National Park Service
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Natural Resource Stewardship and Science

North Coast and Cascades Network Climate Monitoring Report

North Cascades National Park Service Complex; Water Year 2016

Natural Resource Data Series NPS/NCCN/NRDS—2018/1152

ON THE COVER

Damage to Colonial Creek Campground from a flood event in November 2015. Flood waters from Colonial Creek undercut stream banks and toppled trees adjacent to two campsites. In a two day period the Newhalem climate station received over 6 inches of rain.

Photograph by: NPS

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Michael A. Larrabee

National Park Service
North Coast and Cascades Network
North Cascades National Park Service Complex
810 State Route 20
Sedro-Woolley, WA 98284

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The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Data Series is intended for the timely release of basic data sets and data summaries. Care has been taken to assure accuracy of raw data values, but a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

This report is available in digital format from the North Coast and Cascades Network Inventory and Monitoring website and the Natural Resource Publications Management website.

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Executive Summary

Climate and weather events define the ecological characteristics found in national parks and are key to understanding and interpreting changes in natural resources. Everyday park operations including; fire management, search and rescue, maintenance of park infrastructure, and visitor use are influenced by weather. Collecting weather data and maintaining climate records provides essential information needed to support park operations and to monitor park resources.

This report summarizes climate data collected in North Cascades National Park Service Complex (NOCA) during the 2016 water year, and is part of a set of climate summary reports from seven national and historic parks in the North Coast and Cascades Network. Published in the National Park Service's Natural Resource Data Series, annual climate summary reports are intended to provide basic data sets and data summaries in a timely manner, with minimal interpretation and analyses. We intend that the primary audience for this document will be National Park staff, especially decision makers, planners, and interpreters; partners; and interested public.

Climate data are presented from eleven weather stations located within North Cascades National Park Service Complex: Beaver Pass (3630' elevation), Brown Top (5830'), Easy Pass (5270'), Marblemount (407'), Noisy Creek (6590'), Newhalem (520'), Park Creek Ridge (4600'), Ross Dam (1240'), Silver Lake (7670'), Stehekin (1270') and Thunder Basin (4320'). Data were recorded using automated and manual instruments operated by the National Park Service and other collaborators, including the Natural Resources Conservation Service, National Oceanic and Atmospheric Administration, and National Weather Service. Monthly averages of daily average temperature are reported for all stations and monthly total precipitation is reported for nine stations. Comparisons are made to the 30-year normal (1981-2010) for Newhalem and Stehekin, two stations with long term climate records. Snow water equivalent (SWE) is reported and compared to the 30 year normal for three SNOTEL stations within the park and monthly snow depth is reported for seven stations within the park.

Average annual temperatures were above normal for Water Year 2016. The warm temperatures resulted in significant departures from normal and set records in daily highs, most notably in April. Annual precipitation varied across the Cascades Range; stations on the west slope received above normal precipitation and east slope sites were below normal. There was also a notable temporal split in precipitation during the water year, with the first half wetter than normal and the second half drier than normal. Heavy rainfall events in October and November resulted in debris flows and erosion, damaging park infrastructure. Mountain snowpack on April 1st was above normal but melted rapidly in spring due to above normal temperatures.

Acknowledgments

North Cascades National Park Service Complex relies on several cooperating agencies to help support and maintain a long-term climate monitoring program as part of the North Coast and Cascades (NCCN) climate monitoring program. These agencies include:

- National Oceanic and Atmospheric Administration – US Climate Reference Network
- National Weather Service – National Weather Service Cooperative Observer Program
- Natural Resources Conservation Service - National Water and Climate Center, SNOTEL and Snow Survey Program

Data management is critical to provide for the availability and analysis of climate data. We depend on the NCCN Data Managers; the Western Regional Climate Center; and the National Climate Data Center for climate data management.

Acronyms

COOP	Cooperative Observer Station
I&M	Inventory and Monitoring
NCCN	North Coast and Cascades Network
NOCA	North Cascades National Park Service Complex
NPS	National Park Service
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
NWS	National Weather Service
SNOTEL	Snowpack Telemetry
SWE	Snow Water Equivalent
USCRN	United States Climate Reference Network

Glossary

Climate: Complete and entire ensemble of statistical descriptors of temporal and spatial properties comprising the behavior of the atmosphere. These descriptors include means, variances, frequency distributions, autocorrelations, spatial correlations and other patterns of association, temporal lags, and element-to-element relationships. The descriptors have a physical basis in flows and reservoirs of energy and mass. Climate and weather phenomena shade gradually into each other and are ultimately inseparable (Davey et al. 2006).

Climate Normals: A long-term average value of a meteorological parameter (i.e. temperature) measured at a specific station. For example, "temperatures are normal for this time of year" means that temperatures are at or near the average climatological value for a given time period. Climate normals are usually taken from data averaged over a 30-year period (e.g., 1981-2010), and are concerned with the distribution of data within limits of common occurrence.

NWS-COOP: An extensive network of manually operated weather stations overseen by the National Weather Service. Many Cooperative Observer Program weather sites were established in the late 1800's and as such, provide the best long term climate data. At each station, an observer records daily maximum and minimum temperature, as well as total rain and snowfall.

Period of Record: The total span of time that climate data have been collected at a specific location. The longer the period of record, the more likely the climate data will not be biased by singular weather events or cyclic climate anomalies such as those associated with the Pacific Decadal Oscillation and the El Niño/La Niña-Southern Oscillation.

RAWS: A network of Remote Automated Weather Stations overseen by the National Interagency Fire Center. RAWS stations provide real-time weather data to assist land management agencies in monitoring wildland fire fuels, rating fire danger and predicting fire behavior. RAWS stations all operate during summer months and many at lower elevations operate on a year round basis.

SNOTEL: An automated network of snowpack data collection sites operated by the Natural Resources Conservation Service (NRCS). A standard SNOTEL station consists of a snow pillow, snow depth sensor, a storage type precipitation gage and air temperature sensor. Enhanced sites also measure soil moisture.

Snow Course: A permanent site where trained observers manually measure snow depth, snow water equivalent and density at a series of points along an established transect. Measurements are taken the last week of each month during winter and early spring. Values are recorded as the first of the month.

Snow Water Equivalent (SWE): A measurement describing the amount of water contained within the seasonal snowpack. It can be thought of as the depth of water that would theoretically result if you melted the entire snowpack instantaneously.

Water Year: The Water Year (or Hydrologic Year) is most often defined as the period from October 1st to September 30 of the following year. It is called by the calendar year in which it ends. Thus, Water Year 2016 is the 12-month period beginning 01 October 2015 and ending 30 September 2016. The period is chosen so as to encompass a full cycle of precipitation accumulation.

