



Climate Monitoring Protocol for the North Coast and Cascades Network (Mount Rainier National Park, Olympic National Park, North Cascades National Park, Lewis and Clark National Historical Park, Ebey's Landing National Historical Reserve, San Juan Island National Historical Park, Fort Vancouver National Historic Site)

Volume 1. Narrative and Appendices, Version 5/26/2010

Natural Resource Report NPS/NCCN/NRR—2010/240



ON THE COVER

High Elevation Weather Station, Mount Rainier National Park, Sunrise precipitation site
Photograph by: Mark Moore, Northwest Weather and Avalanche Center

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Natural Resource Report NPS/ NCCN/NRR—2010/240

Rebecca Lofgren¹, Barbara Samora¹, Bill Baccus², Bret Christoe¹
National Park Service
North Coast and Cascades Network
Mount Rainier National Park
Ashford, Washington 98304

¹Mount Rainier National Park,
55210 238th Ave. East
Ashford, WA 98304

²Olympic National Park,
600 East Park Avenue
Port Angeles, WA 98362

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Revision History Log

Protocol Narrative or SOP	Revision Date	Author of Revision and Affiliation	Changes Made, Location in Document	Reason for Change

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List of Standard Operating Procedures (SOPs), Volume 2.

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Executive Summary

This protocol narrative outlines the rationale, sampling design and methods proposed for monitoring climate in the North Coast and Cascades Monitoring Network (NCCN). The NCCN, one of 32 networks of parks in the National Park System, comprises seven national park units in the Pacific Northwest, including three large, mountainous, natural area parks (Mount Rainier [MORA] and Olympic [OLYM] National Parks, North Cascades National Park Service Complex [NOCA]) and four small historic-cultural parks (Ebey's Landing National Historical Reserve [EBLA], Lewis and Clark National Historical Park [LEWI], Fort Vancouver National Historical Park [FOVA], San Juan Island National Historical Park [SAJH]). This narrative reflects decisions made by the NCCN climate monitoring group, which includes National Park Service (NPS) representatives from each of the large parks in the Network and with the assistance of several agencies including National Oceanic Atmospheric Administration (NOAA), National Resource Conservation Service (NRCS), and the U.S. Forest Service (USFS).

The primary reasons for monitoring climate in the NCCN are:

1. To provide easily accessed, quality climate data for cooperating researchers, park managers and other NCCN monitoring programs
2. To increase the number of measurement locations and better document climate in a region known for extreme spatial variability
3. To organize and manage climate data to be readily accessible and useable for the interpretation of ecosystem patterns and processes

This protocol is published in two volumes, Volume 1. Narrative and Appendices, and Volume 2. Standard Operating Procedures (SOPs) of the Climate Monitoring Protocol for the North Coast and Cascades Network (Mount Rainier National Park, Olympic National Park, North Cascades National Park, Lewis and Clark National Historical Park, Ebey's Landing National Historical Reserve, San Juan Islands National Historical Park, Fort Vancouver National Historic Site), Version 5/26/2010.

Acronym List

AC	Alternate Current
ACU	Acquisition Control Unit
AOMC	Automated Operations and Monitoring Center
ACARS	Aircraft Communication Addressing and Reporting System
ACIS	Applied Climate Information System
ARD	Air Resource Division
ASOS	Automated Surface Observation System
BLM	Bureau of Land Management
CASTNET	Clean Air Status and Trends Network
CIG	Climate Impacts Group
CRN	Climate Reference Network
DCP	Data Collection Package
DOD	Department of Defense
EBLA	Ebey's Landing National Historic Reserve
ENSO	El Nino-Southern Oscillation
EPA	Environmental Protection Agency
FGDC	Federal Geographic Data Committee
FOVA	Fort Vancouver National Historic Park
GOES	Geostationary Operational Environmental Satellite
GPS	Global Position System
HCN	Historical Climate Network
I&M	Inventory and Monitoring
LEWI	Lewis and Clark National Historic Park
MORA	Mount Rainier National Park
NCCN	North Coast and Cascades Network
NCDC	National Climatic Data Center
NEPA	National Environmental Policy Act
NCEP	National Centers for Environmental Prediction
NFDRS	National Fire Danger Rating System
NIFC	National Interagency Fire Center
NOAA	National Oceanic and Atmospheric Administration
NOCA	North Cascades National Park Service Complex
NPClimate	Climate Data for Park

Acronym List (continued)

NPS	National Park Service
NRCS	Natural Resource Conservation Service
NWAC	Northwest Weather and Avalanche Center
NWS-COOP	National Weather Service Cooperative Stations
OBS	Observing Systems Branch
OLYM	Olympic National Park
ONPS	Operations of the National Park Service
PDA	Personal Digital Assistant
PDO	Pacific Decadal Oscillation
PNW	Pacific Northwest
PRISM	Parameter Regression on Independent Slopes Model
RAWS	Remote Automated Weather Stations
RF	Radio Frequency
RRS	Radio Replacement System
SAO	Surface Airways Observation
SAJH	San Juan Island National Historical Park
SCS	Soil Conservation Service
SNOTEL	Snowpack Telemetry
SOD	Summary of the Day
SQL	Structured Query Language
SWE	Snow Water Equivalent
USDA	United States Department of Agriculture
USFS	United States Forest Service
VHF	Very High Frequency
WACAP	Western Airborne Contaminant Assessment Project
WSDOT	Washington State Department of Transportation
WIMS	Weather Information Management System
WRCC	Western Regional Climate Center

1 - Background and Objectives

1.1 Description of Climate in NCCN Parks

The NCCN includes seven parks in western Washington and the northwestern corner of Oregon (Figure 1.1). The network includes four small parks and three larger, mountainous parks, and both coastal and continental environments. Mountainous topography and a maritime climate create notable environmental gradients.

Collectively, these seven parks span an elevation gradient from just below sea level to over 4,300 m (14,000 ft), with topographic relief as much as 3,900 m (12,800 ft) on Mount Rainier, typically 2000 m (6500 ft) in the Cascades and Olympics, and less than 100 m (330 ft) in the historic parks. These elevational gradients result in an ecologic diversity spanning 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).

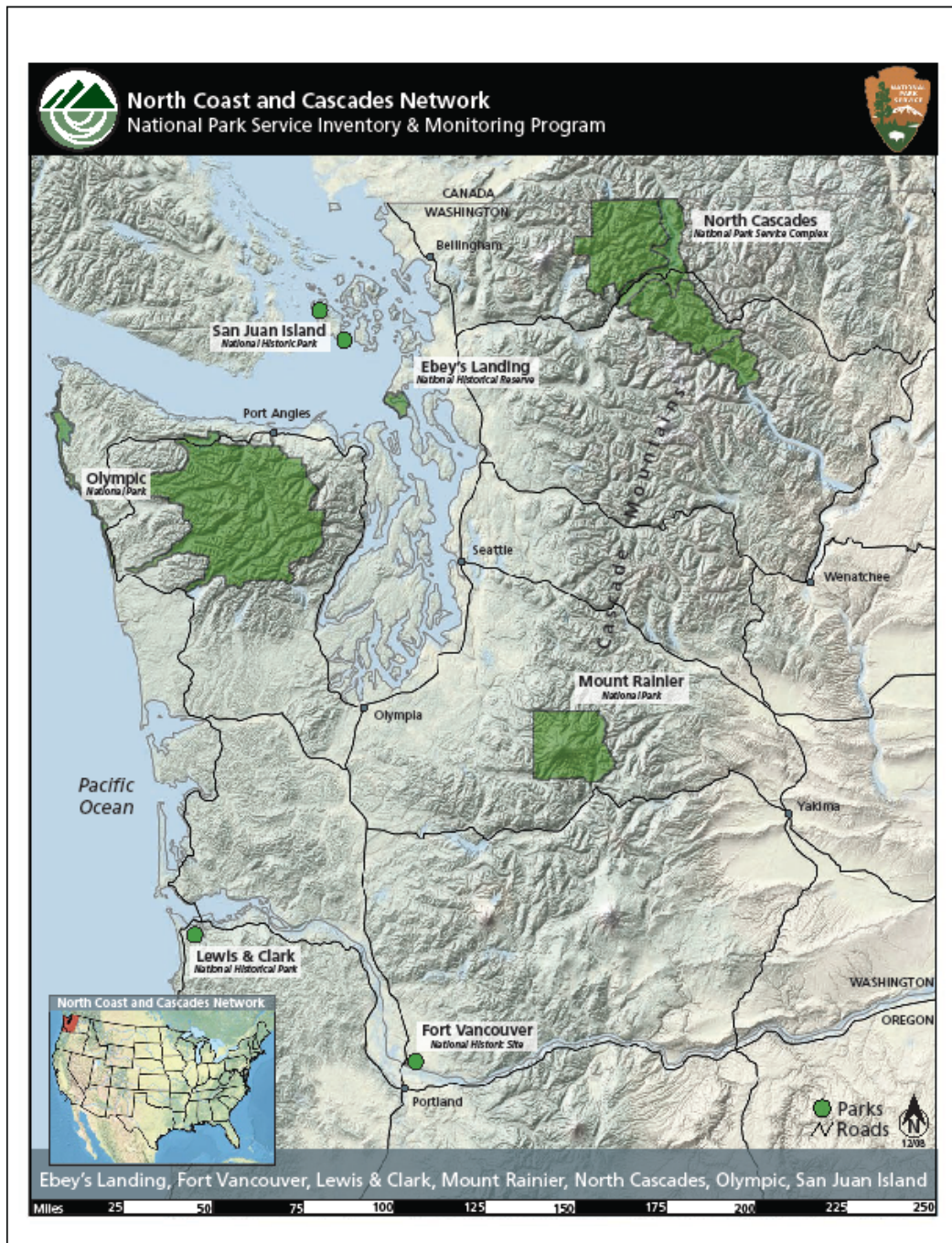


Figure 1.1. North Coast and Cascades Network Park (NCCN).

1.1.1 Spatial Variability

Factors that Create Spatial Variability: The climate of the NCCN is influenced by the region's topography and by its proximity to the Pacific Ocean. The topographical characteristics of the NCCN introduce significant spatial variability in the region's climate, while the Pacific Ocean moderates this variability, especially on the western side of the Cascade Mountains. Many of the storms that affect the NCCN are winter storms that are associated with the semi-permanent Aleutian Low generally positioned in the Gulf of Alaska.

The elevations represented in the NCCN parks range from just below sea level to over 4,300 m (14,000 ft), with correspondingly large gradients in temperature and precipitation. The Cascade and Olympic Mountain Ranges act as major barriers that intercept much of the moisture from storms off of the Pacific Ocean, creating a large gradient in precipitation between the western slopes (wet) and eastern slopes (dry) of these ranges. These environmental gradients result in a large variety of plant and animal communities and ecosystems in the NCCN, as showcased by the three largest parks: MORA, NOCA, and OLYM.

Range of Temperature and Precipitation: Much of the NCCN is cool and wet, lying at or west of the crest of the Cascade Mountains. Slopes on the west sides of the Cascade and Olympic mountains receive heavy precipitation which in some places exceeds 5000 mm (200 in) annually (Figure 1.2). The NCCN does, however, include an anomalously warm and dry region on the northeastern Olympic Peninsula and the nearby islands in Puget Sound. This region includes EBLA on Whidbey Island and SAJH on San Juan Island. These conditions are created primarily by the rainshadowing effects of the Olympic Mountains. Mean annual precipitation in these locations is as low as 500 mm (20 in) and is accompanied by mild mean annual temperatures (Figure 1.3).

A large amount of the precipitation at higher elevations falls as snow. In response to these precipitation patterns, rivers and streams in the NCCN generally have one peak of runoff in the spring months, with timing depending on elevation. At higher elevations of the Olympic and Cascade Mountain Ranges, annual snowfall totals can regularly exceed 15 m (49 ft) (Figure 1.4). The annual snowfall record for the entire nation is at Mt. Baker Ski Area, just northwest of NOCA. During the winter of 1998–1999, the ski area received 2896 cm (95 ft) of snowfall, which was verified by the National Climate Extremes Committee (Leffler et al. 2001). This broke the previous record of 2850 cm (93.5 ft) set at Paradise Ranger Station at MORA in the winter of 1971–1972 (Ruscha and Meyers 1972).

Mild temperatures are shared at most of the lower elevations of the NCCN, where mean annual temperatures are around 9°C (e.g., SAJH) or higher (e.g. FOVA). Higher elevations have much colder temperatures, with the annual average temperature estimated at below -2°C in the upper reaches of Mt. Rainier (Davey et al. 2006).

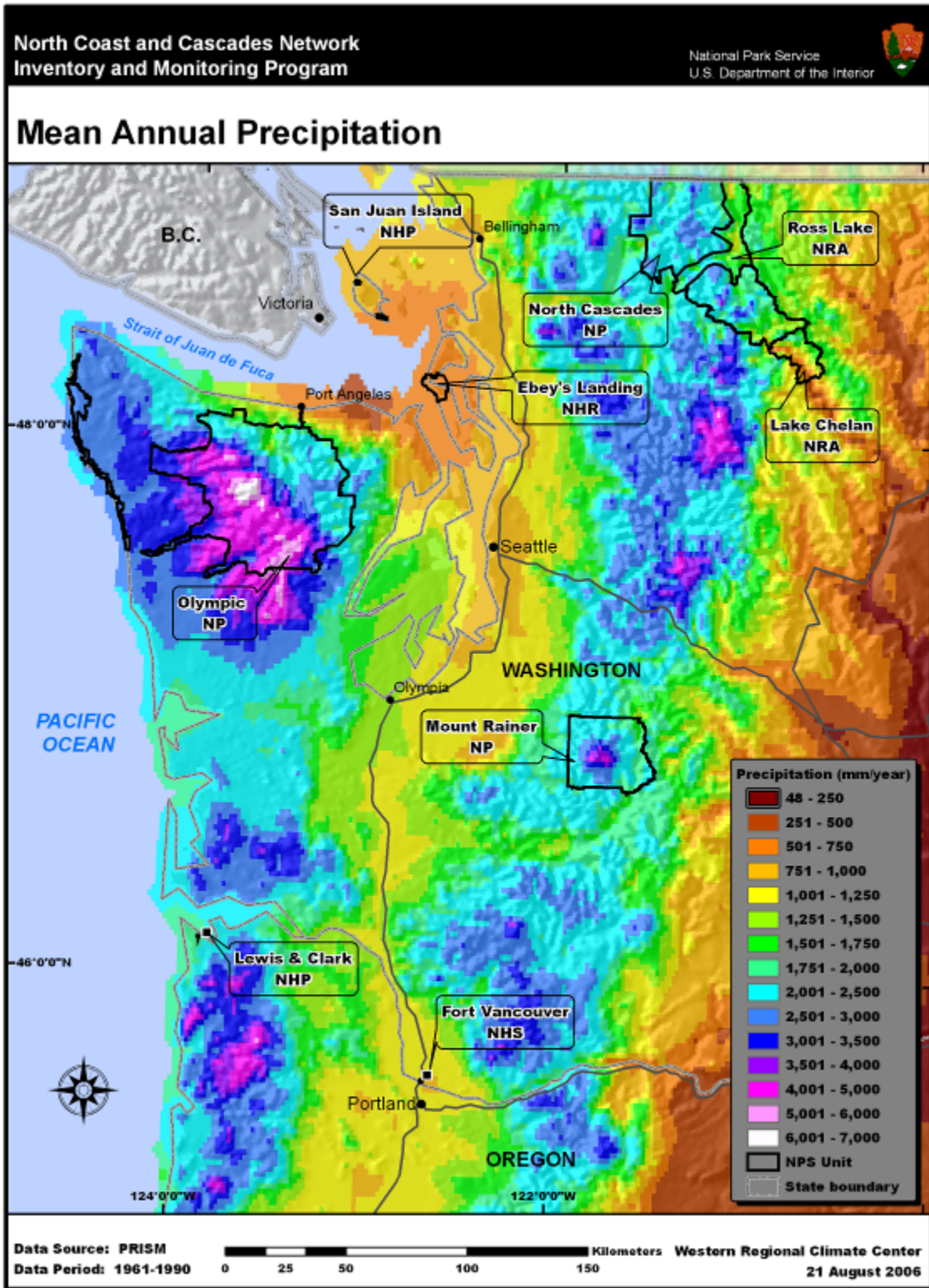


Figure 1.2. Mean annual precipitation, 1961–1990 for the NCCN.

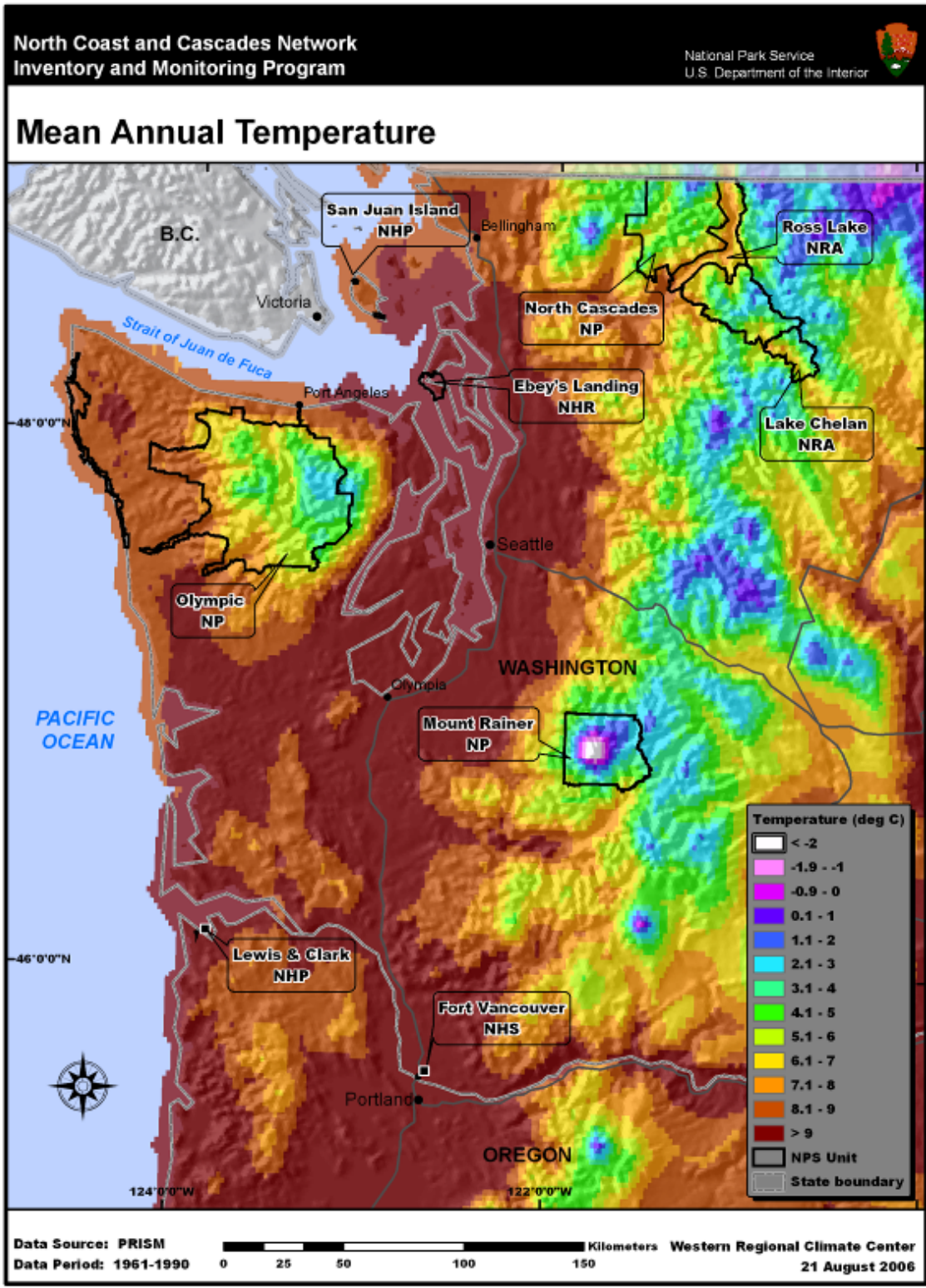


Figure 1.3. Mean annual temperature, 1961–1990, for the NCCN.

During the winter, mean monthly temperatures in the coldest mountain locations of the NCCN regularly drop below -10°C (Figure 1.5). Arctic cold-air outbreaks are relatively rare in the NCCN but the normally mild temperatures of winter are occasionally interrupted by cold outbreaks. In northern portions of the NCCN, these cold air masses usually come down the Fraser River Valley in Canada and bring prolonged periods of snow and temperatures below freezing. Southern portions of the NCCN, particularly along the west edge of the Columbia River Gorge (includes FOVA), experience occasional cold outbreaks which are sometimes associated with severe ice storms.

Summer temperatures are mild to warm throughout the NCCN and generally increase from north to south (Figure 1.6). The Pacific Ocean moderates temperatures near the coast. July maximum temperatures range from under 10°C at upper elevations of MORA, to around 25°C at FOVA. Most precipitation in the NCCN falls during the late fall and winter months (Figure 1.7). With the exception of the western slopes of OLYM and northwest portions of NOCA, the summer months are universally dry regardless of location within the NCCN.

Parameter Regression on Independent Slopes Model (PRISM): Climate parameter maps are presented in Figures 1.2–1.6. They were generated using the Parameter Regression on Independent Slopes Model (PRISM). This model was developed to address the extreme spatial and elevation gradients exhibited by the climate of the western United States (Daly et al. 1994; 2002; Gibson et al. 2002; Doggett et al. 2004). Such modeling provides a coarse, yet comprehensive perspective of the diverse climate characteristics across the NCCN.¹

¹ The maps produced through PRISM have undergone rigorous evaluation in the western U.S. This model was originally developed to provide climate information at scales matching available land-cover maps to assist in ecologic modeling. The PRISM technique accounts for the scale-dependent effects of topography on mean values of climate elements. Elevation provides the first-order constraint for the mapped climate fields, with slope and orientation (aspect) providing second-order constraints. The model has been enhanced gradually to address inversions, coast/land gradients, and climate patterns in small-scale trapping basins. Monthly climate fields are generated by PRISM to account for seasonal variations in elevation gradients in climate elements. These monthly climate fields then can be combined into seasonal and annual climate fields. Since PRISM maps are grid maps, they do not replicate point values but rather, for a given grid cell, represent the grid-cell average of the climate variable in question at the average elevation for that cell. The model relies on observed surface and upper-air measurements to estimate spatial climate fields.

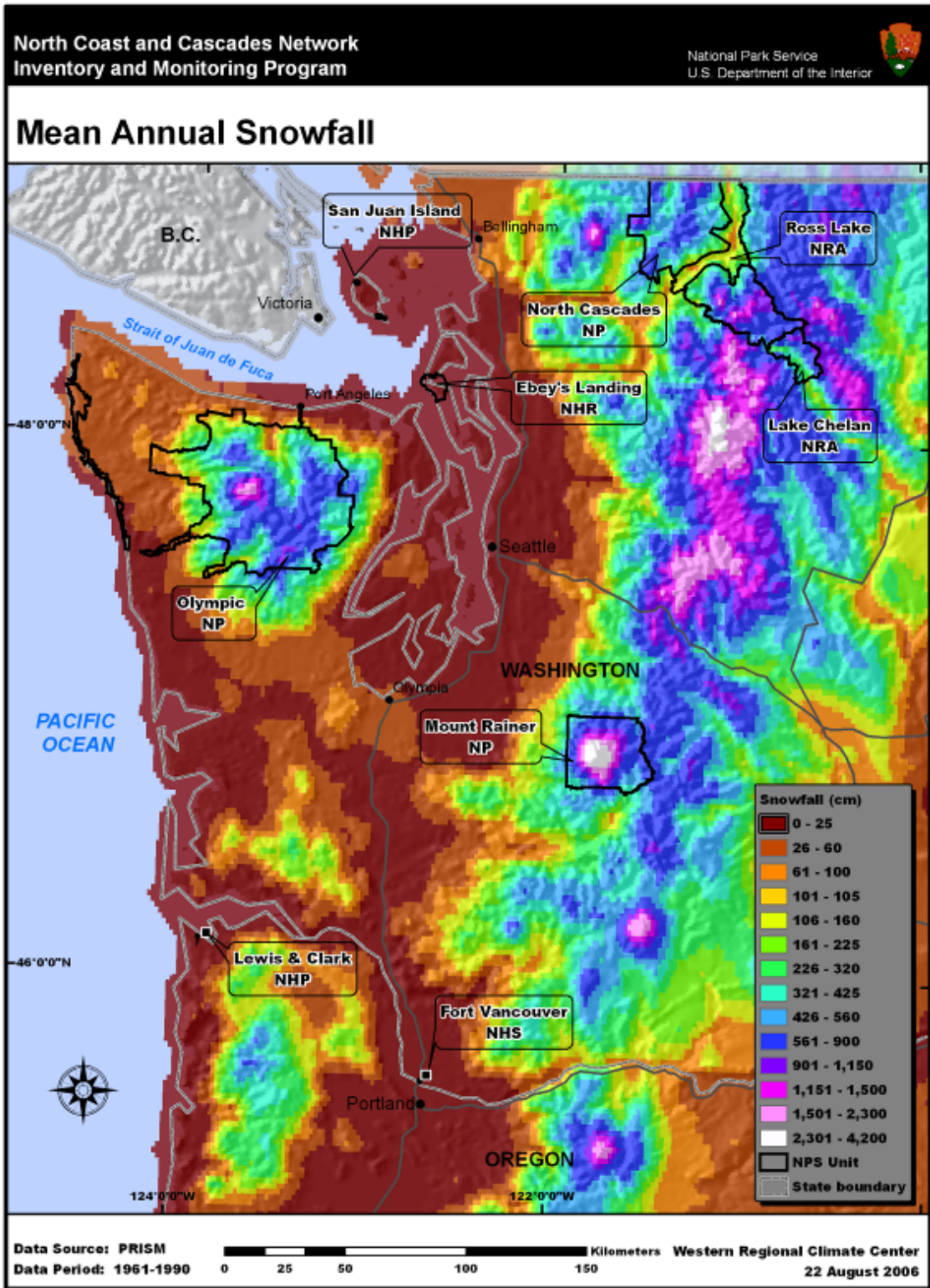


Figure 1.4. Mean annual snowfall, 1961–1990, for the NCCN.

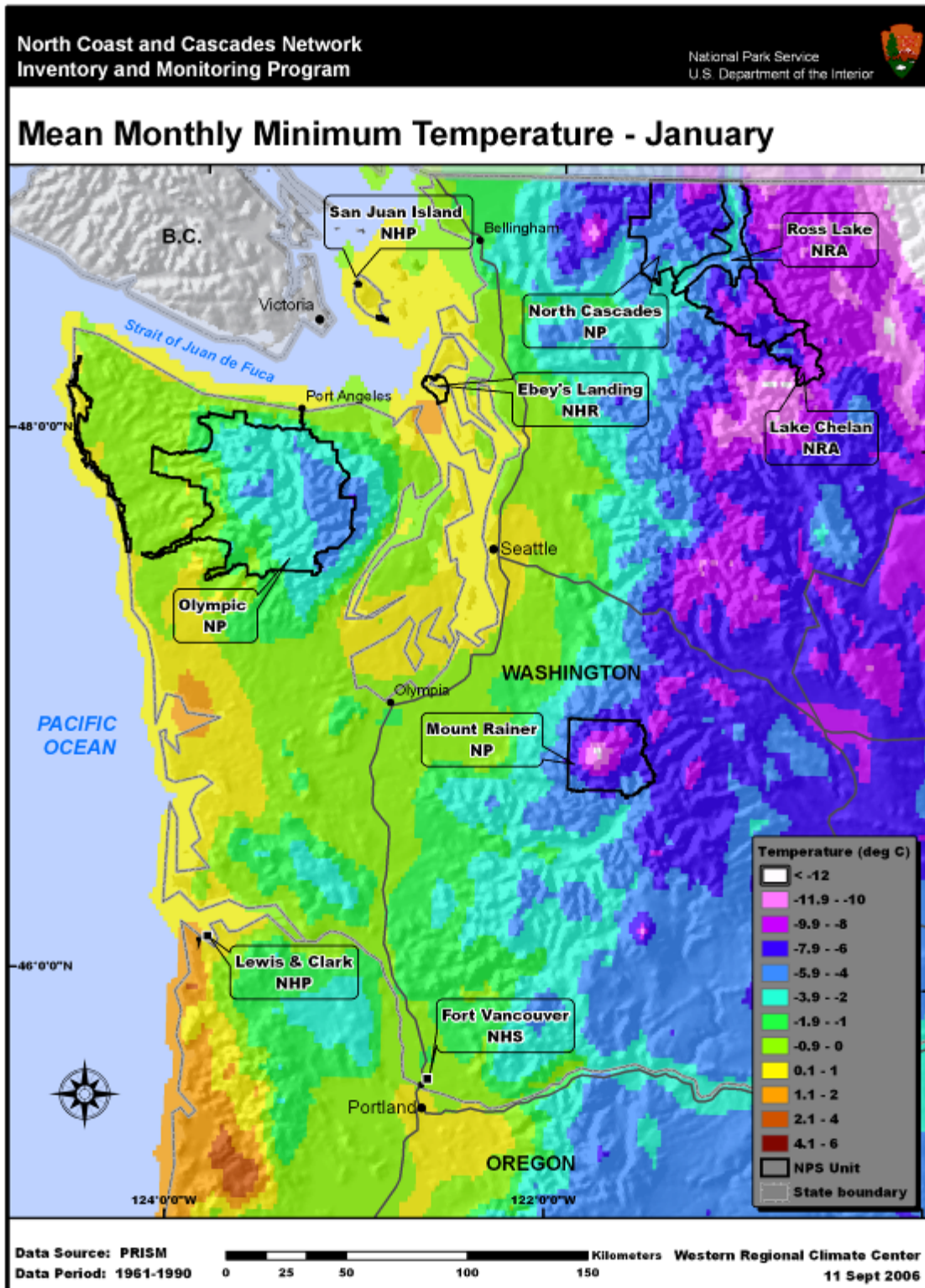


Figure 1.5. Mean January minimum temperature, 1961–1990, for the NCCN.

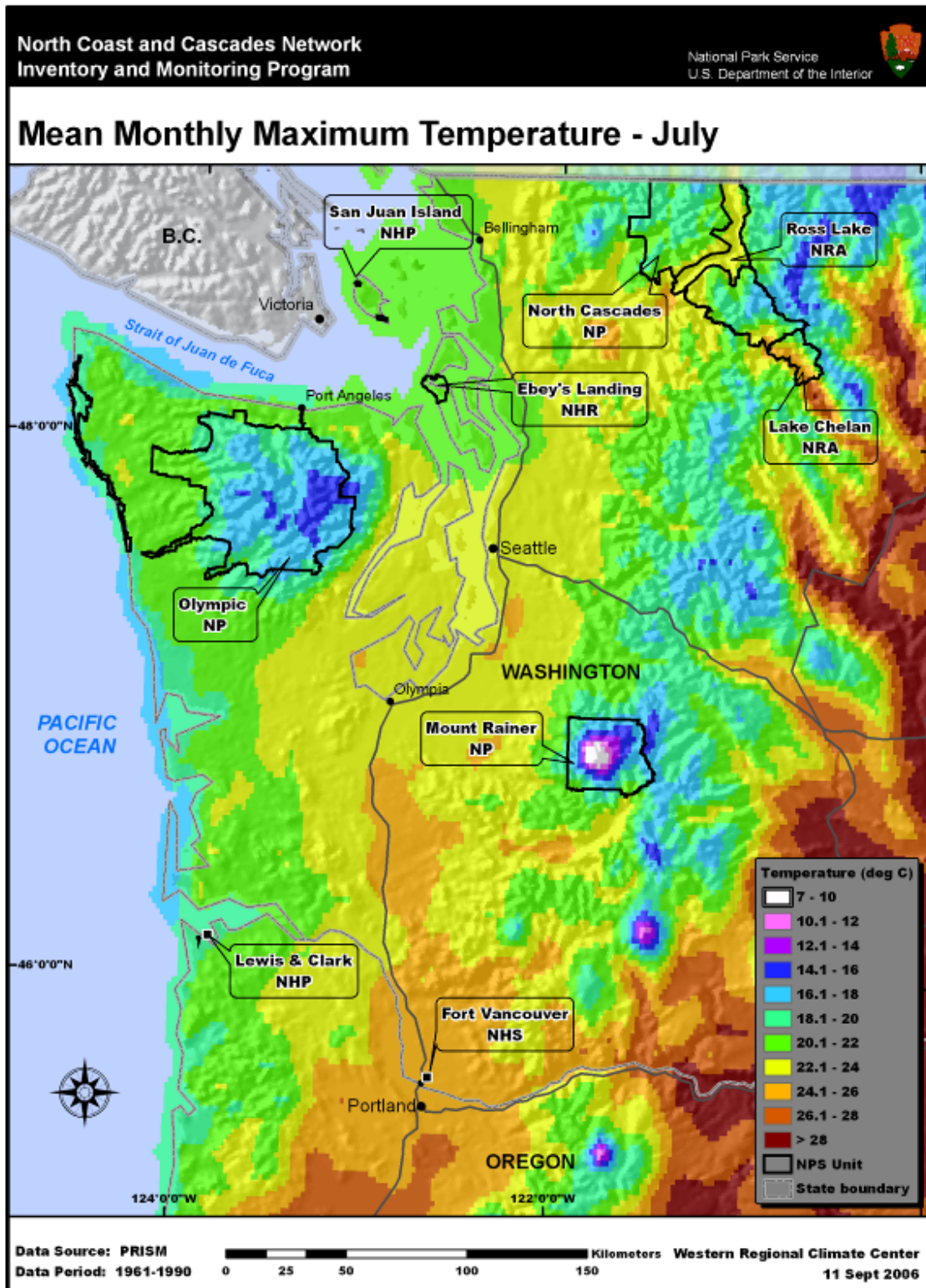
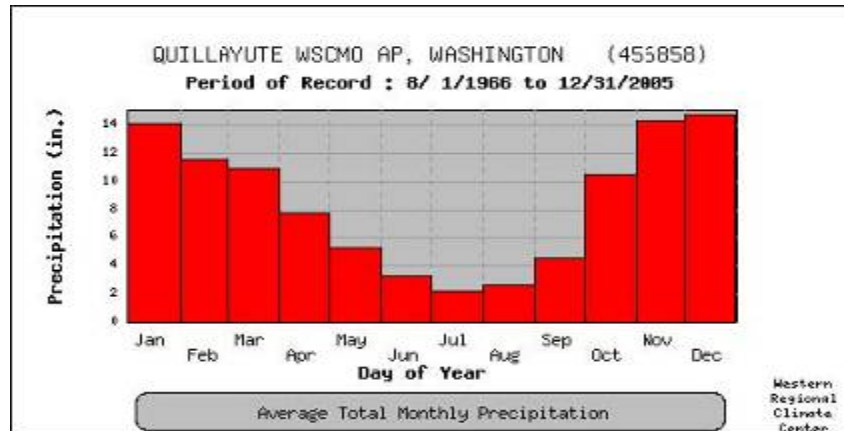


Figure 1.6. Mean July maximum temperature, 1961–1990, for the NCCN.

(a)



(b)



(c)

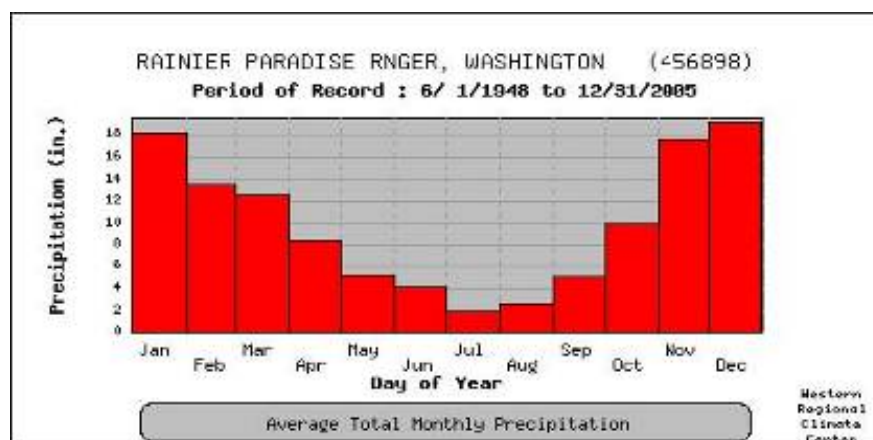


Figure 1.7. Mean monthly precipitation at selected locations in the NCCN. The locations are Quillayute, Washington, near Olympic National Park (a); Astoria, Oregon, near Lewis and Clark National Historic Park (b); and Mount Rainier National Park (c) (Davey et al. 2006).

A significant amount of fog or cloudwater deposition is a key climatic feature of NCCN parks. Figure 1.8 shows the 30-yr U.S. average heavy fog days, defined as visibility less than 0.25 miles. NCCN parks 30-year average ranges between 30.5 to 40.4 days of heavy fog per year. Atmospheric sulfur, nitrogen, and other air contaminants are deposited through cloudwater deposition, which can affect ecosystem processes and integrity.

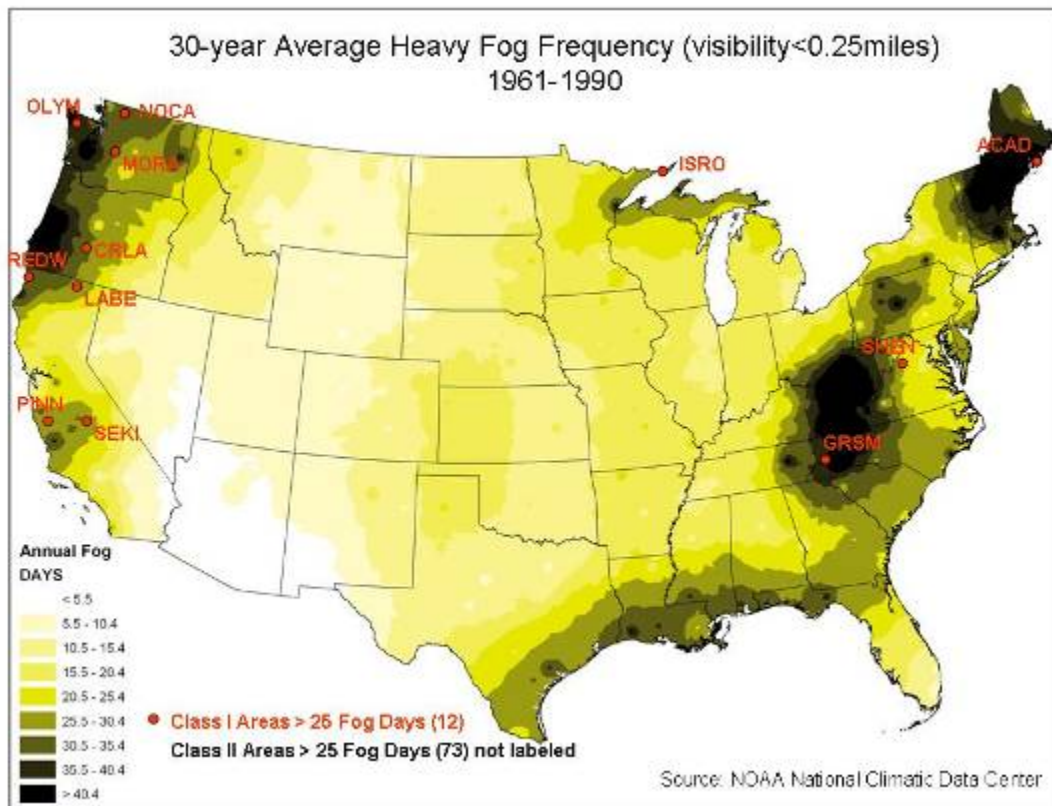


Figure 1.8. Thirty-year average heavy fog days for the U.S.

1.1.2 Temporal Variability

Drivers of Temporal Variability: The Pacific–North America Oscillation (Wallace and Gutzler 1981) is an important contributor to variability of storm frequencies and tracks during a given year, with variations that occur on the order of weeks.

Both the El Niño–Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO) cause interannual climate variations in the NCCN (Mantua et al. 1997; Cayan et al. 1998; Mote 2006). El Niño conditions and/or positive phases of the PDO are associated with warmer and drier than normal conditions in the NCCN, while La Niña conditions and/or negative phases of the PDO are associated with cooler and wetter than normal conditions. Fig 1.9 shows the relationship between PDO and precipitation at Mount Rainier.

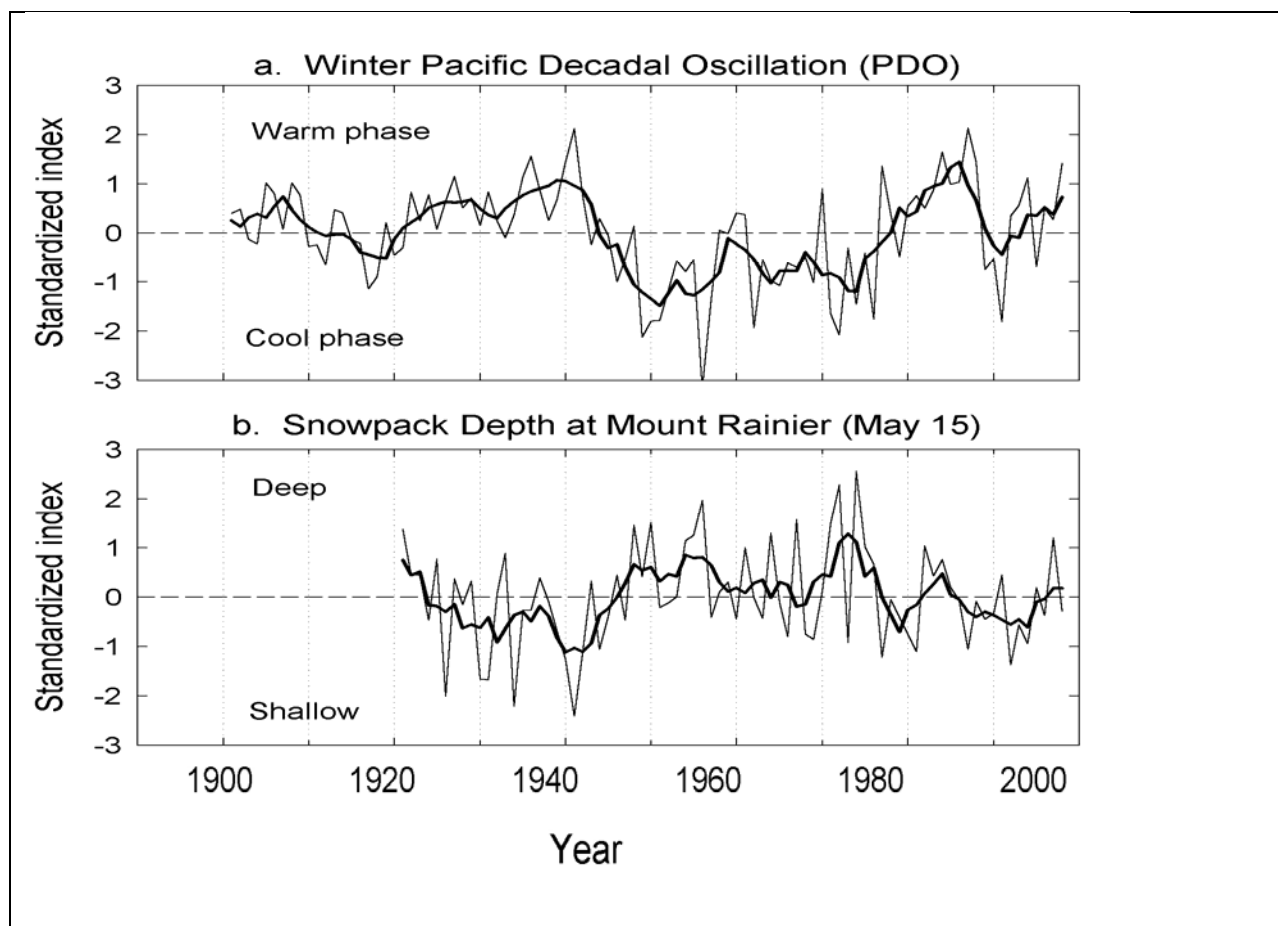
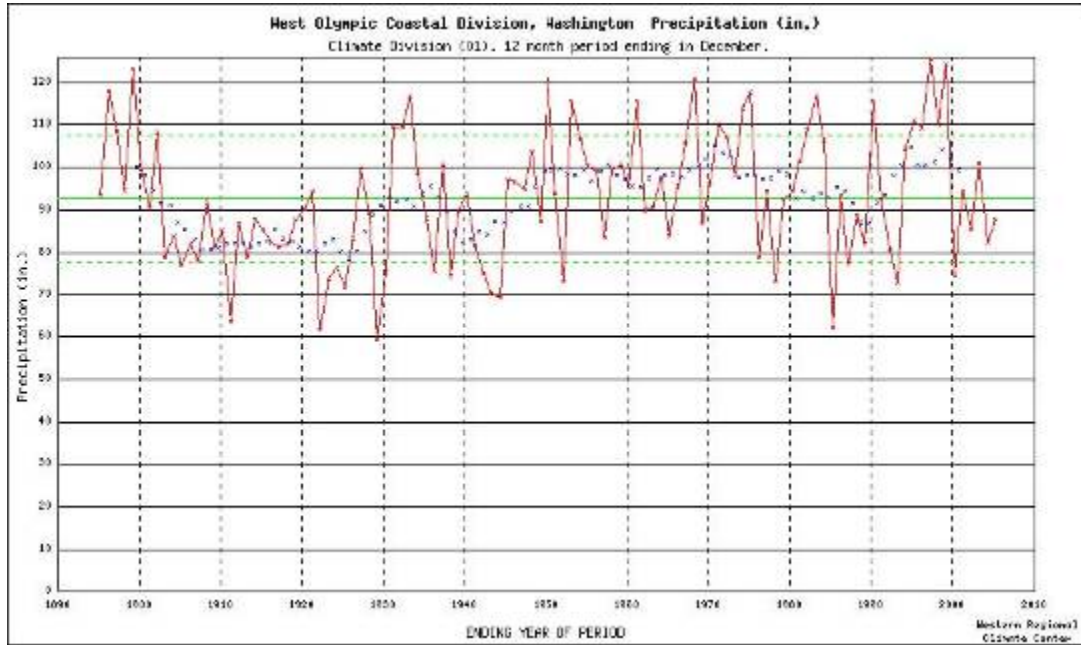


Figure 1.9. Pacific Decadal Oscillation (PDO) compared with snowpack depth at Paradise, Mount Rainier National Park (Peterson and Peterson 2001).

Observed Long-term Changes in Temperature and Precipitation: Subregional precipitation and temperature time series from 1895 to 2005 are shown for the western Olympic Mountains, Puget Sound, and the Cascade Mountains in Figures 1.10 and 1.11. Precipitation in the region does not appear to show any significant trend (Figure 1.10). Long-term temperature records, however, appear to indicate warming, especially in the last three decades (Figure 1.11). Scientists with the University of Washington Climate Impacts Group estimate that surface temperatures in the Pacific Northwest (PNW) have increased approximately 1.5°F (0.8°C) over the last century; (Mote 2003). Studies also suggest that mountain snowpacks in the region have decreased over the last several decades (Mote et al. 2005). Best estimates of April 1st snow water equivalent (SWE) in the Cascade Mountains of Washington State indicate a substantial (roughly 15–35%) decline from midcentury to 2006. Larger declines at low elevations and smaller declines or increases at high elevations suggest a correlation with increasing temperatures (Mote et al. 2008). The degree of these changes which can be attributed to global warming versus decadal climate variations is still being debated by local experts.

a)



b)

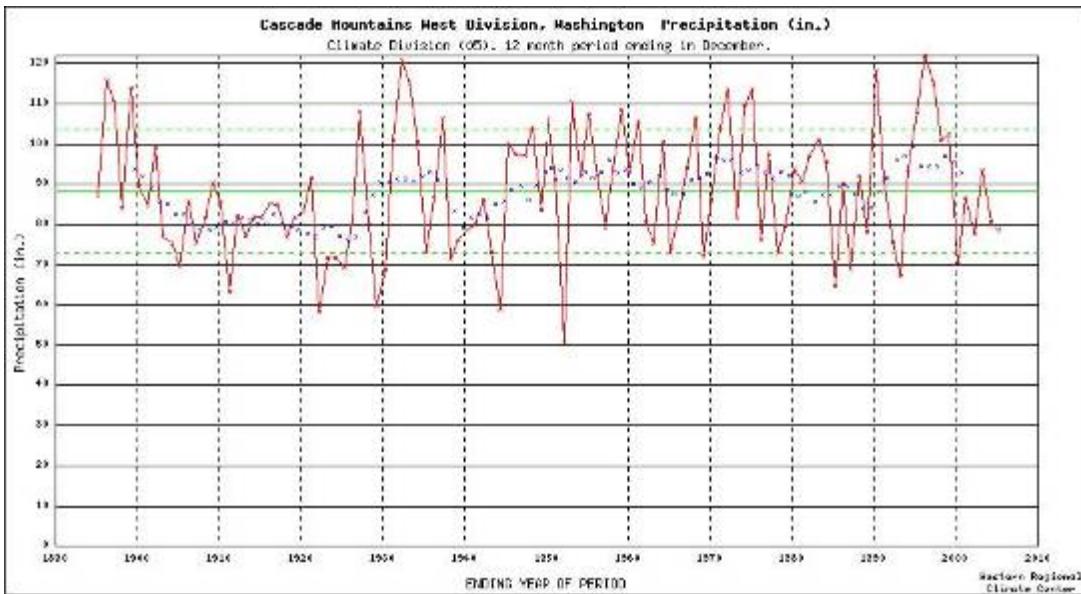


Figure 1.10. Precipitation time series, 1895–2005, for selected regions in the NCCN. These include twelve month precipitation (ending in December) (red), 10-year running mean (blue), mean (green), and plus/minus one standard deviation (green dotted). Locations include the western Olympic Mountains (a) and the western Cascade Mountains (b) (Davey et al. 2006).

