focused on historical sites noted for Dolly Varden. Bull trout/Dolly Varden were documented in the Puyallup, Carbon and White River watersheds.

Passive techniques for removing fish from some lakes in the park are being investigated. The effects of fish stocking on native lake biota is also being investigated.

Recorded information on amphibians collected in the park date to the early part of the century. Edwin Cooper Van Dyke, Curator of the Department of Entomology, California Academy of Sciences, collected at least one salamander specimen (Van Dyke Salamander) on a collecting trip to the park in July, 1905 (Van Denburg 1906). Amphibians were studied in the park by Storer in 1911 and by Slevin in 1928 (Snyder 1956). Slater (1933) listed seven salamanders and five frogs occurring in the park. Additional Collections were made in the park by Henry and Twitty in 1940 (Snyder 1956), Bishop in 1943 (Blair 1953), Blair in 1952 (Blair 1953), and Snyder in 1952 (Snyder 1953). Snyder (1956) compared the life history of *Ambystoma gracile* (northwest salamander) over an elevational gradient in the park. Short reports of observations made on the south side of the park were reported by (Kardong 1984, 1985, 1986, 1987).

Summary of Aquatic Biota research, inventories and monitoring.

Location	Monitoring Program or relevant Study-Stressor *projects listed in bold are ongoing monitoring programs*	Parameters/Frequency	Period of Record	Inventory (I) Monitoring (M) Research (R)
ALGAE				
Ohanapecosh Hot Springs	Stockner, J. G.	Study of primary production, efficiencies of energy transfer, and information on the natural history of cyanophycean algal species	1968	R
Park Lakes	Larson et. al, NPS	Limnology of park lakes: included phytoplankton described for approximately 27 park lakes	1988-1998	I
Invertebrates				
Park Lakes	Larson et. al, NPS	Limnology of park lakes: included zooplankton described for approximately 27 park lakes	1988-1998	I
Mowich Lake	**Larson et. al NPS Stressors addressed: park land use; recreational impacts; atmospheric pollutants; fish stocking effects**	**Limnology of Mowich Lake: includes zooplankton collected biweekly during the snow-free season**	**1997-present**	**M**
Louise, Bench, Snow, Green, Eunice, George, Shriner, Clover, Reflection	**NPS Stressors addressed: park land use; recreational impacts; atmospheric pollutants; fish stocking effects**	**Limnological monitoring three times between July and September. Zooplankton collected during sampling.**	**1999-present**	**M**

Appendix 1.1. NCCN Water Quality Resource Status Overview (continued).

Location	Monitoring Program or relevant Study-Stressor *projects listed in bold are ongoing monitoring programs*	Parameters/Frequency	Period of Record	Inventory (I) Monitoring (M) Research (R)
ALGAE				
Mowich Lake	NPS	Limnology monitoring at least once during snow free season.	1989-1998	I
Park Streams				
Selected Park Streams	Pike 1939	Macroinvertebrates in fish-bearing streams to determine "fish food."	1938	I
Nisqually, White Rivers	Stamford 1982	Examined glacial stream insects from headwaters to the mouth of the Nisqually and White Rivers.	1981	R
Selected habitats	Weisseman 1986	Sampled 21 freshwater habitats to collect Trichoptera species (caddisflies). Many of the specimens were nymphs or larvae and were not identified to species.	1985	I
Nisqually River	Publicover 1986	Conducted a physical, chemical and biological study of the Nisqually River and collected benthic invertebrates.	1985	I
Seven Selected Streams (13 sites), one spring near Cougar Rock Campground	Furnish 1986	Collected aquatic insects	1985	R
INVERTEBRATES				
Mazama Ridge Ponds	Girdner 1994	Studied zooplankton communities in several Mazama Ridge ponds	1993	R
Parkwide Wetlands Survey	NPS- Samora and Leslie 1997	Invertebrates collected at 72 wetland sites	1997	I
Parkwide –Lakes, Springs (17 lakes and ponds including 9 of the long-term monitoring sites; Crystal Creek, Ohanapecosh hot springs, one seep	NPS-Noon and Samora in prep	Fifty six samples were collected from twenty aquatic areas. At the long term monitored lakes and other aquatic sites, aquatic insects were collected from many types of microhabitats using D-frame nets, mollusk pole strainers, and hand collecting. Examples of microhabitats sampled include aquatic vegetation, organic detritus, coarse woody debris, sand, silt, cobble, and boulder. Samples were also collected from different microhabitats around each lake. For example, aquatic insects were collected from inlet and outlet areas, talus sections, and shaded and non-shaded areas. 54 genera of aquatic insects were collected from 20 different sample sites ;639 specimens were collected, sorted, and identified to genus or family. The more highly diverse areas sampled during the field season were Snow Lake and Lake George, with 25 and 23 taxa present, respectively. Trichoptera (caddisflies) represented the aquatic insect order with the highest diversity to the genus level. Thirteen genera of Trichoptera (caddisflies) were collected and identified during the 2000 aquatic field season.	2000	I
Ohanapecosh River, White River and Laughingwater Creek, and Meadow Creek	Hawkins and Ostermiller, Utah State University	Benthic macroinvertebrate samples and environmental characteristics were collected using a standard protocol (fixed area and fixed time qualitative procedures).	1998-1999	R

Appendix 1.1. NCCN Water Quality Resource Status Overview (continued).

Location	Monitoring Program or relevant Study-Stressor *projects listed in bold are ongoing monitoring programs*	Parameters/Frequency	Period of Record	Inventory (I) Monitoring (M) Research (R)
INVERTEBRATES				
Parkwide	Kondratieff, B.C. and R. Lechleitner	110 sites in riparian areas; looking for endemics and baseline inventory of Plecoptera species. 14 new state records were found and one new species. 74 total species found. (Western North American Naturalist publication submitted) Trichoptera also surveyed – 91 species found; not all samples processed	1994-ongoing	I
FISH				
Streams in Carbon, Huckleberry watersheds	NPS	Qualitative surveys to determine fish presence	1984	I
Streams in Carbon, Huckleberry, Nisqually, Ohanapecosh, White, Cowlitz, Puyallup watersheds	NPS	Qualitative survey for bull trout/Dolly Varden presence/absence; other Salmonids also documented; Bull trout/Dolly Varden documented in Puyallup, Carbon, White River watersheds.	1993	
Carbon River tributary streams	NPS	bull trout/Dolly Varden presence/absence; other Salmonids also documented. Bull trout/Dolly Varden documented in most Carbon River tributaries	1995	
Parkwide streams: Carbon, Huckleberry, White, Ohanapecosh, Nisqually and Puyallup watersheds	NPS (Samora and Feola 1999)	In August through October 1999, 22 stream segments were surveyed to document Salmonid presence/absence. A non-random sample design was used to select survey sites. Estimates of fish abundance were made by direct observation by snorkeling. Electroshocking methods were used to verify presence or absence of fish in reaches not surveyed by snorkeling. . Fish were not present in Cataract Creek, an upper segment of the Ohanapecosh River, Ollalie Creek and Dewey Creek. Rainbow trout were present in five streams in the Nisqually, Ohanapecosh and White River watersheds. Cutthroat, present in 13 streams, were most widely distributed and found within all watersheds surveyed with the exception of the Carbon. The introduced Eastern Brook Trout was found only in surveyed streams in the Ohanapecosh and White River watersheds. Native char (bull trout/Dolly Varden) was found at only one survey site, in Fryingpan Creek in the White River watershed. Sculpins were found only in Fish Creek in the Nisqually watershed.	1999	I
Parkwide streams	NPS (report in prep)	62 sites were surveyed for bull trout presence/absence. Bull trout were documented at 10 sites. Bull trout were present in the Mowich and West Fork watersheds, in addition to the previously identified watersheds (White, Puyallup, Carbon). Other fish species were identified for sites surveyed.	2000	I
Streams in White, Huckleberry and Carbon watersheds	Puyallup Tribe (ongoing) J. Iverson	Anadromous fish foot spawning surveys are being conducted. To date, anadromous fish presence in mainstem rivers has been difficult to assess due to the low visibility of field sites. Bull trout spawning was documented in Klickitact Creek in the White River watershed.	2000-2001	I

Appendix 1.1. NCCN Water Quality Resource Status Overview (continued).

Location	Monitoring Program or relevant Study-Stressor *projects listed in bold are ongoing monitoring programs*	Parameters/Frequency	Period of Record	Inventory (I) Monitoring (M) Research (R)
FISH				
Parkwide Lakes	NPS	Fish presence was determined using gill nets for 47 lakes. Fish present in 32 lakes.	1994-1999	I
Lakes in White River and Huckleberry Watersheds	BRD	Passive techniques for removing fish from are being investigated. Number of fish removed documented for 4 lakes	1996-present	R
AMPHIBIANS				
Parkwide	Aubry 1985	US Forest Service established 14 old growth forest study plots in the park in 1984. Data were collected on amphibians in each old growth plot using time-constrained searches and/or pitfall traps	1984	I
Parkwide	NPS (Schlegel, Pidgeon, Brokes)	Qualitative surveys of non-randomly selected sites throughout the park. 12 species documented	1991-92	I
Lakes in White River and Huckleberry Watershed	NPS	Snorkel and Visual encounter surveys of lakes with and without fish. Focus was on Ambystoma salamander species.	1993-1995	I
Parkwide	NPS, BRD (report in prep)	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. Lotic sites were sampled using modified protocols described by Bury and Corn 1991. 114 lotic and 205 lentic sites were inventoried using a stratified random sample design. Nine species and their relative abundances were documented.	1996-1999	I
Parkwide	NPS	Surveys for terrestrial amphibian species, targeting two Species of Special Concern, were conducted using methods developed by Crissafulli (1999) for Larch Mountain salamanders, and by Jones 1999 and Crissafulli 1999 for Van Dyke Salamanders. Van Dyke habitat was inventoried by USFS staff through cooperative efforts with the PNW Research Station (Crissafulli) (2000); these efforts will continue in 2000.	1999-ongoing	I
Lakes in White River and Huckleberry Watersheds	BRD (R. Hoffman)	Passive techniques for removing fish and salamander distribution after fish removal is being investigated. Quantitative snorkel surveys conducted to document Ambystoma species present.	1996-present	R

1.1.2 Olympic National Park

Olympic National Park encompasses 922,651 acres in the center of Washington's Olympic Peninsula and along a 65-mile strip of wilderness coastline on the Pacific Ocean. Nearshore waters affect major park biotic communities and fisheries, and are directly influenced by coastal streams coming from the Park's interior. Park ecosystems range from the rich intertidal zone, to rainforests, montane forests, alpine meadows, and glaciers. Eleven major rivers radiate from the mountainous core of the park and 260 glaciers and over 400 lakes and wetlands lie within these watersheds. Several federally and state listed species of concern are dependent on park water resources. Most of the park's land base, 96% is designated Wilderness. The park is also recognized as both a World Heritage Site, and an International Biosphere Reserve. The park is subject to pressures from near and in-park development, increasing recreational use, air pollution, and past fish stocking actions.

1.1.3 North Cascades National Park

North Cascades National Park contains 318 glaciers, 530 lakes, and 6500 km of rivers and streams. In addition NOCA contains the headwaters for tributaries of three major river systems: the Columbia, Fraser and Skagit. Several federally and state listed species of concern are dependent on park water resources. Non-native stocks of rainbow trout, cutthroat trout, brook trout, golden trout, and kokanee salmon are also found within North Cascades NPS Complex. Three reservoirs exist within Ross Lake NRA, all behind dams built to provide hydroelectric power. A small hydroelectric project on Newhalem Creek provides further power via a stream diversion. Lake Chelan, which developed within a deep, glacial trough, is the third deepest natural lake in the United States. It was dammed in the 1920's to regulate its elevation for hydroelectric power. All four reservoirs provide recreational opportunities and transportation routes as well as power. Dams also influence stream processes downstream and the migration of fish throughout the watershed. Most of the park's land base, 93% is designated Wilderness. In addition to in-park developments, the park is subject to pressures from increasing recreational use, air pollution and fish stocking actions.

Appendix 1.1 NCCN Water Quality Resource Status Overview (continued).

In general, existing water quality of the Complex is believed excellent. Relatively low human visitation and short duration precludes significant water quality deterioration associated with urban population centers. In the future, water quality may deteriorate with increasing visitation as well as from dry and wet atmospheric deposition. Baseline information and long-term monitoring is needed to detect changes.

The Complex straddles the crest of the northern Cascade Range. Most drainage headwaters are contained entirely within the Complex, and as such are not subject to terrestrial source contamination from outside areas. Major exceptions include the headwaters of the Skagit River and Lightning Creek in British Columbia; and Ruby Creek and Bridge Creek, both on non-wilderness national forest lands. Minor exceptions include 6 streams draining the west side of the Pasayten Wilderness into Ross Lake, 9 streams draining the east side of Glacier Peak Wilderness into the Stehekin River, and portions of Alma and Copper creeks draining into the Skagit River below Newhalem. These latter streams flow into the ROLA while originating in outside drainage headwaters.

Land management practices in southern British Columbia and on non-wilderness forest lands in the United States (Ruby, Canyon, Granite and Bridge creeks) might result in water pollution problems in Ross Lake and in the upper Stehekin River valley. There is little likelihood of pollution originating from streams with headwaters located within the national forest wilderness areas. Terrestrial contamination of surface waters from outside sources would include acid mine wastes, siltation, chemicals (pesticides and herbicides), and coliform bacteria.

The potential for degradation of water quality also exists from sources entirely within the Complex. For example, water quality could be degraded by activities associated with Seattle City Light hydroelectric projects, recreational boats on the 4 large lakes, commercial trucks along SR-20, maintenance activities along SR- 20, and NPS operations. In addition, waters of the lower Stehekin valley and head of Lake Chelan may be affected by small additions of fertilizers, household detergents, and other miscellaneous household-use chemicals such as pesticides and herbicides. Additional impacts to stream habitat on the lower Stehekin River have been associated with channel manipulations protecting roads and private in-holdings.

During the past, intermittent low levels of total coliform and fecal coliform bacteria have been identified in surface waters adjacent to human-use developments. In most instances bacteria levels have been well below Washington State permissible levels for Class AA (Extraordinary waters).

The potential for deterioration of pristine air quality is very high because the Complex lies in the path of prevailing westerly winds blowing across the several, large urban-industrial areas of the Puget Sound lowlands. These areas stretch from Portland, Oregon in the south to Vancouver, B.C., in the north. Within this area potential air pollution sources are known to be located in Tacoma, Everett, March Point, Centralia, Port Townsend, Port Angeles, Bellingham, Ferndale and Cherry Point, Washington, and in the Vancouver, B.C. metropolitan area. These pollution sources range from 41 miles (67 km) at Bellingham to 102 miles (163 km) at Tacoma, measured

to the Mount Shuksan area of the North Park Unit. Various chemical pollutants enter the aquatic ecosystem as either acid precipitation or dry particulate deposition. Non-attainment air quality areas to the west are major sources of total suspended particulates, sulfur dioxide, nitrous oxides, carbon monoxide, ozone, lead, arsenic, fluoride and some pesticides. Recent studies of mercury in lakes indicated that some subalpine lakes had higher than expected levels of mercury in fish tissue samples.

The rivers and tributaries of the Complex contain 11 known fish species distributed among 3 families. These include 9 species of salmonids (salmon, trout, charr and whitefish), 1 Cyprinid (minnows and dace), and 1 Catostomid (suckers). Up to 12 additional species and 4 additional families may also occur, including Cottidae (sculpins), Gasterosteidae (sticklebacks), Petromyzontidae (lampreys), and Acipenseridae (sturgeons). Of these species, chinook salmon and bull trout have been added to the Federal list of threatened and endangered species.

The native fish species of the lower Stehekin River and of Lake Chelan have been severely impacted by the introduction of alien aquatic species including: opossum shrimp (*Mysis*), rainbow trout (*Oncorhynchus mykiss*), brook trout (*Salvelinus fontinalis*), kokanee salmon (*O. nerka*), chinook salmon (*O. tshawytscha*), and lake trout (*S. namaycush*). Before the introduction of the alien species, the dominant native sport fish were Lake Chelan cutthroat trout (*O. clarki lewisi*) and bull trout (*S. confluentus*). Bull trout may now be extirpated from Lake Chelan and the Stehekin River; no bull trout have been reported recently in either location. The introduction of other genotypes of cutthroat trout and stocking of rainbow trout make it doubtful that remnants of the native genotype of this fish exist in the lower 6 miles of the Stehekin River or in Lake Chelan.

The practice of stocking fish in mountain lakes of North Cascades National Park Service Complex (NOCA) may seriously jeopardize the health and distribution of native animal communities found in these waters. Several studies have documented negative effects, correlated with the presence of introduced fish populations, on zooplankton, benthic macroinvertebrates, amphibians, and native fish. All the high lakes in NOCA were devoid of fish life due to natural barriers to fish migration in their outlet streams. Today, over 75 high lakes of the NOCA Complex support introduced populations of rainbow trout, cutthroat trout, brook trout and golden trout.

The Skagit River system is one of the few watersheds within the Puget Sound area that is managed for natural production of salmon. Over the last 30 years Skagit River salmon stocks have been considerably impacted by loss of habitat from logging, hydropower development and non-point source pollution. In addition these stocks have been subjected to exploitation in commercial, tribal, and sport fisheries. Important anadromous salmon stocks are also found in the Chilliwack Watershed which is located at the north end of the park. The Chilliwack River drains into the Fraser River in British Columbia. The health of populations of steelhead, sockeye salmon, and coho salmon in this basin can be affected by management decisions made by Canadian resource agencies.

Appendix 1.1 NCCN Water Quality Resource Status Overview (continued).

Very little emphasis has been placed on non-game fish species. These species are generally unaffected by exploitation. Within the Complex they are not currently at risk from impacts affecting habitat quality. Transboundary non-game species exhibiting greater mobility may be affected by land use practices outside the Complex boundaries. Management efforts enhancing native sport fish and commercial fish populations and non-native species and strains may induce increased predatory and competitive stress. Conversely, declining populations of native species may allow species-specific expansion of some non-game fish to the detriment of other non-game and/or game fish species.

1.1.4 Lewis and Clark National and State Historical Parks

Lewis and Clark National and State Historical Parks encompass 1625 acres with park ecosystems ranging from the estuarine mudflats and tidal marshes, to shrub and forested swamps and upland coniferous rainforest, dominated by Sitka spruce as large as 6 feet in diameter. Ten types of wetlands occur within the park in palustrine, estuarine and riverine systems, as identified by the National Wetland Inventory; wetlands comprise approximately half the park acreage. Surface water consists of the tidally influenced Lewis and Clark River, low-gradient brackish sloughs, freshwater ponds and small freshwater streams and springs. The park is affected by adjacent land-use including water withdrawals from the Lewis and Clark River. Congress recently passed legislation to create the Lewis and Clark National and State Historical Park, a joint venture between the NPS and the States of Oregon and Washington. New lands have been added to the park, however, the jurisdictional responsibilities and land ownership details are not available at this time. Consideration for monitoring additional sites in LEWI will be given when land management details have been finalized.

Approximately 50% of the park is freshwater or estuarine wetlands. Ten types of wetlands occur within the park, as identified by the National Wetland Inventory. Seven of these are palustrine: PEM/SSR, PFO/SSR, PSS/EMR, PEMA, PSSC, PEMC and PSSR. Two are estuarine: E2EMN and E1UBL, and one is riverine: R1UBV

Water within and surrounding the park has been greatly diverted and altered. The Lewis and Clark River has been extensively diked for flood control, reducing or eliminating fertile floodplains. The former floodplains are now utilized for agriculture and development. Logs, rootwads and other woody debris have been historically removed from the river to improve its navigability, increasing its flow rate and decreasing wildlife habitat quality. Many activities within the Lewis and Clark River drainage may impact Lewis and Clark’s water quality and wetlands. These activities include pesticide and fertilizer use, runoff from agricultural and logging operations, potential contamination due to tidal influences (such as oil spills), illegal dumping of household and industrial rubbish and toxic materials, erosion from forest roads and logging operations, and encroaching development.

The park's extensive and diverse wetlands support a relatively high number of amphibians. Of 10 confirmed species, three are uncommon or rare. Imperiled due to habitat loss, the Columbia torrent salamander (*Rhyacotriton kezeri*) is an aquatic inhabitant of small cold streams. The
Appendix 1.1 NCCN Water Quality Resource Status Overview (continued).

Pacific giant salamander (*Dicamptodon tenebrosus*) lives in the park's small streams and adjacent moist forests. The northern red-legged frog (*Rana aurora aurora*), a federal species of concern, inhabits the park's forests and freshwater wetlands.

Several lower Columbia River salmonid fish stocks are federally listed. Of these, coho and chum salmon (*Oncorhynchus kisutch* and *O. keta*) and cutthroat trout (*Oncorhynchus clarkii clarkii*) have been found in park streams and sloughs. Fall Chinook (*O. tshawytscha*) were documented in spawning records for the Lewis and Clark River previous to 1996, but have not been encountered in more recent surveys. Future estuarine restoration projects will reestablish spawning and rearing habitat for these species.

