National Park Service
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Natural Resource Stewardship and Science

North Coast and Cascades Network Climate Monitoring Report

Mount Rainier National Park; Water Year 2012

Natural Resource Data Series NPS/NCCN/NRDS—2014/705

ON THE COVER
View of the Three Lakes Fire, ignited by lighting on September 8th, 2012.
Photograph by: Mount Rainier National Park

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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.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available from the North Coast and Cascades Network Inventory and Monitoring website (http://science.nature.nps.gov/im/units/nccn/reportpubs.cfm) and the Natural Resource Publications Management website (http://www.nature.nps.gov/publications/nrpm/). To receive this report in a format optimized for screen readers, please email irma@nps.gov.

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Contents

Figures

Figures (continued)

Page

Figures (continued)

Page

Tables

Appendices

Page

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 provide essential information needed to support park operations and to monitor park resources.

This report summarizes climate data collected in Mount Rainier National Park during the 2012 water year, and is part of a set of climate summary reports from six national park units 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.

Temperature and precipitation data are presented from eight weather stations located within Mount Rainier National Park: Camp Muir (10,100' elevation), Carbon River (1735'), Cayuse (5200'), Longmire (2760'), Ohanapecosh (1950'), two stations at Paradise (5550' and 5120'), and Sunrise (6420'). Data were recorded using automated and manual instruments operated by the National Park Service and other collaborators, including the National Weather Service, National Interagency Fire Center, Natural Resources Conservation Service, and Northwest Weather and Avalanche Center. Monthly averages of daily average temperatures and monthly total precipitation are reported for all stations. Comparisons are made to the 30-year normal (1981-2010), as defined by the National Climate Data Center (NCDC), for Longmire and Paradise, two stations with long term climate records. Snow water equivalent (SWE) is reported and compared to the 30-year normal for one SNOTEL station within the park and monthly snow depth, measured on the first of the month, is reported for four stations within the park.

Daily and monthly air temperature, precipitation and snowpack for the eight park weather stations are presented in individual appendices. Each appendix includes comparisons to the period of record, which varies by station. Highlights of important weather events and maintenance issues from each site are also noted.

Weather data collected in Water Year 2012 indicated that this year had near normal annual temperatures and near normal annual precipitation. The fall and winter were characterized by periods of heavy precipitation followed by stretches of dry weather and high freezing levels. The snowpack built slowly in the early winter months due to below normal precipitation, but by March the snowpack reached above normal conditions that persisted through early July. An extremely dry and warm August and September provided ideal conditions for lightning strikes to ignite several fires when a storm cell moved through the park in early September.

Acknowledgments

Mount Rainier National Park 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 Interagency Fire Center – Remote Automated Weather Stations Program
- National Weather Service – National Weather Service Cooperative Observer Program
- Natural Resources Conservation Service - National Water and Climate Center, SNOTEL and Snow Survey Program
- Northwest Weather and Avalanche Center – High Elevation Weather Stations
- Western Regional Climate Center
- National Climate Data Center

The NPS would also like to thank the Office of the Washington State Climatologist for their regional and statewide weather and climate summaries.

Acronyms

COOP	Cooperative Observer Station
I&M	Inventory and Monitoring
MORA	Mount Rainier National Park
NCCN	North Coast and Cascades Network
NCDC	National Climatic Data Center
NPS	National Park Service
NOAA	National Oceanic and Atmospheric Administration
NOCA	North Cascades National Park Service Complex
NRCS	Natural Resources Conservation Service
NWAC	Northwest Weather and Avalanche Center
NWS	National Weather Service
PNW	Pacific Northwest
RAWS	Remote Automated Weather Stations
SNOTEL	Snowpack Telemetry
SWE	Snow Water Equivalent
USDA	United States Department of Agriculture
WRCC	Western Regional Climate Center

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 based on the distribution of data within limits of common occurrence.

Fall: The National Weather Service defines fall as the months of September, October and November.

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.

Spring: The National Weather Service defines spring as the months of March, April and May.

Summer: The National Weather Service defines summer as the months of June, July, and August.

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 2012 is the 12-month period beginning October 1, 2011 and ending September 30, 2012. 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).

Winter: The National Weather Service defines winter as the months of December, January and February.

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 dependent 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). Disturbance events such as forest fires, windstorms, and floods are strongly related to climate (Littell and Gwozdz 2011). These events can have a major impact on park landscapes and their associated ecosystems.

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 National Park Service (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 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, and provides supplemental information on snowpack.

This report summarizes climate data collected from 8 weather stations located in Mount Rainier National Park during the 2012 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 the 8 weather stations are summarized in the results section of this report. Detailed climate data recorded from each weather station are presented in Appendices A to G.

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 parks (NCCN).

Methods

Station Locations

This report incorporates data collected from weather stations operated by the NPS, the Natural Resource and Conservation Service (SNOTEL), the National Weather Service (COOP), and the National Interagency Fire Center (RAWS) (Table 1 and Figure 2).

Table 1. Weather stations referenced in this report.

Station Name	Station Type	Location	Elevation (ft)	Forest Zone	Period of Record
Camp Muir High Elevation	NPS	Interior	10100	Alpine	2006 to Present
Carbon River	NPS	Northwest	1735	Forest	2008 to Present
Cayuse Pass	SNOTEL	Southwest	5200	Subalpine	2006 to Present
Longmire	COOP	Southwest	2760	Forest	1909 to Present
Ohanapecosh	RAWS	Southeast	1950	Forest	2003 to Present
Ohanapecosh[1]	NPS	Southeast	1950	Forest	2011 to Present
Paradise	COOP	Southwest	5400	Subalpine	1916 to Present
Paradise	SNOTEL	Southwest	5120	Subalpine	1981 to Present
Sunrise High Elevation	NPS	Northeast	6420	Subalpine	2004 to Present

[1] Due to continued power issues at the Ohanapecosh RAWS during the winter months resulting in loss of data, a NPS station requiring less power was installed in October, 2011 to ensure future year-round data collection.

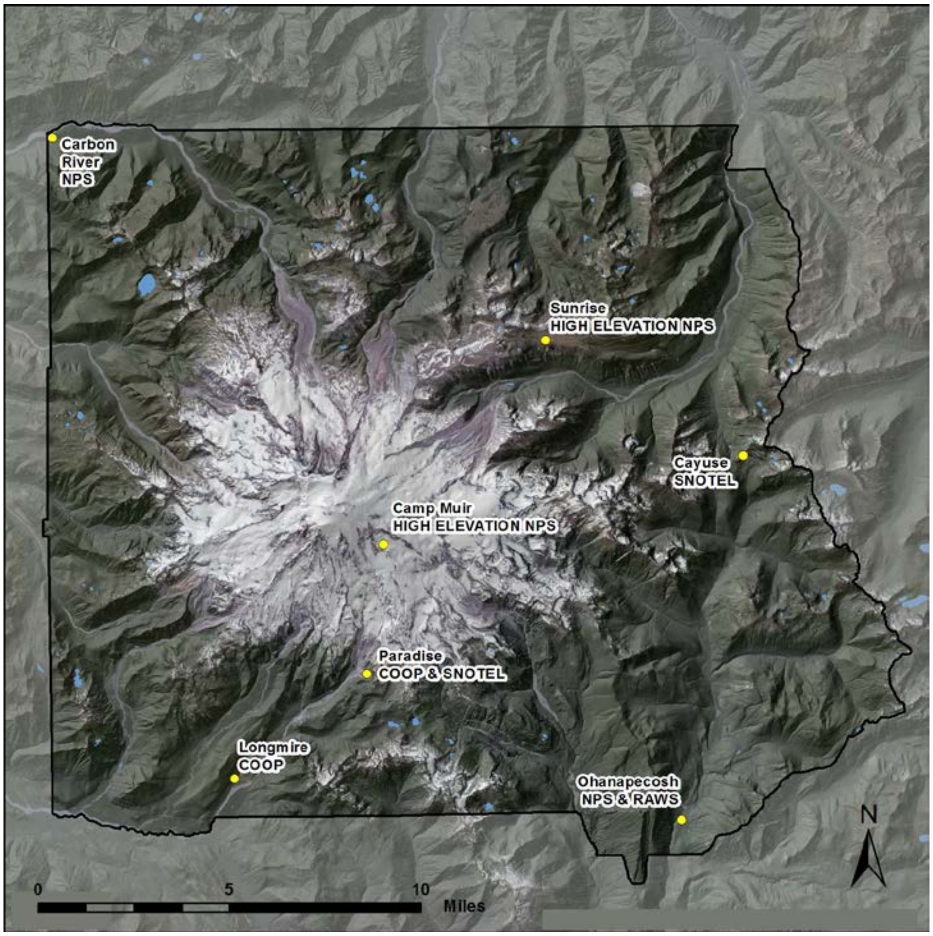

Figure 2. Location of weather stations referenced in this report. The Paradise SNOTEL and Paradise COOP stations are in two separate locations within the same general area. The Ohanapecosh NPS and Ohanapecosh RAWS are in the same location.

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 among 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 Mount Rainier National Park.

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

Station Name	Managing Agency – Station Type	Air Temperature	Relative Humidity	Precipitation	Snow Depth	Snowfall	Snow Water Equivalent	Solar Radiation	Wind Speed & Direction	Soil Temperature	Soil Moisture
Camp Muir High Elevation	NPS-High Elevation[1]	**X**	X					X	**X**		
Carbon River	NPS[1]	**X**	X	**X**	**X**					X	X
Cayuse Pass	NRCS-SNOTEL[2]	**X**		**X**	**X**		**X**			X	X
Longmire	NWS COOP[3]	**X**		**X**	**X**	**X**					
Ohanapecosh	NIFC-RAWS[4]	**X**	X	**X**				X	X		
Ohanapecosh	NPS[1]	**X**	X	**X**	**X**					X	
Paradise	NWS COOP[3]	**X**		**X**	**X**	X					
Paradise	NRCS-SNOTEL[2]	**X**		**X**	**X**		**X**			X	X
Sunrise High Elevation	NPS-High Elevation[1]	**X**	X		**X**			X	X	X	X

[1]NPS stations utilize a standard array of automated weather instruments. Parameters are measured at 5 minute intervals and output as hourly averages.

[2]SNOTEL stations utilize a standard array of automated weather instruments in support of water supply forecasting. Parameters are measured every 60 seconds, and output as hourly averages. Soil temperature and moisture sensors were added on 9/1/2011.

[3]NWS stations rely on a standard array of manually operated weather instruments. Parameters are measured and recorded daily.

[4]RAWS utilize a standard array of automated weather instruments in support of fire weather, which are measured at 10 minute intervals and output as hourly averages.

Data Quality Assurance and Control

NWS COOP station and NRCS SNOTEL station data presented in this report are acquired directly from the managing agencies (National Climate Data Center 2013 and National Water and Climate Center 2013, respectively). Quality assurance and control is provided by these agencies and is described in the NCCN Climate Monitoring Protocol (Lofgren et al. 2010).

The daily data in this report from the NPS operated stations are derived from hourly data which have been evaluated through manual display and graphing of single and multiple parameters to identify unusual values or trends. Data not meeting standards are removed or flagged as suspect and omitted from daily summaries (Lofgren et al. 2011). 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 a nearby weather station for the purposes of reporting monthly and annual totals. This only occurs when nearby data are available and a known correlation exists between the sites. When estimates are generated from nearby stations, data are footnoted and a description of the quantity and source of data replacement is given.

Water Year 2012 Data Quality

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

Precipitation from the Paradise COOP weather station during the month of December appeared suspect when compared to other stations referenced in the report. A recording error was found on December 29 with 8.9 inches of precipitation recorded. This value was corrected to 0.89 inches of precipitation. A total of nine days of data are missing from the Paradise COOP in January due to a park closure in response to a major law enforcement incident. Missing January Paradise COOP data were replaced with precipitation values, totaling 5.2 inches, and daily maximum, minimum, and average temperatures from the nearby Paradise SNOTEL. The nine days of missing snow depth data were linearly interpolated from adjacent daily values. Nine days of Longmire COOP temperature data are missing during the same time period, but were not replaced due to a lack of a nearby station with a known correlation. Therefore, monthly January temperature and annual temperature summary data are not available for Longmire.

Precipitation data are missing from the Sunrise High Elevation weather station during all months. Power limitations restrict the use of a heated tipping bucket at Sunrise, and heavy winter precipitation and low temperatures have tested the limits of the existing precipitation system. Alternative methods to capture year round precipitation at Sunrise continue to be evaluated. At a minimum, a non-heated precipitation gauge will be installed during summer months to capture summer precipitation.

A snowfall adapter is installed on the precipitation gauge at the Ohanapecosh NPS station during the winter to capture precipitation falling as snow (McCaughey and Farnes 1996). The design of the system results in potential recording delays of hours to tens of hours and is not suitable for real time precipitation measurements; therefore daily precipitation data are not presented.

The wind speed sensor at the Camp Muir High Elevation station is not heated and can become ice encrusted during cold, wet conditions. Data gaps represent periods when wind speed recorded zero for more than three hours. These data were removed for analysis purposes. Several repairs were performed on the Camp Muir High Elevation station during the summer due to multiple sensor failures (Figure 3). The wind speed sensor, which failed on March 10, 2012, was removed and sent in for repair in late April after multiple attempts to repair the sensor on-site. It was finally replaced on June 10th. An electrical short occurred at the station on August 9-10 and August 17-23 resulting in a loss of all data. Power to the station was down from September 5-12 due to the logistics of replacing batteries and coordinating helicopter flights. Due to data gaps greater than five days in August and September, monthly summary data for these months and annual data are not available.

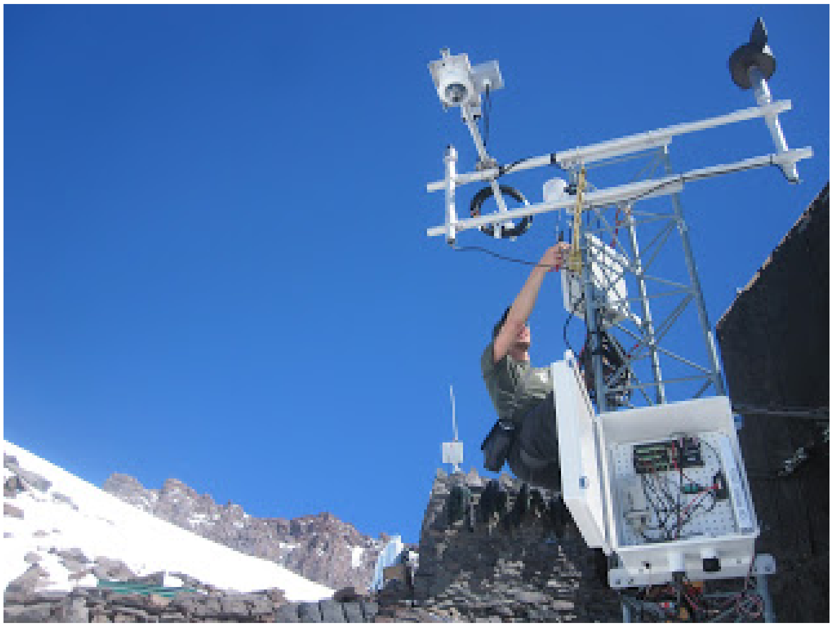

Figure 3. Equipment repairs at the Camp Muir High Elevation station, August, 2012.

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 that generally begins in late October and ends 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, the magnitude and timing of stream flow, emergence and flowering of plants and the migratory timing of bird species.

Seasons in this report follow National Weather Service standards for the Northern Hemisphere, which define 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 Table 2. While routinely collected in metric units, the data are presented in Fahrenheit and inches to more easily facilitate use and interpretation by park staff and the public. Two stations with long term records, Paradise and Longmire, are compared to the 30-year climate normal. Snow water equivalent (SWE) is reported and compared to the 30-year climate normal for one SNOTEL within the park, and monthly snow depth at the first of each month is reported for Cayuse, Longmire, Paradise and Sunrise stations.

Data from each individual weather station are presented in separate appendices. The appendices report daily data for precipitation, temperature, and snowfall or snow water equivalent when available, as well as average, maximum, minimum temperatures and total precipitation for each month. While the main report compares Water Year 2012 with the 30-year climate normal (1981 to 2010), the appendices compare 2012 with the period of record for that station. This is due to the fact that most of these stations were established within the last decade and therefore do not have a 30-year data record for establishing a climatic normal. Maximum wind speeds are provided for the Camp Muir High Elevation station. Detailed discussion of maintenance issues or data concerns associated with each specific station is also presented.

Updated Climate Normals

Climate normals refer to the calculated long-term value of a meteorological parameter at a specific location. Normals are generally based on a 30-year average of temperature and precipitation data and serve as a baseline average of climate variables. In this report, we compare monthly temperature and precipitation data from several weather stations to climate normals, in order to place the conditions of the current water year into a broader temporal context.

In July of 2011, the National Climatic Data Center (NCDC) released new normals, based on 1981-2010 climate data. These new values were incorporated into National Weather Service climate products as of August 1, 2011, and replace the previous 30-year normal based on 1971 to 2000 data. The NRCS released new normals for SWE in late 2012. For consistency purposes, this report will compare temperature, precipitation and SWE data to these new (1981-2010) normals.

In the Pacific Northwest, the effect of using new NCDC normals will be slight. A small increase in temperature and little to no decrease in precipitation are found when comparing 1971-2000 climate normals to the 1981-2010 values. This is primarily due to an extended cool and wet period in the 1970’s which influenced the previous normal, and a warmer and slightly drier period from 2001-2010 which influenced the 1981-2010 normal. The notable contrast to the regional trends at Mount Rainier National Park is the Longmire NWS-COOP station, where the new normal for minimum monthly temperatures is notably cooler than the 1971-2000 normals, resulting in cooler average monthly and annual temperatures. Arguez et al. 2012 presents an overview of the computation of the 1981-2010 climate normals.

New normals for SWE vary throughout the Pacific Northwest, but the overall trend shows a decrease in SWE when comparing the 1971-2000 normals to the 1981-2010 values (NRCS, 2013). Within Mount Rainier National Park, the Paradise SNOTEL shows an annual average decrease in SWE by 5.7% when compared to the old normal.

Results

Temperature

Water Year 2012 began with near normal to slightly below normal average October temperatures. Temperatures were cooler than normal in November with temperatures between 2 and 3°F below normal. December brought warmer than normal temperatures within the park, particularly at upper elevation sites due to a strong inversion that lasted several weeks (Figures 4 and 5). The Paradise COOP at 5,400 in elevation, recorded an average temperature of 31.1°F in December, only 0.3°F cooler than Longmire (2,760') and 0.4°F cooler than Ohanapecosh (1,950') (Table 3). The Camp Muir weather station recorded December average temperatures 6.4°F above the six year average (Appendix B, Figure B-1).

January, February and March averaged cooler than normal, with March temperatures averaging greater than 3.0°F below normal. Temperatures in April and May were mild, with slightly warmer than normal average temperatures recorded in April and near normal temperatures in May. It was a notably cool June with temperatures averaging 2-4°F below normal (Figures 4 and 5). Statewide, the average June temperatures ranked among the top ten coolest at several locations for the period of record (OWSC 2012a). July was relatively mild with average monthly temperatures near normal. A long, warmer than normal period began in August and lasted through the end of the water year.

Table 3. Average monthly air temperatures (°F) from weather stations within Mount Rainier National Park in Water Year 2012.

Season	Month & Year	Camp Muir High Elevation NPS	Carbon River NPS	Cayuse Pass SNOTEL	Longmire NWS COOP	Ohanapecosh NPS	Paradise NWS COOP	Sunrise High Elevation NPS
Fall	October 2011	26.5	45.5	39.6	44.8	45.8	38.6	36.0
	November 2011	13.9	36.4	29.4	33.4	34.1	27.9	25.6
Winter	December 2011	21.8	32.8	31.7	31.4	31.5	31.1	30.5
	January 2012	14.6	34.6	28.5	----[2]	32.1	27.7[3]	26.6
	February 2012	15.9	35.3	28.4	32.9	33.0	27.4	25.2
Spring	March 2012	11.6	35.1	28.1	33.2	33.9	27.3	25.1
	April 2012	18.7	42.7	35.4	42.0	42.5	34.9	32.7
	May 2012	25.5	48.0	39.8	47.4	48.9	39.8	37.8
Summer	June 2012	30.2	51.0	42.4	50.9	53.0	41.7	40.7
	July 2012	41.3	59.3	53.8	60.8	63.0	53.2	54.1
	August 2012	----[1]	60.9	56.8	64.2	64.7	56.2	56.3
Fall	September 2012	----[1]	54.5	53.8	58.7	58.0	53.5	53.5
Water Year		----[1]	44.7	39.0	----[2]	45.0	38.3	37.0

[1] Data are missing due to equipment error.

[2] Nine days of temperature data are missing in January.

[3] Nine days of missing temperature data were replaced with Paradise SNOTEL data.

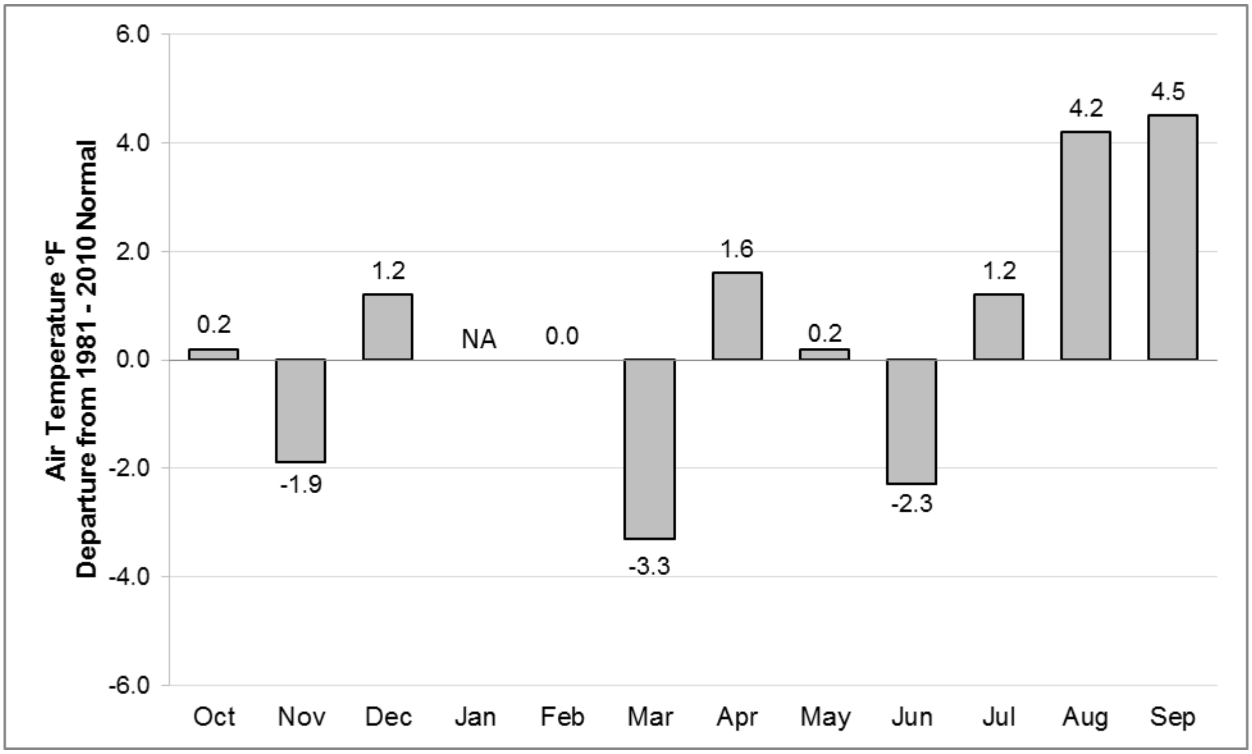

Figure 4. Comparison of average monthly temperature (°F) for Longmire (COOP) in Water Year 2012 against monthly averages for the climatological normal 1981-2010.

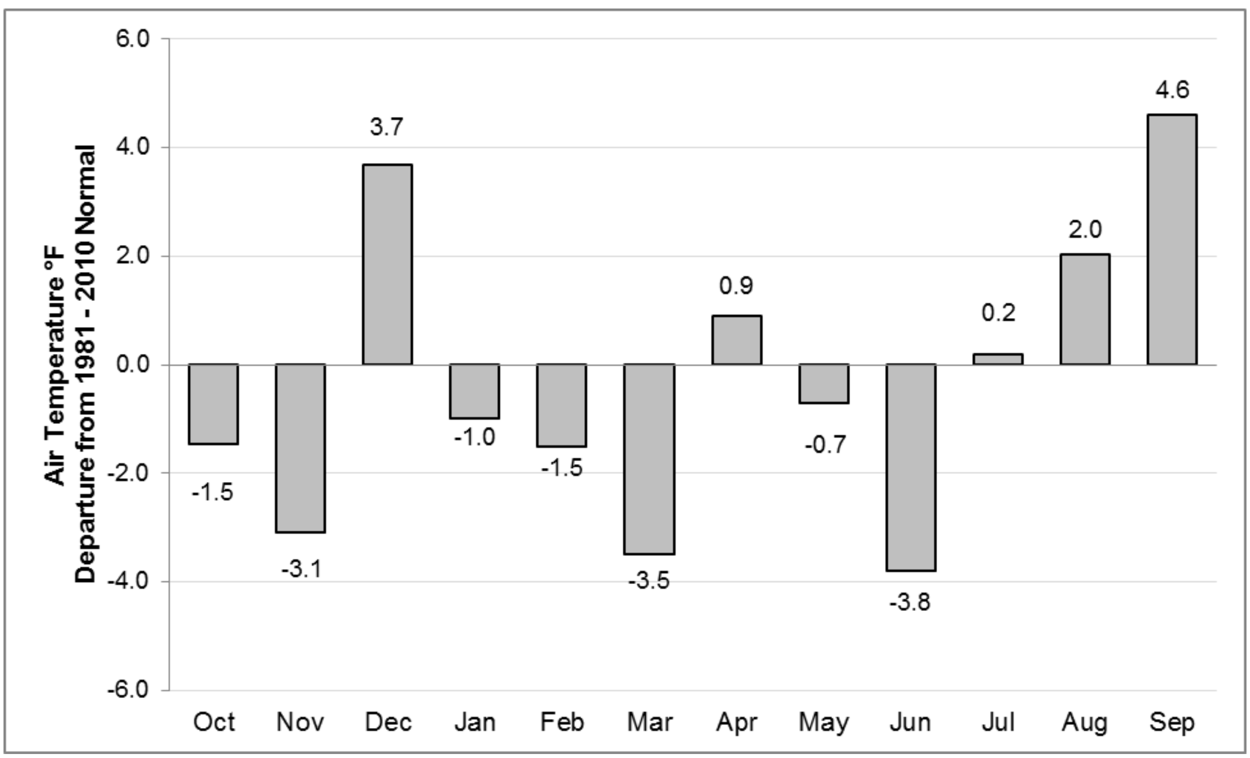

Figure 5. Comparison of average monthly temperature (°F) for Paradise (COOP) in Water Year 2012 against monthly averages for the climatological normal 1981-2010.

Precipitation

Monthly precipitation was below normal at Longmire and Paradise stations in the fall and early winter months of Water Year 2012 (Figures 6 and 7), even though a heavy rain event in late November brought 4-5 inches of precipitation in the park over a two day period (Appendices A, C, and F, Figures A-5, C-5, and F-5, respectively) December was notably dry for the Pacific Northwest, and was ranked among the top ten driest Decembers for many locations in Washington State due to a large and strong ridge of high pressure that lasted until December 25 (OWSC 2012b). Total monthly precipitation in January was near normal with a dry first half of the month and wet second half. A shift to wetter conditions occurred in February and lasted through June. June represented the largest deviation from normal with Longmire recording 163% of normal precipitation and Paradise recording 217% of normal precipitation (Figures 6 and 7). July was a transition month with near normal precipitation, followed by an extremely dry August and September. The Longmire COOP and Carbon NPS stations recorded the only precipitation within the Park for the month of August, a meager 0.06 and 0.01 inches, respectively (Table 4).

Table 4. Total monthly precipitation (inches) from weather stations within Mount Rainier National Park in Water Year 2012.

Season	Month & Year	Carbon River NPS	Cayuse Pass SNOTEL	Longmire NWS COOP	Ohanapecosh RAWS	Paradise NWS COOP
Fall	October 2011	7.3	6.6	7.6	6.5	8.1
	November 2011	11.2	9.0	12.8	11.1	18.3
Winter	December 2011	6.4	4.6	7.4	7.5	10.4
	January 2012	7.8	18.5	10.7	12.7	17.0
	February 2012	7.3	15.5	9.2	10.8	16.7
Spring	March 2012	9.5	23.8	8.0	10.9	17.2
	April 2012	8.6	7.2	7.0	4.9	8.5
	May 2012	8.3	7.3	6.3	3.9	8.1
Summer	June 2012	9.3	5.3	6.3	3.5	8.9
	July 2012	1.6	0.7	1.8	0.9	1.7
	August 2012	0.0[1]	0.0	0.0[2]	0.0	0.0
Fall	September 2012	0.3	0.4	0.4	0.4	0.5
Water Year		77.4	98.9	77.6	72.9	115.4

[1] 0.01

[2] 0.06

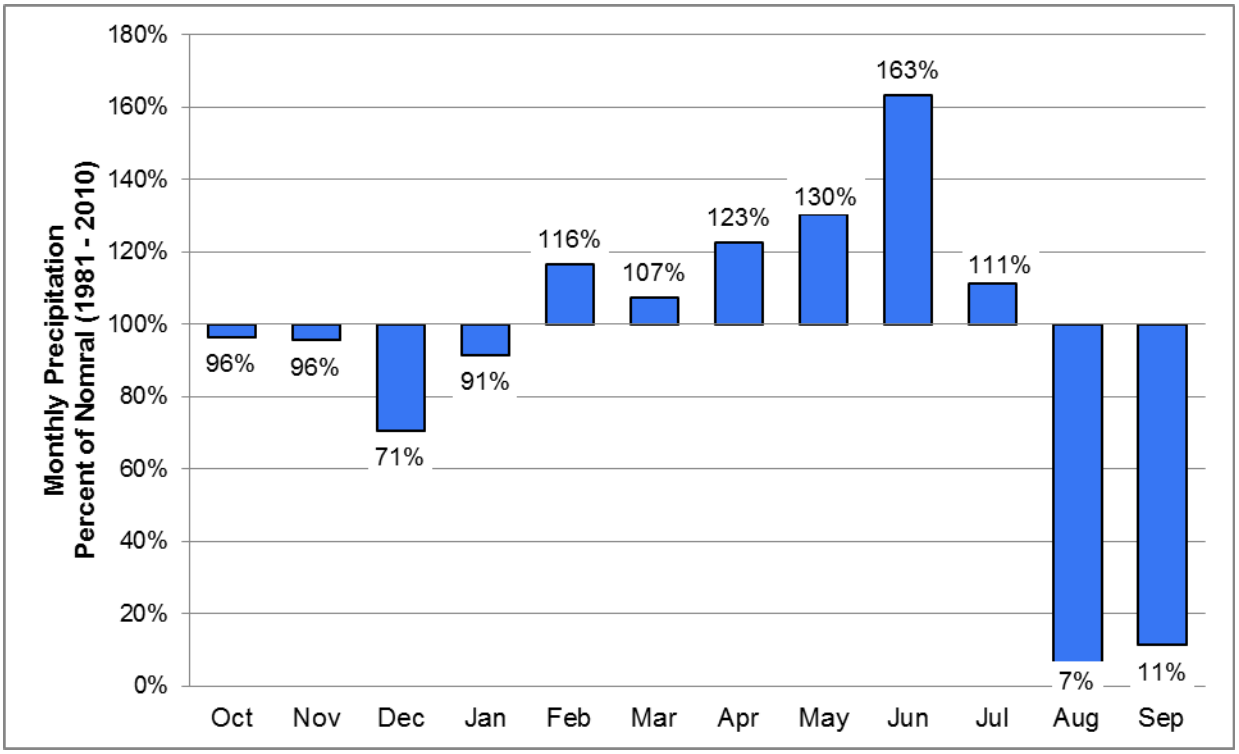

Figure 6. Comparison of monthly total precipitation (inches) as a percent of normal at the Longmire (COOP) in Water Year 2012 against the climatological normal 1981-2010.

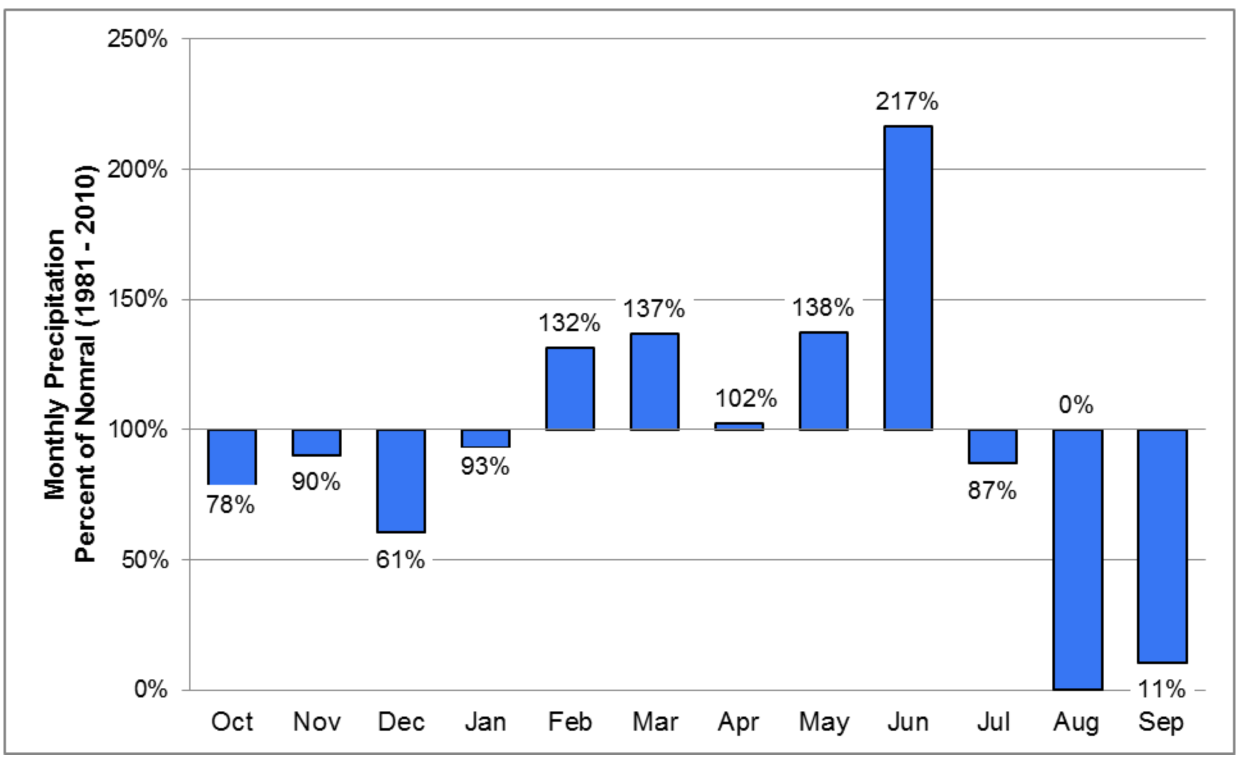

Figure 7. Comparison of total monthly precipitation (inches) as a percent of normal at the Paradise (COOP) in Water Year 2012 against the climatological normal 1981-2010.

Snow

Despite the drier than normal conditions in November, several late November storms contributed to an above normal snowpack by December 1. Snow water equivalent (SWE) at Paradise was 115% of normal as of December 1 (Figure 8). Due to the dry conditions, only small contributions were made to the snowpack in December. By January 1, snow depth at Paradise had only increased 18 additional inches during the entire month of December (Table 5). Overall, snowpack and SWE remained below normal from mid-January to mid-February, with the exception of a few storms that brought temporary spikes in the snowpack.

Mid-February marked a return to wetter conditions. Significant new snow at the end of February, colder than normal temperatures and heavy snowfall in March, contributed to an above normal snowpack and SWE that lasted from March through July (Table 5, Figure 8). A colder and wetter than normal June contributed to a prolonged summer snowpack, although not as long as in the 2011 Water Year. The snow melted at Paradise on July 28, almost a month earlier than in Water Year 2011. The snowpack melted slightly earlier on the eastside of the park, with the last snow melting at the Sunrise weather station on July 10 followed closely by the Cayuse Pass SNOTEL on July 16 (Appendix C, Figure C-6; Appendix G, Figure G-3).

Table 5. Snow depth (inches) measured on the first day of the month at SNOTEL, COOP, and NPS stations within Mount Rainier National Park during Water Year 2012.

Month & Year	Cayuse Pass SNOTEL	Longmire NWS COOP	Paradise NWS COOP	Sunrise High Elevation
October 1, 2011	0	0	0	0
November 1, 2011	0	0	0	0
December 1, 2011	44	6	60	30
January 1, 2012	65	5	78	44
February 1, 2012	115	17	132	72
March 1, 2012	166	24	174	96
April 1, 2012	220	25	228	145
May 1, 2012	163	0	185	112
June 1, 2012	128	0	156	81
July 1, 2012	69	0	105	36
August 1, 2012	0	0	0	0

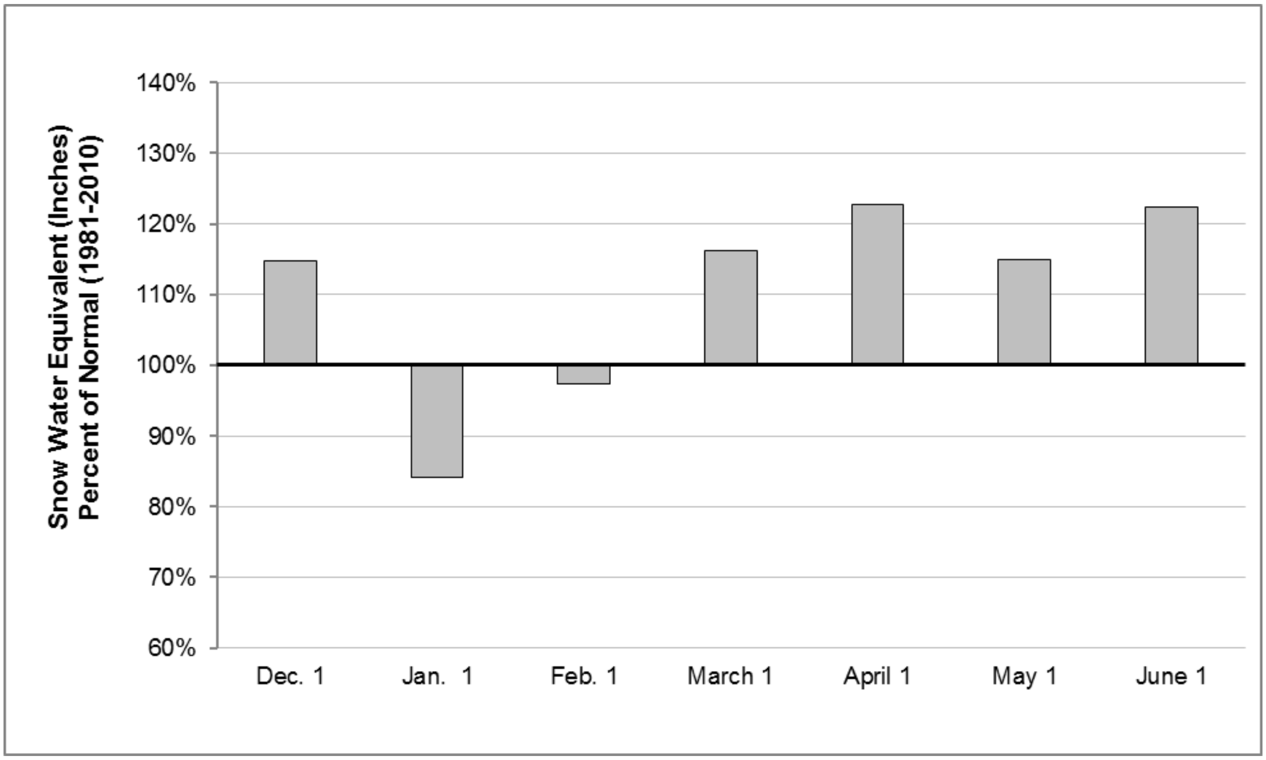

Figure 8. Comparison of snow water equivalent (inches) on the first day of each month at the Paradise Snow Course in Water Year 2012 against the climatological normal 1981-2010.

2012 Water Year in Review

Significant Weather Events and Patterns

Despite the drier than normal conditions for the month November, several storms brought periods of heavy precipitation and snow at low elevations. Over 120 inches of snow fell at Paradise from November 15-25, bringing the snow depth to 62 inches by November 25. On November 21, record daily maximum precipitation records were set at several locations throughout Washington State (OWSC 2011). December brought warm temperatures to upper elevations due to a strong inversion and below normal precipitation throughout the park. A strong storm moved through on December 25 and brought winds of 122.6 miles per hour at Camp Muir and heavy precipitation throughout the park for several days.

The beginning of January was relatively dry and warm, but mid-January brought a return of cold and wet conditions with lowland snow. Very large additions to the snowpack were made from mid-February through March, as an active weather pattern brought heavy snow to the mountains and produced cooler and wetter than normal conditions. From February 17-March 17, over 200 inches of snow fell at Paradise.

Overall, the winter was characterized by periods of heavy snowfall followed by stretches of dry weather and high freezing levels. These conditions resulted in several weak layers within the snowpack, setting the stage for large avalanches. Sections of the Comet Falls trail were closed for part of the season due to a large amount of debris and ice covering the trail from a large avalanche (Figure 9).

Figure 9. Photos captured from the same location, one year apart show the massive amount of snow deposited in the canyon below Comet Falls by an avalanche.

June was notably wetter and colder than normal throughout the Park. More precipitation fell during the month of June at Paradise and Carbon than in either April or May, close to 9.0 inches. July brought several thunderstorms to the area. A large thunderstorm on July 20 brought close to 0.5 inches of precipitation to all stations in the park, representing more than half of the total monthly precipitation at Cayuse and Ohanapecosh.

An unusually long, warm and dry period began in August and extended to October 12, in Water Year 2013. Record dry conditions were experienced throughout Washington State (OWSC 2012c). The total combined monthly precipitation in August and September within the Park ranged from 0.31 inches recorded at the Carbon to 0.5 inches recorded at Paradise. The dry and warm weather provided ideal conditions for lightning strikes to ignite several fires when a storm cell moved through the park on September 8. The largest fire of approximately 5 acres, located near Three Lakes, resulted in the closure of the Laughingwater Creek Trail for approximately one week while the fire was contained.

Parkwide Precipitation Summary

Orographic effects produce heavy precipitation on the upper elevation, west-facing slopes of Mount Rainier National Park. The northeastern and eastern sides of the mountain receive less precipitation due to the rainshadow effect and prevailing southwesterly winds (Hemstrom and Franklin 1982). For Water Year 2012, precipitation at upper elevation weather stations neared or exceeded 100 inches, while lower elevation weather stations ranged between 72-78 inches. The highest recorded amount of precipitation, 115.4 inches, occurred on the southwest slopes at Paradise (5,400 ft.), whereas on the eastern slopes of Mount Rainier, 98.9 inches was recorded at Cayuse Pass (5,200 ft.) (Figure 10).

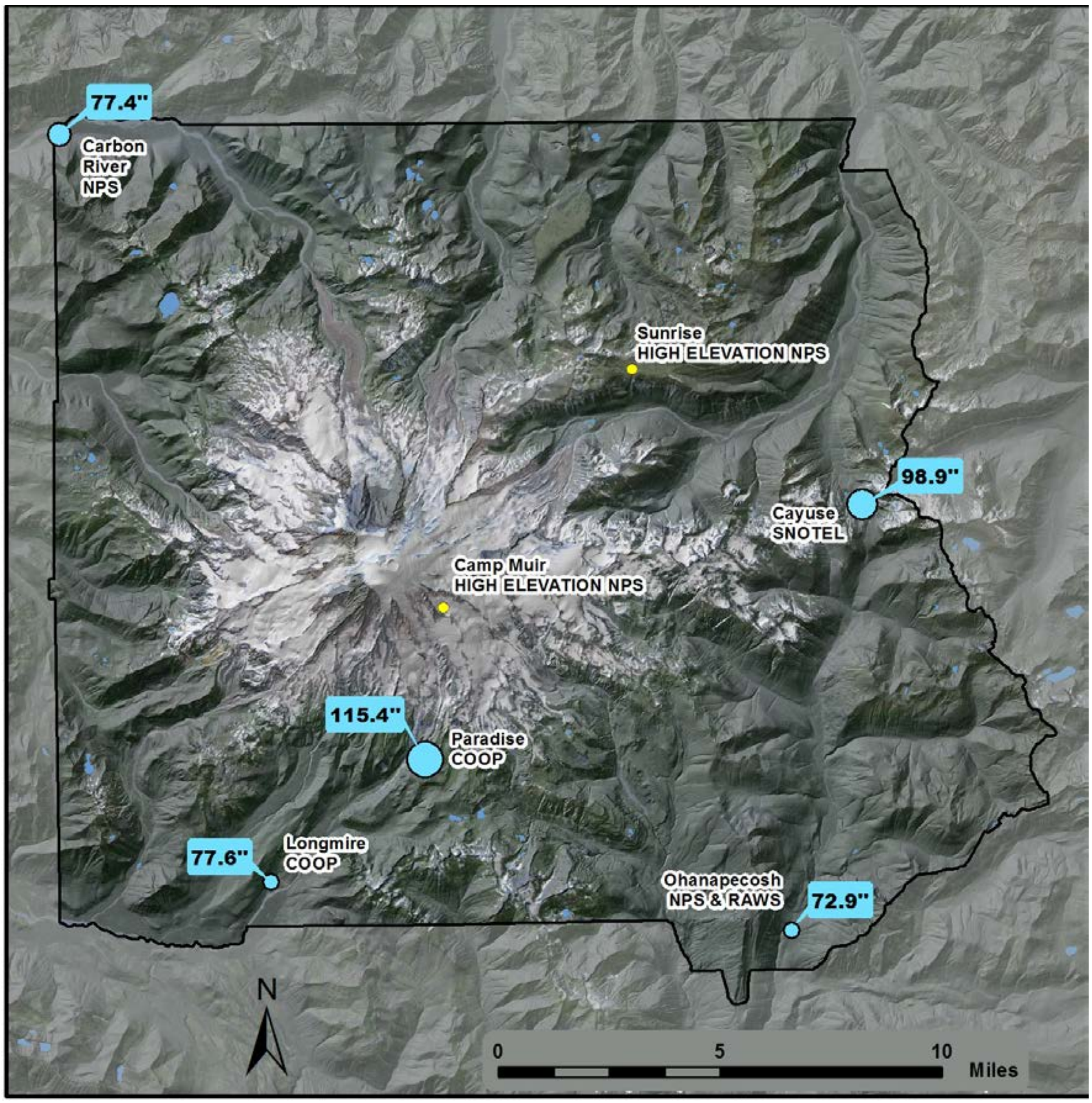

Figure 10. Total precipitation measured at weather stations located within Mount Rainier National Park during Water Year 2012. Blue circles are proportional to the total amount of precipitation measured at each site. Annual precipitation values are not captured at Sunrise due to lack of AC power and large winter snowfall. Precipitation is not measured at Camp Muir due to lack of AC power, exposure to wind, and below freezing conditions.

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Appendix A: Carbon River NPS – Water Year 2012

Temperature, precipitation, and snowfall summaries from the Carbon River NPS weather station for WY 2012 are shown in Tables A-1 and A-2 and Figures A-1 to A-6. The NPS Carbon River weather station was installed in February of 2008, making recent period of record comparisons unavailable for this location. However, a NWS COOP station was operated year round at the Carbon River Ranger Station from 1906-1974, adjacent to the current location of the NPS weather station. The period of record average for precipitation and temperature from this COOP station was used for comparison purposes.

Average annual temperature at the Carbon River NPS station was 44.7°F (Table A-1). Daily temperatures ranged from an extreme low of 22.5°F to a high of 87.7°F (Table A-2). The highest mean daily average temperature was 72.1ºF on August 5. The coldest recorded mean daily temperature was 25.5ºF on December 12 (Figure A-2). Annual precipitation totaled 77.4 inches (Figure A-3), 112% compared to the period of record (1906-1974). The highest daily precipitation of 2.6 inches fell on November 22 (Figure A-5). The colder and wetter than average late spring, and warmer and drier than average summer reflected in the data match the trends recorded throughout the park (Figures A-1, A-3, and A-4). The late November snow brought approximately 14 inches of snow to the area (Figure A-6).

Table A-1. Monthly summary data, Carbon River Station, Water Year 2012

Season	Month & Year	Mean Air Temp °F	Mean Daily Max Air Temp °F	Mean Daily Min Air Temp °F	Precipitation (inches)
Fall	October 2011	45.5	50.1	41.5	7.3
	November 2011	36.4	42.5	31.9	11.2
Winter	December 2011	32.8	36.4	29.9	6.4
	January 2012	34.6	39.1	30.9	7.8
	February 2012	35.3	39.3	32.0	7.3
Spring	March 2012	35.1	39.8	31.5	9.5
	April 20112	42.7	50.5	37.0	8.6
	May 2012	48.0	57.3	40.7	8.3
Summer	June 2012	51.0	58.4	45.1	9.3
	July 2012	59.3	68.3	51.6	1.6
	August 2012	60.9	72.3	51.6	0.0
Fall	September 2012	54.5	65.6	46.1	0.3
Water Year		**44.7**	**51.7**	**39.2**	**77.4**

Table A-2. Air temperature extremes, Carbon River Station, Water Year 2012.

Date	Max Air Temp °F	Date	Min Air Temp °F
August 5, 2012	87.7	January 16, 2012	22.5
August 17, 2012	87.0	November 20, 2011	23.0
August 4, 2012	86.2	February 27, 2012	23.2
August 16, 2012	85.1	December 13, 2011	23.8
August 6, 2012	82.6	December 12, 2011	23.9

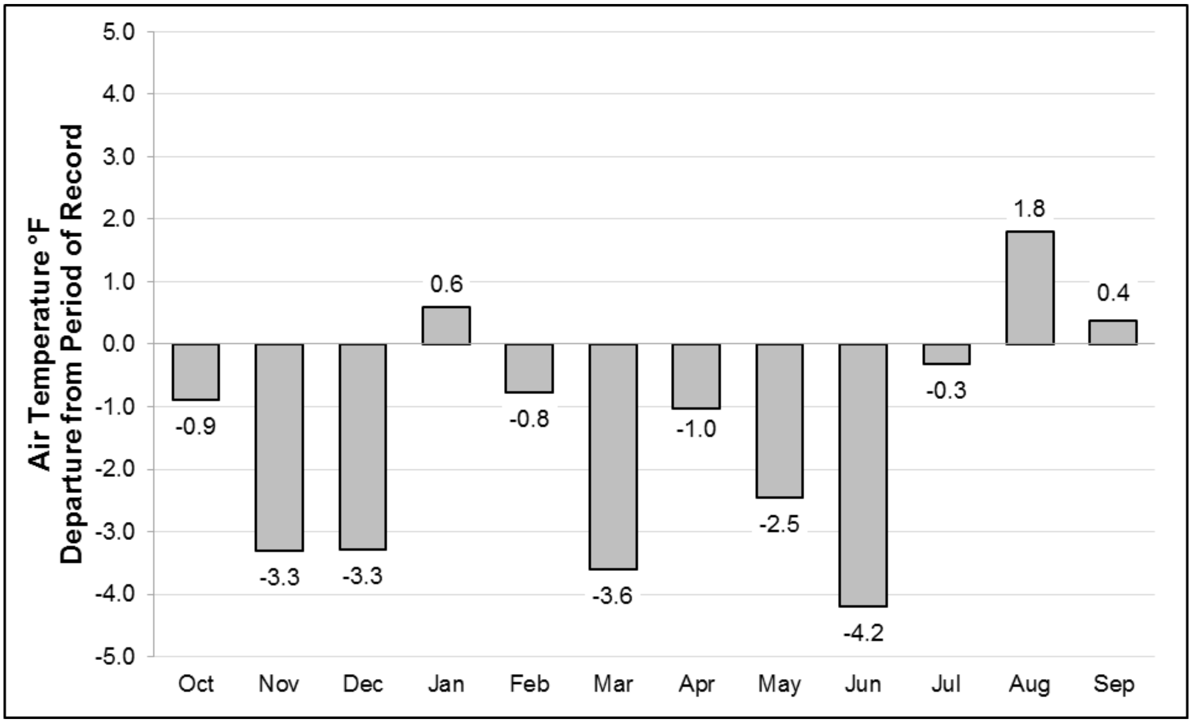

Figure A-1. Comparison of average monthly temperature (°F) for Carbon River Station in Water Year 2011 against monthly averages for the period of record (1906-1974).

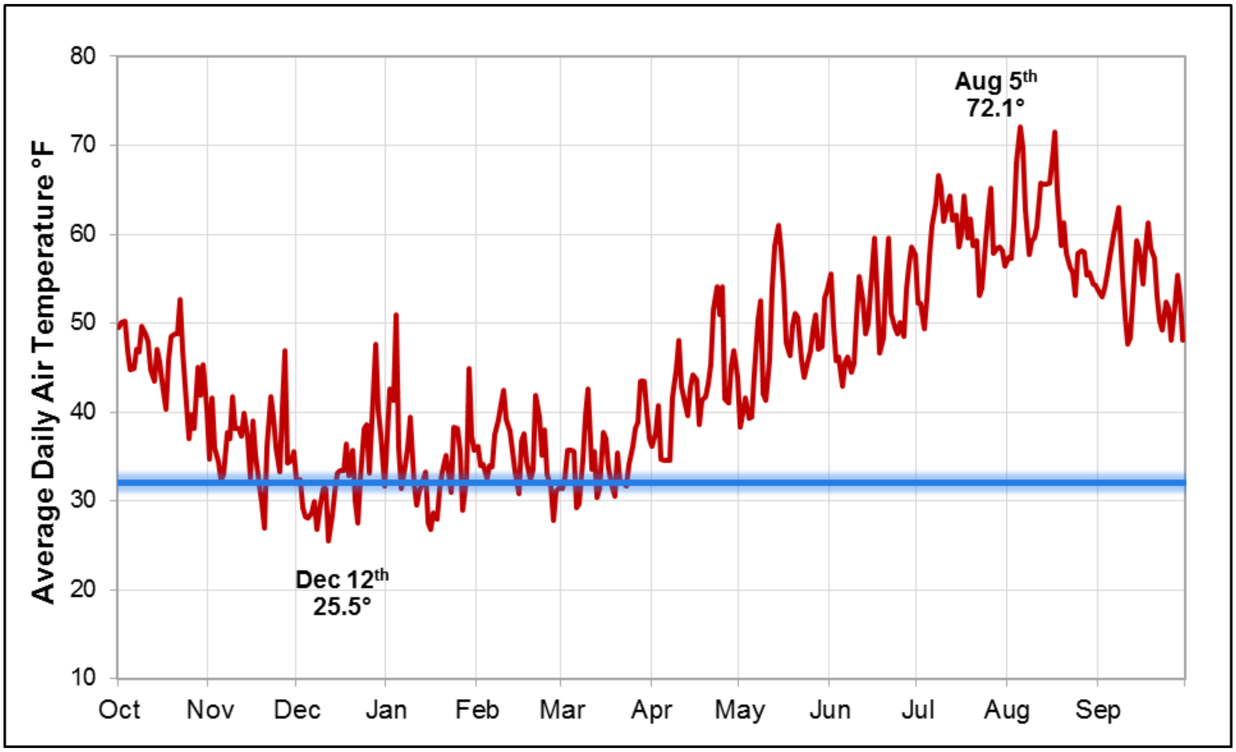

Figure A-2. Daily average air temperature (°F) at the Carbon River Station, Water Year 2012. Blue line indicates 32ºF, the freezing point of water.

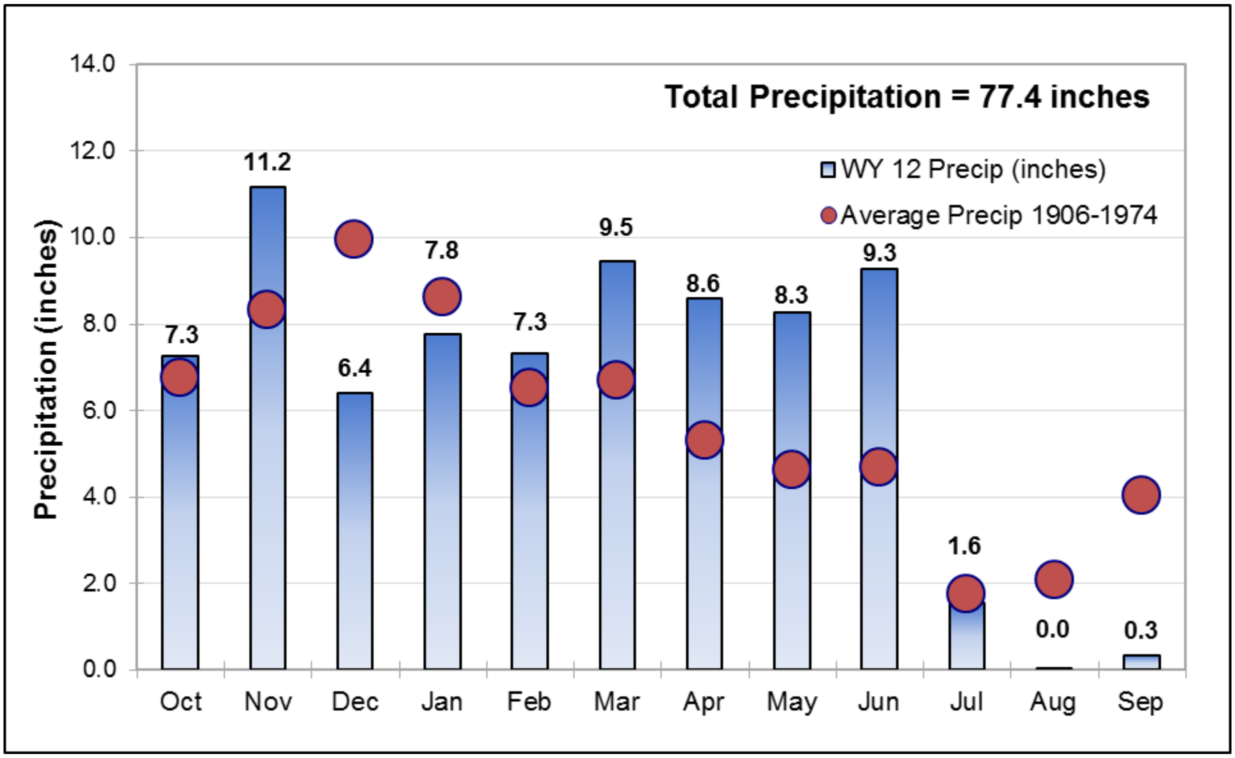

Figure A-3. Monthly precipitation (inches) at the Carbon River Station, Water Year 2012.

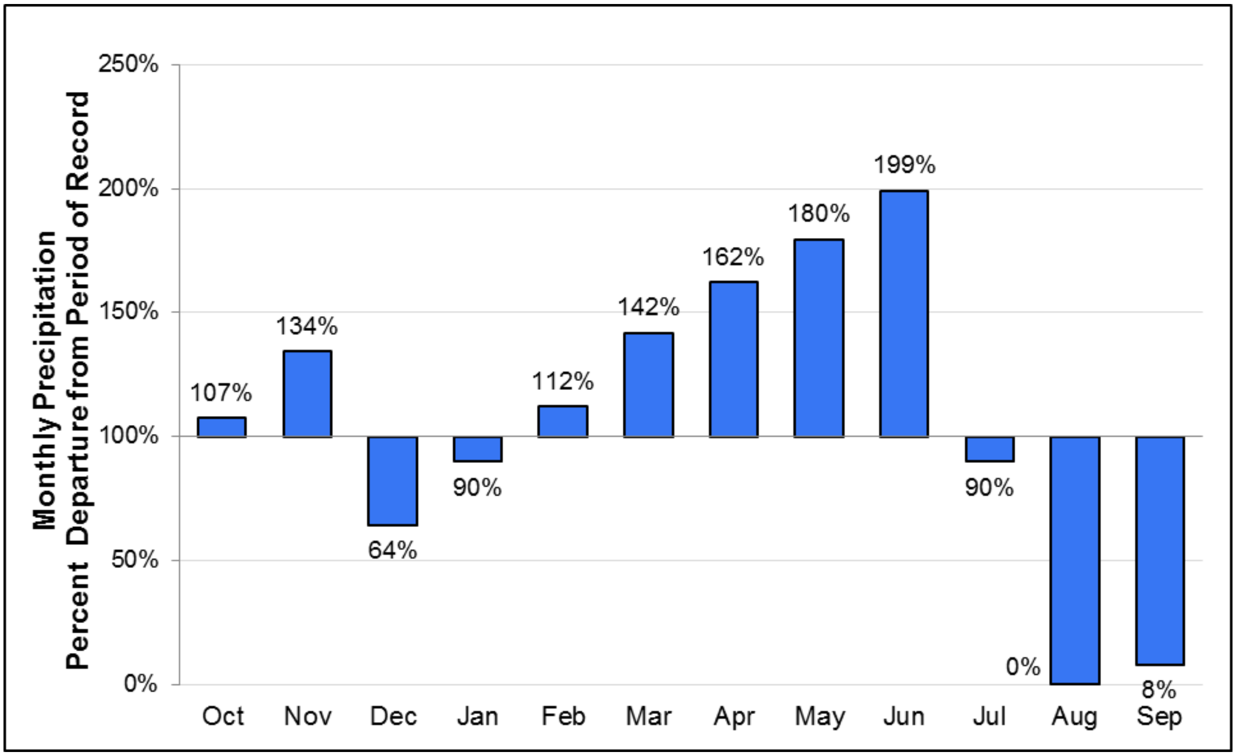

Figure A-4. Percent of average precipitation for the period of record (1906-1974) at the Carbon River Station in Water Year 2012.

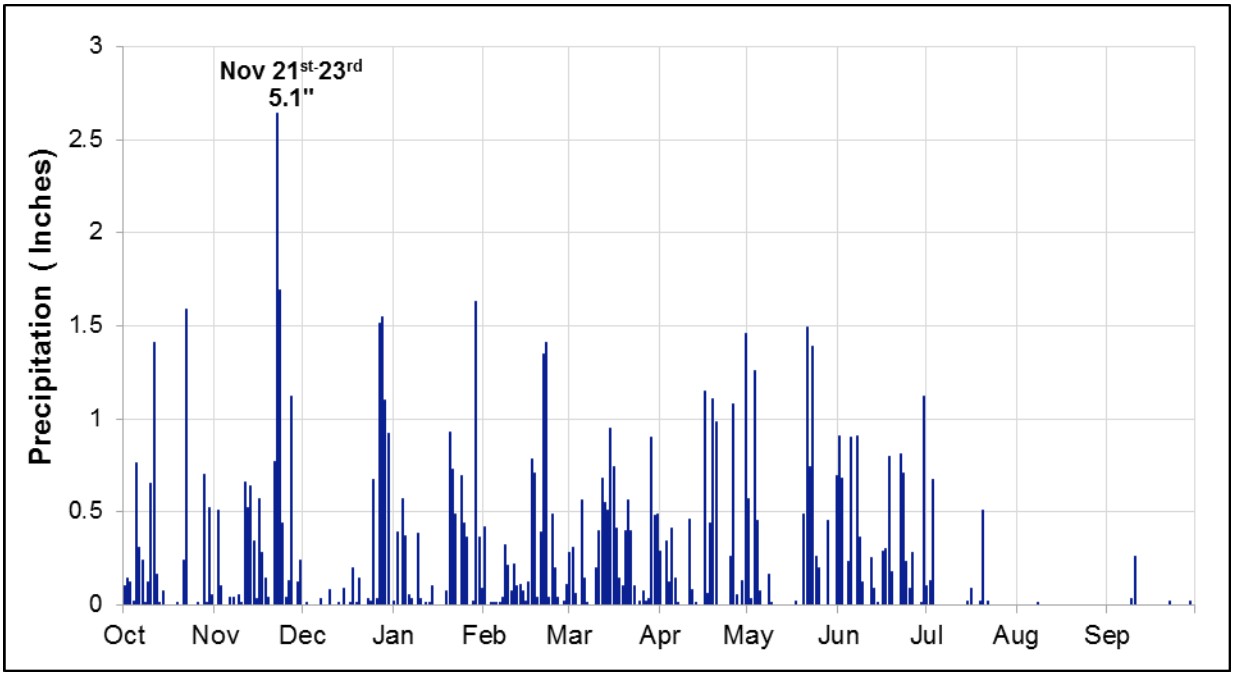

Figure A-5. Daily total precipitation (inches) at the Carbon River Station, Water Year 2012.

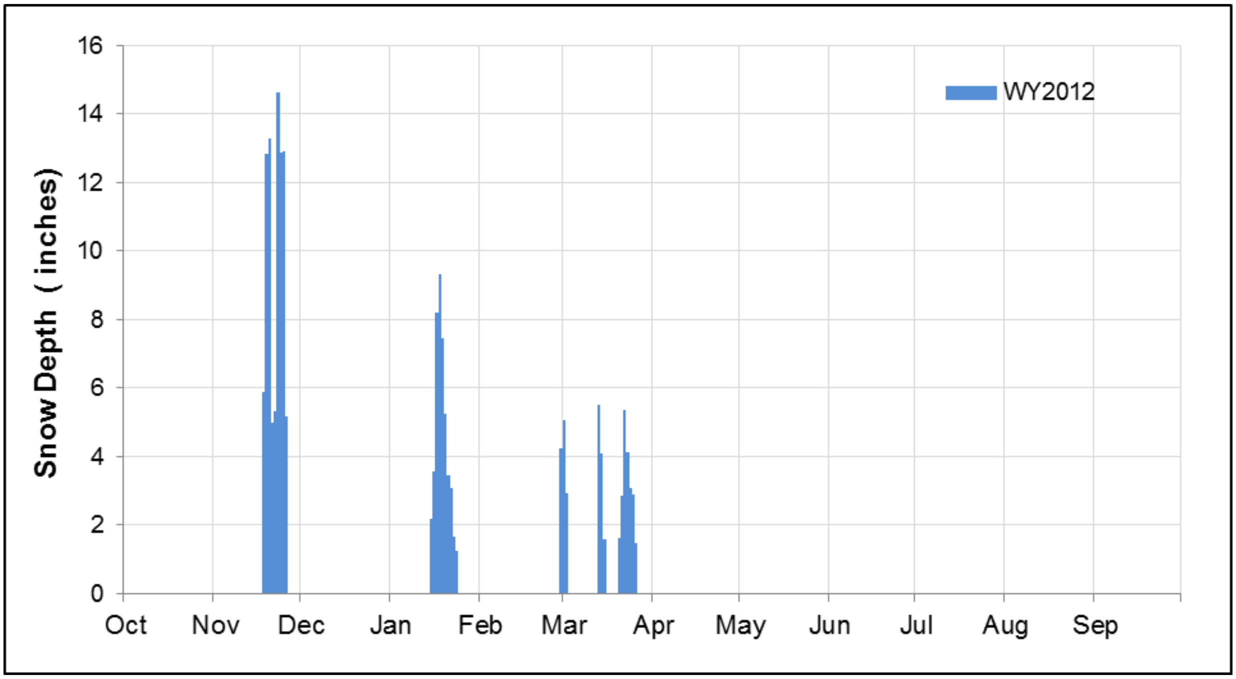

Figure A-6. Daily snow depth (inches) at the Carbon River Station, Water Year 2012.

Appendix B: Camp Muir High Elevation – Water Year 2012

Temperature and wind summaries from the Camp Muir High Elevation weather station for WY 2012 are shown in Tables B-1 and B-2 and Figures B-1 to B-3.

Temperatures observed at the Camp Muir High Elevation weather station ranged from -9.5 to 62.9°F[1] (Table B-2). The coldest recorded mean daily temperature was -6.8°F on January 15, 2012 (Figure B-1). The maximum recorded hourly wind speed was also recorded in August, measuring 122.9 mph (Table B-1, Figure B-2). Data from this site reflect a notably cooler November, January, March, and June than the averages from 2006-2011 and a warmer than average December (+6.4°F), reflective of the unusual high pressure conditions that led to a significant inversion where warmer temperatures were at upper elevations.

The wind speed sensor is not heated and can rime[2] during cold, wet conditions. The daily average wind speed recorded during cold wet periods may not capture actual average wind speed due to riming events interfering with the rotation of the anemometer[3]. Data gaps represent periods when zero wind speed was recorded for more than 3 hours. These data were removed from this analysis. The wind speed sensor was inoperable from March 10-June 10. An electrical short occurred at the station on August 9-10 and August 17-23 resulting in a loss of all data. Power to the station was unavailable from September 5-12 due to the logistics of replacing batteries and coordinating helicopter flights.

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[1] Twelve days of temperature data are missing for August and six days of temperature data are missing for September. Maximum air temperatures may have been higher than indicated.

[2] Rime is a coating of ice that forms when the water droplets in fog freeze to the outer surfaces of objects. High elevation features such as trees and rocks are often covered with a thick glaze of this tenacious material.

[3] An anemometer is an instrument which measures wind speeds. Wind forces metal cups to spin on an axis. The rate of this rotation is translated into wind speeds.

Table B-1. Monthly summary data, Camp Muir High Elevation Station, Water Year 2012.

Season	Month & Year	Mean Air Temp °F	Mean Daily Max Air Temp °F	Mean Daily Min Air Temp °F	Maximum Wind Speed (mph)[2]
Fall	October 2011	26.5	31.5	21.6	100.6
	November 2011	13.9	20.0	8.1	103.7
Winter	December 2011	21.8	28.5	15.1	121.6
	January 2012	14.6	20.3	8.3	121.0
	February 2012	15.9	21.9	10.1	107.6
Spring	March 2012	11.6	18.2	5.3	109.3
	April 2012	18.7	24.3	13.7	----[1]
	May 2012	25.5	33.1	20.2	----[1]
Summer	June 2012	30.2	38.6	24.1	80.0
	July 2012	41.3	46.5	36.7	67.3
	August 2012	----[1]	----[1]	----[1]	122.9
Fall	September 2012	----[1]	----[1]	----[1]	51.0
Water Year		----[1]	----[1]	----[1]	

[1] Multiple days of data are missing due to equipment error.

[2] Wind speed and direction sensors are not heated and can rime during cold, wet conditions. Data represent recorded maximum hourly wind speed, but may not capture actual maximum wind events due to riming.

Table B-2. Air temperature extremes, Camp Muir High Elevation Station, Water Year 2012.

Date	Max Air Temp °F[1]	Date	Min Air Temp °F
June 15, 2012	62.9	January 15, 2012	-9.5
August 5, 2012	62.3	March 19, 2012	-8.6
September 20, 2012	60.5	January 16, 2012	-8.5
June 13, 2012	59.5	March 6, 2012	-8.5
July 11, 2012	59.4	February 27, 2012	-7.2

[1] Twelve days of temperature data are missing for August and six days of temperature data are missing for September. Maximum air temperatures may have been higher than indicated.

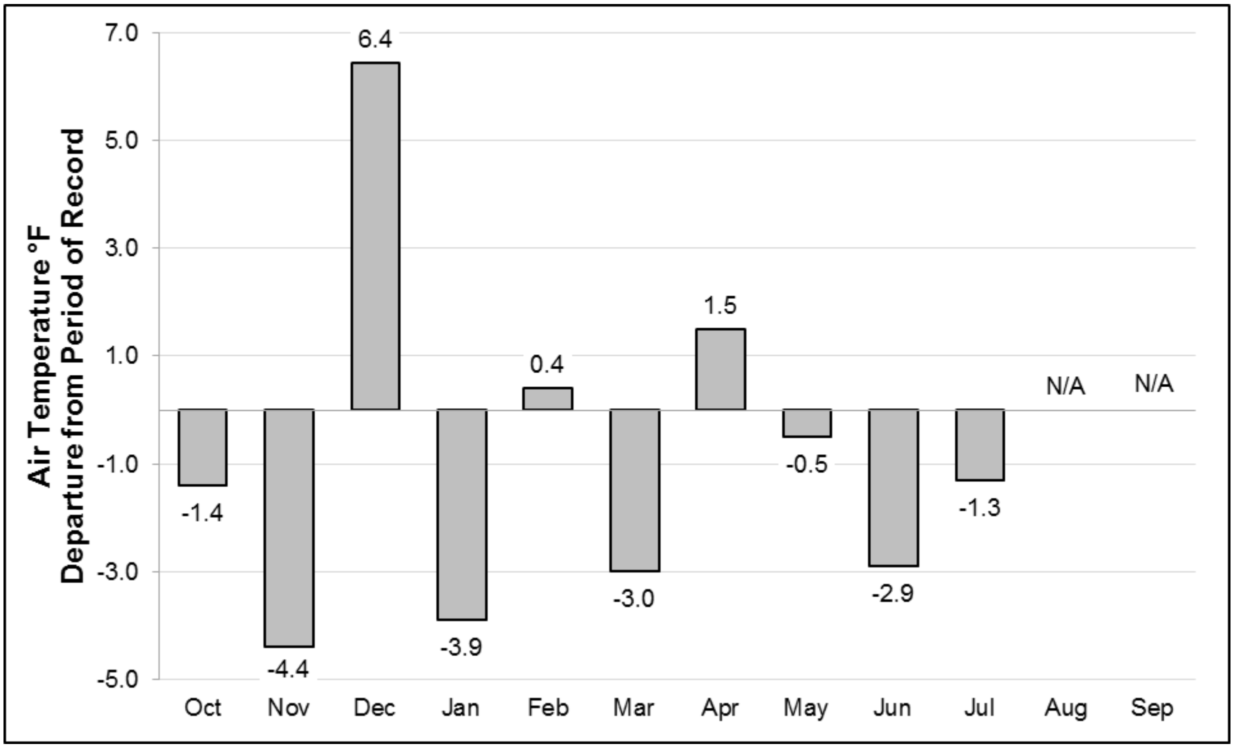

Figure B-1. Comparison of average monthly temperature (°F) for the Camp Muir High Elevation Station in Water Year 2012 against monthly averages for the period of record (2006-2011).

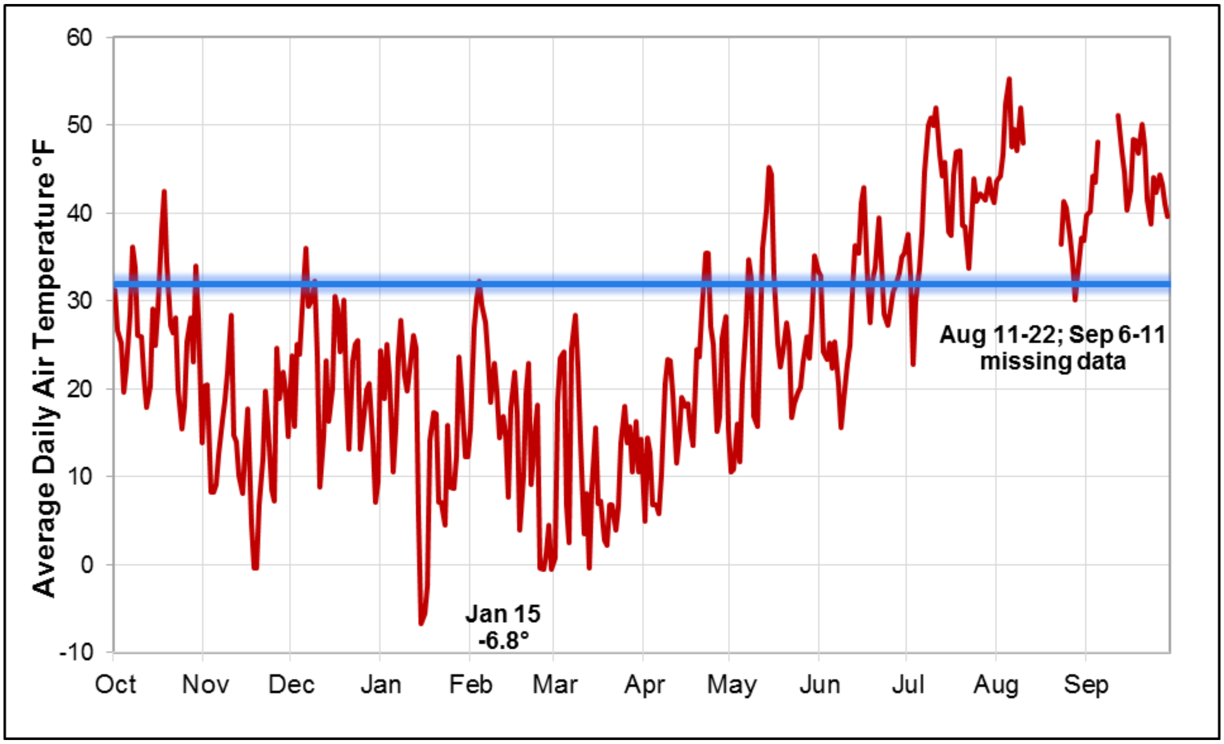

Figure B-2. Daily average air temperature (°F) at the Camp Muir High Elevation Station, Water Year 2012. Blue line indicates 32ºF, the freezing point of water.

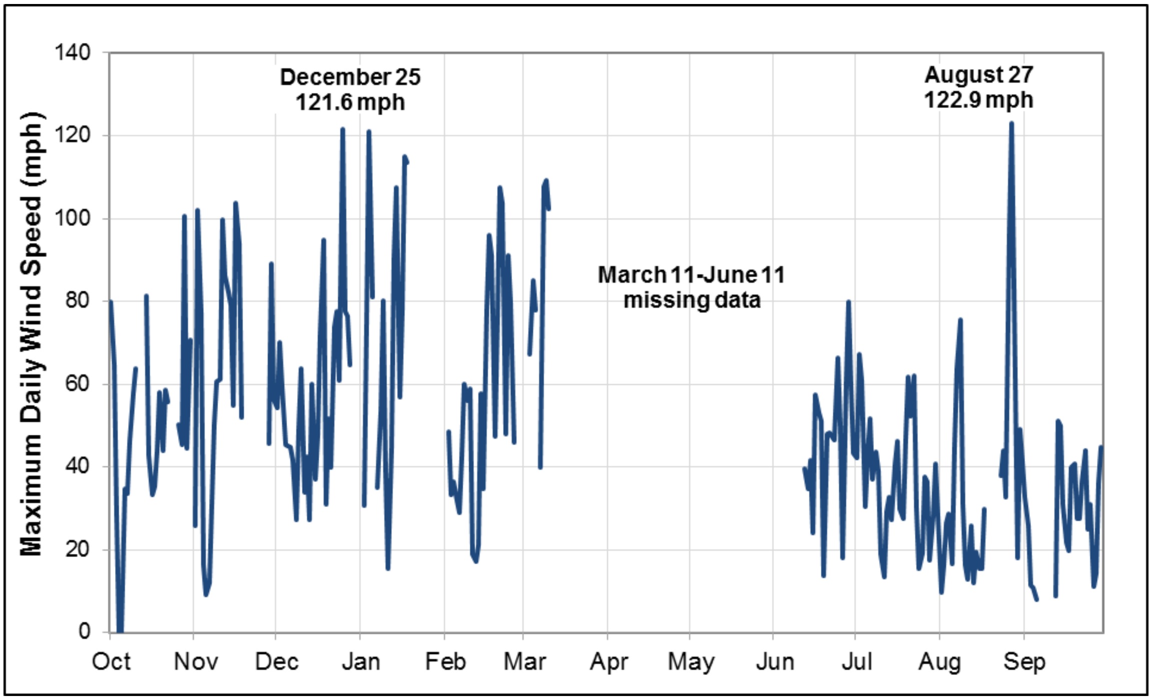

Figure B-3. Maximum daily wind speed (mph) recorded at the Camp Muir High Elevation Station, Water Year 2012. Wind speed sensor is not heated and can rime during cold, wet conditions. Data represent recorded daily maximum wind speed, but may not capture actual average wind speed due to riming events. Data gaps represent periods when wind speed recorded zero for more than 3 hours. These data were not included in the analysis.

Appendix C: Cayuse Pass SNOTEL – Water Year 2012

Temperature, precipitation and snowfall summaries from the Cayuse Pass SNOTEL weather station for WY 2012 are shown in Tables C-1 and C-2 and Figures C-1 to C-6.

Average annual temperature at the Cayuse SNOTEL was 39.0°F (Table C-1). Temperatures ranged from an extreme low of 11.0°F to a high of 82.0°F (Table C-2). The coldest average daily temperature recorded was 16°F on January 17, 2012. The warmest average daily temperature of 70°F was recorded on August 18, 19, and September 21, 2013 (Figure C-2). Temperature departure (from the relatively short period of record) reflects the cooler than average November followed by a warmer than average December at upper elevations, cooler than average January, February, and March, and warmer than average July, August, and September (Figure C-1).

Total annual precipitation was 98.9 inches, 112% compared to the period of record from 2007-2011 (Table C-3). The highest daily precipitation of 3.2 inches was recorded during a particularly wet period at the end of March that brought a total of 7.0 inches of precipitation over a three day span (Figure C-5). Snow water equivalent reached its peak on April 20, with 77.5 inches on the ground (Figure C-6). Snowpack began accumulating on November 4, 2011 and melted July 16, 2012, persisting for 256 days, 29 days shorter than Water Year 2011.

Table C-1. Monthly summary data, Cayuse Pass SNOTEL, Water Year 2012.

Season	Month & Year	Mean Air Temp °F	Mean Daily Max Air Temp °F	Mean Daily Min Air Temp °F	Precipitation (inches)
Fall	October 2011	39.6	44.7	35.3	6.6
	November 2011	29.4	34.6	24.9	9.0
Winter	December 2011	31.7	38.2	26.5	4.6
	January 2012	28.5	34.1	23.4	18.5
	February 2012	28.4	33.8	24.3	15.5
Spring	March 2012	28.1	34.0	23.3	23.8
	April 2012	35.4	42.7	30.1	7.2
	May 2012	39.8	47.6	33.2	7.3
Summer	June 2012	42.4	48.8	37.0	5.3
	July 2012	53.7	63.7	46.3	0.7
	August 2012	56.8	67.6	48.4	0.0
Fall	September 2012	53.8	63.9	44.1	0.4
Water Year		**39.0**	**46.1**	**33.1**	**98.9**

Table C-2. Air temperature extremes, Cayuse Pass SNOTEL, Water Year 2012.

Date	Max Air Temp °F	Date	Min Air Temp °F
August 6, 2012	82.0	January 17, 2012	11.0
July 9, 2012	81.0	November 21, 2010	14.0
August 18, 2012	80.0	January 1, 2012	14.0
August 13, 2012	77.0	February 28, 2012	14.0
September 21, 2012	79.0	January 18, 2012	15.0

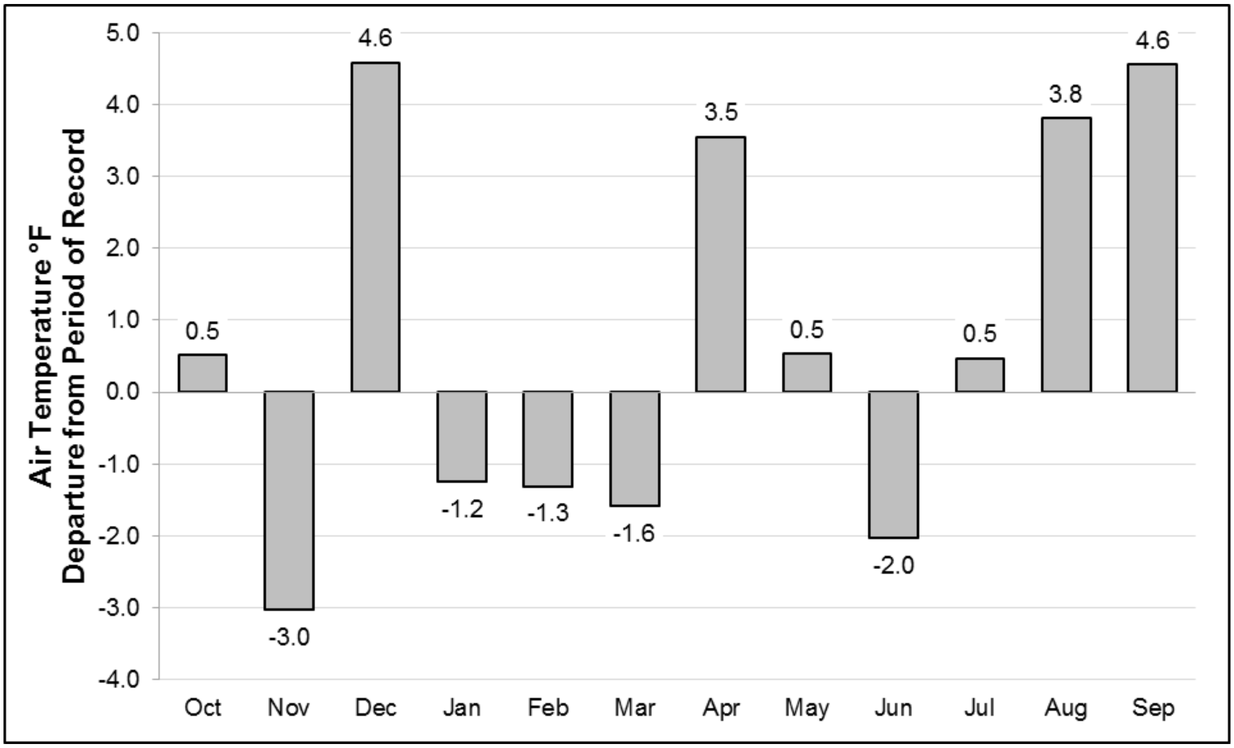

Figure C-1. Comparison of average monthly temperature (°F) for the Cayuse SNOTEL Station in Water Year 2012 against monthly averages for the period of record (2007-2011).

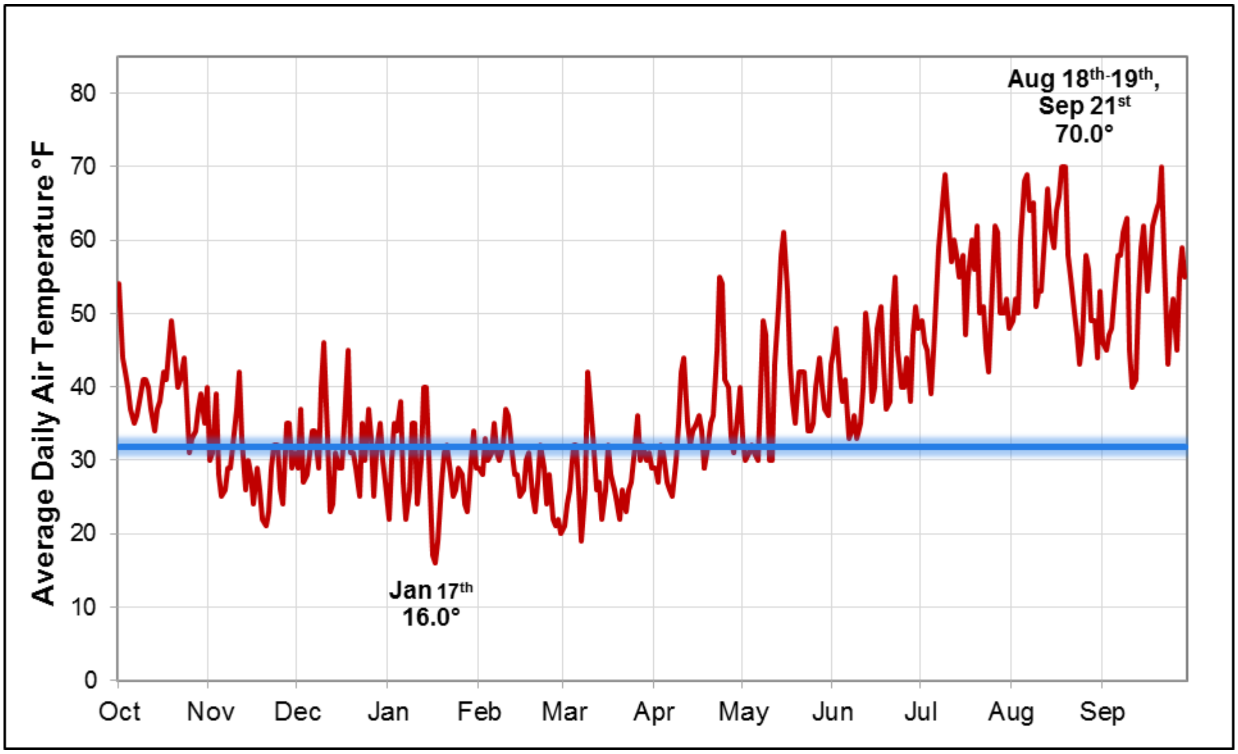

Figure C-2. Daily average air temperature (°F) at the Cayuse Pass SNOTEL, Water Year 2012. Blue line indicates 32ºF, the freezing point of water.

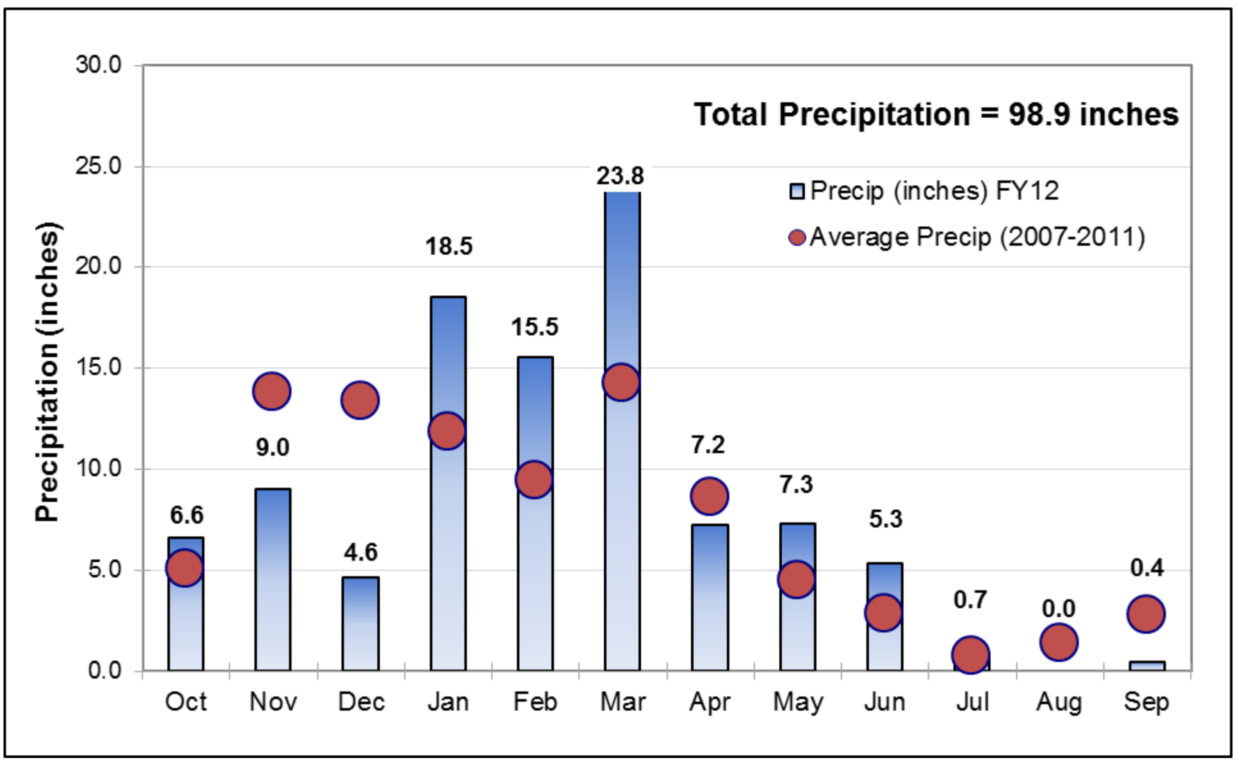

Figure C-3. Monthly total precipitation (inches) at the Cayuse Pass SNOTEL, Water Year 2012, compared to the monthly averages for the period of record (2007-2011).

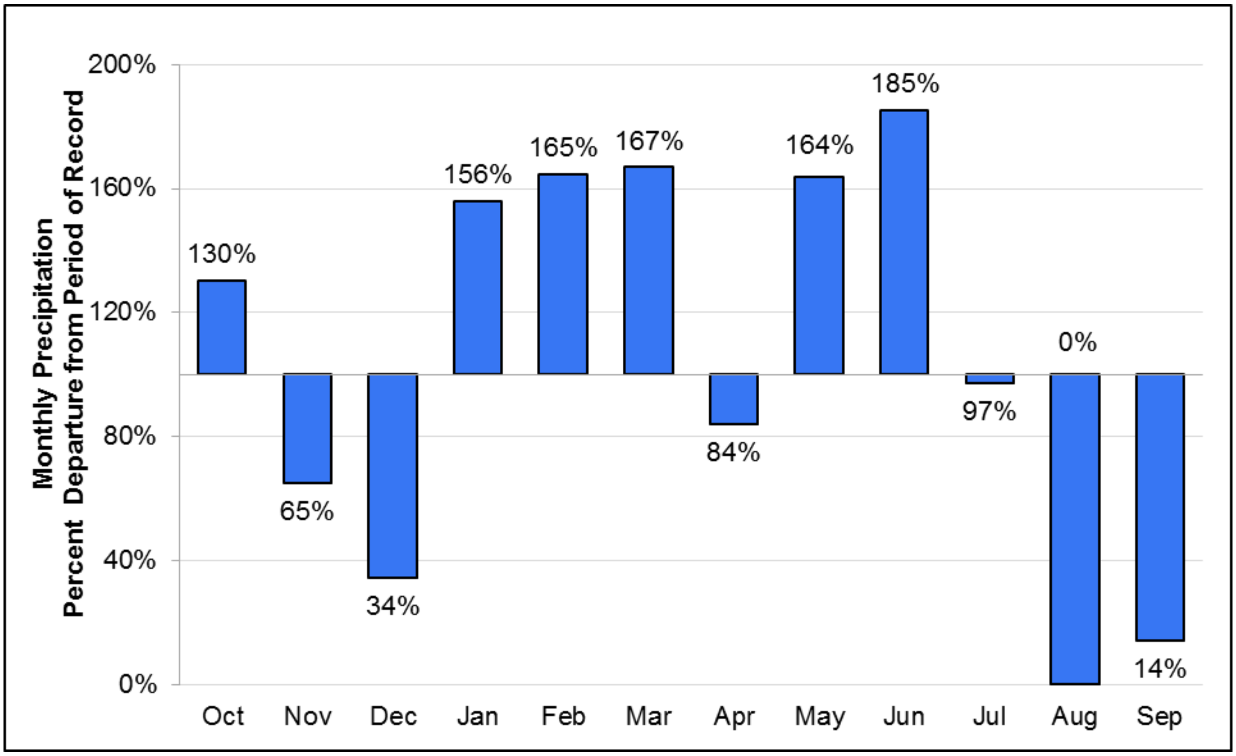

Figure C-4. Percent of average precipitation for the period of record (2007-2011) at the the Cayuse SNOTEL Station in Water Year 2012.

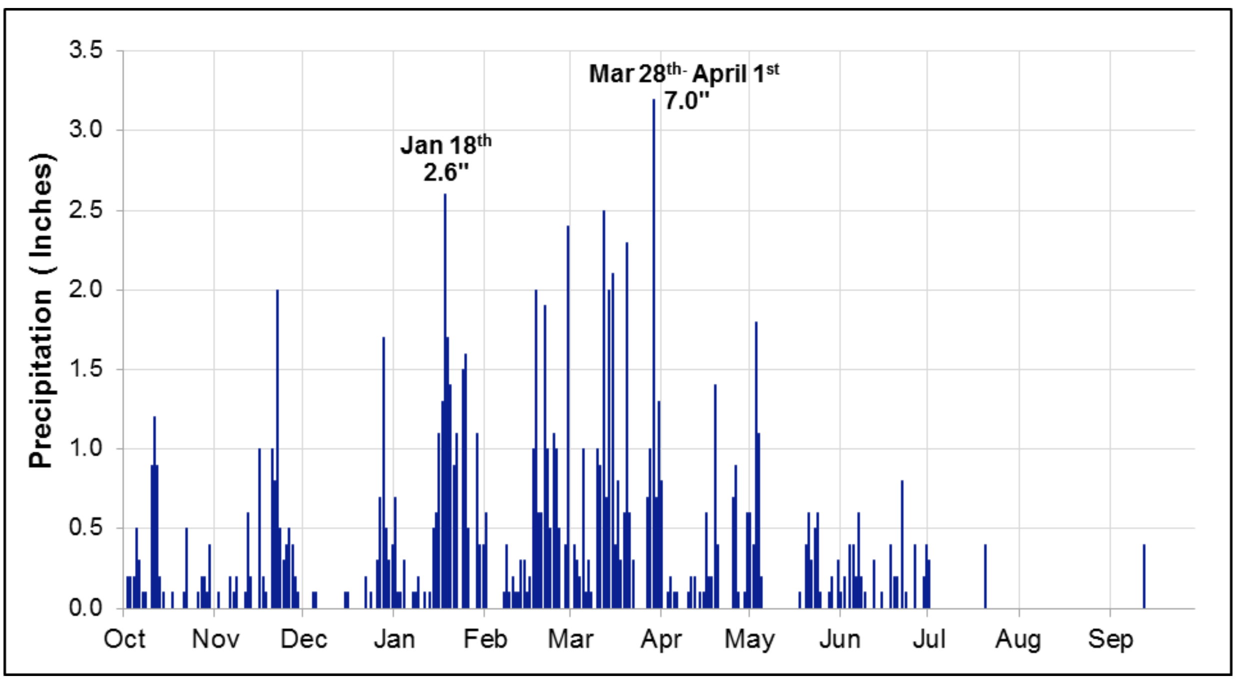

Figure C-5. Daily total precipitation (inches) at the Cayuse Pass SNOTEL, Water Year 2012.

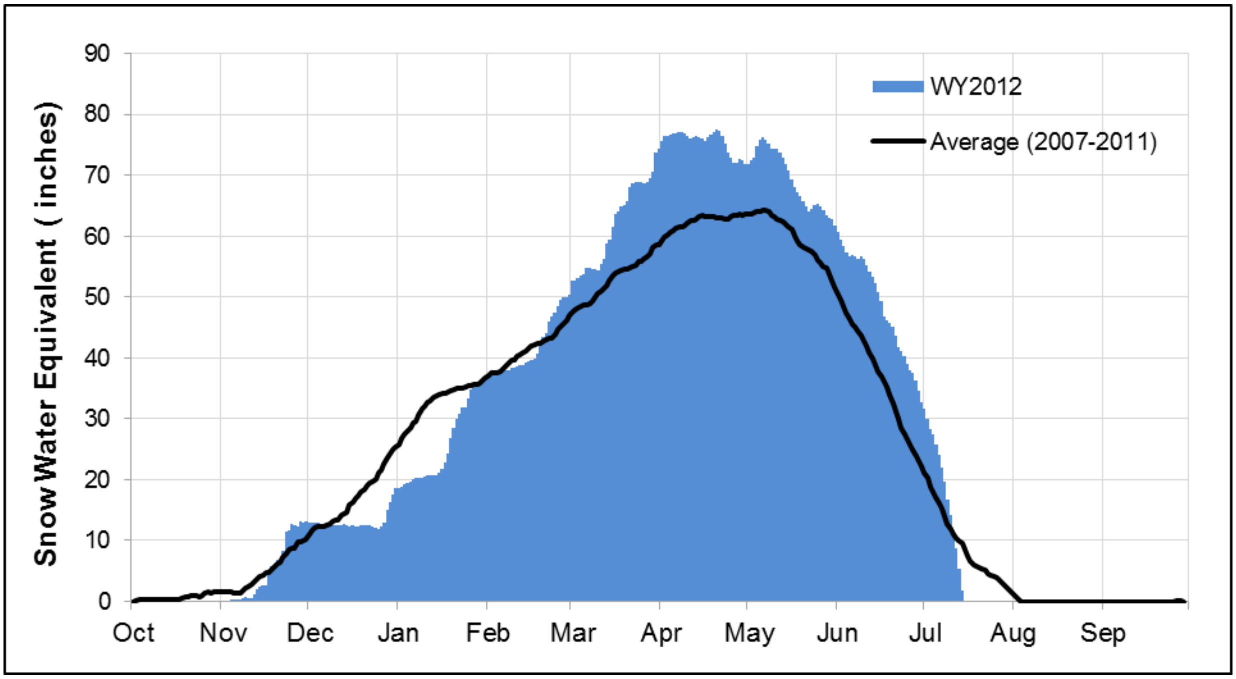

Figure C-6. Daily snow water equivalent (inches) at the Cayuse Pass SNOTEL, Water Year 2012, compared to the period of record daily average (2007-2011).

Appendix D: Longmire COOP – Water Year 2012

Temperature, precipitation and snowfall summaries from the Longmire COOP weather station for WY 2012 are shown in Tables D-1 and D-2 and Figures D-1 to D-6.

Nine days of Longmire COOP temperature data are missing in January; therefore, monthly January temperature and annual temperature summary data are not available for Longmire (Table D-1). Temperatures observed at the Longmire COOP station ranged from a low of 15.0°F to a high of 96.0°F (Table D-2). Monthly average temperature departures from the period of record (1909-2010) reflect a cooler than average fall and late spring, with near average winter monthly temperatures and a notably warmer than average August and September (Figure D-1). The coldest day was January 17, 2012 and the hottest day was on August 6, 2012 (Figure D-2).

Annual precipitation totaled 77.6 inches, 96% compared to the period of record (1909-2011) (Figure D-3). Monthly precipitation values in October, November, February and March were near normal with a drier than normal December and January. The wetter than normal late spring and earlier summer followed by a very dry August and September are reflected in the data (Figure D-4). The wettest period was February 22 to 23, 2012, when 4.3 inches of precipitation fell (Figure D-5). The 2012 water year began with above normal snowpack due to an early November storm, followed by a period of below average conditions that lasted most of the winter due to below average precipitation during this period (Figure D-6). By March, the snowpack reached average conditions and that lasted into April. The snowpack peaked on March 22 with 35 inches of snow on the ground and persisted until April 22, 2012.

Table D-1. Monthly summary data, Longmire COOP Station, Water Year 2012.

Season	Month & Year	Mean Air Temp °F	Mean Daily Max Air Temp °F	Mean Daily Min Air Temp °F	Precipitation (inches)
Fall	October 2011	44.8	52.6	37.1	7.6
	November 2011	33.4	38.7	28.2	12.8
Winter	December 2011	31.4	37.2	25.6	7.4
	January 2012	----[1]	----[1]	----[1]	10.7
	February 2012	32.9	37.9	27.8	9.2
Spring	March 2012	33.2	38.6	27.8	8.0
	April 2012	42.0	50.8	33.1	7.0
	May 2012	47.4	58.4	36.4	6.3
Summer	June 2012	50.9	60.4	41.3	6.3
	July 2012	60.8	73.5	48.2	1.8
	August 2012	64.2	78.8	49.5	0.1
Fall	September 2012	58.7	73.0	44.3	0.4
Water Year		----[1]	----[1]	----[1]	**77.6**

[1] Nine days of temperature data are missing in January

Table D-2. Air temperature extremes, Longmire COOP Station, Water Year 2012.

Date	Max Air Temp °F	Date	Min Air Temp °F[1]
August 6, 2012	96.0	November 21, 2011	15.0
August 18, 2012	95.0	February 27, 2012	15.0
August 5, 2011	93.0	December 12, 2011	17.0
August 17, 2012	92.0	December 14, 2011	17.0
August 16, 2012	90.0	February 28, 2012	17.0

[1] Nine days of temperature data are missing in January. Minimum air temperatures may have been lower than indicated.

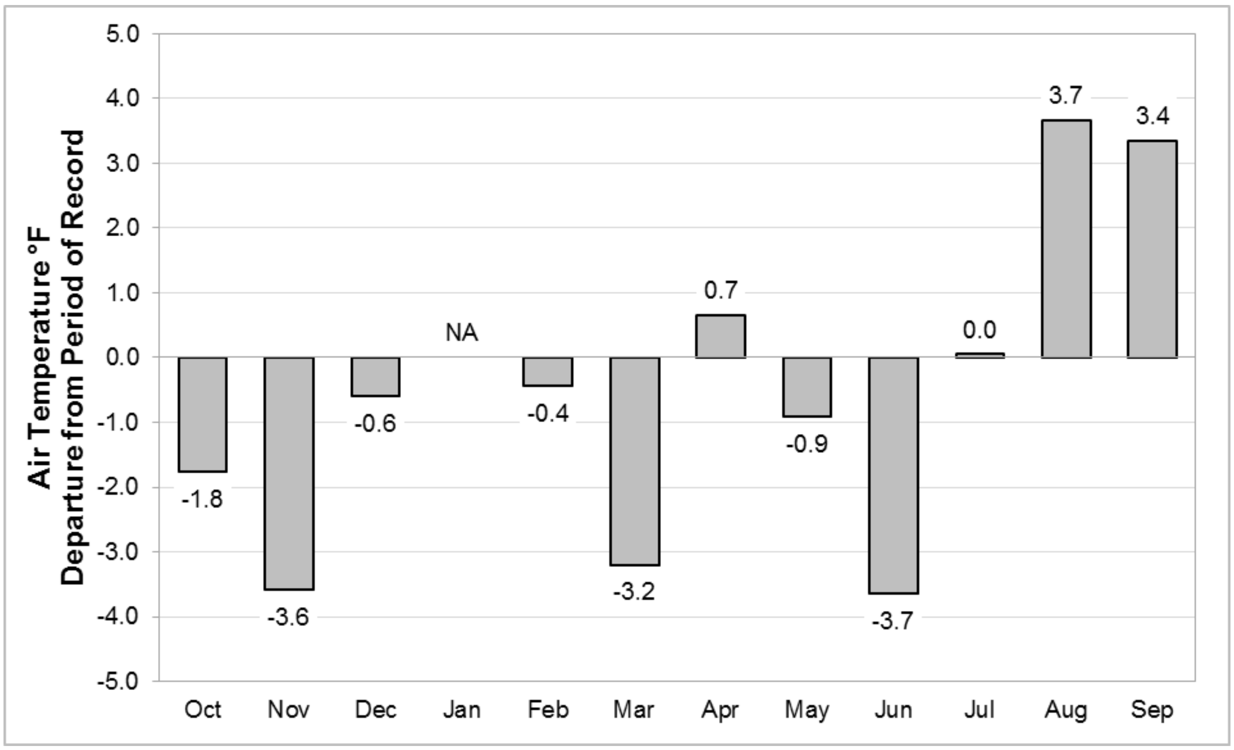

Figure D-1. Comparison of average monthly temperature (°F) for the Longmire COOP Station in Water Year 2012 against monthly averages for the period of record (1909-2011).

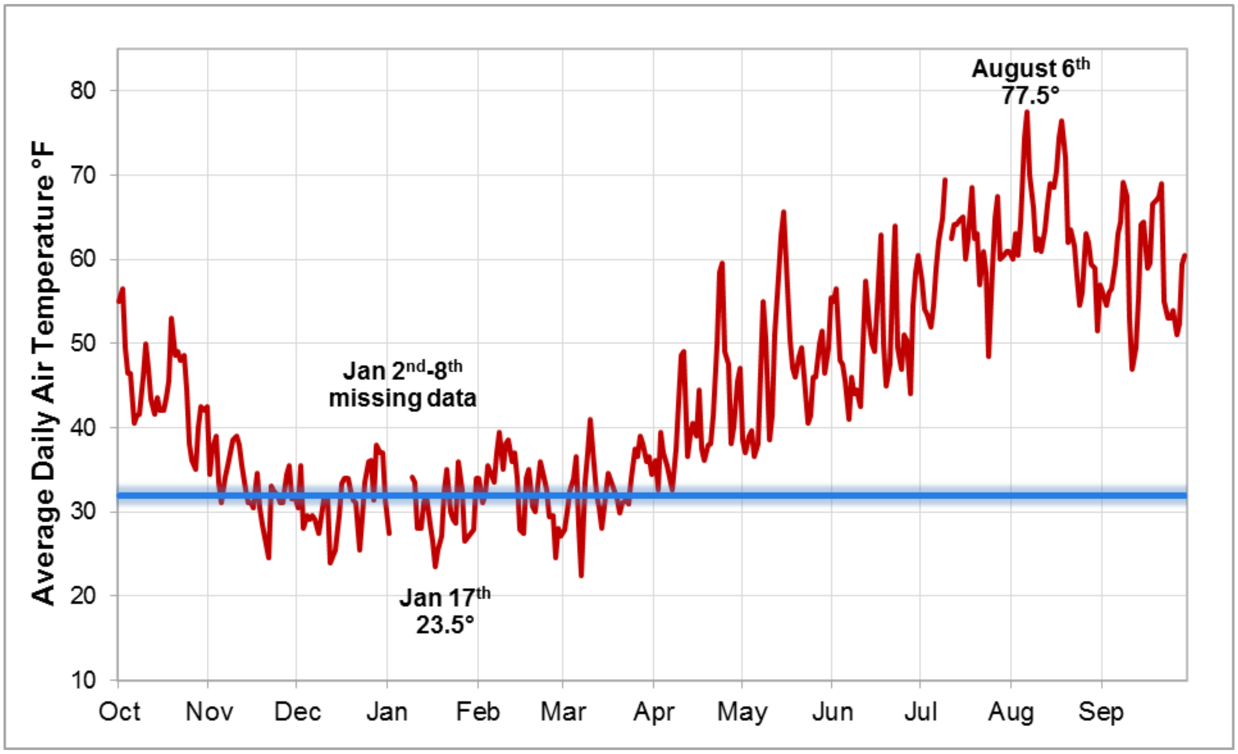

Figure D-2. Daily average air temperature (°F) values at the Longmire COOP Station, Water Year 2012. Blue line indicates 32ºF, the freezing point of water.

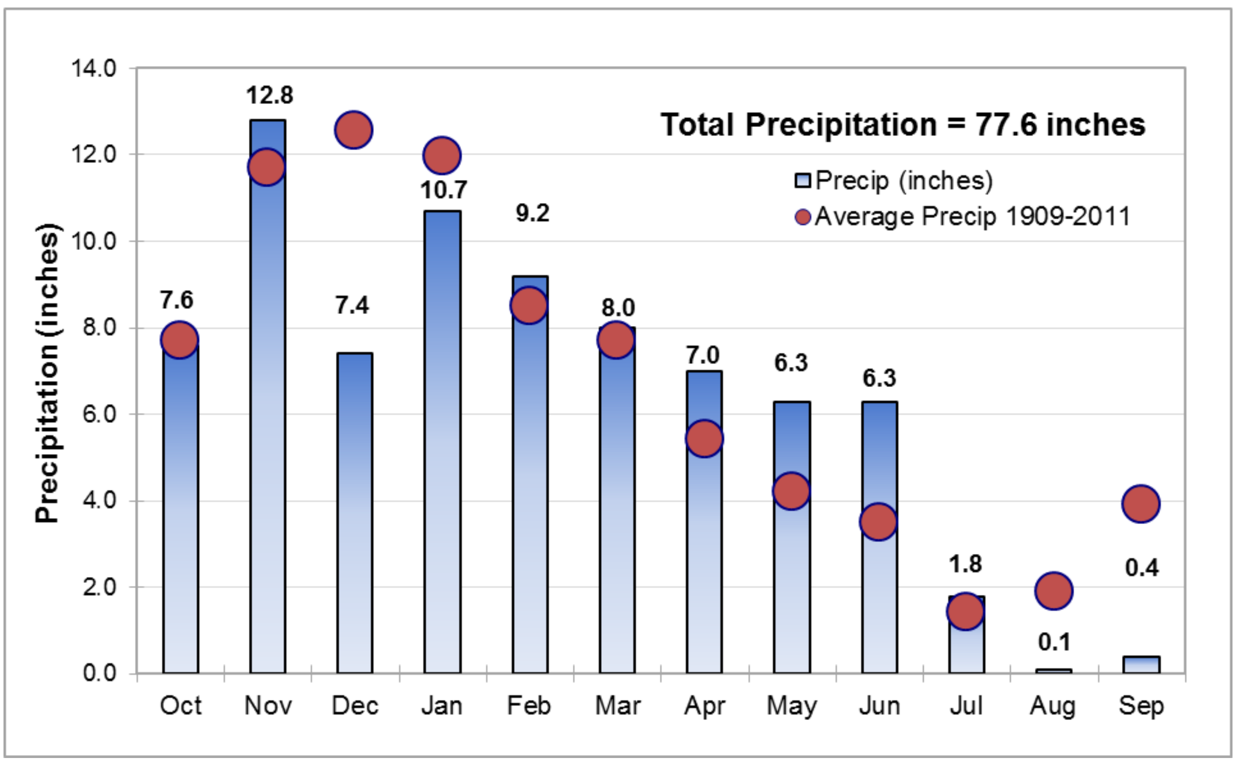

Figure D-3. Monthly precipitation (inches) at the Longmire COOP Station, Water Year 2012, compared to the monthly averages for the period of record (1909-2011).

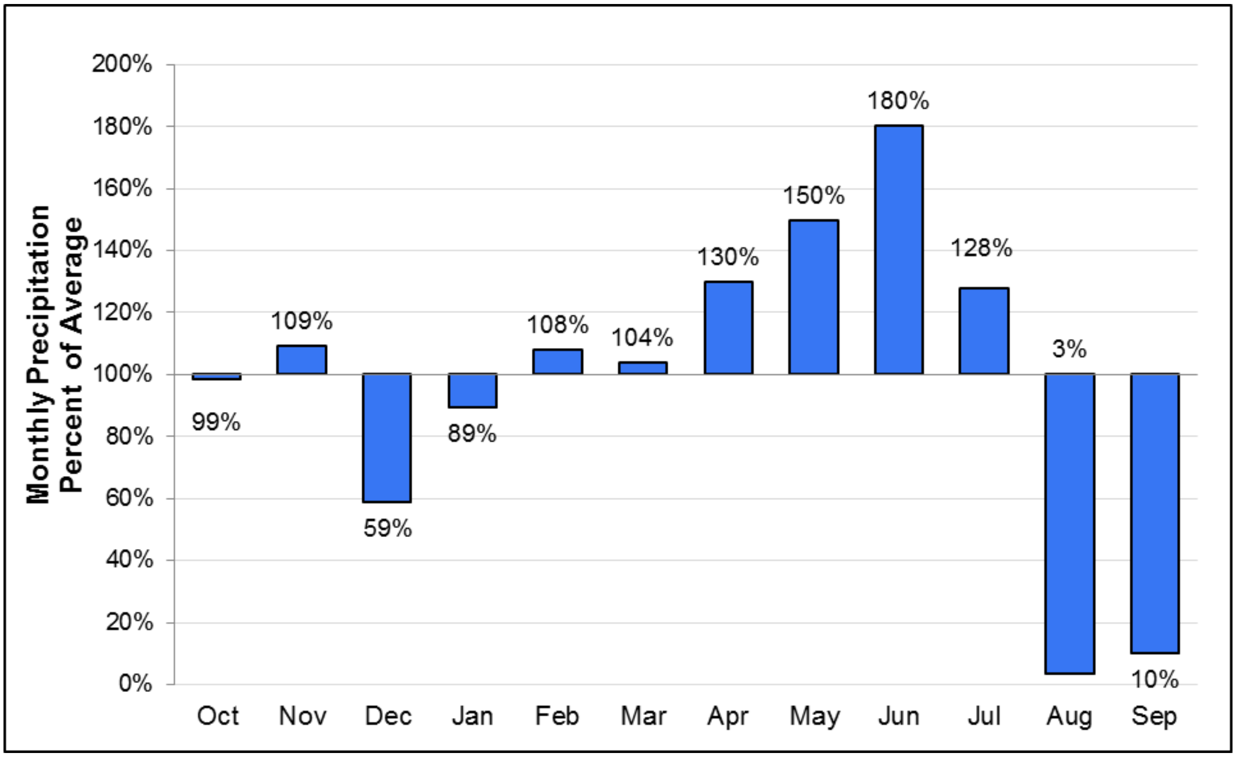

Figure D-4. Percent of average precipitation for period of record (1909-2011) at the Longmire COOP Station in Water Year 2012.

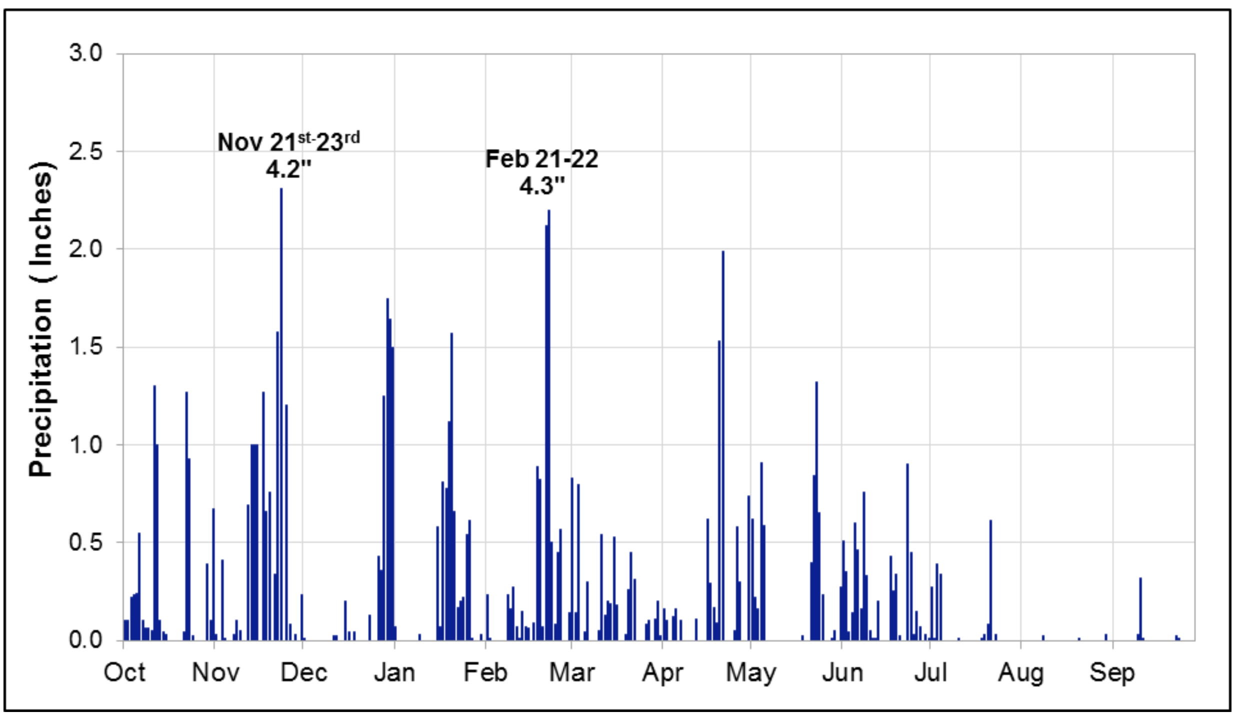

Figure D-5. Daily total precipitation (inches) at the Longmire COOP Station, Water Year 2012.

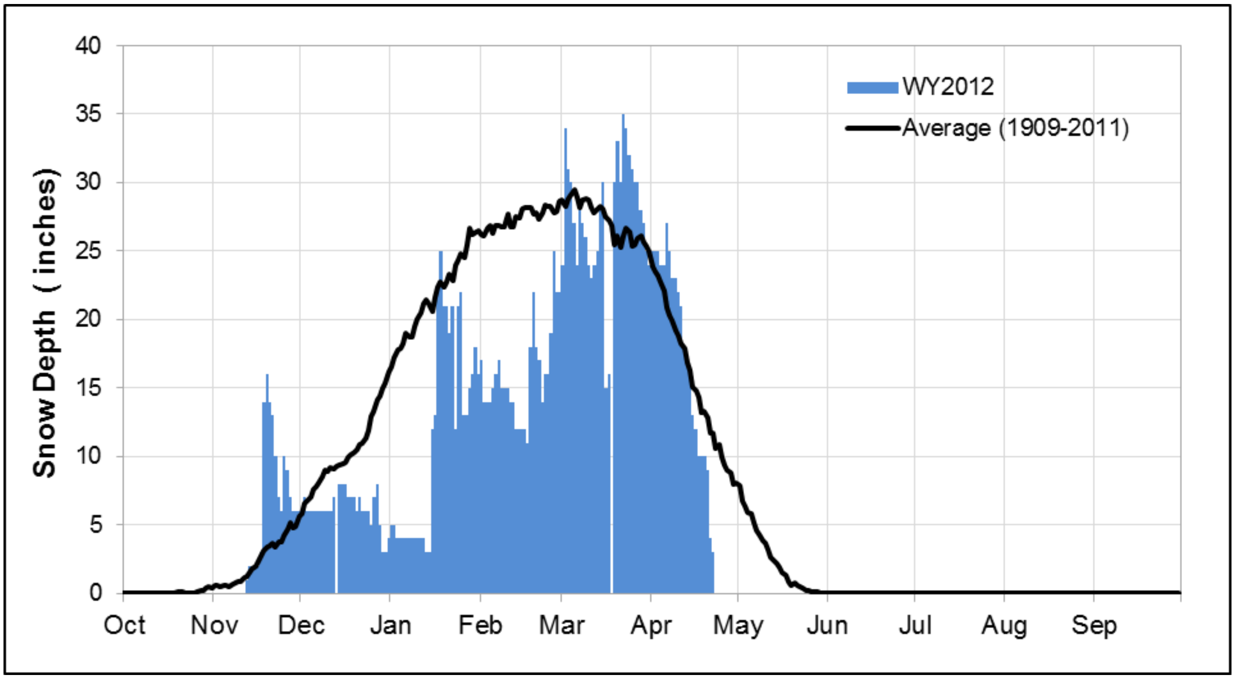

Figure D-6. Daily snow depth (inches) at the Longmire COOP Station, Water Year 2012, compared to the period of record daily average (1909-2011).

Appendix E: Ohanapecosh NPS-Water Year 2012.

Temperature, precipitation and snowfall summaries from the Ohanapecosh NPS weather station for WY 2012 are shown in Tables E-1 and E-2 and Figures E-1 to C-4.

Due to intermittent power outages at the RAWS Ohanapecosh, data collection has been sporadic during the winter months since installation. To ensure year round data collection, an NPS station requiring less power to operate was installed adjacent to the Ohanapecosh RAWS station in October, 2011. Due to the short period of record of the new station and intermittent winter data at the RAWS, no reliable period of record comparisons can be made. However, a NWS COOP station was operated year round at Ohanapecosh from 1926-2001, and provides a consistent long term precipitation record for that period. This period of record average was used for comparison purposes. Temperature records are not available from the NWS COOP station. A snowfall adapter is installed on the precipitation gauge at the Ohanapecosh NPS station during the winter to capture precipitation falling as snow. The design of the system results in delays and is not suitable for real time precipitation measurements; therefore daily precipitation data are not presented.

Average annual temperature at the Ohanapecosh NPS station was 45.0°F (Table E-1). Daily temperatures ranged from an extreme low of 21.5°F to a high of 96.0°F (Table E-2). The coldest average daily temperature recorded was 24°F on December 12, 2011. The warmest average daily temperature of 73.9°F was recorded on August 5 (Figure E-1). Temperatures reflect near normal average monthly temperatures in October, November and December, a cooler than average January, February, and March and warmer than average July, August, and September (Figure E-1).

Total annual precipitation was 98.9 inches, 98% compared to the period of record (1926-2001) (Figure E-3). Monthly precipitation values in October, November, February and March were near normal with a drier than normal December and January (Figure E-4). The wetter than normal late spring and earlier summer followed by a very dry August and September are reflected in these data. Snowpack began accumulating on November 12, 2011 and melted April 15, 2012, with a maximum depth of 27 inches on January 18, 2012 (Figure E-5).

Table E-1. Monthly summary data, Ohanapecosh NPS Station, Water Year 2012.

Season	Month & Year	Mean Air Temp °F	Mean Daily Max Air Temp °F	Mean Daily Min Air Temp °F	Precipitation (inches)
Fall	October 2011	45.8	52.2	40.7	6.5
	November 2011	34.1	38.1	29.9	11.1
Winter	December 2011	31.5	36.0	27.4	7.0
	January 2012	32.1	35.0	29.7	12.7
	February 2012	33.0	37.3	30.2	10.8
Spring	March 2012	33.9	38.7	30.7	10.9
	April 2012	42.5	52.2	36.1	4.9
	May 2012	48.9	60.8	39.9	3.9
Summer	June 2012	53.0	62.4	45.7	3.5
	July 2012	63.0	76.0	53.4	0.9
	August 2012	64.7	79.9	53.5	0.0
Fall	September 2012	58.0	73.5	47.4	0.4
Water Year		**45.0**	**53.5**	**38.7**	**72.4**

Table E-2. Air temperature extremes, Ohanapecosh RAWS Station, Water Year 2012.

Date	Max Air Temp °F	Date	Min Air Temp °F
August 17, 2012	96.0	February 27, 2012	21.5
August 5, 2012	95.1	December 22, 2011	22.0
August 4, 2012	94.5	March 7, 2012	22.6
August 16, 2012	92.5	January 16, 2012	23.3
August 12, 2012	91.3	February 28, 2012	23.6

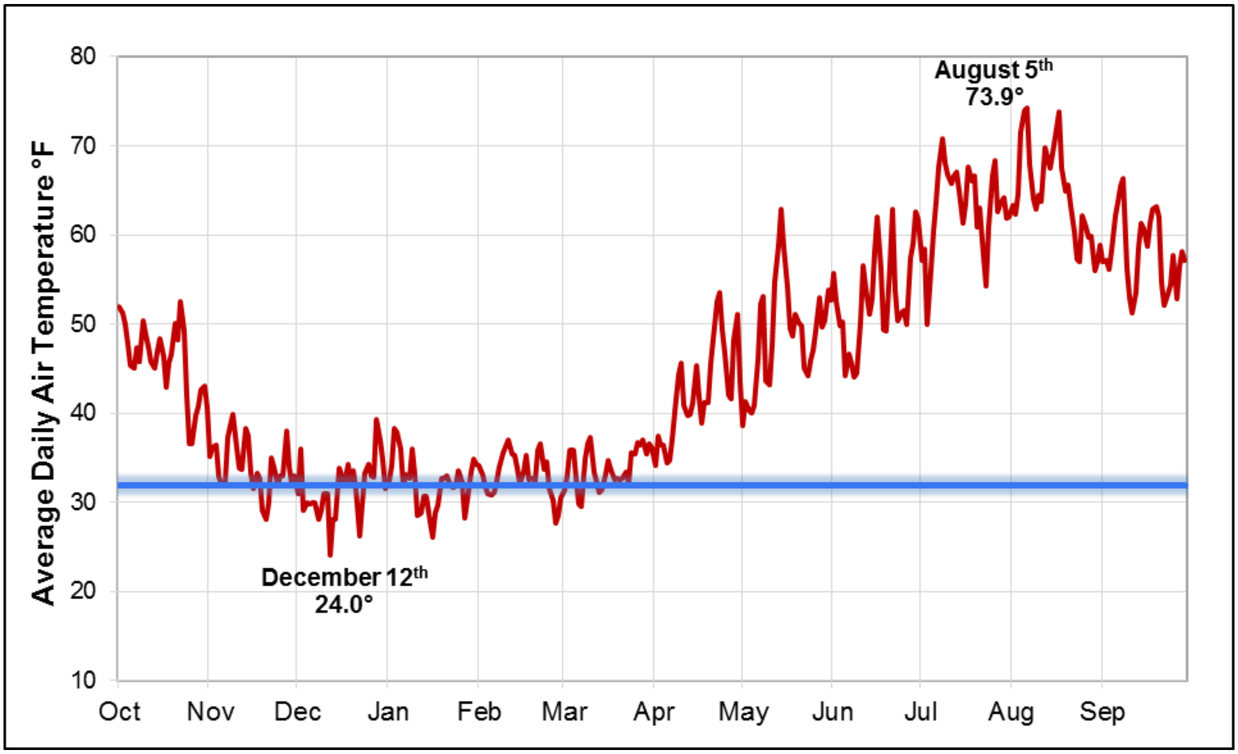

Figure E-1. Daily average air temperature (°F) at the Ohanapecosh RAWS Station, Water Year 2012. Blue line indicates 32ºF, the freezing point of water.

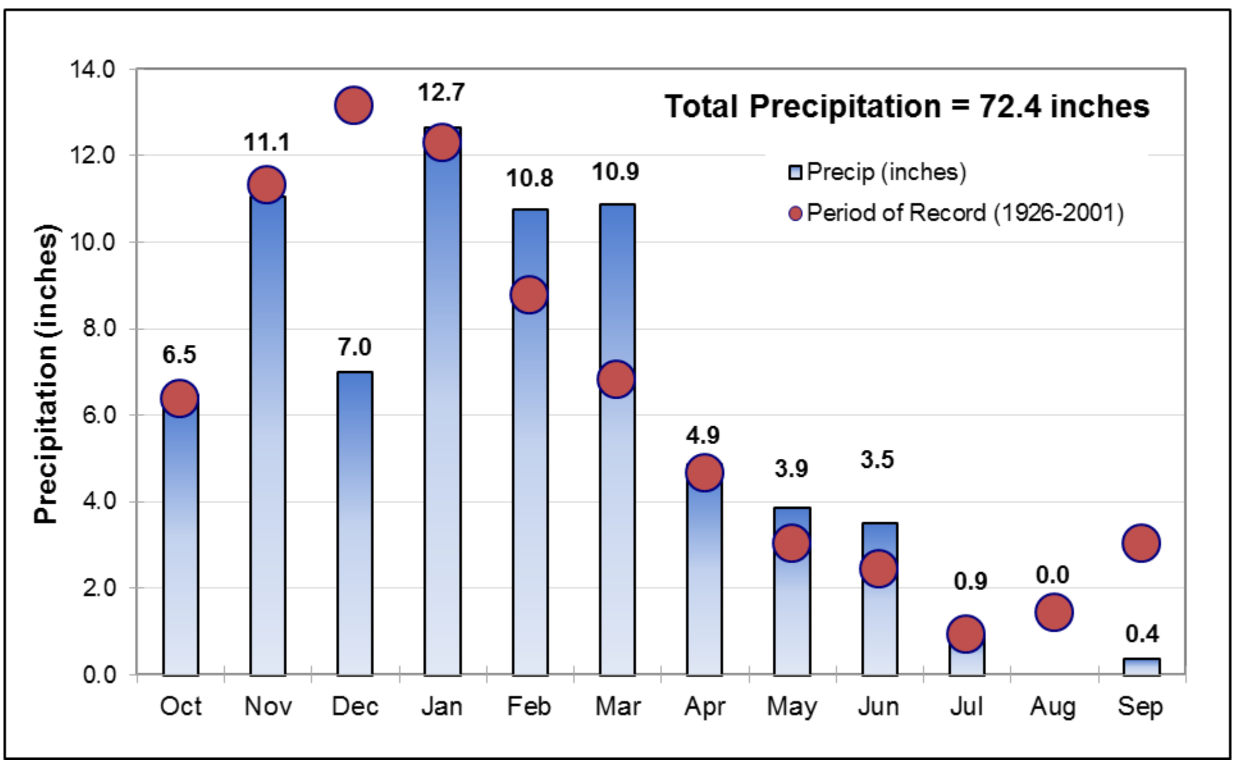

Figure E-2. Monthly precipitation (inches) at the Ohanapecosh NPS Station, Water Year 2012, compared to the monthly averages for the period of record (1923-2001).

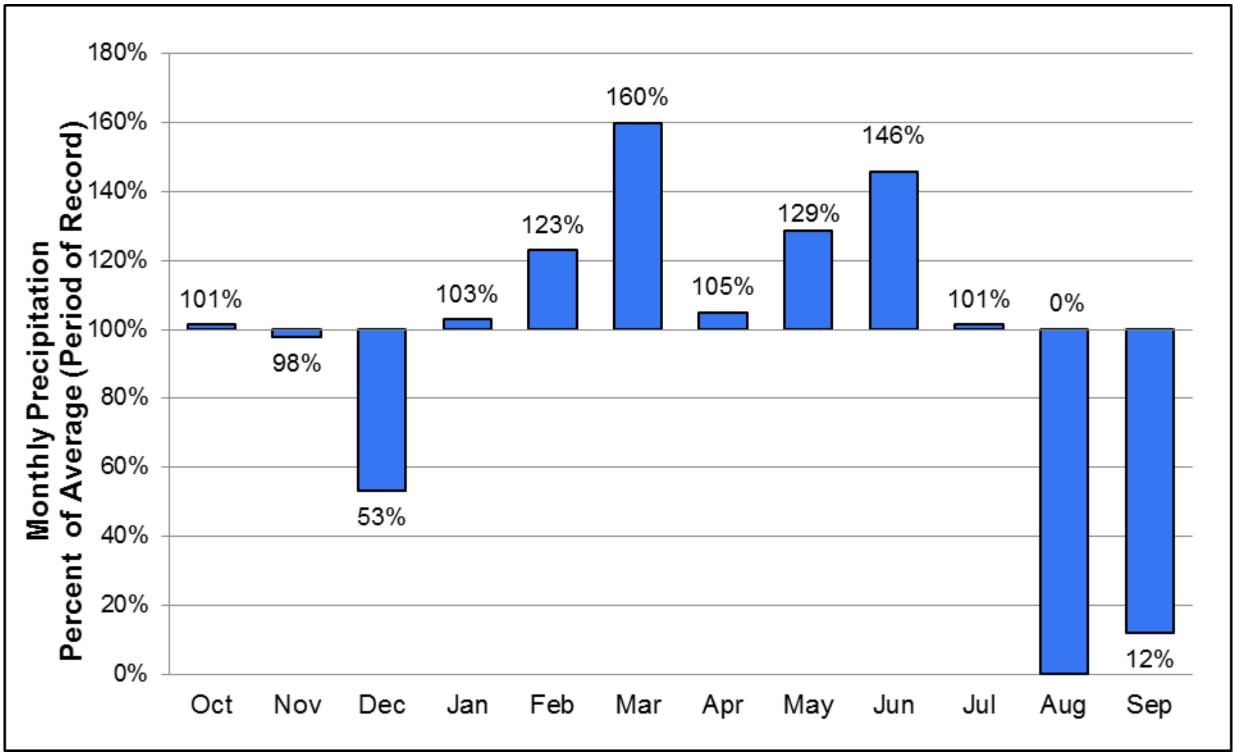

Figure E-3. Percent of average precipitation for period of record (1926-2001) at the Ohanapecosh NPS Station in Water Year 2012.

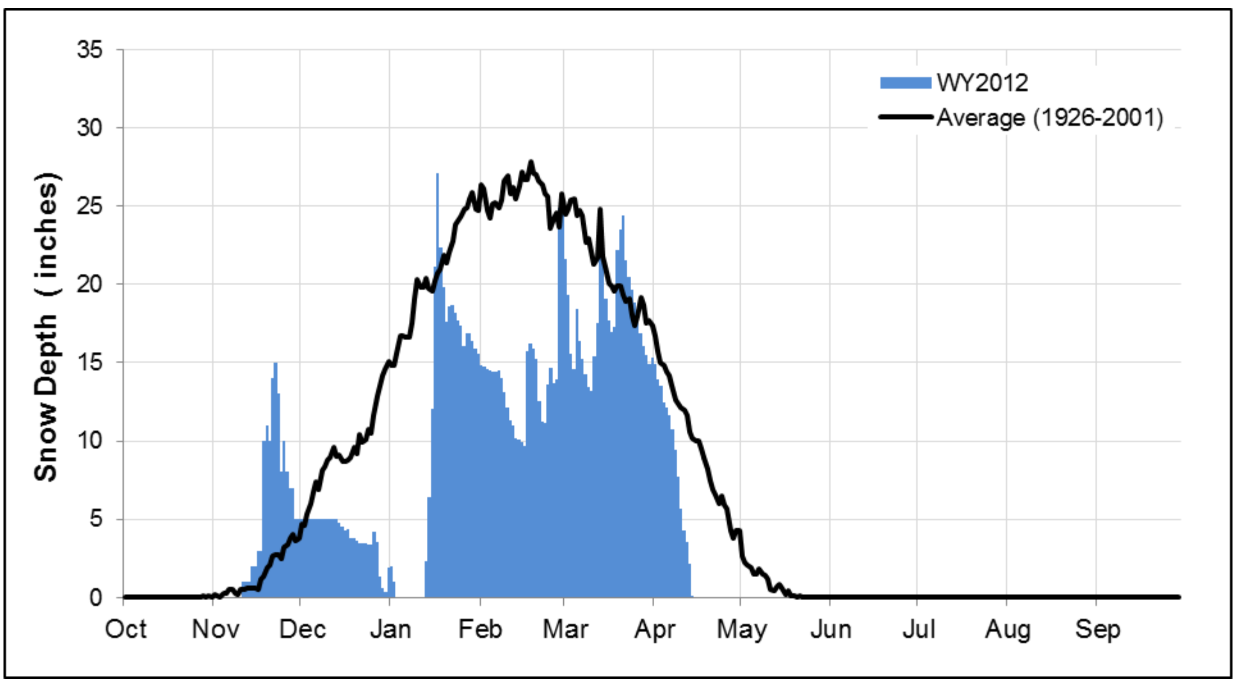

Figure E-4. Daily snow depth (inches) at the Ohanapecosh NPS Station, Water Year 2012, compared to the period of record daily average (1926-2001).

Appendix F: Paradise NWS COOP and SNOTEL - Water Year 2012.

Temperature, precipitation, and snowfall summaries from the Paradise COOP weather station for WY 2012 are shown in Tables F-1 and F-2 and Figures F-1 to F-6. Snow water equivalent summaries from the Paradise SNOTEL weather station for WY 2012 are shown in Figures F-7 and F-8.

Average annual temperature at the Paradise COOP was 38.3°F (Table F-1). Daily temperatures ranged from a low of 7.0 to a high of 79.0°F (Table F-2). Monthly average temperatures were cooler than average (1916-2010) in October and November followed by a warmer than average December and January. February through March was slightly cooler than normal with the exception of April, which was 1.8°F warmer than average. Temperatures in August and September reflected similar conditions as the rest of the park, with warmer than average conditions (Figure F-1). The coldest average daily of the year was January 16, with 16°F recorded (Figure F-2). September recorded the warmest average daily temperature of the year, 70°F on September 18th.

Total annual precipitation was 115.5 inches, 103% compared to the period of record (Figure F-3). The wettest dates of the year occurred between February 21 and 22 when Paradise received 8.1 inches (Figure F-5) of precipitation. The 2012 water year began with above normal snowpack due to an early November storm. By November 23, 65 inches of snow were on the ground. This was followed by a period of below average snow conditions that lasted until March (FigureF-4). A drier than average December led to a below average snowpack which remained below normal through January. By March, the snowpack started to build and remained above average through mid-July (Figures F-6 and F-7). The snowpack peaked on April 2 with 233 inches of snow on the ground and persisted until July 28, 2012.

Table F-1. Monthly summary table, Paradise COOP Station, Water Year 2012.

Season	Month & Year	Mean Air Temp °F	Mean Daily Max Air Temp °F	Mean Daily Min Air Temp °F	Precipitation (inches)
Fall	October 2011	38.6	44.1	33.2	8.1
	November 2011	27.9	33.8	22.0	18.3
Winter	December 2011	31.1	37.9	24.3	10.4
	January 2012	27.6	33.9	22.3	17.0
	February 2012	27.4	33.2	21.6	16.7
Spring	March 2012	27.3	34.4	21.3	17.2
	April 2012	34.9	42.8	28.4	8.5
	May 2012	39.8	48.8	32.4	8.1
Summer	June 2012	41.7	48.6	35.7	8.9
	July 2012	53.2	61.2	45.2	1.7
	August 2012	56.2	65.2	47.3	0.0
Fall	September 2012	53.5	62.2	44.9	0.5
Water Year		**38.3**	**45.5**	**31.5**	**115.5**

[a] Nine days of precipitation data, totaling 0.5 inches, were estimated from the Paradise SNOTEL due to missing data.

Table F-2. Air temperature extremes, Paradise COOP Station, Water Year 2012.

Date	Max Air Temp °F[1]	Date	Min Air Temp °F
August 6, 2012	79.0	January 18, 2012	7.0
August 18, 2012	79.0	March 22, 2012	7.0
July 9, 2012	78.0	February 27, 2012	10.0
July 10, 2012	78.0	November 20, 2012	11.0
August 5, 2011	78.0	March 6, 2012	11.0

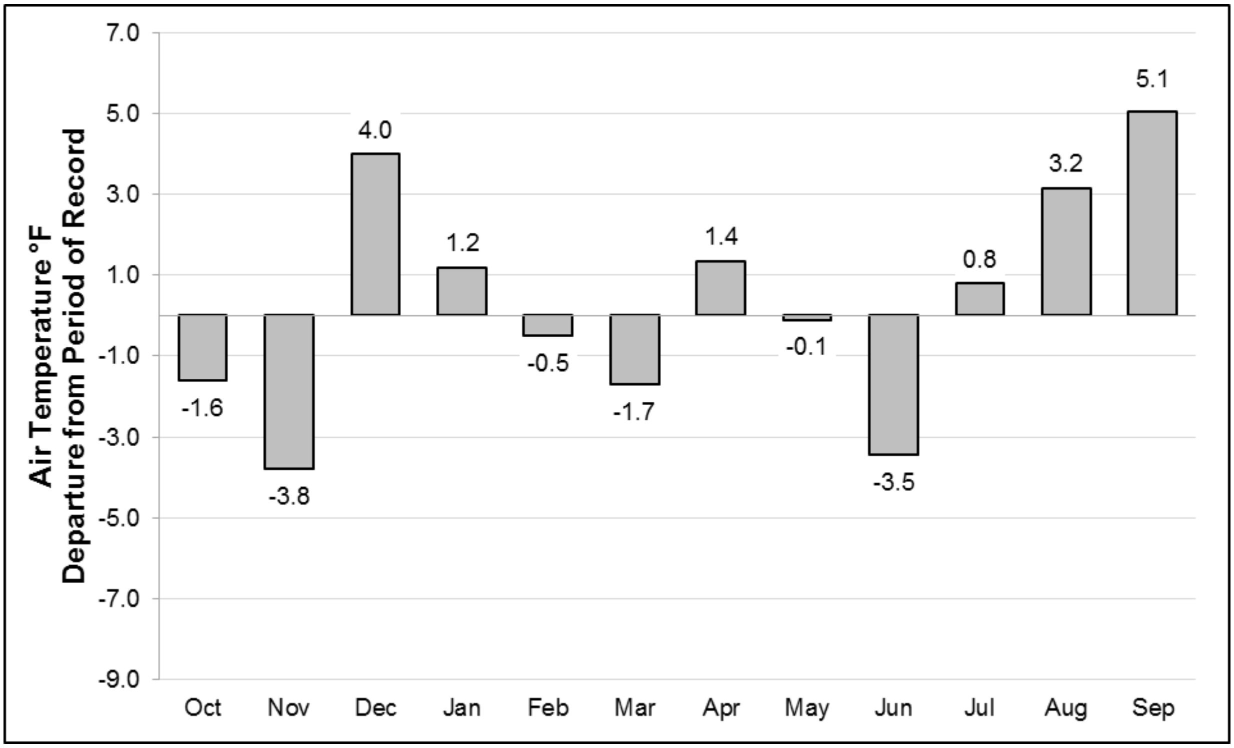

Figure F-1. Comparison of average monthly temperature (°F) for the Paradise COOP Station in Water Year 2012 against monthly averages for the period of record (1916-2011).

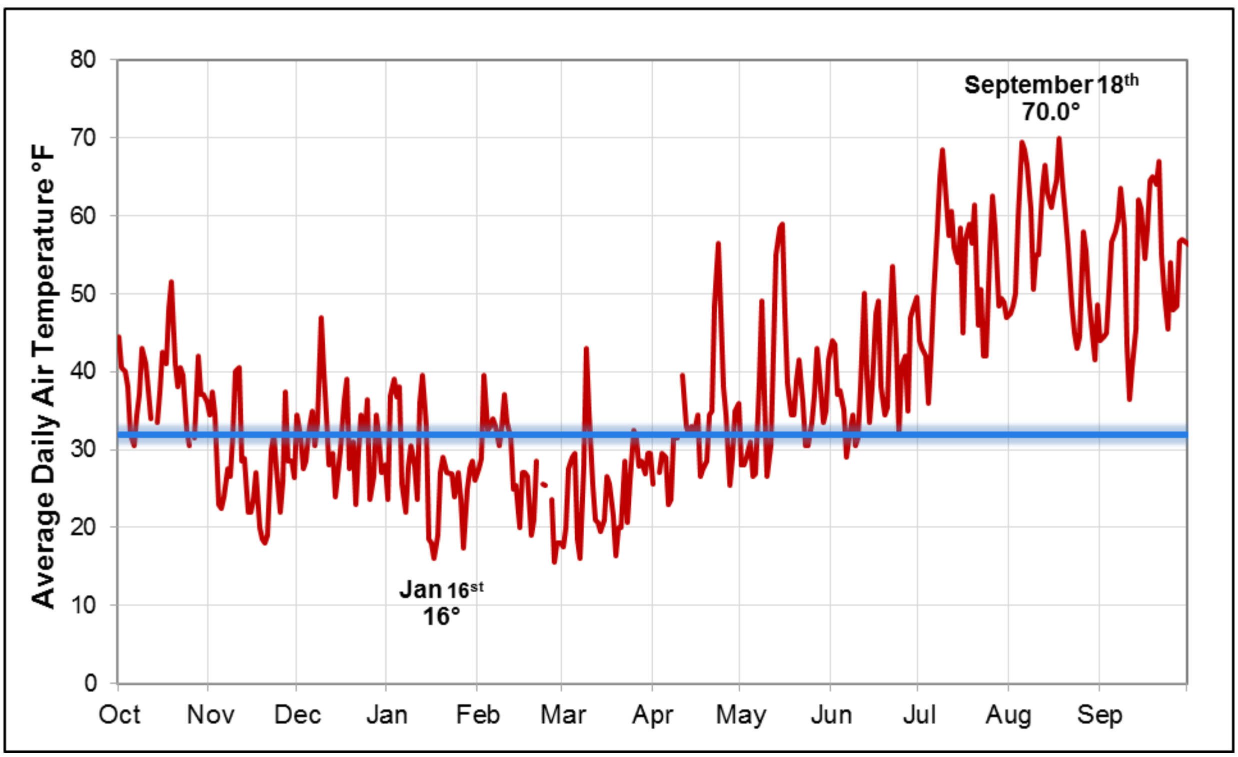

Figure F-2. Daily average air temperature (°F) at the Paradise COOP Station, Water Year 2012. Blue line indicates 32ºF, the freezing point of water.

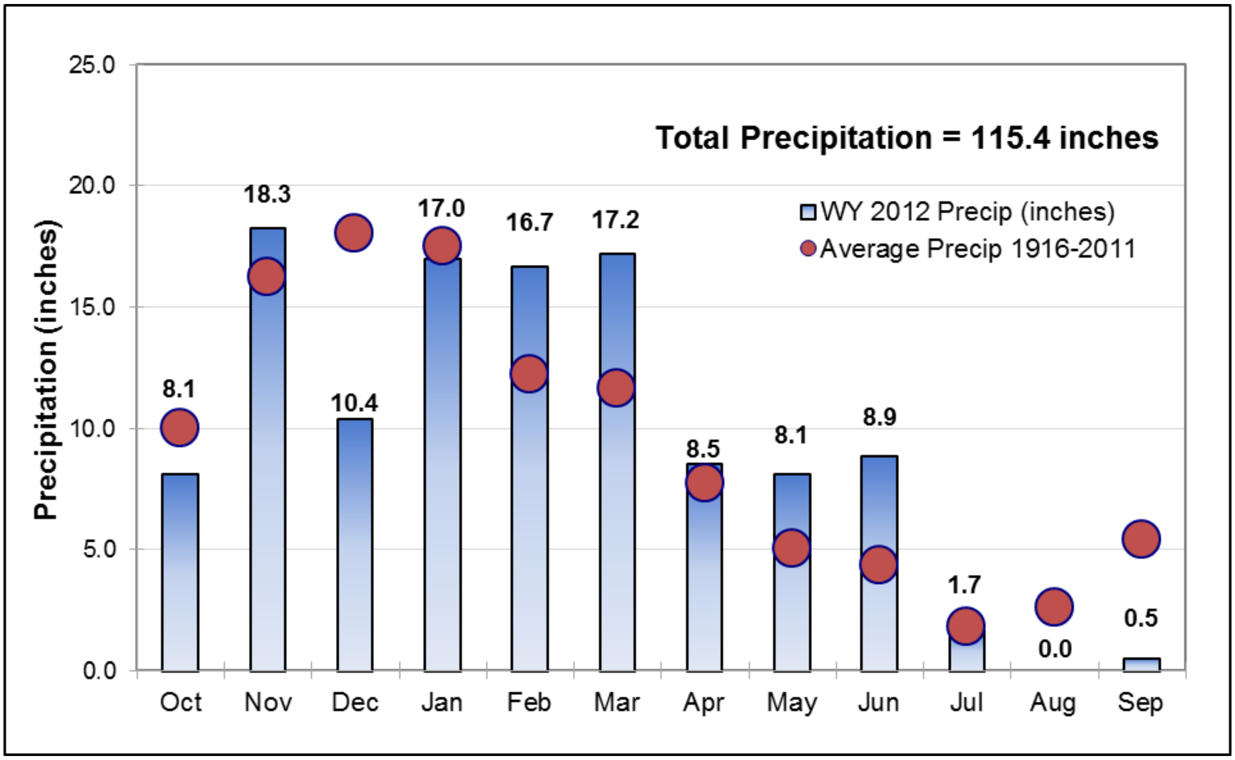

Figure F-3. Monthly precipitation (inches) at the Paradise COOP Station, Water Year 2012, compared to the monthly averages for the period of record (1916-2011).

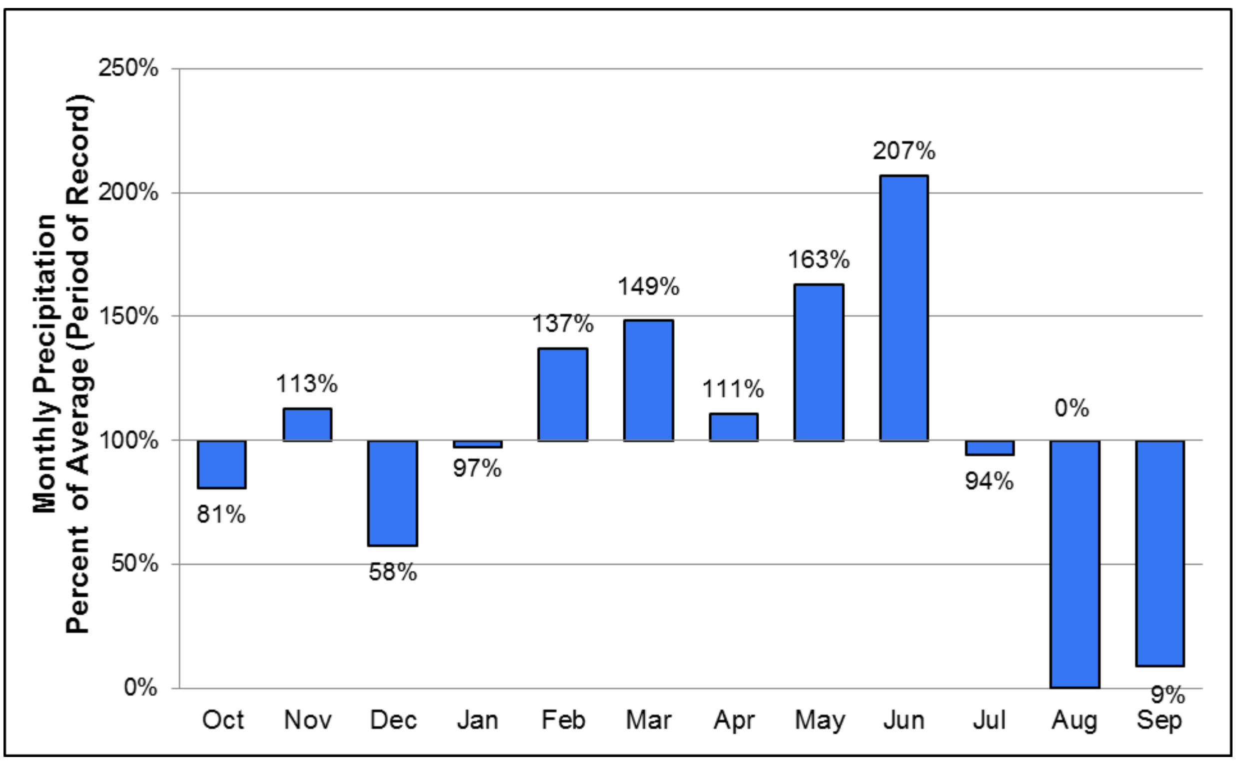

Figure F-4. Percent of average precipitation for the period of record (1916-2011) at the Paradise COOP Station in Water Year 2012.

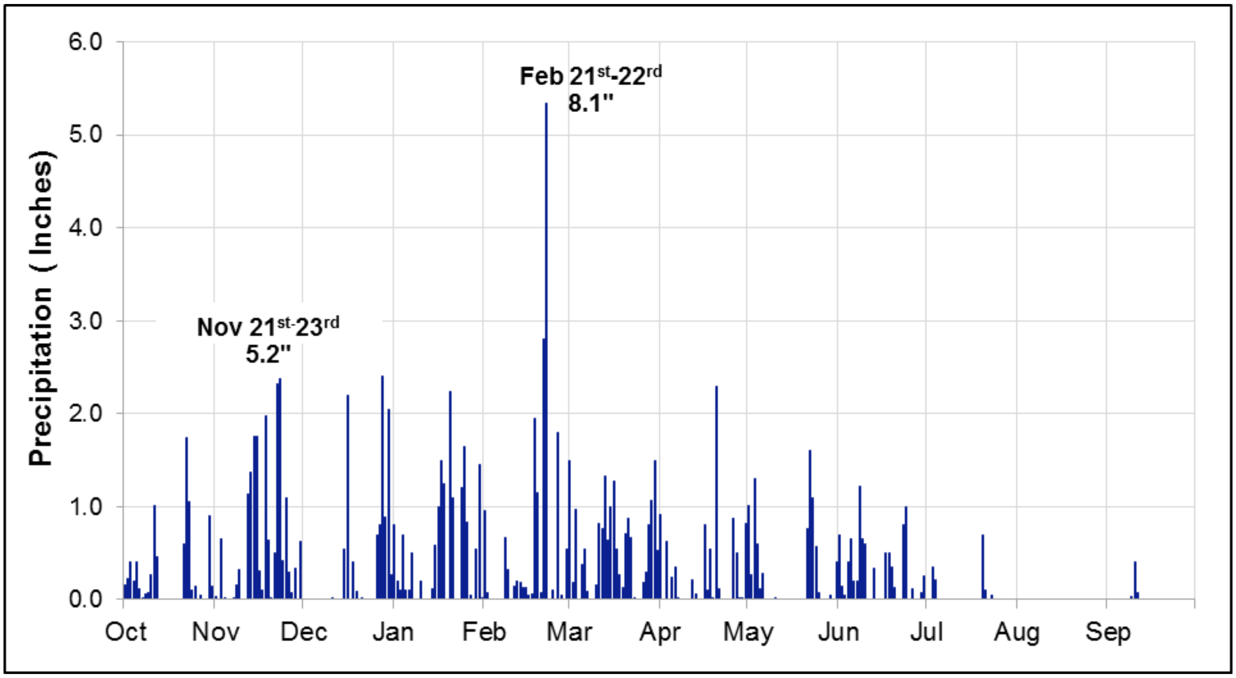

Figure F-5. Daily precipitation (inches) at the Paradise COOP Station, Water Year 2012.

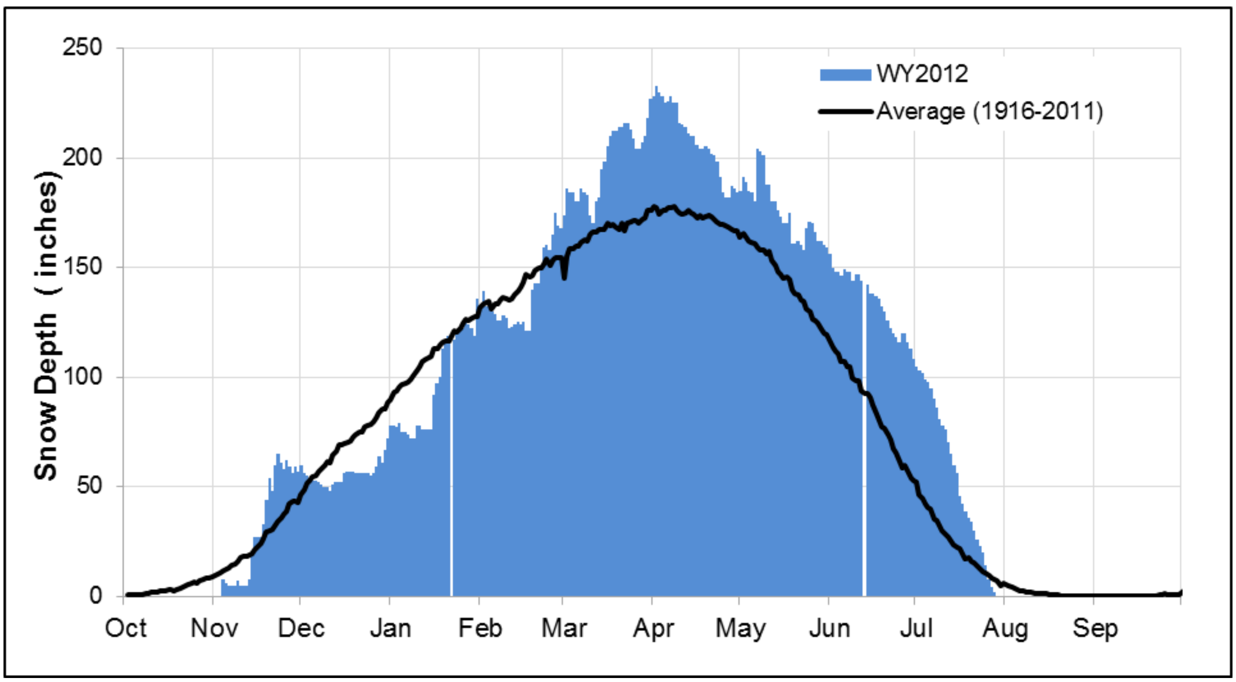

Figure F-6. Daily snow depth (inches) at the Paradise COOP Station, Water Year 2012, compared to the period of record daily average (1916-2011).

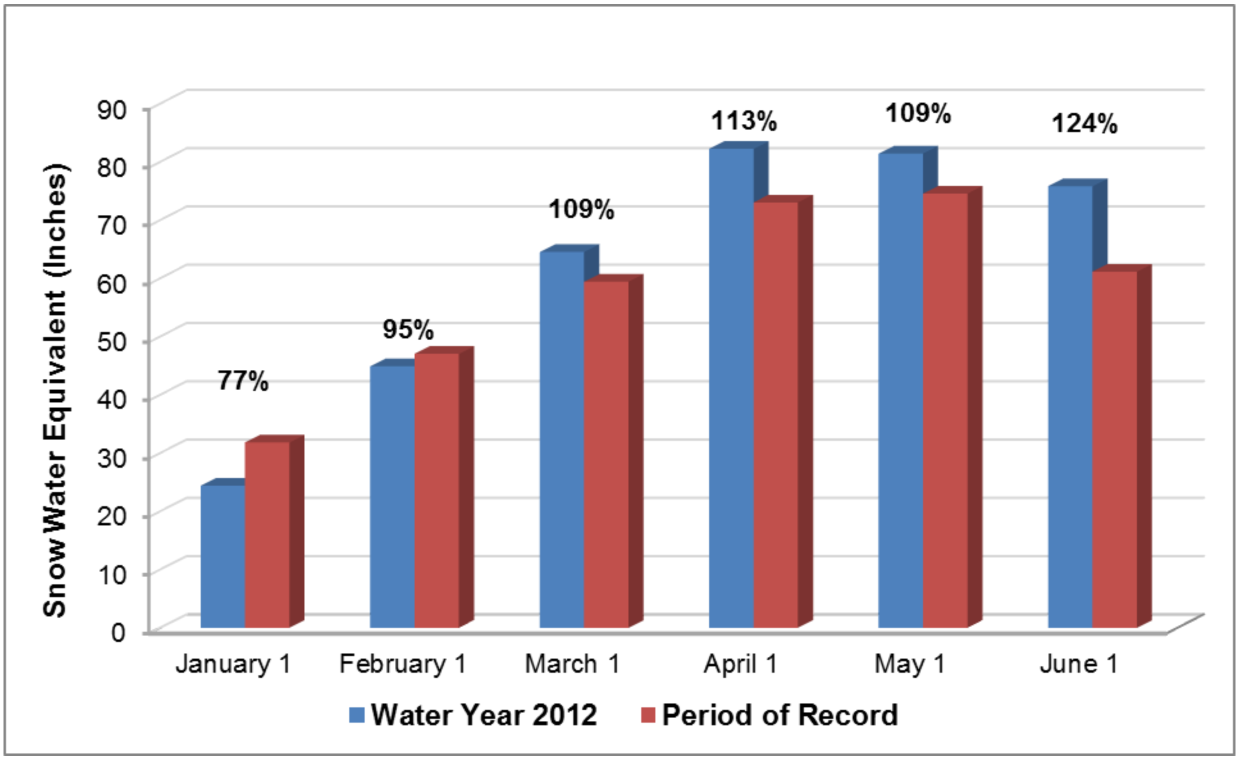

Figure F-7. First of the month snow water equivalent (inches) at the Paradise snow course in Water Year 2012, compared with the period of record (1940-2011).

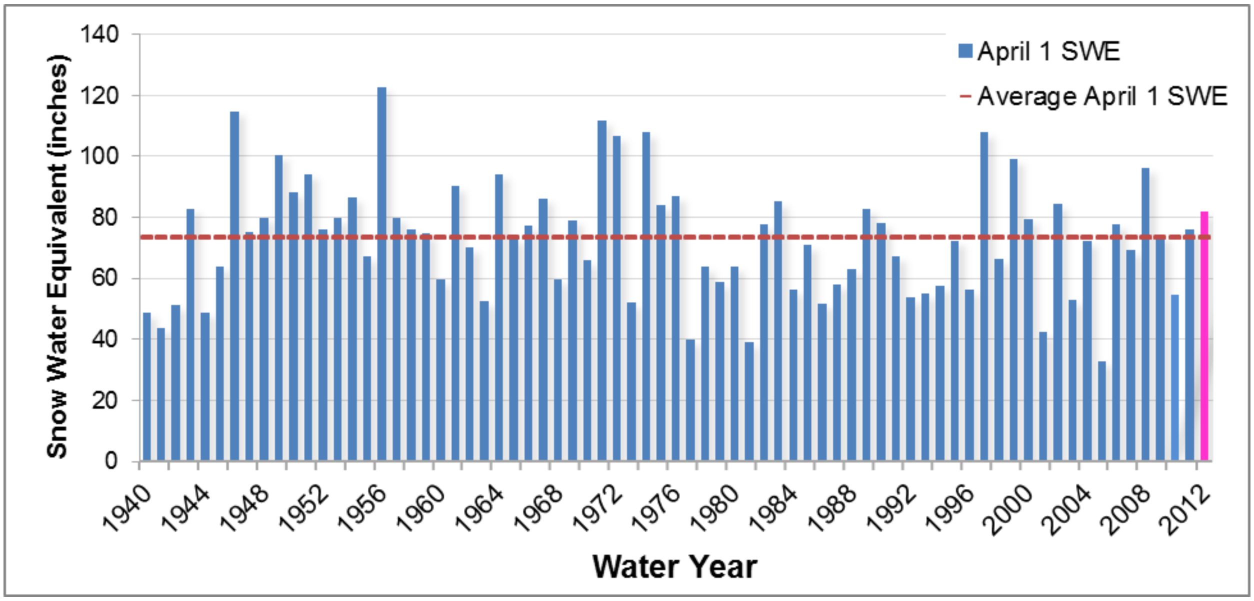

Figure F-8. April 1 snow water equivalent (inches) at the Paradise snow course for the period of record (1940-2012). Highlighted column indicates Water Year 2012.

Appendix G: Sunrise High Elevation – Water Year 2012

Temperature and snowfall summaries from the Sunrise High Elevation weather station for WY 2012 are shown in Tables G-1 and G-2 and Figures G-1 to G-3.

Average annual temperature at the Sunrise High Elevation station was 37.0°F (Table F-1). Daily temperatures observed at the Sunrise High Elevation station ranged from 4.3 to 79.7°F (Table G-2). Temperature departure from the period of record (2004-2011) reflects the cooler than average November followed by a warmer than average December at upper elevations (Figure C-1). These data also reflect the cooler than average January, February, and March and warmer than average August, and September (Figure G-1). The coldest day of the year was January 16, 2012 and the warmest day was August 18, 2012 (Figure G-2). The snowpack at Sunrise started out with above average depths in November, but remained below average during most of December and January (Figure G-3). Snowpack began accumulating on November 4, 2011 and melted July 10, 2010, persisting for 251 days.

Precipitation data are not available from the Sunrise High Elevation station. Power limitations restrict the use of a heated tipping bucket at Sunrise, and heavy winter precipitation and low temperatures have tested the limits of the existing precipitation system. We continue to evaluate alternative methods to capture year round precipitation at Sunrise.

Table G-1. Monthly summary table, Sunrise High Elevation Station, Water Year 2012.

Season	Month & Year	Mean Air Temp °F	Mean Daily Max Air Temp °F	Mean Daily Min Air Temp °F
Fall	October 2011	36.0	42.2	31.1
	November 2011	25.6	32.5	19.5
Winter	December 2011	30.5	37.6	24.0
	January 2012	26.6	33.7	19.8
	February 2012	25.2	31.6	20.2
Spring	March 2012	25.1	32.4	18.8
	April 2012	32.7	40.8	25.6
	May 2012	37.8	45.4	30.1
Summer	June 2012	40.7	48.1	34.0
	July 2012	54.1	63.3	45.5
	August 2012	56.3	66.4	47.7
Fall	September 2012	53.5	62.9	45.4
Water Year		**37.0**	**44.7**	**30.1**

Table G-2. Air temperature extremes, Sunrise High Elevation Station, Water Year 2012.

Date	Max Air Temp °F	Date	Min Air Temp °F
August 5, 2012	79.7	January 16, 2012	4.3
July 8, 2012	79.3	February 27, 2012	6.6
August 12, 2012	78.1	January 15, 2012	7.7
August 17, 2012	77.7	November 20, 2011	8.5
August 4, 2012	77.3	March 19, 2012	8.5

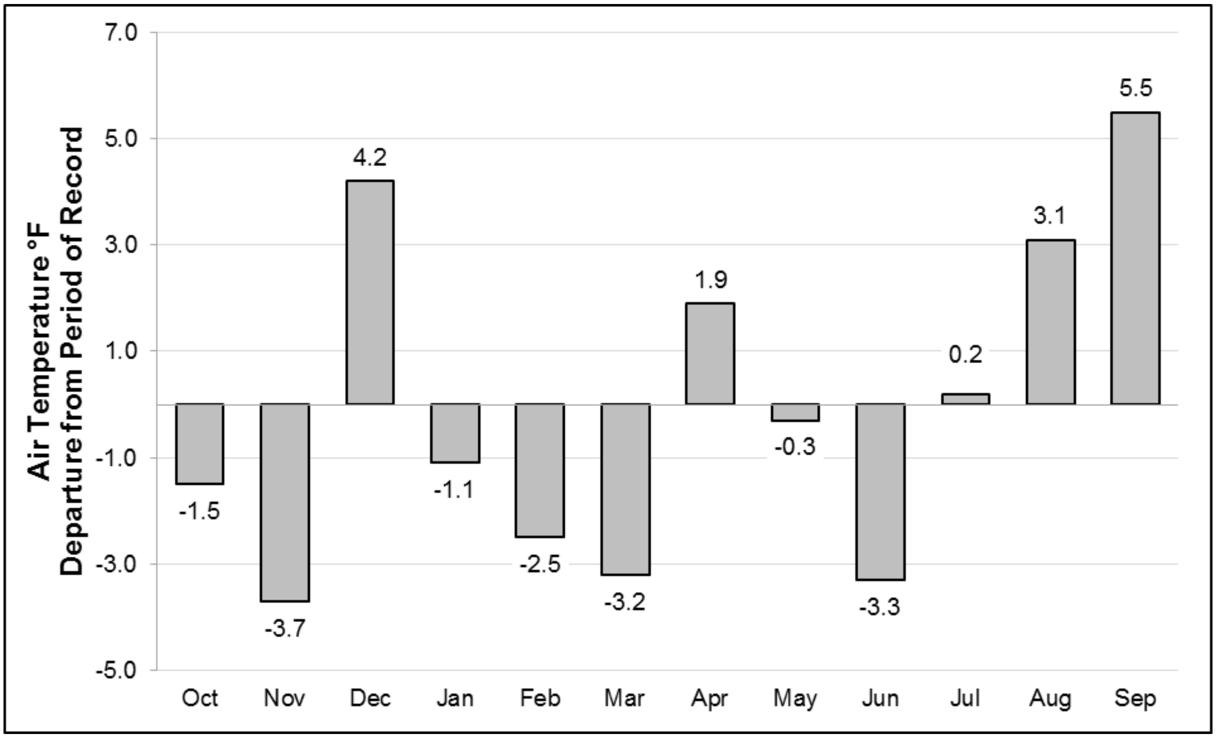

Figure G-1. Comparison of average monthly temperature (°F) for the Sunrise High Elevation Station in Water Year 2012 against monthly averages for the period of record (2004-2011).

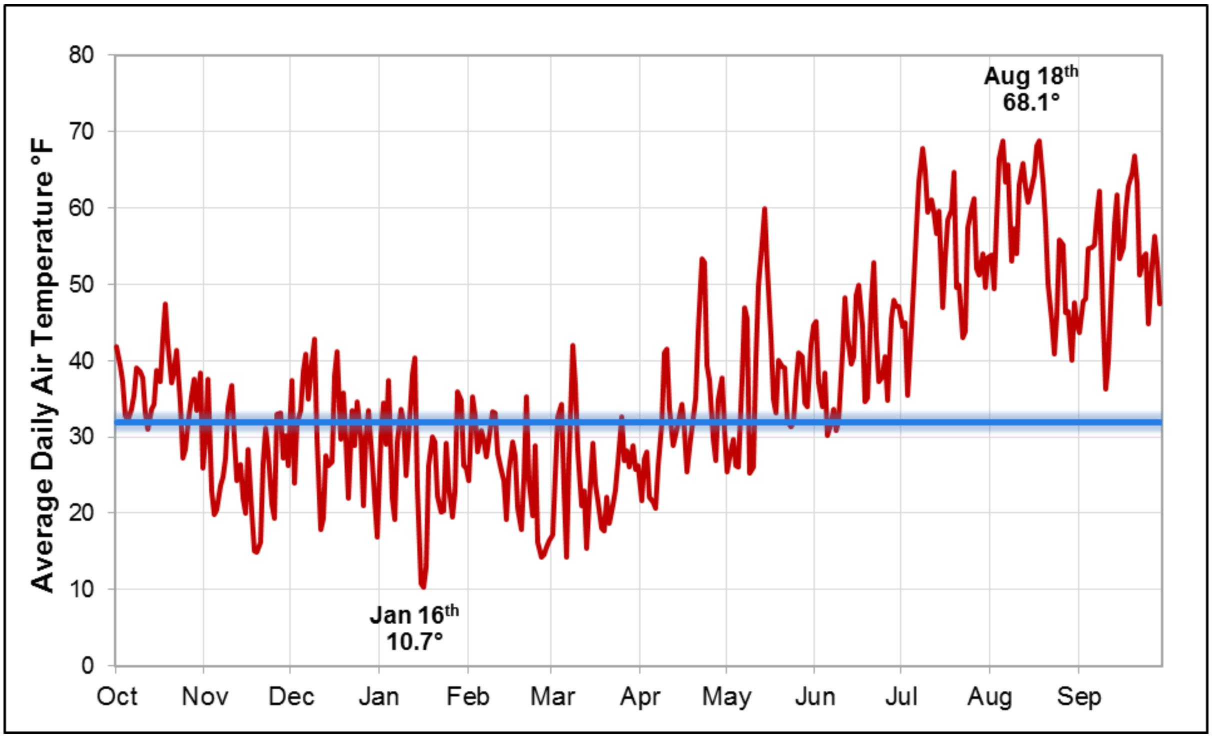

Figure G-2. Daily average air temperature (°F) at the Sunrise High Elevation Station, Water Year 2012. Blue line indicates 32ºF, the freezing point of water.

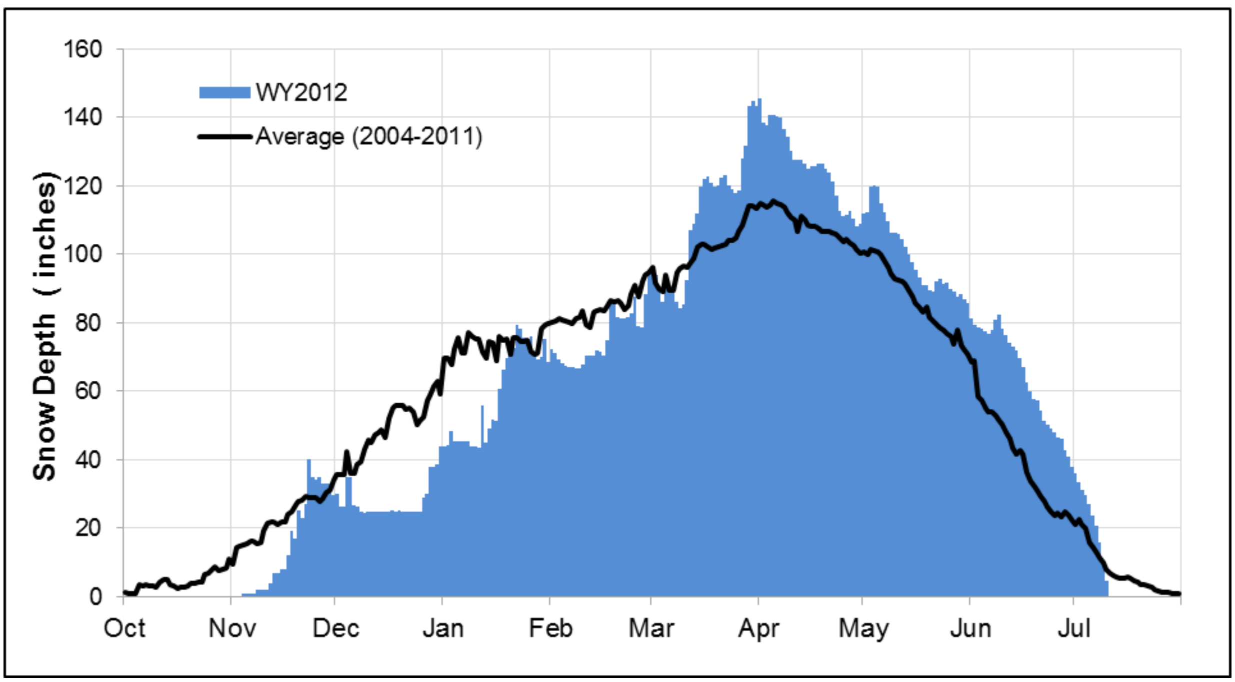

Figure G-3. Daily snow depth (inches) at the Sunrise High Elevation Station, Water Year 2012, compared with the period of record daily average (2004-2011). Twenty days of missing snow depth data in December and January were linearly interpolated from adjacent daily values.

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 105/126578, September 2014

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