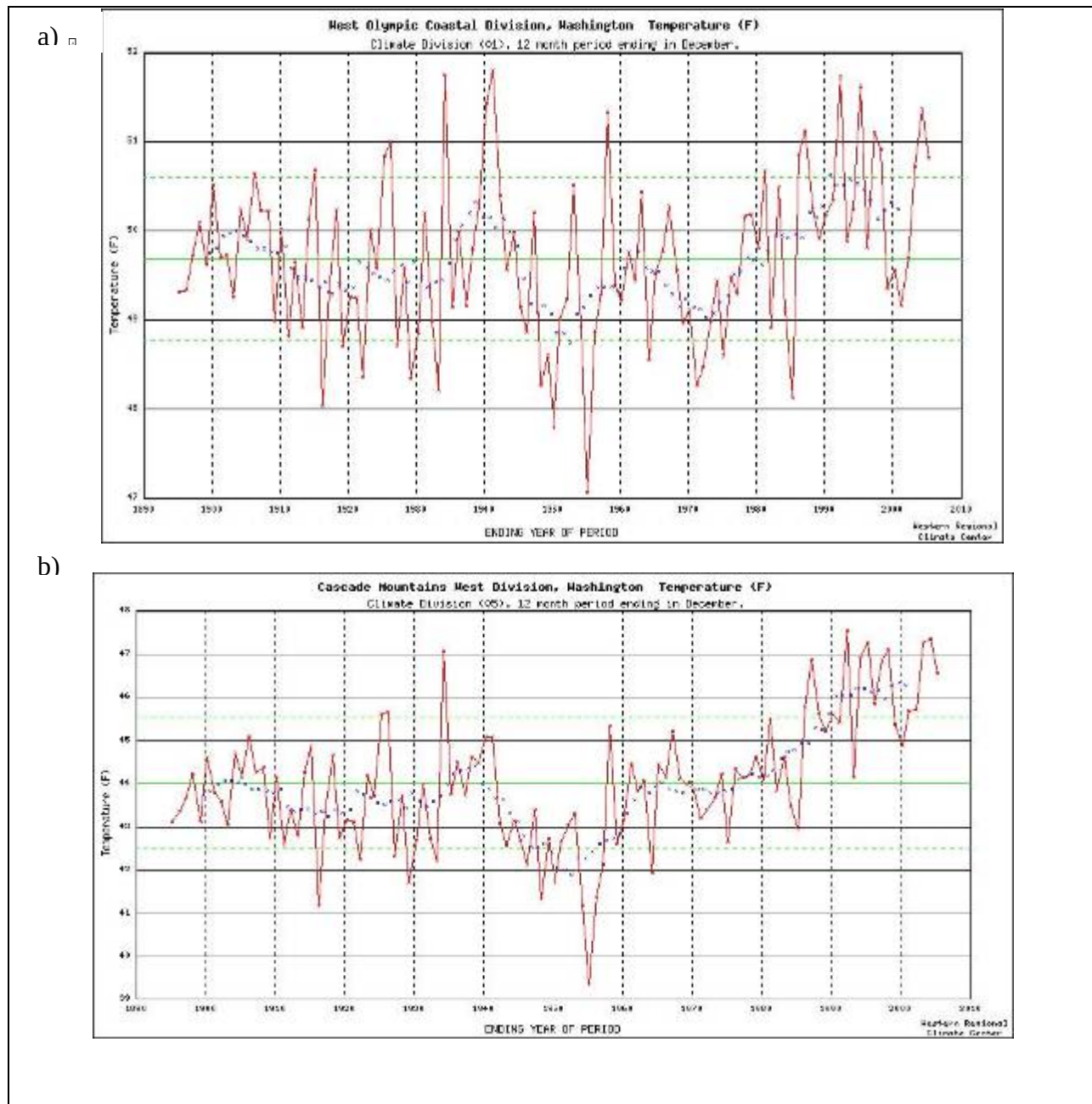


Figure 1.11. Temperature time series, 1895–2005, for selected regions in the NCCN. These include twelve month temperature (ending in December) (red), 10-year running mean (blue), mean (green), and plus/minus one standard deviation (green dotted). Locations include the western Olympic Mountains (a) and the western Cascade Mountains (b) (Davey et al. 2006).

Predicted Changes in Climate: The warming rate in the Pacific Northwest for the next century is projected to be in the range of 0.1–0.6° C/decade, with an average of 0.3° C/decade warming projected for the Pacific Northwest (PNW) from 20 simulations of future climate by global climate models (Salathé et al. 2007). While future changes in precipitation are less certain, overall, most models project long-term trends with increases in winter precipitation and decreases in summer precipitation for the PNW. Projected precipitation changes are relatively modest and unlikely to be distinguishable from

natural variability until late in the 21st century (Mote et al. 2005, Salathé et al. 2007). Model simulations have large interdecadal variability so that the ten-year averaged changes commonly reported are not necessarily indicative of a monotonic trend or of anthropogenic influence (Mote et al. 2005).

Potential Effect of Climate Change: Climate directly influences all aspects of the ecosystems within the NCCN. For this reason, a change in climate due to global warming is likely to have a major effect on organisms within these ecosystems.

Glaciers, which are threatened by climate change, provide important functions in many mountainous areas of the world, including much of the NCCN. Next to Alaska, the state of Washington has the largest glacier cover in the United States. The glaciers in the NCCN are melting rapidly in response to recent climate changes. Some estimates indicate that glacier area in NOCA has declined 44 percent in the last 150 years (Granshaw 2001). Recent studies indicate that the retreat of the past ~150 years has now brought many Northwest glaciers back to levels last seen ~6,000 years ago, a time near the end of a prolonged warm and dry period that is indicated by ancient pollen records and moraines (Walker and Pellatt 2003). The sensitive and dynamic response of glaciers to variations in both temperature and precipitation makes them useful indicators of regional and global climate change at multiple time scales (Bitz and Battisti 1999; Pelto and Riedel 2001).

Glaciers are the sole habitat for certain species (Hartzell et al. 2005). They also greatly influence the habitat and hydrologic characteristics of these regions. Many freshwater aquatic species in the NCCN benefit from the buffering hydrological influences that glaciers provide to many mountainous stream and river systems, particularly during seasonal and inter-annual droughts (Meier 1969; Meier and Roots 1982).

Freshwater systems are an extremely important component of the NCCN. Most famously, streams and rivers of the NCCN are known for their distribution and abundance of Pacific salmonids. These systems also support unique amphibians, invertebrates and wildlife species. Climate change may significantly alter the hydrologic cycles, temporal temperature patterns, productivity, and distributions and abundance of aquatic biota within these freshwater systems. In riparian areas of the NCCN, predicted increases in winter floods may alter the frequency of disturbance events that significantly reshape local channel characteristics and supply sediment and large woody debris to stream channels (Ziemer and Lisle 1998). This, in turn, would influence the rate and characteristics of changes to the physical, chemical and biotic features of streams (Bilby and Bisson 1998).

Water temperature, which can be affected by increases in air temperature and declining snow packs, is as a primary control on ecological processes in rivers such as litter decomposition (Robinson and Jolidon 2005) and the structure and composition of benthic communities (Milner and Petts 1994). Native char such as bull trout (*Salvelinus confluentus*) are dependent upon cold headwater stream areas. Tailed frogs (*Ascaphus truei*) are also dependent on rock-strewn mountain streams that have cold fast-flowing water. Aquatic invertebrates are highly sensitive to temperature, so glacial melt water is important for maintaining the trophic structure of stream communities (Lowe and Hauer 1999).

NCCN parks contain nearly 1500 mountain lakes. Lake and river ice phenology is expected to change with climate warming. Ice-cover durations for inland waters have decreased over the entire northern hemisphere (IPCC 2007; Magnuson et al. 2000). Lake ice influences biogeochemical cycling, including gas exchange with the atmosphere, habitat availability (through changes in pH and dissolved oxygen), biodiversity, and seasonal succession (Arnell et al. 1995; Cushing 1997).

Marine intertidal areas of the NCCN are considered the most bio-diverse marine regions on the west coast of North America (Schoch et al. 2006). The changes in ocean currents and the timing and extent of coastal upwelling which may result from global climate change can greatly affect aquatic marine organisms. Intertidal invertebrate communities are uniquely sensitive to the effects of climate change, as they are exposed to both marine waters and air (Helmuth et al. 2006). Survivorship, fecundity and dispersal of intertidal organisms are directly affected by increasing water and air temperatures.

Climate significantly affects the air quality of NCCN parks. Winds carry air pollutants from nearby metropolitan areas as well as from trans-Pacific sources. Temperature increases significantly affect the formation of tropospheric ozone. While the air quality of the Pacific Northwest is generally considered better than other areas of the U.S., there is potential for both long-term and short-term degradation that could affect human health, vegetation, aquatic resources, and biogeochemical processes.

Parks within 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, Portland, and Vancouver, BC. Trans-Pacific transport of persistent organic pollutants is also occurring (Blais et al. 1998; Jaffe et al. 1999; Bailey et al. 2000). Recent studies have demonstrated some key linkages between air masses on the west coast of North America and Eurasian industrial and agricultural sources (Jaffe et al. 2005; Weiss-Penzias et al. 2007). For the three NCCN parks in remote and mountainous environments, atmospheric deposition is likely the most important source of contamination (Biddleman 1999). 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, Clow and Campbell 2008). Potential effects of atmospheric deposition 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 (EPA 2006);
- 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, Clow and Campbell 2008); and
- Particulate pollutants, which reduce visibility of scenic views and may cause respiratory distress in some visitors (Wilson 1996).
- Higher concentrations of anthropogenic aerosols have been shown to alter cloud properties in mountainous regions causing a reduction in snowfall in certain areas (Borys and Lowenthal 2003).

Climate change can have significant impacts on wetland structure and function, primarily through alterations in hydrology, especially water-table level (Clair et al. 1998; Clair and Ehrman 1998). Wetland flora and fauna respond very dynamically to small changes in water-table levels (Poiani et al. 1996; Schindler 1998). Sea-level rise will result in loss of coastal wetlands in many areas, with potentially important effects on ocean fisheries (Michener et al. 1997; Turner 1997).

Connections between climate and terrestrial ecosystems include: (1) the seasonal timing of life-cycle events or phenology; (2) responses of plant growth or primary production and; (3) biogeographic distribution (Field et al. 2007). Direct impacts on organisms interact with indirect effects of ecological mechanisms (competition, herbivory, disease) and disturbance (wildfire, hurricanes, and human activities) (Field et al. 2007).

Impacts on ecosystem structure and function may be amplified by changes in extreme meteorological events and increased disturbance frequencies. Ecosystem disturbances, caused either by humans or by natural events, accelerate both loss of native species and invasion of exotics (Sala et al. 2000).

In alpine environments, surface soils on slopes are expected to become drier as thaw depth increases (McKane et al. 1997; McGuire et al. 2000). The rise in upper treeline in response to past warming of climate is well-documented. The boundary between alpine tundra and subalpine forest is controlled by extremes of temperature, moisture, and wind. Vegetation in both ecosystems is long-lived, and changes will proceed slowly and in a manner that depends on whether total annual snowpack decreases or increases and whether melt occurs earlier; both factors control the growth of alpine and subalpine species. The eventual effect of upward movement of the treeline will be to shrink the extent of alpine tundra in North America, possibly causing species loss and ecosystem degradation through greater fragmentation (Field et al. 2007).

In NCCN parks, forests at upper (cold) and lower (dry and/or hot) timberlines are most likely to show strong direct effects of climatic variation on tree growth, since they are closer to their physiological limits and, therefore, more prone to stress at these locations (Case and Peterson 2007, Peterson and Peterson 2001). Rapid establishment of trees in subalpine ecosystems during this century is increasing forest cover and reducing meadow cover at many subalpine locations in the western US, and precipitation (snow depth) is a critical variable regulating conifer expansion (Fagre et al. 2003). Changes in plant species composition in response to climate change can facilitate other disturbances, including fire (Smith et al. 2000) and biological invasion (Zavaleta and Hulvey 2004).

Increased temperature in the future will likely extend fire seasons throughout the western United States, with more fires occurring earlier and later than is currently typical. It will also increase the total area burned in some regions (Westerling et al. 2006). A warming climate encourages wildfires through a longer summer period that dries fuels, promoting easier ignition and faster spread. If climate change increases the amplitude and duration of extreme fire weather, we can expect significant changes in the distribution and abundance of dominant plant species in some ecosystems, which would thus affect habitat of some sensitive plant and animal species. Some

species that are sensitive to fire may decline, whereas the distribution and abundance of species favored by fire may be enhanced (Westerling et al. 2006).

Population and community dynamics will also be affected by climate change. For many amphibians, whose production of eggs and migration to breeding ponds is intimately tied to temperature and moisture, mismatches between breeding phenology and pond drying can lead to reproductive failure (Beebee 1995). Differential responses among species in arrival or persistence in ponds will likely lead to changes in community composition and nutrient flow in ponds. Amphibians may be especially susceptible to climatic change because they have moist, permeable skin and eggs and often use more than one habitat type and food type in their lifetimes (Lips 1998). Many amphibious species appear to be declining, although the exact causes (e.g., climate change, fungus, UV radiation, or other stresses) are difficult to determine (Laurance 1996; Berger et al. 1998; Houlahan et al. 2000). Disappearance and decline of several amphibian species in the rainforests of Costa Rica appear to be linked to climate warming (Pounds and Crump 1994; Pounds et al. 1999).

Insect dispersal to favorable areas to make effective use of microclimatic differences is a common response to changing climate (e.g., Fielding et al. 1999). Warming and changed rainfall patterns also may alter host plant-insect relations, through community or physiological responses (e.g. host plant food quality) (Masters et al. 1998). Multiple factors, including climate change, have been implicated in driving outbreaks of Mountain Pine Beetle in North America (Romme et al. 2006, Logan and Powell 2001, Logan et al. 2003).

Movement of species in regions of North America in response to climate warming is expected to result in shifts of species ranges poleward, and upward along elevational gradients (Parmesan 2006). Bird ranges reportedly have moved poleward in North America (Price et al. 2000). Spring and elevational range of some species has changed in response to climate change (Prop et al. 1998, Pounds et al. 1999). The ranges of butterflies in Europe and North America have been found to shift poleward and upward in elevation as temperatures have increased (Pollard 1979, Ellis et al. 1997, Parmesan et al. 1999, Parmesan 2006). Changes in mammal abundance can occur through changes in food resources caused by climate-linked changes or changes in exposure to disease vectors (Hart et al. 1985).

1.2 History of Monitoring Climate in the NCCN

Historical climate stations are presented in Fig. 1.12 and detailed park specific maps of current climate station locations are included in Appendix B. Climatic conditions have been monitored at some locations in NCCN park units since the early 1900's. Currently there are nine programs, operating 59 climate stations within NCCN park boundaries. These programs are primarily administered by other federal agencies (Table 1.1). In addition, NCCN staff operate and maintain automated climate stations.

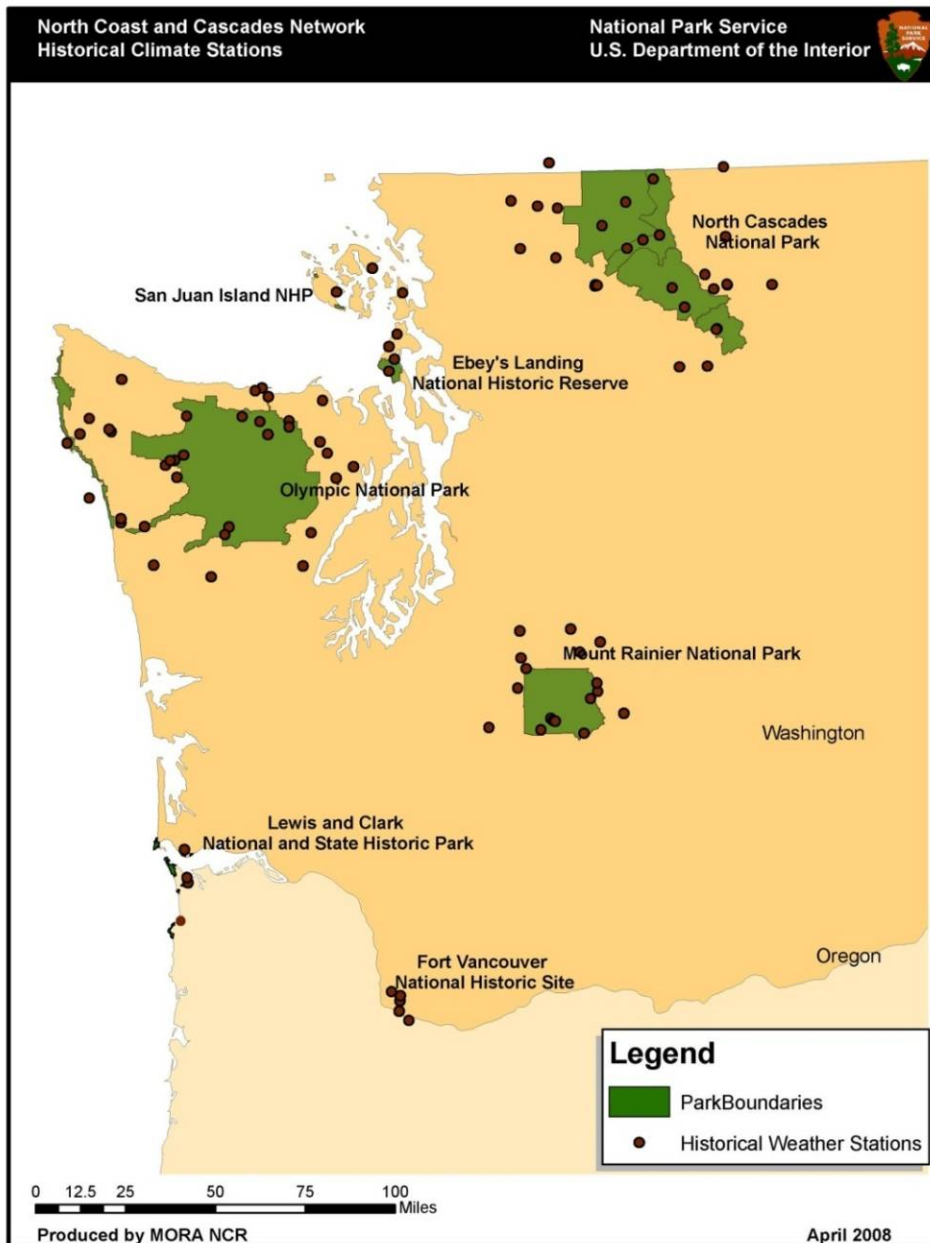


Figure 1.12. Historic climate stations in the NCCN. Snow Course site locations are not included in the figure.

Climate data summaries can be obtained from a number of sources:

- The Western Regional Climatic Center (WRCC) has compiled a summary of historical climate data generated from National Weather Service Cooperative (NWS-COOP) and Remote Automated Weather Stations (RAWS) stations. Monthly, annual, and period of record statistics are available at: <http://www.wrcc.dri.edu/climsum.html>.
- The National Climatic Data Center (NCDC) provides hourly and daily Automated Surface Observing System (ASOS), Climate Reference Network (CRN), and NWS-COOP weather station data at: <http://www.ncdc.noaa.gov/oa/climate/climatedata.html>

- Historical Snowpack Telemetry (SNOTEL) data is available through the Natural Resource Conservation Service at: <http://www.wcc.nrcs.usda.gov/snotel/>
- A summary of recent climate patterns occurring in the Pacific Northwest, specifically the Pacific Decadal Oscillation (PDO) and El Nino/Southern Oscillations (ENSO) are available from the Climate Impacts Group². Trends can be identified from the data generated from NWS-COOP weather stations, particularly those stations with a long period of record (~100 years). <http://www.iphc.washington.edu/Staff/hare/html/decadal/post1977/pdoenso1.jpg>

1.2.1 Description of Climate Monitoring Programs in the NCCN

Table 1.1 summarizes the climate monitoring programs that have been historically conducted in the NCCN parks. Detailed descriptions of these programs follow.

Table 1.1. Climate monitoring programs.

Climate Monitoring Program	Agency	Stations within NCCN Park boundaries
RAWS	National Interagency Fire Center (NIFC) (Bureau of Land Management (BLM), USFS, NPS, et al.)	4
NWS-COOP	National Weather Service (NWS)	11
CRN	NOAA	2
SNOTEL/Modified SNOTEL	National Resources Conservation Service (NRCS)	12
NWAC (Northwest Avalanche Center) High Elevation Weather Stations	USFS, NWS, NPS, et al	4
Snow Course ; Aerial Markers	NRCS	15
ASOS	Federal Aviation Administration (FAA), Department of Defense (DOD), NWS	2
NPS Climate Stations	NPS	9
NWS Upper Air Observations Program	NWS	1 located outside OLYM Boundary

National Weather Service Cooperative Observer Program (NWS-COOP): The NWS-COOP Program is a nationwide weather and climate monitoring network comprised of volunteer citizens and institutions observing and reporting weather information on a 24-hour basis. NWS-COOP observations form the backbone of temperature and precipitation (including snowfall) records describing U.S. climate. Eleven COOP stations are located within the NCCN, some in operation as early as 1920. Three stations occur in MORA, two in OLYM, four in NOCA and one each in EBLA and LEWI.

The Cooperative Observer Program was formally created in 1890 under the Organic Act and operated under the Weather Bureau (renamed in 1967 to the National Weather Service). Its mission is two-fold:

²The Climate Impacts Group (CIG) is an interdisciplinary research group studying the impacts of natural climate variability and global climate change (“global warming”) on the U.S. Pacific Northwest (PNW).

- To provide observational meteorological data, usually consisting of daily maximum and minimum temperatures, snowfall, and 24-hour precipitation totals, required to define the climate of the United States and to help measure long-term climate changes
- To provide observational meteorological data in near real-time to support forecast, warning and other public service programs of the NWS.

Core observations from the NWS-COOP stations include 24-hour minimum and maximum temperatures and 24-hour precipitation (rain and water-equivalent of snow fall). Additionally, observations of precipitation duration and other general climatic conditions may be recorded daily. Park personnel are responsible for recording daily measures, reporting daily measures to regional NWS offices, and reporting monthly tallies of all climatic observations to the NWS (SOP 7). The NWS-COOP stations have the longest period of record of all weather stations deployed in the NCCN and are commonly referenced for analyzing annual and long term trends. The NWS maintains all COOP weather stations. The WRCC (www.wrcc.dri.edu), located in Reno Nevada, and the NCDC (<http://www.ncdc.noaa.gov/oa/ncdc.html>) are the official repositories for NWS-COOP data.

Automated Surface Observing System (ASOS): ASOS is an automated observing system sponsored by the Federal Aviation Administration (FAA), NWS and the Department of Defense (DOD). ASOS provides weather observations which include: temperature, dew point, wind, barometric pressure, visibility, sky condition, and precipitation and are installed at airports throughout the country. Implementation of ASOS began in the mid-1990s. ASOS stations with a period of record prior to 1990 relied on manual hourly observations until the ASOS platform and sensor complement was deployed in the mid-1990s. The earlier type of hourly stations often resulted in what has been called the Surface Observation (SAO) program.

ASOS's functions include measurement of weather elements, data processing and display, communication, and data storage (archiving). The ASOS automatically collects, processes, and error checks data and formats, displays, archives, and reports the weather elements included in a surface weather observation. The ASOS also accepts inputs from observers (when present), who may override or add information to the automatically generated observation. The observing systems work continuously, updating observations every minute. By providing information on the atmosphere, these systems are designed to improve the safety and efficiency of aviation operations as well as being the key to improving forecasts and warnings. There are two ASOS stations located within NCCN parks: Pearson Airpark ASOS is located within the boundaries of FOVA and Oak Harbor Air Park is located within the boundaries of EBLA. Three ASOS stations are also located immediately adjacent to OLYM and one adjacent to LEWI. An ASOS station is also located on San Juan Island, within four miles of American Camp at SAJH.

Remote Automated Weather Stations (RAWS): Originally in support of wildland fire management, four RAWS systems operate in three NCCN park units (two in NOCA and one each in MORA and OLYM). An additional RAWS station will be added to English Camp at SAJH. The RAWS network is comprised of climate stations located on land managed by federal, state and local agencies. These stations are supported by the respective agencies and are used by fire-management personnel (including NCCN park staff) to estimate a fire-danger rating in support of preventive measures, and to forecast the behavior of wildland fires. RAWS stations

have been incorporated into NCCN climate monitoring program due to their abundance throughout the PNW, ease of maintenance and data transmission, and the ability to add an entire suite of automated sensors. RAWS stations may operate year round or only during summer months.

RAWS stations consist of automated sensors that record air temperature and relative humidity, precipitation, wind speed and direction, fuel moisture and fuel temperature. Snow depth sensors may also be added to RAWS stations. RAWS stations generally operate on low voltage solar power and are equipped with an unheated precipitation gauge. For this reason, winter and annual precipitation cannot be collected from RAWS locations where winter precipitation routinely includes snow and Alternate Current (AC) power is not available.

Data are recorded every 15 minutes and are automatically transmitted to the National Interagency Fire Center (NIFC) in Boise, Idaho via the Geostationary Operational Environmental Satellite (GOES). The GOES is operated by NOAA.

Snow Survey/Snow Course: The cooperative snow survey program was initiated in 1935 by the Department of Agricultural, Soil Conservation Service (SCS), to aid in forecasting summer water supplies. Manual snow surveys require two-person teams to measure snow depth and water content at designated snow courses. A snow course is a permanent sampling transect that represents snowpack conditions at a given elevation in a given area. A particular snowpack may have several courses. Generally, the snow courses consist of 10 sample locations, are about 300 m long, and are situated in small meadows protected from the wind. Measurements are taken on or near the first of every month during the snowpack season from January to May. Locations that are too hazardous or costly to measure on the ground can be equipped with Aerial Markers, depth markers that can be read from passing aircraft. There are two aerial marker sites at NOCA. Snow courses have been in operation in NCCN Parks (MORA, NOCA, OLYM), since as early as 1940.

The cooperative snow survey program is the pre-cursor to the Snowpack Telemetry (SNOTEL) program (see below).

Snowpack Telemetry Program (SNOTEL): In 1977, the SCS (renamed Natural Resource Conservation Service, NRCS in 1994) began developing a network of automated radio telemetry data sites for collecting snow survey data in the mountainous regions of the Western United States. This SNOTEL network provides NRCS offices with daily or more frequent information on streamflow potential. The NRCS currently installs, operates, and maintains an extensive, automated system.

SNOTEL stations provide real-time snow and climate data using automated remote sensing. Basic SNOTEL sites have a pressure sensing snow pillow (snow water equivalent), storage precipitation gage, and air temperature sensor. In addition, some SNOTEL sites are being upgraded to include soil temperature and moisture readings. On-site microprocessors provide functions such as computing daily maximum, minimum, and average temperature information. These stations are operated year round and provide useful winter and summer data to the NCCN Network. Most stations report data hourly.

The major purpose of the SNOTEL network is to aid in providing long-term climatic information to support water supply forecasting, detect short and long-term trends, and to provide basic hydroclimatic information in support of water resource management functions. The information collected by the telemetry system and snow surveyors is translated into water supply forecasts that NRCS State offices issue monthly from January to June in cooperation with the NWS. SNOTEL sites have operated in MORA, NOCA, and OLYM from as early as 1959 to the present and currently there are 10 SNOTEL sites in these parks and two modified SNOTEL in NOCA; see <http://www.wcc.nrcs.usda.gov/factpub/sntlfct1>.

U.S. Climate Reference Network (CRN): The CRN is a network of climate stations developed as part of a NOAA initiative. Two CRN climate stations are located in the NCCN, one in OLYM (2006) and one outside of NOCA (2004). The primary goal is to provide long-term observations of temperature and precipitation that can be coupled with past long-term observations for the detection of climatic change. The automated CRN stations are designed to operate over a wide range of environmental conditions but are located in areas that are anticipated to be unaffected by factors that could modify local environmental conditions (e.g., urban expansion). The final network was established as of September 2008 and consists of approximately 114 stations nationwide.

The CRN records air temperature, precipitation, ground-surface temperature, solar radiation, wind speed, and sensor performance. Data are 5 minute temperature and precipitation readings and are aggregated to 15 minute, hourly, and daily summaries. Data are automatically transmitted to the NCDC data management and processing facility in Asheville, NC. NCDC provides data ingest, quality control, data processing and archiving, and eventually distributes data to the climate research community and the public.

Clean Air Status and Trends Network (CASTNet): CASTNet is primarily an air-quality monitoring network managed by the Environmental Protection Agency (EPA). Standard hourly weather and climate elements are measured and include temperature, wind, humidity, solar radiation, soil temperature, and sometimes moisture. These elements are intended to support interpretation of air-quality parameters that are also measured at CASTNet sites. Data records at CASTNet sites are generally one to two decades in length. CASTNet sites are located in the two Class I Air Quality parks, MORA and NOCA³ and have been in operation since the 1980s.

National Weather Service (NWS) Upper Air Observations Program: Understanding and accurately predicting changes in the atmosphere requires adequate observations of the upper atmosphere. Since the late 1930s the (NWS) has measured vertical profiles of pressure, temperature, relative humidity, and wind velocity through the use of balloon-borne radiosondes. Observations from network stations are made twice daily. The NWS Upper-air Observations Program is managed by the Observing Systems Branch (OSB), which is part of NWS Headquarters located in Silver Spring, Maryland. Radiosonde observations are applied to a broad spectrum of efforts. Data applications include: input for computer based weather prediction models, local severe storm, aviation, and marine forecasts, weather and climate change research, input for air pollution models, and ground truth for satellite data.

³The NOCA CASTNet site was removed in January of 2008 due to lack of air quality funding.

The Quillayute Radiosonde is located west of OLYM and has provided data on Pacific air masses as they approach land and pass over the Olympic Mountains since 1948.

More information on the NWS Upper Air Observations Program is available on their website: <http://www.ua.nws.noaa.gov/>.

High Elevation Climate Stations – Northwest Weather and Avalanche Center (NWAC): The NWAC, administered by the USFS, maintains a network of automated high elevation weather stations primarily for avalanche forecasting (<http://www.nwac.us>). The NWAC currently maintains or assists in maintaining weather stations located in units of the NPS, Washington State Department of Transportation (WSDOT), and ski area sites throughout the Cascade Mountains. These stations provide real-time temperature, relative humidity, wind, precipitation and snowfall information automatically via phone and radio connections. The NWAC utilizes the mountain weather data to support more accurate forecasts, and cooperators utilize the information for planning, maintenance, avalanche control purposes, climate monitoring, and research applications (Moore 2004).

The NWAC operates two stations within the boundaries of the NCCN (Hurricane Ridge at OLYM and Paradise at MORA) as part of their avalanche forecasting responsibilities. The NPS (park base dollars) contributes funding to maintain these stations, provide avalanche forecasting, and on-line access to real time data.

Because of the NWAC's expertise in operating meteorological stations in high elevation areas, and the reliability of these stations in the harsh conditions found within the NCCN, the network has adapted these stations to fill several data gaps at high elevation sites within MORA. The NWAC assists MORA in maintaining two stations (Sunrise & Camp Muir) through an interagency agreement. The NPS is responsible for funding these stations, installing and maintaining the stations with the assistance of NWAC and other contractors as needed, and is ultimately responsible for data management.

In addition, two other NWAC sites operated in partnership with the WSDOT are located at Washington Pass, located just outside the eastern boundary of NOCA, and Chinook Pass, located just outside the eastern boundary of MORA. These sites are operated in cooperation between the NWAC and Washington State Department of Transportation. Another station, Crystal Mountain, is located outside the northeast boundary of MORA and is operated in cooperation between the NWAC and Crystal Mountain Ski Area. Data generated from all three sites are utilized by the parks. Due to siting criteria (see SOP 2), wind sites and precipitation sites are often located in separate locations. See SOP 2, Appendix A for information on each site. Crystal Mountain Ski Area has two precipitation sites located within the park and one wind site.

Real-time weather data and seasonal weather and avalanche forecasts are available at: www.nwac.noaa.gov. The NWAC also produces seasonal summaries, annual reports, summary climatological data, and general avalanche information. Real-time weather data and archiving of all data is available for the sites operated within NCCN parks.

The NWAC utilizes the mountain weather data to support more accurate avalanche and mesoscale mountain weather forecasts, and disseminates the information to cooperators for planning, maintenance and avalanche control purposes.

An NCCN “weather workshop” was held in April of 2003 to develop a strategy for long-term monitoring of climate within the seven NCCN parks. One of the primary goals identified at the workshop was to fill large spatial gaps and focus on higher elevations sites where data are lacking. A list of sites of high elevation weather monitoring data gaps were identified (SOP 2).

National Park Service Automated Stations (NPS Climate Stations): OLYM operates eight automated climate stations within its boundaries, many of which were initially installed by the Environmental Protection Agency’s (EPA) for studies of forest response to global climate change. The stations were installed between 1999 and 2004. Parameters measured at these stations include air temperature, humidity, precipitation, windspeed, photosynthetic active radiation (PAR), soil temperature and soil moisture. These stations are now part of the OLYM climate monitoring network and are operated by NCCN staff. An additional NPS station was installed at the Carbon River Ranger Station in MORA in February of 2008. A temporary NPS station was installed at English Camp in SAJH in 2008 until a permanent location for a RAWS station is determined. Future installation of NPS Climate Stations are proposed for NCCN parks, to fill gaps in existing climate and environmental data and to provide a comprehensive understanding of park-wide climate patterns for the interpretation of ecological studies.

Each NPS site is automated and provides at a minimum, air temperature, relative humidity and precipitation. NPS stations collect data at 5 minute intervals and record data hourly. These stations do not provide real time data, but otherwise are instrumented and deployed similar to a RAWS. Data is downloaded manually, approximately every three months. NCCN staff are responsible for managing these stations.

1.3 Rationale for Monitoring Climate

Climate is an ecosystem driver operating at multiple scales of time and space. Climate influences almost all physical and ecological processes by controlling ecosystem fluxes of energy and matter as well as the geomorphic and biogeochemical processes underlying the distribution and structure of these ecosystems (Jacobson et al. 2000, Schlesinger 1997, Bonan 2002). Long-term patterns in temperature and precipitation provide first-order constraints on potential ecosystem structure and function (Whitford 2002). Secondary constraints are realized from the intensity and duration of individual weather events and, additionally, from seasonality and inter-annual climate variability. These constraints influence the fundamental properties of ecologic systems, such as soil–water relationships, plant–soil processes, and nutrient cycling, as well as disturbance rates and intensity. These properties, in turn, influence the life-history strategies supported by a climatic regime (Neilson 1987, Garman et al. 2004).

Climate exerts such strong controls over ecological processes that it is imperative to provide accurate and spatially robust climate data for the study of natural ecosystems. For this reason, climate has been identified as a primary vital sign by all 32 Inventory and Monitoring (I&M) networks within the NPS (Gray 2008). Climate data, derived from the NCCN climate network

will play an important role in understanding and interpreting the physical and ecological processes documented by other I&M programs within NCCN parks (see Table 1.2).

Table 1.2. NCCN climate parameters relevant to selected vital signs.

Vital Sign Protocol	Climate Links
Landscape Dynamics	Snow depth, snow extent, air temperature, precipitation, windspeed, wind direction, relative humidity, soil temperature, soil moisture
Forest Vegetation	Soil temperature, air temperature, snow extent, snow depth, precipitation, soil moisture, solar radiation
Prairie Vegetation	Soil temperature, air temperature, precipitation, soil moisture, solar radiation
Subalpine Vegetation	Soil temperature, air temperature, snow extent, snow depth, precipitation, soil moisture, solar radiation
Landbirds	Snow depth, snow extent, air temperature
Elk	Snow depth, snow extent, air temperature
Large Lakes	Air temperature, precipitation
Fish Assemblages	Air temperature, precipitation, snow depth, SWE
Mountain Lakes	Air temperature, precipitation, SWE, snow extent, ice phenology, wind direction
Intertidal Communities	Air temperature, precipitation
Glaciers	Air temperature, precipitation, snow depth, snow extent, SWE

As previously discussed, global climatic change is likely to play affect future landscapes and ecosystems of the NCCN. Warming of the global climate is unequivocal. There is ample evidence of increases in global average air and ocean temperatures, of widespread melting of snow and ice, and of rising global mean sea level. Eleven of the last twelve years (1995 –2006) rank among the 12 warmest years in the instrumental record of global surface temperature (since 1850). The linear warming trend over the last 50 years (0.13 +/- 0.03°C per decade) is nearly twice that for the last 100 years (IPCC 2007). Climate records show that the Pacific Northwest has warmed about 1.0 °C since 1900, or about 50% more than the global average warming over the same period (Mote 2003). These changes are likely affecting natural system processes in the NCCN.

Climate data will provide NCCN scientists with the ability to place recent climatic events or variations into a long-term perspective and better discern affects of natural variability from global trends.

1.4 Measureable Objectives

The primary objective is to provide NCCN parks with spatial (climate zone, elevation, aspect), and temporal (monthly, seasonal, annual, decadal) data, data summaries and trends in air temperature and precipitation (including snow, snow depth, and snow water equivalent (SWE)). A secondary objective is to provide data on wind speed, wind direction, soil temperature and moisture, relative humidity and solar radiation.

1.4.1 Climate Monitoring Parameters Covered in Other NCCN Protocols

Lake Ice Phenology: Continuous temperature data loggers are used to determine ice phenology (lake ice-out/ice-in) at lakes selected for the NCCN mountain lakes monitoring program. This will provide MORA, NOCA and OLYM with spatial, annual and decadal trends in lake ice phenology (lake ice-out). Techniques for obtaining data are detailed in SOP 8 (Continuous Water Temperature Sampling) from the NCCN Mountain Lakes Monitoring Protocol (see Appendix A for details on accessing this SOP.)

Glacier Mass Balance: Glacier observations will be analyzed in detail in the NCCN glacier monitoring program. Annual data can be directly linked to climate and ecosystem changes in NCCN parks. This information will be incorporated into the Periodic (5 year) Climate Summaries.

1.4.2 Description of Climate Parameters

The NCCN climate protocol will provide the following hourly and daily data:

Primary:

- Air Temperature
- Precipitation
- Snowfall (high elevation sites)
- Snow depth (high elevation sites)
- Snow Water Equivalent (SWE) (high elevation sites)

Secondary:

- Wind Speed and Direction (select locations)
- Relative Humidity
- Soil Moisture
- Soil Temperature
- Solar radiation

Table 1.3. Summary of the parameters measured by each climate monitoring program.

Program	Air temp.	Soil Temp/ Moisture	Precip.	RH	Wind speed/ Direction	Solar Radiation	Snow Depth	Snow Fall	SWE
NWS-COOP	X		X				X	X	
RAWS	X	At some locations	X	X	X	X			
Snow Course							X		X
SNOTEL	X	At some locations	X	X			X	X	X
CRN	X		X		X ¹				
ASOS	X		X	X	X		X	X	
NWS Upper Air Program	X			X	X				
High Elevation Stations	X	X	X	X	X	X ²	X	X	
NPS Climate Stations	X	X	X	X	X	X	X		
NOCA Modified SNOTEL	X			X	X	X			

¹CRN Stations only measure wind speed, not direction and only at eye level in support of primary temperature and precipitation measurements.

²Currently no High Elevation Stations measure solar radiation. Solar radiation will be added to existing high elevation sites as funding allows.

Temperature: Air temperature is a basic parameter that affects many other climate parameters and biological processes. An electronic thermistor is used to automatically measure and record air temperature inside a naturally aspirated shield at all sites with the exception of select NWS-COOP sites. At those sites, a maximum-minimum thermometer is used to manually measure air temperature. Station equipment is listed in Appendix C.

Precipitation: Precipitation is measured as the volume and intensity of moisture deposition in liquid form. A major factor in the hydrologic cycle, the temporal and spatial variability of rainfall is recorded through a network of rain gauges.

Snow Fall: The amount of new snow since last measurement. Snowfall is measured by means of a 24-hour snow board. The snow board is measured and cleaned of snow once within a 24 hour period. An automated acoustic snow depth sensor may be used in combination with a snow board, but must be cleaned of snow within a 24 hour period.

Snow Depth: Snow depth refers to the total depth of snow on the ground. Acoustic snow depth gages, which measure the distance from the sensor to a target (in this case snow), are the primary method to measure snow depth at remote sites. The sensor works by measuring the time required for an ultrasonic pulse to travel to and from a target surface. Once the distance from sensor to snow surface has been measured, this distance is subtracted from the previously measured and stored height of the sensor above the ground, thus providing the total snow depth. Snow stakes

are used to manually measure snow depth. Snow depth is measured to the nearest whole inch or centimeter.

Snow-Water Equivalent (SWE): SWE is the amount of water contained within the snowpack and is the product of depth and density. Snow water equivalent can be presented in units of meters or feet of depth of liquid water that would result from melting the snow. SWE is determined manually using a snow tube or by melting the depth of the relevant snow pack (new or total, depending on which SWE is needed). Automated SWE observations use snow pillows, which are envelopes of stainless steel or synthetic rubber, about 4 –6 feet square or rectangular, containing an antifreeze solution. As snow accumulates on the pillows, it exerts pressure on the solution. Automatic measuring devices in a nearby shelter house convert the weight of the snow into an electrical reading of the snow's water equivalent, or the actual amount of water in a given volume of snow.

Wind Speed/Direction: Wind speed and wind direction are important to understanding the effects of storm events on the natural disturbance regime, especially wind storms. Wind direction is important for tracking storm events. It is common to measure the components of the wind vector separately; i.e., wind speed (the magnitude of the wind vector using an anemometer) and wind direction (the orientation of the wind vector using a wind vane). The rotating cup anemometer consists of three hemispherical-shaped cups mounted symmetrically about a vertical axis of rotation. The wind vane consists of a tail section attached to one end of a horizontal shaft, which is mounted on a vertical axis; the tail and shaft rotate in a horizontal plane. The wind vane measures the azimuth angle the wind is blowing from in degrees clockwise from true north.

Relative Humidity: Water vapor plays an important role in determining weather conditions. When it condenses, the result is dew, fog, rain and other forms of precipitation. Fog is an especially important component of the NCCN forested areas. A measurement of the amount of water vapor in the surrounding air is dependent upon temperature because warmer air is capable of holding much more water than cooler air. Thus, relative humidity is defined as the amount of water vapor presently in the air, divided by the maximum amount of water vapor that the air could hold, given the current temperature. The result is expressed as a percentage. Absolute humidity is defined as how much vapor is actually in the air, expressed as a ratio, or in terms of dew point. Relative humidity is temperature dependent and depends on water vapor content plus temperature.

Soil Temperature: Soil Temperature can be determined through a soil temperature probe. The two factors that greatly affect soil temperature are ambient air temperature and depth from the soil surface, however surface insulation (e.g. duff/snow), solar radiation, soil density and texture, soil moisture, and microbial processes can also contribute to differences in soil temperature. All soil temperature data will have an associated measurement of depth. Metadata is critical for the interpretation of soil climate data. Specific information about what is being measured and how must be recorded.

Soil Moisture: Soil moisture refers to the water content of the soil and is measured in two different methods: quantitatively by amount of water in the soil, and qualitatively, which is an indication of how tightly the water is held by soil particles. The NCCN measures soil moisture

quantitatively with water content reflectometers, which measure the volumetric water content of the soil (expressed as a value between 0% to saturation). All soil moisture data has an associated measurement of depth. Metadata is critical for the interpretation of soil climate data. Specific information about what is being measured and how must be recorded.

Solar Radiation: Solar radiation is a measure of the amount of sunlight reaching the earth's surface. Three types of sensors are used to measure Solar Radiation in the NCCN Climate Network: a Pyranometer, Quantum Sensor, or a Net Radiometer. Pyranometers measure total solar radiation received and includes both direct beam (global sun) and diffuse sky radiation. The wavelength range is 400 to 1100 nanometers and the unit of measurement is watts per square meter (W m^{-2}). Quantum Sensors measure a smaller portion of total radiation, the wavelength range of 400 to 700 nanometers in micromoles per second per square meter ($\mu\text{mol s}^{-1} \text{m}^{-2}$). This range is known as photosynthetic active radiation (PAR) and is a measure of the amount of radiation available for plant growth. Net Radiometers measure incoming (shortwave) radiation and outgoing (longwave) radiation and records the net difference. This instrument is primarily used for energy balance studies and is currently installed on two NCCN weather stations associated with glacier mass balance studies (Noisy Glacier and Silver Glacier).

2 - Sampling Design

2.1 Rationale for Selecting Sampling Design over Others

The goals and objectives of external (non-NPS) climate monitoring programs have dictated the numbers and locations of most weather stations in the NCCN. In most cases, a rigid sampling design was not used to locate stations. NWS-COOP stations were located based on year-round ease of access and are located in park developed areas or communities adjacent to park lands. RAWS stations are located in areas where information relevant to wildfire threats is needed. CRN stations were located as part of a larger program to establish a systematic grid of climate stations across the U.S. CASTnet weather stations are co-located with air quality monitoring stations. Most of the High Elevation stations were established near winter use areas to provide information essential for avalanche forecasting. A sampling design is more apparent for SNOTEL locations, where coverage of mountainous areas motivates station placement. However, SNOTEL site locations are focused on water uses and interest in river flow forecasting.

In April 2003, a “Climate Workshop” for the NCCN was held⁴. Atmospheric scientists and meteorologist from several agencies attended, including NOAA National Weather Service (NWS-COOP) and RAWS program managers), the Western Regional Climate Center, Natural Resources Conservation Service (SNOTEL/Snow Course and National Water and Climate Programs), Washington Department of Ecology, Washington Department of Natural Resources, EPA, Puget Sound Clean Air Agency, National Park Service (Air Resource Division), U.S. Forest Service (Northwest Avalanche Control Center), and other scientists from the University of Washington and Central Washington University. Representatives from other NCCN technical working groups also attended this workshop.

The objectives of the workshop were to develop a strategy for monitoring climate within the seven NCCN parks; integrate NPS monitoring with other programs and agencies; and develop recommendations for maintaining existing stations and locating new stations, including type of equipment and sites that would assist in refining the regional climate models being developed within the Puget Sound region. Working groups were formed to evaluate each Park’s existing climate programs and to address an overall sampling design for placement of new stations within NCCN parks. The proposals for placement of new stations were based on coverage for overall spatial and elevational gradient within the parks.

As part of a Servicewide effort to assist Networks in developing climate monitoring protocols, the Western Regional Climate Center (WRCC) prepared the report, “Weather and Climate Inventory National Park Service North Coast and Cascades Network.” (Davey et al. 2006). This project was initiated to inventory past and present climate monitoring efforts and drew largely from information already compiled by NCCN staff. The report provided an overview of broad-scale climatic factors and zones important to NCCN park units; an inventory of weather and climate station locations in and near NCCN park units; results of an inventory of metadata on

⁴A complete record of the 2003 NCCN Climate Workshop, including presentations and discussion is located on the NCCN website at <http://www.nccn.nps.gov/im/air/Weather%20Workshop/Forms/AllItems.aspx>

each weather station, an initial evaluation of the adequacy of coverage for existing weather stations and recommendations for improvements in monitoring weather and climate.

Davey et al. (2006) recommended that the primary goal for placement of additional stations should be characterization of the main climate elements (temperature and precipitation, including snow) across the major biomes of each park. The report noted that high-elevation zones were under-represented and yet highly valuable to understanding the characteristics of NCCN alpine ecosystems. Despite the higher maintenance costs of these sites their applications include hydrologic studies and responses of high-altitude ecosystems to climate change, particularly the status of the region's abundant glaciers.

2.1.1 MORA, NOCA, OLYM

Climate stations are sparsely distributed across the larger NCCN park units. Although additional sites have been installed since the original study, the report determined that it would be cost-prohibitive to install a sufficient number of sites to adequately describe the fine-scale climatic patterns over a park's landscape, particularly the three large parks where topography is complex. Therefore, a coarse scale sampling design was suggested with the option of introducing additional sites as the funding and opportunities arise. Existing and proposed NCCN stations included in this protocol are presented in Fig. 2.1.

The response of glaciers to climate change is of particular importance at MORA, NOCA, and OLYM, due to the extensive land area covered by glaciers, about 5%. At present, there are significant tracts of montane and alpine areas in the larger parks that have very little or no reliable weather/climate station coverage, including interior and southeastern OLYM, northern NOCA and northern MORA. These areas are often adjacent to areas just outside parks that have at least one or two automated stations (both RAWS and SNOTEL). Despite this, the topographic complexity of the larger NCCN parks lowers the representativeness of any nearby stations, particularly for spatial precipitation patterns. Therefore, as resources allow, and as recommended in Davey et al. (2006), the NPS will seek to partner with the NRCS to install at least one enhanced SNOTEL station in each of these areas.

2.1.2 SAJH, EBLA, FOVA, LEWI

The Workshop group and Davey et al. (2006) determined that the NCCN parks located along the Columbia River (FOVA, LEWI) and the Puget Sound region (EBLA, SAJH) generally have sufficient station coverage to determine climate trends. Reliable real-time weather observations are provided by ASOS stations at airports near most of these parks. It is important that the existing manual COOP sites with long data records that are near these park units be retained for the purpose of long-term climate monitoring. The NPS would likely benefit by working with the local NWS offices (Portland, Seattle) to encourage the continued operation of these stations.