A Water Quality Baseline Inventory of LEWI was initiated in September of 1995. Sites included in this inventory included the Lewis and Clark River, 2 permanent streams, 1 ephemeral stream, 2 ephemeral springs, 3 ephemeral ponds and 1 slough. All sites were sampled 3 times per month throughout the year, in the case of the ephemeral sites until they dried up in the summer and beginning again in the fall when the water returned.

Water quality samples included readings and measurements for temperature, conductivity, salinity, turbidity, pH, alkalinity, and dissolved oxygen. Stream flow measurements were taken in the streams and springs. Nutrient and ion analyses were performed by an outside contractor 3 times during the inventory. No obvious impacts from human-related activities were observed, with the exception of dioxin/furan contamination of the sediment in the Lewis and Clark River. The dioxin/furan data was reported in as study done by Tetra Tech (Tetra Tech: Lewis and Clark National and State Historical Parks: Water and Sediment Quality TC 1082-01). Samples were collected in August 1996, south of the canoe landing on the Lewis and Clark River. That report also found that River sediment analysis indicated that mean concentrations of several metals (arsenic, beryllium, nickel, and zinc) exceed typical levels in soils, perhaps due to anthropogenic sources. Three sites within LEWI are identified as being 303(d) impaired waters by the State of Oregon. These are the Lewis and Clark River (for dissolved oxygen and temperature exceedances), the Skippanon River (for dissolved oxygen), and the Columbia River (near Gray's Harbor) for fecal coliform.

In November of 1998 the Baseline Inventory was ended and the Long Term Monitoring Inventory was begun. The sites chosen for long term monitoring were based on results of the Baseline Survey. Sites included the Lewis and Clark River, 2 permanent streams, 2 ephemeral ponds and 1 ephemeral spring. A sampling schedule has been set up for each individual site and is based on seasonality and results of the Baseline Survey. This monitoring program is ongoing at the present time.

1.1.5 San Juan Island National Historical Park

The major surface water resources in the park are three tidal lagoons located along the north shore of American Camp's Griffin Bay. Freshwater resources in the park consist of groundwater (accessed through wells), small springs, a perennial pond, intermittent ponds or wetlands, and an
Appendix 1.1 NCCN Water Quality Resource Status Overview (continued).

intermittent stream. The perennial pond and intermittent ponds are the primary sources of freshwater that provide habitat to wildlife populations such as migratory birds and amphibians. An intermittent stream in English Camp drains several pond and wetland areas. As the largest natural area on the island, the park is subject to ever-increasing pressures from near-park development, increasing visitation, and different kinds of recreational uses.

In 1998, a wetland survey was conducted at SAJH by Ronald Holmes. Holmes mapped twenty-six wetlands in the American Camp unit and nine wetlands in the British Camp unit.

Studies have shown groundwater to be a main water quality issue in the park. Since 1981, increased levels of chloride, manganese, and dissolved solids have been found in the domestic supply well at American Camp. Chloride concentrations in ground water can indicate the presence of sea water intrusion. The park and most island residents rely on groundwater as the source of domestic water supply. Acting to prevent saltwater intrusion is of utmost concern for park managers, particularly at American Camp, in order to maintain an adequate freshwater supply.

In the spring of 1999 to winter of 1999, the USGS Water Resource Division, conducted a Level 1 Water-Quality Inventory and Monitoring Program at San Juan Island National Historic Park. Site sampled included a well at English Camp, an unnamed creek at English Camp, a well at American Camp, a spring at American Camp, and a pond at American Camp. Samples were collected three times from each site (Spring, Fall, Winter).

Water quality samples included readings and measurements for temperature, conductivity, fecal-indicator bacteria, pH, alkalinity and dissolved oxygen. Water samples were collected and sent to the USGS National Water Quality Laboratory to be analyzed for concentrations of nutrients, chloride, major ions, and arsenic.

Conclusions of the report indicate that overall quality of ground water and surface water in the study area is generally good; however there is some evidence that land use activities might be affecting water quality at the park. The well at American camp had elevated conductance and chloride concentrations, indicating seawater intrusion. Manganese concentrations at this site were also found to be high. Samples from all surface water sites had concentrations of bacteria, and E. coli was found in samples from water at American camp spring and English camp spring. Nitrate concentrations in the spring and stream were also elevated.

1.1.6 Ebey's Landing National Historical Reserve

Ebey’s Landing National Historical Reserve is a 25 square mile historical reserve encompasses a mixture of federal, state, county and private property, all managed in a way that preserves its historic essence. The west shore of the reserve, along Admiralty Inlet, is an eight-mile strip of narrow sand and stone beaches that give way to dramatic bluffs and ravines. Elevations range from sea level to just over 200 feet. Many of the bluffs are sparsely vegetated, relatively unstable, and in a constant state of erosion and accretion. Large glacial kettles created

depressions in excess of 200 feet in some places. A more sheltered but equally rich beach character, Penn Cove covers over 4,000 surface acres. Penn Cove is listed as a 303(d) site. The shoreline varies between low beach front, to uplifted banks. Along the west edge of the cove, the low lands fill out into lagoons providing habitats for various waterfowl and migratory birds. Park water resources are affected by land-use practices, recreational use, and air pollution. Several other county, state and federal agencies have on-going monitoring programs within these waters.

Surface freshwater resources within Ebey’s Landing National Historic Park include Lake Pondilla (a kettle pond) and several small wetlands. There is a broad diversity of marine resources including Penn Cove, Kennedy's Lagoon, Grasser's Lagoon, Perego's lake and Crockett Lake.

Salt water intrusion in EBLA is a concern. Groundwater pumping exceeds recharge in and around EBLA causing saltwater intrusion in some areas. The groundwater aquifer on Whidbey Island had been designated as a "sole source aquifer" since almost the entire island relies on this for its drinking water supply. This designation provides the aquifer with the state of Washington's highest level of regulatory protection.

The Department of Ecology monitors water quality at approximately 20 sites in Penn Cove where salinity, temperature, fecal coliform, and PSP/biotoxins are monitored monthly for commercial and recreational shellfish harvesting. Data has shown excursions in dissolved oxygen, but according to the Department of Ecology these excursions beyond the criterion were considered a natural condition with no direct human caused influence. There are two permitted effluent discharges into Penn Cove.

A Central/South Whidbey Watershed Baseline Water Quality Monitoring Program was initiated by the Island County Health Department in 1997 to characterize the quality of surface waters from various land uses on Central/South Whidbey Island. Six sample site, including one within Ebey's Landing National Historic Reserve, were sampled three times in 1997. The Ebey monitoring station is located on a perennial stream that receives drainage from the 2,265 acre Ebey watershed, where land use is approximately 95 percent Agriculture and 5 percent Residential. Agricultural uses include a few small farms and two large dairies with associated feed crops.

In this preliminary analysis of water quality in the Central/South Whidbey area, watershed land uses exerted some influence on water runoff quality. Runoff from the watershed dominated by agriculture (Ebey) exhibited the highest concentrations of nitrate + nitrite, ammonia, phosphorus and fecal coliform bacteria. Sources of these contaminants are likely due to poor agricultural practices, animal fecal wastes and fertilizers.

1.1.7 Fort Vancouver National Historic Site

Fort Vancouver National Monument encompasses some 170 acres in a variety of conditions. The natural environment of the site has been heavily impacted over time by the Hudson's Bay Company and by development, primarily US Army, which moved into the area in 1849. As a result of these impacts, almost none of the site's historic natural environment remains. The park contains no surface waters within its boundaries and are not included in the NCCN water quality monitoring program. FOVA boundary borders the Columbia River but waters are not included within the park boundary. Several agencies have responsibility for monitoring water quality in the Columbia River.

Appendix 1.2. Impaired and Potentially Impaired Sites.

Washington’s Water Quality Assessment Categories are presented in Table 1.2.1. Listed or proposed 303(d) waters are presented in Table 1.2.2. The sites within EBLA are not under the jurisdiction of the NPS and several other agencies have responsibilities for monitoring water quality of Penn Cove and Crockett Lake. Proposed sites (Category 5) will be included in the NCCN water quality monitoring program. The Penn Cove site is part of the Washington State Department of Ecology (WDOE) Ambient Monitoring program. WDOE reported eight excursions beyond the criterion out of 14 samples (57%) at this site. between 9/91 and 9/96. WDOE remarked that these excursions beyond the criterion were considered a natural condition with no direct human caused influence based on the 6/97 judgment of John Glynn (Dept. of Ecology). They noted that no actions were required for this site.
Site ID#3 (Solduc River in OLYM) is just downstream of a natural hot spring and a hot spring resort. It is not clear whether the pH excursion is a natural phenomenon or caused by the resort. Further study of this site will be conducted.

Table 1.2.1. Washington State Water Quality Assessment Assessment Categories.

<table>
<tr><td>Category 1. Meets Tested Standards</td><td rowspan="3">Not impaired, or not known to be impaired</td><td rowspan="4">EPA approval and TMDL not required</td></tr>
<tr><td>Category 2. Waters of Concern</td></tr>
<tr><td>Category 3. No Data</td></tr>
<tr><td>Category 4. Impaired But Does Not Require A TMDL
4a. Has a TMDL
4b. Has a Pollution Control Plan
4c. Impaired by a Non-Pollutant</td><td rowspan="2">Impaired</td></tr>
<tr><td>Category 5. The 303(d) List</td><td>EPA approval and TMDL required</td></tr>
</table>

Appendix 1.2. Impaired and Potentially Impaired Sites (continued).

Table 1.2.2. 303(d) sites in NCCN parks in Washington State.

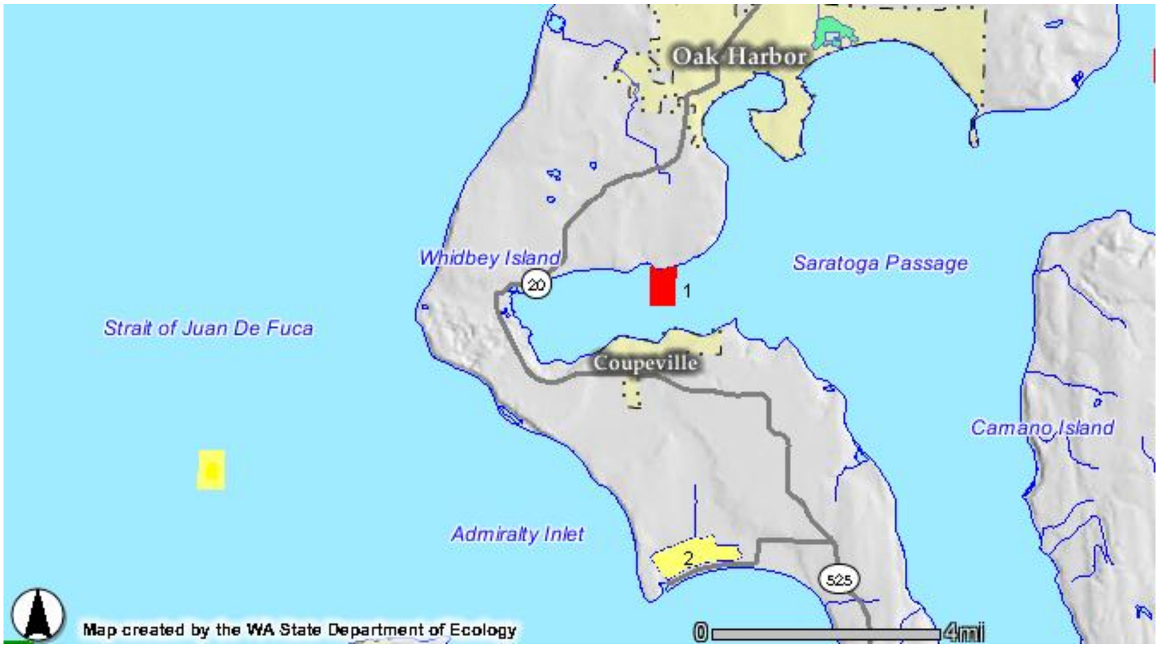
ID	Water body	Park	Category	Parameter	Listed	Proposed 2002/ 2004	Comments
1	Penn Cove	EBLA	5	Dissolved Oxygen	Yes	Yes	Not within NPS jurisdiction
2	Crockett Lake	ELBA	2	Total Phosphorus	No	Yes	Not within NPS jurisdiction
3	Soleduck River	OLYM	5	pH	No	Yes	OLYM commented that conditions were likely natural but WDOE determined that further study was needed. Kept as Category 5.
4	West Twin Creek	OLYM	2	pH	No	Yes	WDOE changed from category 5 to 2 based on park's comments that low pH was likely a natural condition.
5	Big River	OLYM	5	pH			Not within NPS jurisdiction, outside boundary
6	Sams River*	OLYM	5	Temperature	No	Yes	Not within NPS jurisdiction, outside boundary
7	Coal Creek*	OLYM	5	pH	No	Yes	Not within NPS jurisdiction, outside boundary
9	Crooked Creek	OLYM	5	pH			Not within NPS jurisdiction, outside boundary
10	Kalaloch Creek	OLYM	5	temperature			Not within NPS jurisdiction, outside boundary

Category 2 Waters: Waters where the data are not sufficient for listing a water body segment as impaired but may still raise a concern about water quality.

Category 5 Waters: Waters for which at least one characteristic or designated use is impaired, as evidenced by failure to attain the applicable water quality standard for one or more pollutant.

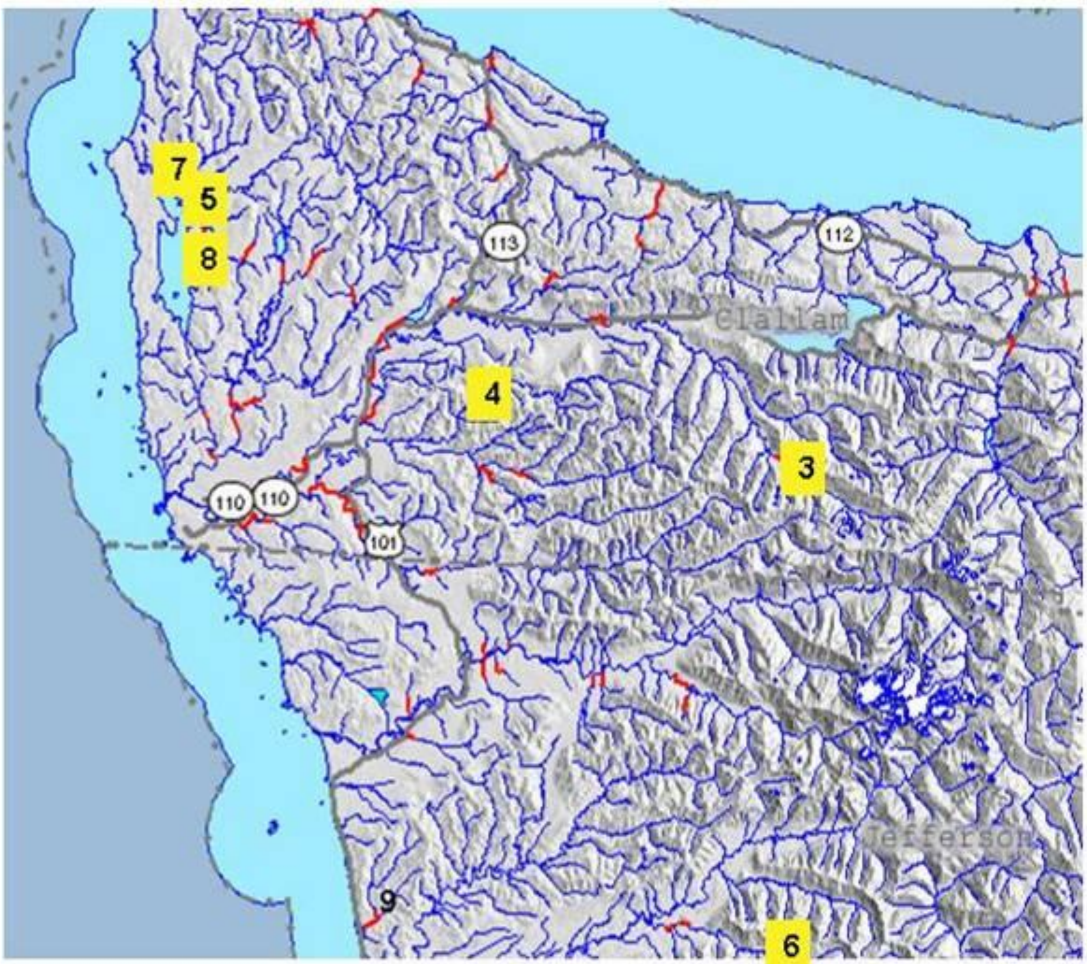
Appendix 1.2. Impaired and Potentially Impaired Sites (continued).

Figure 1.2.1. Ebey's Landing National Historic Reserve proposed 2002/2004 303(d) waters.



Appendix 1.2. Impaired and Potentially Impaired Sites (continued).

Figure 1.2.2. Olympic National Park proposed 2002/2004 303(d) waters.



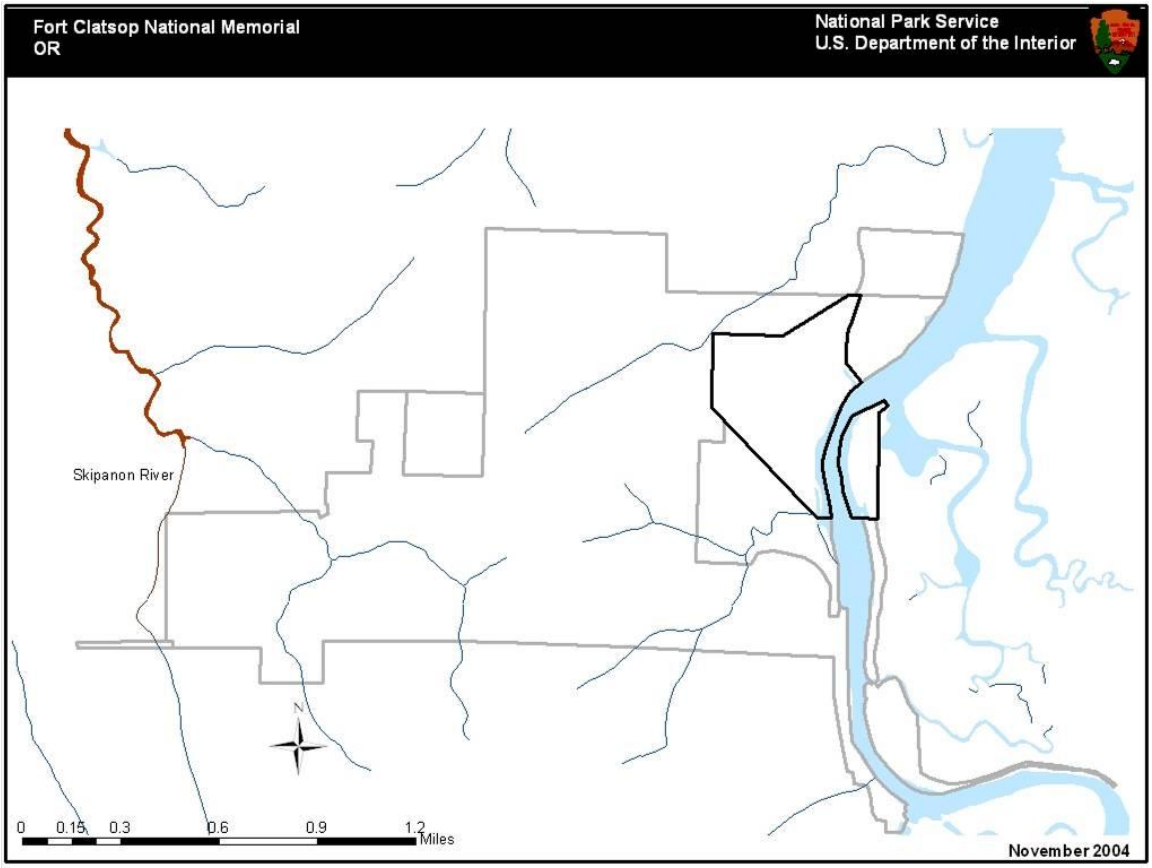
There are three 303(d) waters identified by the state of Oregon in LEWI. These are the Lewis and Clark River (for dissolved oxygen and temperature exceedances), the Skippanon River (for dissolved oxygen), and the Columbia River (near Gray's Harbor) for fecal coliform.

Table 1.2.3. 303(d) sites in NCCN parks in Oregon.

Water body Name	Parameter	Listing Status
Columbia River	Fecal Coliform	303(d) List
Lewis and Clark River	Dissolved Oxygen	303(d) List
Skippanon River	Dissolved Oxygen	303(d) List

Appendix 1.2. Impaired and Potentially Impaired Sites (continued).

Figure 1.2.3. Lewis and Clark National and State Historical Parks 303(d) sites.