Weather: Instantaneous state of the atmosphere at any given time, mainly with respect to its effects on biological activities. As distinguished from climate, weather consists of the short-term (minutes to days) variations in the atmosphere. Popularly, weather is thought of in terms of temperature, precipitation, humidity, wind, sky condition, visibility, and cloud conditions (Davey et al. 2006).

Introduction

Climate is a dominant driver of the physical and ecologic processes of the North Coast and Cascades Inventory and Monitoring Network Parks (NCCN, Figure 1) (Davey et al. 2006). Trends in rainfall and temperature influence how an ecosystem and its organisms function. The quantity and timing of rainfall and snow can influence the productivity and health of forests (Nakawatase and Peterson 2006), the amount of water flowing in streams and rivers (Hamlet et al. 2007) and the increase or decrease in size and terminus position of mountain glaciers. Likewise, temperature can influence the quantity and timing of plant growth and stream runoff, or the extent and duration of winter snowpack and lake ice (Thompson et al. 2009). Through direct and indirect methods, climate affects the behavior and reproduction of terrestrial and aquatic animal species (Crozier et al 2008). Climate is one of the primary causes of disturbance events such as forest fires (Littell and Gwozdz 2011) avalanches, windstorms, debris flows and floods. These events can have a major impact on park landscapes and their associated ecosystems, as well as park infrastructure such as roads and campgrounds.

Given the importance of climate, it has been identified as a primary vital sign by all 32 Inventory and Monitoring (I&M) networks within the NPS (Gray 2008). The NCCN monitors climate in order to understand variations in other park resources being monitored; to compare current and historic data to understand long-term trends; and to provide data for modeling impacts to park facilities and resources in the future (Lofgren et al. 2010). Climate data, derived from the NCCN climate network will play an important role in understanding and interpreting the physical and ecological Vital Signs monitored within NCCN parks.

The NCCN climate monitoring program capitalizes on climate stations operated by partnering agencies. The NCCN climate monitoring program compiles data from over 60 weather stations in and adjacent to the parks, of which 15 are operated by the National Park Service. While a wide variety of climate parameters are measured as part of the NCCN climate program, this report focuses on two key parameters: precipitation and air temperature, while providing supplemental information on snowpack.

This report summarizes climate data collected from eleven weather stations located in North Cascades National Park Service Complex (NOCA) during the 2016 water year, and is part of a set of climate summary reports from seven national and historic parks in the NCCN (Figure 1). Temperature, precipitation, and snow data from these weather stations are summarized in the results section of this report.

Annual climate summary reports are intended to provide basic data sets and data summaries in a timely manner, with minimal interpretation and analyses. National Park staff, especially decision makers, planners, and resource educators; partners; and interested public are the primary audience.

Figure 1. North Coast and Cascades Network suite of National Parks (NCCN).

Methods

Station Locations

This report incorporates data collected from weather stations operated by the NPS (GLACIER), the Natural Resource and Conservation Service (SNOTEL), and the National Weather Service (COOP and USCRN) (Table 1). All stations are located within North Cascades National Park Service Complex or lands managed by the National Park Service (Marblemount USCRN) (Figure 2).

Table 1. Weather stations referenced in this report.

Station Name	Station Type	Location	Elevation (ft)	Forest Zone	Period of Record
Beaver Pass	SNOTEL	West	3630	Forest	2002 to Present
Brown Top	SNOTEL	West	5830	Subalpine	2009 to Present
Easy Pass	SNOTEL	West	5270	Subalpine	2009 to Present
Marblemount (Darrington 21 NNE)	USCRN	West	407	Forest	2003 to Present
Noisy Creek	GLACIER	West	6590	Alpine	2009 to Present
Newhalem	COOP	West	520	Forest	1909 to Present
Park Creek Ridge	SNOTEL	East	4600	Subalpine	1979 to Present
Ross Dam	COOP	Interior	1240	Forest	1960 to Present
Silver Lake	GLACIER	Interior	7670	Alpine	2009 to Present
Stehekin	COOP	East	1270	Forest	1906 to Present
Thunder Basin	SNOTEL	West	4320	Subalpine	1988 to Present