SAJH: Of the smaller NCCN park units, SAJH has the least sufficient spatial coverage of weather/climate stations. There are no long-term climate records on San Juan Island, where SAJH is located. The longest data record on San Juan Island is at the ASOS station at Friday Harbor Airport, providing about 25 years of data. The closest long-term records are from NWS-COOP stations that are almost 30 km away and are located either on different islands (e.g. Olga 2 SE) or on the mainland (e.g., Anacortes). Despite their not being located on San Juan Island, these two stations provide the best long-term records for the SAJH region. Two ASOS stations in

Canada (Patricia Bay, Victoria Gonzales Heights) also provide long data records, although they are somewhat shorter in length than the NWS-COOP stations previously mentioned. The ASOS station on San Juan Island (Friday Harbor Airport) provide the most applicable weather observations for SAJH and is located near the American Camp unit of SAJH. The Workshop group recommended, and Davey et al. (2006) concurred, that an additional station be considered for placement on the northwest side of the park at English Camp. A RAWS station has been purchased and will be operational by 2010 in this location.

EBLA: Ebey's Landing National Historical Reserve has two weather/climate stations located within its boundaries. One of these is a long-term COOP station (Coupeville 1 S) while the other is an ASOS station at Oak Harbor Air Park. The COOP station "Coupeville 1 S" has a fairly complete data record. The ASOS station (Oak Harbor Air Park) has provided data since 1981 and is a reliable source of near-real-time data for EBLA.

In addition to these two stations, we have identified 27 active stations within 30 km of EBLA. Of these stations, six are COOP stations and five are ASOS stations. The longest data record among the active COOP stations is found at "Port Townsend", a station that is directly across Admiralty Inlet from EBLA (10 km southwest of EBLA) and has been in operation since 1891. A significant portion of this data record is missing in the late 1960s and early 1970s. Occasional data gaps of one to three months have occurred during the fall about once every 5–10 years. In general, the data record at Port Townsend has been quite reliable for the past 15 years. One ASOS station exists within 30 km of EBLA (Whidbey Island NAS) and has provided data since 1943. The data records for the other three active SAO stations around EBLA are much shorter but are still respectable, ranging from 25 years up to 43 years in length.

EBLA has satisfactory station coverage (Davey et al. 2006). Reliable real-time weather observations are provided by ASOS stations at airports near the park. NPS will work with the NWS to ensure that the existing manual COOP sites with long data records that are near EBLA s be retained for the purpose of long-term climate monitoring.

FOVA: One station exists within the boundaries of FOVA (ASOS station "Vancouver Pearson Airport") and has operated since 1981. Due to its location in the urban areas of Portland, Oregon and Vancouver, Washington, FOVA has several stations that provide high-quality data within 10 km of the park unit. The COOP station "Vancouver 4 NNE" has the longest data record of the weather/climate stations we have identified for FOVA. This station is about 6 km north of FOVA and has been operating since 1856. The data record for "Vancouver 4 NNE" is very complete, with virtually no data gaps. Portland International Airport, about five kilometers southeast of FOVA, has a COOP station and an ASOS station. Both of these sites have been operating since 1926 and provide data records that are of high quality. The ASOS station has provided automated data for the last few decades.

LEWI: LEWI has one weather/climate station located within its boundaries. This is a COOP station located in Fort Clatsop and it has been operating since 1998. Five other COOP stations are currently operating within 30 km of LEWI. The COOP station "Astoria Regional Airport", about five kilometers north of LEWI, has been operating since 1899 and has a complete data record. The best source of automated weather data for LEWI is an ASOS station which has been

operating at this same location since 1993. The COOP station “Seaside”, about 20 km southwest of LEWI, has operated since 1930 and has a reliable data record.

2.2 Site Selection

As discussed in Section 2.1, the primary goal for climate site selection should be the characterization of temperature and precipitation, including snow) across the major biomes of each park. In addition, the NCCN Climate Workshop group and Davey et al. (2006) provided the following guidance for selecting new sites to fill existing data gaps.

2.2.1 OLYM

Workshop participants and Davey et al. (2006) noted a lack of precipitation and temperature data on the west side of the park at higher elevations (3,500–5,500 ft.). Installation of several SNOTEL stations would help to characterize the precipitation that occurs on the very wet crest of the Olympic Mountains. Chris Daly, a primary author of the PRISM model suggested a site in the park interior on the leeward side of the crest would further characterize the steep precipitation gradient found in the Olympics. The Workshop participants also recommended that an already existing network of RAWS weather stations (currently used in the summer for fire weather forecasting) could fill many of the spatial low elevation gaps, but it would be necessary to negotiate winter operation of these sites with local USFS, DNR and tribal operators. Buckinghorse SNOTEL, located near the interior of OLYM, was installed in 2008.

2.2.2 NOCA

The Workshop group and Davey et al. (2006), recommended that at least one site in the northern area of the park be enhanced to a full SNOTEL station to augment the existing temperature and precipitation data already collected at these sites. Easy Pass and Browntop snow courses were both upgraded to full SNOTEL sites in 2008 and 2009, respectively. In addition, the Workshop group recommended that additional climate stations be installed to represent high elevations in the northern section of the park. Modified SNOTEL sites were installed at the Silver Glacier (2008) and Noisy Glacier (2009) specifically to provide accurate local data to help researchers further understand glacier response to climate variations and also to provide high elevation weather data.

2.2.3 MORA

The Workshop group recommended enhancing existing weather sites and additional representation of high elevation, northwest and northeast side weather data as high priorities at MORA. For example, there is a USGS operated weather station which recorded only snow water equivalent that could be upgraded to a full SNOTEL site. USGS discontinued operation of the site in 2005. This site was upgraded to a full SNOTEL by the NRCS in fall of 2007. High elevation sites were installed at Sunrise (2005) and Camp Muir (2006).

2.2.4 SAJH

An NPS operated RAWS station is proposed for the English Camp area of SAJH. A temporary NPS operated station was installed in 2008 until a permanent location for a RAWS is determined.

2.2.5 EBLA, LEWI, FOVA

No additional sites are proposed.

2.3 Sampling Frequency and Replication

Table 2.1 shows the sampling frequency for data collected at each station type. At a minimum, daily data will be available from all climate sites. Station replication for sites located within park boundaries is presented in Table 2.2.

Table 2.1. Sampling frequency by station type.

Program/Station	Data Collection Frequency	Download	Reported
NWS COOP	Once per day (24 hours)	Daily	Daily, monthly, annually
RAWS	Hourly	Automated	Hourly
SNOTEL	Hourly	Automated	Hourly
Snow Course	January to May. Years with heavy snow fall may require monitoring to commence in November	n/a	Monthly, annually
NWAC-NPS	Hourly	Automated	Hourly
NPS	Hourly	Every 3 months	Annually or as needed
ASOS	Hourly	Automated	Real-time
NPS Upper Air Program (Radiosonde)	Twice per day	Daily	Monthly

Table 2.2. Replicated sites in the NCCN.

Park	Site Name	Program	General Location	Elevation (ft)
MORA	Paradise	NWS-COOP, SNOTEL, High Elevation	South side	5,500
MORA	Ohanapecosh	RAWS NWS-COOP	Southeast side	1,900
NOCA	Marblemount	NWS-COOP, RAWS, CASTNET, CRN	West side	357
NOCA	Hozomeen	SNOTEL RAWS	Northeast	1,700
OLYM	Hurricane Ridge	NWAC RAWS SNOTEL	North	5,200

2.4 Recommended Number and Location of Sampling Sites

Figure 2.1 shows the number and location of existing and proposed stations within NCCN Parks. Proposed stations are in yellow.

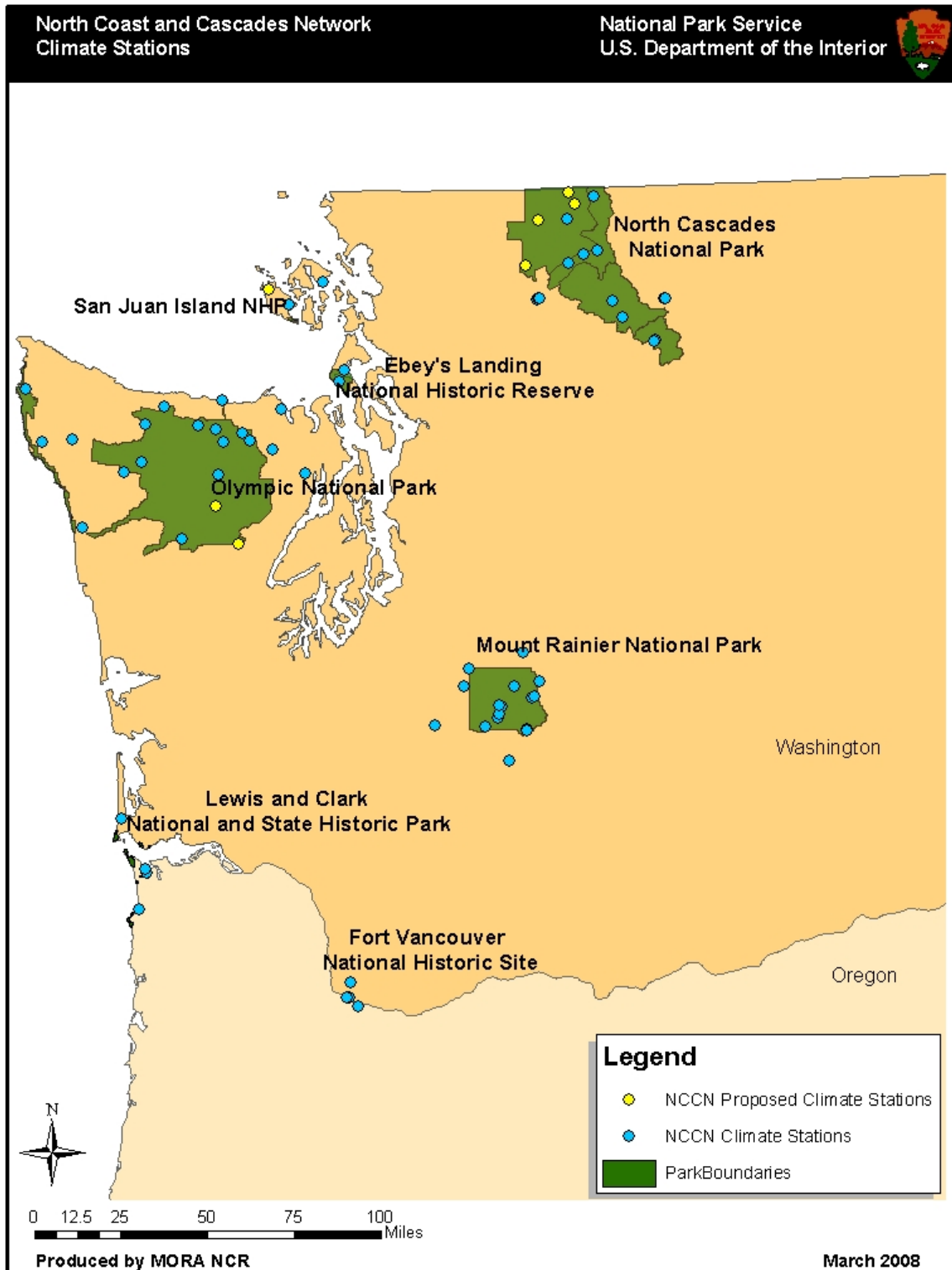


Figure 2.1. NCCN Stations included in the climate monitoring protocols. Proposed stations are in yellow.

Table 2.3 lists the existing and proposed stations providing data directly relevant to the NCCN Climate Monitoring Protocol. The highest priority sites proposed for installation are in *italics*.

Table 2.3. Existing and proposed climate stations to be included in the NCCN climate monitoring protocol (Station in *italics* are not installed).

Name	Network	Air Temp	Precipitation	Relative Humidity	Soil Temp Soil Moisture	Wind Speed/ Direction	Snow Depth	SWE	Solar Radiation
MORA									
Longmire	COOP	X	X				X		
Paradise Ranger Station	COOP	X	X				X		
Ohanapecosh	COOP		X						
Rainier Carbon River	COOP		X						
Carbon River	NPS	X	X	X	X	X	X		X
Packwood	COOP	X	X				X		
Tahoma Woods	CASTNET	X	X	X		X			X
Ohanapecosh	RAWS	X	X	X		X			X
Paradise	SNOTEL/	X	X				X	X	
	Snow Course								
Cayuse Pass	SNOTEL/	X	X				X	X	
	Snow Course								
Mowich	SNOTEL	X	X				X	X	
Huckleberry	SNOTEL	X	X				X	X	
Paradise High Elevation Site	NWAC	X	X	X		X	X		
Camp Muir High Elevation Site	NPS/ NWAC	X		X		X			
Sunrise High Elevation Site	NPS/ NWAC	X	X	X	X	X	X		
Crystal Mountain	NWAC	X	X	X	X	X	X		
Chinook Pass	NWAC	X	X	X	X	X	X		
NOCA									
Newhalem	COOP	X	X				X		
Diablo Dam	COOP	X	X				X		
Ross Dam	COOP	X	X				X		
Marblemount Ranger Station	COOP		X						
Stehekin	COOP	X	X				X		
Darrington 21 NNE	CRN	X	X			X			X
Hozomeen	RAWS	X	X						
Marblemount	RAWS	X	X	X		X			X
Stehekin	RAWS	X	X	X	X	X			X
Beaver Pass	SNOTEL/	X	X				X	X	
	Snow Course								
Park Creek Ridge	SNOTEL/	X	X		X		X	X	X
Thunder Basin	Snow Course								
	SNOTEL	X	X				X	X	

Table 2.3. Existing and proposed climate stations to be included in the NCCN climate monitoring protocol (continued). (Stations in *italics* are not installed).

Name	Network	Air Temp	Precipitation	Relative Humidity	Soil Temp Soil Moisture	Wind Speed/ Direction	Snow Depth	SWE	Solar Radiation
Hozomeen Camp	SNOTEL/ Snow Course	X	X				X		
Brown Top Mountain	SNOTEL/ Snow Course	X	X		X		X	X	
Beaver Creek Trail	SNOTEL/ Snow Course						X	X	
Easy Pass AM	SNOTEL/ Snow Course	X	X		X			X	
Meadow Cabins	SNOTEL/ Snow Course						X	X	
Mt. Blum AM	SNOTEL/ Snow Course						X	X	
Granite Creek	SNOTEL/ Snow Course						X	X	
Washington Pass	NWAC/ WADOT	X	X	X		X	X		
Noisy Glacier	Modified SNOTEL	X		X		X			X
Silver Glacier	Modified SNOTEL	X		X		X			X
OLYM									
Hurricane Ridge	NWAC	X	X	X		X	X		
Hoh Ranger Station	COOP	X	X				X		
Elwha Ranger Station	COOP	X	X				X		
Sequim	COOP	X	X				X		
Forks	COOP	X	X				X		
Clearwater	COOP	X	X				X		
Port Angeles	COOP	X	X				X		
Quillayute State Airport	COOP	X	X				X		
Quinault 4 NE	CRN	X	X			X			
Quillayute	Radiosonde	X		X		X			
Quillayute State Airport	ASOS	X	X	X		X	X		X
Cougar Mountain	RAWS	X	X	X		X			X
Waterhole	SNOTEL	X	X				X	X	
Mt. Crag	SNOTEL	X	X				X	X	
Deer Park	Snow Course						X	X	
Hurricane	Snow Course						X	X	
Cox Valley	Snow Course						X	X	
Bunch Field Quinault	NPS	X	X	X	X	X			
Hoh Valley	NPS	X	X	X	X	X			
Waterhole	NPS	X	X	X	X	X	X	X	X

Table 2.3. Existing and proposed climate stations to be included in the NCCN climate monitoring protocol (continued). (Stations in *italics* are not installed).

Name	Network	Air Temp	Precipitation	Relative Humidity	Soil Temp Soil Moisture	Wind Speed/ Direction	Snow Depth	SWE	Solar Radiation
Lake Crescent	NPS	X	X	X		X	X		
Ozette R.S.	NPS	X	X	X	X	X	X		
Deer Park Ranger Station	NPS	X	X	X	X		X		
Deer Park Road	NPS	X	X	X	X	X	X		X
Upper Elwha Valley(Hayes R.S.)	NPS	X	X	X	X	X			X
<i>Staircase R.S.</i>	<i>NPS</i>	X	X	X	X	X	X		X
Buckinghorse Ridge	SNOTEL	X	X				X	X	
LEWI									
Astoria Regional Airport	ASOS	X	X	X		X	X		X
Fort Clatsop	COOP	X	X				X		
Astoria Regional Airport	COOP	X	X				X		
Seaside	COOP	X	X				X		
Long Beach Exp. Station	COOP	X	X				X		
FOVA									
Vancouver, Pearson Airpark	ASOS	X	X	X		X	X		X
Portland International Airport	ASOS	X	X	X		X	X		X
Vancouver 4 NNE	COOP	X	X				X		
Portland WSFO	COOP	X	X				X		
Vancouver Interstate Bridge	COOP	X	X				X		
EBLA									
Oak Harbor Airpark	ASOS	X	X	X		X	X		X
Coupeville	COOP	X	X	X		X	X		X
SAJU									
Friday Harbor Airport	ASOS	X	X	X		X	X		X
Olga 2 SE	COOP	X	X				X		
<i>English Camp</i>	<i>NPS or RAWS</i>	X	X	X		X			X

2.4.1 Proposed Sites:

Table 2.4 identifies the additional sites recommended by the NCCN Climate Workshop and in the Weather and Climate Inventory for the NCCN (Davey et al., 2006). Funding is available for only the high priority sites (in bold). Lower priority sites are also listed. If additional funds become available, these stations may be installed.

The NCCN will continue to encourage cooperative partnerships with other agencies to support climate monitoring in our parks. OLYM will work to coordinate year round operation of summer operated RAWS stations surrounding the Park that fill high priority gaps.

Full met includes all year temp, precipitation (tipping bucket, heating precipitation gage, snow depth where applicable), relative humidity, wind speed and direction, soil temperature, and soil moisture. **Basic weather** (NOCA) includes year temperature, snow depth, and radiation, summer wind speed and direction. Snow density is measured in spring with glacier visit.

Three stations were installed at MORA as part of the protocol testing phase. These include Sunrise (representing the northeast portions of the park), Ohanapecosh (southeast), and Camp Muir (high elevation). As of 2009, all high priority sites (in bold) have been installed with the exception of Staircase at OLYM and a permanent RAWS or NPS climate station at English Camp.

Table 2.4. NCCN climate monitoring stations recently installed or proposed. The highest priority sites are listed in **bold**.

Site Name	Data Type	Represents	Comments
MORA			
Camp Muir	Full met. (High Elevation Station)	High elevation	Installed in 2006
Carbon	Upgrade to full met and automate (NPS Climate Station)	Low elevation North west	Installed 2008
Cayuse Pass	Upgrade to full SNOTEL site	Mid elevation East	Upgraded by NRCS in 2007
Ohanapecosh	Full met. (RAWS)	Low elevation Southeast	Installed 2005
Sunrise	Full met. (High Elevation Station)	High Elevation Northeast	Installed 2005
Longmire	Automate station	Low elevation South west	Manual NWS Coop Station in operation since 1931
Mowich	SNOTEL	Mid elevation, West side	
Schurman	Full met. (High Elevation Station)	High elevation	
Summit	Temperature (Hobo)	High elevation	
White River	Full met. (NPS Climate Station)	Low elevation, North east	
NOCA			
Brown Top Mountain	Basic Weather SNOTEL	Mid elevation central	Funded by Seattle City Light. Upgraded 2009
Easy Pass	Basic Weather SNOTEL	High Elevation West slope	Funded by Puget Sound Energy. Upgraded 2008
Noisy Glacier	Basic weather Modified SNOTEL	High elevation west slope	Funded by Seattle City Light. Installed 2008
Silver Glacier	Basic Weather Modified SNOTEL	High elevation Central	Installed 2009
Washington Pass	NWAC	High elevation East slope	Funded by WADOT Installed 2005
Hozomeen	RAWS	low elevation central	Installed; cost-share with NIFC
OLYM			
Buckinghorse Ridge	SNOTEL	High elevation West/Interior	Funded through NRCS and installed 2008
Staircase	Full met. (NPS Climate Station)	Low elevation Southeast/Interior	
Upper Elwha (Elkhorn/Hayes R.S.)	Full met. (NPS Climate Station)	Mid elevation, East/Interior	Funded and installed
Anderson Glacier	Basic Weather SNOTEL	High elevation, East side/Interior	
Dosewallips or Supplement Mt. Crag	Full met. (NPS Climate Station)	Mid elevation East slope/Interior	
Kalaloch	Full met. (NPS Climate Station)	Low elevation/Coastal West side	
Ozette	Full met. (NPS Climate Station)	Low elevation, West side Coastal	Funded and installed
SAJU			
English Camp	RAWS or NPS	English Camp (northwest)	RAWS purchased Temporary NPS station installed 2008

2.5 Detecting Change

Spatial variation will be described using climate stations distributed across the NCCN park unit, which are sparsely distributed and provide point-based measures of climate. As previously discussed, measures from the existing network of climate stations will not fully capture the inherent climate variability over a park's landscape. With local variations across short horizontal and vertical distances, topography introduces considerable fine-scale structure to mean climate (temperature and precipitation). Issues encountered in mapping mean climate are discussed in Davey et al. (2006) and in Redmond et al. (2005). Although these data are of value, they do not necessarily provide a means to interpolate climatic patterns over a park's landscape. Therefore, by design, this protocol pertains to monitoring coarse-scale climatic conditions.

Data from climate stations with initially short-term records will be related to existing stations which have a long period of record and which will allow trend detection on a monthly, seasonal and annual basis. Collectively, NCCN climate-station data will offer important insights into sub-regional trends in climate. Some stations such as the NWS-COOP stations provide an important record of historical trends and a basis for evaluating climatic extremes and change. One of the most important uses of climate data will be to explain interannual variation in measurements from other protocols – a use that does not require detecting trend.

3 - Field Methods

3.1 Equipment Setup, Maintenance, and Inspection

Seasonal preparations and equipment setup are minimal given that most climate stations are operated year round. Maintenance and calibration of climate stations tend to be the responsibility of external agencies (Table 3.1) except NPS operated stations. RAWs stations are typically maintained and operated by park staff and do require seasonal set-up preparations and checks if they are not operated year round.

Data from NWS-COOP and SNOTEL stations are consistently monitored by NWS and NRCS, respectively, to determine aberrant values and possible equipment malfunction. NRCS has a maintenance staff to support SNOTEL stations. Park staff are responsible for daily readings and minor maintenance of NWS COOP stations. Otherwise, regional NWS representatives service these stations. Both programs require agency representatives to inspect climate stations once a year. CRN stations are supported and monitored by NOAA in Asheville, NC. A park representative is contacted to resolve minor problems; otherwise NOAA specialists maintain CRN stations. The NWAC monitors data consistently and performs maintenance and calibration as necessary.

Following is a more detailed summary of individual program maintenance and inspection schedules

3.1.1 NWS-COOP Stations

Stations are established, supervised, and inspected by NWS personnel. Biannual visits to cooperative stations are made for the purpose of observer training, equipment maintenance verification of station forms, and network integrity.

Routine maintenance performed by the cooperative observer is described in SOP 7 Cooperative Handbook Number 2. Instruments and equipment furnished to the station should be maintained in accordance with instructions for each instrument.

Damaged or defective Weather Service equipment and instruments are reported by the cooperative observer to the NWS representative, who will then inform the observer about arranging for the repair or replacement of the equipment and/or instruments.

See Appendix B and C for individual site information and instrument standards for NWS-COOP stations.

3.1.2 RAWs

RAWs stations located in the NCCN Parks require maintenance by park staff prior to the beginning of each fire season. Standardized procedures for the inspection and checkout are provided on the Interagency RAWs web page (www.fs.fed.us/raws) under Field Guide and Tech Notes Forms. Standard Operating Procedure 5 contains instructions, or details to obtain instructions, for the following procedures: pre-inspection and inspection; programming the Data Collection Platform; accessing the Automated Sorting, Conversion and Distribution System (ASCADS), which is used to record sensor performance. In addition, see SOP 5 for information

on the National Wildlife Coordinating Group, National Fire Danger Rating System (NFDRS) weather station standards.

During operation of RAWS stations, equipment malfunction is reported by National Interagency Fire Center (NIFC) to a park contact (e.g., a member of the fire management team), typically through the ASCADS. Park staff are responsible for immediate resolution of equipment problems. Malfunctioning sensors are returned to the RAWS Depot Repair Facility for repair and calibration at no cost. The RAWS Depot Repair Facility maintains a centralized rotatable pool of RAWS component parts and modules. For more information, see SOP 5.

The RAWS program does support on-site maintenance for RAWS stations with an associated cost. This may be a viable option in the future depending on funding and NPS staff availability.

See Appendix B and C for individual site information and instrument standards for RAWS stations.

3.1.3 CRN

At a minimum, there is at least one scheduled annual maintenance visit to each site. This visit includes routine and corrective equipment maintenance and instrument field calibration, diagnosis, replacement, and repair. Sensor and system performance is routinely monitored and evaluated by NCDC personnel and partners through the examination and analysis of the hourly data transmitted from the site and the Summary of the Day (SOD) statistics. Malfunctioning and damaged equipment and instruments are repaired or replaced, typically within a few days (SOP 8-b)

Preventive maintenance includes:

- Monthly: Instrument cleaning, inspect for physical damage, etc. 1,000 ml precipitation gauge calibration verification.
- Annually: Re-calibration and refurbishment in accordance with the Schedule (Annual) Maintenance Checklist (see SOP 8 Field Site Maintenance,).
- As Needed: Emptying of the precipitation gage upon reaching a predetermined threshold or in advance of a significant predicted rainfall event (see SOP 8 of Field Site Maintenance).

See Appendix B and C for individual site information and instrument standards for CRN stations.

3.1.4 ASOS

Overall site maintenance is provided for by the ASOS Automated Operations and Monitoring Center (AOMC). The AOMC is part of the Systems Operations Center. The AOMC provides around-the-clock operational and maintenance support for ASOS.

Maintenance of ASOS equipment is accomplished following authorized guidance (e.g., technical manuals, modification notes, maintenance notes). Centralized web access to ASOS technical information (i.e., maintenance procedures, technical documentation, modification and

maintenance notes) is provided at: <http://www.weather.gov/asos/>. The ASOS User's Guide and NWS, ASOS Maintenance (SOP 9) are included in this protocol to ensure accessibility.

See Appendix B and C for individual site information and instrument standards for ASOS stations.

3.1.5 NWS Upper Air Radiosonde Balloon

It is the National Weather Service overall responsibility to ensure that all aspects of the station's operations run smoothly. The Observing Systems Branch monitors upper-air station performance through analysis of operational soundings, flight summary data, and reports prepared by the National Centers for Environmental Prediction (NCEP) and the NCDC. For checking data quality, NCEP uses computers to compare the actual upper-air data received from an upper-air station with that generated from a 6-hour numerical weather prediction model. When problems are identified, the station or radiosonde manufacturer is notified and corrective action is taken if necessary. The on-site observer is also responsible for a certain amount of data accuracy.

Additional observation and maintenance instructions are described in the National Weather Service Observing Handbook No. 10 (SOP 10). General information about radiosonde data is available in the Federal Meteorology Handbook No. 3 (OFCM 1997, <http://www.ofcm.gov/fmh3/fmh3.htm>).

See Appendix B and C for specific site information.

3.1.6 SNOTEL/Snow Course

Stations are established, maintained and inspected by NRCS personnel. See Appendix C for individual site information and instrument standards for SNOTEL and snow course stations.

3.1.7 High Elevation Stations

The NWAC maintains and operates previously existing stations within the NCCN Parks (Paradise, MORA and Hurricane Ridge, OLYM). The NWAC, along with their partners, operate and maintain the Crystal Mountain, Washington Pass, and Chinook Pass stations (all MORA). Mount Rainier National Park is responsible for the maintenance and operation of the Sunrise and Camp Muir high elevation weather stations, and utilizes park staff, contractors and partners to maintain these stations.

Although these systems are automated, they need human oversight and continued attention to provide the quality of data that will be useful for creating a long term climate record. For high quality output, a maintenance visitation schedule of at least twice/year (fall and spring) is recommended, with other repair or maintenance trips scheduled as needed.

The most effective method for determining problems is to monitor station data on a regular basis and compare such data with other nearby stations or with NWS radiosonde sounding, Aircraft Communication Addressing and Reporting System (ACARS) information or forecast model data. For more specific information see SOP 2, High Elevation Climate Stations.

3.1.8 NPS Climate Stations

All NPS stations are installed and maintained by NPS Park staff. Stations are visited on a quarterly basis (every 3 months) with additional visits as required for emergency repairs. Data from NPS stations must be manually downloaded on site. To ensure high quality data and limit data loss, it is important that these remote stations receive regular inspection and maintenance. For specific information see SOP 1, NPS Climate Stations.

Table 3.1. Personnel responsible for recording and reporting climate data, and maintaining climate stations.

Climate Network	Observation Recording and Reporting: Responsible Personnel	Maintenance and Calibration	
		Frequency	Responsible Personnel
NWS-COOP	Park Staff (Ranger Division)	Twice per Year	Regional district NWS staff, Park Ranger Division staff
RAWS	Automated recording and transmission	Once per year at the minimum.	Park Natural Resource Division and Wildland Fire staff/fire – management staff
Snow Course	Park Staff (Ranger Division and Natural Resource Division)	Monthly (Feb 1–May 1)	Field measurements: NPS (Ranger and Natural Resource Division)and USDA-NRCS staff
SNOTEL	Automated recording and transmission	3–4 times/year at NOCA; 2/year at MORA and OLYM	NRCS
CRN	Automated recording and transmission	Once per year	NOAA, Park Natural Resource Division staff
ASOS	Automated recording and transmission	Once per year	NOAA
NWS Upper Air Program	Automated recording and transmission	Continuous	NWS
NWAC – High Elevation Stations	Automated recording and transmission	Two times/year	Park Natural Resource and Maintenance staff, NWAC
Park Climate Stations	Automated recording. Park Staff Manual data download.	Quarterly (every 3 months)	Park Natural Resource Division staff

3.2 Observation Methods and Data Transmission

Observations for all station types except NWS-COOP and Snow Course are automated.

3.2.1 NPS Climate Stations

Data are manually downloaded by NPS staff from dataloggers in the field. Detailed descriptions for each method are available in SOP 1, NPS Climate Stations. Upon return from the field, raw data files are immediately transferred from portable devices to park network drives (which are backed up daily). Climate data originating at NPS operated stations follows a standard data handling procedure which includes several layers of quality assurance review and documentation (SOP 1, NPS Climate Stations). Table 3.2 describes the timing of these activities.

Table 3.2. Field activities for managing NPS climate stations.

Period	Activity Highlights Performed by Natural Resource Division staff
October 1 to November 15 th	“Pre-winter” Site Maintenance Download final data for last water year Change, check or supplement batteries Calibrate snow depth sensor
January 1 to February 15 th	Site Maintenance Download data for last calendar year
April 1 to May 15 th	Site Maintenance Download data Tipping Bucket calibration Equipment change-out (Factory Calibration)
July 1 to August 15 th	Site Maintenance Download data Equipment change-out (Factory Calibration)

3.2.2 High Elevation Stations

Data from High Elevation Mountain Weather sites are downloaded in the field, accessed remotely (automated) via phone telemetry using a phone modem, or accessed remotely through a combination of RF (radio frequency) communication to a phone modem. Automated data transmission allows the user to view the data real-time and display data on-line for multiple users. The three types of data transmission are defined as Direct Connection, Phone Modem, and Phone to RF. Data are backed up daily. Detailed descriptions for data download and standard data handling procedures are described in SOP 2, High Elevation Climate Stations.

Table 3.3. Field activities for managing NPS high elevation stations.

Time Frame	Activity
Weekly	Monitor station data on a regular basis and compare such data with other nearby stations, with National Weather Service balloon sounding or forecast model data. Utilize Northwest Weather and Avalanche Center to analyze the data for potential problems.
6 months	Download data from datalogger Clean debris from precipitation gage Clean the radiation shield Check wind speed/direction sensor Clean the enclosure Replace desiccant in enclosure
Annual	Calibrate temperature/relative humidity sensor Calibrate snowdepth sensors Replace Glycol Ethanol (see SOP 2, Appendix K for instructions)
2–5 Years	Replace temperature/relative humidity sensor Replace batteries Calibrate precipitation gauge Calibrate the datalogger. Check with Campbell Scientific
5–10 Years	Replace soil temperature probes Replace wind speed/direction sensors Replace sensors and sensor cables as necessary
General Maintenance	Inspect station Check sensor leads for damage Ensure tower is straight and stable Check alignment of antenna Clean glass on solar panel

3.3 Details of Taking Measurements

3.3.1 Snow Course

Snow Course sites in the NCCN are monitored once a month, generally from January to May. Years with heavy snow fall may require monitoring to commence in November. Snow surveys are conducted along transects (snow course) that were established when the snow course measurement were initiated at the particular site. Snow depths and snow-water equivalents are measured. Procedures, equipment lists, and example data sheets for snow course measures are documented in SOP 6. Data sheets are sent to NRCS monthly or at the end of the snow season. The data are archived by NRCS, and made available on the NRCS Snow Course web page: (<http://www.wcc.nrcs.usda.gov/snowcourse/>)

3.3.2 NWS-COOP Stations

Observer-based NWS-COOP stations require manual recording of climate observations on a daily basis. Although some of these stations have electronic instrumentation, they lack automated transmission capability. Daily observations are obtained by park personnel by directly reading instruments (e.g., min-max thermometers), by reading digital displays connected to electronic sensors, and by manual measurements (e.g., using a snow stick to measure snow depth and a dipstick to measure rainfall). Procedures for the calibration and maintenance of equipment, for

reading instrumentation, and for manual measurements are provided in the NWS Observing Handbook No. 2 (July 1989) (see SOP 7).

An updated procedure for measuring snow attributes was published in 1996, and is included as SOP 7. Daily measures are recorded on a NWS paper form. Stations without an evaporation pan record observations on NWS Form B91 (SOP 7). With few exceptions, 24-hour temperature and precipitation observations are immediately reported after manual field measurements are completed to designated regional offices of the NWS.

Two transmission methods are employed in the NCCN. Observations are transmitted by phone to a recording device or entered into a NWS web-page (WXCODER III). Both of these methods prompt the observer for specific information, and thus do not require specific SOPs for operation. The monthly summary of daily measures is distributed to a designated regional office of the NWS. Forms B91, B92 are mailed or uploaded in WXCODER by the 3rd of the following month. Punch tapes from the Belfort Rain Gauge (B18) are mailed by the 15th of the following month. NCDC eventually receives all monthly reports, transcribes the data from paper copies to electronic data bases (where necessary), archives the data, and distributes error-checked daily values to cooperating agencies (e.g., regional climate centers, national parks).

3.3.3 RAWS

RAWS units collect, store, and forward data to a computer system at the National Interagency Fire Center (NIFC) in Boise, Idaho via the Geostationary Operational Environmental Satellite (GOES). Data are recorded every 15 minutes. The GOES is operated by the NOAA. These data are automatically forwarded to several other computer systems including the Weather Information Management System (WIMS) (<http://www.fs.fed.us/fire/planning/nist/wims.htm>) and the Western Regional Climate Center in Reno, Nevada (www.wrcc.dri.edu). Other Automated Weather Stations (AWS) transmit their data to the WIMS system via phone telemetry.

WIMS is the host site for the National Fire Danger Rating System (NFDRS), and is designed to manage forestry weather information nationwide, to maintain fire weather, and for purposes of fire-danger rating forecasting. Support personnel for WIMS are the US Forest Service, National Information Systems Team Support Group in Boise, Idaho, located at NIFC. The WRCC is the official repository for RAWS data.

3.3.4 SNOTEL

Data are transmitted to two master receiving stations using a meteor burst communication technique. This technique involves bouncing Very High Frequency (VHF) signals off gas trails of meteors that disintegrate in the 50–80 mile high region of the atmosphere. Master stations located near Boise, Idaho, and Ogden, Utah, receive the data and transmit it to the Central Computer Facility of the National Water and Climate Center located in Portland, OR. Once on CFS, the data are in a relational database, where various analysis and graphics programs are available. Current and historical data and analyses are available by dialing in to the CFS, by disk or tape media, paper copy, or more recently via NRCS homepage and internet: www.wcc.nrcs.usda.gov/snotel.

3.3.5 CRN

Precipitation data, recorded every five minutes, and the other hourly observations are collected and stored in a data logger attached to the tower. These data are transmitted within a few minutes after each hour via a GOES satellite transmitter for further delivery to the National Climatic Data Center (NCDC), Asheville, NC. Summary of the Day (SOD) statistics will be computed operationally at the NCDC. Data undergo a quality control check and are placed on the internet several times a day (SOP 8).

3.3.6 ASOS

The Data Collection Platform (DCP) processes weather data received from the ASOS weather sensors and transfers the data to the Acquisition Control Unit (ACU). The DCPs function as data links between ASOS sensors and the ACU. A single DCP may handle data exchanges for up to 16 sensors. Data exchanges between the DCP and externally mounted sensors are accomplished via fiber optic cabling. Data transfers between the DCP and ACU are accomplished via radio frequency (RF) communication. The DCP also provides AC power for each linked sensor (SOP 9).

The ACU performs final processing, formatting, quality control, storage and retrieval of the data, and makes ASOS data available to users through various outlets (SOP 9). The ACU of an ASOS site automatically generates the maintenance flag when a fault is detected or other maintenance is required (SOP 9).

3.3.7 NWS Upper Air Program

Sensors are linked to a battery powered radio transmitter that sends the sensor measurements to a sensitive ground receiver at 1 to 2 second intervals. This information is used to derive wind speed and direction aloft while the Radio Replacement System (RRS) tracking system uses GPS to determine wind speed and direction. A computer is used to process, encode, and disseminate the data. See SOP 10 for additional information.

3.4 Compliance with the National Environmental Policy Act

Installations of new stations and equipment will comply with NPS National Environmental Policy Act (NEPA) mandates including effects on Wilderness and cultural resources. NEPA, the National Historic Preservation Act (NHPA) and Department Manual 516 establish the legal foundation for evaluating the impacts of federal actions. Director's Order 12 (DO-12) provides the policies and procedures for complying with NEPA, and Director's Order 28 (DO-28) provides the same for NHPA within the National Park Service (NPS). NPS Director's Order 41 (DO-41) provides the policies and procedures for evaluating actions and developing alternatives for projects proposed in wilderness, including the wilderness minimum requirement analysis. These standard operating procedures also reflect legal requirements and policy mandated by other applicable environmental legislation, rules, and regulations.

3.5 Post Collection Processing of Samples

There is no post collection processing of climate data except as it pertains to quality control and quality assurance of the data which is addressed in Chapter 4.

3.6 End-of-Season Procedures

Since weather data are being collected continually, there is no “end of season.” Procedures for downloading the data are addressed above and in more detail within the corresponding SOPs for each program. Procedures for addressing the integrity (QA/QC) of the data collected are addressed in Chapter 4.

4 - Data Handling, Analysis, and Reporting

This chapter describes the procedures for data handling, analysis, and report development. Additional details and context for this chapter may be found in the NCCN Data Management Plan (Boetsch et al. 2005), which describes the overall information management strategy for the network. The NCCN website (<http://science.nature.nps.gov/im/monitor/DataManagement.cfm>) also contains a series of guidance documents on information management topics (e.g., report development, sensitive information handling, GIS development, GPS use).

4.1 Project Information Management Overview

Project information management may be best understood as an ongoing or cyclic process, as shown in Figure 4.1. Specific yearly information management tasks for this project and their timing are described in Table 6.1, Annual Workload and Schedule. Readers may also refer to each respective chapter section below for additional guidance and instructions.

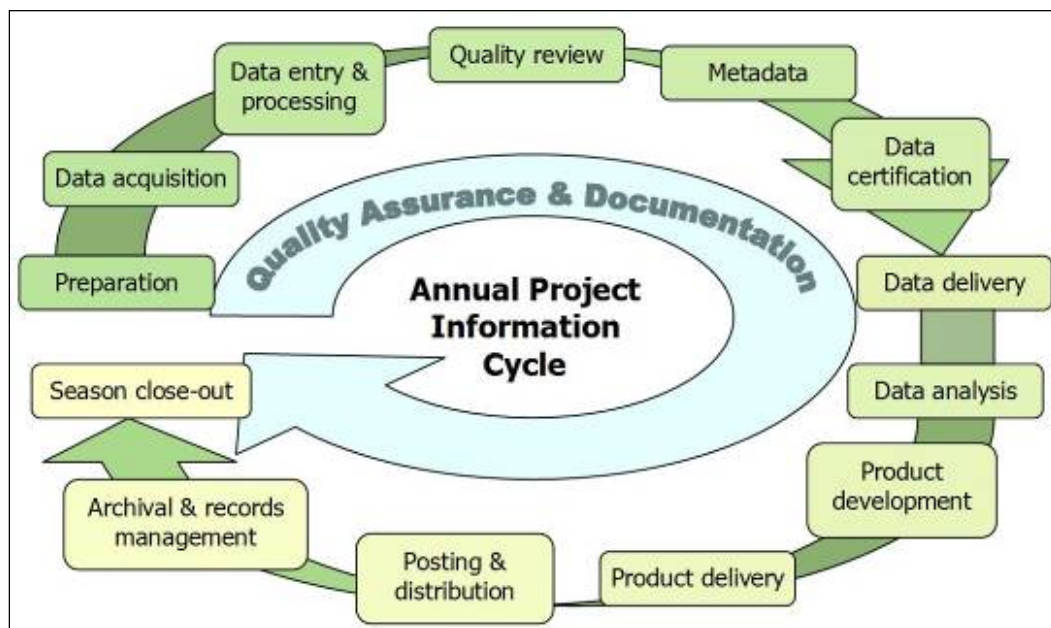


Figure 4.1. Idealized flow schematic of the cyclical stages of project information management, from pre-season preparation to season close-out. Note that quality assurance and documentation are thematic and not limited to any particular stage.

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

- *Preparation* – Training, logistics planning, print forms and maps
- *Data acquisition* – Field trips to acquire data
- *Data entry & processing* – Data entry and uploads into the working copy of the database, Global Positioning System (GPS) data processing, etc.
- *Quality review* – Data are reviewed for quality and logical consistency

- *Metadata* – Documentation of the year’s data collection and results of the quality review
- *Data certification* – All available data are certified as complete for the period of record
- *Data delivery* – Certified data and metadata are delivered for archival and upload to the master project database
- *Data analysis* – Data are summarized and analyzed
- *Product development* – Reports, maps, and other products are developed
- *Product delivery* – Deliver reports and other products for posting and archival
- *Posting & distribution* – Distribute products as planned and/or post to NPS clearinghouses
- *Archival & records management* – Review analog and digital files for retention (or destruction) according to NPS DO# 19. Retained files are renamed and stored as needed.
- *Season close-out* – Review and documentation of needed improvements to project procedures or infrastructure, complete administrative reports, develop work plans for the coming season

4.2 Preparations for Information Management

4.2.1 Set up Project Workspace

A section of the networked file server at each host park is reserved for this project, and access permissions are established so that project staff members have access to needed files within this workspace. As new staff become involved, the Project Lead should make sure that network accounts are established for each new staff member, and that the Data Manager is notified to ensure access to the project workspace and databases.

A copy of all raw data will be stored unedited, and in their original file format. To enhance autonomy and longevity of individual files, when possible, an ASCII formatted file will also be stored. All of the data from this program, including hard copies and electronic format data will be archived in accordance with standards described in the NCCN data management plan.

The recommended file structure within this workspace is shown in Figure 4.2 and is further described in SOP 13. Certain folders – especially those for GPS data and images – should be retained in separate folders for each year as shown in Figure 4.2. This will make it easier to identify and move these files to the project archives when required.



Figure 4.2. Recommended file structure for project workspace. Note that the workspace folder name includes 'CLa01', the NCCN project code. The same code is also under the GPS_data folder to make it easier to select the correct project folder within the GPS processing software.

4.2.2 Implement Working Database Copy

Each year, the Data Manager will implement a blank copy of the working database and ensure proper access on the part of the project staff. Refer to Section 4c for additional information about the database design and implementation strategy.

4.3 Acquiring Data

Local storage and import of data from NCCN climate stations will improve data access and facilitate their use in analysis. Evaluations of climatic trends and trend analyses of other vital signs may be enhanced with data from climate stations in close proximity to park lands, particularly with those nearby stations exhibiting similarities in climate. Such stations lend themselves well to extrapolation, to provide improved coverage in data sparse regions inside NCCN parks. Table 4.1 describes the NCCN's role in acquiring, QA/QC, and archiving data from each climate station included in the program, whether it is managed solely by NCCN parks or outside agencies. The NCCN will acquire data for all stations listed in Table 2.3.

Procedures have been developed to access observations for all of the various stations types. NWS-COOP, RAWS, and SNOTEL data are provided by WRCC. WRCC stores all western-U.S. COOP data, and is the national repository for historical RAWS data. WRCC also acquires NRCS SNOTEL data and provides data-quality flags in the downloadable versions of the data. Procedures for accessing RAWS, SNOTEL and snow course, NWS-COOP, CRN, ASOS, NWS Upper Air Data data are described in more detail within the corresponding SOPs for each program. Procedures are based on current access restrictions. A Memorandum of Understanding between the National Park Service and WRCC is being developed that will result in more efficient and comprehensive data access.

A climate initiative, NPCLime (Climate Data for Parks), between the National Park Service and WRCC is being developed that will result in more efficient and comprehensive access of data from multiple organizations. NPCLime builds upon the capabilities of the Applied Climate Information System (ACIS). ACIS is a cooperative system supported by all the NOAA regional climate centers. NPS enhancements will provide geographic queries and downloads, and address Inventory and Monitoring data storage and distribution needs.

Management of NCCN climate data continues to evolve with a Service-wide effort underway but not yet available for our use (as of February 2010). The National Park Service has a long-term goal to provide staff with tools to discover and use climate data to satisfy both routine needs and for sophisticated analyses. NPCLime (Climate Data for Parks) has been initiated to meet this goal. Our NCCN data management efforts began well in advance of the NPCLime initiative and the database described in this protocol will continue to be utilized for NPS and High Elevation Climate Stations. In addition, until NPCLime is available, data from the other agency managed stations included in the NCCN climate protocol will be downloaded from agency websites and archived, annually, in our NCCN data files so that they can be used for analysis needed in annual and periodic climate reports, and be accessible for use in other NCCN vital sign projects, and for park purposes.

NPCLime Projected Capabilities will include:

- Single portal for access to multiple climate data sources
- View climate station metadata
- Select, visualize and return data
- Summarize, analyze and export climate products
- Choose from multiple data and extraction formats

While it is expected that NPCLime will have little effect in the manner in which we manage data from Park Operated Stations, we expect that the web based tools under development will provide a full suite of management capabilities when it comes to non-NPS stations. For additional information on NPCLime see <http://science.nature.nps.gov/im/inventory/climate/wrcc/index.cfm>.

Table 4.1. Description of personnel roles for individual climate stations in the NCCN climate program. Stations in *italics* are not installed.

Park ¹	Station(s) ²	Climate Monitoring Program	Lead Agency	Data recording	Equipment Maintenance and calibration	Data QA/QC	Data Downloading/ Processing/ Metadata creation	Obtain Data From Collaborator		Data Archiving
				• Responsible Personnel • Frequency	• Responsible Personnel • Frequency	• Responsible Personnel • Frequency	• Responsible Personnel • Frequency	• Responsible Personnel • Frequency	Collaborator	• Responsible Personnel • Frequency
NOCA	• Hozomeen • Marblemount • Stehekin	RAWS	National Interagency Fire Center BLM, USFS, NPS, et al.	• Automated recording and transmission • Hourly	• Park staff/fire –management staff • Once per year at the minimum	• Automated Oversight System, local station manager (Park Staff) • Continuous	• Western Regional Climate Center (WRCC) • Monthly	• NCCN Data Manager/ Project Lead • Yearly	WRCC	• NCCN Data Manager • Yearly
MORA	• Ohanapecosh	RAWS	National Interagency Fire Center (BLM, USDA, NPS, et al.)	• Automated recording and transmission • Hourly	• Park staff/fire –management staff • Once per year at the minimum	• Automated Oversight System, local station manager (Park Staff) • Continuous	• WRCC • Monthly	• NCCN Data Manager/ Project Lead • Yearly	WRCC	• NCCN Data Manager • Yearly
OLYM	• Cougar Mountain • Toms Creek • Owl Mountain • Jefferson Creek	RAWS	National Interagency Fire Center (BLM, USDA, NPS, et al.)	• Automated recording and transmission • Hourly	• Park staff/fire –management staff • Once per year at the minimum	• Automated Oversight System, local station manager (Park Staff) • Continuous	• WRCC • Monthly	• NCCN Data Manager/ Project Lead • Yearly	WRCC	• NCCN Data Manager • Yearly
MORA	• Longmire • Paradise Ranger Station • Ohanapecosh • Rainier Carbon River • Packwood	NWS-COOP	NOAA, NWS	• Park Staff (Ranger Division) • Daily	• Regional district NWS staff, Park Staff • Twice per year	• NWS • Monthly	• NCDC, NWS, WRCC • Monthly	• NCCN Data Manager/ Project Lead • Monthly	NCDC, WRCC, Park	• NCCN Data Manager • Yearly
OLYM	• Hoh Ranger Station • Elwha Ranger Station • Sequim • Forks • Clearwater • Port Angeles	NWS-COOP	NOAA, NWS	• Park Staff (Ranger Division) • Daily	• Regional district NWS staff, Park Staff • Twice per year	• NWS • Monthly	• NCDC, NWS, WRCC • Monthly	• NCCN Data Manager/ Project Lead • Monthly	NCDC, WRCC	• NCCN Data Manager • Yearly

Table 4.1. Description of personnel roles for individual climate stations in the NCCN climate program (continued).