In addition to the State proposed lists, we will use our Watershed Scale Stream Disturbance and Function Evaluation ratings to identify potentially impaired watersheds. Surface waters with high disturbance category rankings will be incorporated into the NCCN water quality monitoring program.

Pristine Waters: Both Washington State ((WAC 173-201A-300) and Oregon (OAR 340-041-0026 have proposed anti-degradation and Outstanding Resource Waters policies for surface waters. No park waters are presently listed as Outstanding Resource Waters. However, we feel that waters within the legislated Wilderness lands of MORA, NOCA and OLYM qualify for this designation. Park staff may pursue this designation sometime in the future. Potentially pristine waters have been incorporated into the NCCN water quality monitoring program.

Appendix 1.3. NCCN Air Quality Monitoring Overview.

1.3.1 Table of Air Quality Monitoring Sites in NCCN.

Station name	Location	In/Near Park	Map ID	Elevation (m)	Start	End	Data Collected
Ross Dam, North Cascades National Park	Ross Dam	NOCA	1	573	2000	Present	Improve Aerosol Sampler (PM 10, PM 2.5)
Marblemount Ranger Station	Marblemount	NOCA	2	109	1996	Present	Dry Deposition Filter Pack (CASTNET)
Marblemount Ranger Station	Marblemount	NOCA	3	123	1984	Present	Deposition Chemistry (NADP); precip (Dry/Wet Collector)
Chilliwack Airport	Chilliwack, BC	NOCA	4	<15	1984	Present	CO, NO2, O3, PM10, PM 2.5, Light Scatter, Wind, Temp., Sol. Rad., RH, BP
Hope Airport	Hope, BC	NOCA	5	131	1996	Present	CO, NO2, O3, PM10, Wind, Temp., RH
Hoh Ranger Station, Olympic National Park	Hoh, Olympic National Park	OLYM	6	176	1980	Present	Deposition Chemistry (NADP); precip (Dry/Wet Collector)
Olympic National Park Air Quality Station	Blyn Mountain	OLYM	7	600	2001	Present	Improve Aerosol Sampler (PM 10, PM 2.5)
Olympic National Park Air Quality Station	Port Angeles	OLYM	8	125	1997	Present	Dry Deposition Filter Pack (CASTNET)
Olympic National Park Air Quality Station	Port Angeles	OLYM	9	125	1991	Present	Ozone and SO2 (1983-present), Wind (S/D), Temp, RH, Solar Radiation, Precip.
Hurricane Ridge Lodge	Hurricane Ridge, Olympic National Park	OLYM	10	1596	1998	Present	O3, Light Scatter (nephelometer) - during summer
Stevens Middle School	Port Angeles	OLYM	11		1998	Present	Light Scatter (Nephelometer)
Blue Heron Middle School	Port Townsend	OLYM	12		2000	Present	Light Scatter (Nephelometer)
Ozette	Lake Ozette Ranger Station	OLYM	13	9	1999	Present	Dioxin (NDAMN)
Olympic Primenet (UV-B)	Ediz Hook, Port Angeles	OLYM	14		1997	Present	UV-B
Pack Forest	Charles L Pack Forest	MORA	15	280	1985	Present	Ozone
Mud Mountain	Enumclaw	MORA	16		1998	Present	O3 (May - September)
Packwood Dam	Packwood Lake	MORA	17		1995	Present	O3 (May - September)
Carbon River Ranch		MORA	18		1994	Present	Light Scatter (Nephelometer)

Appendix 1.3. NCCN Air Quality Monitoring Overview (continued).

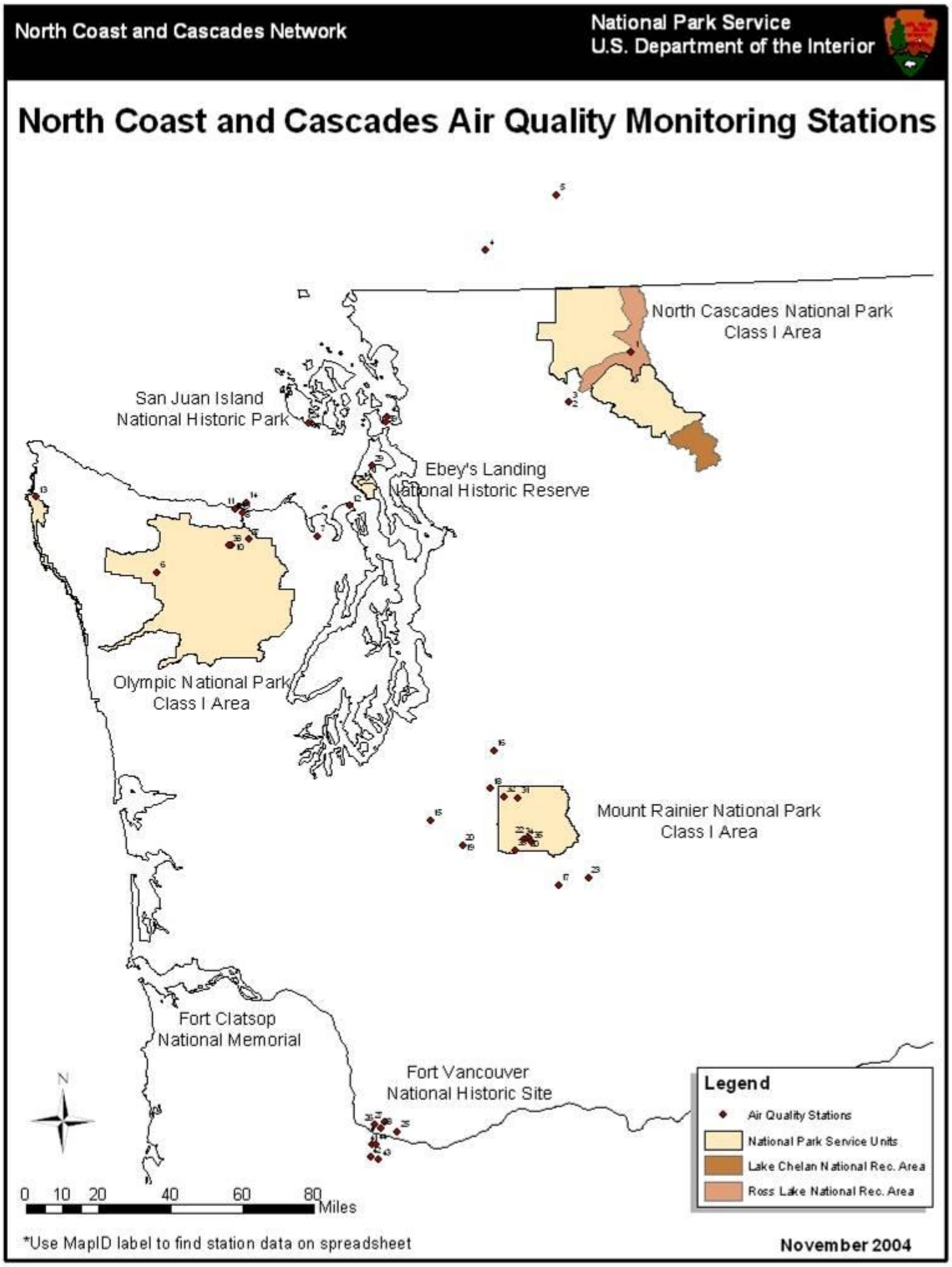
Station name	Location	In/Near Park	Map ID	Elevation (m)	Start	End	Data Collected
Tahoma Woods	Mount Rainier National Park	MORA	19	421	1988-1990	Present	IMPROVE Aerosol Sampler (PM2.5, PM10), Light Scatter, CASTNET (dry deposition), wind (S/D), temp, RH,
Tahoma Woods	Mount Rainier National Park	MORA	20	421	1999	Present	Precipitation chemistry (NADP), precip total (Dry/Wet Collector)
Paradise	Mount Rainier National Park	MORA	21	1650	1995	Present	O3, Light Scatter (1993-present)
Paradise	Mount Rainier National Park	MORA	22	1692	1986	Present	Cations, Anions (analyzed weekly)
White Pass	White Pass	MORA	23	1830	2000	Present	Improve Aerosol Sampler (PM 10, PM 2.5)
San Juan Islands	Visitor Center, American Camp	SAJU	24	60	2001	Present	Digital Camera (Visibility)
Mt. View High School	Vancouver	FOVA	25		1988	Present	Ozone (operates from May through Sept.)
Atlas/Cox	2101 E. 4th Plain Blvd., Vancouver	FOVA	26		1986	Present	CO
Moose Lodge	8205 E 4th Plain Blvd., Vancouver	FOVA	27		1990	Present	PM2.5, PM10
Mcloughlin Middle School	Vancouver	FOVA	28		2000	Present	Light Scatter (Nephelometer)
Oak Harbor ****	Oak Harbor Middle School	EBLA	29				In the process of installing a nephelometer
Paradise	Mount Rainier National Park	MORA	30	1650	1998	Present	Passive Ozone Monitor (operates during summer)
Carbon River	Mount Rainier National Park	MORA	31	853	1998	Present	Passive Ozone Monitor (operates during summer)
Eunice Lake	Mount Rainier National Park	MORA	32	1632	1998	Present	Passive Ozone Monitor (operates during summer)
Longmire	Mount Rainier National Park	MORA	33	512	1998	Present	Passive Ozone Monitor (operates during summer)
Glacier Bridge	Mount Rainier National Park	MORA	34	1193	1998	Present	Passive Ozone Monitor (operates during summer)
Reflection Lakes	Mount Rainier National Park	MORA	35	1478	1998	Present	Passive Ozone Monitor (operates during summer)

Appendix 1.3. NCCN Air Quality Monitoring Overview (continued).

Station name	Location	In/Near Park	Map ID	Elevation (m)	Start	End	Data Collected
Olympic National Park Air Quality Station	Port Angeles	OLYM	36	125	1995	Present	Passive Ozone Monitor (operates during summer)
Weather Station Point	Hurricane Ridge Parkway,	OLYM	37	938	1995	Present	Passive Ozone Monitor (operates during summer)
Hurricane Ridge/Idaho Springs	Hurricane Ridge	OLYM	38	1536	1995	Present	Passive Ozone Monitor (operates during summer)
S. Texaco, March Point	Anacortes		39		1988	Present	Sulfur Dioxide Wind speed/ direction
Kiesser, March Point	Anacortes		40		1969	Present	Total suspended particulates, Particle fallout, Sulfur dioxide, Sulfation Rate
Portland	Central Fire Station	FOVA	41				Light Scatter (Nephelometer) (approx. UTM)
Portland	SW 4th and Alder	FOVA	42				CO2 (approx. UTM)
Portland	5824 SE Lafayette	FOVA	43				CO2, NO2, Light Scatter (Neph), PM10, PM2.5, wind, temp (approx. UTM)
Portland	NE Portland at Roselawn	FOVA	44				Total suspended particulates, PM 2.5, Pb (approx. UTM)

Appendix 1.3. NCCN Air Quality Monitoring Overview (continued).

1.3.1. Map of Air Quality Monitoring Sites in NCCN.



Appendix 4. Sampling Design.

Appendix 4.1. Watershed Scale Stream Disturbance and Function Evaluation.

Recreational	Score
1. Remote-difficult travel, mostly cross country to few trails, primarily overnight use. No established backcountry camp sites.	(0-3)
2. Mixture of off-trail and moderate trail development with use limited to foot traffic or horses, overnight use only. Established backcountry camping sites.	(4-6)
3. Same use a in No. 2 with inclusion of front country trails (within three miles of trail head) and moderate road connections.	(7-10)
4. High road density providing for areas of dispersed recreation developed drive-in campgrounds, moderate to high trail development multiple trailheads, moderate or greater ORV use.	(11-15)
Agricultural (grazing and/or croplands)	
1. No to very little influence – less than 5% of lands along riparian corridor used for crops and/or pasture.	(0-5)
2. Minimal influence – 6 to 10% of lands along riparian corridor used for crops and/or pasture.	(6-10)
3. Moderate influence – 11 to 25% of lands along riparian corridor used for crops and/or pasture.	(11-15)
4. High influence – greater than 25% of lands along riparian corridor used for crops and/or pasture.	(16-20)
Urban Development (housing and other developments)	
1. No or very little development.	(0-5)
2. Low amounts of development.	(6-10)
3. Moderate amounts of residential and/or commercial development within riparian corridor.	(11-15)
4. High amounts of residential and/or commercial development in riparian corridor. Storm water drains to stream though culverts from adjacent urban development.	(16-20)
Hydraulic Modifications (channelization, levees, dams, riprap)	
1. No modifications to flow upstream from sample site.	(0)
2. Minimal or isolated modifications to stream flow (less than 5% of stream bank impacted).	(1-5)
3. Moderate levels of channel modifications and flood control structures (less than 10% of stream bank length impacted).	(6-10)
4. High levels of channel modifications that may directly influence site flow velocity, channel migration, substrate texture, gravel recruitment or large woody debris recruitment (More than 10% of stream bank impacted).	(11-20)

Appendix 4.1. Watershed Scale Stream Disturbance and Function Evaluation (continued).

LoggingScore

1. 0% of watershed area logged within the last 40 years.	(0)
2. Up to 10% of watershed logged within the last 40 years.	(1-9)
3. 10 to 19% of watershed area logged within the last 40 years.	(10-19)
4. 20 to 29% of watershed area logged within the last 40 years.	(20-29)
5. 30% or greater logged within the last 40 years.	(30-39)

Road Density

1. No roads in the watershed up stream of the sample reach.	(0)
2. Up to 1.0 mile of roads/sq. miles of upstream catchment area.	(1-10)
3. 1.0 to 1.99 miles of roads/sq. miles of upstream catchment area.	(11-19)
4. 2.0 to 2.99 miles of roads/sq. miles of upstream catchment area.	(20-29)
5. 3.0 or greater miles of roads/sq. miles of upstream catchment area.	(30-39)

Mining

1. No mining activity.	(0)
2. 1 to 2 mines/claims upstream of sample reach within the catchment, with no to minimal amounts of historical development.	(1-5)
3. 3 to 7 mines/claims upstream of sample reach within the catchment, with minimal to moderate amounts of historical development.	(6-10)
4. 8 to 18 mines/claims upstream of sample reach within the catchment, with minimal to moderate amounts of historical development.	(11-15)
5. More than 19 mines in the catchment, and/or active mining, and/or high amounts of historical development upstream of sample reach within the catchment.	(16-20)

Fire

1. Low occurrence of fires during the last 200 years. Forest type (excluding logged areas) dominated by old growth or mature seral stages.	(0-5)
2. Less than 25% of the catchment area burned during the last 100 years and forest (excluding logged areas) dominated by mature and mixed mature and younger seral stages.	(6-10)
3. Moderate occurrence of fires (25 to 50%) of catchment) during the last 100 years with some recent (<30 years) fires. Forest (excluding logged areas) is mixed mature younger seral stages.	(11-15)
4. High occurrence of fires in the last 100 years (>50% of catchment area) and/or large scale recent fires with forest (excluding logged areas) dominated by younger seral stages.	(16-20)

Appendix 4.2. General Overview of NCCN Water Quality Monitoring Program.

Water resources in the NCCN are affected by atmospheric stressors such as air pollution and climate change, as well and land use within and surrounding the parks. We define water quality as the physical, chemical, and biological characteristics of park waters. We have developed an integrated monitoring approach that includes these characteristics for each surface water body type

Table 4.2.1. Resource types and general overview of the NCCN Water quality monitoring program.

Water Body Type	Size	Perennial/ Intermittent	Core Water Quality Parameters	Water Chemistry	Invertebrates	Fish	Amphibians	Physical Habitat	Water Quantity
Montane lakes and ponds	<75 ha	perennial	X	X	X	X	X	X	X
Small park lakes and ponds	<75 ha	both	X	X	X		X	X	X
Large Lowland Lakes	>75 ha	perennial	X	X	X			X	X
Wadeable Streams	Generally <30m wetted width and most pools <2m during summer low flows	perennial	X	X	X	X	X (MORA only)	X	X
Non-wadeable Streams/Large Rivers	> 30 m wetted width and most pools >2 m depth) during summer low-flows; and those not already included in the wadeable streams	perennial	X	X		X		X	
Marine/ Intertidal Waters	N/A	N/A	Temperature only		X			X	

Appendix 4.2. General Overview of NCCN Water Quality Monitoring Program (continued).

Table 4.2.1. Resource types and general overview of the NCCN Water quality monitoring program (continued).

Water Body Type	Size	Perennial/ Intermittent	Core Water Quality Parameters	Water Chemistry	Invertebrates	Fish	Amphibians	Physical Habitat	Water Quantity
Targeted Waters	Wetlands, springs, and potentially impaired streams, lakes, and ponds that fall outside of the other monitoring programs	both	X	X	X				

Appendix 4.3. Detailed Maps and Descriptions of the Monitoring Sites Chosen for NCCN Aquatic Monitoring Program.

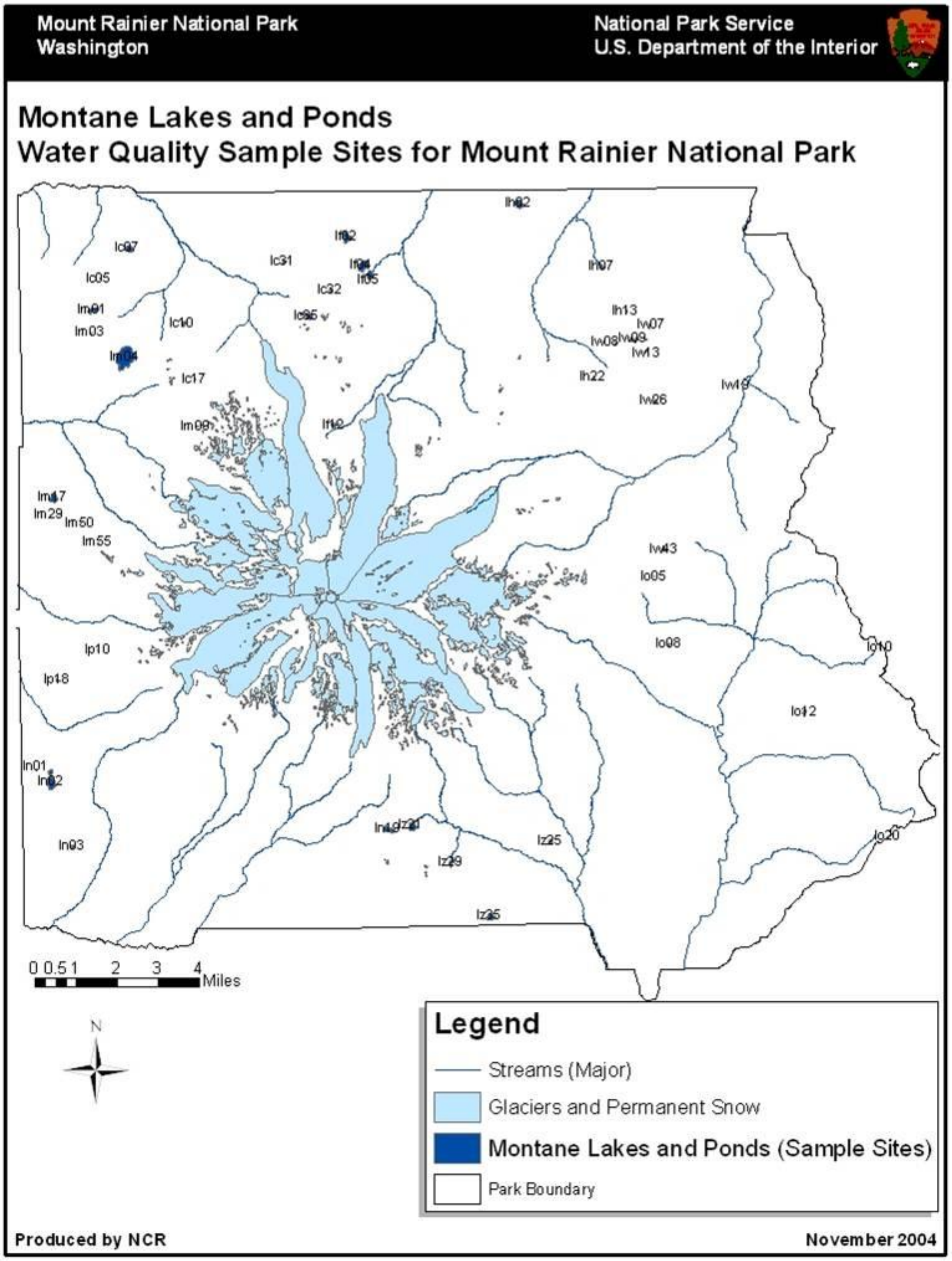
Lakes and Ponds
Freshwater lakes and ponds in the NCCN have been divided into three categories: montane, small park, and large lowland lakes. Montane lakes and ponds occur only in MORA, NOCA and OLYM. Small park freshwater lakes and ponds include Lake Pondilla in EBLA as well as palustrine wetlands in EBLA, SAJH and LEWI. Monitoring SOPs for the small park lakes will follow those described for Montane Lakes and Ponds.