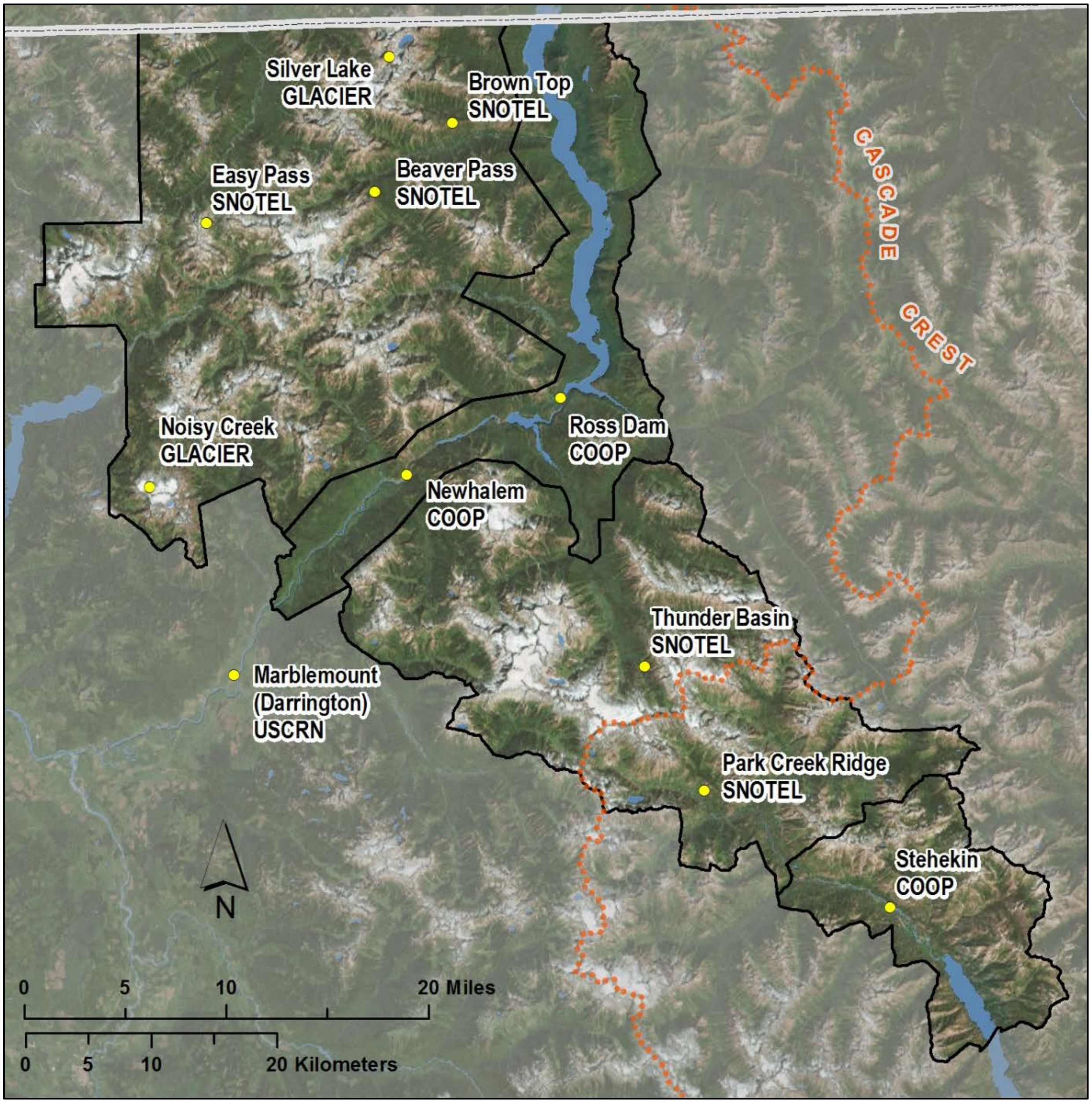

Figure 2. Location of weather stations referenced in this report.

Weather Station Measurements

Weather stations within the NCCN are managed by a variety of different agencies, each with a specific primary purpose. For this reason, instrumentation, method and period of collection may vary between sites. Table 2 describes the parameters measured at each station, highlights the data presented in this report, and indicates additional data that are available by request from North Cascades National Park Service Complex.

Table 2. Parameters measured at weather stations included in this report. X indicates the parameter is measured and data are presented in this report; ✓ indicates parameter is measured and data are available on request.

Station Name	Managing Agency – Station Type	Air Temp.	Relative Humidity	Precip.	Snow Depth	Snowfall	Snow Water Equivalent	Solar Radiation	Wind Speed & Direction	Soil Temp.	Soil Moisture
Beaver Pass	NRCS - SNOTEL[3]	X	✓	X	X	–	X	–	–	✓	✓
Brown Top	NRCS - SNOTEL[3]	X	✓	X	X	–	X	–	✓	✓	✓
Easy Pass	NRCS - SNOTEL[3]	X	✓	X	–	–	X	✓	✓	✓	✓
Marblemount (Darrington 21NNE)	NWS - USCRN[1]	X	✓	X	–	–	–	✓	✓	–	–
Noisy Creek	NPS - GLACIER[2]	X	✓	–	–	–	–	✓	✓	–	–
Newhalem	NWS – COOP[4]	X	–	X	✓	✓	–	–	–	–	–
Park Creek Ridge	NRCS - SNOTEL[3]	X	✓	X	X	–	X	✓	–	✓	✓
Ross Dam	NWS - COOP[4]	X	–	X	X	✓	–	–	–	–	–
Silver Lake	NPS - GLACIER[2]	X	✓	–	–	–	–	✓	✓	–	–
Stehekin	NWS - COOP[4]	X	–	X	X	✓	–	–	–	–	–
Thunder Basin	NRCS - SNOTEL[3]	X	✓	X	X	–	X	–	–	–	–

[1] NWS-USCRN has a standard array of automated weather instruments. Parameters are measured every 5 minutes and output as hourly averages.

[2] NPS-GLACIER station has a standard array of automated weather instruments which are measured at 60 second intervals and output as hourly averages. A single snow water equivalent measurement is taken at adjacent glaciers as part of the long term glacier monitoring program.

[3] NRCS-SNOTEL has a standard array of automated weather instruments in support of water supply forecasting. Parameters are measured every 60 seconds, and output as hourly averages.

[4] NWS-COOP station has a standard array of manually operated weather instruments. Parameters are measured and recorded daily.

Data Management

NWS COOP station and NRCS SNOTEL station data used in this report are acquired directly from the managing agencies. Quality assurance and control is provided by these agencies and is described in the NCCN Climate Monitoring Protocol and other supporting documents (Lofgren et al. 2010 and 2011).

The daily data used in this report from NPS stations are derived from hourly data which have been evaluated through automated queries and manual display and graphing. Hourly data flagged or identified as suspect are omitted from daily summaries. If more than two hours of data are missing on a given day, no daily values are presented.

Monthly values are generated and presented for stations where five or fewer daily values are missing. In the case of missing precipitation values, daily quantities may be substituted from another nearby weather station for the purposes of reporting monthly and annual totals. This will only occur when nearby data are available and a known correlation exists between these sites. In these cases where estimates are generated from nearby stations, data are footnoted and a description of the quantity and source of data replacement is given.

Data Quality

Due to problems associated with equipment failure and access to these remote sites, data gaps exist at several stations.

Gaps in data exist for Noisy Creek GLACIER station between November 10 2015 and April 18 2016, totaling 161 days. The missing data are a result of the long term malfunction of the charging system at the site. Due to the remoteness of the site, the NPS was unable to access the site until spring.

At the Silver Lake Glacier station, no data exists for water year 2016 due to data logger malfunction. The malfunctioning of the data logger is attributed to repeated power outages at the site.

At the Park Creek Ridge SNOTEL, no temperature data exists for water year 2016 due to sensor malfunction. Due to the remoteness of the site, the NRCS was unable to access the site until after the end of the water year.

Data Reporting

Data in this report are based on the hydrologic or water year and organized by month and seasons. Ecosystems in the Pacific Northwest are dominated by two distinct hydrological periods, a wet season generally beginning in late October and ending in June, and a drought season that generally extends from July to September. While a calendar year divides the wet winter season, the use of a water year closely reflects the timing and seasonality of many physical and ecological processes that are driven by climate, such as soil saturation and forest evapotranspiration, onset and breakup of lake ice, glacial accumulation and ablation balances, magnitude and timing of stream flow, emergence and flowering of plants and migratory timing of bird species.

Seasons in this report are distinguished based on National Weather Service (NWS) standards for the Northern Hemisphere. The NWS defines December, January, and February as winter; March, April, and May as spring; June, July, and August as summer, and September, October, and November as fall.

The main report provides monthly averages of daily average temperatures and monthly total precipitation for all stations listed in Tables 1 and 2. While routinely collected in metric units, data are presented in Fahrenheit and inches to facilitate use and interpretation by the public and park staff. Two stations with long term records; Newhalem and Stehekin COOP sites, are compared to the 30-year climate normal. Snow water equivalent (SWE) is reported and compared to the 30-year climate normal for three SNOTEL stations within the park, and monthly snow depth and SWE at the first of each month is reported for two COOP stations and five SNOTEL stations. Available upon request are hourly, daily, or monthly weather data from each station noted in Tables 1 and 2.

Results

Temperature

Annual air temperatures for Water Year 2016 were above normal across NOCA, with warmer temperatures persisting throughout most of the year. Both Newhalem and Stehekin COOP sites observed departures from normal for the year of +2.5 and +1.4^{o} F, respectively (Figures 3 and 4).