Park ¹	Station(s) ²	Climate Monitoring Program	Lead Agency	Data recording	Equipment Maintenance and calibration	Data QA/QC	Data Downloading/ Processing/ Metadata creation	Obtain Data From Collaborator	Data Archiving	
				• Responsible Personnel • Frequency	• Responsible Personnel • Frequency	• Responsible Personnel • Frequency	• Responsible Personnel • Frequency	• Responsible Personnel • Frequency	Collaborator	• Responsible Personnel • Frequency
LEWI	• Fort Clatsop • Astoria Regional Airport • Seaside • Long Beach Exp. Station	NWS-COOP	NOAA, NWS	• Park Staff (Ranger Division) • Daily	• Regional district NWS staff, Park Staff • Twice per year	• NWS • Monthly	• NCDC, NWS • Monthly	• NCCN Data Manager/ Project Lead • Monthly	NCDC, WRCC	• NCCN Data Manager • Yearly
NOCA	• Newhalem • Diablo Dam • Ross Dam • Marblemount Ranger Station • Stehekin	NWS-COOP	NOAA, NWS	• Park Staff (Ranger Division) • Daily	• Regional district NWS staff, Park Staff • Twice per year	• NWS • Monthly	• NCDC, NWS • Monthly	• NCCN Data Manager/ Project Lead • Monthly	NCDC, WRCC	• NCCN Data Manager • Yearly
ELBA	• Coupeville	NWS-COOP	NOAA, NWS	• Park Staff (Ranger Division) • Daily	• Regional district NWS staff, Park Staff • Twice per year	• NWS • Monthly	• NCDC, NWS • Monthly	• NCCN Data Manager/ Project Lead • Monthly	NCDC, WRCC	• NCCN Data Manager • Yearly
SAJH	• Olga 2 SE	NWS-COOP	NOAA, NWS	• Park Staff (Ranger Division) • Daily	• Regional district NWS staff, Park Staff • Twice per year	• NWS • Monthly	• NCDC, NWS • Monthly	• NCCN Data Manager/ Project Lead • Monthly	NCDC, WRCC	• NCCN Data Manager • Yearly
FOVA	• Vancouver 4 NNE • Portland WSFO • Vancouver Interstate Bridge	NWS-COOP	NOAA, NWS	• Park Staff (Ranger Division) • Daily	• Regional district NWS staff, Park Staff • Twice per year	• NWS • Monthly	• NCDC, NWS • Monthly	• NCCN Data Manager/ Project Lead • Monthly	NCDC, WRCC	• NCCN Data Manager • Yearly
NOCA	• Darrington 21 NNE	CRN	NOAA, NCDC	• Automated recording and transmission/ • Hourly	• NOAA, Park Staff • Once per year	• NCDC • Continuous	• NCDC • Daily	• NCCN Data Manager/ Project Lead • Monthly	NCDC	• NCCN Data Manager • Yearly
OLYM	• Quinault 4 NE	CRN	NOAA, NCDC	• Automated recording and transmission/ • Hourly	• NOAA, Park Staff • Once per year	• NCDC • Continuous	• NCDC • Daily	• NCCN Data Manager/ Project Lead • Monthly	NCDC	• NCCN Data Manager • Yearly

Table 4.1. Description of personnel roles for individual climate stations in the NCCN climate program (continued).

Park ¹	Station(s) ²	Climate Monitoring Program	Lead Agency	Data recording	Equipment Maintenance and calibration	Data QA/QC	Data Downloading/ Processing/ Metadata creation	Obtain Data From Collaborator	Data Archiving
				• Responsible Personnel • Frequency	• Responsible Personnel • Frequency	• Responsible Personnel • Frequency	• Responsible Personnel • Frequency	• Responsible Personnel • Frequency Collaborator	
NOCA	• Beaver Pass • Park Creek Ridge • Thunder Basin • Hozomeen Camp • Easy Pass AM • Brown Top Ridge • Silver Glacier • Noisy Glacier	SNOTEL	NRCS	• Automated recording and transmission/ • Hourly	• NRCS • 3–4 times/year at NOCA;	• NRCS • Continuous	• NRCS • Monthly	• NCCN Data Manager/ Project Lead • Once per year	• NCCN Data Manager • Yearly
OLYM	• Waterhole • Mt Crag • Buckinghorse Ridge	SNOTEL	NRCS	• Automated recording and transmission/ • Hourly	• Park Staff, NWAC • 2 per year at OLYM	• NRCS • Continuous	• NRCS • Monthly	• NCCN Data Manager/ Project Lead • Once per year	• NCCN Data Manager • Yearly
MORA	• Paradise • Cayuse Pass • Mowich • Huckleberry	SNOTEL	NRCS	• Automated recording and transmission/ • Hourly	• Park Staff, NWAC • 2 per year at MORA	• NRCS • Continuous	• NRCS • Monthly	• NCCN Data Manager/ Project Lead • Once per year	• NCCN Data Manager • Yearly
NOCA	• Beaver Pass • Park Creek Ridge • Thunder Basin • Hozomeen Camp • Brown Top Ridge • Beaver Creek Trail • Meadows Cabin • Mt. Blum AM • Granite Creek	Snow Course	NRCS	• Field measurements U SDA- NRCS/ Park Staff • Monthly (Feb 1– May 1)	• NA • NA	• NRCS, Park Staff • Monthly	• NRCS	• NCCN Data Manager/ Project Lead • Yearly	• NCCN Data Manager • Yearly

Table 4.1. Description of personnel roles for individual climate stations in the NCCN climate program (continued).

Park ¹	Station(s) ²	Climate Monitoring Program	Lead Agency	Data recording	Equipment Maintenance and calibration	Data QA/QC	Data Downloading/ Processing/ Metadata creation	Obtain Data From Collaborator		Data Archiving
				• Responsible Personnel • Frequency	• Responsible Personnel • Frequency	• Responsible Personnel • Frequency	• Responsible Personnel • Frequency	• Responsible Personnel • Frequency	Collaborator	• Responsible Personnel • Frequency
NOCA	• Easy Pass AM	Aerial Markers	NRCS	• Field measurements • SDA-NRCS/ Park Staff • Monthly (Feb 1– May 1)	• NA • NA	• NRCS, Park Staff • Monthly	• NRCS	• NCCN Data Manager/ Project Lead • Yearly	NRCS	• NCCN Data Manager • Yearly
OLYM	• Deer Park • Hurricane • Cox Valley	Snow Course	NRCS	• Field measurements • Park Staff Monthly (Feb 1– May 1)	• NA • NA	• NRCS, Park Staff • Monthly	• NRCS	• NCCN Data Manager/ Project Lead • Yearly	NRCS	• NCCN Data Manager • Yearly
MORA	• Paradise	Snow Course	NRCS	• Field measurements • Park Staff • Monthly (Feb 1– May 1)	• NA • NA	• NRCS, Park Staff • Monthly	• NRCS	• NCCN Data Manager/ Project Lead • Yearly	NRCS	• NCCN Data Manager • Yearly
MORA	• Cayuse Pass • Mowich • Huckleberry	Snow Course	NRCS	• Field measurements • NRCS Staff • Monthly (Feb 1– May 1)	• NA • NA	• NRCS, Park Staff • Monthly	• NRCS	• NCCN Data Manager/ Project Lead • Yearly	NRCS	• NCCN Data Manager • Yearly
NOCA	• Washington Pass	NWAC	WSDOT, NWAC	• Automated recording and transmission • Hourly	• NWAC • Two times per year	• NWAC • Continuous	• NWAC • Daily	• NCCN Data Manager/ Project Lead • Yearly	NWAC, Park	• NCCN Data Manager • Yearly
OLYM	• Hurricane	NWAC	• NWAC	• Automated recording and transmission • Hourly	• NWAC • Two times per year	• NWAC • Continuous	• NWAC • Continuous	• NCCN Data Manager/ Project Lead • Yearly	NWAC, Park	• NCCN Data Manager • Yearly

Table 4.1. Description of personnel roles for individual climate stations in the NCCN climate program (continued).

Park ¹	Station(s) ²	Climate Monitoring Program	Lead Agency	Equipment Maintenance and calibration	Data QA/QC	Data Downloading/ Processing/ Metadata creation	Obtain Data From Collaborator		Data Archiving
				• Responsible Personnel • Frequency	• Responsible Personnel • Frequency	• Responsible Personnel • Frequency	• Responsible Personnel • Frequency	Collaborator	• Responsible Personnel • Frequency
MORA	• Sunrise High Elevation Site • Camp Muir High Elevation Site • Paradise High Elevation Site	NWAC	• NPS, NWAC	• Automated recording and transmission • Hourly	• NPS/ NWAC • Two times per year and as needed	• NPS/ NWAC • Continuous	• NPS/ NWAC • Continuous	• NCCN Data Manager/ Project Lead • Yearly	• NCCN Data Manager • Yearly
MORA	• Chinook Pass	NWAC	• NWAC	• Automated recording and transmission • Hourly	• NWAC • Two times per year and as needed	• NWAC • Continuous	• NWAC • Continuous	• NCCN Data Manager/ Project Lead • Yearly	• NCCN Data Manager • Yearly
MORA	• Crystal Mountain	NWAC	• NWAC/ Crystal Ski Area	• Automated recording and transmission • Hourly	• NWAC/ Crystal Ski Area • Two times per year and as needed	• NWAC • Continuous	• NWAC • Continuous	• NCCN Data Manager • Yearly	• NCCN Data Manager • Yearly
FOVA	• Vancouver, Pearson Airpark • Portland International Airport	ASOS	FAA, DOD, NWS	• Automated recording and transmission • Hourly	• NOAA • Once per year	• ASOS Operations and Monitoring Center • Continuous	• NCDC	• NCCN Data Manager/ Project Lead • Yearly	• NCCN Data Manager • Yearly
EBLA	• Oak Harbor Airpark	ASOS	FAA, DOD, NWS	• Automated recording and transmission • Hourly	• NOAA • Once per year	• ASOS Operations and Monitoring Center • Continuous	• NCDC	• NCCN Data Manager/ Project Lead • Yearly	• NCCN Data Manager • Yearly
SAJU	• Friday Harbor Airport	ASOS	FAA, DOD, NWS	• Automated recording and transmission • Hourly	• NOAA • Once per year	• ASOS Operations and Monitoring Center • Continuous	• NCDC	• NCCN Data Manager/ Project Lead • Yearly	• NCCN Data Manager • Yearly
LEWI	• Astoria Regional Airport	ASOS	FAA, DOD, NWS	• Automated recording and transmission • Hourly	• NOAA • Once per year	• ASOS Operations and Monitoring Center	• NCDC	• NCCN Data Manager • Yearly	• NCCN Data Manager • Yearly

Table 4.1. Description of personnel roles for individual climate stations in the NCCN climate program (continued).

Park ¹	Station(s) ²	Climate Monitoring Program	Lead Agency	Data recording	Equipment Maintenance and calibration	Data QA/QC	Data Downloading/ Processing/ Metadata creation	Obtain Data From Collaborator	Data Archiving
				• Responsible Personnel • Frequency	• Responsible Personnel • Frequency	• Responsible Personnel • Frequency	• Responsible Personnel • Frequency	• Responsible Personnel • Frequency Collaborator	
OLYM	• Quillayute State Airport	ASOS	FAA, DOD, NWS	• Automated recording and transmission • Hourly	• NOAA • Once per year	ASOS Operations and Monitoring Center	• NCDC	• NCCN Data Manager • Yearly	• NCCN Data Manager • Yearly
OLYM	• Bunch Field • Quinault • Hoh Valley • Waterhole • Lake Crescent • Ozette R.S. • Deer Park • Ranger Station • Deer Park Road • Upper Elwah Valley • Staircase	NPS Climate Stations	NPS	• Automated recording. • Hourly	• Park Staff • Three times per year	• Park Staff • Twice per year	• Park • Quarterly	N/A Park	• NCCN Data Manager/ Project Lead • 3 times/ year
MORA	• Carbon River	NPS Climate Stations	NPS	• Automated recording. • Hourly	• Park Staff • Three times per year	• Park Staff • Twice per year	• Park • Quarterly	N/A Park	• NCCN Data Manager/ Project Lead • 3 times/ year
SAJU	• <i>English Camp (permanent location)</i>	NPS Climate Stations	NPS	• Park Staff Manual data download • Three times/year	• Park Staff • Three times per year	• Park Staff • Twice per year	• Park • Quarterly	N/A Park	• NCCN Data Manager/ Project Lead • 3 times/ year
OLYM	• Quillayute	NWS Upper Air Observation Program	NWS	• Manual measurements/NWS Staff • Twice/day	• NWS • Continuous	• NWS • Daily	NCDC	NCDC NCDC	• NCCN Data Manager/ Project Lead • 3 times/ year
MORA	• Tahoma Woods	CASTNET	Air Resource Division, NPS	• Automated recording • Continuous	• NPS Staff • Once per week • Continuous	• Air Resource Division (ARD), NPS • Daily	• ARD • Daily	• NCCN Data Manager • Yearly	• NCCN Data Manager • Yearly

¹Includes the designated National Park and an area 20 miles outside the park boundary.²See maps in Appendix B for additional station location information.

4.4 Overview of Database Design

A relational database application has been developed for managing data from park operated stations. The design of this database is consistent with NPS I&M (<http://science.nature.nps.gov/im/apps/template/index.cfm>) and NCCN standards (see NCCN Database Standards, NCCN 2005), and is documented in the data dictionary provided in Appendix D.

The database is divided into two major components – one for importing, qualifying and error-checking data for the current calendar year (i.e., the “working database copy”), and another that contains the complete set of certified data for the monitoring project (i.e., the “master project database”). A functional comparison of these two components is provided in Table 4.2.

Table 4.2. Functional comparison of the climate master project database and the working database copy.

Project Database Functions and Capabilities	Working Database	Master Database
Software platform for back-end data	MS Access	MS SQL* Server 2000
Contains full list of sampling locations	X	X
Forms for importing and qualifying current year data	X	
Quality assurance and data validation tools	X	
Preliminary data summarization capabilities	X	
Full analysis, summarization and export tools		X
Pre-formatted report output		X
Contains certified data for all observation years		X
Limited editing capabilities, edits are logged		X
Full automated backups and transaction logging	X	X

*SQL (Structured Query Language) Server is a Relational Database Management System (RDBMS) from Microsoft. SQL Server is an advanced, industry standard database application designed for client-server and web applications involving a database backend. Its primary query language is Transact-SQL, an implementation of the ANSI/ISO standard SQL used by both Microsoft and Sybase.

The working database application, implemented in Microsoft Access, has input forms for data uploading, data flagging, and data quality validation.

The master database component contains the analysis and summarization tools, including pre-formatted report output and exports to other software (e.g., *statistical analyses software*). The master database component is to take advantage of the backup, transaction logging, and mass distribution capabilities of this enterprise database software.

4.5 Data Import and Processing

The working database application will be found in the project workspace. For enhanced performance, it is recommended that users copy the front-end database onto their workstation hard drives and open it there. This front-end copy may be considered “disposable” because it does not contain any data, but rather acts as a pointer to the data that resides in the back-end working database. Whenever updates to the front-end application are made available by the Data Manager, a fresh copy should be made from the project workspace to the workstation hard drive.

The functional components for data entry into the working database are described in SOP 1. The flow of data entry should generally proceed as follows:

1. Climate station selection and editing screen
2. Data download pointer
3. Data import screen
4. Data quality flags screen
5. Data import processing log

Each data entry form has built-in quality assurance components such as pick lists and validation rules to test for missing data or illogical combinations. Although the database permits users to view the raw data tables and other database objects, users are strongly encouraged only to use these pre-built forms as a way of ensuring the maximum level of quality assurance.

4.5.1 Regular Data Backups

Automated on-site and off-site backup routines are run on the database server. See table 4.3 for a list of SQL Server backup types and schedule. In order to free up space on the server, these periodic backup files are deleted once enough subsequent backups are made.

Table 4.3. List of structured query language (SQL) server backup types and schedule.

Backup type	Filename/Location	Frequency
Full	\\inpmoragis\GIS\Data\MSSQL\Backups\prod_CLa01_be.bak	Monthly
Differential	\\inpmoragis\GIS\Data\MSSQL\Backups\ prod_CLa01_be.bak	Weekly
Transaction Log	\\inpmoragis\GIS\Data\MSSQL\Backups\ prod_CLa01_be.trn	Daily

A copy of all raw data will be stored unedited, and in their original file format. To enhance autonomy and longevity of individual files, when possible, an ASCII formatted file will also be stored. All of the data from this program, including hard copies and electronic format data will be archived in accordance with standards described in the NCCN Data Management Plan (Boetsch et al. 2005).

4.5.2 Data Verification

Quality Assurance Tools are built into the front-end working database application to check for logical inconsistencies and data outliers.

4.5.3 Image Handling Procedures

Photographic images documenting sites may be considered a type of data, and as such should be handled and processed with care. Refer to SOP 4 for details on how to handle and manage these files.

4.5.4 GPS Data

The following general procedures should be followed for GPS data:

1. GPS data should be downloaded from the units at the end of each station visit and stored in the project workspace (Figure 4.2).
2. Raw files should be sent to the GIS Specialist for processing and correction.
3. The GIS Specialist will process the raw GPS data and store the processed data in the project workspace.
4. The GIS Specialist will upload corrected coordinate information into the database.

Project leads should periodically review the processed GPS data to make sure that any problems are identified early on.

4.6 Quality Review

After the data have been imported and processed, they need to be reviewed by the Project Lead for quality, completeness and logical consistency. The working database application facilitates this process by showing the results of pre-built queries that check for data integrity, data outliers and missing values, and illogical values. The user may then fix these problems and document the fixes. Not all errors and inconsistencies can be fixed, in which case the documentation and resulting errors are then documented and included in the metadata and certification report.

4.6.1 Geospatial Data

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

4.7 Metadata Procedures

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, defined as structured information about the content, quality, condition and other characteristics of data. Additionally, metadata provides 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. Metadata for all NCCN monitoring data will conform to Federal Geographic Data Committee (FGDC) guidelines and will contain all components of supporting information such that the data may be confidently manipulated, analyzed and synthesized.

For long-term projects initial metadata creation can be time consuming, but once created metadata remains static from one year to the next. As a result, metadata records in subsequent years generally will require only minor updates.

Specific procedures for metadata development and posting are found in NCCN Metadata Development Guidelines (NCCN 2007). The general flow is as follows:

1. Download the NCCN Metadata Interview form from:
http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm. This form greatly

facilitates metadata creation by structuring the required information into a logical arrangement of 15 main questions, many with additional sub-questions.

2. Complete the metadata interview form and maintain it in the project workspace. Much of the interview form can be filled out by cutting and pasting material from other documents (e.g., reports, protocol narrative sections, and SOPs).
3. Deliver the completed interview form to the Data Manager according to Table
4. The Data Manager (or GIS Specialist for spatial data) will then extract the information from the interview form and use it to create and update an FGDC- and NPS-compliant metadata record in XML format.
5. The Project Lead should update the metadata interview content as changes to the protocol are made, and each year as additional data are accumulated. Edits within the document should be tracked so that any changes are obvious to those who will use it to update the XML metadata file.

At the conclusion of the field season (according to the schedule in Table 6.1), the NPS Lead and Project Lead will be jointly responsible for providing a completed, up-to-date metadata interview form to the Data Manager. The Data Manager and GIS Specialist will facilitate metadata development by consulting on the use of the metadata interview form, by creating and parsing metadata records from the information in the interview form, and by posting such records to national clearinghouses as described in NCCN Metadata Development Guidelines (NCCN 2007).

4.8 Data Certification and Delivery

Data certification is a benchmark in the project information management process that indicates that: 1) all available data are complete for the period of record (some data may be missing due to automated or manual collection errors); 2) they have undergone and passed the quality assurance checks (Section 4e); and 3) that they are appropriately documented and in a condition for archiving, posting and distribution as appropriate. Certification is not intended to imply that the data are completely free of errors or inconsistencies which may or may not have been detected during quality assurance reviews. See SOP 3 for additional information on data delivery, posting, and certification.

To ensure that only quality data are included in reports and other project deliverables, the data certification step is an annual requirement for all tabular and spatial data. The Project Lead is primarily responsible for completing the NCCN Project Data Certification Form, http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm. The completed form, certified data and updated metadata should be delivered to the NPS Project Lead and the Data Manager according to the timeline Table 6.1.

To package the certification materials for delivery, the Project Lead should follow these steps:

1. Create a compressed file (using WinZip® or similar software) and add the back-end database file to that file.
2. Add the completed metadata interview form to the compressed file (Section 4f).

3. Add the completed certification report to the compressed file.
4. Add any geospatial data files that aren't already in the possession of the GIS Specialist.
5. Add the directory of photographic images for the current year according to the instructions in SOP 4.
6. All file names – except for image files and geospatial data files – should include the NCCN project code (“CLa01”), in addition to the year or span of years for the data being certified. (e.g., CLa01_2007_certified.mdb, CLa01_2007_cert_report.doc, CLa01_2007_metadata_interview.doc, etc).
7. The compressed file may then be uploaded to the new submissions folder of the NCCN Digital Library. The Data Manager and NPS Lead should be notified of this submission by email.

Upon receiving the certification materials, the Data Manager will check them in and store them in the NCCN Digital Library, and upload the certified data to the master project database. The GIS Specialist will update the project GIS layers with any geospatial data that are submitted. Upon notification that the year's data have been uploaded and processed successfully, the Project Lead may then proceed with data summarization, analysis and reporting.

4.9 Recommendations for Routine Data Summaries and Statistical Analyses

An annual climate report will be produced for each park within the NCCN network. While a wide variety of climate parameters are measured as part of the NCCN climate program, reporting will focus on two key parameters: precipitation and air temperature. All data, reported and non-reported, from NCCN climate stations will be quality checked and be stored in a readily available format. An annual park climate report (including the regional overview section) will be distributed by March 31st of the following year.

There are five components to the annual park climate report:

1. Park Climate Overview: a narrative describing the climate and climate variations within each NCCN park.
2. Climate Station Data Summaries: this section includes final data, displayed in tabular and graphical form, for a select number of individual park climate stations. Summaries will consist of monthly, seasonal and annual data, and will include several stations with a 30 year period of record to allow a comparison of current-year conditions with previous years and historical trends. The selected park climate stations will represent climate zones within the park.
3. Snow Pack Summary: a narrative description of the winter snow pack, including tabular and graphical data from park SNOTEL Stations and Snow Courses.
4. Significant Weather Events: Data and discussion of significant weather events (e.g. floods, windstorms) occurring within the park during the reporting year.
5. Operations Review: includes a discussion of major changes and large scale maintenance issues at NCCN climate stations.

In addition to annual reporting, a Comprehensive Climate Report, which includes an analysis of long term patterns and trends in climate, will be produced on a 5–10 year basis.

Table 4.4. Climate reporting requirements.

Title	Analysis Performed	Due	Frequency
Annual Report	Annual data summary which includes climate summaries and highlights on a park and regional scale within the NCCN Network. Individual park climate summaries including, monthly, seasonal and annual data, comparing current-year conditions with historical trends.	March 31 st	Annual
Comprehensive Report	Analysis of patterns and trends in climate change at January 1st Network and Park scale; summary statistics		Periodic; as needed

4.10 Report Format with Examples of Summary Tables and Figures

Annual reports and trend analysis reports will use the Natural Resource Technical Report Draft and associated .dot template: <http://www.nature.nps.gov/publications/NRPM/index.cfm>. Distribution of final products will be completed according to SOP 3.

The report format is described below.

4.10.1 Park Overview

This section will interpret data from important or “key” locations within the park, including one or two stations which have extensive periods of record (30 years) and which adequately represent climate regions within the park (e.g. windward and leeward slopes or elevation gradients). Analysis will include seasonal, monthly and annual climate comparisons for the reporting year and interpret whether particular seasons were wet or dry, and hot or cold with respect to the historical record. The summary may also briefly describe significant weather events influencing specific park resources and which are detailed in the significant events section of the report. The narrative will be supported with tables and graphics which display variations within the park. See Tables 4.5 and 4.6 and Figure 4.5 for examples.

Table 4.5. Precipitation comparison table at key climate stations: OLYM.

Olympic National Park 2003 Monthly Total Precipitation (mm)									
Month	Quinault Valley	Hoh Ranger Station	Hayes River Guard Station	Waterhole	Deer Park	Quillayute Field COOP	Quillayute Field COOP Departure from 1971-2000 Normal	Port Angeles COOP	Port Angeles COOP Percent of 1971-2000 Normal
January	751	506	N/A	305	179	368	108%	101	103%
February	154	158	N/A	20	16	113	35%	16	22%
March	896	719	N/A	432	189	413	149%	110	203%
April	273	250	N/A	124	85	257	136%	40	127%
May	50	73	N/A	51	40	72	53%	21	77%
June	30	39	N/A	3	9	32	33%	13	56%
July	37	30	N/A	13	4	43	73%	3	21%
August	19	15	N/A	0	11	7	11%	5	28%
September	79	63	N/A	20	19	80	72%	23	80%
October	890	617	N/A	401	220	479	196%	163	255%
November	589	513	N/A	338	174	445	118%	128	113%
December	485	409	N/A	267	82	346	95%	64	58%
Annual	4253	3391	N/A	1974	1027	2656	103%	686	104%

Table 4.6. Temperature comparison table at key climate stations: OLYM.

Olympic National Park 2003 Average Maximum Daily Temperature (C)									
Month	Quinault Valley	Hoh Ranger Station	Hayes River Guard Station	Waterhole	Deer Park	Quillayute Field COOP	Quillayute Field COOP Departure from 1971-2000 Normal	Port Angeles COOP	Port Angeles COOP Departure from 1971-2000 Normal
January	8.4	11.0	N/A	3.0	8.4	11.4	3.1	9.3	1.7
February	8.5	10.3	N/A	1.6	6.1	9.6	0.1	8.0	-0.8
March	9.7	10.0	N/A	1.4	5.9	10.2	-0.9	10.1	-0.7
April	11.3	11.1	N/A	2.9	5.8	11.0	-2.1	11.1	-1.9
May	16.3	15.5	N/A	7.8	10.4	14.1	-1.7	14.0	-1.9
June	21.6	20.6	N/A	14.1	17.2	19.0	1.3	19.1	1.1
July	24.2	22.8	N/A	16.7	19.9	20.2	0.1	20.2	-0.1
August	23.7	22.8	N/A	16.2	19.7	20.3	-0.4	19.6	-0.9
September	22.0	21.8	N/A	15.2	18.0	19.8	0.4	19.1	0.4
October	14.4	15.4	N/A	7.8	13.0	14.8	-0.4	13.7	-0.5
November	7.1	8.8	N/A	-0.7	4.7	9.8	0.2	8.6	-0.4
December	5.4	6.5	N/A	-1.7	4.6	8.3	0.2	7.7	0.1
Annual	173	177	N/A	84	134	14.0	-0.1	13.4	-0.4

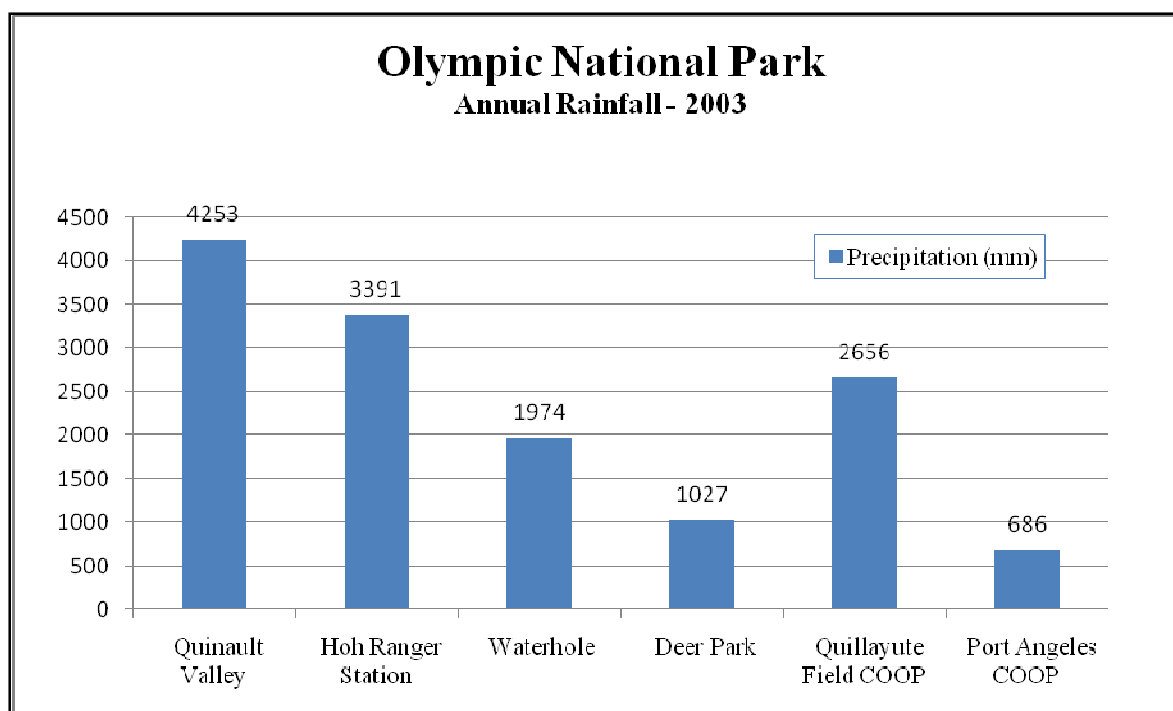


Figure 4.5. Precipitation at key climate stations: OLYM.

4.10.2 Climate Station Summaries

Data from key park climate stations will be summarized and presented annually. These stations will be representative of different climate regions within the park. Summaries will include monthly, seasonal and annual data. Climate stations located outside the park unit may be included in data summaries if no representative station is located within the park. All stations to be included in the annual reports are identified in Table 4.7.

Summaries will be tailored to provide minimum, maximum, and average temperatures, as well as precipitation. Data will be presented in tabular and graphic displays of monthly, seasonal and annual climatic variables. Assessments of climatic extremes comparing current-year conditions with historical trends for key stations will also be displayed. See Table 4.8 and Figures 4.6 and 4.7 for examples.

This section will also include a standard statement, describing that NCCN parks have a more extensive climate network (i.e. more stations, more parameters) than described within the summarized data section. A link will be provided where readers can access complete metadata for NCCN climate sites.

Table 4.7. Key Climate stations for reporting. Climate stations in *italic* are funded for installation, but are not installed.

Name	Network
MORA	
Longmire	COOP
Paradise Ranger Station	COOP
Paradise	Snow Course
Carbon River	NPS
Ohanapecosh	RAWS
Camp Muir High Elevation Site	NPS/NWAC
Sunrise High Elevation Site	NPS/NWAC
NOCA	
Ross Dam	COOP
Darrington (Marblemount)	CRN
Stehekin	COOP/RAWS
Park Creek	SNOTEL/Snow Course
Noisy Glacier	Modified SNOTEL
Silver Glacier	Modified SNOTEL
OLYM	
Hoh Ranger Station	COOP
Hoh Valley	NPS
Quillayute State Airport	COOP
Quinault 4 NE	CRN
Port Angeles	COOP
Waterhole	SNOTEL
Deer Park Ranger Station	NPS & Snow Course
Hayes Ranger Station	NPS
Buckinghorse Ridge	SNOTEL
LEWI	
Fort Clatsop	COOP
Seaside	COOP
FOVA	
Vancouver, Pearson Airpark	ASOS
Vancouver 4 NNE	COOP
EBLA	
Coupeville	COOP
SAJH	
Friday Harbor Airport	ASOS
<i>English Camp</i>	RAWS

Table 4.8. Example monthly summary table for an NCCN climate station.

Deer Park Road 1999 – Monthly Summary Table

Month	Mean Air Temp	Maximum Air Temp	Minimum Air Temp	Precipitation (mm)
January	1.5	12.3	-5.3	239
February	0.3	9.9	-7.2	183
March	0.7	16.8	-5.2	76
April	4.4	20.5	-3.5	16
May	5.7	23.3	-2.7	34
June	8.5	24.1	0.2	66
July	12.8	23.7	2.7	32
August	14.3	27.4	4.8	38
September	13.1	26.2	2.3	1
October	8.1	20.7	-0.1	97
November	4.5	18.1	-2.6	262
December	4.5	19.7	-2.8	133
Annual	6.5	27.4	-7.2	1,178

Month with Maximum Temp Value



Month with Minimum Temp Value



Driest Month



Wettest Month



Warmest Month: August, 14.3 C

Day with Hottest Temperature: August 27th, 27.4 C

Coldest Month: February, 0.3 C

Day with Coldest Temperature: February 9th, -7.2 C

Wettest Month: November, 262 mm (10.3 inches)

Wettest Day: January 28th, 79 mm (3.1 inches)

Driest Month: September, 1 mm (0.06 inches)

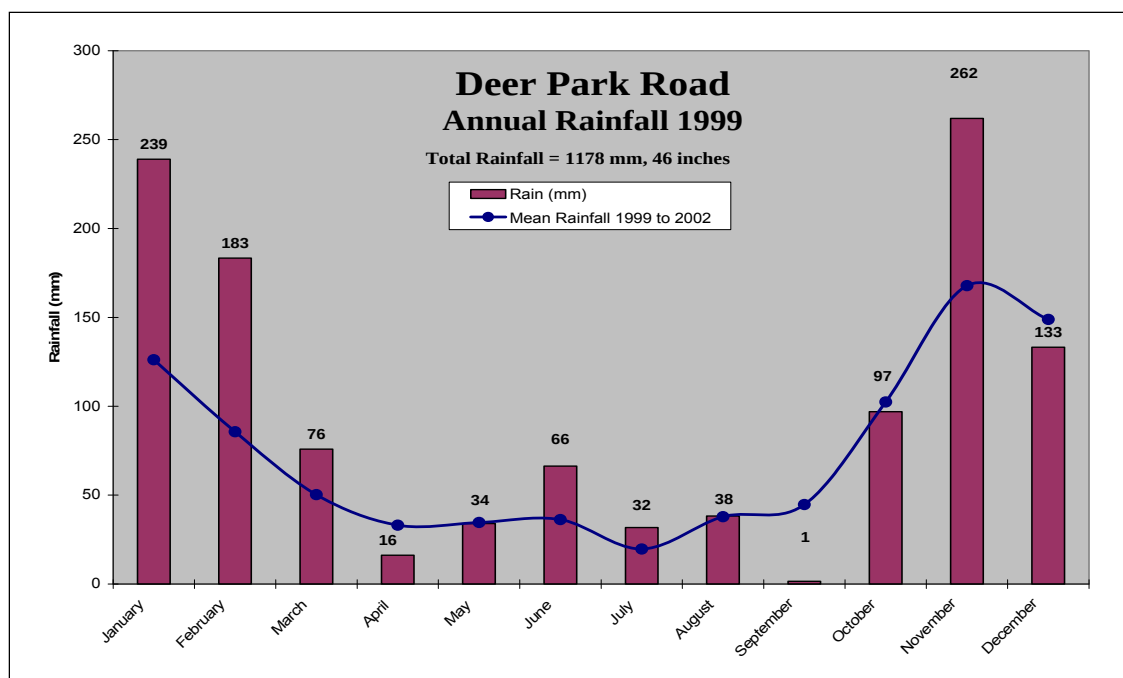


Figure 4.6. Monthly precipitation comparison for an NCCN climate station.

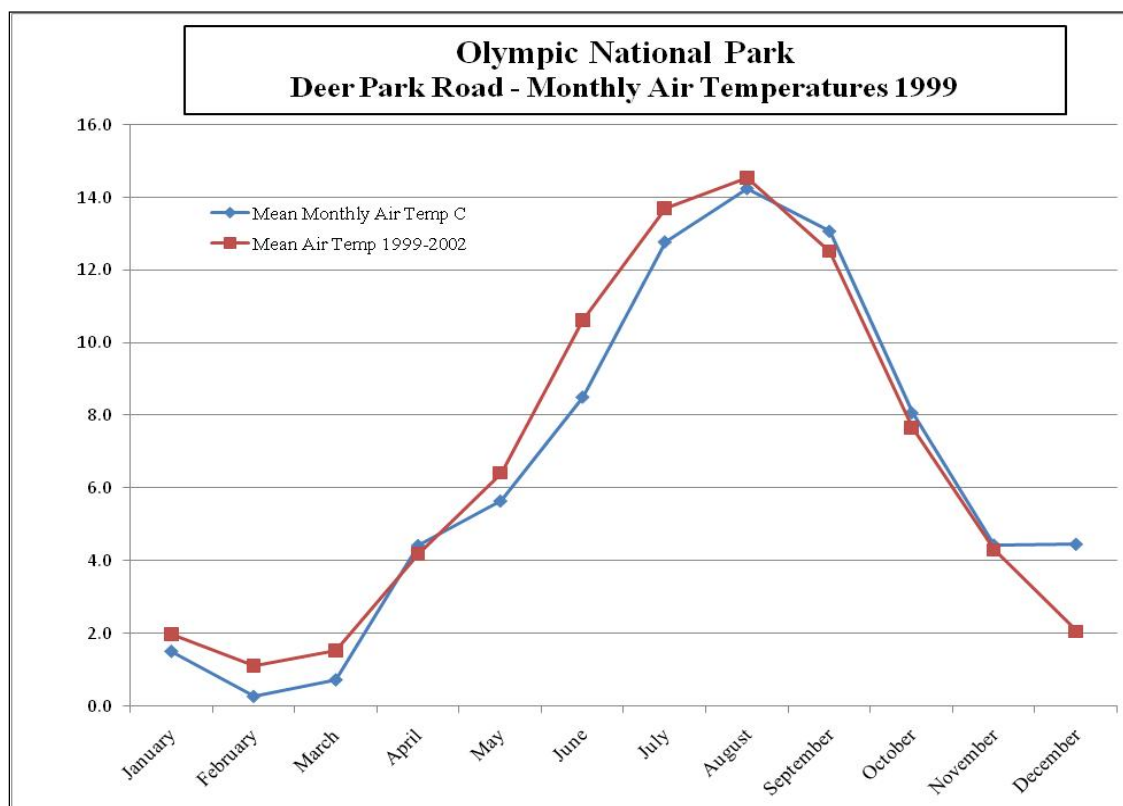


Figure 4.7. Monthly air temperature comparison for an NCCN climate station.

4.10.3 Mountain Snow Pack

This section will include regional and park specific narratives describe the winter snow pack and unusual events which would pertain to the climatic record or which could influence other NCCN protocols (e.g. the narrative would discuss unusual snow conditions or weather conditions triggering avalanche cycles or “rain on snow” events which led to extensive flooding or loss of snow pack). Data will be presented from SNOTEL and Snow Courses, describing the annual snowpack in mountainous parks of the NCCN (NOCA, MORA & OLYM). Data tables and graphs will be offset from calendar year data presented in the rest of this report, as snow pack data generally begins in October of the prior year, continuing until early summer of the reporting year (i.e. a report for 2007 would include snow pack data from Oct. to Dec. 2006 and Jan. to July 2007). This section will also correlate data from other protocols including glacier mass balance and mountain lake ice-out events. See Figures 4.8 and 4.9 for examples.

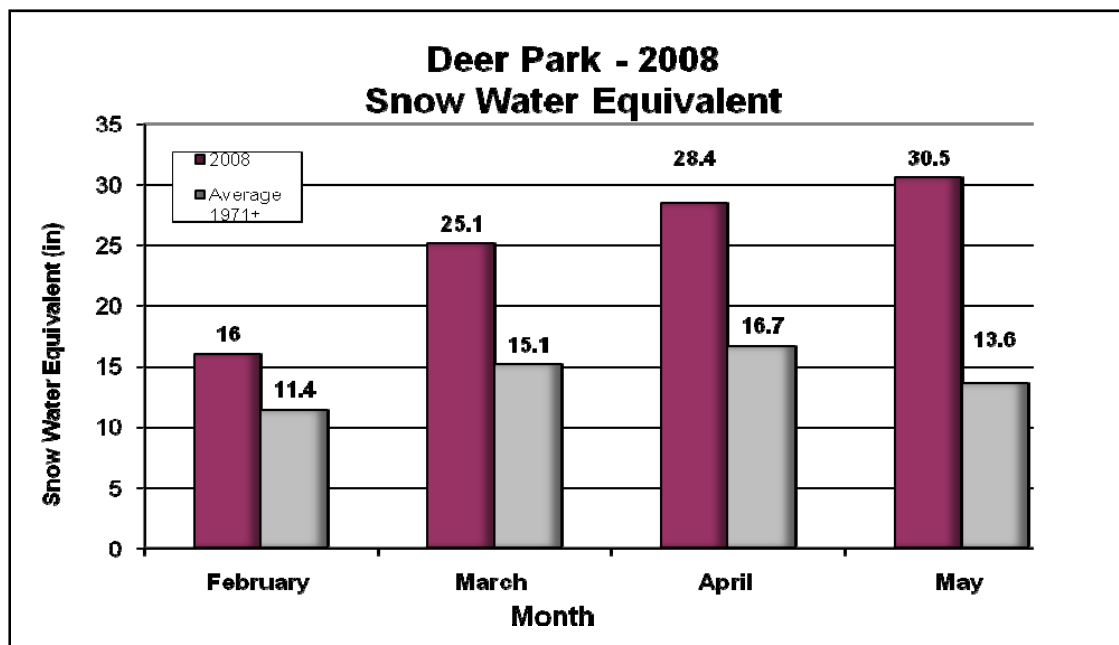


Figure 4.8. Example of monthly snow water equivalent (snow surveys – 4 months).

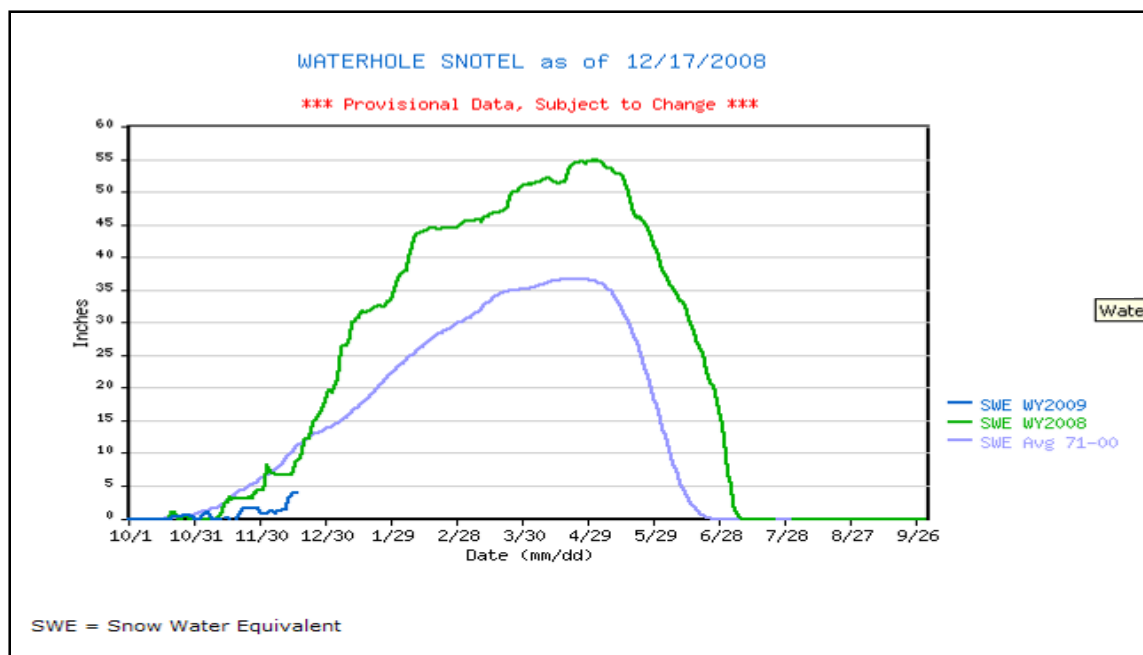


Figure 4.9. Example of daily snow water equivalent from a SNOTEL climate station (Courtesy of USDA-NRCS).

4.10.4 Significant Weather Events

This section will discuss major weather events taking place during that year. Events may be unusual due to extent (such as a major rain event or an unusually long freeze event) or due to timing (such as a large rain event in July or a period of high temperature in January). Events are significant in that they may affect organisms (a freezing event) or entire landscapes (snow triggered avalanches or major wind storms). Narrative descriptions of events will be supplemented by tables, photographs and graphs, placing the event into context to past events or related events in other NCCN parks. See Figure 4.10 for an example.

4.10.5 Operations Review

This section will discuss major operational concerns during the year that may affect the quality or amount of data available from this year. Examples might include the loss of a climate sites or climate instrumentation due to catastrophic events or major data loss at a site due to instrument failures. The section would also discuss positive changes to the climate network such as the addition of a new climate site or updated instrumentation at an existing site.

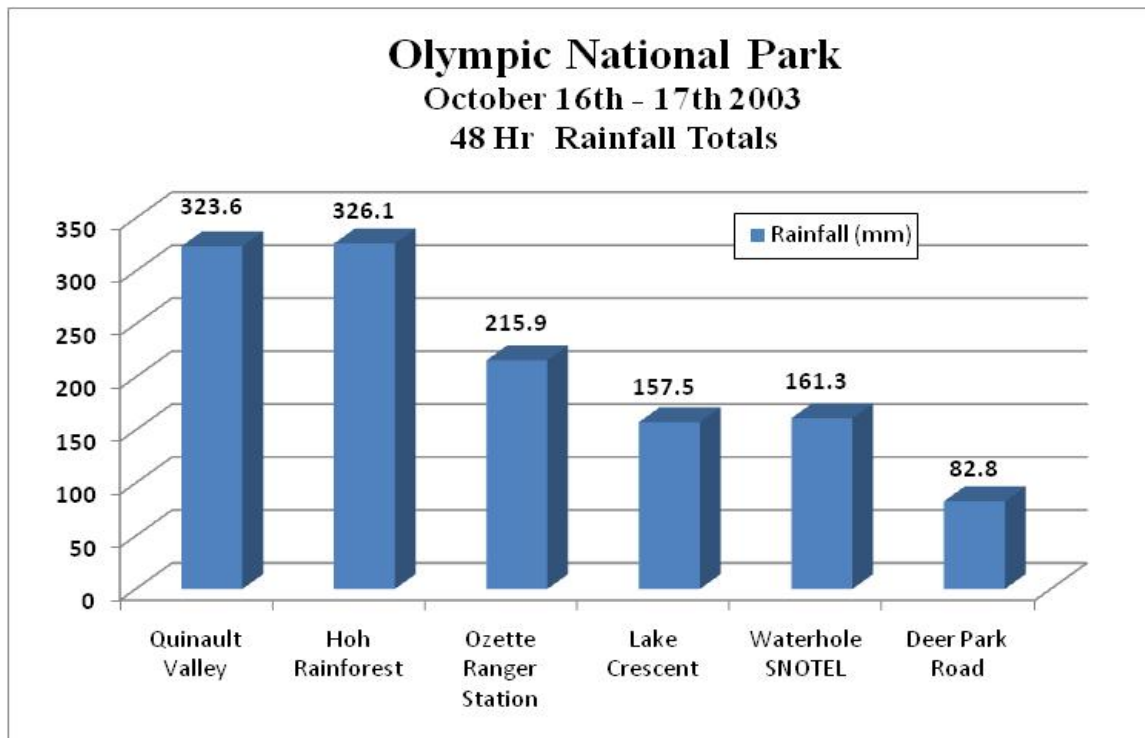


Figure 4.10. Precipitation data from NCCN climate sites: October 16–17th storm event.

4.10.6 Periodic Comprehensive Reports

Comprehensive climate reports will be produced as needed. The objectives and content of the reports will be determined by management needs. Comprehensive reports may include: trend analysis of climate variables and trend comparisons with other environments in the region (e.g., are rates of change similar between Puget Sound lowlands and high-elevation stations in NCCN parks; between Cascade parks and the Olympics; between coastal areas, etc.).

We will produce periodic reports that will include trend analysis of climate at the local (park), network, and regional (Pacific Northwest) scales. The NPS National Inventory and Monitoring Climate group is developing procedures for long-term trend analysis for climate monitoring. This protocol will be updated when these procedures become available, within the next few years.

4.11 Procedures for Making Changes to and Archiving Previous Versions of the Protocol

Revisions to the Protocol Narrative and SOPs will be inevitable over time. Explicit documentation of these changes is critical for proper acquisition, processing, interpretation, and analysis of climate data. Procedures for changing the protocol narrative and related SOPs are documented in SOP 14 (Vol. 2). The Protocol Narrative and all SOPs are labeled with version numbers, and included in a Revision History Log. Changes to either document type are to be accompanied by changes in version numbers; version numbers and dates, the changes, reasons for the changes, and the author of the changes are to be recorded in the Revision History Log. Previous versions of the Protocol Narrative and SOPs must be archived.

5 - Personnel Requirements and Training

5.1 Roles and Responsibilities

Recording and reporting measures from climate stations is the role of either park staff or is automated (Table 5.1). Personnel responsible for equipment maintenance, inspection, and calibration of climate stations are discussed above in Section 3.

Data acquisition and storage on the NCCN server is the responsibility of the NCCN Data Manager. The acquisition and archiving of data for each climate station in the NCCN will be performed at least once a year by NCCN Data Management. However, data can be accessed more frequently if necessary to support ongoing data analyses or in response to requests by NCCN collaborators and researchers.