Montane and Small Park Lakes and Ponds: Naturally occurring montane lakes and ponds up to 75 ha in surface area will be monitored in MORA (48), NOCA (64) (See Table 4.2.1.). OLYM has chosen to monitor only five lakes and ponds due to other park vital sign priorities. If additional funding and resources become available, additional sites at OLYM will be added. Monitoring will be conducted by park staffs (funded in part through Water Quality and Vital Signs), for MORA, NOCA, and OLYM. At least one lake or pond will be selected for monitoring for the required WRD core parameters in each of the small parks. Monitoring in EBLA, LEWI and SAJH will be conducted cooperatively by park staff with assistance from staff at MORA and NOCA. The Montane Lakes and Ponds protocols have been in development for several years, most of the SOPs have been peer reviewed and (December 2004) submitted to the I&M program for review (http://www1.nature.nps.gov/im/units/nccn/reports)

Location of montane lake and pond monitoring sites is presented in Table 4.3.1 and Fig. 4.3.1 and 4.3.2 for MORA and NOCA. All lakes and ponds included in the sample population for EBLA, SAJH and LEWI are presented in Figs. 4.3.3 through 4.3.6.

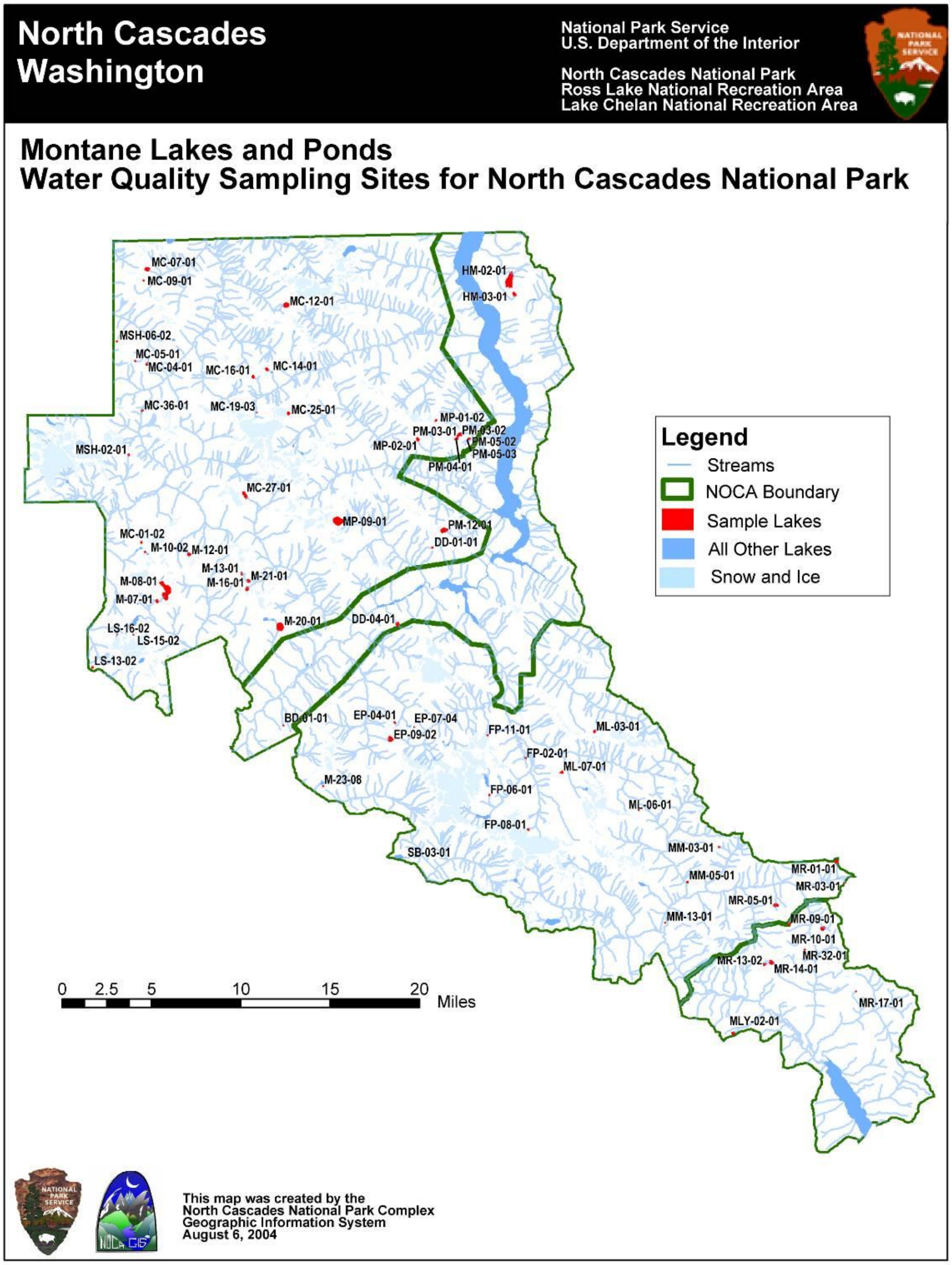
Appendix 4.3. Detailed Maps and Descriptions of the Monitoring Sites Chosen for NCCN Aquatic Monitoring Program (continued).

Figure 4.3.1. Mount Rainier National Park Montane Lakes and Ponds Sample Sites.



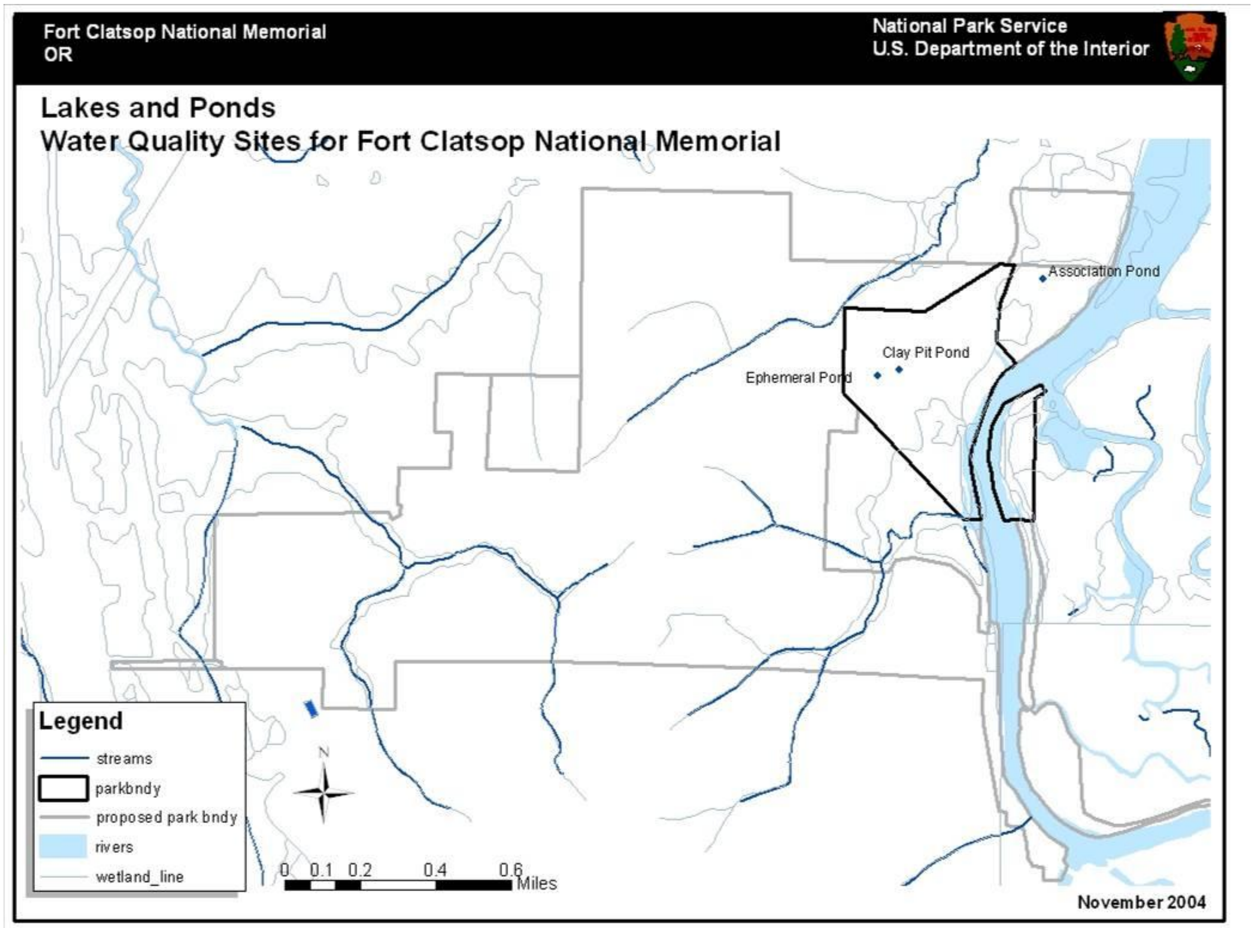
Appendix 4.3. Detailed Maps and Descriptions of the Monitoring Sites Chosen for NCCN Aquatic Monitoring Program (continued).

Figure 4.3.2. North Cascades National Park Montane Lakes and Ponds Sample Sites.



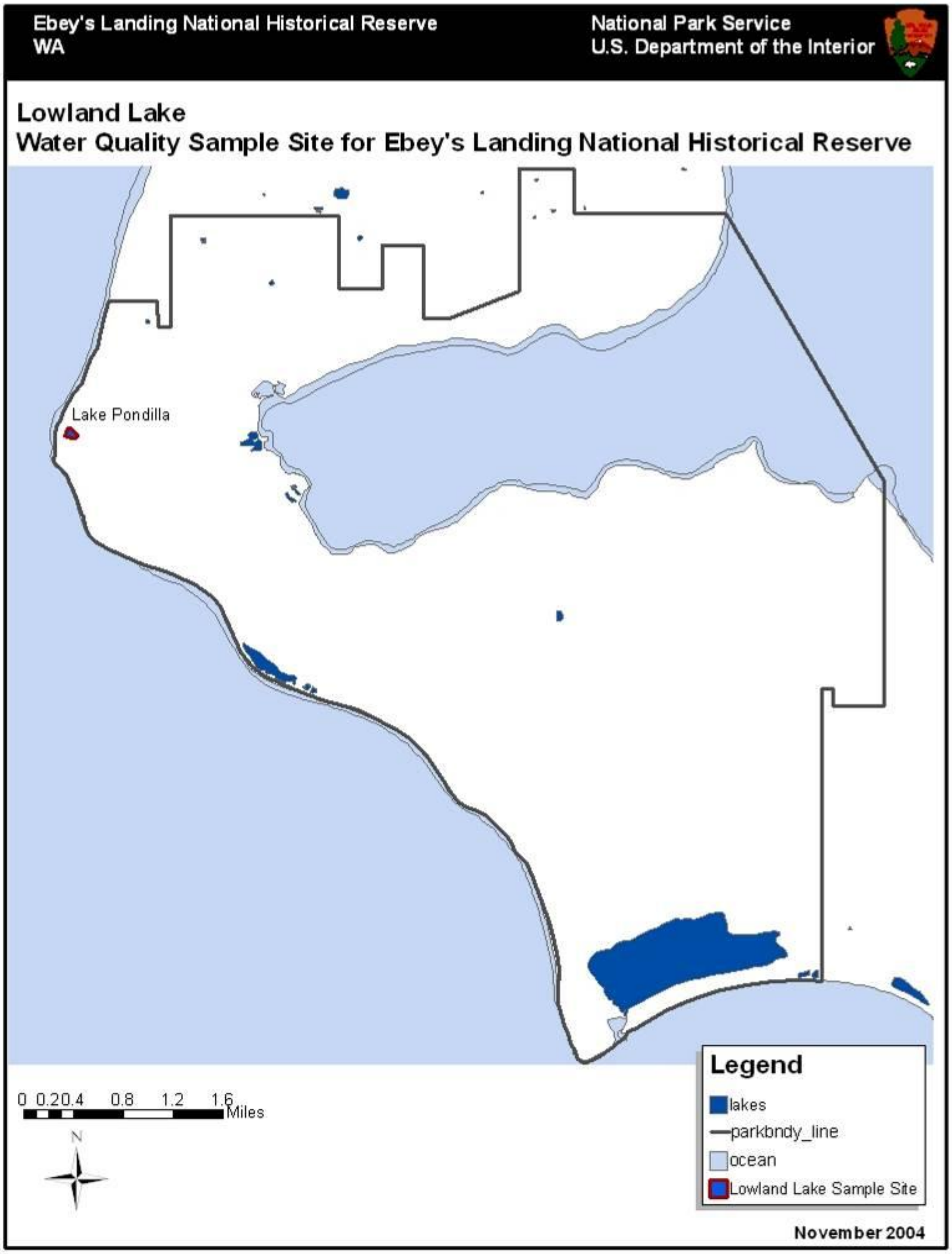
Appendix 4.3. Detailed Maps and Descriptions of the Monitoring Sites Chosen for NCCN Aquatic Monitoring Program (continued).

Figure 4.3.3. Lewis and Clark Ponds Sample Population.



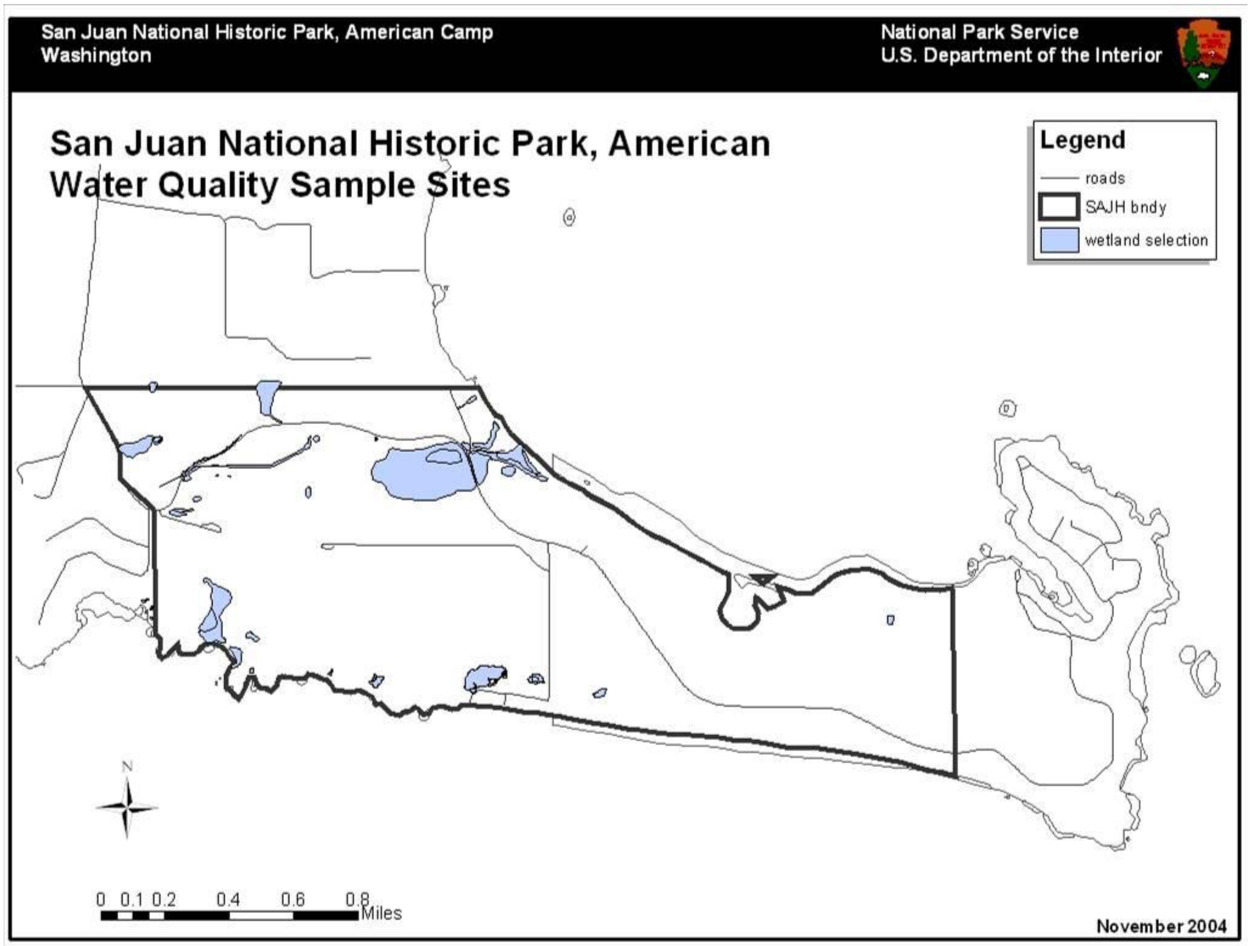
Appendix 4.3. Detailed Maps and Descriptions of the Monitoring Sites Chosen for NCCN Aquatic Monitoring Program (continued).

Figure 4.3.4. Ebey's Landing, Lake Pondilla.



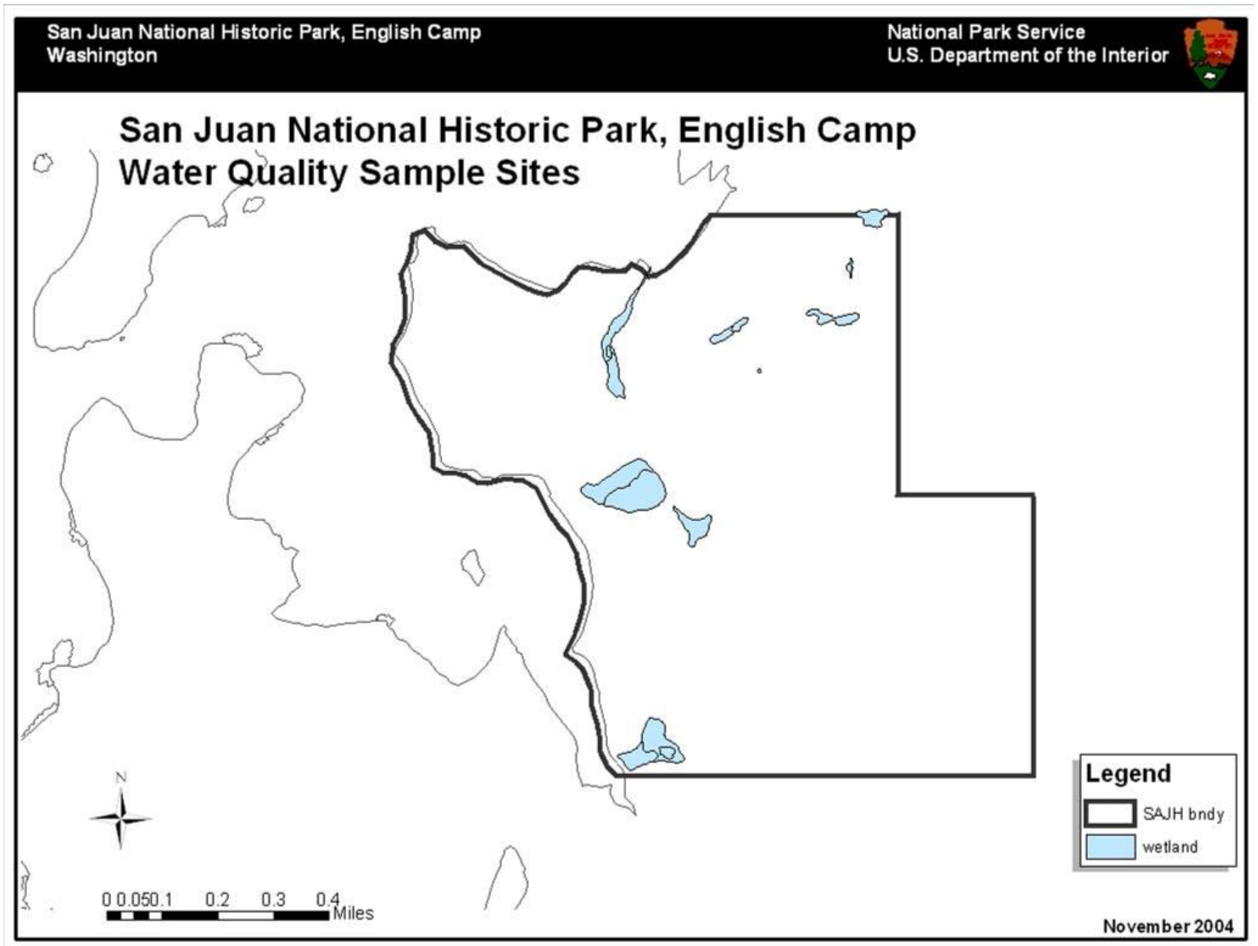
Appendix 4.3. Detailed Maps and Descriptions of the Monitoring Sites Chosen for NCCN Aquatic Monitoring Program (continued).

Figure 4.3.5. San Juan Island NHP, American Camp Ponds Sample Population.



Appendix 4.3. Detailed Maps and Descriptions of the Monitoring Sites Chosen for NCCN Aquatic Monitoring Program (continued).

Figure 4.3.6. San Juan Island NHP, English Camp Ponds Sample Population.



Appendix 4.3. Detailed Maps and Descriptions of the Monitoring Sites Chosen for NCCN Aquatic Monitoring Program (continued).

Table 4.3.1. Montane and Small Park Lakes and Ponds.

Mount Rainier National Park Montane Lakes and Pond Sites				
STRATA 1 (<0.2 ha)				
NAME	**WATERSHED**	**GISCODE**	**ELEV_M**	**Sample type**
UNNAMED LAKE	CARBON	lc05	1338.561	5 yr rot-1 visit
UNNAMED LAKE	PUYALLUP	lp23	1462.041	5 yr rot-1 visit
UNNAMED LAKE	MOWICH	lm29	1499.962	5 yr rot-1 visit
UNNAMED LAKE	MOWICH	lm50	1539.280	5 yr rot-1 visit
UNNAMED LAKE	OHANAPECOSH	lo05	1581.348	5 yr rot-1 visit
UNNAMED LAKE	CARBON	lc17	1623.676	5 yr rot-1 visit
UNNAMED LAKE	PUYALLUP	lp10	1672.081	5 yr rot-1 visit
UNNAMED LAKE	MOWICH	lm55	1747.077	5 yr rot-1 visit
UNNAMED LAKE	WHITE RIVER	lw07	1803.083	Annual-1 visit
UNNAMED LAKE	MOWICH	lm09	1864.428	5 yr rot-1 visit
UNNAMED LAKE	HUCKLEBERRY	lh13	1988.400	5 yr rot-1 visit
STRATA 2 (0.2 TO <0.8 ha)				
UNNAMED LAKE	WHITE RIVER	lw19	984.077	5 yr rot-1 visit
UNNAMED LAKE	MOWICH	lm03	1307.086	5 yr rot-1 visit
THREE LAKES	OHANAPECOSH	lo20	1426.446	5 yr rot-1 visit
UNNAMED LAKE	NISQUALLY	ln01	1478.218	5 yr rot-1 visit
UNNAMED LAKE	OHANAPECOSH	lo08	1505.322	Annual-1 visit
UNNAMED LAKE	WHITE RIVER	lw42	1582.066	5 yr rot-1 visit
UNNAMED LAKE	OHANAPECOSH	lo10	1635.482	5 yr rot-1 visit
UNNAMED LAKE	WHITE RIVER	lw13	1673.257	5 yr rot-1 visit
UNNAMED LAKE	WHITE RIVER	lw11	1729.876	5 yr rot-1 visit
UNNAMED LAKE	HUCKLEBERRY	lh22	1805.543	5 yr rot-1 visit
UNNAMED LAKE	HUCKLEBERRY	lw08	1950.695	5 yr rot-1 visit
STRATA 3 (0.8 TO <4.0 ha)				
MARSH LAKES	COWLITZ	lz25	1203.00	5 yr rot-1 visit
UNNAMED LAKE	PUYALLUP	lp18	1378.41	5 yr rot-1 visit
LAKE ALLEN	NISQUALLY	ln03	1397.00	5 yr rot-1 visit
SHRINER LAKE	OHANAPECOSH	lo12	1490.21	5 yr rot-1 visit
CHENUIS LAKES	CARBON	lc31	1515.59	Annual-1 visit
OWYHIGH LAKE	WHITE RIVER	lw43	1580.00	5 yr rot-1 visit
UNNAMED LAKE	CARBON	lc10	1605.06	5 yr rot-1 visit
UNNAMED LAKE	HUCKLEBERRY	lh07	1675.23	5 yr rot-1 visit
MYSTIC LAKE	WEST FORK	lf12	1740.54	5 yr rot-1 visit
UNNAMED LAKE	CARBON	lc32	1751.31	5 yr rot-1 visit
HIDDEN LAKE	WHITE RIVER	lw09	1806.48	5 yr rot-1 visit

Appendix 4.3. Detailed Maps and Descriptions of the Monitoring Sites Chosen for NCCN Aquatic Monitoring Program (continued).

Table 4.3.1. Montane and Small Park Lakes and Ponds (continued).

Mount Rainier National Park Montane Lakes and Pond Sites **NAME**	**WATERSHED**	**GISCODE**	**ELEV_M**	**Sample type**
STRATA 4 (4.0 ha +)				
LAKE GEORGE	NISQUALLY	ln02	1308.00	5 yr rot-1 visit
LAKE ETHEL	WEST FORK	lf04	1326.00	Annual-1 visit
LAKE JAMES	WEST FORK	lf05	1349.00	5 yr rot-1 visit
BLUE LAKE	COWLITZ	lz35	1352.00	5 yr rot-1 visit
GOLDEN LAKES	MOWICH	lm17	1372.06	5 yr rot-1 visit
OLIVER LAKE	WEST FORK	lf02	1392.00	5 yr rot-1 visit
LOUISE LAKE	COWLITZ	lz21	1401.00	5 yr rot-1 visit
LAKE ELEANOR	HUCKLEBERRY	lh02	1519.00	5 yr rot-1 visit
EUNICE LAKE	MOWICH	lm01	1634.69	5 yr rot-1 visit
CRESCENT LAKE	CARBON	lc35	1696.67	5 yr rot-1 visit
STRATA 5 (PROBABILITY = 1.0 SAMPLE)				
SUNRISE LAKE	WHITE RIVER	lw26	1750.37	Annual-2visit
SNOW LAKE	COWLITZ	lz29	1426.00	Annual-2visit
GREEN LAKE	CARBON	lc07	973.65	Annual-2visit
REFLECTION LAKES	NISQUALLY	ln19	1479.00	Annual-2visit
MOWICH LAKE	MOWICH	lm04	1501.89	Annual-2visit
North Cascades National Park Montane Lakes and Ponds Sites				
STRATA 1 (<0.2 ha)				
Lake Name	**Watershed Name**	**NOCA Lake Code**	**Elevation (m)**	**Sample Type**
UNNAMED	BRIDGE CREEK	MM-13-01	777	5 yr rot-1 visit
UNNAMED	SKAGIT	BD-01-01	1274	5 yr rot-1 visit
SKYMO POND EAST	SKYMO CREEK	PM-05-03	1387	5 yr rot-1 visit
UNNAMED	LITTLE BEAVER CREEK	MC-19-03	1445	5 yr rot-1 visit
UNNAMED	IRENE CREEK	M-23-08	1512	5 yr rot-1 visit
UNNAMED	BACON CREEK	LS-15-02	1539	5 yr rot-1 visit
UNNAMED	LITTLE CHILLIWACK	MC-09-01	1554	5 yr rot-1 visit
UNNAMED	NOISY CREEK	LS-13-02	1572	5 yr rot-1 visit
UNNAMED	NOISY CREEK	LS-16-02	1631	5 yr rot-1 visit
SKYMO POND EAST	SKYMO CREEK	PM-03-02	1658	5 yr rot-1 visit
UNNAMED POND	NEWHALEM CREEK	EP-07-04	1704	5 yr rot-1 visit
BLUM LAKE TARN	BLUM CREEK	M-10-02	1725	5 yr rot-1 visit

Appendix 4.3. Detailed Maps and Descriptions of the Monitoring Sites Chosen for NCCN Aquatic Monitoring Program (continued).

Table 4.3.1. Montane and Small Park Lakes and Ponds (continued).

Lake Name	**Watershed Name**	**NOCA Lake Code**	**Elevation (m)**	**Sample Type**
North Cascades National Park Montane Lakes and Ponds Sites				
STRATA 1 (<0.2 ha)				
HIDDEN LAKE POND	NORTH FORK CASCADE	SB-03-01	1745	Annual-1 visit
UNNAMED	MCALLISTER CREEK	FP-11-01	1829	5 yr rot-1 visit
TWISP PASS POND SOUTH	MCALESTER CREEK	MR-03-01	1871	5 yr rot-1 visit
UNNAMED	RAINBOW CREEK	MR-32-01	2070	5 yr rot-1 visit
STRATA 2 (0.2 TO <0.8 ha)				
THUNDER CREEK SWAMP	MIDDLE THUNDER	FP-02-01	616	5 yr rot-1 visit
UNNAMED	NORTH FORK BRIDGE	MM-05-01	899	Annual-1 visit
PHANTOM PASS LAKE	CRYSTAL CREEK	MSH-02-01	1250	5 yr rot-1 visit
SKYMO POND EAST	SKYMO CREEK	PM-05-02	1387	5 yr rot-1 visit
JEANITA LAKE	STETATTLE CREEK	DD-01-01	1495	5 yr rot-1 visit
UNNAMED	SILESIA CREEK	MSH-06-02	1554	5 yr rot-1 visit
EGG LAKE	SILESIA CREEK	MC-04-01	1579	5 yr rot-1 visit
UNNAMED	NEWHALEM CREEK	EP-04-01	1623	5 yr rot-1 visit
UNNAMED	UPPER SILESIA CREEK	MC-05-01	1664	5 yr rot-1 visit
KLAWATTI POT #2	WEST FORK THUNDER	FP-06-01	1689	5 yr rot-1 visit
BLUM LAKE #2 SMALL TARN	BLUM CREEK	MC-01-02	1713	5 yr rot-1 visit
UNNAMED	LOWER FISHER CREEK	ML-07-01	1765	5 yr rot-1 visit
UNNAMED LAKE SOUTH	NO NAME CREEK	MP-01-02	1836	5 yr rot-1 visit
LAST CHANCE LAKE	UPPER BRIDGE CREEK	MM-03-01	1896	5 yr rot-1 visit
UNNAMED	GRIZZLY CREEK	ML-06-01	1957	5 yr rot-1 visit
OPEN WATER	BOULDER CREEK	MR-17-01	2063	5 yr rot-1 visit
STRATA 3 (0.8 TO <4.0 ha)				
CHILLIWACK PASS LAKE	PASS CREEK	MC-36-01	1121	5 yr rot-1 visit
DOUG'S TARN	TERROR CREEK	M-21-01	1204	5 yr rot-1 visit
BERDEEN LAKE LOWER	WEST FORK BACON	M-07-01	1359	5 yr rot-1 visit

Appendix 4.3. Detailed Maps and Descriptions of the Monitoring Sites Chosen for NCCN Aquatic Monitoring Program (continued).

Table 4.3.1. Montane and Small Park Lakes and Ponds (continued).

North Cascades National Park Montane Lakes and Ponds Sites Lake Name	Watershed Name	NOCA Lake Code	Elevation (m)	Sample Type
STRATA 3 (0.8 TO <4.0 ha)				
MT TRIUMPH LAKE	TERROR CREEK	M-16-01	1461	5 yr rot-1 visit
LONESOME LAKE	BALD EAGLE CREEK	M-12-01	1487	5 yr rot-1 visit
SKAGIT QUEEN #1 LAKE	SKAGIT QUEEN	FP-08-01	1523	5 yr rot-1 visit
DESPAIR LAKE UPPER	TERROR CREEK	M-13-01	1554	5 yr rot-1 visit
SKYMO LAKE UPPER	SKYMO CREEK	PM-04-01	1611	Annual-1 visit
BATTALION LAKE	STEHEKIN RIVER	MLY-02-01	1628	5 yr rot-1 visit
FIRN LAKE	39-MILE CREEK	MP-02-01	1668	5 yr rot-1 visit
EAST LAKE UPPER	LITTLE BEAVER	MC-14-01	1705	5 yr rot-1 visit
MIDDLE LAKE UPPER	LITTLE BEAVER	MC-16-01	1737	5 yr rot-1 visit
RAINBOW LAKE UPPER SOUTH	RAINBOW CREEK	MR-13-02	1788	5 yr rot-1 visit
UNNAMED	MCALESTER CREEK	MR-09-01	1812	5 yr rot-1 visit
TORMENT LAKE	UPPER PANTHER	ML-03-01	1969	5 yr rot-1 visit
WILEY LAKE	LUNA CREEK	MC-25-01	2042	5 yr rot-1 visit
STRATA 4 (4.0 ha +)				
HOZOMEEN LAKE	HOZOMEEN CREEK	HM-02-01	860	5 yr rot-1 visit
RIDLEY LAKE	HOZOMEEN CREEK	HM-03-01	957	5 yr rot-1 visit
BOUCK LAKE	GORGE CREEK	DD-04-01	1173	5 yr rot-1 visit
AZURE LAKE	AZURE LAKE	MP-09-01	1236	5 yr rot-1 visit
THORNTON LAKE LOWER	THORTON CREEK	M-20-01	1367	Annual-1 visit
SOURDOUGH LAKE	PIERCE CREEK	PM-12-01	1409	5 yr rot-1 visit
WILD LAKE	CRESCENT CREEK	MC-27-01	1487	5 yr rot-1 visit
BERDEEN LAKE	WEST FORK BACON	M-08-01	1524	5 yr rot-1 visit
KWAHNESUM LAKE	LITTLE CHILLIWACK	MC-07-01	1555	5 yr rot-1 visit
STOUT LAKE (MYSTERY)	NEWHALEM CREEK	EP-09-02	1590	5 yr rot-1 visit
SKYMO LAKE	SKYMO CREEK	PM-03-01	1608	5 yr rot-1 visit

Appendix 4.3. Detailed Maps and Descriptions of the Monitoring Sites Chosen for NCCN Aquatic Monitoring Program (continued).

Table 4.3.1. Montane and Small Park Lakes and Ponds (continued).

North Cascades National Park Montane Lakes and Ponds Sites **Lake Name**	**Watershed Name**	**NOCA Lake Code**	**Elevation (m)**	**Sample Type**
STRATA 4 (4.0 ha +)				
KETTLING LAKE	BRIDGE CREEK	MR-05-01	1638	5 yr rot-1 visit
MCALESTER LAKE	MCALESTER CREEK	MR-10-01	1679	5 yr rot-1 visit
RAINBOW LAKE LOWER	RAINBOW CREEK	MR-14-01	1716	5 yr rot-1 visit
BEAR LAKE	BEAR CREEK	MC-12-01	1766	5 yr rot-1 visit
STILETTO LAKE	MCALESTER CREEK	MR-01-01	2071	5 yr rot-1 visit
Non-montane lakes (<75 ha)	**Lake/Pond Type**	**Sample Site**		
Lewis and Clark National Memorial	Freshwater ephemeral ponds; CLAY PIT POND	specific sites not yet selected but will include sites currently being monitored by the park staff		
Ebeys Landing National Historical Reserve	Freshwater lake	Lake Pondilla		
San Juan National Historical Park	Palustrine wetland	specific sites not yet selected		

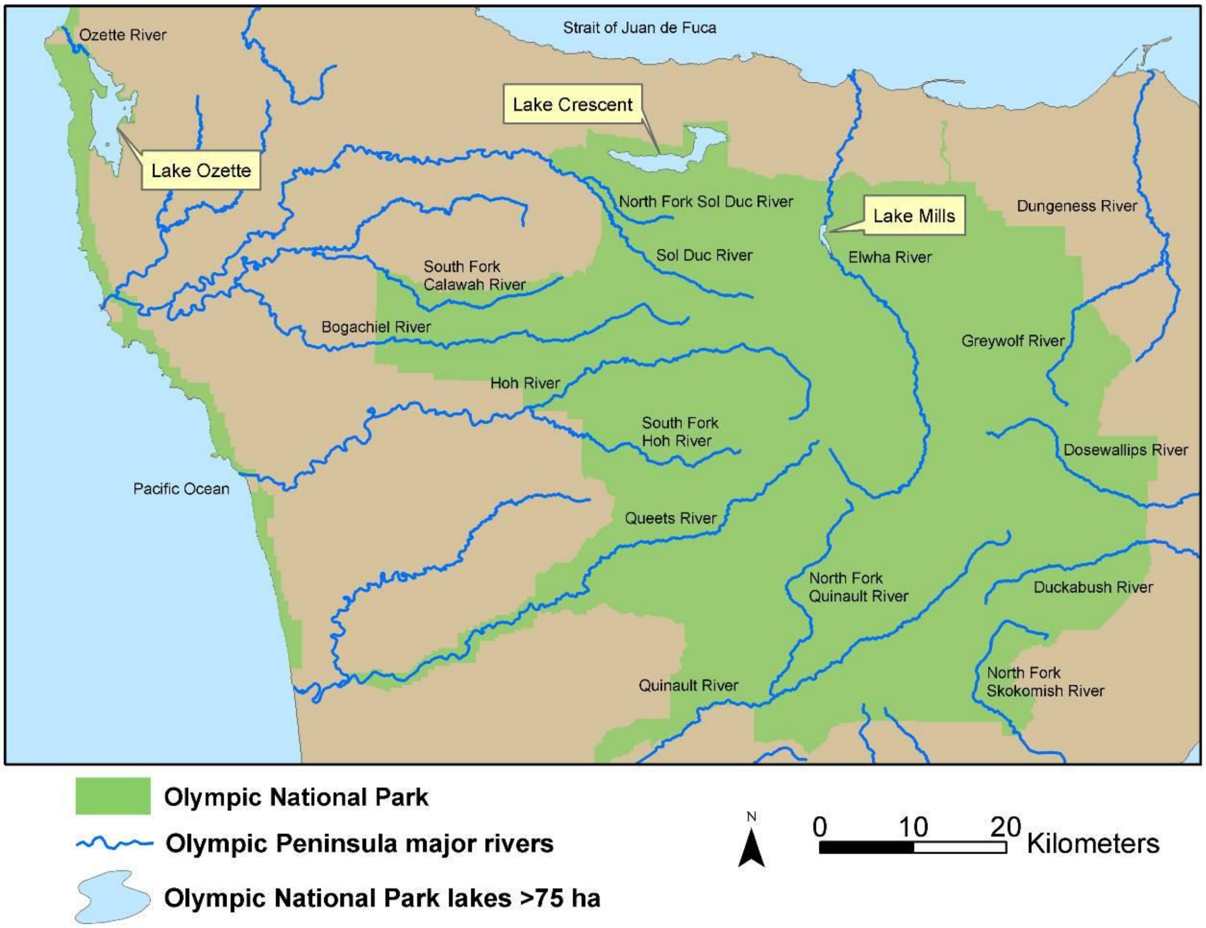
Large lowland lakes: Sufficient funding is not available to monitor all large lowland lakes presented in Table 4.3.2. However, Lake Crescent will be included in the NCCN water quality monitoring program. The core water quality parameters will be measured by OLYM staff for Lake Crescent , however sufficient funding to fully address monitoring needs for Lake Crescent are not available from the NCCN. As such, the shortfall will be made up for by using OLYM base funds. With additional funding, we propose to expand the monitoring in OLYM to include Lake Ozette and also expand to include NOCA lakes. Large Lake monitoring will be conducted by OLYM staff and cooperators. Locations of large lowland lakes are presented in Fig. 4.3.8, 4.3.9, and 4.3.8 for OLYM and NOCA, respectively.

Table 4.3.2. Potential NCCN Large Lowland Lake Population.

NOCA	**Elevation (m)**	**Area (ha)**	**Depth (m)**
Chelan		13,500	433
Ross	487	4,726	155
Diablo	367	368	97
OLYM			
Ozette	9	2075	190
Crescent	177	3151	100

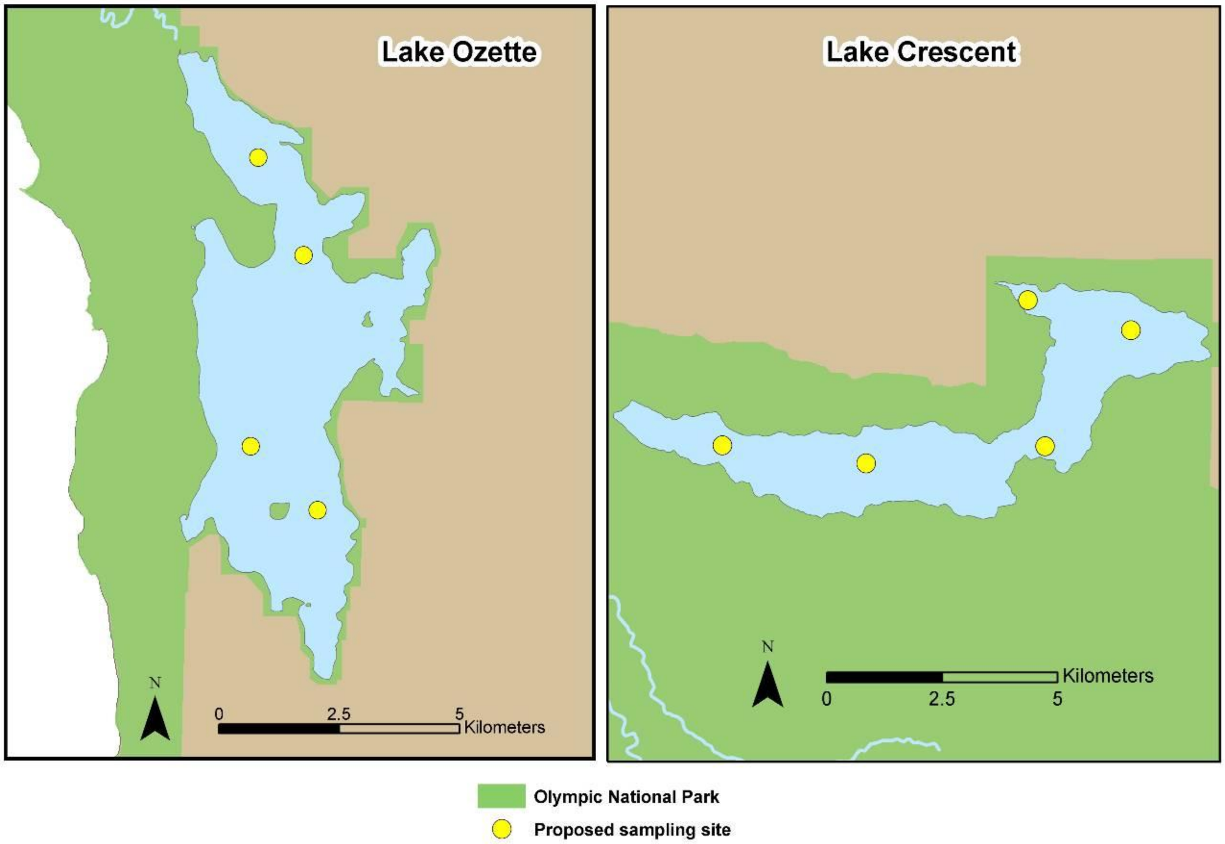
Appendix 4.3. Detailed Maps and Descriptions of the Monitoring Sites Chosen for NCCN Aquatic Monitoring Program (continued).

Fig. 4.3.7. Large Lowland Lakes OLYM.



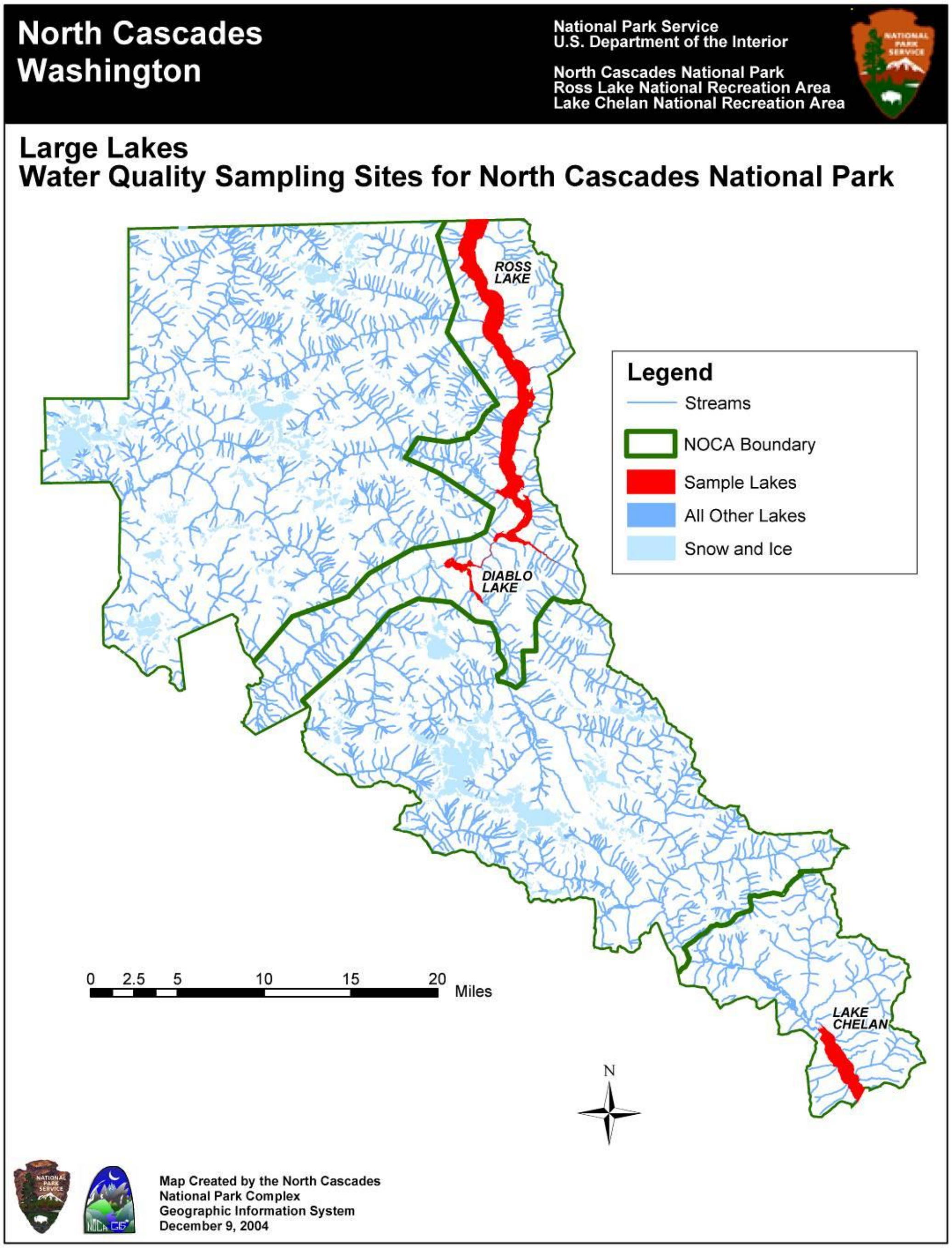
Appendix 4.3. Detailed Maps and Descriptions of the Monitoring Sites Chosen for NCCN Aquatic Monitoring Program (continued).

Fig. 4.3.8. Large Lowland Lakes OLYM (Lake Ozette and Lake Crescent).



Appendix 4.3. Detailed Maps and Descriptions of the Monitoring Sites Chosen for NCCN Aquatic Monitoring Program (continued).

Fig. 4.3.9. Large Lowland Lakes NOCA.



Appendix 4.3. Detailed Maps and Descriptions of the Monitoring Sites Chosen for NCCN Aquatic Monitoring Program (continued).

Streams and Rivers
Streams and rivers have been divided into two separate categories: wadeable, and non-wadeable (rivers).

Wadeable streams: A summary of the wadeable stream monitoring program is presented in Table 4.3.4. Streams from 0-4% gradient will be monitored in all NCCN parks with streams. In addition, stream amphibians will be monitored along with other water quality indicators in MORA wadeable streams from 0-20% gradient. Specific wadeable stream sites have not yet been selected for Network parks. Figs. 4.3.10 through 4.3.14 list the sample population for each park. The NCCN wadeable streams monitoring program is described in detail within each protocol (see Chapter 5). Monitoring will be conducted by park staffs (funded in part by Water Quality and Vital Signs). Wadeable stream monitoring in EBLA, SAJH, and LEWI will be conducted by park staff with assistance from MORA , NOCA and OLYM staff. Physical (temperature, habitat), chemical (nutrients, ions), and biological (benthic macroinvertebrates, fish, and stream amphibians for MORA) indicators are included in the monitoring protocols. Stream amphibians may be monitored in NOCA and OLYM if additional funding and resources become available.

Appendix 4.3. Detailed Maps and Descriptions of the Monitoring Sites Chosen for NCCN Aquatic Monitoring Program (continued).

Table 4.3.4. NCCN Wadeable Streams Monitoring in MORA, NOCA, OLYM:
Sample sites not yet selected but the table below describes the proposed sampling parameters by stream gradient for each park.

NCCN Wadeable Streams

Y - Still in proposal but reduced sample size, generally retains parkwide inference but may be marginal.

N - Dropped from proposal

M - Maybe included but at much reduced level or dropped. Marginal or no inference.

	NOCA	OLYM	MORA	LEWI, SAJH, EBLA
4/12/04 budget (All parks with 20 core - 0-8% gradient sites, and 32 - 8-20% gradient, amphibian sites. Total $204k)	Core Sites = 16/yr Amphibian sites = 0	Core Sites = ?/yr Amphibian sites = 0	Core Sites = ?/yr Amphibian sites = ?	Minimum one site/park
BIOLOGICAL INDICATORS				
Amphibian			Y	
1. Spatial distribution	N	N	Y	
2. Frequency of occurrence	N	N	Y	
3. Relative abundance	N	N	Y	
Fish (native and non-native)				
1. Spatial distribution	Y	M	N	
2. Frequency of occurrence	Y	Y	M	
3. Abundance (pop. est. in pool habitat)	N	N	N	
4. Growth and size composition	M	M	M	
Benthic Macroinvertebrates (BMI)				X
1. Individual community metrics	Y	Y	Y	
2. Specific indicator species	Y	Y	Y	
3. Multimetric Index (IBI- Index of Bio. Integrity)	Y	Y	Y	
4. Predictive Model (O/E- observed/expected taxa)	Y	M	M	
Wildlife use	M	M	M	
Invasive plants	M	M	M	

Appendix 4.3. Detailed Maps and Descriptions of the Monitoring Sites Chosen for NCCN Aquatic Monitoring Program (continued).

Table 4.3.4. NCCN Wadeable Streams Monitoring in MORA, NOCA, OLYM (continued).

NCCN Wadeable Streams

Y - Still in proposal but reduced sample size, generally retains parkwide inference but may be marginal.

N - Dropped from proposal

M - Maybe included but at much reduced level or dropped. Marginal or no inference.

	NOCA	OLYM	MORA	LEWI, SAJH, EBLA
4/12/04 budget (All parks with 20 core - 0-8% gradient sites, and 32 - 8-20% gradient, amphibian sites. Total $204k)	Core Sites = 16/yr Amphibian sites = 0	Core Sites = ?/yr Amphibian sites = 0	Core Sites = ?/yr Amphibian sites = ?	Minimum one site/park
PHYSICAL INDICATORS				
1. Water temperature-continuous	Y	Y	Y	X
2. Stream canopy cover	Y	Y	Y	
3. Streamflow -discharge single site visit	Y	Y	Y	
4. Streamflow- extent of dewatered channels	N	N	Y	
5. Stream size - width and depth (longitudinal and x-section)	N	N	N	
6. Stream size - width and depth (rapid assessment)	Y	Y	Y	
7. Gradient (slope)	Y	Y	Y	
8. Sinuosity (bearing)	N	N	N	
9. Substrate particle size	M	M	M	
10. Fine sediment (<2mm)	M	M	M	
11. Streambed Stability and sediment supply	N	N	N	
12. Channel habitat units	N	N	N	
13. Large Pools - number/area/residual depth	Y	Y	Y	
14. LWD- single pieces, and total including logjams	Y	Y	Y	
15. LWD - log jams	Y	Y	Y	
16. Off-channel habitat	N	N	N	
17. Eroded Bank	Y	Y	Y	
18. Channel constraint	Y	Y	Y	
19. Debris torrent evidence	Y	Y	Y	
20. Human Influence	Y	Y	Y	
21. Riparian Canopy - size, type, % cover	M	M	M	

Appendix 4.3. Detailed Maps and Descriptions of the Monitoring Sites Chosen for NCCN Aquatic Monitoring Program (continued).

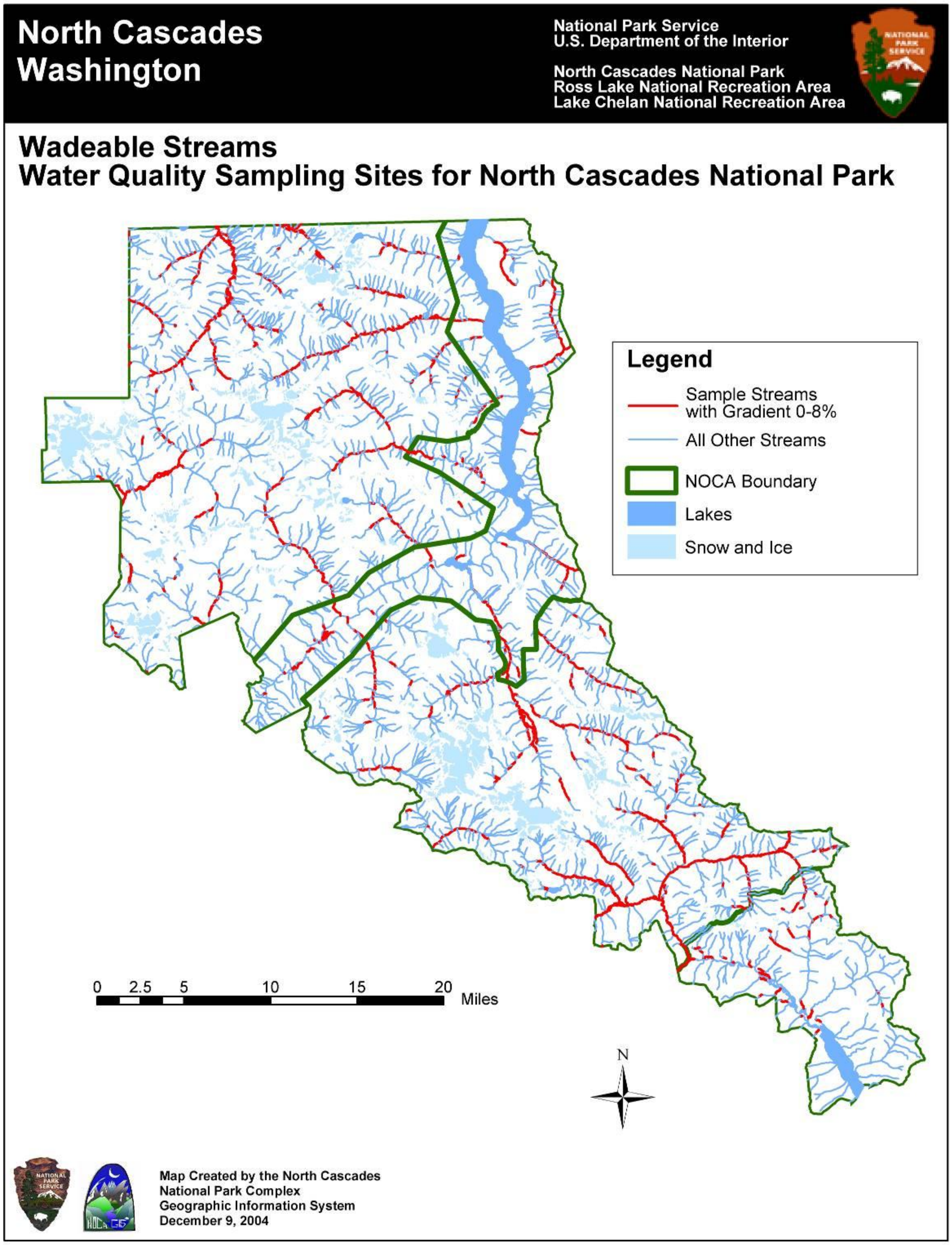
Table 4.3.4. NCCN Wadeable Streams Monitoring in MORA, NOCA, OLYM (continued).

NCCN Wadeable Streams
Y - Still in proposal but reduced sample size, generally retains parkwide inference but may be marginal.
N - Dropped from proposal
M - Maybe included but at much reduced level or dropped. Marginal or no inference.

	NOCA	OLYM	MORA	LEWI, SAJH, EBLA
4/12/04 budget (All parks with 20 core - 0-8% gradient sites, and 32 - 8-20% gradient, amphibian sites. Total $204k)	Core Sites = 16/yr Amphibian sites = 0	Core Sites = ?/yr Amphibian sites = 0	Core Sites = ?/yr Amphibian sites = ?	Minimum one site/park
CHEMICAL INDICATORS				
1. Conductivity	Y	Y	Y	X
2. Alkalinity	Y	Y	Y	
3. Dissolved Oxygen	Y	Y	Y	X
4. pH	Y	Y	Y	X
5. Suspended Sediments	M	M	M	
6. Turbidity	Y	Y	Y	
7. Dissolved Organic Carbon	M	M	M	
8. Nutrients	Y	Y	Y	
9. Anions and Cations	Y	Y	Y	
10. Metals	N	N	N	
11. Organic contaminants/pesticides	N	N	N	

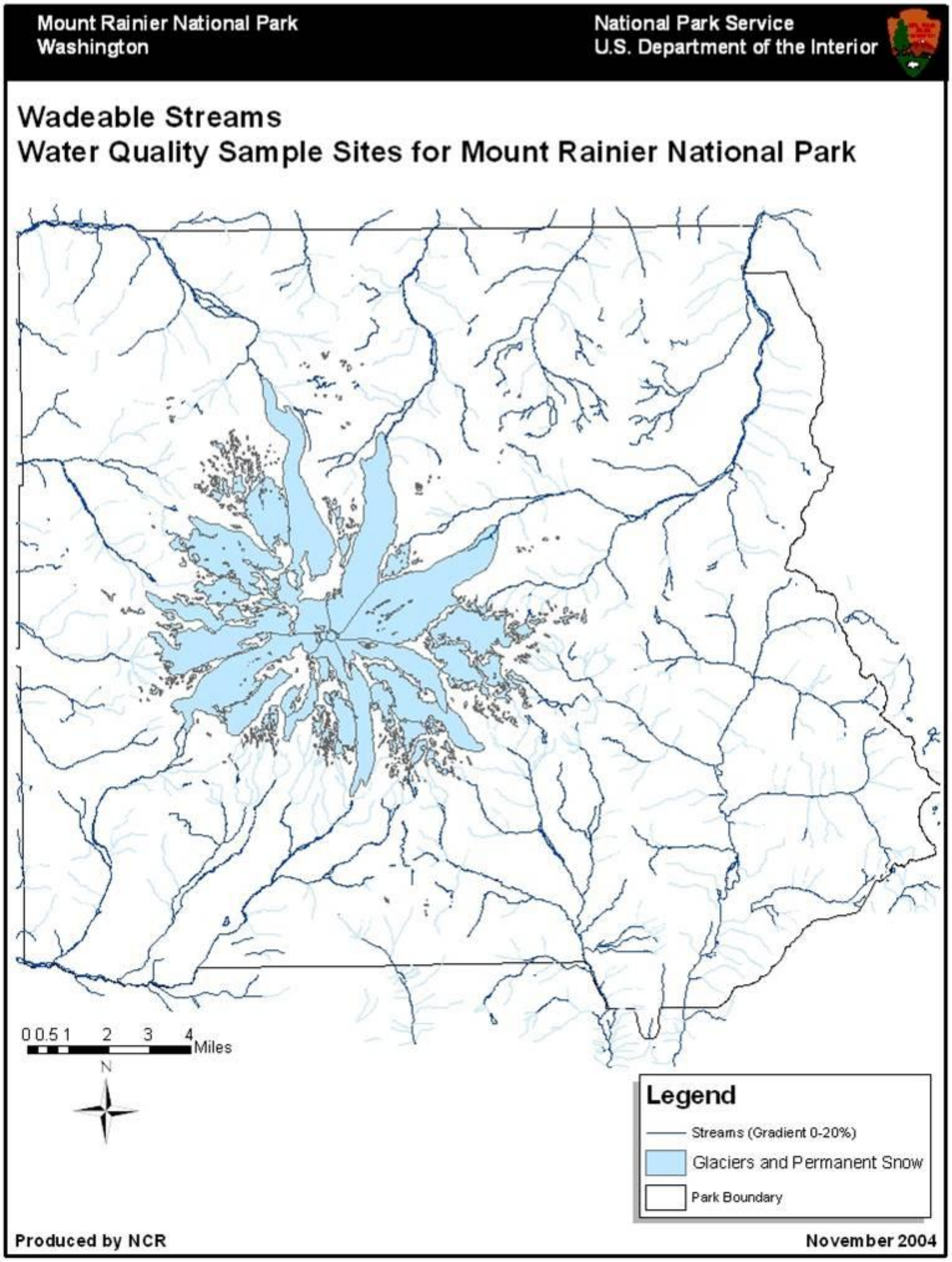
Appendix 4.3. Detailed Maps and Descriptions of the Monitoring Sites Chosen for NCCN Aquatic Monitoring Program (continued).

Figure 4.3.10. Wadeable Stream Sample Population in North Cascades National Park.



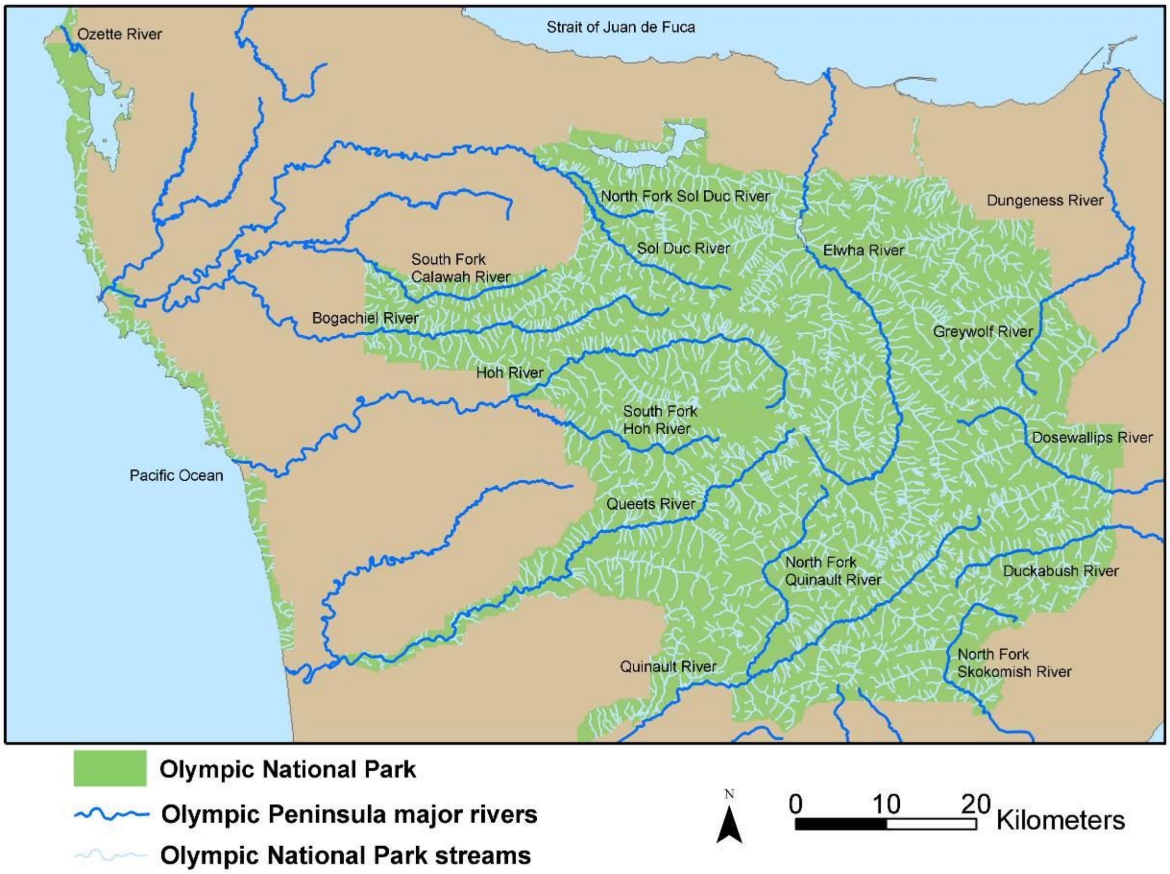
Appendix 4.3. Detailed Maps and Descriptions of the Monitoring Sites Chosen for NCCN Aquatic Monitoring Program (continued).

Figure 4.3.11. Wadeable Stream Sample Population for Mount Rainier National Park.



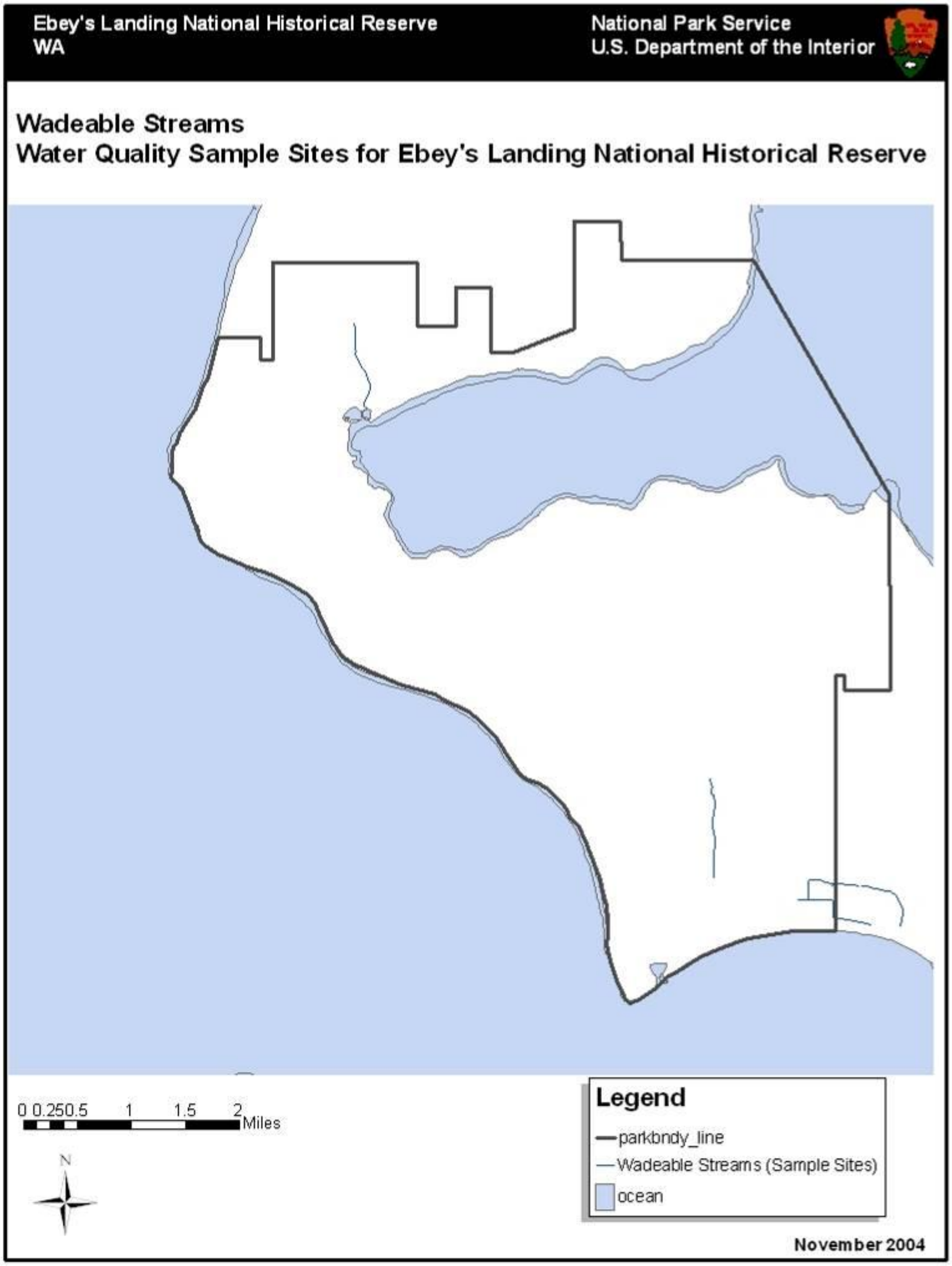
Appendix 4.3. Detailed Maps and Descriptions of the Monitoring Sites Chosen for NCCN Aquatic Monitoring Program (continued).

Figure 4.3.12. Wadeable Stream Sample Population in Olympic National Park.



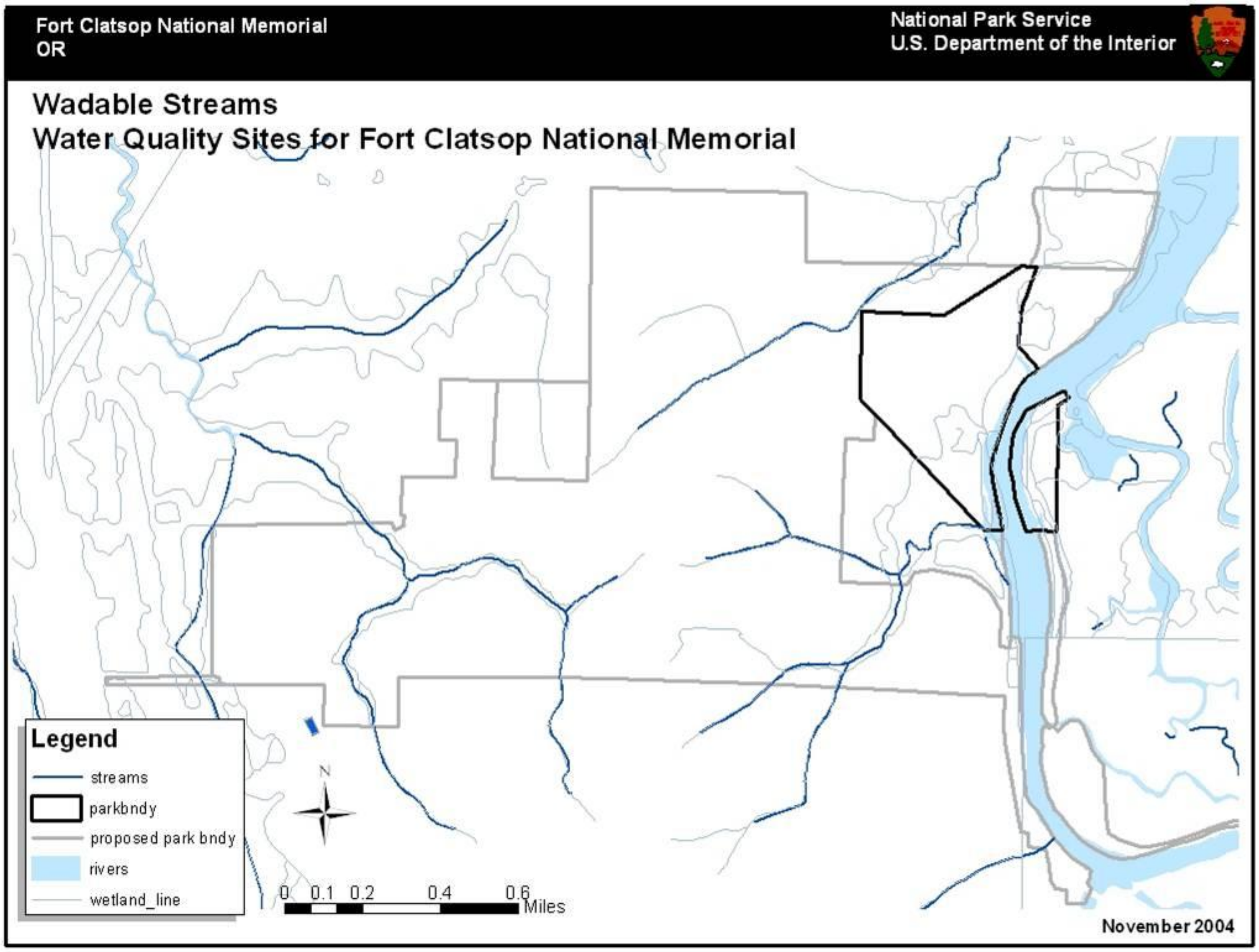
Appendix 4.3. Detailed Maps and Descriptions of the Monitoring Sites Chosen for NCCN Aquatic Monitoring Program (continued).

Figure 4.3.13. Wadeable Streams in EBLA.



Appendix 4.3. Detailed Maps and Descriptions of the Monitoring Sites Chosen for NCCN Aquatic Monitoring Program (continued).

Figure 4.3.14. Wadeable Streams LEWI.



Appendix 4.3. Detailed Maps and Descriptions of the Monitoring Sites Chosen for NCCN Aquatic Monitoring Program (continued).

Non-wadeable streams: Large Rivers or streams too large to be waded, will be monitored in OLYM , MORA, and LEWI. In LEWI, one site, the Lewis and Clark River, will be monitored. Specific non-wadeable stream sites have not yet been selected for OLYM and MORA but the sample populations are presented in Table 4.3.5 and Figs 4.3.15, 4.3.16, and 4.3.17. If additional funding becomes available, two sites in NOCA will be added. Non-wadeable stream monitoring will be conducted by OLYM staff (Brenkman, lead) with assistance from MORA and LEWI staffs.

Table 4.3.5. NCCN Potential Non-wadeable/large river sites. Specific sites not yet selected.

OLYMPIC NATIONAL PARK	**Total Length in Miles In Park**	**Glacial (G) or Non-Glacial (NG)**	**Fish Life History Forms Present**	**Stream Order**	**% of Watershed in Park**	**Water Chemistry**	**Fish**	**Habitat**
Bogachiel	46.5	NG	Anadromous and Potamodromous	NA	NA	X	X	X
Calawah	31.1	NG	Anadromous and Potamodromous	NA	NA	X	X	X
Dosewallips	28.3	G	Potamodromous only	NA	79	X	X	X
Duckabush	24.1	NG	Potamodromy only	NA	67	X	X	X
Greywolf	32	NG/G	Anadromous and Potamodromous	NA	36	X	X	X
Elwha	44.8	G	Not at present	NA	85	X	X	X
Hoh	56.1	G	Anadromous and Potamodromous	NA	65	X	X	X
S. Fk. Hoh	14	NG			NA	X	X	X
N. Fk. Skokomish	41.9	NG	Potamodromy only	NA	28	X	X	X
Ozette River	13.3	NG	Anadromous and Potamodromous	NA	NA	X	X	X
Sol Duc	65.2	NG	Anadromous and Potamodromous	NA	28	X	X	X
Queets	51.4	G	Anadromous and Potamodromous	NA	33	X	X	X
Quinault	68.8	NG?	Anadromous and Potamodromous	NA	64	X	X	X

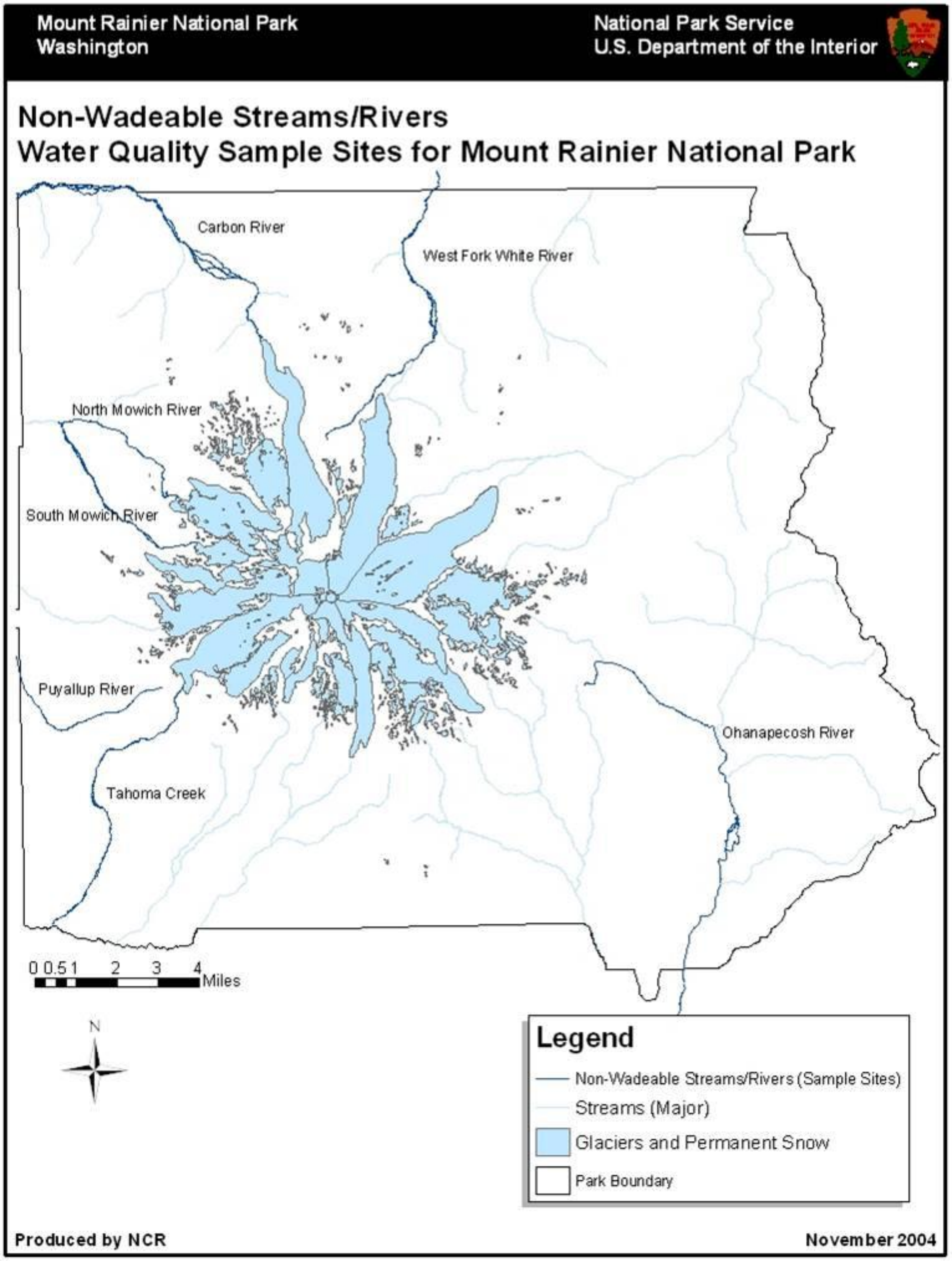
Appendix 4.3. Detailed Maps and Descriptions of the Monitoring Sites Chosen for NCCN Aquatic Monitoring Program (continued).

Table 4.3.5. NCCN Potential Non-wadeable/large river sites. Specific sites not yet selected (continued).

MOUNT RAINIER NATIONAL PARK	**Total Length in Miles In Park**	**Glacial (G) or Non-Glacial (NG)**	**Fish Life History Forms Present**	**Stream Order**	**% of Watershed in Park**	**Water Chemistry**	**Fish**	**Habitat**
Carbon	20.51	G	Anadromous	4	54	X	X	X
North Mowich	4.6	G	Anadromous	4	69	X	X	X
North Puyallup	4.98	G	Anadromous	3	44	X	X	X
Ohanapecosh	13.35	NG	Potamodromous	5	95	X	X	X
South Mowich	8.57	G	Anadromous	2	69	X	X	X
South Puyallup	4.25	G	Anadromous	2	44	X	X	X
Tahoma Cr.	11.02	G	Potamodromous	3	100	X	X	X
West Fork	13.66	G	Anadromous	3	42	X	X	X
White	33.66	G		4	99	X	X	X
NORTH CASCADES NATIONAL PARK	**Total Length in Miles In Park**	**Glacial (G) or Non-Glacial (NG)**	**Fish Life History Forms Present**	**Stream Order**	**% of Watershed in Park**	**Water Chemistry**	**Fish**	**Habitat**
Stehekin	16	G	NA	NA	90 (5TH Order)	X	X	X
Big Beaver Cr.	7	G	NA	NA	100 (5th Order)	X	X	X
LEWIS AND CLARK NATIONAL MEMORIAL	**Total Length in Miles In Park**	**Glacial (G) or Non-Glacial (NG)**	**Fish Life History Forms Present**	**Stream Order**	**% of Watershed in Park**	**Water Chemistry**	**Fish**	**Habitat**
Lewis and Clark River (currently included in the park's water quality monitoring program)	1.3	NG	Anadromous			X	X	X

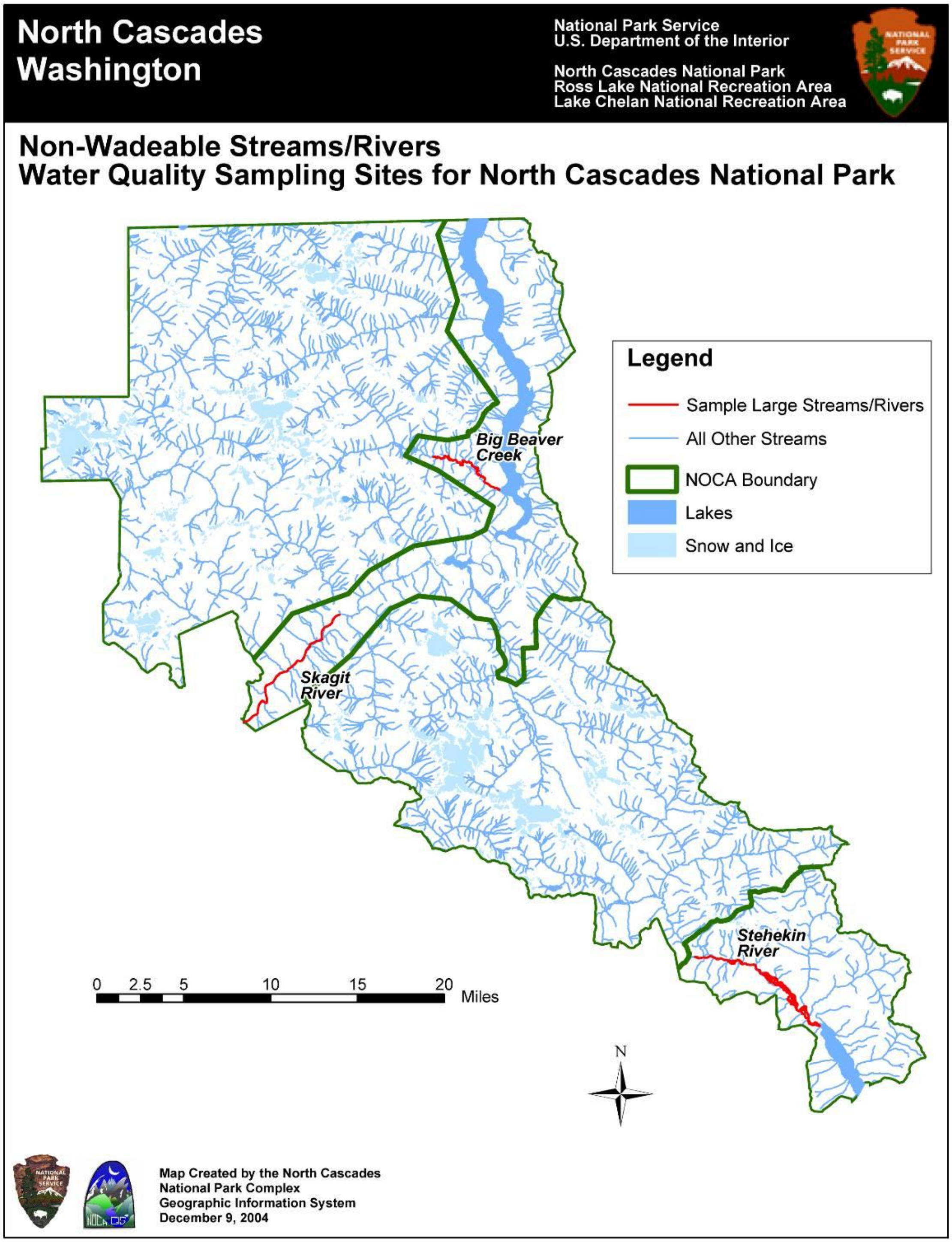
Appendix 4.3. Detailed Maps and Descriptions of the Monitoring Sites Chosen for NCCN Aquatic Monitoring Program (continued).

Figure 4.3.15. Non -Wadeable Stream Sample Population for Mount Rainier National Park.



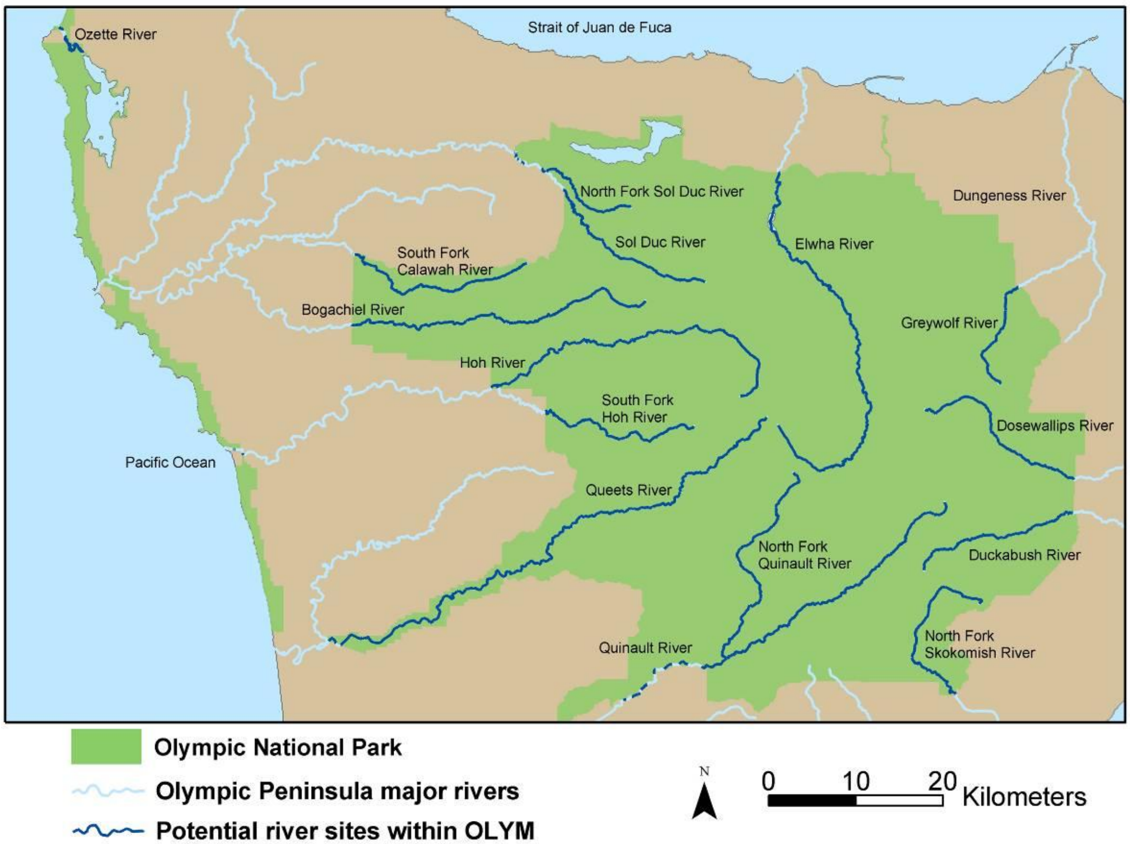
Appendix 4.3. Detailed Maps and Descriptions of the Monitoring Sites Chosen for NCCN Aquatic Monitoring Program (continued).

Figure 4.3.16. Non -Wadeable Stream Sample Population for North Cascades National Park.



Appendix 4.3. Detailed Maps and Descriptions of the Monitoring Sites Chosen for NCCN Aquatic Monitoring Program (continued).

Figure 4.3.17. Non -Wadeable Stream Sample Population for Olympic National Park.



Appendix 4.3. Detailed Maps and Descriptions of the Monitoring Sites Chosen for NCCN Aquatic Monitoring Program (continued).

Long-term Stream Hydrology: Streamflow is a critical abiotic factor for aquatic and terrestrial ecosystems, and has significant impacts to NPS roads, campgrounds and other facilities. In the Pacific Northwest, sensitivity to climate change, frequent, large floods, and pronounced summer drought underscore its importance. Further, variability in terrain and microclimate in the NCCN renders the small number of existing sites inadequate for monitoring streamflow. This protocol includes long-term monitoring at index sites in MORA and NOCA (see Table 4.3.6 and Figs 4.3.18, 4.3.19 and 4.3.20). Numerous stream gages already exist in OLYM to measure streamflow so no additional sites will be included. Streamflow will also be monitored as part of the wadeable stream and non-wadeable stream/large river protocols.

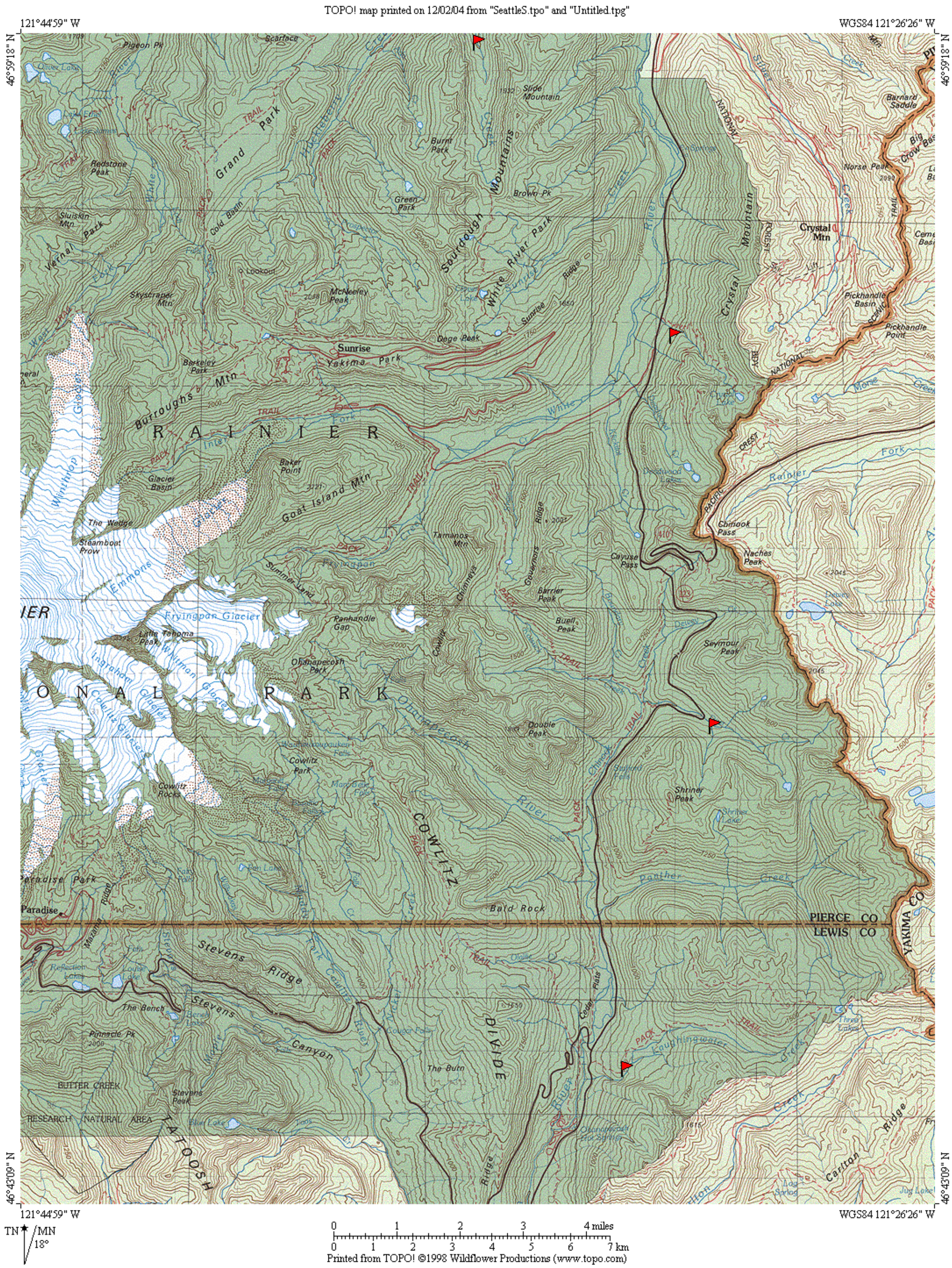
Table 4.3.6. Hydrology Protocol.

Target Sites: MORA, NOCA, OLYM. Sample sites have been selected for MORA and NOCA. .

Park	Site	Method
MORA	Lost Creek adjacent to park	Stream gage
MORA	Crystal Creek	Stream gage
MORA	Laughingwater Creek	Stream gage
MORA	Deer Creek	Stream Gage
NOCA	Neve	Stream Gage
NOCA	Devils Creek	Stream Gage
NOCA	#6	Stream Gage
NOCA	McAllister Creek	Stream Gage
NOCA	Thunder Creek at Triconi	Stream Gage
NOCA	Fisher Creek at Triconi	Stream Gage
NOCA	Fisher Creek at Fisher Camp	Stream Gage
OLYM	Park	Remote sensing (watershed level processes, disturbance, river morphology)
MORA	Park	Remote sensing (watershed level processes, disturbance, river morphology)
NOCA	Park	Remote sensing (watershed level processes, disturbance, river morphology)

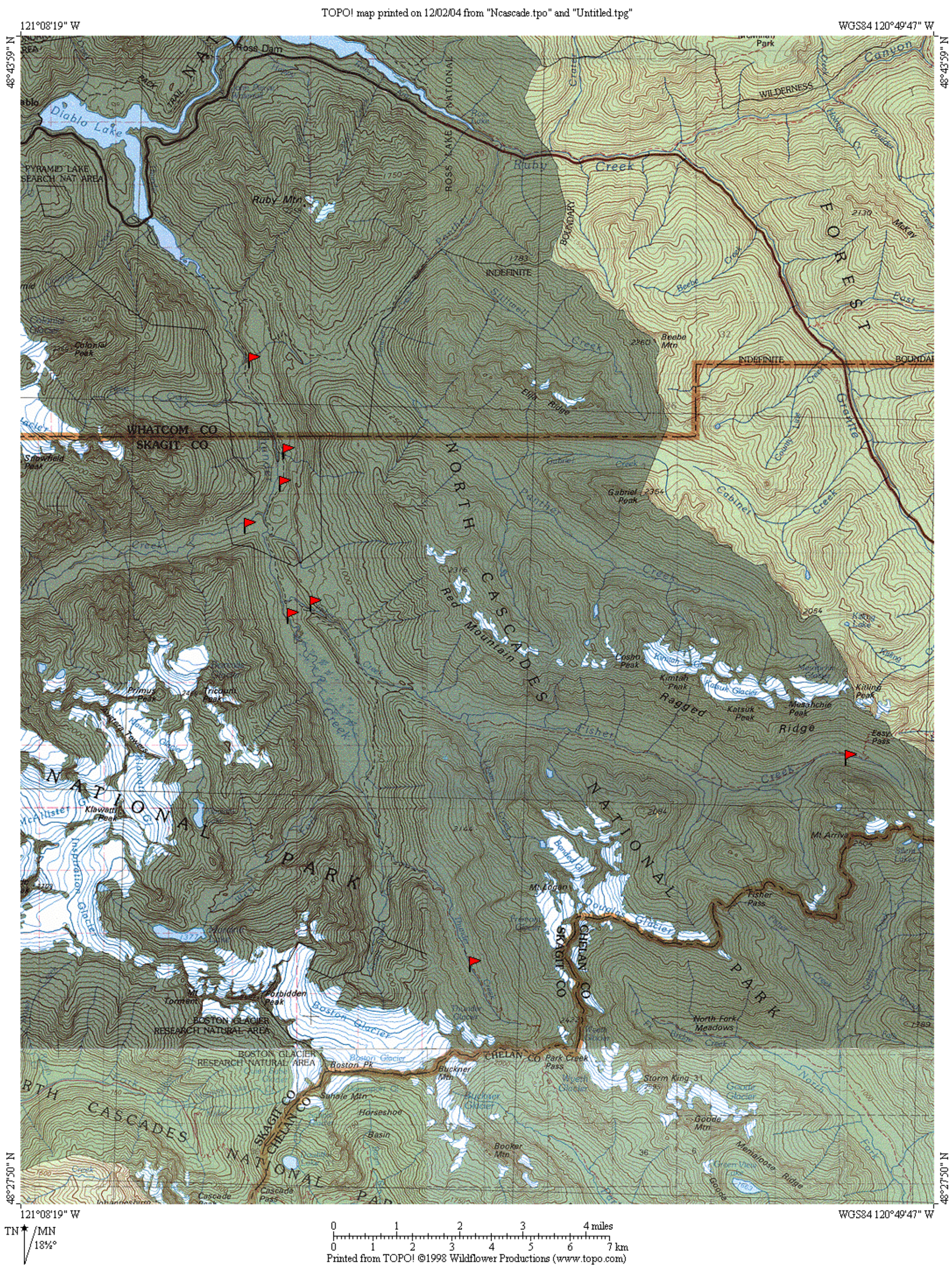
Appendix 4.3. Detailed Maps and Descriptions of the Monitoring Sites Chosen for NCCN Aquatic Monitoring Program (continued).

Figure 4.3.18. Stream Flow Sites in Mount Rainier National Park.



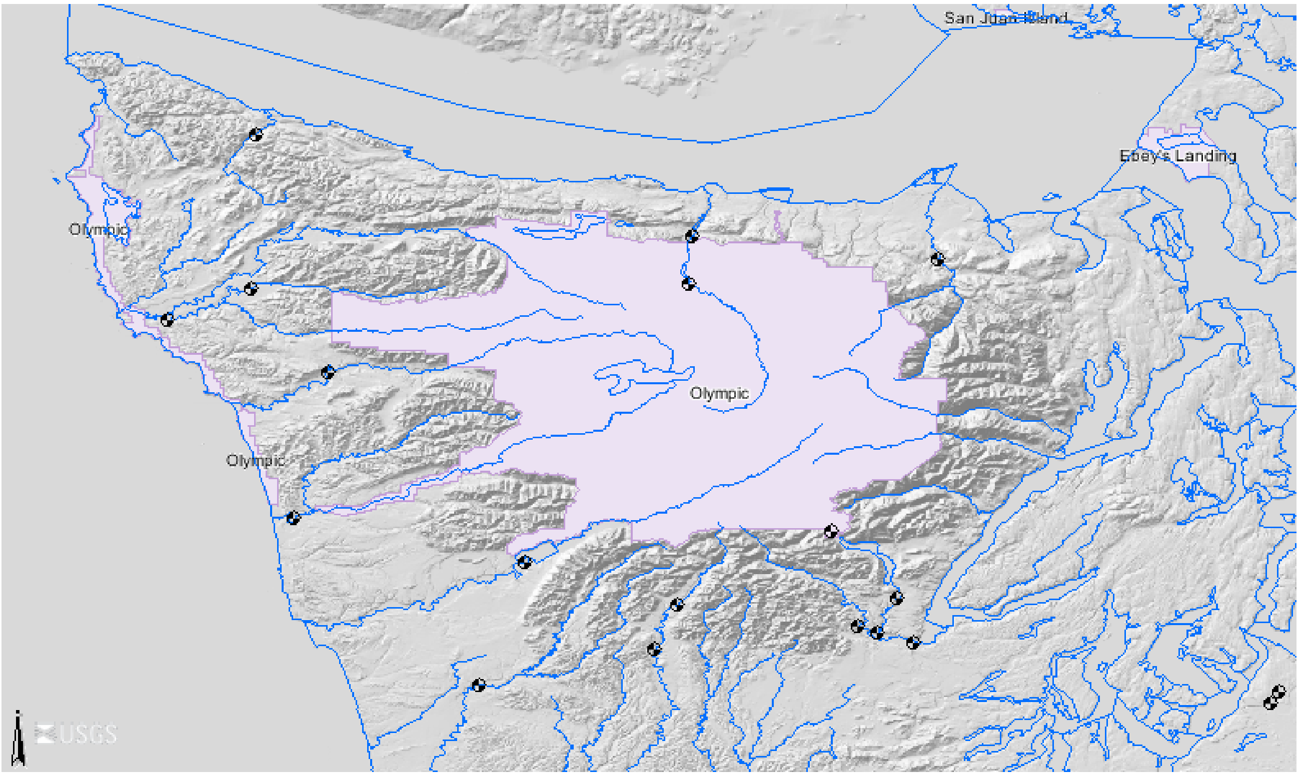
Appendix 4.3. Detailed Maps and Descriptions of the Monitoring Sites Chosen for NCCN Aquatic Monitoring Program (continued).

Figure 4.3.19. Stream flow sites in North Cascades National Park.



Appendix 4.3. Detailed Maps and Descriptions of the Monitoring Sites Chosen for NCCN Aquatic Monitoring Program (continued).

Figure 4.3.20. Stream Flow Sites in Olympic National Park.



Appendix 4.3. Detailed Maps and Descriptions of the Monitoring Sites Chosen for NCCN Aquatic Monitoring Program (continued).

Marine/Intertidal Waters
Marine sites are limited to intertidal areas in OLYM (See Table 4.3.7, Figures 4.3.21 and 4.3.22). Further implementation of a subset of these protocols may proceed at LEWI (sand habitat protocols), EBLA, and SAJH if additional funding and resources become available. It should be noted that marine waters in EBLA and SAJH are not under the jurisdiction of the NPS**.** The patchwork of tideland ownerships at SAJH is complicated and not yet completely resolved, but portions of the nearshore are under the jurisdiction of the NPS. In addition, several other agencies have responsibilities for monitoring marine and intertidal areas within these parks. Any additional monitoring that would be conducted in EBLA and SAJH would complement, rather than duplicate existing monitoring efforts.

Table 4.3.7. Marine Water Quality Sites.

Program	**Site**	**Description**	**Station**
Temperature	OLYM	Water Temp	1
	OLYM		2
	OLYM		3
	OLYM		4
	OLYM		5
	OLYM		6
	OLYM		7
	OLYM		8
	OLYM		9
Community structure	OLYM	Rocky platform	1
	OLYM		2
	OLYM		3
	OLYM		4
	OLYM		5
	OLYM		6
	OLYM		7
	OLYM	Sand beach	1
	OLYM		2
	OLYM		3
	OLYM		4
	OLYM		5
	OLYM		6
	OLYM		7

Appendix 4.3. Detailed Maps and Descriptions of the Monitoring Sites Chosen for NCCN Aquatic Monitoring Program (continued).

Table 4.3.7. Marine Water Quality Sites (continued).

Program	Site	Description	Station
Ebey's Landing National Historical Reserve			
Water Quality	EBLA	Penn Cove	
San Juan National Historical Park			
Intertidal community Structure	SAJH	Rocky platform/ sand beach	This protocol is currently in development and will rely upon collaborators (i.e. University of Washington, Washington Department of Fish and Wildlife, etc.).
Water quality	SAJH	Nearshore marine	This protocol is currently in development and will rely upon collaborators (i.e. Washington Department of Fish and Wildlife, etc.) because marine waters are outside of park boundary.

Figure 4.3.21. Marine/Intertidal Monitoring Sites in OLYM.

Figure 4.3.22. Marine/Intertidal Temperature Monitoring Sites in OLYM.

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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National Park Service
U.S. Department of the Interior

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