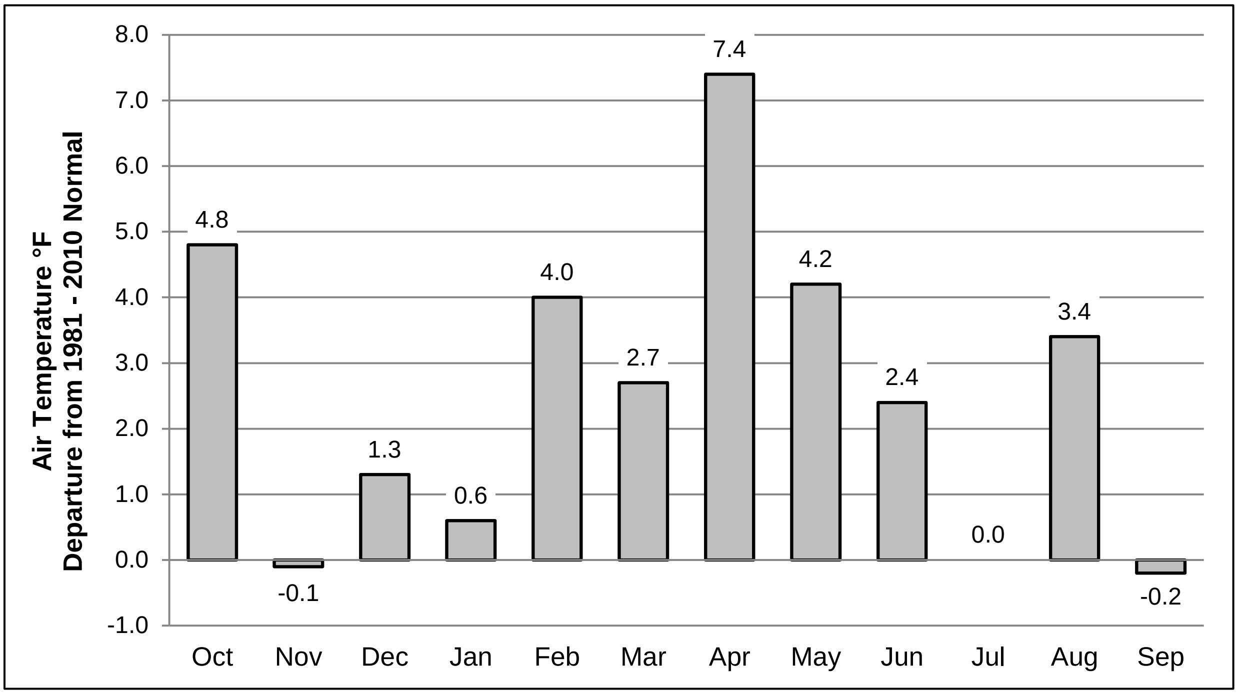

Figure 3. Comparison of average monthly temperature (°F) for Newhalem (COOP) in Water Year 2016 against monthly averages for the climatological normal 1981-2010.

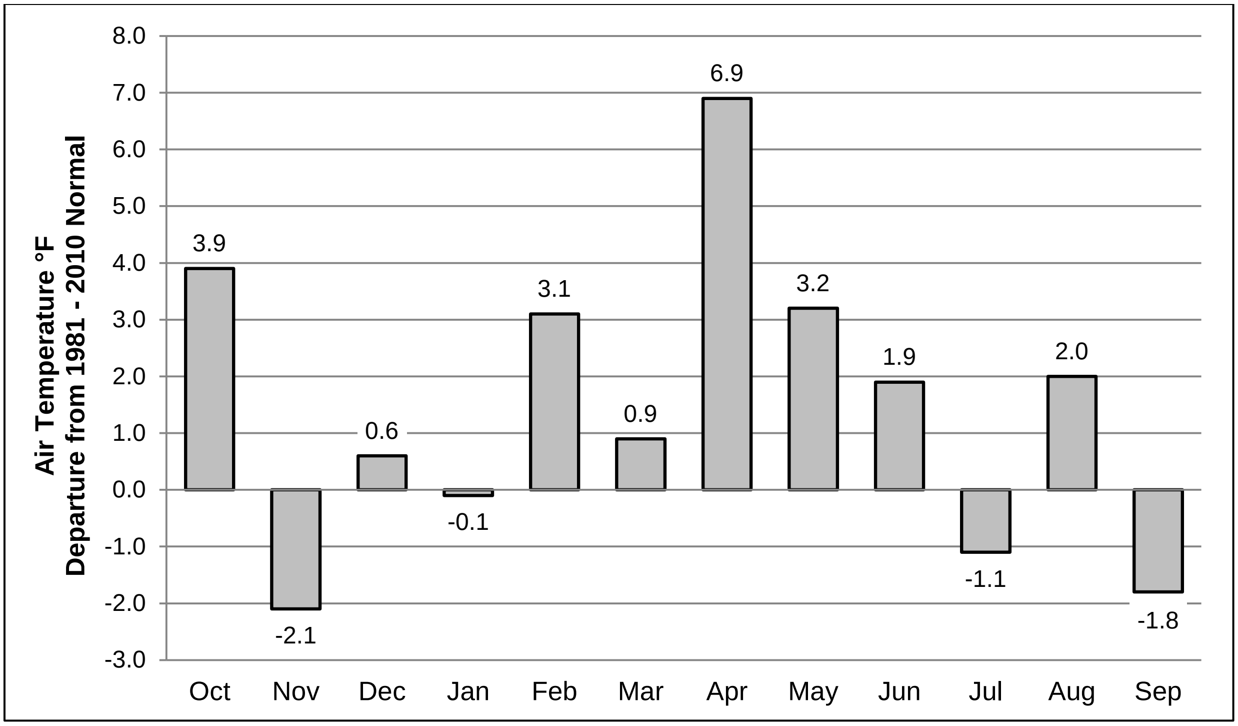

Figure 4. Comparison of average monthly temperature (°F) for Stehekin (COOP) in Water Year 2016 against monthly averages for the climatological normal 1981-2010.

The water year began with warmer temperatures in October; Newhalem averaged 54.7 ^{o}F, a departure of +4.8^{o} F above normal (Table 3). Temperatures moderated in late fall and early winter, with values closer to normal. Overall December was the coldest month for most sites, with Brown Top SNOTEL recording the lowest monthly average temperature at 25.0 ^{o}F.

Warmer temperatures returned in late winter through early summer. Average February temperatures at all reporting sites, excluding Brown Top SNOTEL, were above freezing. April was notably warmer than normal, Newhalem and Stehekin COOP sites recorded departures from normal of +7.4 and +6.9 ^{o}F, respectively. In April, nearly all sites had monthly temperatures at or above 40 ^{o}F.

Temperatures cooled in July to near normal before rebounding in August to above normal. August was the warmest month of the year at all sites with Stehekin recording the highest monthly average temperature for reporting sites at 71.6 ^{o}F. The water year ended with below normal temperatures in September.

Table 3. Average monthly air temperatures (°F) from weather stations within North Cascades National Park Service Complex in Water Year 2016.

Season	Month & Year	Marble-mount USCRN	Newhalem COOP	Ross Dam COOP	Noisy Creek GLACIER	Silver Lake GLACIER	Easy Pass SNOTEL	Beaver Pass SNOTEL	Brown Top SNOTEL	Thunder Basin SNOTEL	Park Cr. Ridge SNOTEL	Stehekin COOP
Fall	October 2015	53.2	54.7	52.8	42.2	–	45.0	45.0	44.0	44.0	–	51.4
	November 2015	39.0	40.5	38.1	–	–	31.0	31.0	32.0	28.0	–	33.9
Winter	December 2015	36.3	36.8	34.5	–	–	27.0	29.0	25.0	26.0	–	29.4
	January 2016	36.9	36.9	33.8	–	–	31.0	30.0	29.0	28.0	–	29.5
	February 2016	42.3	42.2	39.5	–	–	33.0	33.0	31.0	33.0	–	35.6
Spring	March 2016	44.1	45.3	42.6	–	–	32.0	34.0	31.0	33.0	–	40.2
	April 2016	52.5	55.8	53.2	–	–	41.0	40.0	41.0	39.0	–	54.6
	May 2016	56.3	59.1	57.4	38.0	–	43.0	46.0	43.0	43.0	–	59.4
Summer	June 2016	59.4	62.3	62.0	41.9	–	47.0	52.0	47.0	49.0	–	64.9
	July 2016	62.8	64.9	65.2	44.6	–	50.0	56.0	50.0	52.0	–	69.1
	August 2016	64.4	68.9	69.2	49.5	–	54.0	59.0	54.0	53.0	–	71.6
Fall	September 2016	56.1	59.5	58.6	40.3	–	45.0	48.0	44.0	45.0	–	58.6
Water Year		50.3	52.2	50.6	42.7	–	39.9	41.9	39.3	39.4	–	49.9

Precipitation

For Water Year 2016, annual precipitation was above normal across the North Cascades Range (Figures 5 and 6). Newhalem COOP, on the west side of the Cascades, was 114% of normal (87.6 inches). Stehekin COOP, located on the east side of the range, was 139% of normal (50.2 inches; Table 4). Easy Pass SNOTEL received the greatest total precipitation at 145.4 inches.

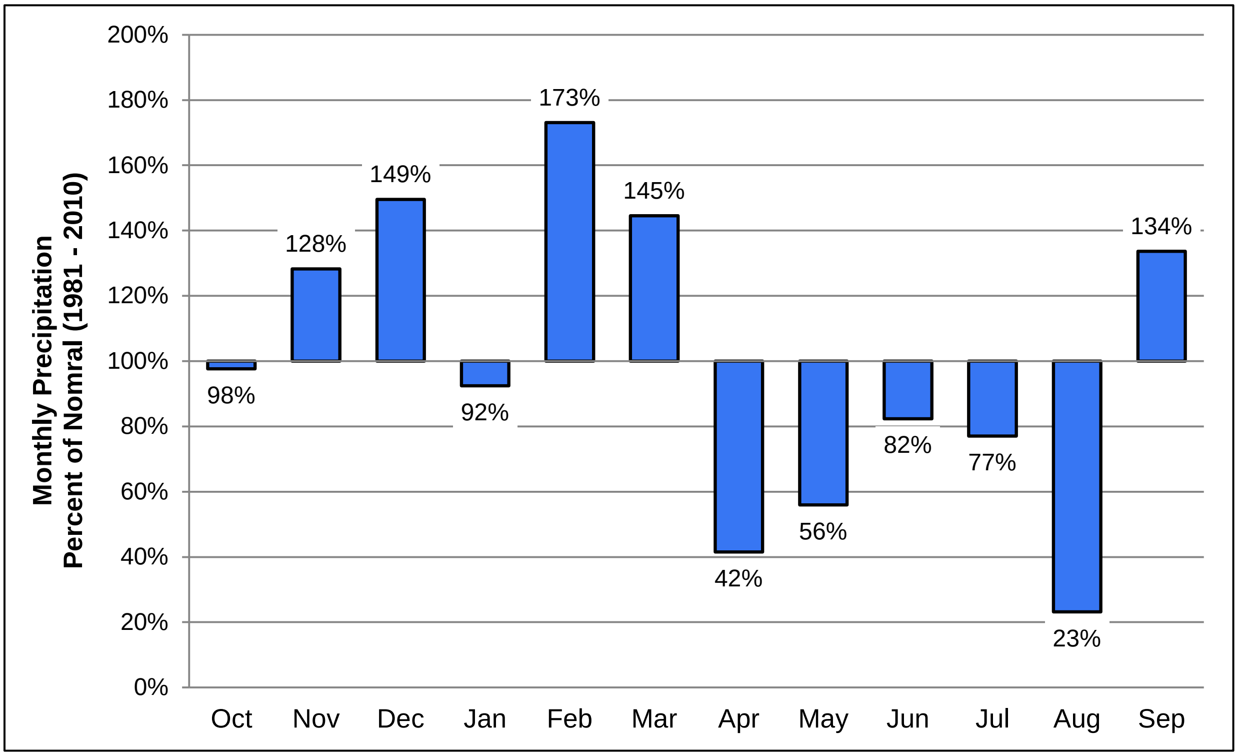

Figure 5. Comparison of total monthly precipitation (inches) at Newhalem (COOP) in Water Year 2016 against the climatological normal 1981-2010.

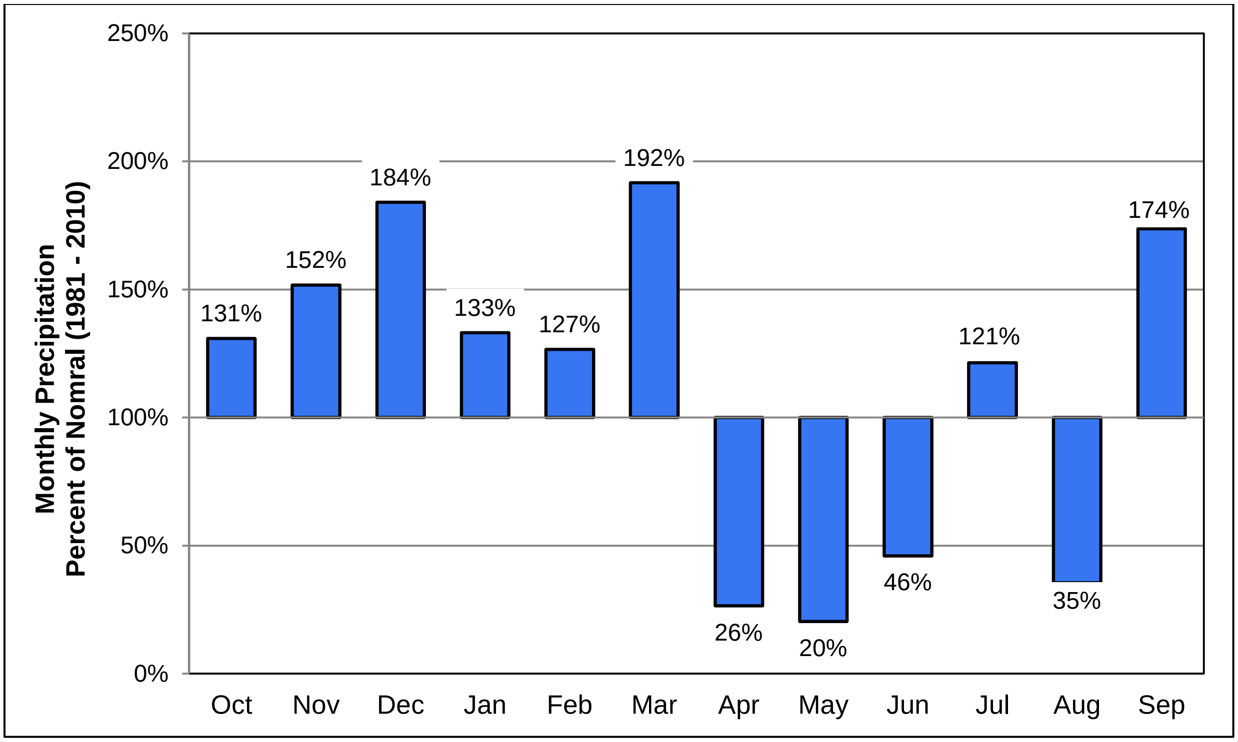

Figure 6. Comparison of total monthly precipitation (inches) at the Stehekin (COOP) in Water Year 2016 against the climatological normal 1981-2010.

Late fall 2015 through early spring 2016 was generally wetter than normal. December was the wettest month of the year at most climate stations, with the Stehekin COOP receiving 12.5” (184% of normal) of precipitation and Easy Pass SNOTEL receiving over 2 feet, falling predominately as snow. February and March were significantly wetter than normal; the Newhalem COOP had 173% and Stehekin COOP had 192% of the normal precipitation for February and March respectively.

April through August was notably drier than normal. In April, Stehekin received only 0.4 inches of rainfall, or about a quarter of normal. August was the driest month for all sites; Newhalem received 0.4 inches (23% of normal) and Stehekin received 0.2 inches (35% of normal), the least on any reporting site.

Table 4. Total Monthly precipitation (inches) from weather stations within North Cascades National Park Service Complex in Water Year 2016.

Season	Month & Year	Marblemount USCRN	Newhalem COOP	Ross Dam COOP	Easy Pass SNOTEL	Beaver Pass SNOTEL	Brown Top SNOTEL	Thunder Basin SNOTEL	Park Creek Ridge SNOTEL	Stehekin COOP
Fall	October 2015	9.6	8.1	5.5	13.5	8.0	6.6	10.9	9.1	4.4
	November 2015	15.9	18.0	16.2	19.9	15.3	14.0	14.8	12.5	10.5
Winter	December 2015	16.0	16.4	13.2	24.5	20.3	17.7	16.4	19.0	12.5
	January 2016	11.4	10.9	8.3	22.0	14.4	12.9	11.8	13.0	8.8
	February 2016	11.5	12.1	8.8	17.0	11.2	13.4	9.3	9.5	4.9
Spring	March 2016	10.1	10.0	7.7	19.7	10.0	12.6	9.6	9.2	5.5
	April 2016	2.1	2.0	1.1	4.0	1.1	1.3	1.9	1.1	0.4
	May 2016	2.0	1.9	1.1	4.5	1.4	1.3	1.8	1.1	0.2
Summer	June 2016	3.5	2.2	1.2	7.7	2.2	2.0	1.9	1.3	0.4
	July 2016	1.5	1.3	0.9	4.5	1.3	1.1	1.1	1.9	0.7
	August 2016	0.4	0.4	0.3	1.2	0.5	0.8	0.3	0.7	0.2
Fall	September 2016	5.2	4.3	2.9	6.9	3.4	3.0	4.2	3.4	1.7
Water Year		89.2	87.6	67.2	145.4	89.1	86.7	84.0	81.8	50.2

Snowpack

Mountain snowpack was above normal in winter 2016, a result of above normal precipitation. The April 1st snow water equivalent (SWE) values ranged from 118-139% of normal (Figure 7). First of the month measurements of snow depth and SWE indicate values peaked in April. The maximum April 1st snow depth occurred at Brown Top SNOTEL (153 inches) and maximum SWE occurred at Easy Pass (91.9 inches; Table 5).

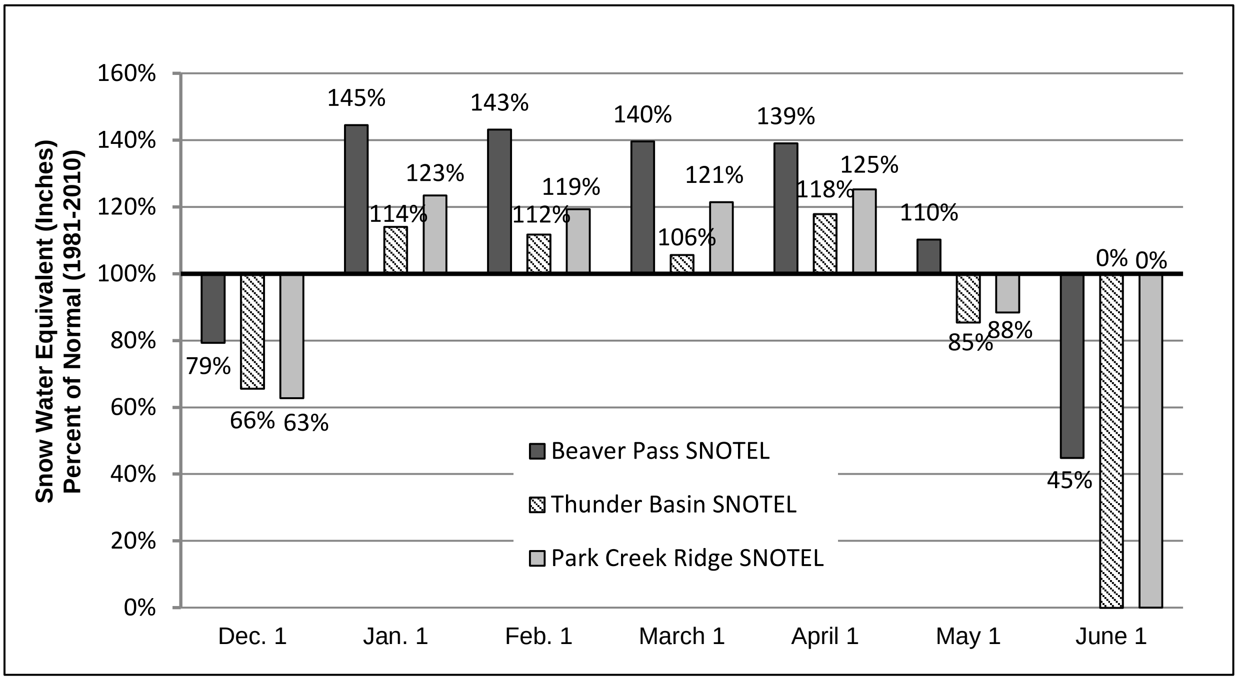

Figure 7. Comparison of snow water equivalent (inches) on the first day of each month at the Beaver Pass, Thunder Basin and Park Creek Ridge SNOTEL stations in Water Year 2016 against the climatological normal 1981-2010. Climatological normals are calculated by NRCS, this includes estimates for Beaver Pass and Thunder Basin SNOTEL with records starting after 1981.

Table 5. Snow depth and snow water equivalent (SWE) (units=inches) measured on the first day of the month at SNOTEL, and COOP stations within North Cascades National Park Service Complex during Water Year 2016.

Month & Year	Ross Dam COOP		Beaver Pass SNOTEL		Easy Pass SNOTEL		Thunder Basin SNOTEL		Brown Top SNOTEL		Park Creek Ridge SNOTEL		Stehekin COOP	
	Snow Depth	SWE	Snow Depth	SWE	Snow Depth	SWE	Snow Depth	SWE	Snow Depth	SWE	Snow Depth	SWE	Snow Depth	SWE
October 1st 2015	0	–	0	0	–	0	0	0	0	0	0	0	0	–
November 1st 2015	3	–	0	0	–	0.3	0	0	5	0.5	0	0	8	–
December 1st 2015	0	–	19	4.2	–	17.8	11	4.2	46	13.8	19	5.9	23	–
January 1st 2016	11	–	68	22.4	–	42.7	49	16.2	100	33.2	75	23.7	30	–
February 1st 2016	0	–	91	33.2	–	58.7	67	23.8	122	45.5	99	37.7	17	–
March 1st 2016	0	–	90	38.8	–	75.9	66	28.2	139	59.5	104	47.0	0	–
April 1st 2016	0	–	96	45.6	–	91.9	78	35.0	153	72.0	111	55.6	0	–
May 1st 2016	0	–	72	36.7	–	78.9	38	22.2	98	54.1	56	31.1	0	–
June 1st 2016	0	–	20	9.6	–	57.8	0	0	30	17.6	0	0	0	–
July 1st 2016	0	–	0	0	–	0	0	0	0	0	0	0	0	–
August 1st 2016	0	–	0	0	–	0	0	0	0	0	0	0	0	–

After a slow start to the accumulation season, snowpack developed quickly in early December due to above normal precipitation combined with near normal temperatures (Figure 8). Above normal precipitation steadily built snowpack at higher elevations through March. In spring, unseasonably warm temperatures in April and May melted snow rapidly. Park Creek SNOTEL was snow free on May 25th, 10 days earlier than the normal of June 4th (Figure 8).

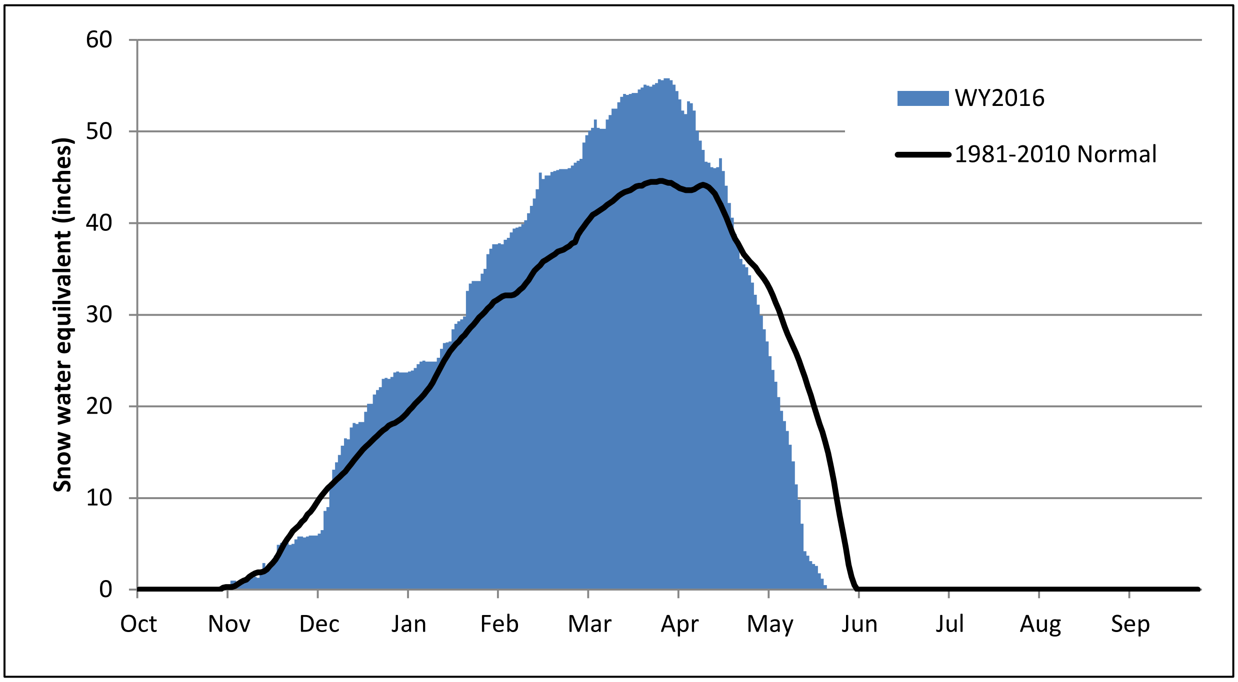

Figure 8. Daily snow water equivalent (inches) at Park Creek SNOTEL, for water year 2016 and 1981-2010 normal.

2016 Water Year in Review

Significant Weather Events and Patterns

Water Year 2016 started warmer and wetter than normal. For Stehekin, the average temperature in October (51.4° F) tied 1988 as the warmest on record dating back to 1906. A heavy rainfall event occurred on October 29th and continued through November 4th, during this 5-day period the Newhalem COOP site received 7.62 inches of rain. Both Newhalem and Stehekin COOPs had single day precipitation records on November 1st (2.18 and 1.96 inches respectively). The heavy rainfall elevated streamflows, with peak discharge for the year observed at many sites. Stream discharge, measured by the US Geological Survey, on Thunder Creek peaked at 2750 cubic feet per second (CFS). A second rainfall event occurred from November 13th-18th, deposited 12.02 inches of rain in Newhalem over 6 days; with 6.3 inches falling in the first 2 days.

The storms triggered erosion and debris flows at multiple locations across the park, damaging park infrastructure. Damage included two large debris flows on the Cascade River Road blocking access at mile markers 21.5 and 19; bank erosion along Colonial Creek that damaged two campsites (see photo on front cover), and a debris flow from Rhode Creek that filled a culvert and blocked access to Colonial Creek Campground (Figure 9).

Figure 9. Debris flow from Rhode Creek clogging a culvert and spilling over the access road at Colonial Creek Campground, November, 2015.

November and December temperatures were cool enough to support growing snow packs at all elevations. Snowfall totals during this time topped 8 inches in Newhalem, nearly 5 feet in Stehekin and 100 inches at the Brown Top SNOTEL.

Temperatures were above normal from February through May. April was notable for two periods of unseasonably warm weather from April 7^{th}-9^{th} and April 17^{th}-21^{st}. Several daily records were set during this time, including on April 21^{st} when Newhalem and Stehekin had daily highs of 88 and 80^{o} F, respectively.

April was also the beginning of a period of below normal precipitation that continued through August. Total rainfall from April through August for Newhalem was 7.85 inches, the 6^{th} driest since 1909; Stehekin received 2 inches of rain, the 10^{th} driest since 1916. The seasonal drought resulted in low stream flows in August and September. At Thunder Creek, the average discharge for August and September combined (624 CFS) were the 7^{th} lowest dating back to 1931.

Parkwide Precipitation Summary

North Cascades National Park Complex spans the Cascade Crest, which has a strong orographic effect on precipitation. Precipitation varies considerably by geographic area and elevation, with the greatest deposition occurring on the west slopes of the range and at higher elevations. This results in a strong west to east precipitation gradient.

Annual precipitation for each of the weather stations in Water Year 2016 is shown graphically in Figure 10. The highest measured annual precipitation occurred at Easy Pass (5270'), with 145.4 inches. Approximately ten miles to the east, precipitation at Brown Top (5830') was nearly 59 inches lower, at 86.7 inches. At lower elevation sites, the highest precipitation occurred in Marblemount (407'), with 89.2 inches. Annual precipitation dropped to 67.2 inches at Ross Dam, 34 miles to east. At Stehekin (1270'), the most eastern site, total precipitation was 50.2 inches.

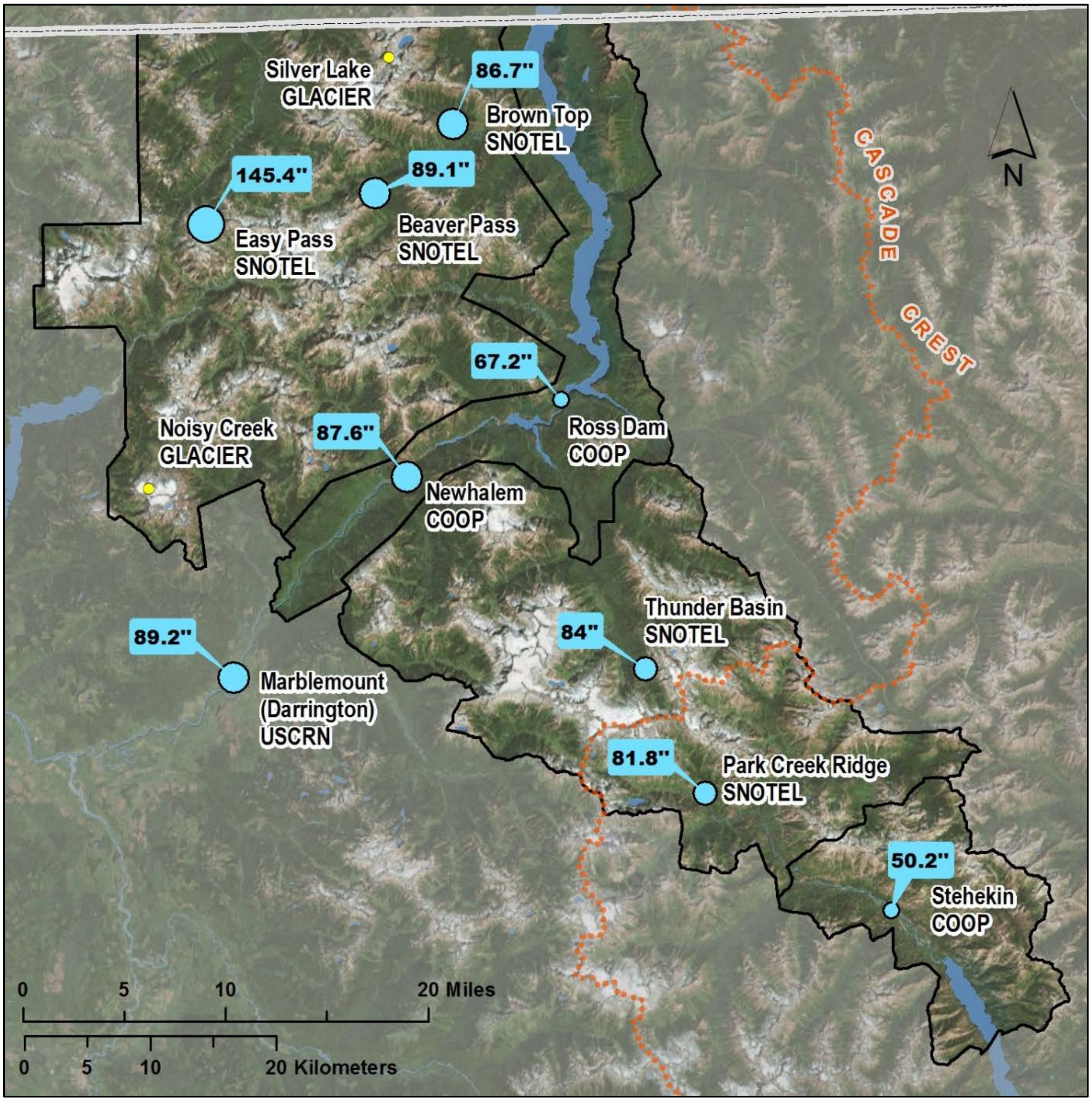

Figure 10. Total precipitation measured at weather stations located at North Cascades National Park Complex during Water Year 2016. Blue circles are proportional to the total amount of precipitation measured at each site.

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National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

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