The collection of data, reporting of summaries and assessments will be the responsibility of the MORA Biological Technician, and the OLYM and NOCA Physical Science Technicians, under the direction of the MORA Biologist and NOCA Geologist (NPS Leads). Responsibilities of all personnel involved with this project are indicated in Table 5.1

Table 5.1. Roles and responsibilities of the NCCN climate monitoring program.

Role	Responsibilities	Name / Position
NPS Leads	Project oversight and administration. Track project objectives, budget, requirements, and progress toward meeting objectives Implement climate monitoring program including planning and coordination Facilitate communications between NPS and cooperators Coordinate and ratify changes to protocol Review reports, data and other project deliverables Seek additional funding opportunities planning and coordination	Biologist, MORA ¹ Geologist, NOCA ²
Project Leads /Data Analyst	Project operations and implementation including planning and coordination, maintenance and calibration of weather stations Acquire and maintain field equipment Operation, data collection and archiving of data from stations and verify accurate data transcription into database Certify data for quality and completeness Maintain and archive project records Prepare data summaries and analysis and other project deliverables. Suggest changes to protocol as appropriate	Biological Technician, MORA ³ Physical Science Technician, OLYM ⁴ Physical Science Technician, NOCA
Park Rangers and Other Park Staff	Recording daily observations of NWS-COOP stations. Inspection and calibration of RAWS stations prior to the fire season, and emergency service Collecting snow course data approximately twice per month from January–June	Park Rangers(MORA COOP Stations); MORA Biological Science Technician, Physical Science techs at OLYM and NOCA

Table 5.1. Roles and responsibilities of the NCCN climate monitoring program (continued).

Role	Responsibilities	Name / Position
Data Manager	Consultant on data management activities. Facilitate check-in, review and posting of data, metadata, reports, and other products to national databases and clearinghouses according to schedule Maintain and update database application Provide database training as needed	Data Manager, MORA ⁵
GIS Specialist	Consultant on spatial data collection, GPS use, and spatial analysis techniques Facilitate spatial data development and map output generation Work with Project Leads to analyze spatial data and develop metadata for spatial data products Primary steward of GIS data and products	MORA GIS Specialist ⁶ (with assistance from MORA Biological Technician)
Network Coordinator	Review of annual reports for format editing; content meets Network goals and objectives, including management applications; and completeness	NCCN Network Coordinator ⁷
Park Curator	Receive and archive copies of annual reports, 5-year analysis report, and other publications Facilitate archival of other project records (e.g., original field forms, etc.)	Park Curators and Collections Managers at OLYM, NOCA and MORA
Program Managers of Other Agency Climate Monitoring Programs	Consultant on technical issues related to project sampling design, statistical analyses, or other issues related to changes in protocol and SOPs Technical assistance in equipment installation and maintenance	NWS-COOP, NWAC, SNOTEL, RAWs, Regional Climate Center

¹Barbara Samora as of 2/2010²Jon Riedel as of 2/2010³Rebecca Lofgren as of 2/2010⁴Bill Baccus as of 2/2010⁵Brett Christoe as of 2/2010⁶Darin Swinney as of 2/2010⁷Mark Huff as of 2/2010

5.2 Qualifications and Training Procedures

The NWS Observing Handbook No. 2 (Cooperative Station Observations) (SOP 7) details procedures for recording and reporting NWS COOP measurements. New observers are required to review this document and to be checked-out onsite by a NWS representative. Also, all observers will review the NWS instructions (SOP 7) to ensure consistency in recording and reporting.

Personnel are instructed on the maintenance and calibration of RAWs stations (SOP 5) and on the Interagency RAWs web page). Contacts for national and regional RAWs coordinators also are provided to aid in resolving questions or problems.

NRCS provides instructions for Snow Course observations in Agriculture Handbook No. 169 (SOP 7). New observers will participate in the “annual snow school for new observers,” training course provided by NRCS.

NPS personnel do not participate in data collection for the Upper-air observations. The program requires their agency staff to take official upper-air observations, an observer must be certified in accordance with NDS 10- 1304 (SOP 10). The observer must pass a written examination, administered by the office manager, with a minimum score of 80 percent. Each observer must pass an eye examination or show proof of visual acuity of 20/30 or better in at least one eye.

NPS Climate stations and High Elevation Stations require knowledge of datalogger programming, station set-up, general maintenance and equipment calibration, and data downloading (See SOP 1, NPS Climate Stations and SOP 2, High Elevation Stations for specific details).

SNOTEL, ASOS, and CRN stations are maintained by their respective agencies. Occasional requests are made from agencies to park staff to perform general maintenance (cleaning out precipitation gage, changing batteries, etc.). In this event, instructions will be given at the time of request.

5.3 Data Acquisition and Archiving

Instructions and procedures for downloading and archiving climate-station data are described in described within the corresponding SOPs for each program. Staff responsible for acquisition and archiving will be required to peruse the SOPs prior to data acquisition; initial engagement in acquisition procedures will be supervised by the NCCN Data Manager.

5.4 Safety

High Elevation stations, SNOTEL and snow survey sites, and NPS climate stations are often in remote areas. Accessing these remote climate weather station sites require the field skills to access sites year round. In most NCCN parks this will include skiing, snowshoeing, extended backpacking, avalanche safety, and helicopter operations. It is critical that employees have proper equipment, training, and fitness. NPS Staff receives training in avalanche safety, aircraft operations, and must complete an annual Job Hazard Analysis for climate monitoring field tasks performed.

The NRCS offers a West Wide Snow Survey Training school for all employees responsible for snow surveys. In addition to remote snow course and SNOTEL sample procedures, training is provided in avalanche awareness, wilderness survival, and wilderness first aid. All NPS field staff working in remote areas will attend this training.

Avalanche Level I courses are available throughout the winter and spring. The courses present basic information about weather, snowpack, and terrain factors which contribute to avalanche hazard. Topics generally include: Tour planning and preparation, pertinent weather phenomena, terrain assessment, snowpack understanding, route finding, basic test procedures and interpretation, decision making, group management, avalanche transceiver use and basic rescue. All NPS personnel traveling in potential avalanche terrain are required to take this training.

Travel during all months requires park staff to carry the Wilderness Ten Essentials (see list below), notify park Communications Center of travel destination, carry a park radio, and be prepared for all conditions.

List of wilderness ten essentials:

- Matches in a waterproof case
- Flashlight, Extra Batteries and Bulb
- Pocket Knife
- First Aid Kit
- Fire Starter
- Map
- Compass
- Sunglasses/Sunscreen
- Extra Clothing
- Extra food

6 - Operational Requirements

6.1 Annual Workload and Schedule

The annual workload and schedule is noted in Table 6.1. This table identifies each task by project stage, indicates who is responsible, and establishes the timing for its execution.

Table 6.1. Annual workload and schedule.

Project Stage	Task Description	Responsibility	Timing
Preparation	Notify Data Manager and GIS Specialist of needs for the coming season (field maps, GPS support, training)	Project Leads	Jan–Feb
	Ensure all project compliance needs are completed for the coming year	Project Leads	Feb–Mar
	Meet (or conference call) to recap past field season, discuss the upcoming field season, and document any needed changes to field sampling protocols or the working database	NPS Leads, Project Leads and Data Manager, GIS specialist	Jan
	Plan schedule and logistics, including ordering any needed equipment and supplies (SOP #1)	NPS Leads	By Apr 30
Data Collection	NPS Stations		
	Implement working database copy	Data Manager	By May 30
	Monitor station data on a regular basis and compare such data with other nearby stations, with National Weather Service balloon sounding or forecast model data.	Project Leads	Weekly for automated stations
	“Pre-winter” Site Maintenance Download final data for last water year Change, check or supplement batteries Calibrate snow depth sensor	Project Leads	October 1 to November 15th
	Site Maintenance Download data for last calendar year	Project Leads	January 1 to February 15th
	Site Maintenance Download data Tipping Bucket calibration Equipment change-out (Factory Calibration)	Project Leads	April 1 to May 15 th
	Site Maintenance Download data Equipment change-out (Factory Calibration)	Project Leads	July 1 to August 15 th
	High Elevation Stations		
	Monitor station data on a regular basis and compare such data with other nearby stations, with National Weather Service balloon sounding or forecast model data. Utilize NWAC to analyze the data for potential problems.	Project Leads	Weekly

Table 6.1. Annual workload and schedule (continued).

Project Stage	Task Description	Responsibility	Timing
	Download data from datalogger if telemetry failed during 6 months	Project Leads	Once/6 months
	Clean debris from precipitation gage		
	Clean the radiation shield		
	Check wind speed/direction sensor		
	Clean the enclosure		
	Replace desiccant in enclosure		
	Calibrate temperature/relative humidity sensor	Project Leads	Annual
	Calibrate snowdepth sensors		
	Replace Glycol Ethanol (see SOP 1, Appendix K for instructions)		
	Replace temperature/relative humidity sensor	Project Leads	2–5 Years
	Replace batteries		
	Calibrate precipitation gauge		
	Calibrate the datalogger. Check with Campbell Scientific		
	Replace soil temperature probes	Project Leads	5–10 Years
	Replace wind speed/direction sensors		
	Replace sensors and sensor cables as necessary		
	Inspect station	Project Leads	Minimum twice/year
	Check sensor leads for damage		
	Ensure tower is straight and stable		
	Check alignment of antenna		
	Clean glass on solar panel		
Photo documentation	Snow course		
	Collect monthly snowcourse data	Project Leads, Park Rangers, NRCS staff	January to May
	Collect and report NWS-COOP station data for manual sites and enter into NWS web page	Park Rangers, Project Leads	Daily
	RAWS		
	Respond to the Automated Sorting, Conversion and Distribution System (ASCADS) to address problems with RAWS.	Project Leads, Park Rangers	As needed
	SNOTEL		
	Assist NRCS staff as needed	Project Leads, Park Rangers	As needed
	Download and process digital images (SOP #4)	Project Leads	after each tour
	Data Entry & Processing		
	Quality review and data validation	Project Leads	After each download By Jan 15
	Update project metadata records	Project Leads, Data Manager	Feb
	Certify the season's data and complete the certification report	Project Lead	Feb

Table 6.1. Annual workload and schedule (continued).

Project Stage	Task Description	Responsibility	Timing
Metadata	Deliver certification report, certified data, digital photographs, and updated metadata to Data Manager	Project Lead	Feb
	Upload certified data into master project database, store data files in NCCN Digital Library ¹	Data Manager	Mar
	Notify Project Lead of uploaded data ready for analysis and reporting	Data Manager	Mar
	Update project GIS data sets, layers and associated metadata records	GIS Specialist, (Project Lead, Mar MORA Biological Science Technician for MORA and Small Parks)	
	Finalize and parse metadata records, store in NCCN Digital Library ¹	Data Manager and GIS Specialist	By Apr 15
	Produce Network and park-wide map output for archives	GIS Specialist/MORA Biological Science Technician	Apr–May
	Generate report-quality map output for reports	GIS Specialists/MORA Biological Science Technician (MORA and small parks)	Apr–May
	Export automated summary queries and reports from database	Data Manager	Oct (water year); Jan (calendar year)
Reporting and Product Development	Analyze station by station trends	Project Leads, Data Manager	Oct–Jan
	Complete field season report for AARWP	NPS Leads, Project Leads	Sept–Oct
	Acquire the proper report template from the NPS website, create annual report	Data Analyst and Project Lead	Apr–May
	Prepare draft Annual Report (Calendar and Water Year)	Project Leads, NPS Leads, Data Manager	Oct–Feb.
Posting & Distribution Archival & Records Management	Submit draft report to Network Coordinator for review	Project Lead	By March 31st
	Review report for formatting and completeness, notify Project Lead of approval or need for changes	Network Coordinator	April
	Upload completed report to NCCN Digital Library ¹ submissions folder, notify Data Manager	Project Lead	upon approval
	Deliver other products according to the delivery schedule and instructions	Project Lead	upon completion
	Create NatureBib ³ record, post reports to NPS clearinghouse	Data Manager	upon receipt
	Submit certified data and GIS data sets to NPS Data Store ²	Data Manager	upon receipt
	Store finished products in NCCN Digital Library ¹	Data Manager	upon receipt
	Review, clean up and store and/or dispose of project files according to NPS Director's Order #19	Project Lead	Nov

Table 6.1. Annual workload and schedule (continued).

Project Stage	Task Description	Responsibility	Timing
	Product check-in	Data Manager	upon receipt
	Submit metadata to NPS Data Store ²	Data Manager	Upon receipt

¹The NCCN Digital Library is a hierarchical digital filing system stored on the NCCN file servers (Boetsch et al. 2005). Network users have read-only access to these files, except where information sensitivity may preclude general access.

²NPS Data Store is a clearinghouse for natural resource data and metadata (<http://science.nature.nps.gov/nrdata>). Only non-sensitive information is posted to NPS Data Store. Refer to the protocol section on sensitive information for details.

³NatureBib is the NPS bibliographic database (<http://www.nature.nps.gov/nrbib/index.htm>). This application has the capability of storing and providing public access to image data (e.g., PDF files) associated with each record.

While this project has been under development, the amount of funds forecasted to be available for the project has been reduced substantially. In response to this reduction in anticipated funding, we anticipate beginning implementation of the monitoring program with a reduction in the number of new stations that will be installed and maintained within NCCN parks. Under this scenario we have scaled back sampling effort by addressing only the top priorities in each of the parks.

Our implementation budget will continue to erode as the annual cost of living (for term technicians) and step increases associated with salaries are not available within this program. In addition, limited funds are available to support the required training requirements associated with all NPS employees (mandatory training for personnel, IT, purchasing, safety), as well as specific training that may be needed for new equipment and procedures. We will continue to seek to leverage assistance through the other climate monitoring programs that have been very instrumental in developing the NCCN climate monitoring protocol.

The NCCN is not directly involved in reading, recording, and reporting the observations from SNOTEL, ASOS, CRN, NWAC, or the NPS Upper Air Station.

6.2 Facility and Equipment Needs

A summary of the climate monitoring programs and the responsibilities of each agency that form the NCCN climate monitoring network is shown in Table 6.2. COOP, SNOTEL, ASOS, CRN, RAWS, and NPS Upper Air stations are supplied with sensors by the administrating agency. These external agencies determine necessary sensor additions or enhancements. Additional sensors can be added to RAWS and SNOTEL stations to meet park needs.

RAWS stations must meet national standards to participate in the Interagency RAWS program (National Wildfire Coordinating Group 2009). Broken sensors can be replaced at no cost through an exchange program with the Interagency Fire Lab, Boise ID, if the damaged sensor is returned to the Lab within a certain time of receiving the replacement. The park is responsible for providing staff to perform the annual maintenance and calibration of RAWS stations, and for emergency service. Otherwise, there are no operating costs.

COOP, ASOS, CRN, NPS Upper Air stations are funded by the administrating agency. There is no annual cost associated with these stations.

The NRCS is responsible for SNOTEL general maintenance, sensor replacement, and data transmission. Some sites require a \$4,000 dollar fee funded by the Park Service for maintenance and data transmission

MORA is responsible for sensor additions and replacement at the Sunrise and Muir High Elevation Stations. NWAC is primarily responsible all other High Elevation Stations identified in SOP 2. NPS Climate Stations are installed and maintained by NPS staff.

Table 6.2. Agencies responsible for climate station installation costs, and repair or replacement costs of equipment at NCCN Parks.

Climate Monitoring Program	Agency	Agency Responsible for Installation Cost, and Repair or Replacement Costs of Equipment at NCCN Parks	Agency Responsible for Installation of Equipment at NCCN Parks
RAWS	NIFC, BLM, USFS, NPS, et al.	NIFC	NPS
NWS-COOP	NWS	NWS	NWS, NPS
CRN	NOAA	CRN	NPS
SNOTEL	NRCS	SNOTEL, NPS	NRCS, NPS
NWAC High Elevation Weather Stations	USFS, NWS, NPS, et al	NWAC and NPS	NWAC, NPS
Snow Course ; Aerial Markers	NRCS	NPS	NPS
ASOS	FAA, DOD, NWS	NWS	NWS
NPS Climate Stations	NPS	NPS	NPS
NWS Upper Air Observations Program	NWS	NWS	NWS

Total costs of installation for facilities and equipment needs for the NCCN climate monitoring network are noted in Tables 6.3–6.7, below.

6.3 Startup Costs and Budget Considerations

The annual operating costs are shown in Table 6.3. Annual costs for the NCCN Climate Monitoring Program in FY 2008 dollars are \$65,460.00 from the Vital Signs Monitoring Program and \$36,900.00 from the Operations of the National Park Service (ONPS). Much of the ONPS costs are on-going from pre-existing stations. Equipment calibration costs are higher at Olympic because they have a greater number of park operated sites and multiple data loggers at older sites, (in forest understory matched with forest gaps).

The start-up costs of the highest priorities in each park (new stations) are listed in Table 6.3 through 6.6. Existing funding is available to fund priorities sites noted in bold. Some stations listed are being funded by other agencies. The total costs for equipment purchase and installation of these highest priority sites is \$73,200.00. Partnerships and funds have already been leveraged to provide RAWS station installation and maintenance at MORA and NOCA; SNOTEL sites at

MORA, NOCA and OLYM; CRN sites at NOCA and OLYM and NWAC sites at NOCA and MORA.

If additional funds become available, lower priority sites may be installed. It is essential for the NCCN Climate Monitoring Program to continue to partner with outside agencies and to also seek additional funding partners in order to maintain a viable long-term climate monitoring network. Stations need constant maintenance, which requires both money for equipment and personnel time. As referenced in Section 6.1, our implementation budget will continue to erode as the annual cost of living (for term technicians) and step increases associated with salaries are not available within this program. We will need to work with the many partners in our Climate Monitoring Network, providing logistical, written, and moral support where we can to ensure those stations continue to operate in the NCCN Network.

Table 6.3. Annual operating costs for climate monitoring protocol: Maintenance of weather stations.

Salaries and Benefits	Job component	PP	Cost/pp	Cost NCCN Climate	Cost NCCN Other	Cost ONPS
Technicians	Project operations and implementation, including: planning and coordination, maintenance and calibration of weather stations. Acquire and maintain field equipment. Operation, data collection and archiving of data from stations and verify accurate data transcription into database. Provide initial QA/QC of data, and certify data for quality and completeness. Prepare data summaries and analysis and other project deliverables. Suggest changes to field protocols, as appropriate.					
GS9/4 PERM/TERM MORA	See above	6	2,800.00	16,800.00		
GS 7/3 TERM/PERM NOCA	See above	2	1,800.00	3,600.00		
GS 7/6 PERM OLYM	See above	12	2,850.00		34,200	
Data Manager	Maintain and archive project records. Prepare data summaries and analysis and other project deliverables.	2.5	3,520.00		8,800.00	
ONPS Contributions						
MORA PERM Biologist GS 12	oversight, supervision	2	3,600.00			7,200.00
NOCA PERM Geologist GS 12	oversight, supervision	2	3,600.00			7,200.00

Table 6.3. Annual operating costs for climate monitoring protocol: Maintenance of weather stations (continued).

Salaries and Benefits	Job component	PP	Cost/pp	Cost NCCN Climate	Cost NCCN Other	Cost ONPS
MORA Park Rangers	Daily weather data collection for Longmire and Paradise COOP station; assist in troubleshooting maint. of Camp Muir station; assist in snow course surveys	6	2,000.00			12,000.00
MORA Maintenance Workers	Assist in maintenance of telemetry and electronics	1	3,000.00			3,000.00
Logistical Support from ONPS MORA	transportation, computer support					2,500.00
Logistical Support from ONPS NOCA	transportation, computer support					2,500.00
Logistical Support from ONPS OLYM	transportation, computer support					2,500.00
Field Per Diem OLYM				650.00		
Field Per Diem NOCA				650.00		
Field Per Diem MORA				460.00		
MORA Interagency Agreement with NWAC				4,000.00		
NOCA Interagency Agreement w/NRCS				1,624.00		
OLYM Interagency Agreement w/NRCS				2,500.00		
OLYM equipment replacement/maintenance/ calibration (includes SAJH)				3,691.00		
SAJH equipment replacement				500.00		
Equipment Replacement MORA				1,245.00		
Equipment Replacement NOCA				1,240.00		
Total Annual Operating Costs				\$36,960.00	\$43,000.00	\$36,900.00

Table 6.4. Installation costs for MORA new climate monitoring stations. The highest priority sites are listed in italics.

Priority/Site Name	Data Type	Estimated Cost
1. <i>Sunrise</i>	Full met	\$10,000 (installed)
2. <i>Ohanapecosh</i>	RAWS	\$5,000 (installed)
3. <i>Camp Muir</i>	Full met* (High Elevation Station)	\$10,000 (installed)
4. <i>Carbon</i>	Upgrade to full met. and automate (NPS Climate Station)	\$8,500 (installed)
5. <i>Cayuse Pass</i>	Upgrade to full SNOTEL site	Funded by NRCS (upgraded)
6. Summit	Temperature (Hobo)	\$200
7. Mowich Lake	SNOTEL	\$25,000
8. White River	Full met. (NPS Climate Station)	\$25,000
9. Schurman	Full met. (High Elevation Station)	\$18,000
10. Longmire	Automate COOP station	\$10,000

*Full met includes air temperature, precipitation, wind speed, wind direction and relative humidity. Solar radiation can be added.

NOCA Funding is available to install site 3, Silver Glacier. All other sites are funded through partnerships.

Table 6.5. Installation costs for NOCA new climate monitoring stations.

Priority/Site Name	Data Type	Estimated Cost
1. Noisy Glacier (Baker)	Modified SNOTEL (basic weather)*	Puget Sound Energy to fund
2. Washington Pass	Modified SNOTEL (basic weather)	Funded –DOT, NWAC
3. Silver Glacier	Modified SNOTEL (basic weather)	Capital cost \$10,000
4. Easy Pass	Modified SNOTEL (basic weather)	Funded by Puget Sound Energy
5. Brown Top	Modified SNOTEL (basic weather)	Funded by Seattle City Light

*Basic weather includes air temperature, snow depth, radiation (net) and continuous, wind speed and direction (summer).

Table 6.6. Installation costs for OLYM new climate monitoring stations. The highest priority sites are listed in *italics*.

Site Name	Data Type	Costs (Capital/ Annual)
1. <i>Buckinghorse Ridge</i>	SNOTEL	Funded and installed NRCS/2,500 NPS annual maintenance cost
2. <i>Elwha (Hayes RS)</i>	Full met.* (NPS Climate Station)	\$7,200 (installed)
3. <i>Staircase -1</i>	Full met.* (NPS Climate Station)	\$6,000
4. <i>Ozette</i>	Full met.* (NPS Climate Station)	\$6,000
5. Anderson Glacier	Limited suite of Instruments	Unknown
6. Kalaloch	Full met.* (NPS Climate Station)	\$6,000*
7. Dosewallips or Supplement Mt. Crag	Full met.* (NPS Climate Station)	\$6,000

*Station may require additional replacement parts due to proximity to the ocean and salt related issues.

Existing funding is available to fund sites 1–3. Site 1, Buckinghorse Ridge SNOTEL is funded through the NRCS. The NCCN contribution is to address NEPA compliance requirements and annual maintenance costs of \$2,500.

Table 6.7. Installation costs for SAJU.

Site Name	Data Type	Represents	Infrastructure	Costs (Capital/ Annual)
English Camp	RAWS	Northwest side of park	110 AC	\$13,000

RAWS equipment was purchased with base dollars in 2008. The OLYM field technician will maintain this site.

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Appendix A. Continuous water temperature sampling.

Annual continuous water temperature data are collected at all lakes in the Mountain Lakes Monitoring Program. Temperature is a major driver of the physical, chemical, and biological processes within lakes. Water temperature data provides a primary source of information for evaluating changes in lake biological communities chemical properties (Fradkin et al 2008).

For purposes of climate monitoring, data from continuous temperature data loggers collected as part of the Mountain Lakes Monitoring Program are used to determine ice phenology (lake ice-out/ice-in). This will provide MORA, NOCA and OLYM with spatial, annual and decadal trends in lake ice phenology (lake ice-out). Ice-on and ice-off dates are useful indicators of climate change (Magnuson et al. 2000).

To continuously monitor temperatures occurring within a mountain lake and to understand the timing and degree of thermal stratification and ice phenology, temperature loggers are placed at three depths within the lake water column (see figure A.1). In addition, ambient air temperature is measured to aid with interpretation of lake temperature variations. The air temperature data also supplements the NCCN climate monitoring program by adding instrumentation in remote mountainous locations and increasing spatial understanding of temperature variations within mountainous regions. Techniques for collecting continuous water temperature data are detailed in SOP 8 (Continuous Water Temperature Sampling) from the NCCN Mountain Lakes Monitoring Protocol and is stored on the NCCN server at <http://science.nature.nps.gov/im/units/nccn/reportpubs.cfm>.

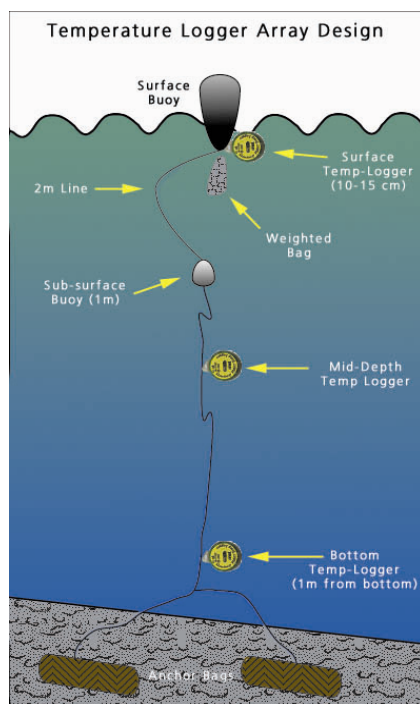


Figure A.1. Temperature Logger Array Design

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Appendix B. Maps of Climate Stations Located in and adjacent to NCCN Park Units

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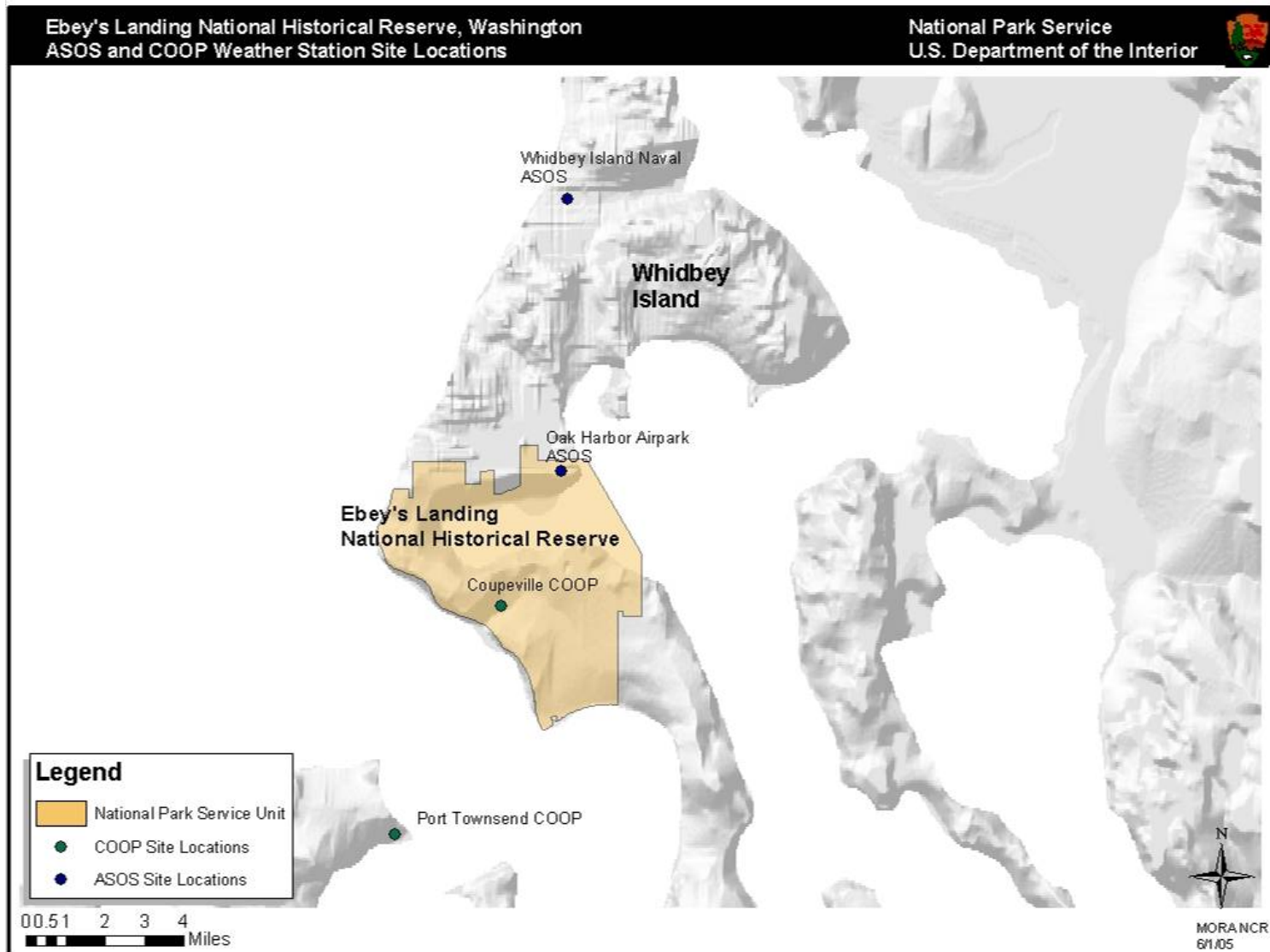


Figure B.1. Ebey's Landing National Historical Reserve ASOS and COOP Station Site Locations.

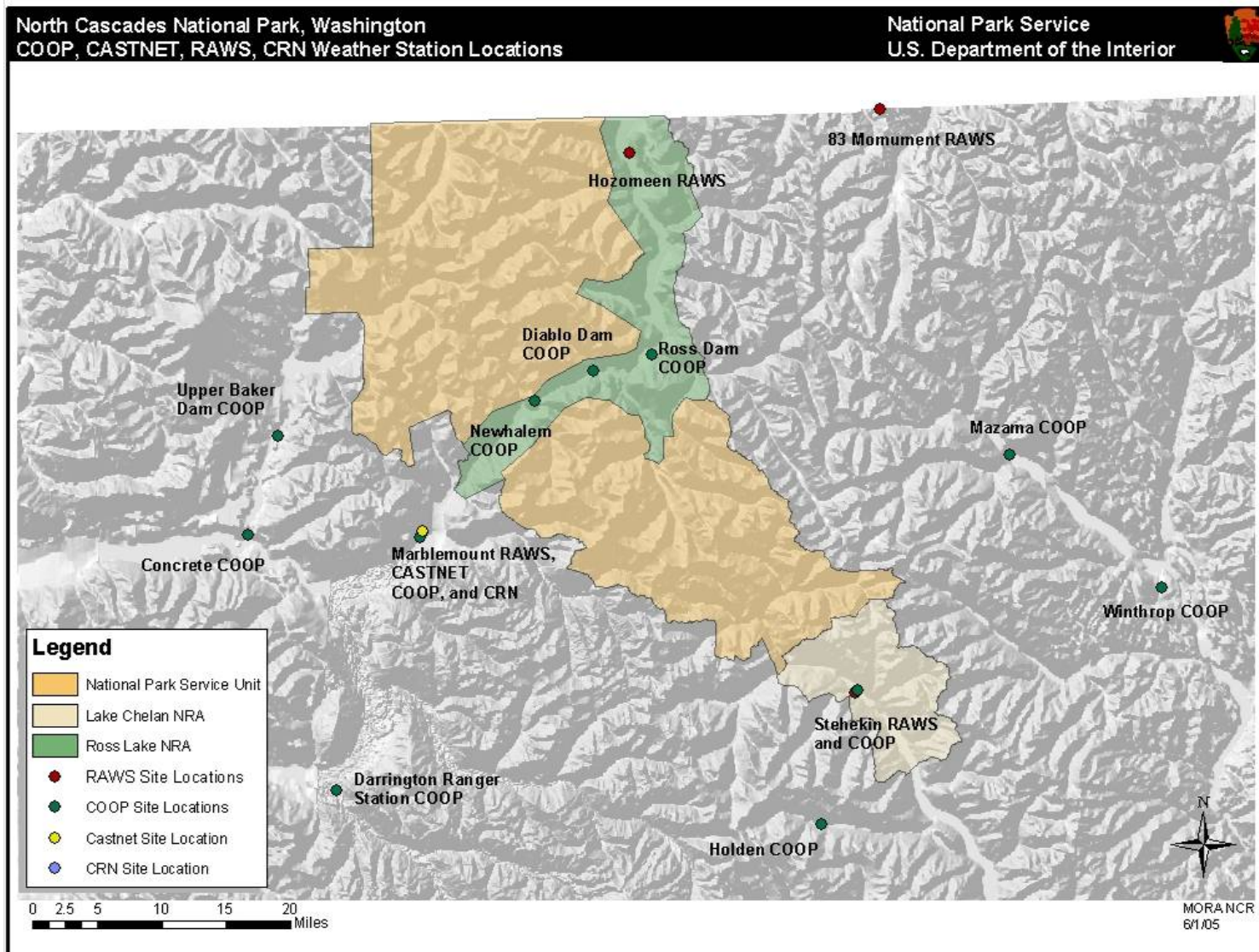


Figure B.2. North Cascades National Park COOP, CRN, CASTNET, and RAWS weather station locations.

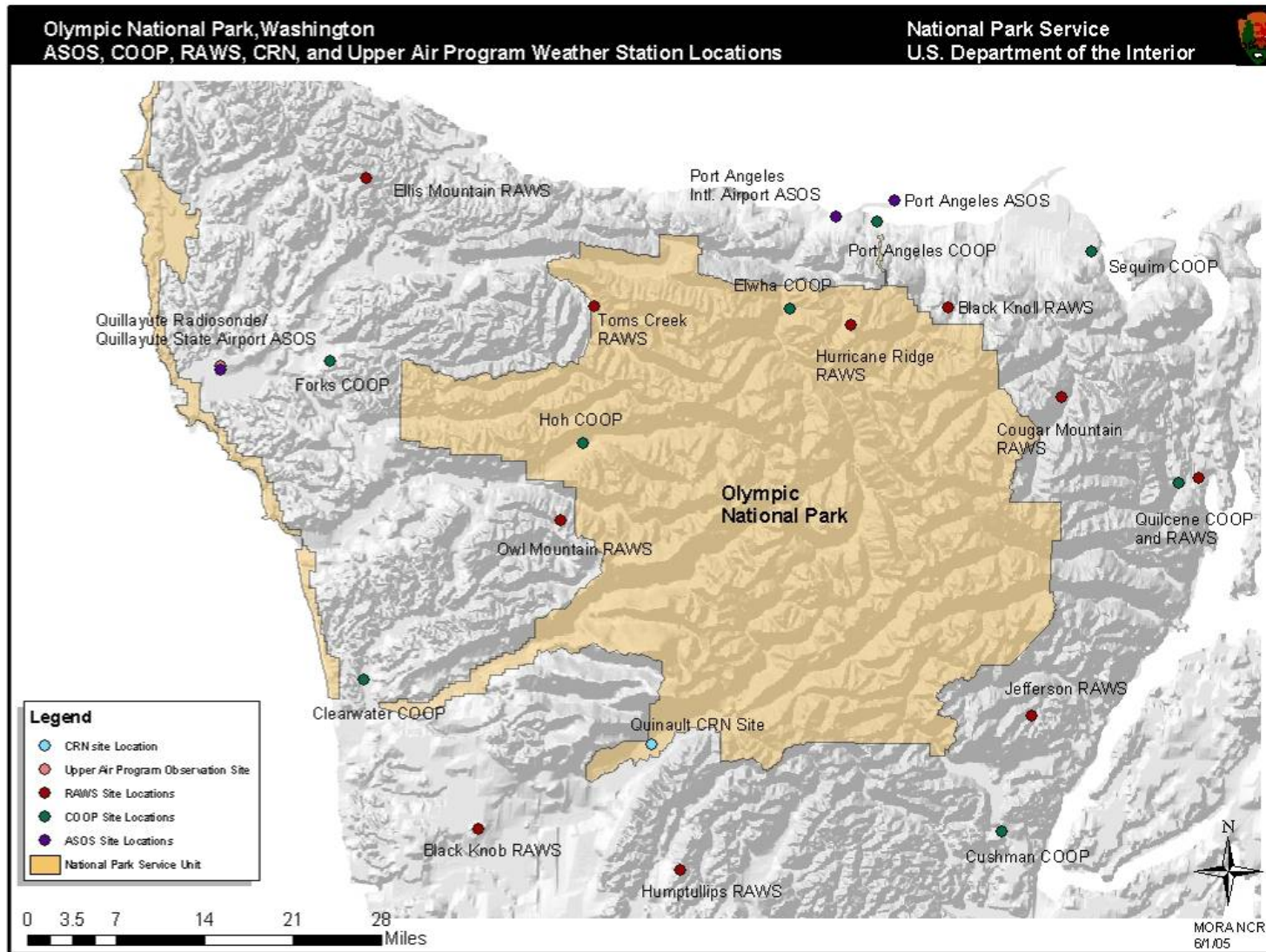


Figure B.3. Olympic National Park ASOS, COOP, RAWS, CRN, and Upper Air Program weather station locations.

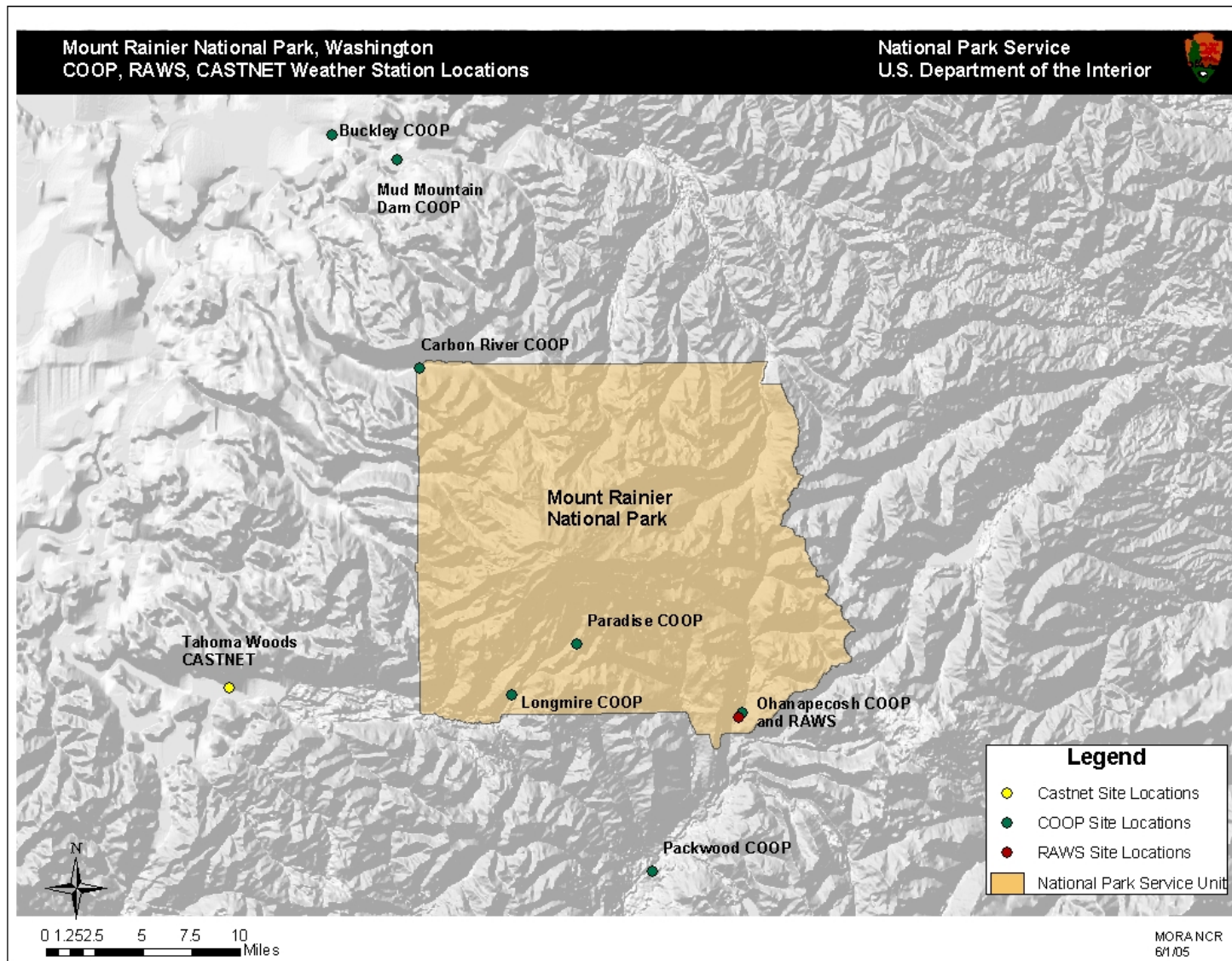


Figure B.4. Mount Rainier National Park ASOS, COOP, and RAWS weather station locations.

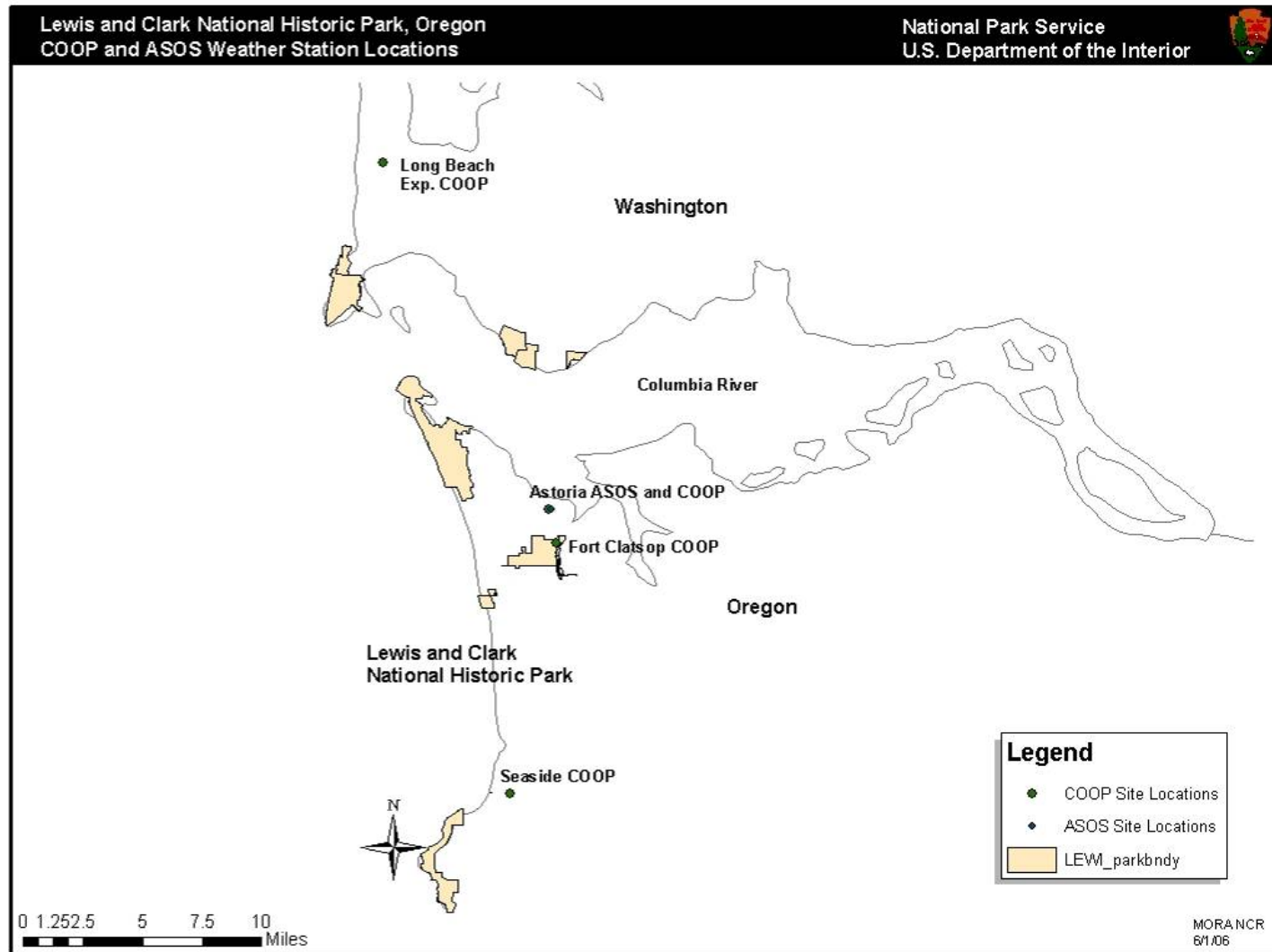


Figure B.5. Lewis and Clark National Historic Park COOP and ASOS weather station site locations.

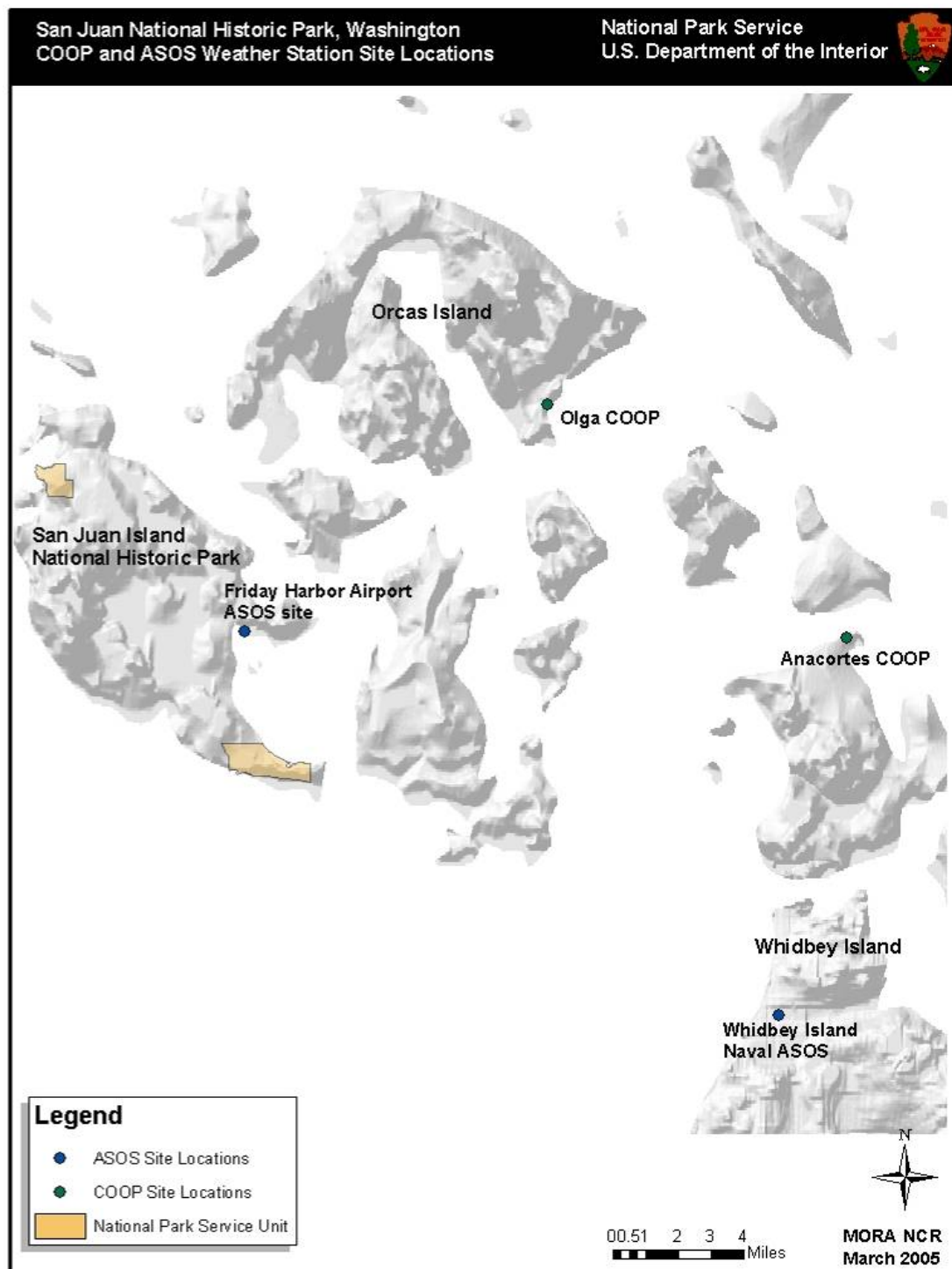


Figure B.6. San Juan National Historic Park COOP and ASOS weather station site locations.

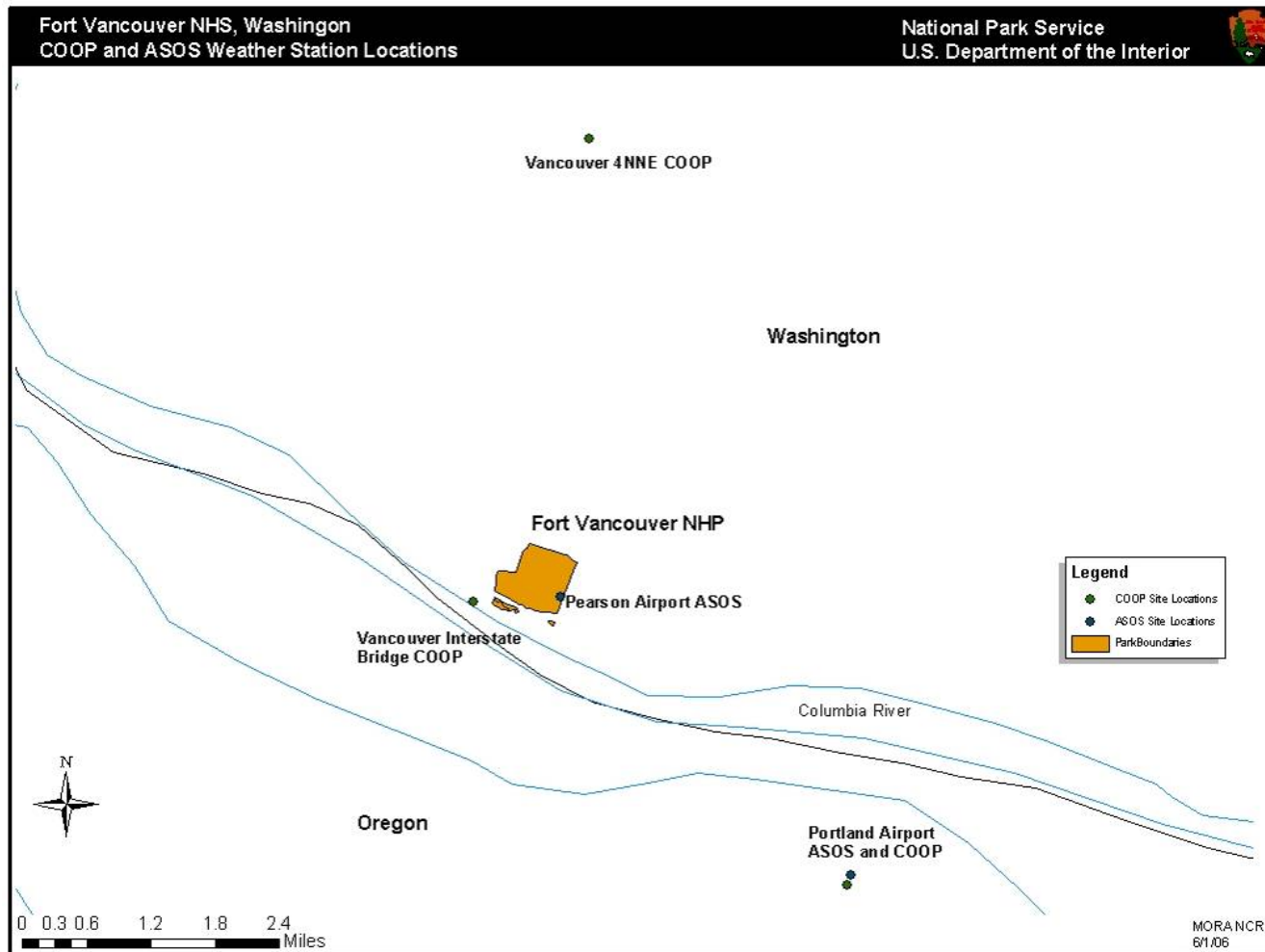


Figure B.7. Fort Vancouver National Historic Site COOP and ASOS weather station site locations.

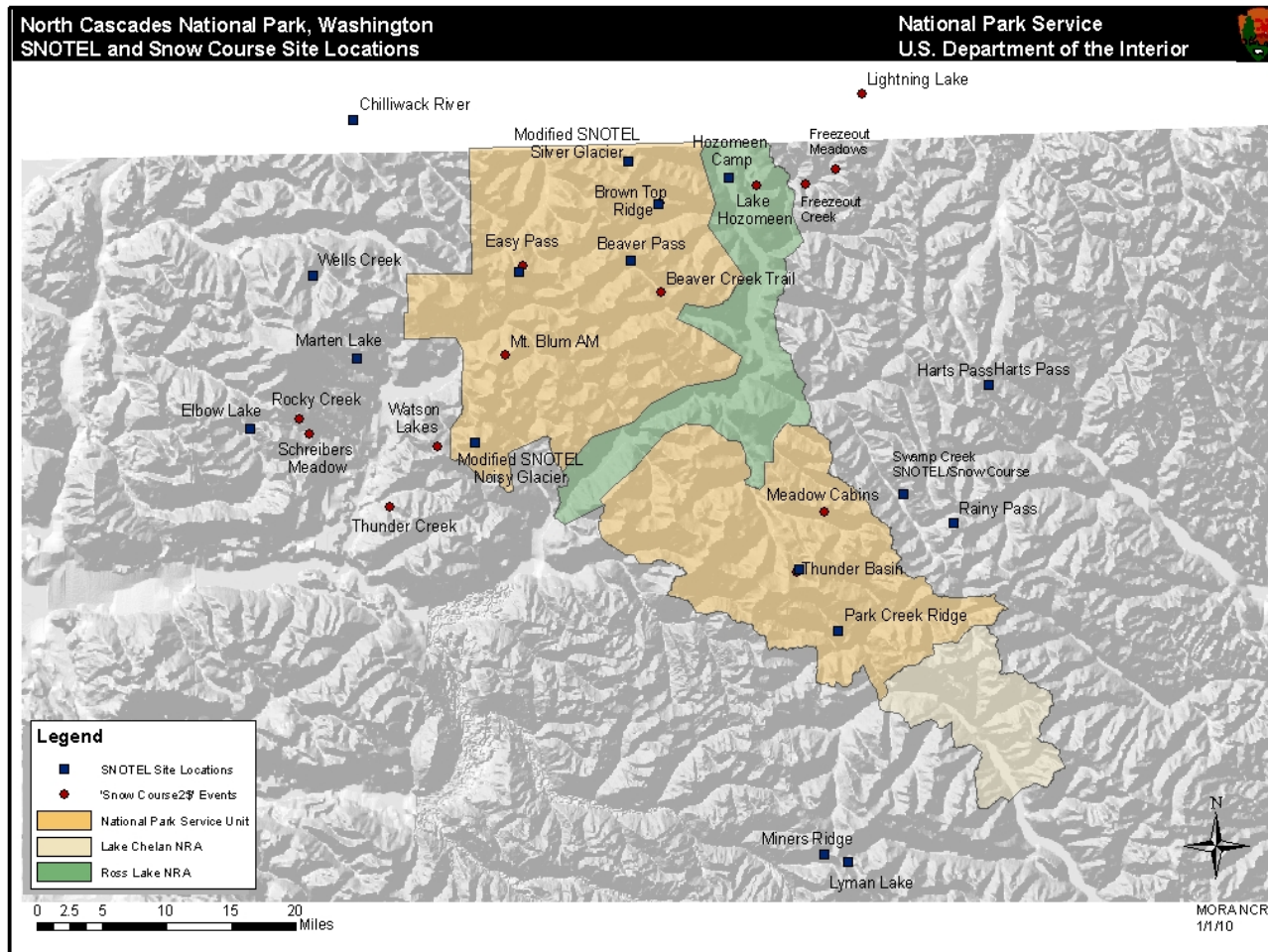


Figure B.8. North Cascades National Park SNOTEL and snow course site location.

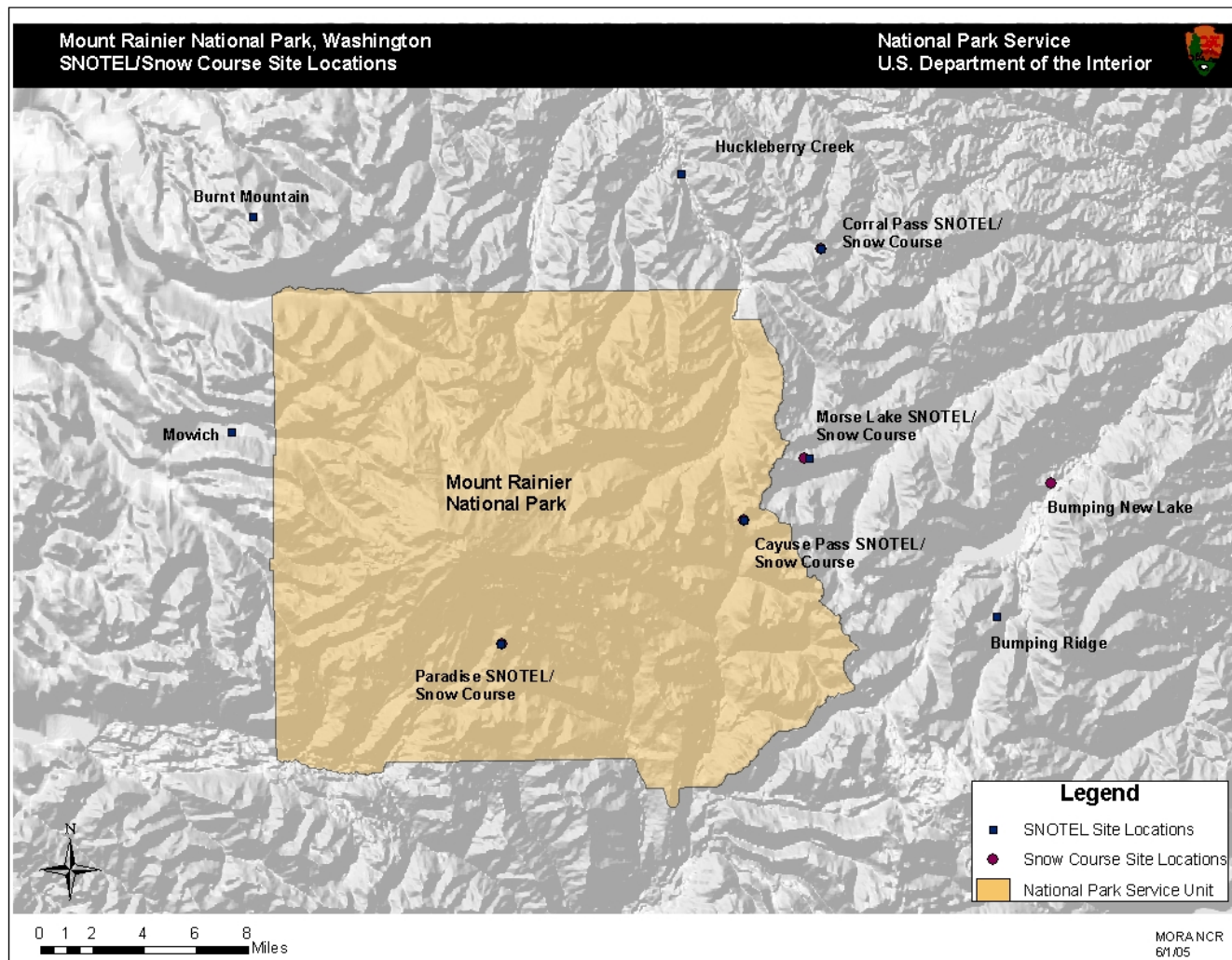


Figure B.9. Mount Rainier National Park SNOTEL and snow course site location.

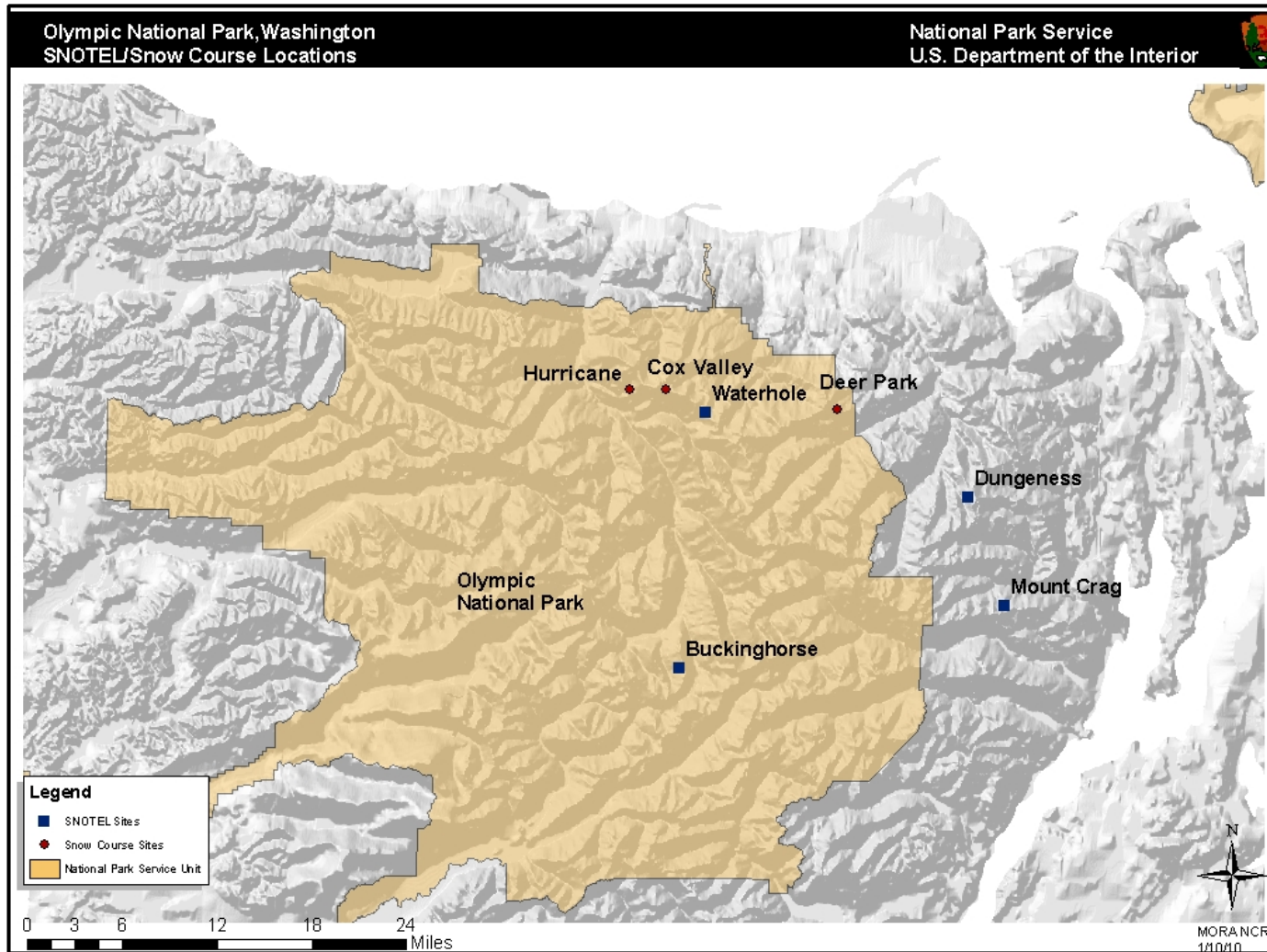


Figure B.10. OLYM SNOTEL and snow course site location.

Appendix C. Locations and Instrumentation Standards for Climate Stations Located in and adjacent to NCCN Park Units

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Table C.1. NWS-COOP site information for stations located in and adjacent to NCCN park units.

Park COOP Station. Name/ID	Elevation m (ft)	Location: UTM (NAD27) Northing Easting	Climate Network¹	Climate Division	Period of Record	Min., max., air temp²	Precip.³	Snow Fall⁴	Snow depth⁵	In Park?
MORA Longmire ⁶ Rainier NPS/ 454764 (456894) ⁷	842 (2,762)	5177844 590384	HCN	Cascade Mountains West	1909– Present	MMTS	SRG	Snow Board	Snow Stake	Yes
MORA Rainier Paradise Ranger Station/ 456898	1,654 (5,427)	5182003 595795	A	Cascade Mountains West	1916– Present	MXTS MXMN (back- up)	SRG	Snow Board	Snow Stake	Yes
MORA Rainier Ohanapecosh/ 456896	594 (1,950)	5176310 609513	A	E Olympic Cascade Foothills	1926– Present Seasonal	MXMN	FP	–	–	Yes
MORA Rainier Carbon River/ 456892	529 (1,735)	5204927 582717	A	E Olympic Cascade Foothills	1906– Present Seasonal	MXMN	FP	–	–	Yes
MORA Buckley 1 NE/ 450945	209 (685)	575484E 5224207N	AB	Cascade Mountains West	1913– Present	MMTS	SRG	–	–	No
MORA Packwood / 456262	323 (1,060)	601549E 5162128N	A	Cascade Mountains West	1924– Present	MMTS	SRG	Snow Board	–	No
MORA Mud Mountain Dam /455704	399 (1,308)	580680E 5221163N	AB	Cascade Mountains West	1939– Present	MXMN	FR/ SRG	–	–	No
NOCA Newhalem/ 455840 (457690) ⁸	160 (525)	5393513 628810	A	E Olympic Cascade Foothills	1909– Present	MMTS	SRG, FP	Snow Board	Snow Stake	Yes
NOCA Diablo Dam/ 452157	272 (891)	5397391 636080	A-B	E Olympic Cascade Foothills	1914– Present	MMTS	SRG, FP	Snow Board	Snow Stake	Yes
NOCA Ross Dam/ 457185	377 (1,236)	5399185 642373	AB	Cascades Mountains West	1947– Present	MXMN	SRG	Snow Board	Snow Stake	Yes

Table C.1. NWS-COOP site information for stations located in and adjacent to NCCN park units (continued).

Park COOP Station. Name/ID	Elevation m (ft)	Location: UTM (NAD27) Northing Easting	Climate Network¹	Climate Division	Period of Record	Min., max., air temp²	Precip.³	Snow Fall⁴	Snow depth⁵	In Park?
NOCA Marblemount Ranger Station/ 454999	106 (348)	5376521 614428	B	E Olympic Cascade Foothills	1948– Present	–	FP	–	–	No
NOCA Darrington Ranger Station/ 451992	168 (550)	603810E 5346028N	A	E Olympic Cascade Foothills	1911– Present	MXMN	SRG, FP	Snow Board	–	No
NOCA Stehekin/ 458059	387.1 (1,270)	5357502 669171	AB	East Slope Cascades	1906– Present	MXMN	SRG, FP	Snow Board	Snow Stake	Yes
NOCA Upper Baker Dam/ 458715	210 (690)	596499E 5389135N	A	E Olympic Cascade Foothills	1964– Present	MXMN	FP	–	–	No
NOCA Concrete Ppl. Fish Stn/451679	59 (195)	592860E 5376867N	AB	E Olympic Cascade Foothills	1905– Present	MMTS	SRG	–	–	No
NOCA Winthrop 1 WSW/ 459376	535 (1,755)	707356E 5370231N	A	East Slope Cascades	1906– Present	MMTS	SRG	Snow Board	Snow Stake	No
NOCA Mazama/ 455133	661 (2170)	688336E 5386924N	A	East Slope Cascades	1948– Present	MMTS	SRG/FP	Snow Board	Snow Stake	No
NOCA Holden Village/ 453730	981 (3220)	5340686 664713	A	East Slope Cascades	1962– Present	MXMN	SRG	Snow Board	Snow Stake	No
OLYM Hoh Ranger Station/ 453710	174(572)	5300817 430235	A	West Olympic Coastal	2004 ⁹ – Present	MMTS/ MXMN	SRG	Snow Board	–	Yes
OLYM Elwha Ranger Station/ 452548	109.7 (360)	5318098 456498	AB	E Olympic Cascade Foothills	1942– Present	MXMN	SRG	Snow Board	Snow Stake	Yes

Table C.1. NWS-COOP site information for stations located in and adjacent to NCCN park units (continued).

Park COOP Station. Name/ID	Elevation m (ft)	Location: UTM (NAD27)		Climate Network ¹	Climate Division	Period of Record	Min., max., air temp ²	Precip. ³	Snow Fall ⁴	Snow depth ⁵	In Park?
		Northing	Easting								
OLYM Sequim/ 457544	15.2 (50)	5325352	495034	A	NE Olympic San Juan	1980– Present	MMTS/ MXMN	SRG	–	–	No
OLYM Cushman (Dam) Powerhouse/ 451934	6 (20)	483655	5251272	AB	West Olympic Coastal	1973– Present		FP	–	–	No
OLYM Forks/ 452914	32 (107)	397952	5311427	A	West Olympic Coastal	1907– Present	MMTS	SRG	–	–	No
OLYM Clearwater/ 451496	7 (24)	402245	5270591	A	West Olympic Coastal	1931– Present	MMTS	SRG FP	–	–	No
OLYM Quilcene 2SW/ 456846	36 (123)	506238	5295708	A	E Olympic Cascade Foothills	1948– Present	MMTS	SRG	–	–	No
OLYM Port Angeles/ 456624	9 (30)	467748	532958	A	NE Olympic San Juan	1933– Present	unkown	FP	–	–	No
EBLA Coupeville/ 451783	15 (50)	5338354	522292	A	NE Olympic San Juan	1895– Present	MMTS	SRG	Snow Board	Snow Stake	Yes
EBLA Port Townsend/ 456678	30 (100)	517938E	5329002N	A	NE Olympic San Juan	1891– Present	MMTS MXMN	SRG	–	–	No
EBLA Anacortes/ 450176	6 (20)	5373580	528309		NE Olympic San Juan	1931– Present	MMTS	SRG	Snow Board		No
SAJU Olga 2 SE/ 456096	24 (80)	5384644	514740	A	NE Olympic San Juan	1891– Present	MMTS MXMN	SRG	Snow Board		No
FOVA Vancouver 4 NNE/ 458773	6 (21)	5058706	527256	C	E-Olympic Cascade Foothills	1856– Present	MXMN	SRG	Snow Board		No

Table C.1. NWS-COOP site information for stations located in and adjacent to NCCN park units (continued).

Park COOP Station. Name/ID	Elevation m (ft)	Location: UTM (NAD27)		Climate Network ¹	Climate Division	Period of Record	Min., max., air temp ²	Precip. ³	Snow Fall ⁴	Snow depth ⁵	In Park?
		Northing	Easting								
FOVA Portland WSFO 356751 ¹⁰	5.8 (18)	531201E 5047614N		B	Willamette Valley	1941– Present	MMTS MXMN	SRG	Snow Board		No
FOVA Vancouver Interstate Bridge/458778	0.6 (2)	525506E 5051727N		B	E-Olympic Cascade Foothills	1902– Present	MMTS MXMN	SRG			No
LEWI Fort Clatsop/ 3530141	13 (42)	5109400 432230		ABX	Coastal Area	1998– Present	MXMN	SRG, FP	Snow Board		Yes
LEWI ¹¹ Astoria Regional Airport/ 350328	2 (7)	431857E 5111645N			Coastal Area	1953– Present	NA	NA			No
LEWI Seaside/ 357641	3 (10)	429094E 5092403N		AB	Coastal Area	1930– Present	MMTS	SRG			No
LEWI Long Beach Exp. Station/ 454748	7.6 (25)	420514E 5135088N		A	Coastal Area	1967– Present	NA	NA			

¹Stations are included in one or more network depending on the NWS programs supported by the observed data (climatology, meteorology, or hydrology) Reference Cooperative Handbook Number 6.

- A: Data from this network are used to describe the climate of the United States. At a minimum, they must observed and report daily 24-hour precipitation totals. Most stations in the network observe 24-hour maximum and minimum temperatures and 24-hour precipitation totals.
- B: Data are used to support NWS hydrologic programs, such as the forecast and warning program and the water resource forecast service program. Stations report 24-hour precipitation (some with recording gauges), and often one or more of the following elements: river stage or lake level, maximum and minimum temperatures, evaporation, and soil temperature.
- C: Data are used to support the meteorological forecast and warning, and public service programs of the NWS. Stations are used primarily for local public service purposes, research and special purposes, or have a period of record of 50+ years with the prospect for continuation with little change in the surrounding environment. Stations report maximum and minimum temperature, and 24-hr precipitation.
- Historical Climatology Network (HCN): This network was established in 1984 to provide a data set suitable for detecting and monitoring secular changes of regional rather than local climate. To minimize artificial changes of local environments, the sites which were selected

should contain few discontinuities (e.g., station moves and instrument changes and relocations). At least 80 years of temperature and precipitation records are required, with no more than 5 percent of the observations missing.

²Standards for minimum/maximum air temperature (Reference Cooperative Handbook Number 2)

- **MXMN** (maximum and minimum thermometers) system: two liquid-in-glass thermometers located within an instrument shelter. The maximum thermometer has a mercury-filled bulb (sensing element). Graduations at 10 intervals are etched on the stem. The minimum thermometer has an alcohol-filled bulb, graduated at 10 intervals. Thermometers must be enclosed in shelters, which act as shields from the sun, rain, snow, and other sources of light, heat, or cold which can cause erroneous readings.
- **MMTS** (maximum-minimum temperature system): electronic thermistor that measures the current temperature average range from -55 to +125 F and compares it to the highest and lowest values stored in the memory of a microcomputer. The maximum and minimum values are read once a day on an electronic display. The 24-hr maximum and minimum temperature and the temperature at time of observation are accessed using a toggle switch on the display.

³Precipitation measurement:

- **SRG** (Standard Non-Recording Rain Gauge): a large diameter outer can with a smaller diameter measuring tube insert. The outer can and top of the funnel are 8 inches in diameter. The funnel directs precipitation into the measuring tube, which is 20 inches tall and holds exactly 2 inches of rainfall (additional rainfall will flow into the overflow can). The gauge is supported by 3, 3' metal legs. Precipitation is observed by manually measuring precipitation accumulation with a graduated, wood measuring stick.
- **Belfort Gauge** (Fischer & Porter): records precipitation on a moving paper scroll every 15 minutes. The gauge has an 8" funnel (top diameter) that directs precipitation into an internal collection bucket. An internal weighing device automatically measures precipitation levels which are recorded onto the paper tape in 0.10" increments. The maximum capacity is 19.5 inches. An internal electronic timer advances the paper scroll. The paper tape is replaced at the first of each month.

⁴Snow boards are used to measure the depth of newly fallen snow (snow having fallen since the previous scheduled time of observation), reported in inches and tenths. A snow board may be made of thin lumber or other light material that will not sink into the snow, yet be heavy enough not to blow away. Official snow boards are painted white to prevent melting from solar radiation or infrared at night.

⁵Snow stakes are used to measure the total depth of snow on the ground (new and old), reported to the nearest whole inch. A snow stake is a graduated wooden stake permanently located on flat ground. Official snow stakes are painted white to prevent melting from solar radiation or infrared at night.

⁶Longmire Rainier NPS is part of the Historical Reference.

⁷Station name was changed from Rainier Longmire to Longmire Rainier NPS in 1978; station location did not change.

⁸Station name was changed from Skagit Power Plant to Newhalem in 1958; location did not change.

⁹Data has been collected and recorded on NWS data sheets by park personnel using NWS COOP protocols since 1967. Data sheets have been sent to the NWS since 1967, however the site was not in the NWS or NCDC data system, nor has the data gone through their QA/QC. In 2004, NWS personnel made a site visit and moved the air temperature sensor. The site was added as an official COOP site in 2004. Data prior to 2004 is available through Olympic National Park.

¹⁰This site is also an ASOS (KDPX, Portland Regional Airport).

¹¹This site is also an ASOS (KAST, Astoria Regional Airport).

Table C.2. NWS-COOP instrumentation standards (NWS 2005).

Parameter	Accuracy	Range	Resolution
Liquid Precipitation Accumulated Amount (in)	±0.02 inches or 4 % of hourly amount (whichever is greater)	0–10 in/hr	0.01 in
Snow Depth (in)	±0.05 in for depth 0-5 in ±1.0 inch for depths>5 to 99 in	0–99 in (auto)	1 inch
Freezing Precipitation (in)	Detection occurs whenever 0.01 in accumulates	0–40 in	0.01 in
Frozen Precipitation (water equivalent in)	±0.04 inches or 1% of total accumulation	0–40 in	0.01 in
Air Temperature	±1.1°C	-62 to -50°C	0.1
	±0.6°C	-50 to +50°C	0.1
	±1.1°C	+50 to +54°C	0.1
Wind speed (knots)	±1 knot up to 10 knots ±10% above 10 knots	2–90 knots	1 knot
Wind direction (degrees)	±5.0 degrees when wind speed is ≥ 5 knots	1–360 degrees	10 degrees

Table C.3. RAWs site information for stations located in and adjacent to NCCN park units.

Park Station name /NESDIS ID	Site Information				Instrumentation & Vaisala (Handar) model number				
	Location: UTM Northing Easting	Elevation m (ft)	Period of record	Data collection platform, data logger, transmitter	Air temperature/ Relative Humidity	Precip.	Wind speed & direction	Solar radiation	Fuel moisture/ Fuel temperature
NOCA 83 Monument, 3262744C	5429934 672065	1,902 (6,242)	1996- present	H555 Vaisala, DCP Serial #: 3233; FTS- 12S data logger, G3/G4 GOES SE 100, Eignal Eng. transmitter	Humidity & temp probe - 435A SN: 58986	Tipping Bucket Rain gage- 444A SN:170	Wind Speed Sensor - 430A; Wind Direction Sensor - 431A	Solar Radiation Sensor – 441A SN: PY30612	Fuel Moisture/ Temp Sensor – 439C
OLYM Hurricane 3280A25A	5315913 464440	(1,585) (5,200)	11/1989 - present	H555 Vaisala DCP, FTS 12S datalogger, SE100 Signal Eng. transmitter	Humidity & Temp. Probe - 435A	6028A All Weather Heated Precip. Gage	Non-standard, Taylor Scientific wind speed/wind direction sensors	Solar Radiation Sensor – 441A	Fuel Moisture Sensor – 439C
OLYM Cougar Mountain 324620E4	5306825 491241	731.5 (2,400)	05/1997 - present	H555 Vaisala DCP SN 2452, FTS 12S datalogger, SE100 Signal Eng. transmitter	Humidity & Temp. Probe - 435A	Tipping Bucket Rain gauge- 444A	Wind Speed Sensor -430A; WindDirection Sensor -431A	Solar Radiation Sensor – 441A	Fuel Moisture Sensor – 439C
OLYM Toms Creek 3260A7D0	5318340 431640	731.5 (2,400)	04/1996 - present	H555 Vaisala DCP FTS 12S datalogger, SE100 Signal Eng. transmitter	Humidity & Temp.Probe - 435A, SN: 2466	Tipping Bucket Rain gauge - 444A, SN: BLM-2	Wind Speed Sensor -430A; Wind Direction Sensor -431A	Solar Radiation Sensor – 441A PY47162	Fuel Moisture/ Temp Sensor – 439C SN: 247
OLYM Ellis Mountain 300020B2	5334694 402580	702.5 (2,305)	05/1996 - present	H555B Vaisala, FTS- 12S data logger, G3/G4 GOES SE 300, Signal Eng. transmitter	Humidity & Temp. Probe -435A	Tipping Bucket Rain gauge - 444A	Wind Speed Sensor -430A; Wind Direction Sensor -431A	Solar Radiation Sensor – 441A PY42925	Fuel Moisture/ Temp Sensor – 439C SN: 00589

Table C.3. RAWS site information for stations located in and adjacent to NCCN park units (continued).

Park Station name /NESDIS ID	Site Information				Instrumentation & Vaisala (Handar) model number				
	Location: UTM Northing Easting	Elevation m (ft)	Period of record	Data collection platform, data logger, transmitter	Air temperature/ Relative Humidity	Precip.	Wind speed & direction	Solar radiation	Fuel moisture/ Fuel temperature
OLYM Humptullips 32465674	5246343 442619	731.5 (2,400)	06/1992 - present	H555 Vaisala DCP SN 3449, FTS 12S datalogger, SE100 Signal Eng. transmitter	Humidity & Temp. Probe -435A	Tipping Bucket Rain gauge - 444A	Wind Speed Sensor -430A; Wind Direction Sensor -431A	Solar Radiation Sensor – 441A PY47158	Fuel Moisture/ Temp Sensor – 439C
OLYM Black Knob 521483C4	5251529 416891	188 (618)	03/2003 - present	H555 Vaisala, FTS 12S datalogger, G3/G4 GOES/Telephone transmitter	Humidity & Temp. THS-1 SN:5128	Tipping Bucket Rain gauge RG-T SN:105999	Wind Speed Sensor Met One 024A/WDM-20; Wind Direction Sensor Met One 014/WSM-20	Solar Radiation Sensor – 441A PY10630	
OLYM Buck Knoll 3008C7E6	5318261 476820	496.8 (1,630)	05/2005- present	H555 Vaisala DCP, FTS 12S datalogger, SE300 Signal Eng. transmitter	Humidity & Temp. Probe -435A	Tipping Bucket Rain gauge - 444A SN:3976	Wind Speed Sensor -430A; Wind Direction Sensor -431A	Solar Radiation Sensor – 441A PY40965	Fuel Moisture/ Temp Sensor – 439C SN:1096
OLYM Quilcene 32367534	5296426 508750	18.9 (62)	04/1993- present	H555 Vaisala DCP #3929, FTS 12S datalogger, SE100(10W), Signal Eng. transmitter	Humidity & Temp. Probe -435A	Tipping Bucket Rain gauge - 444A	Wind Speed Sensor -430A; Wind Direction Sensor -431A	Solar Radiation Sensor – 441A PY43663	Fuel Moisture/ Temp Sensor – 439C
MORA Ohanapecosh	5176100 609212	579 (1900)	8/2003- present	H555 Vaisala DCP #3929, FTS 12S datalogger, SE100(10W), Signal Eng. transmitter	Humidity & Temp. Probe -435A	Qualimetrics Heated 12" precipitation gauge	Wind Speed Sensor -425A; Wind Direction Sensor -425A	Solar Radiation Sensor – 441A PY43663	Fuel Moisture/ Temp Sensor – 439C

Table C.4. RAWS Instrument standards (National Wildfire Coordinating Group 2009).

Parameter	Accuracy	Range	Resolution
Air Temperature (°F)	±0.01 °F	-58°F to +140°F	Not specified
Fuel Temperature (°F)	Not specified	-58°F to +122°F	0.1 ° F
Precipitation (in)	Not specified	0–99.9 in	0.01 in
Relative Humidity (%)	±2.0% from 0-80% at 20°C ±5.0% from 80-100% at 20°C	0–100%	Not specified
Wind direction (degrees)	±2.0 degrees	0–359 degrees	1 degree
Wind speed (mph)	Not specified	0–150 mph	0.25 mph
Solar radiation (W/m ²)	±0.5%	Not specified	Not specified

Table C.5. Climate Reference Network site information for stations located in and adjacent to NCCN park units.

Park CRN Station Name/ID	Elevation m (ft)	Location: UTM (NAD27)		Period of Record	In Park?
		Northings	Eastings		
OLYM Quinault 4 NE	67.3 (221)	5376839 615643	Low elevation West side	2006-Present	Yes
NOCA WA Darrington 21 NNE	114.6 (376)	5376839 615643	Low elevation West side	April 2003- Present	No

Table C.6. Equipment and parameters measured at each Climate Reference Network site.

Parameter	Instrumentation
Temperature (Three Sensors)	Thermometrics Platinum Resistance Thermometer (PRT)
Aspirated Radiation Shield	Met One Instruments Fan Aspirated Shield Model 076B
Fan	Papst Fan Model Series 4200
Precipitation	Geonor Precipitation Gauge Model T-200B
IR Temperature (Ground Surface Temperature)	Precision Infrared Thermocouple Transducer Model IRTS-P, Apogee Instruments Inc.
Solar Radiation	Kipp & Zonen Silicon Pyranometer SP Lite
Wind Speed	Met One Instruments Wind Speed Sensor Model 014A
Tower	Climatronics Corporation Tower Model C-33HD Bottom Section with B-18 Base
Data Logger	Campbell Scientific Inc. Data Logger Model CR23X Serial Number
Data Transmitter	Seimac Limited GOES Transmitter (dist. by Campbell Scientific) Model SAT HDR GOES

Table C.7. Climate Reference Network (CRN) instrument standards (NOAA 2010).

Parameter	Accuracy	Range	Resolution
Air Temperature (°F)	+ 0.04%	-60 to + 300 °F	0.01 ° C
Ground Temperature (°C)	± 0.02 °C from 15-35 ° C ± 0.03 °C from 5-45 ° C	0-50 ° C	0.1 ° C
Precipitation (mm)	0.25 mm	0-12 liters	0.25 mm
Wind speed (m/sec)	± 1.5 %	0-60 m/sec	0.5 m/sec
Solar radiation (W/m ²)	± 0.15% per ° C	0-1000 W/m ²	100 microVolts per W/m ²

Table C.8. ASOS site information for stations located in and adjacent to NCCN park unit.

Park ASOS Station¹ Name/ID	Elevation m (ft)	Location: UTM (NAD27) Northing Easting	Period of Record	Air Temperature/ Dew Point	Wind Speed/Direction	Precip./ LEDWI	Visibility	Ceilometer
SAJU Friday Harbor Airport/KFHR	33.0 (108)	5373910 498769	1981– Present	Hygrothermometer/Automate F420 Resistive Temperature Device	anemometer	Heated Tipping Bucket/ Precipitation Identification Sensor Friez 470/ ScTI	Belfort DX/Forward Scatter Visibility Sensor	Vaisala CT12K
FOVA Vancouver, Pearson Airpark/ KVUO	9.0 (29.5)	5051811 526810	1981– Present	Hygrothermometer/Automate F420 Resistive Temperature Device	anemometer	Heated Tipping Bucket/ Precipitation Identification Sensor Friez 470/ ScTI	Belfort DX/Forward Scatter Visibility Sensor	Vaisala CT12K
FOVA Portland International Airport/ KPDx	6.0 (19)	531201E 5047614N	1926– Present	Hygrothermometer/Automate F420 Resistive Temperature Device	anemometer	Heated Tipping Bucket/ Precipitation Identification Sensor Friez 470/ ScTI	Belfort DX/Forward Scatter Visibility Sensor	Vaisala CT12K
EBLA Oak Harbor Airpark/ K76S	39.6 (130)	5343922 524745	1981– Present	Hygrothermometer/Automate F420 Resistive Temperature Device	anemometer	Heated Tipping Bucket/ Precipitation Identification Sensor Friez 470/ ScTI	Belfort DX/Forward Scatter Visibility Sensor	Vaisala CT12K
EBLA Whidbey Island NAS/ KNUW	10.1 (33.1)	5250013E 5355037N	1943– Present	Hygrothermometer/Automate F420 Resistive Temperature Device	anemometer	Heated Tipping Bucket/ Precipitation Identification Sensor Friez 470/ ScTI	Belfort DX/Forward Scatter Visibility Sensor	Vaisala CT12K
OLYM Port Angeles Intl. Airport/ KCLM	85.0 (278.9)	5329789 462396	1947– Present	Hygrothermometer/Automate F420 Resistive Temperature Device	anemometer	Heated Tipping Bucket/ Precipitation Identification Sensor Friez 470/ ScTI	Belfort DX/Forward Scatter Visibility Sensor	Vaisala CT12K

Table C.7. ASOS site information for stations located in and adjacent to NCCN park unit (continued).

Park ASOS Station¹ Name/ID	Elevation m (ft)	Location: UTM (NAD27) Northing Easting	Period of Record	Air Temperature/ Dew Point	Wind Speed/Direction	Precip./ LEDWI	Visibility	Ceilometer
OLYM Port Angeles International Airport/KCLM	6.2 (20.3)	470009E 5331835N	1947– Present	Hygrothermometer/Automate F420 Resistive Temperature Device	anemometer	Heated Tipping Bucket/ Precipitation Identification Sensor Friez 470/ ScTI	Belfort DX/Forward Scatter Visibility Sensor	Vaisala CT12K
OLYM Quillayute State Airport/ KUIL	54.0 (177.1)	5310304 383861	1966– Present	Hygrothermometer/Automate F420 Resistive Temperature Device	anemometer	Heated Tipping Bucket/ Precipitation Identification Sensor Friez 470/ ScTI	Belfort DX/Forward Scatter Visibility Sensor	Vaisala CT12K
LEWI Astoria Regional Airport/ KAST	7.0 (23)	5111645 431857	1953– Present	Hygrothermometer/Automate F420 Resistive Temperature Device	anemometer	Heated Tipping Bucket/ Precipitation Identification Sensor Friez 470/ ScTI	Belfort DX/Forward Scatter Visibility Sensor	Vaisala CT12K

¹The ASOS program was established in 1994. Stations operating earlier than this date relied on earlier equipment vintages, often manual observations.

²The site was located on Tatoosh Island from March, 1943 through August, 1966. In 1966, the site was moved to the current location of Quillayute.

Table C.9. ASOS instrument standards (NWS, Federal Meteorological Handbook No. 1 1998).

Parameter	Accuracy	Range	Resolution
Liquid Precipitation Accumulated Amount (in)	±0.02 inches or 4% of hourly amount (whichever is greater)	0–10 in/hr	0.01 in
Freezing Precipitation (in)	Detection occurs whenever 0.01 in accumulates	0–40 in	0.01 in
Air Temperature	±1.1°C from -62 to -50°C ±.6°C from -50 to +50°C ±1.1°C from +50 to 54°C	-62 to +54°C	0.1°C
Dew Point	±2.2°C from -34 to -24°C ±1.7°C from -24 to -01°C ±1.1°C from -01 to +30°C	-34 to +30°C	0.1°C
Wind speed (knots)	±1 knot up to 10 knots ±10% above 10 knots	2–90 knots	1 knot
Wind direction (degrees)	±5.0 degrees when wind speed is ≤ 5 knots	1–360 degrees	10 degrees
Station Pressure (inches of mercury)	±0.02	4	0.0005 inch
Altimeter Setting (inches of mercury)	±0.02	4	0.001 inch
Sea-Level Pressure (hectopascals)	±0.68	136	0.1 hectopascal

Table C.10. NWS Upper Air Program information.

Name/ID	Elevation (ft)	Location: UTM (NAD27)		Period of Record	Parameters	Equipment	In Park?
		Northing	Easting				
Quillayute Radiosonde/ KUIL 72797	0–30,000	5310304 383861		1966– Present ¹	temp, relative humidity wind speed/direction, dew point	Sippian VIZ-B2 ART-2	No

¹The site was located on Tatoosh Island from March, 1943 through August, 1966. In 1966, the site was moved to the current location of Quillayute.

Table C.11. Snow course site information for stations located in and adjacent to NCCN park units: North Cascades National Park.

Snow Course Name/ID	Elevation m (ft)	Location: UTM (NAD27)		Period of Record	In Park?
		Northing	Easting		
Beaver Creek Trail/ 21A04	677 (2,221)	5410271 632096		1944-Present	Yes
Beaver Pass/ 21A01	1,120 (3,674)	5422886 615926		1944- Present	Yes
Brown Top Ridge/ 21A28	1,829 (6,000)	5421387 631833		1970-Present	Yes
Easy Pass/ 21A07	1,585 (5,200)	5413598 614897		1959-Present	Yes
Lake Hozomeen/ 21A02	792 (2,598)	5423542 643991		1951-Present	Yes
Meadow Cabins/ 20A08	579 (1,900)	5382981 652418		1945-Present	Yes
Mt. Blum AM/ 21A18	1,768 (5,800)	5402432 612676		1965-Present	Yes
Park Creek Ridge/ 20A12	1,402 (4,599)	5368195 654051		1928-Present	Yes
Thunder Basin/ 20A07	731 (2,398)	5375473 648927		1948-Present	Yes
Lightning Lake/ 3D02B	1,220 (4,003)	5435021 657098		1947-Present	No
Freezeout Meadows/ 20A38	1,536 (5,039)	5425656 653701		1972-Present	No
Freezeout Creek/ 20A01	1,066 (3,497)	5423703 650092		1944-Present	No
Harts Pass/ 20A05	1,981 (6,499)	5398775 672845		1941-Present	No
Granite Creek/ 20A06	1,067 (3,501)	5385108 662198		1951-Present	No
Rainy Pass/ 20A09	1,457 (4,780)	5381584 668452		1930-Present	No
Lyman Lake/ 20A23	1,798 (5,899)	5339311 655332		1928-Present	No
Schreibers Meadow 21A10	1,036 (3,399)	5394563 587072		1959-Present	No
Rocky Creek/ 21A12	640 (2,100)	5392730 588328		1959-Present	No
Thunder Creek/ 21A14	670 (2,100)	5383630 598303		1959-Present	No
Marten Lake/ 21A09	1,097 (3,599)	5402093 594305		1959-Present	No
Watson Lakes/ 21A08	1,371 (4,498)	5391151 604310		1959-Present	No

Table C.12. Snow course site information for stations located in and adjacent to NCCN park units: Mount Rainier National Park.

Snow Course Name/ID	Elevation m (ft)	Location: UTM (NAD27)		Period of Record	In Park?
		Northing	Easting		
Paradise Pillow/ 21C35	1,676 (5,499)	5183499	596660	1961–Present	Yes
Cayuse Pass	1,615 (5,299)	5191173	611783	1940–Present	Yes
Corral Pass/ 21B13	1,829 (6,000)	5207938	616538	1940–Present	No
Morse Lake/ 21C17	1,646 (5,400)	5194949	615523	1956–Present	No
Bumping Lake New/ 21C36	1,036 (3,399)	5193411	630797	1961–Present	No

Table C.13. Snow course site information for stations located in and adjacent to NCCN park units: Olympic National Park.

Snow Course Name/ID	Elevation m (ft)	Location: UTM (NAD27)		Period of Record	In Park?
		Northing	Easting		
Deer Park	1,585 (5,200)	5310554	481332	1949-Present	Yes
Hurricane	1,372 (4,501)	5312514	460188	1949-Present	Yes
Cox Valley	1,371 (4,498)	5312489	463921	1968-Present	Yes

Table C.14. Snow Course measurement standards (Scott Pattee, water supply specialist, NRCS, personal communication Data Parameters).

Parameter	Accuracy	Resolution	Range
Snow depth (in)	0.5 in	0.5	0 – 30 ft
Snow water equivalent (in)	0.5 inches (derived from snow-tube scale that measures inches of water). Deviation among re-measurements required to be < 3%	0.1	0-250 inches of water

Table C.15. CASTNET site information for stations located in NCCN park units.

Site Information				Instrumentation				
Park Station name	Location: UTM (NAD27) Northing Easting	Elevation M (ft)	Period of record	Air temperature, Delta Temperature/ Relative Humidity	Precipitation	Wind speed & direction	Solar radiation	Wetness Sensor
MORA Tahoma Woods	566947E 5178425N	415 (1361)	1991–Present	R.M. Young Temperature/Delta Temperature, Relative Humidity Systems	Climatronics Tipping Bucket	R.M. Young F460 Wind Direction and Wind Speed	Climatronics	R.M. Young Model 57101
NOCA Marblemount Ranger Station	614635E 5377267N	109 (357)	05/1996– present	R.M. Young Temperature/Delta Temperature, Relative Humidity System	Climatronics Tipping Bucket	R.M. Young F460 Wind Direction and Wind Speed	Climatronics	R.M. Young Model 57101

Table C.16. SNOTEL instrument standards (Scott Pattee, water supply specialist, NRCS, personal communication Data Parameters).

Parameter	Accuracy	Range	Resolution
Manual Snow Depth	±0.5 inches	0–30 ft	0.5 inches
Snow Depth (Aerial Markers)	2 inches	0–35 feet	2 inches
Automated Snow Depth	1 cm or 0.4% distance to target	0.5–10 m	0.5 inches
Precipitation Storage Gage (Automated)		0–250 in water (determined by transducer)	0.1 inches
Precipitation Manual Gages	0.1 inches	0–250 in water	0.1 inches
Precipitation Tipping Bucket (Automated) water equivalent inches	±2% at 1–19.7 inches per hour	0–27.6 in per hour	0.01 inches
Air Temperature	±0.5° C over the full scale	Average areas: -40 to +60°C Extreme cold areas: -55 to +60°C	0.1°C
Wind speed	Not specified	Not specified	Not specified
Wind direction	Not specified	Not specified	Not specified

Table C.17. SNOTEL site information: North Cascades National Park. Note that listed sensors are the current suite (as of 29 January 2010), but types of SNOTEL sensors and number of climate elements measured have changed over time.

Name/ID	Elevation M (ft)	Location UTM (NAD27)		Period of Record	Data Transmission	Precip (rain/ snow)	Temperature (max/min)	Snowfall	Snow Depth
		Northing	Easting						
Beaver Pass/ 21A01S	1,103 (3,619)	5414261	628333	2002– Present	Meteorburst System	Cumulative Precipitation-200" Sensotec transducer	Shielded Thermistor, extended range	Snow pillow-200" Sensotec	Sonic Sensor
Park Creek Ridge/ 20A12S	1,402 (4,600)	5368195	654051	1979– Present	Meteorburst System	Cumulative Precipitation-200" Sensotec transducer	Shielded Thermistor, extended range	Snow pillow-200" Sensotec	Sonic Sensor
Thunder Basin/ 20A07S	1,310 (4,298)	5375850	649163	1988– Present	Meteorburst System	Cumulative Precipitation-200" Sensotec transducer	Shielded Thermistor, extended range	Snow pillow-200" Sensotec	Sonic Sensor
Hozomeen Camp/ 21A35S	503 (1,650)	5424566	640546	2001– Present	Meteorburst System	Cumulative Precipitation-200" Sensotec transducer	Shielded Thermistor, extended range	Snow pillow-200" Sensotec	Sonic Sensor
Miners Ridge/ 20A40S	1,890 (6,200)	5340342	652330	1989– Present	Meteorburst System	Cumulative Precipitation-200" Sensotec transducer	Shielded Thermistor, extended range	Snow pillow-200" Sensotec	Sonic Sensor
Rainy Pass/ 20A09S	1,457 (4,780)	5381584	668452	1982– Present	Meteorburst System	Cumulative Precipitation-200" Sensotec transducer	Shielded Thermistor, extended range	Snow pillow-200" Sensotec	Sonic Sensor
Swamp Creek/ 20A41S	1,219 (3,999)	5385108	662198	1988– Present	Meteorburst System	Cumulative Precipitation-200" Sensotec transducer	Shielded Thermistor, extended range	Snow pillow-200" Sensotec	Sonic Sensor
Wells Creek/ 21A31S	1,280 (4,199)	5412379	588752	1996– Present	Meteorburst System	Cumulative Precipitation-200" Sensotec transducer	Shielded Thermistor, extended range	Snow pillow-200" Sensotec	Sonic Sensor

Table C.17. SNOTEL site information: North Cascades National Park (continued).

Name/ID	Elevation M (ft)	Location UTM (NAD27) Northing Easting	Period of Record	Data Transmission	Precip (rain/ snow)	Temperature (max/min)	Snowfall	Snow Depth
Elbow Lake/ 21A32S	975 (3,199)	5393360 580956	1996– Present	Meteorburst System	Cumulative Precipitation-200" Sensotec transducer	Shielded Thermistor, extended range	Snow pillow-200" Sensotec	Sonic Sensor
Lyman Lake	1,798 (5,899)	5339311 655332	1980– Present	Meteorburst System	Cumulative Precipitation-200" Sensotec transducer	Shielded Thermistor, extended range	Snow pillow-200" Sensotec	Sonic Sensor
Harts Pass/* 20A05S	1,981 (6,499)	5398775 672845	1982– Present	Meteorburst System	Cumulative Precipitation-200" Sensotec transducer	Shielded Thermistor, extended range	Snow pillow-200" Sensotec	Sonic Sensor
Brown Top/ 21A285	1,767 (5,800)	5421217 631747	2008- Present	Meteorburst System	Cumulative Precipitation-200" Sensotec transducer	Shielded Thermistor, extended range	Snow pillow-200" Sensotec	Sonic Sensor
Easy Pass	1,606 (5,270)	5412847 614423	2008- Present	Meteorburst System	Cumulative Precipitation-200" Sensotec transducer	Shielded Thermistor, extended range	Snow pillow-200" Sensotec	Sonic Sensor
Silver Glacier (Modified SNOTEL)	2,331 (7,650)	5426489 628052	2008- Present	Meteorburst System				
Noisy Glacier (Modified SNOTEL)	2,331 (6,590)	5391610 608966	2009- Present	Meteorburst System				
Blackwall Peak (BC)/ 2G03P	1,940 (6,365)	5440755 663023	1968– Present	GOES	Cumulative Precipitation-200" Sensotec transducer	Shielded Thermistor, extended range	Snow pillow-200" Sensotec	Sonic Sensor
Chilliwack River (BC)/ 1D17P	1,600 (5,249)	5431735 593805	1991– Present	GOES	Cumulative Precipitation-200" Sensotec transducer	Shielded Thermistor, extended range	Snow pillow-200" Sensotec	Sonic Sensor

*Harts Pass is an enhanced sensor site. Soil temperature and soil moisture are measured.

Table C.18. SNOTEL site information: Mount Rainier National Park. Note that listed sensors are the current suite (as of 29 January 2010), but types of SNOTEL sensors and number of climate elements measured have changed over time.

Name/ID	Elevation m (ft)	Location	Period of Record	Data Transmission	Precip	Temperature (max/min)	Snowfall	Snow Depth	Wind Speed/ Direction	Soil Moisture/ Temperature	Other
		UTM Northing Easting									
Paradise/ 21C35S	1,560 (5,118)	5186849 597623	1981– Present	Meteorburst System	Cumulative Precipitation -200" Sensotec transducer	Shielded Thermistor, extended range	Snow pillow- 200" Sensotec	Sonic Sensor	—	—	
Cayuse Pass 21c41s	1,585 (5,200)	5191173 611783	2006 ¹ – Present	Meteorburst System	Cumulative Precipitation -200" Sensotec transducer	Shielded Thermistor, extended range	Snow pillow- 200" Sensotec	Sonic Sensor	—	—	
Burnt ² Mountain/ 21B63S	1,280 (4,199)	5209946 581288	2000– Present	Meteorburst System	Cumulative Precipitation -250" Sensotec transducer	Shielded Thermistor	Snow pillow- 100" Sensotec	Sonic Sensor	Wind direction/ Speed	Stevens Vital Hydro Probe/ Thermistor	Soil Salinity Relative Humidity
Bumping Ridge/ 21C38S	1,402 (4,600)	5185186 627414	1979– Present	Meteorburst System	Cumulative Precipitation -200" Sensotec transducer	Shielded Thermistor Extended Range	Snow pillow- 200" Sensotec	Sonic Sensor			
Corral Pass/ 21B13S	1,829 (6000)	5207938 616538	1982– Present	Meteorburst System	Cumulative Precipitation -200" Sensotec transducer	Shielded Thermistor Extended Range	Snow pillow- 200" Sensotec	Sonic Sensor			
Huckleberry Creek/ 21B62S	605 (1,984)	5212591 607837	1998– Present	Meteorburst System	Cumulative Precipitation -100" Sensotec transducer	Shielded Thermistor Extended Range	Snow pillow- 100" Sensotec	Sonic Sensor			
Morse Lake/ 21C17S	1,646 (5,400)	5194954 615777	1979– Present								

Table C.18. SNOTEL site information: Mount Rainier National Park (continued).

Name/ID	Elevation m (ft)	Location UTM		Period of Record	Data Transmission	Precip	Temperature (max/min)	Snowfall	Snow Depth	Wind Speed/ Direction	Soil Moisture/ Temperature	Other
		North	East									
Mowich/ 21C40S	960 (3,150)	5196590	579948	1999– Present	Meteorburst System	Cumulative Precipitation -100" Sensotec transducer	Shielded Thermistor Extended Range	Snow pillow- 100" Sensotec	Sonic Sensor	—	—	—

¹A USGS GOES site was located at Cayuse Pass from 1985 to 2005. In 2005, the USGS removed the site. In 2006, the NRCS installed a full SNOTEL.

²Burnt Mountain is an enhanced sensor site. Soil moisture and temperature are measured.

Table C.19. SNOTEL site information: Olympic National Park. Note that listed sensors are the current suite (as of 29 January 2010), but types of SNOTEL sensors and number of climate elements measured have changed over time.

Name/ID	Elevation m (ft)	Location UTM		Period of Record	Data Transmission	Precip	Temperature (max/min)	Snowfall	Snow Depth
		North	East						
Waterhole/ 23B17S	1,524 (5,009)	5310259	468072	1998- Present	Meteorburst System	Cumulative Precipitation- 200" Sensotec transducer	Shielded Thermistor Extended Range	Snow pillow- 200" Sensotec	Sonic
Beaver Pass/ 21A01S	1,103 (3,618)	5414261	628333	2002- Present	Meteorburst System	Cumulative Precipitation- 200" Sensotec transducer	Shielded Thermistor Extended Range	Snow pillow- 200" Sensotec	Sonic
Mt. Crag/ 20B06S	1,402 (4,600)	5368195	654051	1979- Present	Meteorburst System	Cumulative Precipitation- 200" Sensotec transducer	Shielded Thermistor Extended Range	Snow pillow- 200" Sensotec	Sonic
Buckinghorse/ 23B18S	1,484 (4,870)	5284150	465397	2008- Present	Meteorburst System	Cumulative Precipitation- 200" Sensotec transducer	Shielded Thermistor Extended Range	Snow pillow- 200" Sensotec	Sonic

Table C.20. Reporting requirements for the NWS-COOP stations located in NCCN park units.

Park	Daily Measures ¹		Monthly Measures ²	
	NWS recipient	Reporting method ⁴	NWS recipient ³	Reporting Method ⁵
NOCA		WXCORDER		B 91
MORA	Seattle NWS	WXCORDER	John Burg	B91, B18
OLYM		WXCORDER		B 91
FOCL		WXCORDER		B 91
EBLA		WXCORDER		B 91

¹Daily measures include 24-hr minimum and maximum temperature, temperature at the time of observation, 24-hr precipitation, including 24-hr snow fall, and accumulated snow depth.

²Monthly tallies of daily measures, plus daily precipitation duration and general weather conditions (B91, B92 forms). Daily evaporation observations (B92) and hourly precipitation records (B18) are reported only on a monthly basis.

³Seattle office address.

⁴Daily reporting methods:

- WXCORDER: National Weather Service Web Xmitted Cooperative Observer Data Encoded Report (<http://acis.dri.edu/wxcoderIII>). A park-specific Username and UserID are required to connect to the web-based WXCORDER system.

⁵B91 is the monthly report form used by weather observers. Forms are mailed (or uploaded in WXCORDER) by the 3rd of the following month to the agency listed first under Monthly/NWS recipient. Punch tapes (B18) are mailed by the 15th of the following month. NCDC eventually receives all monthly reports, transcribes data from paper copies to electronic data bases, archives the data, and distributes error-checked daily values to cooperating agencies (e.g., Western Regional Climate Center)

Literature

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Appendix D. Weather and Climate Protocol Database Documentation

Figures and Tables

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Database Description

This database consists of three types of tables: core tables describing the “who, where and when” of data collection, project-specific tables, and lookup tables that contain domain constraints for other tables. Although core tables are based on NCCN standards, they may contain fields, domains or descriptions that have been added or altered to meet project objectives. All data types shown are based on the primary system types for Microsoft SQL Server 2000, regardless of the actual platform for database implementation. See Table D.2 for a list of primary data types for Microsoft SQL server and <http://msdn.microsoft.com/enus/library/aa258271%28SQL.80%29.aspx> for an overview of data types. Figure D.1 demonstrates the relationship diagram of the project database. The data dictionary for the database is listed in Table D.1.

The database includes the following standard data tables:

tbl_Locations	Fixed observation collection points (weather stations)
tbl_Coordinates	Coordinate data for weather stations
tbl_GPS_Info	GPS information associated with sample location coordinates
tbl_Observers	Observers for each sampling event
tbl_QA_Results	Quality assurance query results for the working data set
tbl_Edit_Log	Edit log for changes made to data after certification
tbl_Task_List	Checklist of tasks to be completed at each weather station

The following are project-specific data tables:

tbl_Location_Parameters	Suite of weather elements observed for a particular station
tbl_Observations	Climate or weather measurements for a given location
tbl_Parameter_Conversions	Table of parameters and conversion factors for each weather element

The following are standard lookup tables included in this database. These tables are based on design standards across NCCN projects, and they typically have the same domain values among projects:

tlu_Coord_Source	List of coordinate data sources
tlu_Coord_Type	List of coordinate types
tlu_Datum	List of coordinate datum codes
tlu_Edit_Type	List of the types of post-certification edits
tlu_Parks	List of NCCN parks and park codes
tlu_Site_Status	Active inactive historical sites

The following are lookup tables common to many project databases, with domains that may vary from project to project (i.e., template lookups):

tlu_Coord_Label	List of project specific coordinate labels
-----------------	--

tlu_Elevation_Source	List of elevation data source codes
tlu_GPS_Model	List of GPS devices used to collect coordinates
tlu_Location_Type	List of location type codes

The following are lookup tables with structures and domains that are specific to this project database:

tlu_Agency	Agency responsible for maintaining station
tlu_Climate_Division	List of climate division codes developed by NCDC
tlu_Flags	List of data quality and other flags
tlu_Parameters	List of parameters measured by any station
tlu_Station_Type	Type of station and identifier, RAWS, COOP, etc.

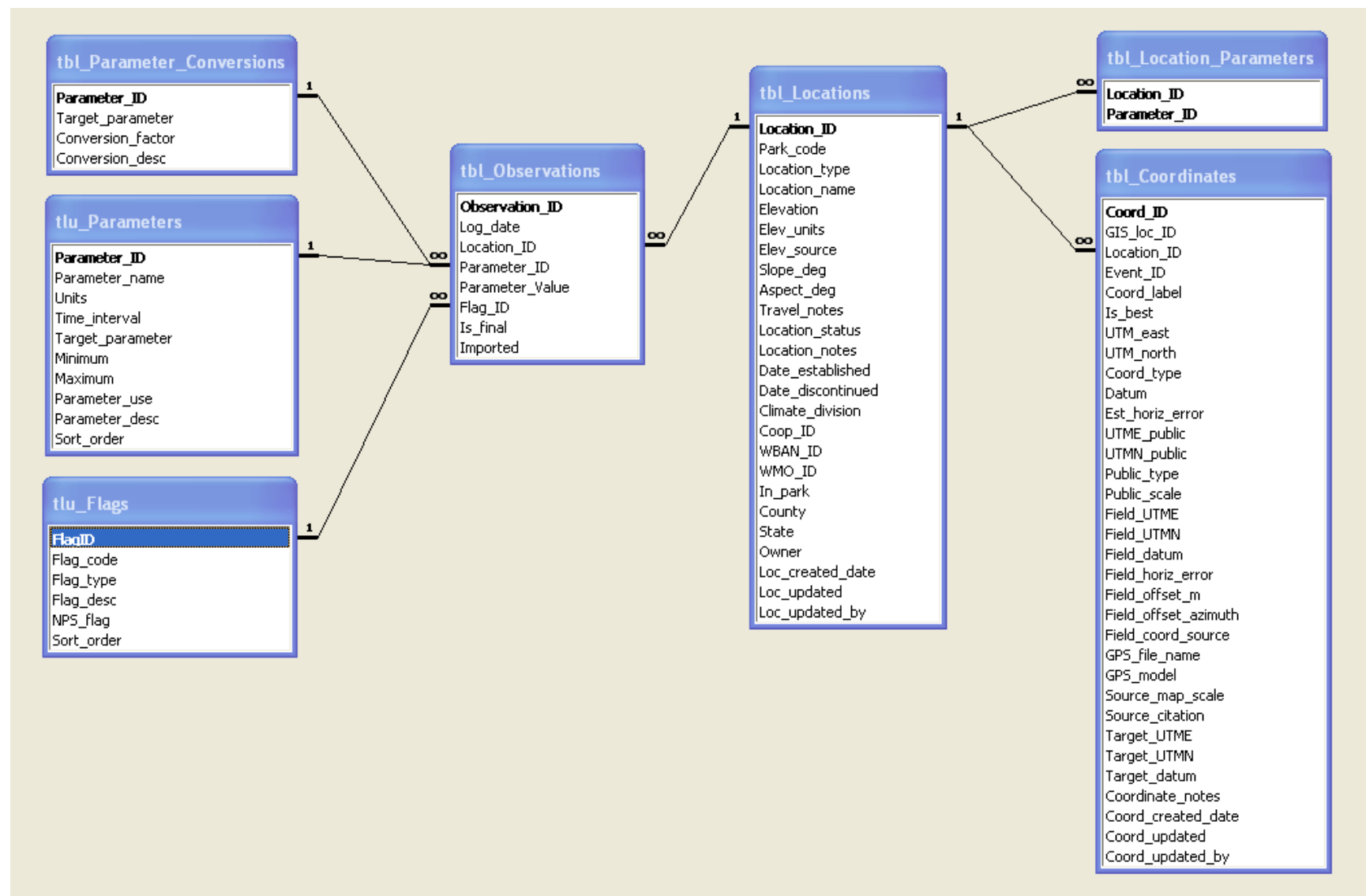
Figure D.1. Entity relationship diagram of the project database.

Table D.1. Data dictionary.

tbl_Coordinates Coordinate data for sample locations (standard)				
Field name	Data type	Index	Default value and domain constraints	Definition
Location_ID	varchar 50	primary (FK)	tbl_Locations	Sample location
Coordinate_date	datetime	primary		Date of coordinate data creation
Is_best	bit	yes	yes, no	Indicates whether this set of coordinates is the best and most current for this location
Coordinate_name	varchar 25	no		Name of the feature for which the coordinates apply (optional)
X_coordinate	decimal 9, 3	no		Easting or longitude
Y_coordinate	decimal 10, 3	no		northing or latitude
Coord_system	varchar 10	yes (FK)	tlu_Coord_System def: 'UTM'	Coordinate system
Datum	varchar 5	yes (FK)	tlu_Datum (required)	Datum of the mapping ellipsoid
Coord_units	varchar 2	no (FK)	tlu_Linear_Unit def: 'm'	Units of the coordinate data
Coord_zone	varchar 5	no		Coordinate zone – especially UTM zone
Coord_method	varchar 12	yes (FK)	tlu_Coord_Method (required)	Means by which coordinates were acquired
GPS_file_name	varchar 50	no		GPS rover file used for data downloads
GPS_type	varchar 25	no (FK)	tlu_GPS_Type	Type of unit used to collect coordinates
Is_diff_corrected	bit	yes	yes, no	Indicates whether coordinate data are differentially corrected (either real-time or post-processed)
Est_horiz_error	decimal 9, 3	no		Estimated horizontal accuracy, in same units as coordinate system
Est_error_type	varchar 12	no (FK)	tlu_GPS_Error_Type; def: 'unspecified'	Method used for estimated horizontal accuracy
Offset_dist_m	decimal 6, 2	no	>=0	Distance in meters from the coordinates to the target
Offset_azimuth	smallint	no	>=0 and <=360	Azimuth (degrees, declination corrected) from the coordinates to the target
Coordinate_notes	varchar	no		notes about this set of coordinates
Coord_created_date	datetime	no	def: (getdate())	Time stamp for record creation

tbl_Edit_Log Edit log for changes made to data after certification (standard)				
Field name	Data type	Index	Default value and domain constraints	Definition
Data_edit_ID	int	primary		Unique identifier for each data edit record
Project_code	varchar 10	yes	def: 'BDa03'	Project code, for linking information with other data sets and applications
Edit_date	datetime	yes	def: (getdate())	Date on which the edits took place
Edit_type	varchar 12	yes	tlu_Edit_Type	Type of edits made: deletion, update, append, reformat, tbl design
Edit_reason	varchar 100	no		Brief description of the reason for edits
User_name	varchar 50	yes	tlu_Project_Crew	Name of the person making changes to the data
Table_affected	varchar 50	no		Table affected by edits

Fields_affected	varchar 200	no		Description of the fields affected
Records_affected	varchar 200	no		Description of the records affected
Data_edit_notes	varchar	no		Comments about the data edits
Edit_rec_ID	uniqueid	no		Global identifier for data edits

tbl_Event_QA Quality assurance checks performed on sampling event data (standard)				
Field name	Data type	Index	Default value and domain constraints	Definition
Event_ID	varchar 50	primary (FK)	tbl_Observations	Observation record
Entered_by	varchar 50	no (FK)	tlu_Project_Crew	Person who entered the data for this event
Entered_date	datetime	yes	def: (getdate())	Date on which data entry occurred
Updated_by	varchar 50	no (FK)	tlu_Project_Crew	Person who made the most recent updates
Updated_date	datetime	yes		Date of the most recent edits
Verified_by	varchar 50	no (FK)	tlu_Project_Crew	Person who verified accurate data transcription
Verified_date	datetime	yes		Date on which data were verified
Certified_by	varchar 50	yes (FK)	tlu_Project_Crew	Person who certified data for accuracy and completeness
Certified_date	datetime	yes		Date on which data were certified
QA_notes	varchar	no		Quality assurance comments for the selected sampling event

tbl_GPS_Info GPS information associated with sample location coordinates (standard)				
Field name	Data type	Index	Default value and domain constraints	Definition
GPS_ID	varchar 50	primary (FK)		Unique identifier for the GPS record
Coor_ID	varchar 50	yes (FK)		Coordinate identifier
Location_ID	varchar 50	primary (FK)	tbl_Locations	Sample location
Feat_type	varchar 20	indexed		Feature type (point, line, or polygon) collected with GPS
Data_dict_name	varchar 50			Data dictionary name used to collect feature
Feat_name	varchar 50			Feature name in data dictionary
GPS_file	varchar 50			GPS file name
GPS_date	datetime			Date GPS file was collected
GPS_time	datetime			Time GPS file was collected
AM_or_PM	char 2			Ante-meridian or post-meridian (AM or PM) if a 12 hour clock was used
Corr_type	varchar 50	indexed		GPS file correction type
GPS_UTME	double			UTM easting in GPS unit
GPS_UTMN	double			UTM northing in GPS unit
UTM_zone	char 5			UTM projection system zone
	Default: "10N"			
GPS_datum	char 5	indexed		Datum of GPS coordinates
Elev_m	double			Elevation (meters) in GPS unit
Num_sat	int			Number of satellites tracked by GPS unit

				during data
GPS_duration	varchar (25)			Length of time GPS file was open
Filt_pos	int			Number of GPS positions exported from GPS file
PDOP	decimal			Position dilution of precision scale
HDOP	decimal			Horizontal dilution of precision scale
H_err_m	decimal			Horizontal error (meters)
V_err_m	double			Vertical error (meters)
Std_dev_m	double			Standard deviation (meters)
GPS_process_notes	varchar (255)			GPS file processing notes

tbl_Locations Weather stations (standard)				
Field name	Data type	Index	Default value and domain constraints	Definition
Location_ID	varchar 50	primary		Unique identifier for each sampling point
Park_code	char 4	no	tlu_Parks	Park code associated with this station
Location_name	varchar 50	no		Brief colloquial name of the sample point, if any; for this project, generally only used as a landmark name for incidental observations
Location_type	varchar 20	yes (FK)	tlu_Location_Type (required)	Indicates the type of sample location
Elevation	decimal 8, 3	no	>=0 and <14500	Elevation of the location
Elev_units	varchar 2	no (FK)	tlu_Linear_Unit def: 'm'	Units for elevation data
Elev_source	varchar 10	no (FK)	tlu_Elevation_Source	Means by which elevation data were acquired
Slope_deg	smallint	no	>=0	Slope steepness, in degrees
Aspect_deg	smallint	no	>=0 and <=360	Dominant slope aspect, in degrees, corrected for declination
Travel_notes	varchar	no		Comments about navigation to the point – kept up to date as conditions change
Location_status	varchar 10	yes (FK)	tlu_Site_Status	Status of the location (blank for incidental locations)
Location_notes	varchar	no		notes about the sample point
Date_established	datetime	no		Date on which the sample location was established
Date_discontinued	datetime	no		Date on which the sample location was discontinued
Climate_division	char 5	no	tlu_Climate_Division	NCDC assigned climate division
Coop_ID	tinyint	no		cooperative station index number assigned by NCDC
WBAN_ID	tinyint	no		Weather Bureau Army-Navy ID
WMO_ID	tinyint	no		World Meteorological Organization assigned identifier
In_park	bit	no		Indicates that the station is located within NPS boundaries
County	varchar 100	no		County that station is located in
State	char 2	no		2 character state or province postal code

Owner	varchar 100	no		Owner/Agency responsible for station maintenance
Loc_created_date	datetime	no	def: (getdate())	Time stamp for when the location record was created

tbl_Location_Parameters Climate measurements for a given location				
Field name	Data type	Index	Default value and domain constraints	Definition
Location_ID	varchar 50	yes (FK)	tbl_Locations	Unique identifier for each sampling location
Parameter_ID	int	yes(FK)		unique identifier for parameter

tbl_Observations Climate measurements for a given location				
Field name	Data type	Index	Default value and domain constraints	Definition
Observation_ID	int	primary		Unique identifier for each observation
Location_ID	varchar 50	yes (FK)	tbl_Locations	Sampling location for this observation
Log_date	datetime	yes		Date and time of the observation
Parameter_ID	int	no	tbl_Location_Parameters	Weather element/parameter recorded
Parameter_Value	decimal	no		Reading, or value recorded
Flag_ID	int	no		Flag code, if any, associated with the measurement process of this element
Is_final	bit	no	Y or N	Is this final data?
Imported	bit	no	Y or N	Has the record been imported into the Multi-Agency database

tbl_Observers Observers for each sampling event (standard)				
Field name	Data type	Index	Default value and domain constraints	Definition
Event_ID	varchar 50	primary (FK)	tbl_Events	Sampling event identifier
Contact_ID	varchar 50	primary (FK)	tbl_Project_Crew	Observer identifier
Assignment	varchar 25	no (FK)	tbl_Assignment	Role of the observer during data collection (optional)
Observer_notes	varchar 200	no		Comments about the observer specific to this sampling event

tbl_Parameter_Conversions Table of parameters measured by a station				
Field name	Data type	Index	Default value and domain constraints	Definition
Parameter_ID	int	primary		unique identifier for parameter
Target_parameter	varchar 10	no		Short name for the parameter
Conversion_factor	varchar 10	no		Conversions run on this parameter
Parameter_desc	varchar 100	no		Full description of the weather parameter

tbl_QA_Results Quality assurance query results for the working dataset (standard)				
Field name	Data type	Index	Default value and domain constraints	Definition
Query_name	varchar 100	primary		Name of the quality assurance query
Query_type	varchar 20	indexed		Severity of data errors being trapped: 1=critical, 2=warning, 3=information
Query_result	varchar 50	indexed		Query result as the number of records returned the last time the query was run
Query_run_time	datetime			Run time of the query results
Query_description	varchar			Description of the query
Query_expression	varchar			Evaluation expression built into the query
Remedy_desc	varchar			Details about actions taken and/or not taken to resolve errors
Remedy_date	datetime			When the remedy description was last edited
QA_user	varchar 50			Name of the person doing quality assurance
Time_frame	varchar 30	primary		Field season year or range of dates for the data being passed through quality assurance checks

tbl_Task_List Checklist of task to be completed at sampling locations (standard)				
Field name	Data type	Index	Default value and domain constraints	Definition
Location_ID	varchar 50	primary (FK)		Sampling location
Request_date	datetime	primary		Date of task request
Task_desc	char 50	primary		Brief description of the task
Requested_by	varchar 50	no		Name of person making the initial request
Date_completed	datetime	no		Date task was completed
Task_notes	varchar 100	no		Notes about the task
Followup_by	varchar 50	no		Name of person following up on task
Followup_notes	varchar 100	no		Notes regarding task followup

tlu_Agency Agency responsible for maintaining station				
Field name	Data type	Index	Default value and domain constraints	Definition
Data_source	varchar 100	primary		
Agency_desc	varchar 100			
Sort_order	tinyint			

tlu_Climate_Division List of climate division codes established by NCDC				
Field name	Data type	Index	Default value and domain constraints	Definition
Division_code	char 4	primary		
Agency_desc	varchar 100			

Sort_order	tinyint			
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tlu_Coord_Label List of project-specific coordinate labels (template)				
Field name	Data type	Index	Default value and domain constraints	Definition
Coord_label	varchar 25	primary		
Coord_label_desc	varchar 100			
Sort_order	tinyint			

tlu_Coord_Source List of coordinate data sources (standard)				
Field name	Data type	Index	Default value and domain constraints	Definition
Coord_source	varchar 12	primary		
Coord_source_desc	varchar 100			
Sort_order	tinyint			

tlu_Coord_Type List of coordinate types (standard)				
Field name	Data type	Index	Default value and domain constraints	Definition
Coord_type	varchar 12	primary		
Coord_type_desc	varchar 100			
Sort_order	tinyint			

tlu_Datum List of coordinate datum codes (standard)				
Field name	Data type	Index	Default value and domain constraints	Definition
Datum	varchar 12	primary		
Datum_desc	varchar 100			
Sort_order	tinyint			

tlu_Edit_Type List of the types of post-certification edits made to data (standard)				
Field name	Data type	Index	Default value and domain constraints	Definition
Edit_type	varchar 12	primary		
Edit_type_desc	varchar 100			
Sort_order	tinyint			

tlu_Elevation Source List of elevation data source codes (template)				
Field name	Data type	Index	Default value and domain constraints	Definition
Elev_source	varchar 12	primary		
Elev_source_desc	varchar 100			

Sort_order	tinyint			
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tlu_Flags List of data quality flags				
Field name	Data type	Index	Default value and domain constraints	Definition
Flag_ID	int	primary		Unique identifier for the record
Flag_code	varchar 25			Short name of the data flag
Flag_type	varchar 25			Type of data flag: measurement deviation or data processing deviation
NPS_flag	varchar 25			NPS designated flag
Flag_desc	varchar 100			Full description of the data quality flag
Sort_order	tinyint			

tlu_GPS_Model List of GPS devices used to collect coordinate data (template)				
Field name	Data type	Index	Default value and domain constraints	Definition
GPS_model	varchar 25	primary		
Sort_order	tinyint			

tlu_Linear_Unit List of units for linear distances (template)				
Field name	Data type	Index	Default value and domain constraints	Definition
Units	varchar 12	primary		
Units_desc	varchar 100			
Sort_order	tinyint			

tlu_Location_Type List of location type codes				
Field name	Data type	Index	Default value and domain constraints	Definition
Location_type	varchar 25	primary		
Loc_type_desc	varchar 100			
Sort_order	tinyint			

tlu_Parameters List of weather elements recorded for a particular station				
Field name	Data type	Index	Default value and domain constraints	Definition
Parameter_ID	int	primary		Unique identifier for the record
Parameter_name	varchar 12			
Units	varchar 12			Measurement units for the parameter; if a parameter has data measured in more than one system of units, create a new parameter for each system
Time_interval	int			Time period of measurement
Target_parameter	varchar 12			Parameter name applied post-conversion
Minimum	decimal			Minimum value allowed

Maximum	decimal			Maximum value allowed
Parameter_use	varchar 12			Where, or in what context is the parameter used
Parameter_desc	varchar 100			Full description of weather element
Sort_order	tinyint			

tlu_Parks List of NCC network parks and park codes (standard)				
Field name	Data type	Index	Default value and domain constraints	Definition
Park_code	char (4)	primary		
Park_name	varchar 100			
Sort_order	tinyint			

Table D.2. Primary data types for Microsoft SQL Server 2000.

Data type	Definition	MS Access equivalent	Storage_size
<u>Character data</u>			
varchar	strings consisting of any combination of letters, symbols, and numeric characters variable-length strings with an 8 kb limit	text or memo (size dependent)	1-8000 bytes
text	very long strings (up to 1 gb), variable length	memo	16 bytes (blob)
char	fixed-length strings with an 8 kb limit	text or memo (size dependent)	1-8000 bytes (2 bytes/char)
<u>Numeric data</u>			
int	numeric data includes whole numbers, positive and negative integers, and fractions integers between – 2,147,483,648 and 2,147,483,647	long integer	4 bytes
smallint	small integers between – 32,768 and 32,767	integer	2 bytes
tinyint	positive integers between 0 and 255	byte	1 byte
bigint	very large integers from -9,223,372,036,854,775,808 to 9,223,372,036,854,775,807	text 255 *	8 bytes
decimal	fixed-point fractions with exact precision up to 38 decimal places	decimal **	variable, 5-17 bytes
float	double-precision, floating-point fractions with precision up to 15 decimal places	double	8 bytes
real	single-precision, floating-point fractions with precision up to seven decimal places	single	4 bytes
money	monetary values from – 922,337,203,685,477.5808 to 922,337,203,685,477.5807; stored as a scaled integer	currency	8 bytes
<u>Binary data</u>			
varbinary	the format in which most proprietary file types (e.g., MS Word) and image file types (e.g., JPEG) are stored variable-length binary data under 8 kb in length	binary or OLE (size dependent)	1-8000 bytes (1 byte/char)
image	variable-length binary data exceeding 8 kb (documents, images, spreadsheets)	OLE object	16 bytes (blob)
binary	binary data of a fixed length (under 8 kb long)	binary or OLE (size dependent)	1-8000 bytes (1 byte/char)
<u>Other data types</u>			
datetime	dates and times in the range from January 1, 1753 through December 31, 9999	date/time	8 bytes
bit	consists of either a 1 or a 0, used when representing TRUE/FALSE, or YES/NO	yes/no	1 bit
uniqueidentifier	128-bit hexadecimal number indicating a globally unique identifier (GUID)	replication id	16 bytes (hex)
sql_variant	can store various SQL Server-supported data types (except text, ntext, timestamp, image, and sql_variant)	text or memo (size dependent)	Variable

*Because MS Access does not have a native format for 8-byte integers, data in this format are exported as text.

**In MS Access, decimal data have a precision up to 28 decimal places.

Appendix E. Administrative Review and Responses



College of Forest Resources Box 352100
University of Washington, Seattle, Washington 98195

James K. Agee, Emeritus Professor of Forest Ecology
112 Winkenwerder Hall

Phone: none Fax: 206-543-3254
email: jagee@u.washington.edu

October 30, 2008

The scientific review for “**Climate Monitoring Protocol for the North Coast and Cascades Network**” is complete. This protocol receives the following decision:

Acceptable with Revision

Attached to this letter are review and informational documents: (1) a PWR Protocol Review Checklist. Each question is addressed in the left column; if scientific, it is addressed by me and the word (Yes, No, In Part, or N.A. [not applicable]) is in bold black font, and if administrative is addressed in regular font. (2) The individual reviews are included, and blind reviewers are identified as R1 or R2 [my comments are PRC]. The reviews are self-explanatory, but what I attempt to do here is place them in an integrated context beyond the abbreviated response in the PWR Protocol Review Checklist.

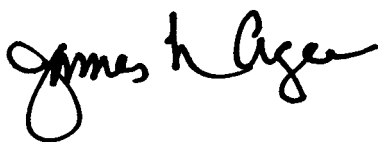
Both reviewers were complimentary of the substantial work represented by this draft. Although the review comments are lengthy, most of the comments deal with specific, minor issues that should be easily remedied. Among the highlights:

- The administrative review highlighted a number of formatting issues that need to be addressed. **The formatting issues were addressed based on the instructions on the Natural Resource Publication Management website and comments by the reviewers.**
- References appear to be somewhat dated and need updating (R1). **References in Sections 1.1.2 and 1.3 related to climate change and rational for monitoring climate were updated.**

- The reporting plan may be a bit ambitious. You may want to rethink this (R1). The reporting plan was scaled back to include a 3-4 page annual report produced for each park within the NCCN. The annual report will include a summary of park/regionwide climate and data summaries/comparisons from key climate stations within the park to include: 6 within MORA, 9 within OLYM, 5 within NOCA, 2 within LEWI, FOVA, and SAJH, and 1 within Coupeville.
- The narrative and SOP's are redundant and too lengthy (R1). PRC suggests that you revisit this, but I'd rather see you err on the redundant side than be too sketchy (an issue with some other protocols).
We agree with reviewer #1 that there is some redundancy between the Narrative and SOP, and that erring on the redundant side is better. We reviewed the manuscript and found discussion on climate change to be particularly redundant and several tables displayed in both SOPs and the narrative. This was fixed this by deleting tables that were included in the SOPs, specifically table 1.2, 1.3, and 4.5. We also reduced discussions on climate change, which was repeated in multiple sections
- The protocol is justified perhaps too much an climate change rationales, while climate data has many other good rationales (R2) Agreed. We added comments specifically addressing the need of climate data for other purposes than climate change in section 1.3 Rationale for Monitoring Climate.

In the revision, please make sure you have addressed the comments (both major and minor) of all reviewers. We expect not only a revised protocol but also a detailed document that specifically shows how each reviewer concern was addressed (or why it was not). This management protocol will not require additional peer review, but will require close attention to the many minor but important points raised. I hope these comments are of use in the revision, and I look forward to receiving and reviewing a revised protocol.

Sincerely,



James K. Agee

PWR Protocol Review Coordinator

Attachments: PWR Protocol Review Checklist, Reviewer comments

PWR PROTOCOL REVIEW CHECKLIST

Protocol Name: NCCN Climate

Science Reviewer: J.K. Agee

Admin. Reviewer: Joel Siderius 9/2008

Red Highlights=extended comments.

	Overall Organization and Presentation of Protocol Narrative
YES	1. Is the overall monitoring protocol well-organized with sections clearly delineated?
In-Part Updated	2. Does the protocol have a title page with authors' names, protocol version number and date? (Protocol version numbers should be constructed to allow for both major and minor changes.) Is there a Table of Contents, abstract, and the three basic sections: 1-Narrative, 2-Standard Operating Procedures (SOPs), and 3-Supplementary Materials or Appendices recommended in the NPS standards published by Oakley et al. 2003 (http://science.nature.nps.gov/im/monitor/protocols/ProtocolGuidelines.pdf).
In-Part Revised and added page numbers to SOPs	3. Is there a complete and accurate table of contents with page numbers? (Chapters should be paginated consecutively, i.e. Chap. 1 (pp. 1-20), Chap. 2 (pp. 21-28), Chap. 3 (pp. 29-44), etc. to allow for modular updates.)
In part	4. Are the tables and figures clearly labeled and understandable?
YES	5. Is the protocol bound so that it lies flat, preferably in a 3-ring binder?
Section 1	A. Background and Objectives (Chapter 1)
Yes, but a bit focused on climate change Addressed in Section 3.1	1. Does the protocol narrative provide a rationale or justification for why a particular resource or resource issue was selected for monitoring? Is the history and background for this resource issue well-referenced with supporting literature cited?
YES-Table 1.4	2. Does the protocol narrative discuss the linkages between this and other monitoring projects?
YES-page 27.	3. Does the protocol narrative describe how monitoring results will inform management decisions?

Yes	4. Does the protocol narrative contain careful documentation of the monitoring objectives or monitoring questions being asked?
No, but OK	5. Does the protocol narrative identify specific measurable objectives such as thresholds or trigger points for management actions?
Section 1	B. Sampling Design (Chapter 2)
Yes	1. Is there a clear and logical rationale for selecting the sampling design over others?
Yes	2a. Were the criteria for site selection clearly discussed including stratification, spatial design, and whether this monitoring will be co-located and/or integrated with other VS monitoring protocols? (See Checklist, Section 1A2.)
Yes	2b. Has the target population or “sampling frame”, and the sampling units, been identified? In other words, is the desired level of inference clear?
Yes	3. Is the sampling frequency and replication identified?
Yes	4. Is the timing of sampling defined?
Yes	5. Are the location of sampling sites clearly identified?
No, but OK	6. Is the level of change that can be detected for the amount or type of sampling being instituted identified? (See Checklist, Section 1A5.)
Section 1	C. Field Methods (Chapter 3)
In-part Appendices 3.18-3.20	1. Are preparations for the field season and equipment setup included? Are requirements for permitting and compliance discussed?
Yes	2. Does the protocol include clear and detailed information on taking measurements with example survey forms included? (Protocol variables and measurements may be discussed in detail in a SOP. A complete set of forms should be included in either the supplementary materials or a SOP.)
Yes	3. Is the method of access for sampling sites provided?
Yes	4. Is there an overview of procedures for establishing, monumenting, and maintenance of plots discussed in one or more SOPs?
N.A.	5. Does the protocol include details for the post-collection processing of samples or vouchers?
Yes	6. Does the protocol include procedures to be followed at the end of the field season?
Section 1	D. Data Handling, Analysis and Reporting (Chapter 4)
YES-page 72	1. Does the protocol provide an <i>overview</i> of the process for entering, editing, and storing data, identification of database software, and whether the database is consistent with the recommended I&M database template structure? (For water quality protocols, see specific

	water quality guidance in Part B or WRD's General Comments 15, and checklist items in Section 2, items 8-10, below.)
Yes	2. Are quality assurance (QA) and quality control (QC) procedures presented for the various levels of data collection and analysis? (See water quality Part B guidance or General Comments 15 as appropriate.)
Yes	3. Is the data structure clearly presented and sufficient to capture the required information to meet the stated goal? Is there an overview of the database design?
In part	4. Are there recommendations for routine data summaries and statistical analysis to detect change?
YES- section 4.9	5. Is there a recommended reporting schedule?
Yes- section 4.10, Figures 4.3-4.6	6. Is there a recommended report format with examples of summary tables and figures?
Yes	7. Is there a recommendation for long-term trend analysis (e.g. every 5 or 10 years)?
Yes	8. Does the protocol narrative include an adequate description of metadata and data archival procedures?
Yes	9. Does the protocol narrative describe the frequency of testing and review of protocol effectiveness?
Section 1	E. Personnel Requirements and Training (Chapter 5)
YES	1. Does the narrative include a listing of the personnel and describe their roles and responsibilities, and qualifications?
Yes	2. Does the protocol include a discussion of training procedures for personnel?
Section 1	F. Operational Requirements (Chapter 6)
In-Part	1. Are facility, vehicle and equipment needs identified?
In-Part Table added:6.2, also addressed in Table 4.1	2. Is there a summary of key partnerships with agencies, organizations and individuals that are part of the monitoring program and a description of their contribution? Is there a list of relevant cooperative agreements and other partnership agreements, if applicable?
YES	3. Is a schedule for the annual fieldwork and administrative needs required to implement this protocol included?
Yes	4. Is there an overall budget that summarizes the annual and periodic costs of implementation of the protocol? Does it seem reasonable?
In-Part Added to Table 6.3	5. Does the staffing plan and budget demonstrate that adequate resources have been allocated to data management, analysis, and reporting activities (ca. 30% are recommended)?
Section 1	G. Literature Cited (Chapter 7)

<i>In part</i>	1. Are the literature citations relevant, sufficient and consistently formatted?
Section 2	Standard Operating Procedures (Selected essential SOPs in addition to those mentioned in the narrative outline are identified in the checklist below. For Water Quality protocols, Part B Guidance or WRD's General Comments 15 should be consulted when developing SOPs.)
YES	1. Is there a table of contents for the SOPs?
YES	2. Are changes to each SOP clearly identified with a title, version number or revision date, and page numbers? Changes to protocol modules (Chapters or SOPs) should be reflected in the overall protocol version number and protocol revision history log either through a minor or major revision; however, you may also wish to develop a numbering scheme for SOPs, e.g. SOP 1.00, 1.01...
NO SOP 13	3. Is there a SOP with instructions for revising the protocol and a revision history log?
NO SOP 11	4. Is there a SOP with instructions for preparation before the field season? Is there a SOP with instructions for procedures and equipment storage during and after the field season? (Also see numbers 10 and 11 below.)
Yes	5. Is there a SOP for training field personnel?
Yes	6. Is there a SOP that clearly defines protocol variables and how to measure them? (See Checklist, Section 1C2.)
No SOP 12	7. Are there clear and detailed driving and other navigational instructions to sampling sites?
Yes	8. Are the details of Data Management identified in one or more SOPs? Topics to be included are at minimum identified in Section 1D and may include customized data management routines. Specifically for water quality monitoring data, does the SOP specify how data will be reported to WRD for entry into the Environmental Protection Agency's STORET database?
N.A.	9. For water quality monitoring and other monitoring as appropriate, is there a quality control SOP associated with each protocol that adequately documents QC objectives for measurement sensitivity (detection limits), measurement precision, measurement systematic error (bias as percent recovery), data completeness (including adequacy of planned sample sizes and statistical power – this topic may be in the SOP on Sampling Design), and (if applicable for lab measurements only) blank control? Are instrument calibration details included either in the QC SOP or in a separate calibration SOP?
N.A.	10. For water quality protocols, is there a SOP that includes an explanation of how data comparability (a quality assurance basic) was considered in choosing which protocols and chemical labs to utilize? Do protocol SOPs contain enough field and lab method details to allow others to determine if data produced is comparable enough to other regional data sets to be considered credible by regulatory agencies interested in the data?
N.A.	11. Do aquatic protocol SOPs adequately describe the details of all Sampling Protocols (Field and Laboratory), as well as equipment needs and operation, sampling techniques, sample preservation and handling and logistics?
No	12. Are all major procedures required for the protocol sufficiently explained? Are any SOPs missing?
Yes	13. Are the literature citations with the SOP relevant, sufficient and consistently formatted?
Section 3	Supplementary Materials or Appendices

<i>N.A.</i>	1. Is there a table of contents with Section 3 – Supplementary Materials that clearly identifies the materials provided in this section of the protocol?
<i>N.A.</i>	2. Are the supplementary materials relevant, sufficient and consistently presented? Consistent formatting is desirable, but not always possible.
<i>Yes</i>	3. Are data collection forms provided either in this section or in an SOP?
See admin comments	4. Is there a section for the Administrative Record that provides the history of protocol development and refinement? A summary event table is highly recommended in addition to the supporting materials required in the Protocol Review File Checklist, e.g. the initial study plan or protocol development summary, the results of protocol development studies, peer review comments and responses during the development phase, and/or any published protocol on which a major portion of the methodology included in this protocol is based. (The published protocol may be presented either in Section 2 or Section 3 depending upon its contribution to the current protocol.)

NCCN Climate Protocol

Extended Administrative Review Comments

Joel Siderius, 9/2008

General Comments

Double –check the formatting of tables several “styles” are used. I.e Table 1.2, Table 1.3, Table 6.2, and Table 6.3 are subtly different.

Be careful with the formatting on 4th order headings. The headings underneath 1.1.1 and 1.2.1 are different.

Overall Organization and Presentation of Protocol Narrative

2. I would advise the authors to closely review the formatting guidance Instructions to Authors on the Natural Resource Publications Management website (<http://www.nature.nps.gov/publications/NRPM/>). There are many inconsistencies with this format notably in the firsts pages of the draft protocol. **These issues were addressed throughout the document**

One example-Protocol version number. The cover page indicates that the report version is Version 2.00 (April 2008). The NRR citation on the cover page indicates that the protocol is from 2006. The header on the cover page (and throughout the entire document) calls it “V3. Review Copy” This inconsistent versioning needs to be sorted out. The Change History Table could easily be accommodated in the missing SOP for changing and revising the protocol.

This error was fixed

3. The Table of contents (TOC) should start on page iii, currently there are no page numbers associated with the document prior to page 1 (the start of the narrative). The TOC does included section 6 of the narrative. I would suggestion moving the Tables and Figures lists to Section 1 of the TOC. Currently it appears that the only tables figures are in Section 4.

This suggestions and errors were fixed.

SECTION 1-Narrative

C. Field Methods Chapter 3

1. Compliance with NEPA is addressed in Section 3.4, however, there is no mention if individual park-level research permits or other compliance measures. **Park Specific NEPA**

Compliance details are covered in:

3.18 MORA NEPA Compliance Procedures for Installation of New Stations or Equipment

3.19 NOCA NEPA Compliance Procedures for Installation of New Stations or Equipment

3.20 OLYM NEPA Compliance Procedures for Installation of New Stations or Equipment

Reviewer may have missed reference to appendices. Final sentence of paragraph referencing Appendices was orphaned. This was remedied by including sentence with main paragraph.

Table 3.1 uses the term “Park Staff” this term seems vague, perhaps specifying what park division is responsible would be helpful. Table 3.2 is always vague with who is responsible. **Specific divisions were identified.**

D. Data Handling, Analysis, and Reporting

Pages 58, Pages 59 are printed out single-sided. **Formatting issues were addressed throughout the document**

E. Personal Requirements and Tracking

Chapter 5’s layout needs improvement. Page 89 is half blank. Table 5.1 spills onto page 91, which is fine, however the headers are not repeated on the table. Page 92 is 80% blank. Table 5.2 has no column headers, should be centered, and uses a different font than 5. **Formatting issues were addressed throughout the document.**

F. Operational Requirements

1. Section 6.2 attempts to address this requirement but it does make it clear what the NCCN is responsible for doing.
2. Including a summary of partnerships would greatly improved the readers understanding of what and how the climate is going to be monitored. Section 6.2 begins to summarize partners but is an obtuse way. **Added Table 6.2 to specify all agencies involved and who is specifically responsible for what.**
5. Based on Table 6.2 it does not appear any of the \$36,900 contributed by NCCN are allocated to Data Management. Table 6.2 is very confusing. In Row 5, it looks likes “Technicians” are doing all the work, particularly the data management component but yet no resources are allocated. **Added data management component and 2.5 PP**

SECTION 2

3. There is no SOP with instructions for revising the protocol and a revision history log? **SOP #12**
4. I am not sure how relevant this SOP would be to this protocol. I think table 6.1 is sufficient. However, for the check box exercise of completing this review there is no SOP dedicated to field season preparations. **See below**
7. Again I am not sure how relevant this requirement is to this protocol. However, for the check box exercise of completing this review there is no SOP dedicated to navigation instructions. PRC NOTE: PLEASE ADD THESE TO THE FINAL VERSION. **Added Field Season SOP 11**

PRC Comments

Before this draft was sent for review, I identified several issues:

“The main issue is where the new stations will be located. There are inconsistencies between the text, figures, and tables. **These inconsistencies were addressed in June, prior to peer review**

In Figure 2.1, it shows 2 new stations in OLYM, 4 in NOCA, 1 in MORA, and 1 in SAJU. But Table 2.3 shows only 1 in OLYM, and none in MORA. Later in Table 4.5, a second station (at least in italics) is identified in the Elwha (Hayes) but figure 2.1 clearly shows the new station to be in Staircase. Please reconcile these errors so the reviewers can determine what it actually being proposed. Also, it is the "Quinault-Elwha" divide not "Quinalt". **These inconsistencies were addressed in June, prior to peer review**

Davey et al. is cited numerous times in the text, and therefore a critically important reference, but is missing from the literature cited.” **This citation was added.**

Also:

P19, figure 1.12: climate stations in the vicinity of NCCN parks. **Fixed.**

P 44, Table 2.4 “Monitoring” spelling. **Corrected.**

Reviewer 1 (R1) Comments

General comments

The protocol seems to have been carefully crafted and it clearly reflects considerable thought about how the Network would like to acquire, process, archive, and report data from a wide variety of stations and climate monitoring networks. In reading the protocol, it seems that it has been developed over a period of years. A lengthy development period is certainly an advantage in allowing much time for reflection, but it has a down side in that many of the references are dated, and more current (and sometimes different) information is now available. The references to IPCC 2001 should be updated to reflect the most recent report, and citations like Parmesan 1996 are better replaced with more recent and more comprehensive studies (e.g., Parmesan and Yohe 2003; Root et al. 2003) or one many other papers. **These references and many others were updated**

I think the entire protocol should be reviewed and as much redundancy as possible removed. This isn't a particularly large task and it should mostly involve substituting a reference to another location and then deleting material. In particular, it seemed like there were several tables that contained virtually the same station information. These should be compressed to as few tables as possible. For example, it would seem that the information in tables 2.3 and 4.5 is largely redundant and these could easily be combined. It was not clear to me why so much material in the SOPs was repeated in the (very long) narrative. It's hard to review, and to maintain, material in multiple locations. See e.g. the information on reporting on p. 78ff and then again in SOP 3 (and btw, SOP 3 is _way_ too long and complex).

We agree with reviewer #1 that there is some redundancy between the Narrative and SOP, and that erring on the redundant side is better. We reviewed the manuscript and found discussion on climate change to be particularly redundant and several tables displayed in both SOPs and the narrative. This was fixed by deleting tables that were included in the SOPs, specifically table 1.2, 1.3, and 4.5. We also reduced discussions on climate change, which was repeated in multiple sections

It seems like the NCCN is committing to a very ambitious reporting plan for climate data. I think the Networks should consider carefully how much work will be required to produce, format, print, and distribute all the graphics associated with the stations. It's clearly worthwhile to acquire and retain all the data, and to do whatever QA/QC is practical, but I would not commit to such a major reporting effort until it was clear that these products will be used. I think park managers are more likely to be interested in region-specific indices that basically tell them whether it was a wet or dry (and how wet/dry) or hot or cold (again, how hot/cold) season or year. Quantitative ecologists and researchers will likely want to reprocess data (preferably already cleaned, with consistent file formats, and ready for use). So a smaller number of plots/tables/indices may be both more efficient to produce and better meet park needs. These could be developed from an aggregate of several stations, or the Network could report selected stations there are considered representative of certain areas.

The reporting plan was scaled back to include a 3-4 page annual report produced for each park within the NCCN. The annual report will include a summary of park/regionwide climate and data summaries/comparisons from key climate stations within the park to include: 6 within MORA, 9 within OLYM, 9 within NOCA, 2 within LEWI, FOVA, and SAJH, and 1 within Coupeville.

Overall, this draft has most of the necessary material, and with some work it will be a very good protocol. I made a number of comments below – hopefully these will help streamline the revision process.

More specific comments

p. 12 Fig 1.9. If you really want to investigate the relationship, it would be informative to (also) plot the indices against PDO. You really want to know how strong the correlations are, and these are not easily estimated from the plots provided. While the reviewer brings up an interesting point to plot the indices against PDO to show the strength of the correlation, we are merely describing PDO as one of the causes of climate variations. Figure 1.9 is used to show the variation in snowpack during PDO years. Demonstrating how strong the correlations are is beyond the scope of this section discussion.

p. 15-18. Much of the material in this section is dated and there have been substantial increases in our understanding. There are some very good review papers published in the past few years, yet none of these are cited. This section needs substantial updating. This section was updated

p. 27. Again, outdated. Use IPCC 2007 rather than 2001 information and other more recent sources. Information was added from IPCC 2007 and citation updated.

p. 27 next to last paragraph needs citations. How are these being developed, and what is the scientific basis for the thresholds? Citations added (Porter 2005, Burns et al. 2008)

p. 38 “MORA” section – GOES refers to a satellite, and you may be upgrading the weather station but I doubt you’ll be upgrading the satellite. It’s not clear what this is referring to – a non-GOES SNOTEL site, a USGS monitoring station that would be upgraded with GOES communication and a SNOTEL snow pillow, or something else. Re-worded based on comments.

p. 50. There’s an inconsistency in visiting station every 3 months (para 2) or three times per year (Table 3.1, last line). Which is it? Quarterly, every 3 months (fixed in text)

p. 82. It will be important to carefully document the “..PC-based programs ...” used to produce reports and analyses. Raw climate data is notoriously difficult to work with and it is _extremely_ easy to make mistakes (or alternatively, very hard to execute a thorough QA/QC process that doesn’t inadvertently modify the data in an unintended way, at least occasionally). The NPCLime program now has a reasonable set of functions using the R language, and the R.seas package (which you could use independently of NPCLime) to produce seasonal plots and other climate-related graphics. Regardless, the “PC-based programs” should be included as a

(perhaps electronic) appendix. The Network plans to rely on NPCLime to produce plots. PC-based programs work initiated in NCCN prior to the development of NPCLime. This reference to PC-based programs was removed. Appendix 5 was enhanced to include the user guide for R language.

Tables 4.6, 4.7 (and there are two tables numbered 4.7). The “Total” appears to be an overall average (not a total) for some columns in table 4.6 and the second table 4.7, and all columns in the first table 4.7. The second table 4.7 uses colors that are much too dark so the printing is illegible. This section was completely re-worked. The tables referenced no longer exist.

A note on reporting climate data: The Network should carefully consider how climate data is displayed, and the apparent inferences from comparisons of one year’s data to a longer term normal. In the second table 4.7, for example, a monthly rainfall 1.5% greater than the long-term averages (see Dec) is certainly NOT “wetter than normal”. This is clearly within the margin of error of measurements. But more generally, it’s much more meaningful to report differences in a way that acknowledges the ‘normal range of variation’. I suggest expressing differences as the number of standard deviations from the long-term average. Thus measures within 1 SD are in the central 68% of observations (assuming you have a sufficiently long record). This is problematic for short records, but in the case of NCCN there appear to be many stations and one could likely estimate an approximate expected variation. We agree that the representation of 1.5% above normal is not “wetter than normal”. Tables were edited to simply represent % value in relation to NWS 30yr normal, but removed color codes and descriptor. We attempt to produce our annual reports in a manner consistent with the WA State climatologist office. The WA State climatologist office represents precipitation as a % of normal and temperature as degrees departure from normal. We agree that deviation is important and the 30-yr normal does not represent ranges within daily climate, but for the purpose of the annual reports represents we feel the deviation from the 30-yr normal meets the purpose of the annual report. Daily and hourly data will be available for the user that requires further statistical analysis of the data.

The suggestion to use an expression that accommodates variation will of course not work in isolation. Most people will also want to know the absolute values and absolute departures. Neither the absolute values nor the difference expressed in SDs, alone, tell enough of the story. Agreed, there are many methods to display the data and explain the story. The NCCN has chosen to display data as a departure from the NWS 30yr normal.

In addition to reporting data from climate station, it would also be useful to report some of the metrics supplied at the climate division level. Metrics like the Palmer Drought Index can really help place a year in broader context. Similarly, some measures of stream/river flow can help express the consequences of a year’s weather pattern. We will incorporate information from the Western Regional Climate Center, the Washington State Climatologist Office, the National Resource Conservation Service and the National Climatic Data Center to put the year in a broader context.

On reporting SnoTel data: I suggest following Steve Gray’s lead (rather than what’s in Fig 4.6) and use the graphic style supplied by the NRCS. See Steve’s 2008 NRTR report for GRYN

(figure 3) – this can be downloaded from

<http://www1.nrintra.nps.gov/im/datamgmt/userboards/boardpages/NPCLime.cfm>

This was incorporated into the reporting section.

p. 97. A few comments:

1) NatureBib and DataStore are being merged as part of IRMA. No revision may be required now, although I think the preferred process is to use the ‘dataset catalog’. This information will need to be revised in the (hopefully) not too distant future. Plans are to have an initial version of the citation service functional in early 2009 – we’ll have to see when this actually occurs. **Noted.**

2) DO 19 (footnote 5) is really irrelevant. The Network needs to practice good data stewardship, and this may include permanent (i.e., long-term) storage of raw data files and perhaps some intermediate products, regardless of DO 19. **Deleted**

3) Delete footnote 4. **Deleted**

Table 6.5. What does * mean? **Added footnote to describe basic suite of sensors**

Section 4. Literature Cited. There are many incomplete citations, inconsistent formats, etc. This entire section needs careful editing. **Edited.**

G. Garmin should be S.L. Garman. **Changed.**

Appendix 1. Acronyms. I suspect that the protocol discusses (or probably should) the HCN and RCN programs. **Added HCN to list of acronyms. RCN refers to CRN?**

Typos: (Page:paragraph)

Header – not sure if this is a 2008 or May 2007 version. **fixed**

p. 15 second line. Misplaced decimal point and incorrect conversion. 1 deg F = 1.8 deg C so should be 3.6 – 8.0 deg F. **fixed**

15:3: change amount to (area, percent?) or perhaps just delete “amount”. But “amount” of cover is grammatically incorrect. I’m not actually sure what the proper metric is in this sentence – is this absolute area, percent of cover, largest glaciers, or something else? **Changed to largest glacier cover**

16:4 ((to (**fixed**

16: last sentence – misplaced “.” **fixed**

17:1 humansor to humans or **fixed**

17:3 and 4: citations should use “et al.” **fixed**

17:4 The key reference for this is Westerling et al. 2006. Science 313:940. **fixed**

26:3 _Additional (delete _) **fixed**

27:1 Hamlet 2006 (delete initials) **fixed**

Garmin should be: Garman, S.L. (in lit cited and text)
fixed

29: - **fixed**

38:2 (2006 delete (fixed

44:1 delete “The following” and begin sentence with “Table ...” fixed

47:2 Park staff “are” fixed

53:3 3”rd” of month. fixed

82

General comments on SOPs

These were really hard to follow and use. First, where appropriate (i.e., not a pdf produced by someone else) they need page numbers. Some SOPs are long, and I think they would be better split into smaller, more focused units. It seems like a lot of the material in the SOP should be in an appendix – I don’t understand why equipment manuals are part of the ‘core’ SOP. The organization was also often unclear. **Agreed that some SOPs are quite lengthy. Separated SOP 3 into smaller sections. Also removed equipment manuals from core SOP and included as an appendix.**

SOP 3.

SOP 3-a did not provide information on acquisition of the data, as suggested by the Table of Contents or protocol. **Changed**

Other parts of SOP 3 were vague – the provided information on web sites from which one can obtain RAWS, radiosonde, etc. data, but did not clearly say what stations the Network was going to acquire data for. The references to multiple appendices just complicated the situation – there needs to be a clear list of stations, preferably in (only) one place. **Noted that the Network will acquire data for all stations listed in Table XX. SOP 3 describes the method (or one of the methods) used to acquire climate data for station listed in Table XX.**

Reviewer 2 (R2) Comments

The entire document was examined, but most of the emphasis of these comments is on the portion before the appendices. Material in several of the (especially, later) appendices is often excerpted from other original material.

General

This protocol contains an impressive amount of detail. Clearly a great deal of effort has gone into its production. The authors seem to have done their homework. Weather and climate monitoring is a complicated enterprise, and there are many details to be mentioned, and thus in some cases to also be incorrect and misinterpreted. This is something to be expected. However, the report does not seem to contain an undue number of such problems.

There is always the question of how much detail to present. The amount given seems about right.

Much of the rationale for the climate monitoring program, and for improvements in it, seems to revolve around climate change. This is ok, but there is a strong implication that this is the sole purpose for climate monitoring. Climate and its variability have long had many effects on each of these parks, and have been and continue to be a very significant influence, even if climate were not to change at all (from human influences). There is ample justification for a robust NCCN climate monitoring program even without climate change. The needs for this information span research, operations, and interpretation.

The above may come off as a moot point, since climate change appears to be under way to some extent, although in this part of the Pacific Northwest, west of the Cascades, the evidence thus far is not entirely unambiguous. There is still an animated discussion to this effect ongoing within universities in the region.

Detailed comments, by page.

P 1 par 2

“The primary reasons for monitoring climate change in the NCCN...” starting sentence goes right into climate change ~immediately~ as if there were no other climate related rationale or issues of interest. **Change in original document. Will also address throughout with revisions.**

P 2 top

Technically, 100 m = 328 feet, rounds to 330 rather than 320. **This has been changed.**

P 3 bottom full par

-2 C as coldest annual temp in MORA (curious about a reference ... is this from PRISM?) **This is based on the PRISM model. The PRISM model run is shown on page 13 and the text interpretation on page 19 in the NCCN Weather and Climate Inventory.**

P 3 bottom onto top of p 4

+10 C is a pretty warm temperature—easy to be lower than this at some point. The minus was missing from the text! It is -10 rather than 10 degrees. I also fixed the text to indicate this was mean monthly temperature, since hourly minimums can obviously drop well below this number.

P 4 top full par

“Columbia River Gorge sometimes are associated”

Ice storms are more common here than in other parts of the PNW, but still are not all that common, and it’s probably stretching things a bit to say that cold outbreaks are “often” associated with severe ice storms. It is, conversely, however, very hard to get ice storms without this cold air. Changed “often” to “sometimes”

P 5-11

Good text and useful figures. Keep them.

P 12 bottom par.

As noted above not all researchers have agreed with Mote on this point.

Fig 1.9b does show something of a reduction from early 1980s onward.

Edited to this version addressing this debate: Unlike precipitation, long-term temperature records appear to indicate warming, especially in the last three decades (Figure 1.11). Scientists with the University of Washington Climate Impacts Group estimate that surface temperatures in the Pacific Northwest have warmed by 1-3°C over the last century (Mote et al. 1999). Studies also suggest that mountain snowpacks in the region have decreased over the last several decades (Mote et al. 2005). The degree of these changes which can be attributed to global warming verses decadal climate variations is still being debated by local experts.

P 13 fig 1.10

Looks good. Fig 1.11 b shows a nice steady rise up to about 1990 but not much increase there after then, more like level.

P 15 top par.

Not that 2-5 C is a temperature increment. So it should translate as an increment, not an absolute. 2-5 C rise should be 3.6 degrees F to 9 degrees F rise. Changed

Also Seager et al (2007?) have a nice graph on their web page on the results of 19 climate models, with a modest rise in precipitation of about 5-7 percent over the next 25 years or less, along the Canadian border.

P 15 second par

Potential [aquatic?] effect of climate change. This par is about aquatic issues...might think about splitting freshwater from saltwater aquatic considerations. Split this paragraph into separate sections and added some details about impacts to intertidal invertebrates.

P 15 par 3

Glaciers as good surrogates for climate measurements. Yes and no. Most such natural indicators filter the climate data in some way, and in effect incorporate such things as temp, precip, wind

speed, relative humidity and solar radiation but in a way that varies a lot from season to season, and thus do not give uniform information about climate, nor all the time. There is also the winter accumulation versus summer ablation issue: which is more important for a given glacier? Still, they nonetheless have a lot of value if used carefully. **We removed this statement. Glaciers are a valuable indicator but perhaps not a “replacement” for climate stations. I think we would have to agree, which is why we placed climate stations on our study glaciers in NOCA.**

P 15 bottom par

Trans-Pacific sources seem to be maybe 5 to maybe 15 or even 20 percent of total aerosol in parts of this area.

P 16 first full par. Bullets.

Aerosols also have an effect on the formation of precipitation, by affecting how small droplets get together. That is, they affect cloud microphysics. The result is to suppress precipitation. Doug Lowenthal and Randy Borys, and Danny Rosenfeld, have papers on this. **Added**

P 16 phenology

Good comment.

P 17 top full par

“Movement of [upper] treeline ... “ note which treeline. Feedback effects of tree line movement on climate change would likely be very minor. **Changed to upper treeline. Removed statement about feedback effects.**

P 17 bottom par

Frog example more complicated than even might be portrayed. Phenology and climate could change together. Though, some things wouldn't, such as those related to photoperiod, which is determined by astronomy. **Complexity duly noted, however will not try to change existing paragraph.**

P 18 3rd par end of section 1.1

Most of the remaining examples of climate use are climate change issues, rather than just issues of climate variability. **We perhaps need to clarify in this section. Is our purpose here to discuss climate change or climate variability? This goes back to the very first comment by this reviewer.**

P 19 Fig 1.12

A little hard to discern the two different symbols. **Combined symbols. There was no need to separate SNOTEL stations from other stations.**

P 20 table 1.1 raws

Is it National Interagency Wildfire Program, or National Interagency Fire Center (NIFC). The latter is well known, but the former Have not heard of such a program. **Changed to NIFC.**

P 21 first full par

...created in 1890 under the [USDA] Organic Act... The NWS was under USDA when it came into existence, and called the “Weather Bureau” at the time (1890), actually was the “Weather

Bureau” starting in 1870. In 1940 the Weather Bureau transferred from USDA to US Dept of Commerce, but kept its name. It was renamed from Weather Bureau to National Weather Service in 1967, and placed under ESSA. **Incorporated these suggested changes into paragraph.**

P 21 discussion of coop, last sentence.

NCDC is also the official repository of US-wide coop data. **Changed.**

P 21 ASOS par

There is a network related to ASOS called AWOS, and the latter is generally used by the FAA. AWOS generally does not record precipitation, or do a very good job of recording precipitation when it does. **No change required.**

P 22 top par

Originally, RAWS was in support of fire, now used for many other purposes. RAWS is worth slightly more explanation, because it is used by many NPS units (at last count, there were something like 140 NPS RAWS sites out of about 2000), and is often suggested as a viable platform for NPS monitoring.

RAWS stations are sometimes shut off in winter, but in NCCN, which is overall not very cold in winter, they can easily be kept running, with very little harm. Above about 4000-5000 feet, snow can get deep enough to bury them, but even in deep snow many of the measurements are of some value, or could be augmented (such as, with snow depth sensors). **This section was expanded to incorporate comments.**

P 22 par 2

Note that precipitation is almost always unheated tipping bucket. Few heated precip gages on RAWS platforms. Thus winter precip is generally worthless, until all remaining snow has had a chance to melt out of the gauge. **Noted**

P 22 snow survey

Department of [Agriculture].

Snow course usually 10 sample locations. **Added**

P 22 Snotel

Many snotel stations now report hourly data, probably the majority of them.

Data are instantaneous readings every 15 minutes, not true summaries during the 15 minute period. Daily statistics are derived from these $4 \times 24 + 1 = 97$ readings. **Noted.**

Snotel stations run year round, have useful summer data too. **Noted.**

P 23 CRN

This network is finished with its final deployment of the original stations, as of Sept 2008. Has either 114 or 120 sites. **Added.**

Data are actually 5 minute temperature and precipitation readings, not 15 min, and are saved this way. In addition for some purposes those readings are aggregated to 15 minute, hourly, and daily summaries. **Changed**

P 23 footnote

Curious why NOCA CASTNet site was removed in Jan 2008 ? **Added in footnote, lack of funding.**

P 24 NWAC (par 3)

“meteorologic[al]” **changed**

“meet [our] needs” **changed**

A bit unclear. NPS apparently owns and runs 2 NWAC sites in the NCCN, but then a little later a couple more are mentioned. Then in the next paragraph a couple more are mentioned, as is yet another station. Maybe this is all self consistent, and maybe refers in part to who owns versus who runs or operates a station, and also whether it is exactly on or off of NPS property. These distinctions do matter, but not usually to typical users. **Explained in further detail**

What is “park ONPS dollars”? What is ONPS? **Park Base Dollars. changed**

P 25 Table 1.2

Several sites have more than one entry. What is the purpose of the later entries? Perhaps to update the instruments? But if so, the dates would be different. For instance, Crystal Mtn has three entries, but some have the same dates, but different instruments.

(Yes, this is tedious to compile, but it seems like the purpose of the table.) **This is explained in the paragraph above the table. Precipitation sites and winds sites are separate due to siting criteria. Hence, multiple entries for one station in table. It is necessary for documenting equipment location.**

P 26 bottom par

[_Additional] would like to be spelled [Additional] **Yes, changed.**

P 27 rationale

After a couple good lead-in sentences, this turns into a discussion entirely dominated by climate change. For the last 50-100 years, and longer, climate has also had an effect here, whether climate was changing or not. **Added more to the discussion in section 3.1**

P 27-28

“it is imperative...” absolutely.

Climate is a little different from other vital signs, in that one vital sign is vital to interpret other vital signs. **Yes.**

P 29 1.4.2 list

Include relative humidity, cheap and easy to do. **Added**

P 30 table 1.5

CRN only measures speed, not direction, and only at eye level in support of the primary temp and precip measurements. **Added as a footnote.**

High elevation sites – why not measure solar radiation? There is little mountain data on solar, it's not expensive, and even with snow issues, can be situated so that snow does not stay on the glass bulb very much. As a rule, in mountains, promote any kind of measurement that can tell us about the energy budget of the snowpack, and non-snow surface in summer. **Yes, agreed, will add as future dollars allow. Added in protocol**

P 30 precipitation

Precipitation is water in liquid or solid form (phase) that falls from the sky. Fog is not precipitation, nor is dew. **Clarified.**

P 31 Humidity

“... dew, fog, and rain ...”

Need to distinguish between absolute and relative humidity.

Absolute: How much vapor is actually in the air, expressed as a ratio, or in terms of dew point

Relative: Temperature dependent, depends on water vapor content, plus temp.

Clarified in explanation.

P 31 snow depth

Also mention snow fall (new snow since last measurements). Snow fall cannot be measured more often than once in six hours (per NWS instructions). More frequent measurement of snow fall causes more snow to be measured because of lack of natural compaction.

Snow fall is measured to nearest 0.1 inch.

Snow depth is measured to nearest whole inch.

Added

P 31 soil temp and soil moisture

Could stress more the need for metadata, which is crucial to proper interpretation of soil climate data. Have to be really clear about what is being measured and how.

Added.

P 31 soil moisture

There are several different methods of doing this. Even if the desire is to be brief, this seems like a topic worth explaining in some detail.

Expanded clarification

P 32 solar

Only 2 companies that make solar radiation, or only 2 types of solar measurement that can be made?? **Clarified. NCCN uses 2 types of solar measurement for monitoring. Yes, more methods exist.**

P 32 SWE

“and [is] the product of “

SWE is not determined from melting daily precipitation, but from melting the depth of the snow pack, or the depth of the new snow, depending on which SWE is needed.

Snow pillows are 4-6 feet square or rectangular, some are more like hexagons, and for deep snow areas are often grouped pairs or quadruples (if that’s a word) because snow can “bridge” over small pillows when deep enough (form ice lenses that do not pack down on the pillow if it is too small). **Explained**

Covert = convert **Changed**

P 33 top par

In very few, almost none, of the existing weather and climate networks was there a rigid or objective sampling design employed. Nearly all weather network station placement is ad hoc or opportunistic. It’s actually a lot of work, and expensive, to be systematic in the placement of stations.

For Snotel, the main consideration, especially for any new sites, is the availability of some kind of cooperator from an agency or organization. **True, but our current network is based on the original placement of other agency stations whether it was opportunistic or based on a sampling design. All agencies have specific goals for monitoring climate – stations were placed based somewhat on those goals.**

P 35 par 3

“directly 3 0 across” ??? **Fixed**

P 35 par 4

Whidbey Island is an ASOS site, but Point No Point would not be, more a Coast Guard site. ASOS sites are usually NWS, or military, or some FAA airports. **OK, fixed.**

P 35 FOVA

Here and elsewhere: A station may have operated for a few decades or longer, but could not have been an ASOS station prior to about 1994 to 1996, because that is when ASOS was invented and began to be deployed. There are no ASOS sites from the early 1990s or earlier. ASOS refers to the platform and the sensor complement. Prior to ASOS, most of the hourly measurements were made by human observers, who noted what the hourly and sometimes partly automated equipment recorded. The earlier type of hourly station often resulted in what has usually been called the Surface Airways Observation (SAO) program, which was a conglomeration of lots of kinds of manned hourly stations. **Added as explanation under ASOS.**

For example Portland airport has hourly data back to the early 1940s at least, but was not an ASOS station until the middle 1990s. It’s also missing the period when the Vanport Flood overran the airport location for several months in 1948.

P 36 LEWI

Astoria was a long term hourly surface airways station, but the ASOS station there was not commissioned until March 1, 1993. **OK, added as a footnote.**

Could not locate a source for the specific measurement for Cape Disappointment starting in 1963. **This reference was deleted.**

P 38 OLYM

Here and elsewhere:

“necessary to negotiate winter operation”

This is usually as simple as not throwing a switch to shut the station down for winter. There seems little cost or risk in letting a RAWS station run all year, since it is there anyway. There may be power issues in winter, on occasion, but cannot think of a good reason not to record whatever data is available all year long. Winter shutdown seems to reflect the mindset of the fire community. Also, the PNW is warm enough that at lower elevations, where many RAWS sites are located, they will be recording rain during much of winter, rather than snow. **Yes, it is true, which is why the NCCN would like to try to operate RAWS stations year round. Added comment under overview of RAWS**

P 39 table 2.1

Snotel is more and more hourly, and mostly hourly by now, but they have a combination of 1, 3, 6 and 24 hourly.

Many RAWS are now 15 minute.

Elsewhere in table: For snotel, it is hard to keep up with this, but a lot of Snotel stations are now starting to have soil temperature and soil moisture sensors added to them. But one often has to check the incoming messages in their raw form (“TK files”) and the sensor label meanings are hard to find on the web.

CRN stations do not record wind direction, just speed (an oversight, and the purpose is to interpret the temperature measurement). **OK.**

P 44 Table 2.4

Nice to see these recent installations.

Where is Shurman?, could not find coordinates or map location. **Schurman is not installed. Noted as a possible future station to install.**

Are all suggested/planned sites on a map someplace? **Yes, Figure 2.1**

Overall a good table, and it gives a sense of priorities.

P 47-48 RAWS

RAWS can either be maintained by NPS staff or by the RAWS program. There is some expense with the latter, but they do a good job, and this is worth considering. But you do have to have a budget that can support this. On-site expertise is good, but in the past the NPS RAWS stations have suffered from a lot of neglect. Recent changes mandating maintenance to keep standards up, and meet FPA requirements, have helped a lot to bring the quality up to where it needs to be. Internal studies have shown that RAWS data can be very valuable and is sufficiently accurate, if these maintenance and upkeep issues are addressed promptly. **Added**

P 48 CRN

1000 mm not ml unless this refers to some calibration procedure. But precip is usually measured as a depth (really as volume divided by area, which has units of depth). **Changed.**

P 50 Table 3.1

In various places in the report, we see references to NWS in some places, and to NOAA in others. NWS is a NOAA agency. Sometimes it is helpful to differentiate, sometimes not. NWS does run the upper air program. NWS does run most ASOS stations, but other non-NOAA agencies also run ASOS stations, as well as AWOS stations. CRN is not run by NWS, but by another branch of NOAA called NESDIS, in concert with OAR (Oceanic and Atmospheric Research), another line office within NOAA, who performs the maintenance of CRN through their ATDD (Atmospheric Turbulence and Diffusion Division) at Oak Ridge National Lab. It's probably acceptable to "just say NOAA" for CRN, rather than go into these details. But this does have real effects, in terms of how the stations are taken care of. **OK**

P 51 NPS climate stations

Flash drives also a good storage medium. Even if a station is generally transmitting reliably, it's a good idea to replace the transmitted version with the version downloaded during a site visit, which is usually more complete in time, and often has additional measurements that could not fit within the communications bandwidth. **Noted**

P 52 Table 3.3

6 months. "Download if telemetry failed within 6 months." Always do this, no matter what. There are very seldom periods of 6 months with totally intact communications. **Very true, changed.**

P 52 snow course

"monitored once a month [in winter and spring]..." **We monitor once a month as noted in protocol.**

P 53 top two par

"after being recorded to..." not sure what this means. This is a manual process. **Explained.** WeatherCoder III is now in wide use, replaces Weathercoder II. This is part of an initiative to eventually go paperless.
"by the 3 of the month" ?? 3rd or 5th working day **3rd.**

P 54 CRN

5 minute data, not 15. **Changed**

P 54 ASOS

DCP = Data Collection Platform. **Changed.**

P 57 bullet 3

Data certification as "complete". It may be that all available data were received (complete transmission) but that not all data were recorded (complete transmission of incomplete data). It's not clear which is meant here. **All available data were received. This was clarified based on reviewer comment.**

P 57 2nd par from bottom

“autonomy, [and] longevity” **Added.**

Table 4.1

Very complete, good job.

P 75 bottom

Certification, still a little confused. We seldom get complete data, even from very good stations. So what seems to need to be certified is that a) all available data were obtained (even if some periods are missing), and b) that those incomplete data are free of certain kinds of errors.

Certification of all available data.

P 82 first par

ASII = ASCII ?? **Changed.**

P 83 table 4.6

Under PAR, what does “Up” mean ? **Removed**

P 83-88

Figures and info generally look ok. Many many possibilities here.

Good to have common products, but am always a little uncomfortable with specifying details too much.

Fig 4.3 Not sure why disconnected data need a curvy line between them. Each month stands on its own merits. The preference should be not to connect anything, just use symbols or (for hydro quantities) bars. **This entire section has changed.**

P 98 top half

Best laid plans. It’s almost inevitable that plans will be scaled back, too bad.

The issue of leveraging, and of pursuing leveraging opportunities, is noted just above 6.2, and this needs reiteration. NPS will not have the resources to measure everything, but should take advantage of other efforts, and provide moral or written support, or other support, to maintain those efforts, from which it benefits a lot. **Reiterated.**

P 102 table 6.3

Costs seem generally reasonable. Muir seems a little on the inexpensive side, given what it will be exposed to, some of the worst conditions in the PNW.

P 103 Table 6.5

Kalaloch site will likely have salt issues. These really eat up a station if near ocean water. At sea level, “near” is about a km or so. Have a lot of replacement part money buried in the mattress. **Added as footnote.**

Appendices.

The maps are useful.

App 2.1

Oak Harbor Airpark (ICAO id KOKH) seems more like an AWOS than a full ASOS, also do not see data after Sep 21, 2007 at weather.gov, but this station is operating and reporting on other web sites, and can be called directly. **OK**

App 2.6

Nice map, very helpful.

App 3.1

Not all elevations in both m/ft. **Edited.**

LEWI Astoria “Costal” area **Added**

Notes:

HCN: This is a designation of certain sites within the NWS Coop Network, but not much more. The HCN stations are not really special in the way in which they are treated. That is, they are usually not treated any better or worse in terms of maintenance and upkeep than any other NWS coop station. Many HCN sites are not in good condition. As a rule they run the gamut in terms of station upkeep and quality. They were not selected on the basis of actual data properties, but only on the basis of metadata. **OK, but still relevant as a designation and left definition of HCN in protocol.**

SRG: “olds” = “holds”. Legs may be 3 feet long, but the precip can sit down inside the legs. The measuring stick is wood, not metal, of a special kind of wood that wets readily when moistened and turns a dark color. There was a batch of these wooden sticks that were recently distributed that wetted very poorly, and made them hard to read.

Snow board. Note that the official snow boards and usually snow stakes are painted white, to prevent melting from solar radiation or IR at night. **Added.**

App 3.5

The NESDIS ID (ex 3262744C) given is the current version (essentially a frequency allocation), but that same station may have used a different frequency in the past. **Noted as a footnote**

App 3.7

Temperature uses a Thermometrics PRT (Platinum Resistance Thermometer).

There have been plans to install soil moisture and temperature sensors on each CRN site, perhaps in the coming year, but cannot confirm that from available info on the web. **Changed**

App 3.9

As noted earlier, ASOS has only been around since about 1994 or so. These locations relied on earlier equipment vintages to make observations for those years.

Port Angeles: not sure of the starting date of hourly information, but 1885 seems especially early. ASOS was commissioned at CLM (William R Fairchild International Airport) on October 16, 1998. **Changed date.**

App 3.11

Quillayute has been the upper air site since August 2, 1966. On that date the site was moved from its former location at Tatoosh Island, 48.38 N 124.73 W, where the record starts on March 15, 1943 and extends thru August 1, 1966, with a change in elevation from 33 to 31 meters on

October 14, 1954. For most purposes the 31 meter elevation is sufficient, although good software can detect this change from station behavior. **Added as a footnote**

App 3.16

This appears to be the current sensor complement. These have changed through time, both in the type and manufacturer, but also in the number of climate elements measured. For example, automated snow depth sensors were not included when the Snotel system was originally deployed. Temperature was not added at most sites until about 1982, some not until 1989, a few even later.

Blackwall Peak shows a Snotel dating from 1968. The Snotel package was not “invented” or deployed until approximately 1977-78 or so. **Added as a footnote.**

App 3.17

WX Coder III has a new web site at acis.dri.edu/wxcoderIII (case sensitive). **Changed.**

App 3.18

Did not go through this in detail as it is an existing NPS document not specific to NCCN climate monitoring, but appears to be quite thorough.

App 4

Looks good. NPCLime is a work in progress, not much to add to this.

All SOP Appendices

Did not go through these in detail, since they are geared toward existing and specific instrumentation for the most part. Some of these networks are run by others, such as NWAC, and this documentation gives very good insights as to how well such groups run their station networks. In addition, it is very useful to have all these SOPs collected in a single place. In particular, NWAC personnel have had considerable field experience with the tough icing conditions characteristic of the Pacific Northwest, and have a lot of practical advice to offer about measurements in these circumstances.

It is possible that some of this may be dated, since instruments often undergo upgrade and evolution cycles. However, certain instruments have been in long use with no particular reason to change.



College of Forest Resources Box 352100
University of Washington, Seattle, Washington 98195

James K. Agee, Emeritus Professor of Forest Ecology
112 Winkenwerder Hall

Phone: none Fax: 206-543-3254
email: jagee@u.washington.edu

March 23, 2009

The review for the revised "Climate Monitoring Protocol for the North Coast and Cascades Network" is complete. This protocol receives the following decision:

Acceptable with Revision

This is the same decision as was made for the first draft, for the reasons explained below. There was a good response to comments made on the first draft. The narrative reads well and contains substantial detail. However, the network needs to attend to two issues: (a) the organization of the SOP's is very convoluted, such that the reader is lost in pagination and trying to understand the relationships of appendixes to other text; and (b) attention to small details is critical. I know this can be somewhat numbing after so much time spent on the protocol, but the small details are still important to an acceptable protocol. The current protocol needs attention to both formatting guidance in the long run, and, particularly for this review, improvements in organization.

- (a) With considerable assistance from Kris Freeman, PWR Technical Editor, the organization of the SOP's and appendixes was reconfigured. Hard copies of SOPs from partnering agencies and almost all manuals were removed. Both manuals and SOPs are referenced with a literature citation and will be available at: <http://science.nature.nps.gov/im/units/nccn/reportpubs.cfm>. Page numbers are consecutive within in the protocol narrative and appendixes. SOP page numbers are consistent within each SOP and are labeled by SOP (SOP n.1). SOP 3 (Data Management) had significant reorganization based on comments from both reviews. Information is SOP 3 was distributed in the appropriate weather station SOPs. For example, all instructions to download and acquire data from all weather stations were included in SOP 3. This led to a very confusing, large SOP. Currently, instructions are available within each respective SOP. Instructions to download Remote Automated Weather Stations (RAWS) data are available in SOP 5, RAWS, instructions to download Climate Reference Network data (CRN) is available in SOP 8 CRN... etc. Please note: information in the SOPs was either moved within the document or removed and referenced. Information was not lost during the reorganization of this document.
- (b) Small details were addressed by both the authors as documented below and with additional assistance from Kris Freeman.

SOP organization

Ideally, the Natural Resources Report (NRR) series requires consecutive pagination through the entire document, including all SOP's. Alternatively, SOP's can be published as separate volumes, but again a consecutive numbering is required. The current draft has multiple pagination even in individual SOP's. SOP #1, for example, has an unnumbered page 1, then continues on to a blank page 20 except it is numbered (blank pages are not supposed to be numbered), then has three unnumbered map pages (appendices A-1 to A-3), then starts over with page 1 for appendix B, and again starts over with page 1's for appendices C-K. SOP #2 includes a manual with separate page numbers, and the manual itself has appendices A-C which are different from SOP #2 appendices A-P (and each SOP appendix starts with a page one). It is very difficult to scroll around and find anything with such organization. Most of the other SOP's have similar issues.

One option is to remove all manuals from the hard copy and then consecutively number all remaining pages. Omitted material can be on the CD or appended as supplementary material after the end of the last SOP. That way everything can be tracked through the table of contents. It's really up to the network to find a solution that will work. The current review process managed through the Pacific West Region and the University of Washington is not designed to provide absolute guidance on pagination and formatting, but current pagination and formatting does not meet the guidance provided in the NRR Instructions to Authors. You should review these guidelines before submitting the document to the NRR series for publication. Our judgment on acceptability of the protocol in this review process does not imply the protocol will be acceptable for submission to the series. We recommend you contact Jason Bennett in Fort Collins if you are having difficulty interpreting the Instructions to Authors.

At a minimum for approval in this review process, the pagination has to be consistent within a single SOP (pages 1-n) and be included in the table of contents. This may not be consistent with guidance from Fort Collins, it is just our way of assuring that the protocol is scientifically acceptable (i.e., understandable). Whether all SOP's are included in a single consecutive numbered system that begins with page 1 being the first page of the narrative, and the last page being the last SOP page (the ideal system), and whether manuals are included are not

(and where) are issues you need to take up with Jason. One approach that you could take is to correct the small errors and then contact Kris Freeman (our new PWR Technical Editor; email: kfreeman@u.washington.edu) for assistance with reorganizing the document.

Attention to Small Details

Here are comments organized by page number (P), paragraph number (par), and line number (l):

P3, par 3, l 6: “EBLA on Whidbey Island and SAJU *on San Juan Island.*” **Added**

P3, par 5, l2 and 4: Two periods after FOVA, Davey et al. is 2006. **Fixed**

P12, par 2, l 8: Mote et al. is just 2003, as there are not two Mote et al.’s for 2003. **Fixed**

P15, par 1, last line: Mott et al. is Mote et al.? **Mote et al.**

P16, par 5, l7: Weiss et al. is listed as 2007 in lit cit. **Added 2007**

P17, par 1: Borys et al. 2003 should be Borys and Lowenthal 2003. **Added Lowenthal**

P17, par 5, last line: Field et al. needs a period after “al” **Added al.**

P17, last par, l4: Case 2007 should be Case and Peterson 2007. **Added Peterson**

P17, last line: Zavaleta et al. should be Zavaleta and Hulvey. **Added Hulvey**

P18, par 4, l4: Price 2000 should be Price et al. 2000. **Added et al.**

P25, par 1, l4: NWAC 2004 missing from lit cit. **Changed reference to Moore 2004**

P26, par 4, last line: Garmin et al. Reviewer 1 last time said this is really Steve Garman not G. Garmin, response noted “changed”, but G. Garmin it still is. Which is really correct? **It is now finally changed to “Garman”**

P27, par 1, second to last line: Mote et al. is just 2003, no “a”. **removed “a”**

Pg. 28, states that Lake Ice Phenology will be provided by the Mountain Lakes protocol. If this is important information needed for Climate monitoring this should be clarified as it is not clear from the Mountain Lakes protocol that this data will be collected.

Data will be collected as part of Mountain Lakes Protocol (See SOP 8, Mountain Lakes Protocol) Further explanation is now provided in section 1.4.1 and Appendix A.

P33, par 3, l11: not clear whether there are one or two stations. Roche Harbor is not near the airport, and what is a SPB? SPB should be included in acronyms on p. 107. **Deleted Roche Harbor SPB**

Pp38-43. Tables 2.3 and 1.4 (1.4 should be renumbered 2.4 and is referred as such below) are a bit confusing to me. Table 2.3 is existing and proposed stations, while 2.4 has recently installed or proposed stations. Your choice, but are these not somewhat redundant? They are somewhat inconsistent. For example, White River is listed in 2.4 as proposed but is not in 1.4. Is Brown Top Ridge (2.3) the same as Brown Top Mtn (2.4)? The last line of p 41 notes that site 5 (Easy Pass) has been installed, but Table 2.4, which lists other recently placed stations as “installed in 200x) doesn’t show Easy Pass as installed. These are all minor issues but the reader doesn’t get a clear idea of what’s actually going on without consistent material in the tables.

The redundancy was fixed and the table renumbered. They are slightly redundant, but the authors wish to provide additional information on the status of stations identified at the weather workshop, therefore will keep Table 2.4

P43, par 1, l7: Davey et al. doesn’t need a comma after Davey. **Removed**

P66, par 1, l4: NCCN 2005b is just NCCN 2005. **Removed**

P67, last line Boetsch et al. 2005. **Added et al.**

Pg. 70 states that reporting will focus on temperature and precipitation. Yet, pg. 27 objectives states that other objectives are to monitor wind speed, wind direction, soil temperature and moisture, relative humidity and solar radiation. If these things are measured and data collected, they should be reported on.

Based on comments from Reviewer 1 (below), the authors scaled back the reporting section considerably. To report on wind speed, wind direction, soil temperature and moisture, relative humidity and solar radiation would considerably increase the length of the report and time to produce the report. We are committed to providing reprocessed data for all these parameters and will be open to providing any additional tables/graphs individuals request for this data.

From Reviewer 1:

It seems like the NCCN is committing to a very ambitious reporting plan for climate data. I think the Networks should consider carefully how much work will be required to produce, format, print, and distribute all the graphics associated with the stations. It’s clearly worthwhile to acquire and retain all the data, and to do whatever QA/QC is practical, but I would not commit to such a major reporting effort until it was clear that these products will be used. I think park managers are more likely to be interested in region-specific indices that basically tell them whether it was a wet or dry (and how wet/dry) or hot or cold (again, how hot/cold) season or year. Quantitative ecologists and researchers will likely want to reprocess data (preferably already cleaned, with consistent file formats, and ready for use). So a smaller number of plots/tables/indices may be both more efficient to produce and better meet park needs. These could be developed from an aggregate of several stations, or the Network could report selected stations there are considered representative of certain areas.

P74, Table 4.5. The third to last and last column should be revised as is done for Table 4.6 on next page. As it now reads the departure for January is over 100%, so if it normally receives 368 mm that month, in 2003 it received either 736 mm

or 184 mm. If it's meant to read 103% of normal then the departure is 3%. Clear this up and make sure the revised table showed the direction of departure. Table 4.6 is clear. **Table is revised to reflect accurate departures from normal.**

P77: Why the italics for Noisy Glacier, Silver Glacier, and English Camp? Explain in the table title. **Added explanation to title "proposed stations"**

Pg. 83: Refers to NCPN. Should this be NCCN? **Changed to NCCN**

P84: Update the people at page bottom to 2009. **Updated to 2009**

Pg. 92: States annual operating costs are in Table 6.2. They are in Table 6.3. **Changed to 6.3**

Literature cited. A fair amount of cleanup needs to be done here. Let's start with the 15 references in the lit cit that I did not find in the text (after 2 reads):

Casola et al. 2005. **Removed**

Daly et al. 2002. **Removed**

Hamlet 2006. **Removed**

Karl et al. 1996 **Removed**

Keeton et al. (in review) **Removed**

Mantua 2000. **Removed**

McCarthy et al. 2001 **Removed**

Douglas et al. 2008. **Removed**

Moore 2004. **Added to text**

Nilsson and Grennfelt 1988 **Removed**

Porter et al. 2005 **Removed**

Redmond et al. 2005 **Removed**

Riedel and Burrows 2005 **Removed**

Sanwald et al. 2000 **Removed**

Wallace and Gutzler 1981 **Removed**

Either cite them or remove them.

Remaining changes by literature citation:

Boetsch et al. period after B. Christoe **Changed**

Borys and Lowenthal needs an "and" between their names. **Changed**

Case and Peterson: same thing **Changed**

Clow and Campbell: initials of Campbell need to precede surname. Also there are two periods after Campbell's name, just need one. **Changed**

Casola et al. is out of alphabetical order **Removed**

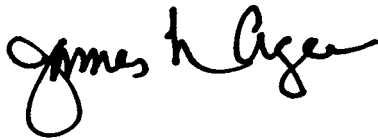
Garmin et al. (is Garman, S. ? – see comment page 26) **Fixed**
Hart et al. needs italics for Latin name **Changed**
Jaffe et al. 2005: Atmos. Environ. **Edited**
Extra space between IPCC and Jacobsen et al. **Changed**
Jacobsen et al. is out of alphabetical order **Moved**
Lips needs an indent on line 2 **Added**
Logan and Powell need a period instead of comma after authors. **Changed**
Logan et al. same thing
Mantua et al. should have date (1997) after Francis, not after title. It also should come after Mantua 2000. **Changed**
Mote 2003a should be just 2003 **Changed**
Mote 2006 should precede Mote et al. 2006. **Changed**
Douglas et al. is way out of alphabetical order **Removed**
NCCN 2005a should be just 2005. **Changed**
Poiani et al. 1996 needs to moved down four spots - is out of alphabetical order **Moved**
Parmesan 2006 should precede Parmesan et al. **Moved**
Peterson and Peterson have coloring and underlining on title – needs to go **Changed**
Porter et al. have initials after surnames, bring to front of surname **Removed reference**
Prop et al. Italics for Latin names **Changed**
Schindler 1998 – period, not comma, after author name. **Changed**
Need space between Westerling and Wilson **Added**
Wilson 1996 is out of alphabetical order **Moved**
Zavalate and Hulvey have no first names or initials. Also remove caps from title, just a journal article. **Added**

The organizational issues listed above apply to the pages following the literature cited, and will not be repeated below. There is an unnumbered set of pages (149-153) which are likely appendix 3-18 (although not identified as such), as they appear between 3-17 and 3-19. I assume the first few pages are NOCA's compliance documents and the next 35 or so are OLYM and MORA's. While ensuring that compliance is accomplished for the protocol, e.g. by being present in a timeline or pre-field season preparations, the process tends to vary by park and does not need to be included here in such great detail.

The authors have decided to remove the detailed compliance documents and simply state that Installations of new stations and equipment will comply with NPS National Environmental Policy Act (NEPA) mandates including effects on Wilderness and cultural resources.

In summary, the attention to small details should be easily accomplished. Addressing the organization of SOPs is much more complex, but, as noted above, you can obtain assistance from the PWR Technical Editor who has been notified of this potential need. Kris can also help you to meet other formatting guidance for the Natural Resource Report Series. The minimum reorganization required may not be sufficient to meet the guidelines of the NRR series, but it will be sufficient for protocol approval by the Pacific West region of NPS. In your response, as before, please address each comment. It was easy to follow the responses from the first review. I look forward to receiving a final draft.

Sincerely,

A handwritten signature in black ink, appearing to read "James K. Agee". The signature is fluid and cursive, with the first name "James" and last name "Agee" clearly distinguishable.

James K. Agee
PWR Protocol Review Coordinator

Attachments: PWR Protocol Review Checklist, Reviewer comments



School of Forest Resources Box 352100
University of Washington, Seattle, Washington 98195

James K. Agee, Emeritus Professor of Forest Ecology
112 Winkenwerder Hall

Phone: none Fax: 206-543-3254
email: jagee@u.washington.edu

May 18, 2010

The review of the revised **NCCN Climate Protocol** has been completed. The protocol decision is:

CONDITIONALLY APPROVED

The protocol is much cleaner and readable than in the previous review. However, there are still a few niggling details that need to be cleaned up before approval. We do not need to see the document again, but an email to Dr. Latham certifying that the changes have been made will be needed. At that time, an approval letter and the formal signed Protocol Review Approval Form will be prepared.

Best of luck in finalizing the protocol and getting it implemented on the ground.

Sincerely,

A handwritten signature in black ink that reads "James K. Agee". The signature is fluid and cursive, with the first letters of the first and last names being capitalized and prominent.

James K. Agee
PWR Protocol Review Coordinator

Attachment: 5/18/10 Comments

NCCN Climate Protocol

5/18/10 Comments

Xvii, line 7: Lewis and Clark National Historical Park (not Site) **Corrected**

Xviii: LEWI, Park, not Site **Corrected**

Xix: SAJH: Historical Park **Corrected**

Page 1: should start on right hand side of document, not left. This is true throughout the document, new sections start on a right hand and odd-numbered page. **Corrected**

P3, par 3: Ruscha 1972 is Ruscha and Meyers 1972 according to lit cited. **Corrected**

P3, par 4: Davey et al. should have no period after the date (2006.) **Corrected**

P6, par 3: There is no Daley et al. 2002 in lit cited. **Added**

P11, sec 1.1.2: Wallace and Gutzler is missing from lit cited **Added**

P15, par 4. Hartzell 2005 is Hartzell et al. 2005. **Added**

P16, par 2. Helmeth et al. 2006 is spelled Helmuth et al. in lit cited **Helmuth is correct spelling**

P16, par 4. No period after date for Bailey et al. 2000. **Corrected**

P16, par 4, last line: no period between “Clow and Campbell” and “2008”. **Corrected**

P18, par 4, l4: Prop et al. missing from lit cited. **Added**

P22, par 2: I didn’t understand the sentence: “RAWS stations generally gauge.” **Corrected sentence**

P42, par 1: Redmond et al. 2005 missing from lit cited. **Added**

P52 seems to be missing. **Corrected**

P57, Table 4., column 4: Lead agency for RAWS is National Interagency Fire Center, not National Interagency Wildfire Program. **Corrected**

P66, last par: NPS 2007 should be NCCN 2007 (as it is on following page). **Corrected**

P86, last par: National Wildfire Coordinating Group is missing from lit cited. **Corrected**

P94: Bonan et al. is a duplicate of same ref on page 93. **Deleted**

P98: NCCN 2007 development, not “fevelopment”. **Corrected**

P98: I did not find Oakley et al. or Office of the Federal Coordinator for Meteorology in the text. **Deleted Oakley. Federal Coordinator for Meteorology is referenced on pg. 45**

P 104-105: Pagination is upside down on page 105, 107, 109, 111, 113. **Corrected**



School of Forest Resources Box 352100
University of Washington, Seattle, Washington 98195

James K. Agee, Emeritus Professor of Forest Ecology
112 Winkenwerder Hall

Phone: none Fax: 206-543-3254
email: jagee@u.washington.edu

June 7, 2010

The review of the revised and reconciled **NCCN Climate Protocol** has been completed. The protocol decision is:

APPROVED

Best of luck in finalizing the protocol and getting it implemented on the ground.

Sincerely,

A handwritten signature in black ink that reads "James K. Agee". The signature is fluid and cursive, with the first letters of the first and last names being capitalized and prominent.

James K. Agee
PWR Protocol Review Coordinator

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.

NPS 963/105553, September 2010

National Park Service
U.S. Department of the Interior



Natural Resource Program Center
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov