National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Greater Yellowstone Network

2011 Climate Data Summary Report

Natural Resource Data Series NPS/GRYN/NRDS—2012/409

ON THE COVER
Recreational skiing at Grand Teton National Park on June 18, 2011. Photo credit: NPS, Grand Teton National Park

Greater Yellowstone Network

2011 Climate Data Summary Report

Natural Resource Data Series NPS/GRYN/NRDS—2012/409

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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.

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 received formal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data, and whose background and expertise put them on par technically and scientifically with the authors of the information.

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List of Acronyms

AGDD	Accumulated Growing Degree Days
BICA	Bighorn Canyon National Recreation Area
BOR	Bureau of Reclamation
COOP	Cooperative Observer Program
GHCN	Global Historical Climatic Network
GRTE	Grand Teton National Park
GRYN	Greater Yellowstone Network
I&M	Inventory & Monitoring
JODR	John D. Rockefeller, Jr. Memorial Parkway
NCDC	National Climatic Data Center
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NRCS	Natural Resources Conservation Service
NWS	National Weather Service
PDSI	Palmer Drought Severity Index
PRISM	Parameter-Elevation Regressions on Independent Slopes Model
RAWS	Remote Automated Weather Station
SNOTEL	Snowpack Telemetry
SPI	Standardized Precipitation Index
SWE	Snow Water Equivalent
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
WRCC	Western Region Climate Center
YELL	Yellowstone National Park

Introduction

This 2011 annual report is a descriptive summary of climate data from four national park units including Yellowstone National Park, Grand Teton National Park, John D. Rockefeller, Jr. Memorial Parkway and Bighorn Canyon National Recreation Area. The report focuses on five key climate metrics: temperature, precipitation, snowpack, drought, and streamflow. The annual report is part of a multi-network strategy for enhanced monitoring to better address rapid climate change in high elevation parks (Bingham et al. 2010). The reporting period is the 2011 calendar year (January-December) for temperature, precipitation, and drought, and the previous water year (October 2010-September 2011) for streamflow and snowpack.

The monitoring objectives for climate are described in the *Rocky Mountain Climate Protocol* (RMCWG 2010). These objectives, as they relate to annual status reports, are to determine the status of the following:

- Minimum, maximum, and mean monthly temperatures, and departures from "normal" or average
- Number of growing degree days per year, timing of first and last frosts, number of frost-free days per year, and number of days per year above or below critical temperature thresholds
- Total accumulated precipitation and departures from average
- Frequency and duration of drought based on established thresholds
- Amount and timing of peak snowpack measured as snow water equivalent
- Number of days with snow cover and timing of snowmelt
- Timing and intensity of peak and average streamflow and departures from average and other seasonal shifts in stream hydrographs

The condition of park natural resources is linked, directly and indirectly, to the climate of a region. The summaries in this report comparing 2011 data to a climatic reference period provide information park managers can use to help understand climatic conditions and effects relating to park planning and operations. Indications of drought and a subsequent increase in fire danger may lead park managers to close areas or change policies regarding fires within the park. By understanding and isolating the effect of climate it becomes possible to discern the effects of other, possibly anthropogenic, drivers of change (RMCWG 2010).

Methods

The *Rocky Mountain Climate Protocol* for the Greater Yellowstone and Rocky Mountain Networks outlines the procedures for station selection and methods used to acquire, quality control, archive, and process climate data used for annual status and periodic trend reporting (RMCWG 2010). For this annual status report we have selected stations with consistent, long-term, and high-quality data and stations that provide adequate spatial representation for the reporting area as suggested by Kittel et al. (2010).

Source and Availability of Provider Data

Data covering the 2011 calendar and water years were obtained from national meteorological and surface water monitoring programs listed in Table 1. Data from these programs were obtained through a variety of online sources. The climate stations from each data source, including the name, station ID, park, and location are further described in Appendix A. Figures 5 and 12 show map locations of key climate and gauge stations in the Greater Yellowstone Network (GRYN).

Table 1. National and state climate monitoring programs used in the 2011 climate report.

Program	Measures and metrics of interest	Spatial scale	Temporal scale
National Weather Service Cooperative Observer Program	Temperature, precipitation	Local stations	Daily
U.S. Department of Agriculture Natural Resource Conservation Service Snowpack Telemetry	Precipitation, SWE	Local stations	Hourly
U.S. Geological Survey Stream Gauging Network	Streamflow	Local stations	Hourly
Oregon State University PRISM Climate Group	Temperature, precipitation	4 km grid	Monthly
U.S. Drought Monitor	Drought	National, State, Region	Weekly
Bureau of Reclamation Hydromet	Lake elevation	Local station	Daily

Note: SWE=snow water equivalent; PRISM=Parameter-elevation Regressions on Independent Slopes Model.

Daily precipitation and maximum/minimum temperature data were pulled directly from the Global Historical Climatology Network (GHCN) which came on board in 2011 as a replacement product to access the National Climate Data Center (NCDC) Cooperative Observer Program (COOP) data sets. The GHCN fills a critical need for historic daily temperature, precipitation, and snow records over global land area and is a composite of climate records from numerous sources that were merged and then subjected to a suite of quality assurance reviews by National Oceanic and Atmospheric Administration (NOAA). The archive includes over 40 meteorological elements including temperature daily maximum/minimum, precipitation, and more. Additional details are available online at http://www1.ncdc.noaa.gov/pub/data/ghcn/daily/readme.txt.

Daily snowpack data from the Natural Resources Conservation Service (NRCS) stations were obtained from a Climate Web Interface designed by Principal Investigator Mike Tercek through a NPS Desert Southwest Cooperative Ecosystems Study Unit task agreement with Sonoran Institute. In September 2012, the web interface URL was: www.ClimateAnalyzer.org.

In 2012 the web interface was in its developmental and proof-of-concept phase for the distribution of climate data in standardized graphical and tabular formats. During the summer 2012 about 60 weather stations were running on the site which handles National Weather Service COOP data, NRCS Snowpack Telemetry (SNOTEL), GHCN daily data, Remote Automated Weather Station (RAWS) data, and U.S. Geological Survey (USGS) stream gages. These data sources, except RAWS, which is not used in this report, are further described in Appendix A. In the fall of 2012, GHCN, USGS stream gage, and NRCS SNOTEL data are updated every 24 hours to provide current data. Data from 2010 through 2012 were used to produce daily Snow Water Equivalent (SWE) figures presented in park-wide climate briefs and to obtain tabular data used to calculate and produce graphics showing SWE on June 1 compared with average SWE on June 1. In both cases, data from the 2012 water year were used in these figures to put the 2011 climate year into perspective.

Regional gridded monthly climate datasets were obtained from the Oregon State University Parameter-Elevation Regressions on Independent Slopes Model (PRISM) project to produce maps showing departures from average conditions at a regional scale. These datasets give a wall-to-wall representation via a statistical modeling technique that interpolates precipitation and temperature values between actual climate observation stations while also accounting for the effects of aspect and elevation. For more information, see http://www.prism.oregonstate.edu/.

Data were downloaded from the U.S. Drought Monitor (http://droughtmonitor.unl.edu/) to map drought intensity across the GRYN. Drought Monitor is a program that syntheses multiple drought indices and impacts. Drought intensity is classified based on the Palmer Drought Severity Index (PDSI), Standardized Precipitation Index (SPI), soil moisture, streamflow, and other indicators of drought such as vegetation health, groundwater levels, and SWE. Drought intensity is expressed on a scale ranging from abnormally dry (D0) to severe drought (D2) in Figure 20, which shows drought intensity in 2010 and 2011. For more drought information, visit http://droughtmonitor.unl.edu/.

Bighorn Lake daily elevation data were obtained directly from the Bureau of Reclamation (BOR) Hydromet (http://www.usbr.gov/gp-bin/arc050_formpl?BHR (Accessed September 8 and 28, 2012).

Quality Control of Provider Data

Much of the data quality control is completed by the provider before it is available to the public for download. Basic data quality control by the NOAA, NRCS, and USGS prevents obvious errors and provides flags for known issues such as estimated versus actual values in original data. PRISM's level of internal quality control permits direct use of the gridded data without additional quality checking.

Additional investigations by the GRYN were conducted to evaluate missing data and resolve data quality flags in GHCN COOP records. The Climate Data Screener and Summarizer version

4.4 (Tercek 2012) was used to generate a series of diagnostic plots that allow the user to visually inspect data for outliers and logical inconsistencies. The Climate Data Screener and Summarizer are available at http://www.yellowstoneecology.com/research/COOP_data.html.

We use a set of decision rules recommended by climatologists (Kittel et al. 2010) to determine whether enough data of sufficient quality is available by month and by year to reliably compute summary statistics. For example, if more than three days of precipitation data are missing for a particular month, then a monthly total is not calculated and the entire month is reported "missing." If more than five days of mean daily maximum temperature (Tmax) or mean daily minimum temperature (Tmin) are missing then monthly average temperatures are not calculated or reported. Figure 1 shows four months with more than three missing days of precipitation data at Lake Yellowstone COOP station in 2011.

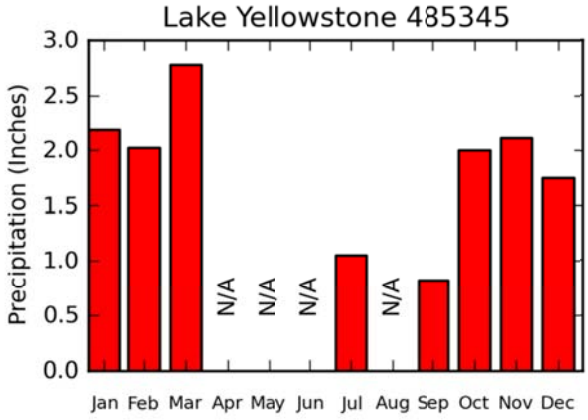

Figure 1. Missing days in the climate record at the COOP station Lake Yellowstone in 2011 precludes the ability to compute reliable monthly and annual precipitation totals.

Our quality control procedures discovered and corrected two types of errors. In both cases, original data forms (B-91 forms from the National Weather Service) were obtained to check and correct data values or to fill missing data values. At Old Faithful (station ID 486845) we discovered three instances of minimum temperatures exceeding maximum temperatures in March and April (see Figure 2). In no circumstances can these values be logical, so the data were rejected before the monthly and annual summaries were calculated. Our investigations also found that most precipitation data were missing from Yellowtail Dam (station ID249240) when temperature data were present. The Bureau of Reclamation COOP observer at this station was interviewed by phone (Webner, pers. comm., 2012) to confirm that days with zero precipitation were left as blank fields on the data sheet. These blank fields were interpreted as missing data in GHCN, so we corrected our data file for Yellowtail Dam to change the missing data to a zero precipitation value.

The original and corrected data sets were maintained as separate files and bundled for distribution and archival with this report in the NPS Data Store. Because quality control for status reporting is considered "mid-level" rather than exhaustive, all data reported here are subject to revision if subsequent data releases with corrected values become available from an original provider.

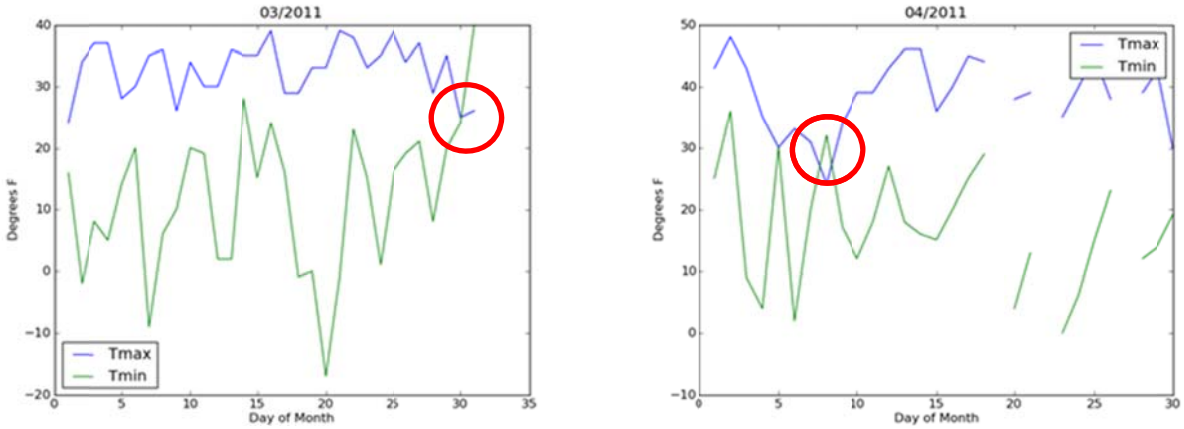

Figure 2. Transposed data most likely explains these instances of minimum temperatures exceeding maximum temperatures at Old Faithful COOP station in 2011.

Averages Used for Statistical Comparisons

In reporting climate conditions, meteorologists and climatologists regularly use normals for placing recent climate conditions into a historical context (NOAA 2012). In this report we try to use the World Meteorological Organization's suggested climate normals ("averages") from the latest three decades, the 1981-2010 period, to put recent climatic conditions into a historic context. Depending on the purpose, or source of the published normal, other baseline periods are also used. For example, the USGS reports average annual run-off values based on the period of record for the gage station. In early 2012, many agencies and organizations had not yet published normals for the 1981-2010 period. Consequently, a combination of 1971-2000 and 1981-2010 averages are used in this report. Appendix A, Tables A1-A4, show the data source and average period for each data type used in this report.

The reference period for comparing 2011 precipitation and temperature observations from COOP stations is the 1981-2010 average published by the NOAA National Climatic Data Center (NCDC). Averages for this period were released from the NCDC in July 2011 replacing the older 1971-2010 product. Comparisons between the 1971-2000 and 1981-2010 normals that demonstrate differences between the two time periods are shown in Figures 3 and 4. The normals (averages) published by NOAA were not designed to be metrics of climate change, consequently "care must be taken when interpreting changes between one normals period and the other" (NOAA 2012).

Averages for the first and last freeze and frost dates, accumulated growing degree days and the number of days exceeding certain thresholds for COOP stations were obtained from General Climate Summary Tables published by the Western Regional Climate Center. The reference periods for these variables are the period of record and will vary by station.

Averages for NRCS SNOTEL data vary by parameter. Published average monthly precipitation values for the 1981-2010 reference period were not available from NRCS at the time of this report, so average statistics were calculated manually by adding together the total precipitation values for each month and then dividing by the number of months. Average monthly values were not calculated for SNOTEL stations that had more than three years of missing data during the

1981-2010 period. Temperature averages are not used in this report because of data quality issues (Kittel et al. 2010). Average daily SWE for the 1981-2010 period were also unavailable, so we used the published average values for the 1971-2000 period instead. Average SWE values on June 1 for the reference period 1981-2010 were calculated manually for SNOTEL stations active during this time period, otherwise averages were calculated for the period of record, which happens to be 2000-2010. Table A2 provides a complete list of SNOTEL stations used in this report and the reference period used to determine average condition.

Averages for USGS gauging stations are two-fold: averages used to determine the percent of average annual runoff are published by the USGS in their 2011 Water-Data Reports and are based on the period of record (i.e., consistent uninterrupted record). Averages used to determine the historical discharge at gauge stations had not been released from the USGS so were based on the previous 30-year period (1971-2000).

Averages for the 1971-2000 PRISM dataset published by the PRISM group at Oregon State University were obtained on-line at: http://www.prism.oregonstate.edu/.

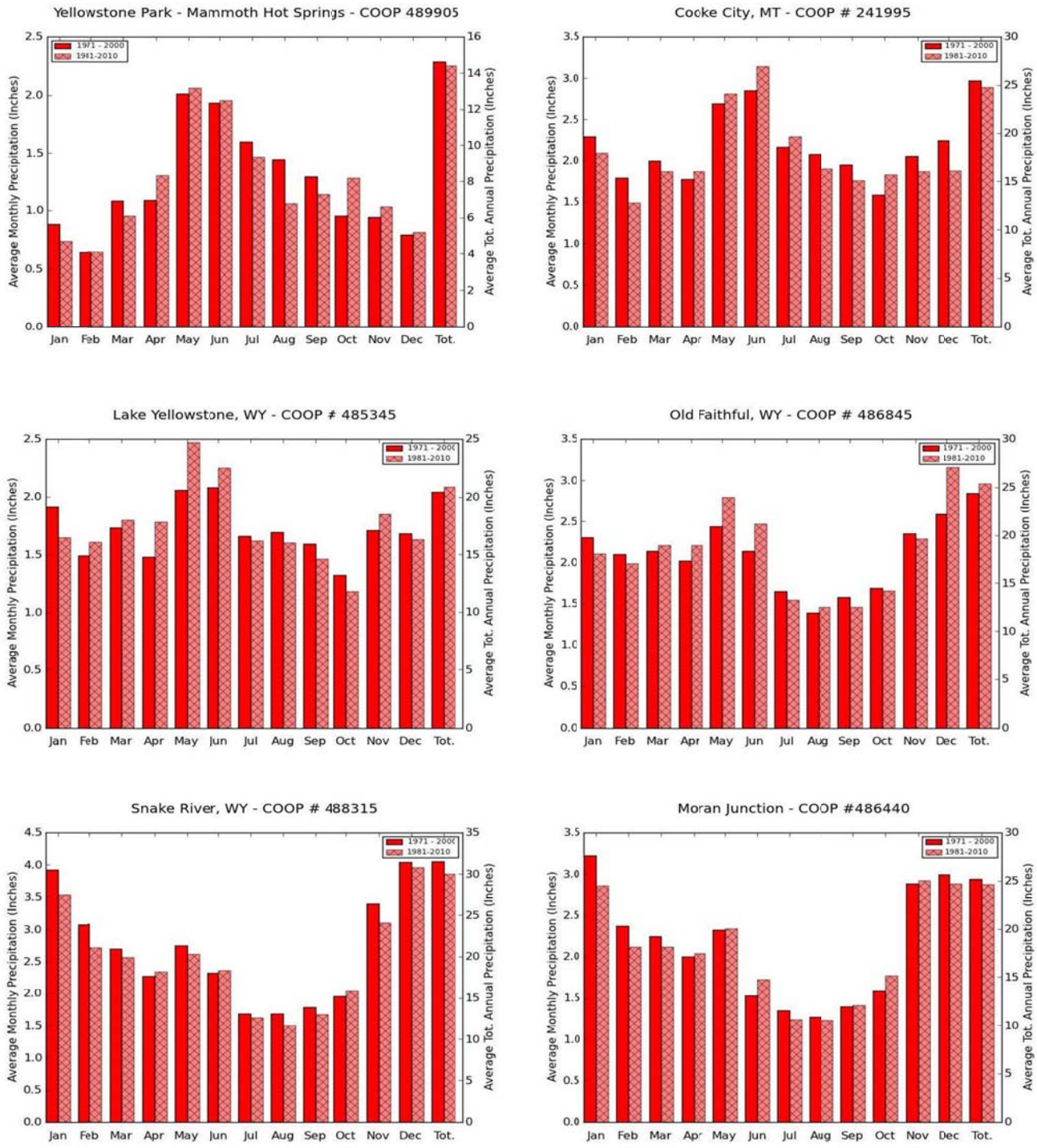

Figure 3. Comparison of the 30-year normals for 1971-2000 (solid bars) vs. 1981-2010 (hatched bars) average monthly precipitation at six weather stations in the Greater Yellowstone Area. Note that annual average totals are on the right axis and monthly averages are on the left axis.

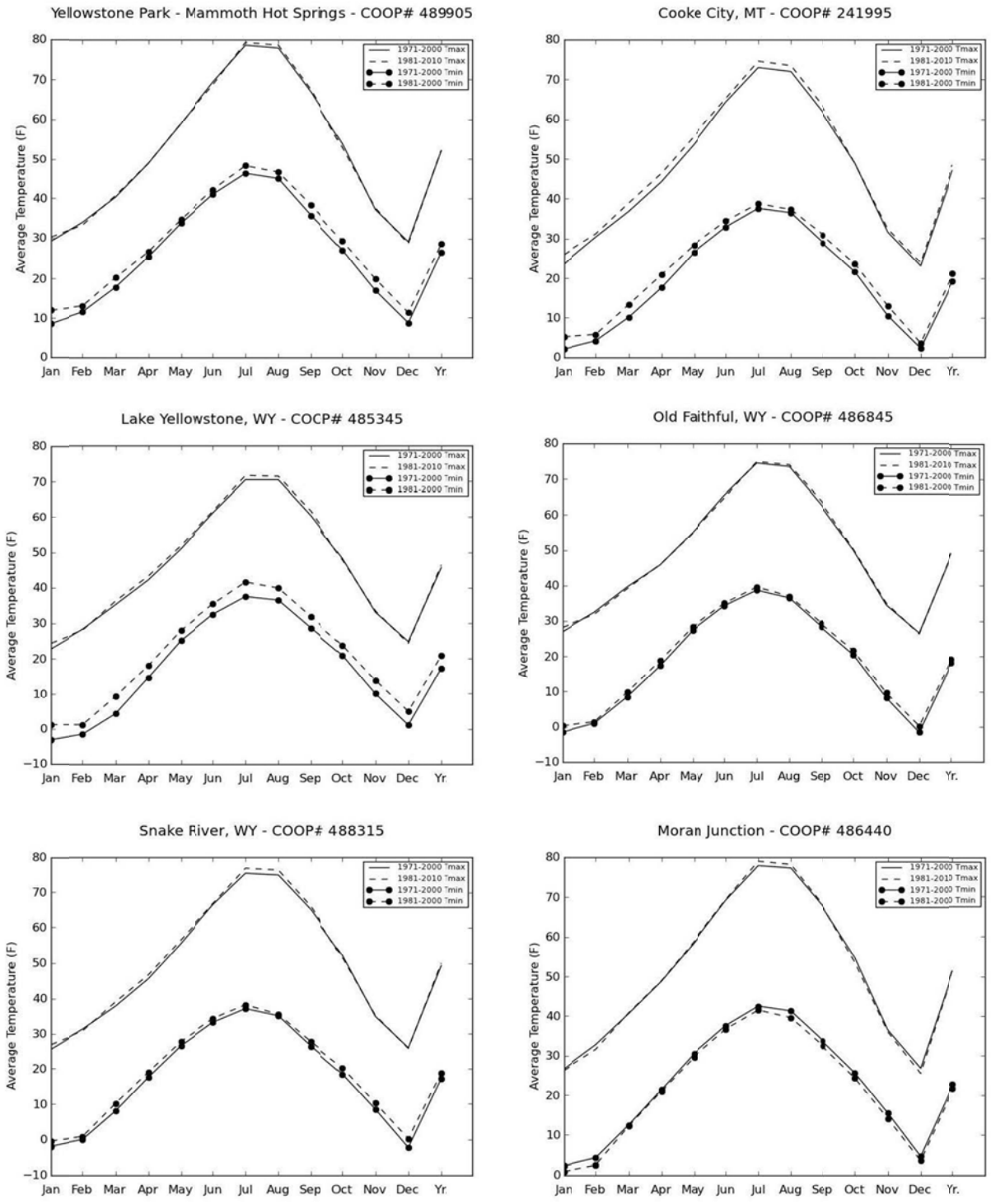

Figure 4. Comparison of 30-year normals for 1971-2000 (solid line) vs. 1981-2010 (dashed line) average daily maximum temperatures (Tmax) and average daily minimum temperatures (Tmin) at six weather stations in the Greater Yellowstone Area.

Data Analysis Methods and Criteria

Most of the summary analysis for this report was completed using the *Climate Data Screener and Summarizer version 4.4* (Tercek 2012) and the Climate Web Interface (Tercek 2012) written to automate the production of annual climate status reports using criteria from Kittel et al. (2010) and the *Rocky Mountain Climate Protocol* (RMCWG 2010). The summarizer is a stand-alone program with a simple user interface to read and process data from GHCN, RAWS, COOP, SNOTEL, and USGS stream gauges. The summarizer program outputs graphs and tables for monthly averages/totals and their departure from 30-year averages, accumulated growing degree days (AGDD), first and last dates of freeze and frost, and the number of days above or below the threshold temperatures 0°F, 32°F, 80°F, and 90°F.

Monthly and annual precipitation totals were calculated from daily COOP and SNOTEL station data and compared with 1981-2010 average values. Average monthly and annual minimum and maximum temperatures were calculated from daily COOP station data and compared with 1981-2010 averages. Daily discharge data from USGS were plotted over the water year to show peak discharge and current midpoint of discharge compared to average.

Precipitation data from COOP and SNOTEL stations were combined into climate zones to show departure of 2011 precipitation from 1981-2010 averages. Climate zones are groups of weather stations having internally consistent seasonal or long-term temporal patterns. The cluster analysis approach used by Tercek et al. (2012) for climate zone delineation in the Greater Yellowstone identified two climate zones (Zones 1 and 2), each containing one subzone (1A and 2A). Zone 1 and 1A weather stations have their greatest preciptation during summer months, and Zone 2 and 2A have their greatest precipatation in the winter.

Results

The results from the annual climate data summary for Yellowstone and Grand Teton national parks (including John D. Rockefeller, Jr. Memorial Parkway) are presented first followed by Bighorn Canyon National Recreation Area.

John D. Rockefeller Jr. Memorial Parkway and Grand Teton and Yellowstone National Parks

2011 Climate at a Glance

- The year stands out as having above average snowpack late in the spring and lasting longer than average into the summer.
- The wet winter and spring coupled with cooler than average springtime temperatures left snowpack 600% of average on June 1 in many places.
- Snowmelt was delayed and flooding was sustained over a period of several weeks as the snow melted in June and July.
- Total annual run-off in 2011 was 130-146% of average on the Yellowstone at Corwin Springs and the Snake River at Moose.
- Total annual precipitation ranged from 80% of average (1980-2010 period) at Mammoth to 120% at Moose.
- Average annual minimum and maximum daily air temperatures were cooler than average overall.
- By the end of the 2011 water year on September 30, Grand Teton and Yellowstone National Parks were 100% free of drought.

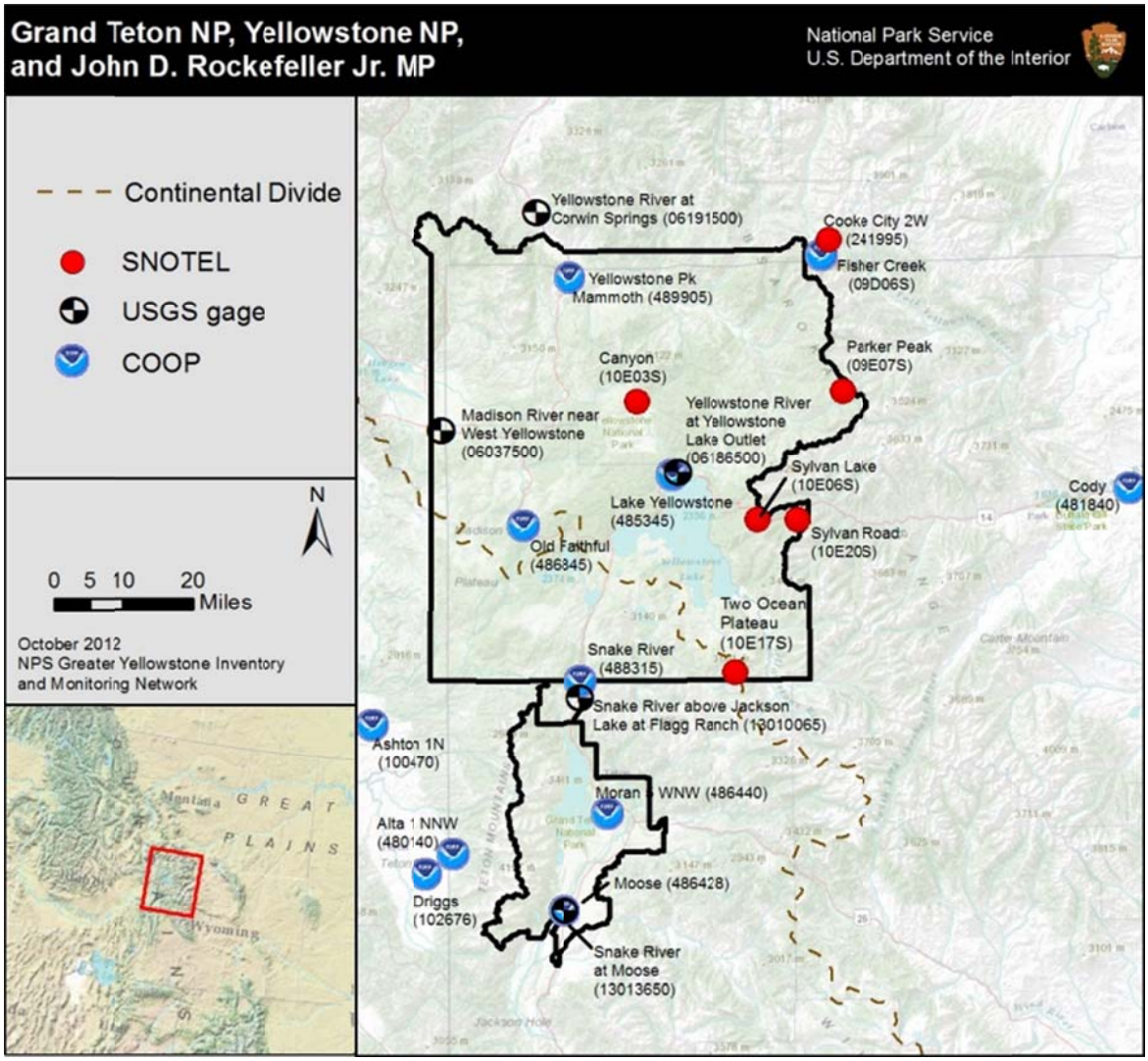

Figure 5. Map showing key climate and stream gauge stations in or near Yellowstone and Grand Teton National Parks and John D. Rockefeller, Jr. Memorial Parkway in northwestern Wyoming, southern Montana, and Eastern Idaho.

Temperature

Average annual maximum air temperatures were -0.37°F to -3.16°F cooler than average during 2011. Maximum air temperatures were notably cooler April through June, turning warmer than average July through October. Average annual minimum air temperatures were near average to -2°F cooler than average during 2011. Maximum and minimum temperatures were especially cooler than average during April through June. At Moose, minimum air temperatures remained cooler than average during the summer and by November and December minimum temperatures had dropped to 7°F-8°F below average. At Yellowstone Park Mammoth, summer minimum air temperatures warmed to above average in July and were 1°F-4°F above average until November. Figure 6 displays temperature and precipitation for weather stations at Moose and Mammoth. Tables B1-B3 in Appendix B displays mean monthly temperatures and departures from average.

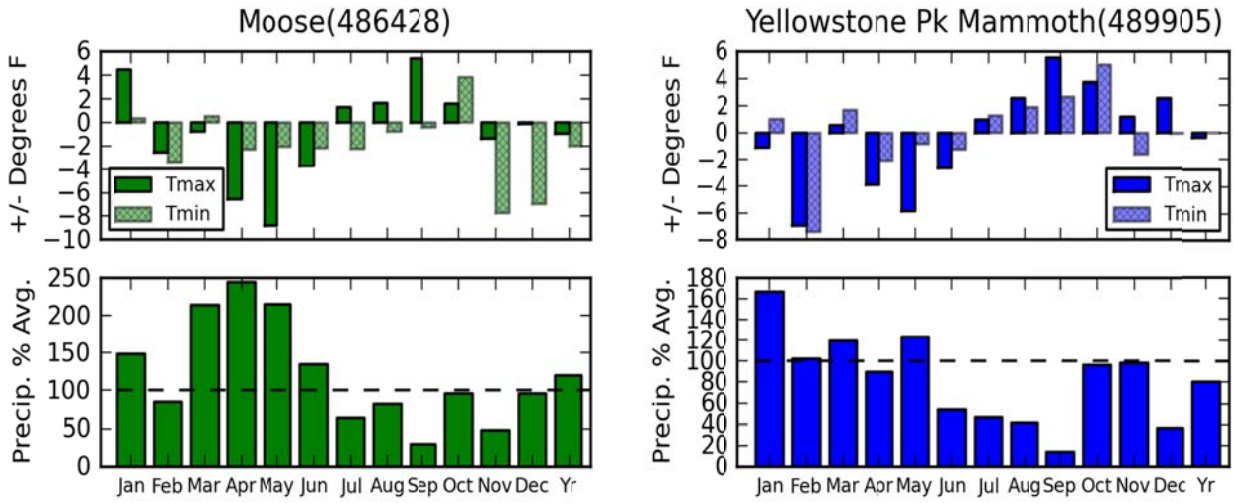

Figure 6. Departure of 2011 average minimum (Tmin) and average maximum (Tmax) daily temperatures and precipitation from 1981–2010 average at COOP stations in Grand Teton and Yellowstone National Parks. Horizontal line depicts average condition.

The onset of spring (i.e. the last date when temperatures drop below 28°F) was early at most weather stations, but later than average at Moose, Snake River, and Ashton. An extended period of summerlike nighttime minimum temperatures into October delayed the onset of fall, when temperatures drop below 28°F. The number of days that air temperatures exceeded 90°F was fewer than average, except at Cody, which had three days higher than average. The number of nights with air temperatures dropping below 32°F were about seven days fewer than average at most stations. Table B4 in Appendix B shows first and last freeze and frost dates, accumulated growing degree days, and days above or below critical temperatures for key stations in the area.

Precipitation

In 2011, total annual precipitation was 80% of average at Yellowstone Park Mammoth and 120% of average at Moose (Figure 6). Winter precipitation was mostly above average and in March, conditions were 150-200% above average. Summer precipitation was below average, and in September, monthly precipitation was only 0-25% of average. Precipitation values that are averaged across zones are shown in Figure 7. Monthly and annual precipitation values and departures from average, expressed as a percentage, are shown in Table B1 in Appendix B.

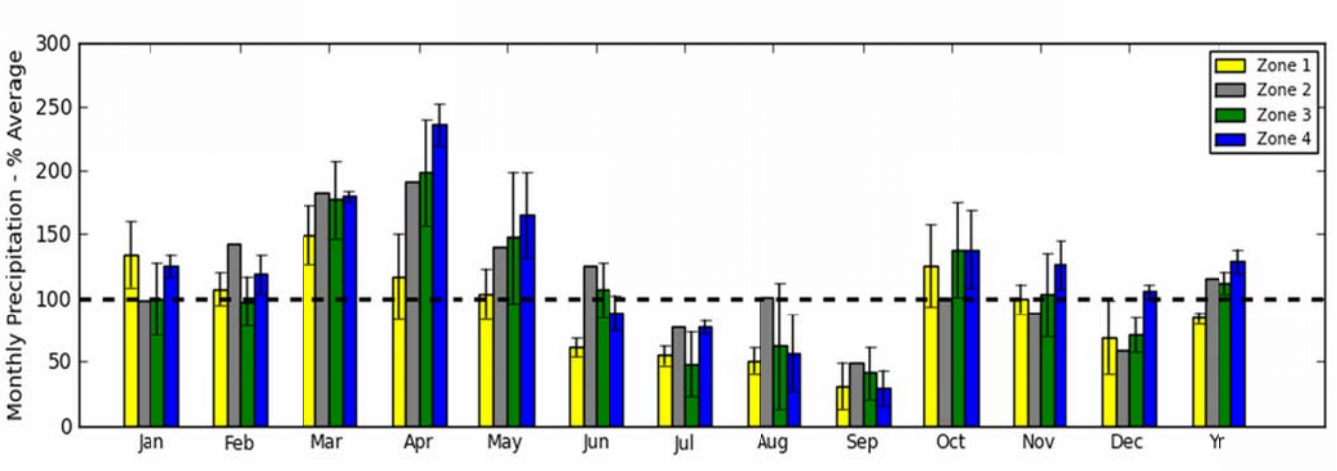

Figure 7. Departure of 2011 precipitation from 1981-2010 average by climate zone. Zones are groups of stations with similar climates. Zone 1=Cooke City, Lake Yellowstone, Yellowstone Park Mammoth; Zone 2 (1A)=Alta; Zone 3 (2)=Moose, Moran, Old Faithful, Snake River, Fisher Creek and Canyon; Zone 4 (2A)=Parker Peak, Sylvan Lake, and Sylvan Road. The horizontal line depicts average condition. Bars indicate one standard error of the mean. Zone 2 is represented by one station, therefore no error bars are included.

Winter Snowpack

The climate of 2011 stands out as having above average snowpack late in the spring and lasting longer than average into the summer. As measured in terms of snow water equivalent (SWE)—the amount of liquid water held in a given volume of snow—snowpack measured at SNOTEL stations were well above average during the 2011 water year. In comparison, the 2012 water year was far below average (Figure 8).

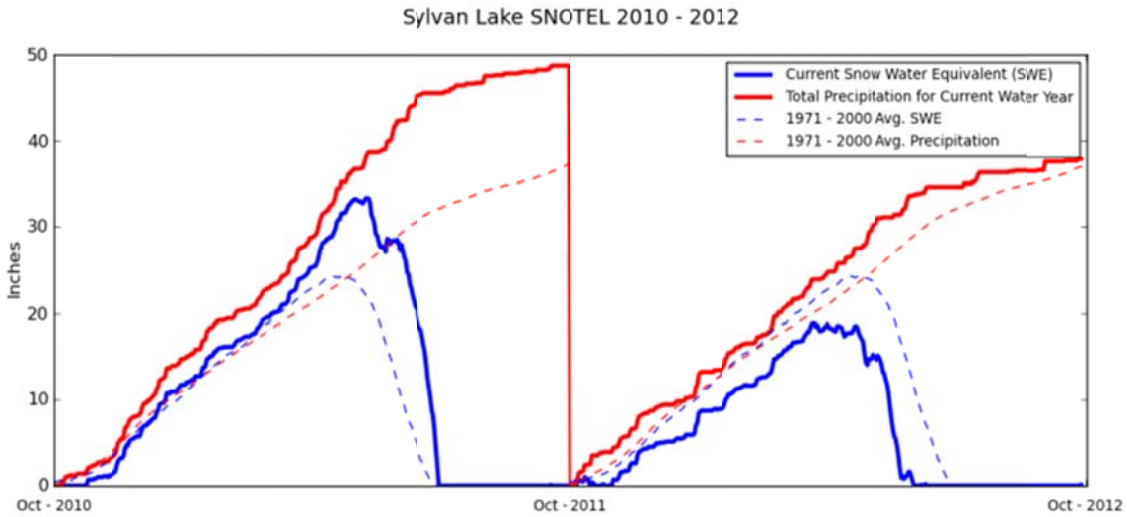

Figure 8. Daily measurements of snow water equivalent (SWE) and total cumulative precipitation from Sylvan Lake SNOTEL station covering the period from October 2009 to October 2012. Values are compared to averages from the 1971–2000 period. The water year runs from October 1 to September 30, therefore, total precipitation (red line) is reset to zero on October 1 each year.

The wet winter and spring coupled with cooler than average temperatures April through May created snowpack that exceeded 600% of average on June 1 at Sylvan Lake (Figure 9). In contrast, snowpack was near average on June 1, 2012 at some SNOTEL stations was below average at Sylvan Lake. Also in 2011, the normal transition from winter to spring to summer was substantially delayed when a series of mountain snow storms in June added to the snow depth, elevating the avalanche danger and prompting Grand Teton park rangers to issue a news release asking visitors to use extreme caution in the backcountry (NPS 2011a).

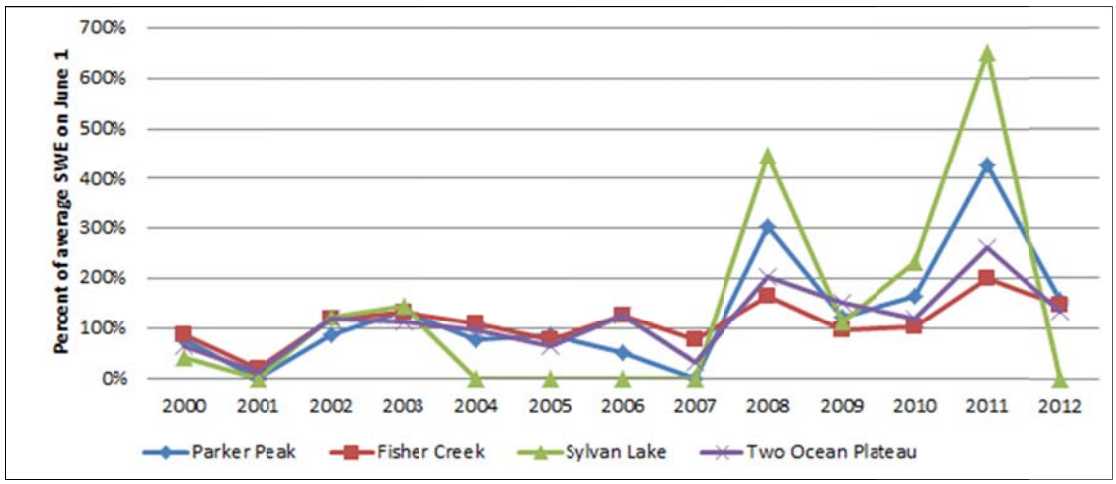

Figure 9. Percent of average snowpack (snow water equivalent (SWE)) on June 1 at four SNOTEL stations in the Greater Yellowstone Area. Provisional data courtesy of the Natural Resource Conservation Service.

Streamflow

The USGS monitors streamflow at key locations along the Yellowstone and Snake Rivers in Montana and Wyoming in 2011. Mean daily discharge was above average beginning April 1 at Moose from mid-May forward on the Snake River at Flagg Ranch and the Yellowstone River at Corwin Springs. In the mountainous areas, the normal transition from winter to spring to summer was substantially delayed due to cooler than average springtime temperatures and peak daily discharge attained maximum discharge volume one to two weeks later than average (Figure. 10), and well above average (Figure 11). At Moose, levels of peak discharge were sustained for several weeks during the summer prompting Grand Teton to assemble a high-water incident management team (NPS 2011b). Total annual runoff was 108-152% of average (see Table 2).

Figure 10. Flooding along the Snake River floodplain in June 2011. Photo credit: NPS Grand Teton NP.

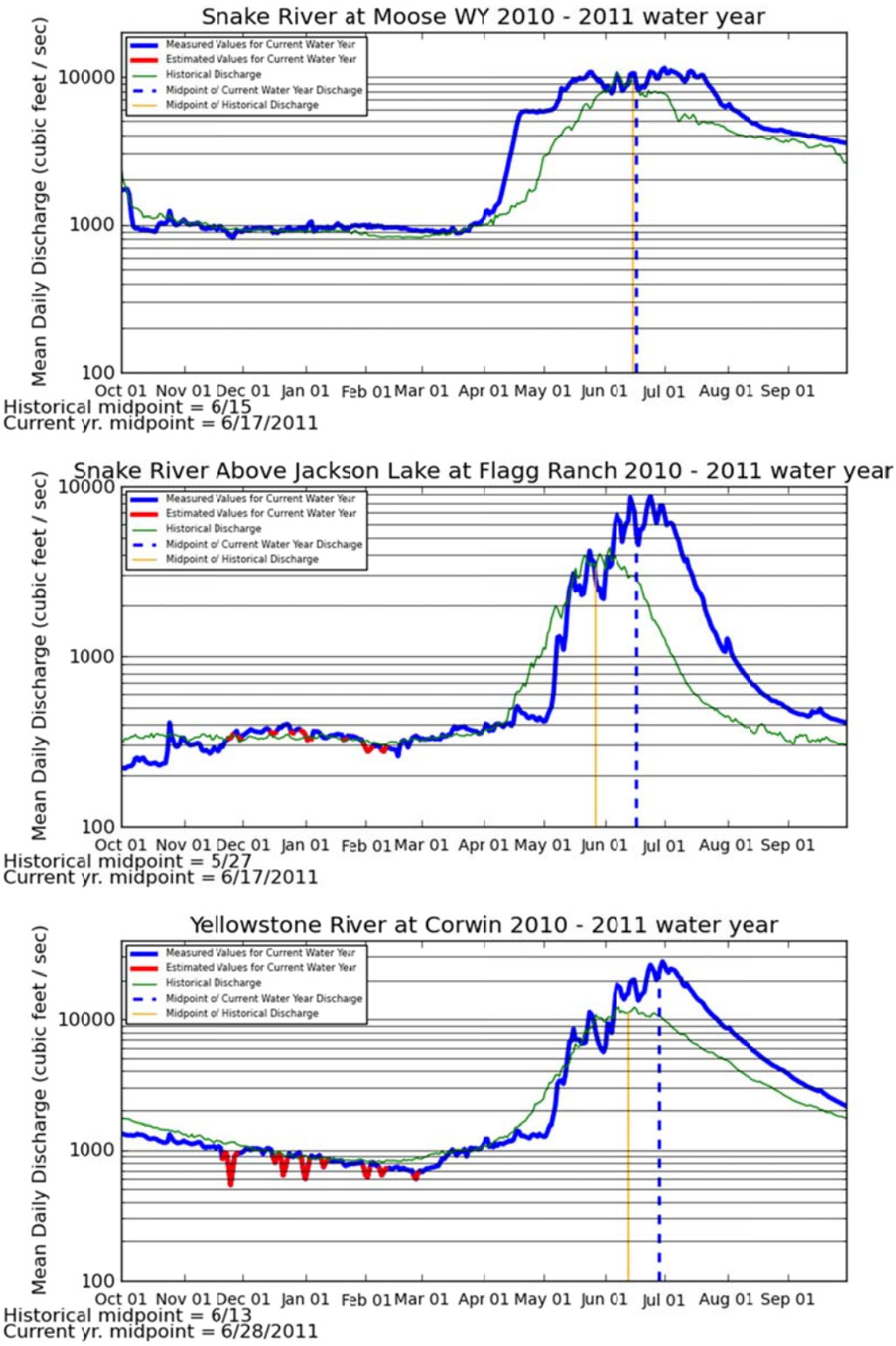

Figure 11. Mean daily discharge from the USGS gauging stations on the Snake River at Moose and Flagg Ranch, and the Yellowstone River at Corwin Springs. Values are compared to averages from the 1971-2000 period.

Table 2. Total annual runoff in acre-feet and percent of average for select USGS Gauge Stations in or near Grand Teton and Yellowstone National Parks and John D. Rockefeller Jr. Memorial Parkway 2011. Average time period is based on the period of uninterrupted record.

Station Name	Total annual runoff (ac-ft) 2011	Total annual runoff (ac-ft) average	Percent of average	Average time period
Madison River	388,900	358,800	108%	1913-2011
Yellowstone River at Corwin Springs	3,303,000	2,261,000	146%	1984-2011
Yellowstone River at Yellowstone Lake Outlet	1,470,000	969,200	152%	1995-2011
Snake River at Moose	2,767,000	2,122,000	130%	1889-2011
Snake River above Jackson Lake	897,700	646,900	139%	1927-2011

Bighorn Canyon National Recreation Area

2011 Climate at a Glance

- Average annual maximum daily air temperatures were 1°F cooler than average at Lovell and 2.3°F cooler than average at Yellowtail Dam.
- Average annual minimum daily air temperatures were 1.2°F warmer than average at Yellowtail Dam and 1.3°F cooler than average at Lovell.
- The onset of spring, the last date when temperatures drop below 28°F, was 2-7 days earlier than average. The onset of fall, the earliest date when temperatures drop below 28°F, was two to three weeks later than average at Yellowtail and Lovell, respectively.
- Total annual precipitation ranged from 129% of average at Yellowtail Dam to 145% of average at Lovell.
- At Bald Mountain, maximum snowpack was nearly twice the average in 2011.
- Above average precipitation in May and June and rapid snowmelt led to higher than average peak flows on the Bighorn and Shoshone Rivers in June and July.

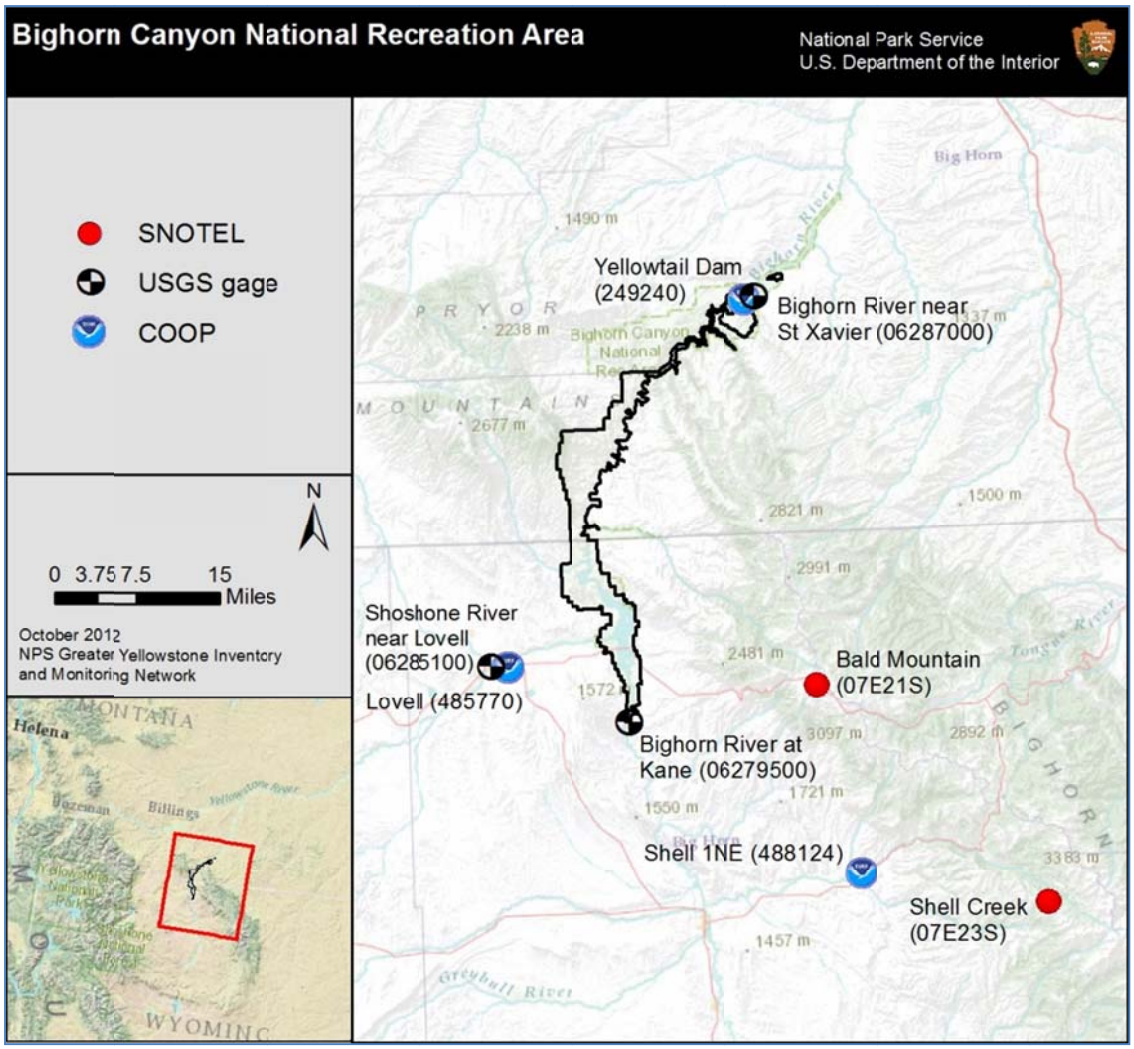

Figure 12. Map showing key climate and stream gauge stations in and near Bighorn Canyon National Recreation Area (NRA) in southeastern Montana and north-central Wyoming.

Temperature

When averaged across the entire 2011 calendar year, maximum daily air temperatures were 1°F to 2.3°F below average compared to the 1981-2010 period. Annual minimum daily air temperatures were 1.2°F above average at Yellowtail Dam and 1.3°F below average at Lovell (Figure 13). February through June was especially cold with daytime and nighttime air temperatures far below average. February was especially cold in Lovell, where maximum and minimum air temperatures were 11°F to 12.4°F below average. Tables showing minimum, maximum, and mean monthly temperatures and departures from average are shown in Appendix B.

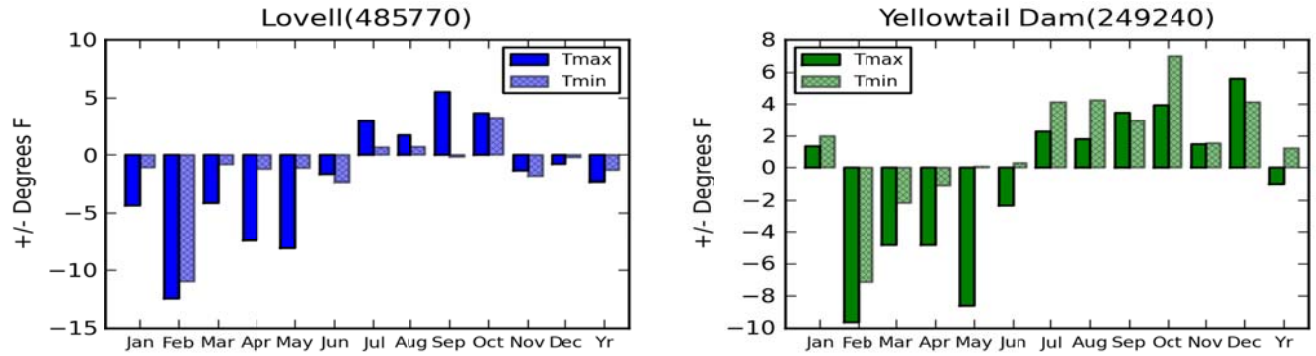

Figure 13. Departure of 2011 average minimum (Tmin) and average maximum (Tmax) daily temperatures from 1981-2010 average at Yellowtail Dam and Lovell COOP stations near Bighorn Canyon National Recreation Area.

Despite the cool spring weather, the onset of spring, the last date in the spring when temperatures drop below 28°F, was 2-7 days earlier than average. Later in the year, the onset of fall, the earliest date temperatures drop below 28°F, was 2-3 weeks later than average. The number of days with air temperatures exceeding 90°F was 11 days fewer than average at Lovell and 13 days fewer at Yellowtail Dam. The number of nights with air temperatures dropping below 32°F was near average. Appendix B shows first and last freeze and frost dates, accumulated growing degree days, and days above or below critical temperature thresholds for key stations in the area.

Precipitation

Bighorn Canyon area experienced above average total annual precipitation during 2011 compared to the 1981-2010 average (Figure 14). Tables in Appendix B show total accumulated precipitation and departures from average for surrounding weather stations.

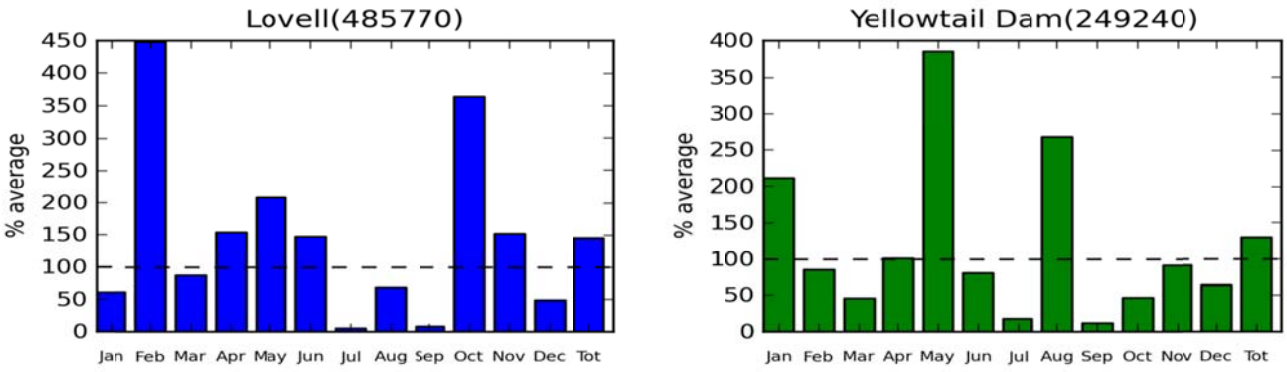

Figure 14. Departure of 2011 average precipitation from 1981-2010 average at Yellowtail Dam and Lovell COOP stations near Bighorn Canyon NRA. Horizontal line depicts average conditions.

Winter Snowpack

As measured in terms of snow water equivalent (SWE)—the amount of liquid water held in a given volume of snow— maximum snowpack at Bald Mountain was nearly twice the amount of average in 2011 (Figure 15). Additionally, cooler than average springtime temperatures contributed to above average snowpack late in the year, which in turn persisted longer than average into the summer (Figure 16).

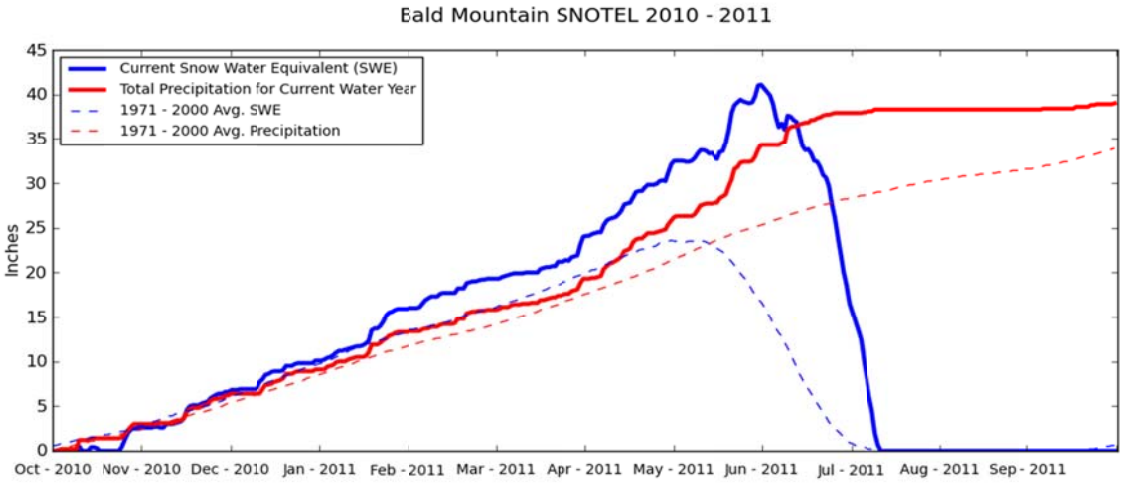

Figure 15. Daily measurements of snow water equivalent (SWE) and total cumulative precipitation from Bald Mountain SNOTEL station covering the period from October 1, 2010 to September 30, 2011. Values are compared to averages from the 1971-2000 period.

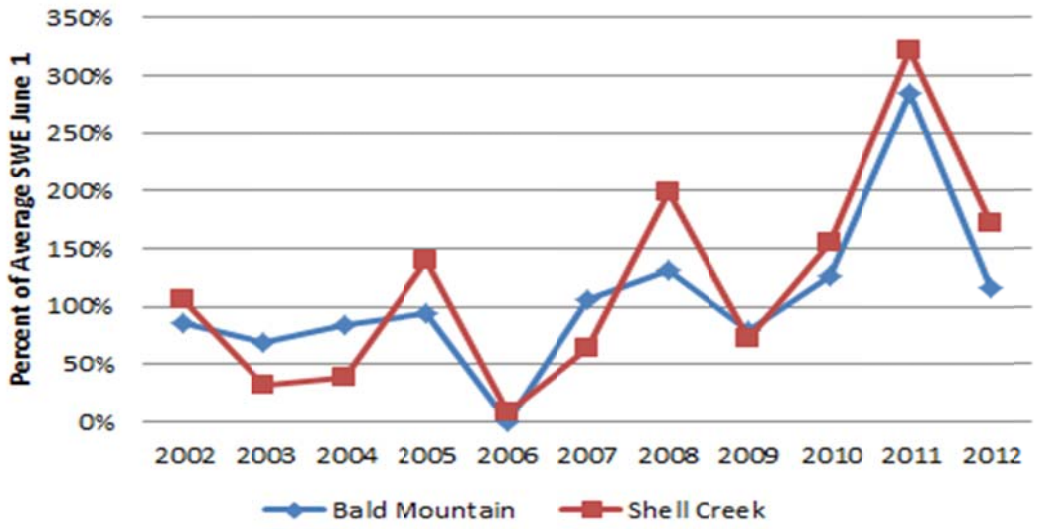

Figure 16. Percent of average snowpack measured on June 1 at Bald Mountain and Shell Creek SNOTEL stations near Bighorn Canyon National Recreation Area from 2002 to 2012. Values are compared to averages from the1981-2010 period.

Streamflow

The USGS monitors streamflow at key locations along the Bighorn and Shoshone Rivers in Montana and Wyoming. Mean daily discharge was above average from mid-May to September (Figure 17) and total discharge was 142-202% above average (Table 3). Total inflows into Bighorn Lake from the Bighorn and Shoshone Rivers combined were 160% of average.

Table 3. Total annual runoff in acre-feet and percent of average for select USGS Gauging Stations near Bighorn Canyon National Recreation Area during 2011. Average time period is based on the period of uninterrupted record.

Station Name	Total annual runoff (ac-ft) 2011	Total annual runoff (ac-ft) average	Percent of average	Average time period
Bighorn River near St. Xavier	3,755,000	2,457,000	153%	1936-2011
Bighorn River Kane	2,216,000	1,558,000	142%	1930-2011
Shoshone River near Lovell	1,301,000	642,700	202%	1967-2011

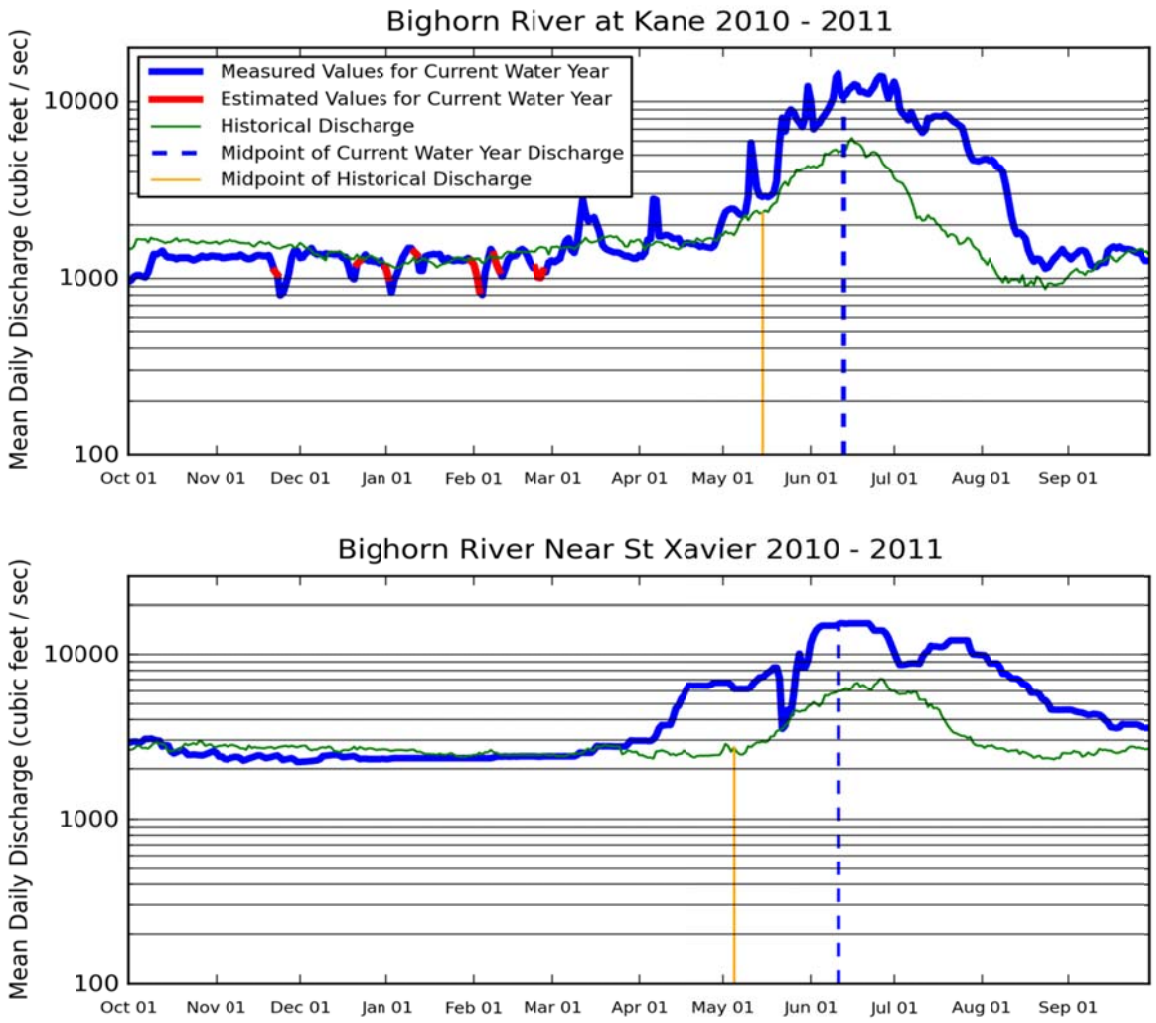

Figure 17. Mean daily discharge from USGS gauge stations on the Bighorn River at Kane Wyoming and near St. Xavier on the Bighorn River in Montana. Values are compared to averages from the 1971-2000 period.

Lake Elevation

The level of Bighorn Lake measured at Forebay by the BOR (Figure 18), dropped below 3625' elevation, the minimum operating level for the Horseshoe Bend swim beach, for 155 days as they released water from the reservoir to make room for spring runoff. The lowest elevation recorded was 3607' on May 19. By June 26, the lake had risen above 3640', full pool elevation, causing temporary closure of campgrounds and lake access. The highest elevation was reached on July 24, 2011 at 3655'. Figure 19 shows flooding at Mason Lovell ranch near Bighorn Lake in July 2011.

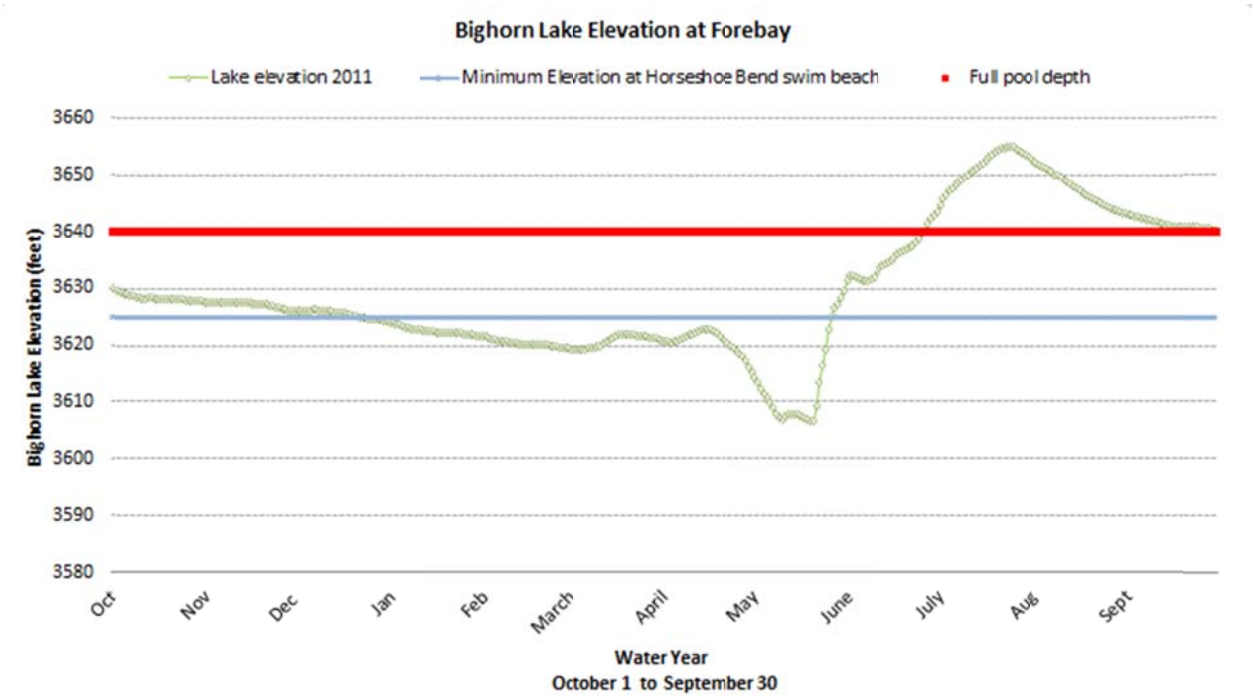

Figure 18. Lake elevation at Forebay on Bighorn Lake during the 2011 water year. Full pool elevation is 3,640'. A minimum lake elevation of 3,625' is required to open the Horseshoe Bend swim beach for recreational swimming.

Figure 19. Flooding at Mason Lovell ranch near Bighorn Lake in July 2011 at Bighorn Canyon National Recreation Area. Photo credit: NPS Bighorn Canyon NRA.

Regional Drought and PRISM Maps

Drought is defined as an extended period of time when an area has a deficiency of precipitation. Consequently, drought severity at the beginning of 2011 is influenced by the drought conditions at the end of 2010. Figure 20 shows that drought was absent in the Greater Yellowstone area and the northern portion of Bighorn Canyon at the end of 2010 and remained absent through the 2011 year. At the southern end of Bighorn Canyon, drought severity was abnormally dry in late

December 2010 and into the early part of January 2011. By June, this part of Bighorn Canyon was drought free. Figure 20 displays the drought index for the four park units.

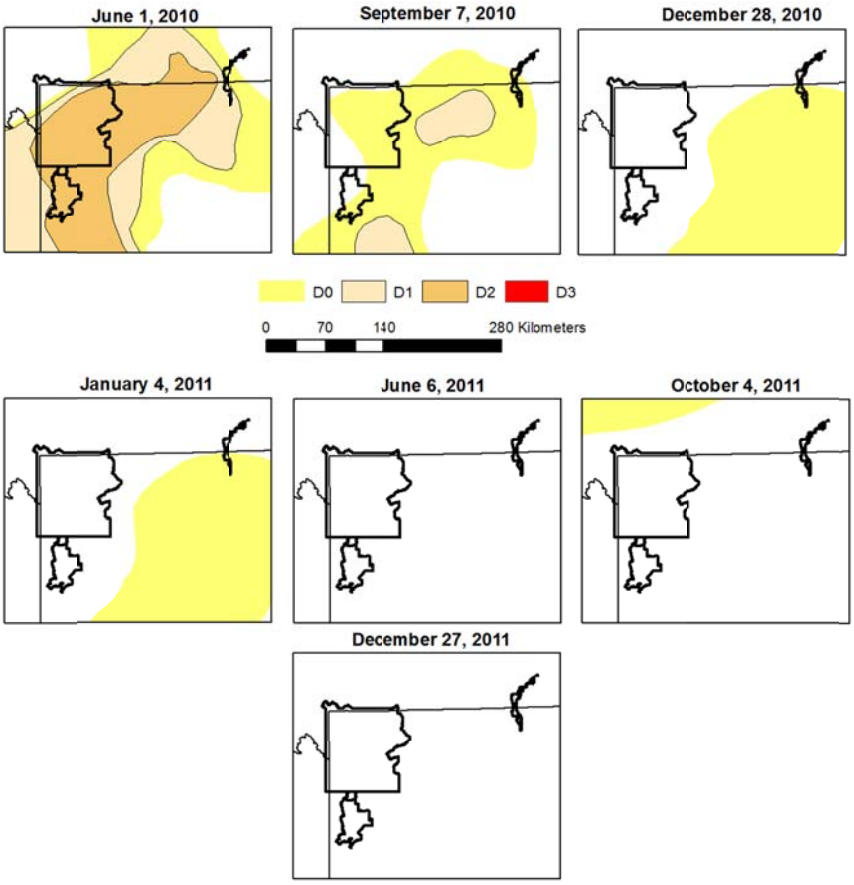

Figure 20. Selected monthly drought maps for GRYN parks in 2010 and 2011 show that by June 2011, the Greater Yellowstone area including Bighorn Canyon NRA was completely free of drought. Drought classifications include "abnormally dry" (D0), "moderate drought" (D1), "severe drought" (D2), and "extreme drought" (D3). Maps courtesy of the U.S. Drought Monitor.

The role of the gridded climate map is to give a wall-to-wall representation of climate status across a park and put park climate variability in perspective within the surrounding region's climate (Kittel et al. 2010). Figures 21, 22, and 23 display regional PRISM gridded climate maps showing percent difference in average 2011 climate from the 1971-2011 reference period for precipitation and minimum and maximum temperatures.

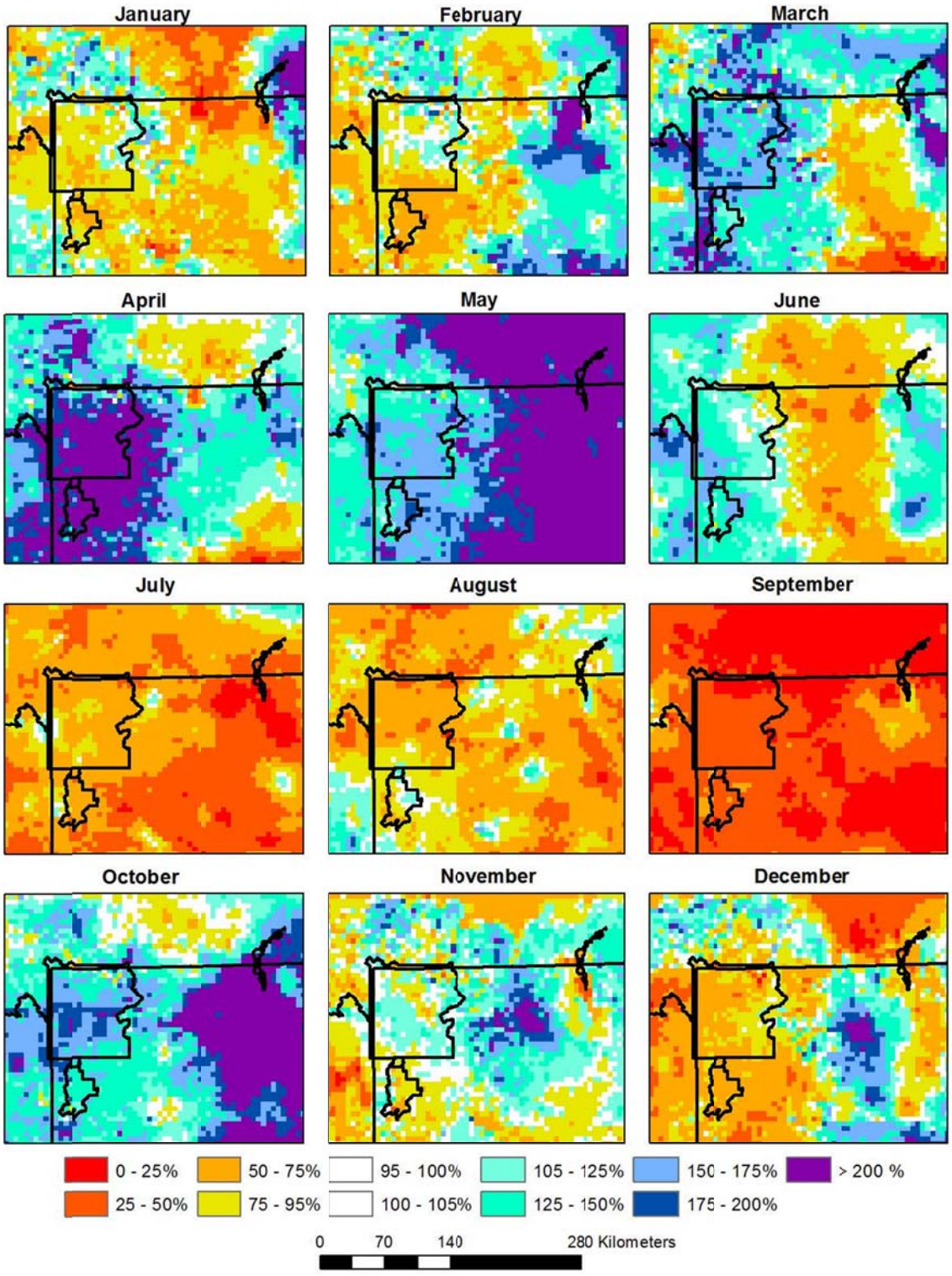

Figure 21. Monthly PRISM maps showing the percent difference in average 2011 precipitation from the 1971-2000 reference period. The black lines on each map represent state boundaries and NPS unit boundaries.

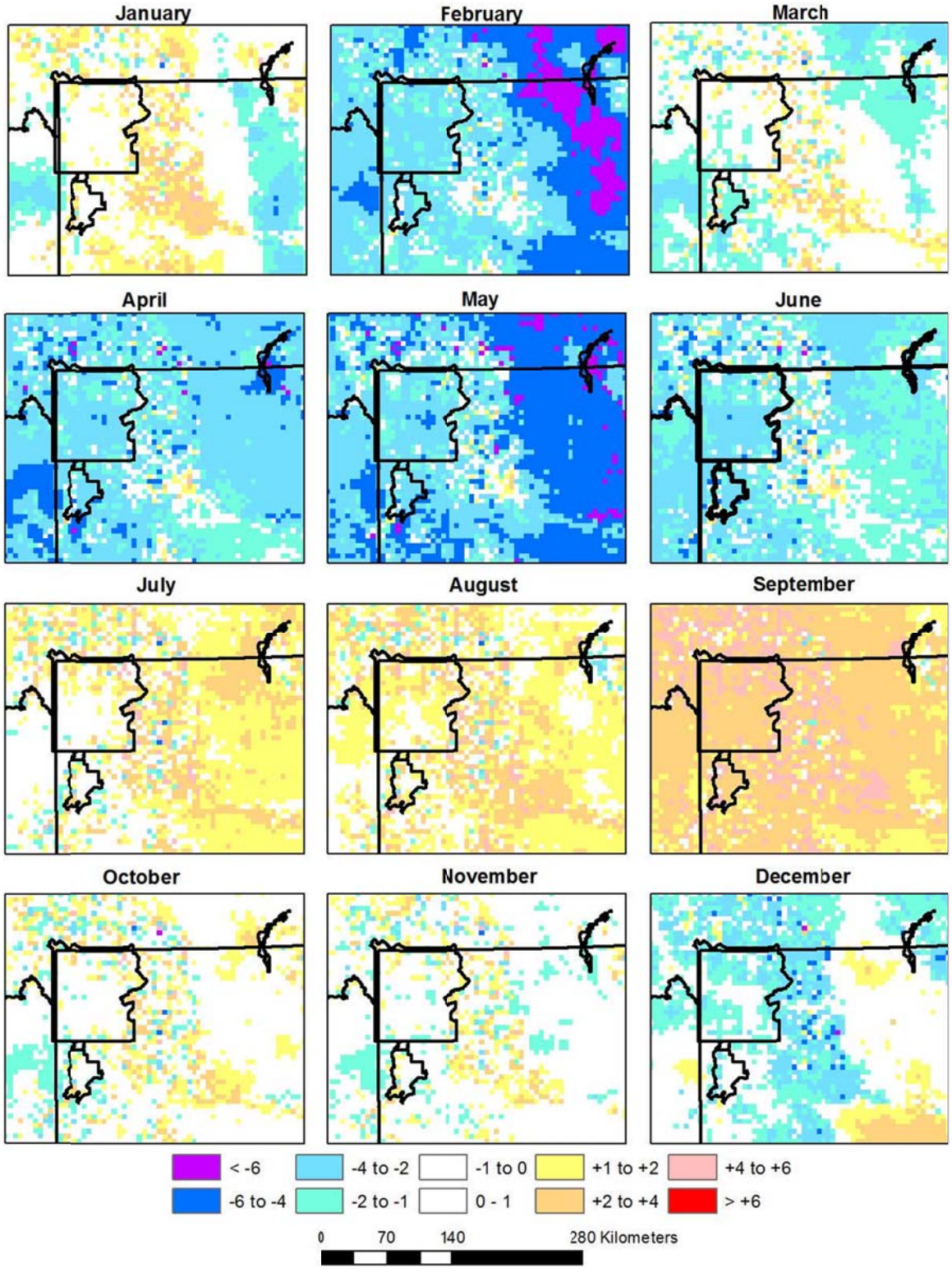

Figure 22. Monthly PRISM maps showing the percent difference in average 2011 maximum temperature from the 1971-2000 reference period. The black lines on each map represent state boundaries and NPS unit boundaries.

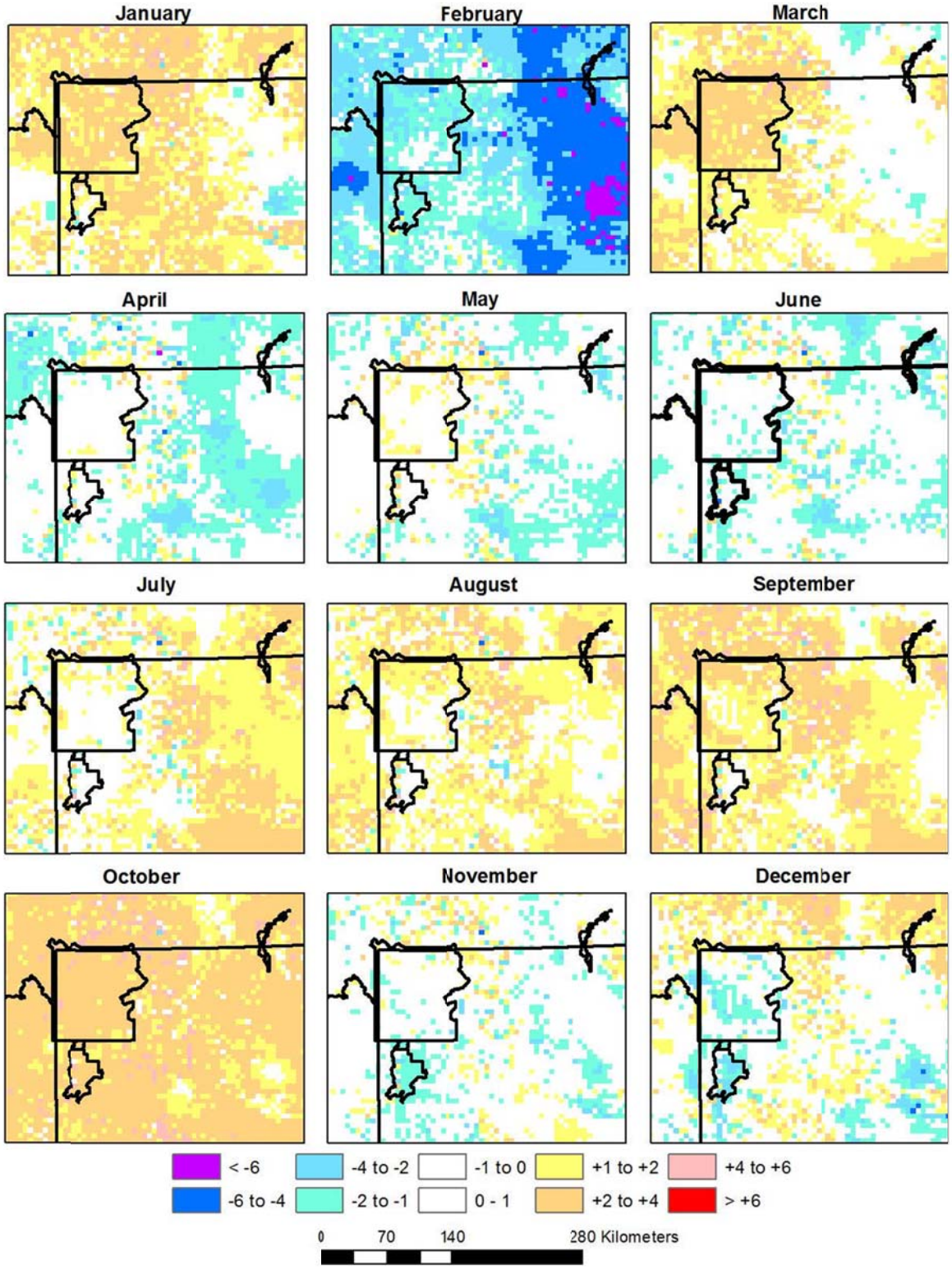

Figure 23. Monthly PRISM maps showing the percent difference in average 2011 minimum temperature from the 1971-2000 reference period. The black lines on each map represent state boundaries and NPS unit boundaries.

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Appendix A: Weather Stations 2011

Table A1. National Weather Service Cooperative Observer Program (COOP) stations and historic baseline period used to determine average conditions used in the 2011 Climate Summary Report

Park	Station ID	Station	Latitude _deg	Longitude _deg	Elevation (ft)	State
BICA	485770	Lovell	44.8375	-108.404	3837	WY
BICA	488124	Shell 1NE	44.5478	-107.763	7360	WY
BICA	249240	Yellowtail Dam	45.3128	-107.938	3305	MT
GRTE/YELL/JODR	480140	Alta 1 NNW	43.7728	-111.034	6437	WY
GRTE/YELL/JODR	100470	Ashton 1N	44.0425	-111.274	5212	ID
GRTE/YELL/JODR	481840	Cody	44.5219	-109.064	5082	WY
GRTE/YELL/JODR	241995	Cooke City 2W	45.0189	-109.955	7483	MT
GRTE/YELL/JODR	102676	Driggs	43.7306	-111.113	6120	ID
GRTE/YELL/JODR	485345	Lake Yellowstone	44.5619	-110.399	7870	WY
GRTE/YELL/JODR	486428	Moose	43.6536	-110.717	6444	WY
GRTE/YELL/JODR	486440	Moran 5 WNW	43.8567	-110.589	6798	WY
GRTE/YELL/JODR	486845	Old Faithful	44.4569	-110.833	7360	WY
GRTE/YELL/JODR	488315	Snake River	44.1333	-110.666	6882	WY
GRTE/YELL/JODR	489905	Yellowstone Pk Mammoth	44.9767	-110.696	6230	WY

Note: BICA=Bighorn Canyon National Recreation Area, GRTE=Grand Teton National Park, JODR=John D. Rockefeller Jr. Memorial Parkway, YELL=Yellowstone National Park.

Table A2. Natural Resources Conservation Service Snowpack Telemetry (SNOTEL) stations and historic baseline period used to determine average condition in this report.

Park	Station ID	Station	Latitude _deg	Longitude _deg	Elevation (ft)	State	Daily Precip/SWE	Monthly Precip	June 1 SWE
BICA	07E21S	Bald Mountain	44.8	-107.833	9380	WY	1971–2000	1981-2010	1981-2010
BICA	07E23S	Shell Creek	44.5	-107.417	9581	WY	1971–2000	1981-2010	1981-2010
GRTE/YELL/JODR	10E03S	Canyon	44.7167	-110.5	7871	WY		1981-2010	
GRTE/YELL/JODR	09D06S	Fisher Creek	45.05	-109.933	9101	MT		1981-2010	2000-2010
GRTE/YELL/JODR	09E07S	Parker Peak	44.7333	-109.9	9400	WY	1971–2000	1981-2010	2000-2010
GRTE/YELL/JODR	10E06S	Sylvan Lake	44.4667	-110.15	8419	WY	1971–2000	1981-2010	2000-2010
GRTE/YELL/JODR	10E20S	Sylvan Road	44.4667	-110.033	7120	WY		1981-2010	
GRTE/YELL/JODR	10E17S	Two Ocean Plateau	44.9	-110.39	9240	WY			2000-2010

Note: BICA=Bighorn Canyon National Recreation Area, GRTE=Grand Teton National Park, JODR=John D. Rockefeller Jr. Memorial Parkway, YELL=Yellowstone National Park.

Table A3. USGS stream gauging stations and baseline period used to determine average annual run-off used in this report.

Park	Station ID	Station	Latitude _deg	Longitude _deg	Elevation (ft)	State	Period to determine average Mean Daily Flow	Period to determine annual runoff
BICA	06279500	Bighorn River at Kane	44.7587	-108.182	3660	WY	1971-2000	1936-2011
BICA	06287000	Bighorn River near St Xavier	45.31696	-107.919	3158	MT	1971-2000	1930-2011
BICA	06285100	Shoshone River near Lovell	44.5019	-108.2604	3856	WY		1967-2011
GRTE/YELL/JODR	06037500	Madison River near West Yellowstone	44.65713	-111.068	6650	MT		1913-2011
GRTE/YELL/JODR	13010065	Snake River above Jackson Lake at Flagg Ranch	44.09848	-110.667	6802	WY	1971-2000	1984-2011
GRTE/YELL/JODR	13013650	Snake River at Moose	43.65379	-110.715	6431	WY	1971-2000	1995-2011
GRTE/YELL/JODR	06191500	Yellowstone River at Corwin Springs	45.11217	-110.794	5079	WY	1971-2000	1889-2011
GRTE/YELL/JODR	06186500	Yellowstone River at Yellowstone Lake Outlet	44.56714	-110.38	7730	WY		1927-2011

Note: BICA=Bighorn Canyon National Recreation Area, GRTE=Grand Teton National Park, JODR=John D. Rockefeller Jr. Memorial Parkway, YELL=Yellowstone National Park.

Appendix B. Climate Summary Tables for the Greater Yellowstone Network Parks

Table B1. Total monthly precipitation in inches and percent of average monthly precipitation compared to 1981-2010 averages for select climate stations in or near Yellowstone and Grand Teton National Parks and John D. Rockefeller Jr. Memorial Parkway during 2011.

Station Name (ID)		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual Total
Alta 1 NNW (480140)		2.43	2.68	3.48	4.25	4.73	2.91	1.32	1.33	0.81	1.99	1.91	1.38	29.22
	% of 30-yr avg.	98	143	182	191	140	126	78	102	49	100	88	59	116
Ashton 1 N (100470)		1.96	1.94	0.92	2.55	3.64	3.22	0	0.15	0.05	3.29	1.33	1.69	20.73
	% of 30-yr avg.	92	137	71	165	161	171	0	18	5	205	63	75	108
Canyon (10E03S)		2.4	2.2	4.2	4.7	3.7	2.2	0.3	0	0.5	2.6	2.4	2	27.2
	% of 30-yr avg.	83	96	168	181	128	88	20	0	36	130	83	65	97
Cody (481840)		0.22	0.52	0.38	2.45	5.15	1.24	0.51	0.69	0.25	2.21	1.33	0.62	15.57
	% of 30-yr avg.	68	156	68	231	283	74	46	75	24	248	277	187	147
Cooke City 2 W (241995)		2.17	1.41	3.26	3.07	2.36	2.15	1.23	1.16	0.42	2	1.61	1.22	22.06
	% of 30-yr avg.	104	95	175	164	84	68	54	61	24	109	86	65	89
Driggs (102676)		(-)	1.85	1.75	2.85	4.28	2.66	0.62	1.25	0.39	1.27	1.8	1.35	(-)
	% of 30-yr avg.	(-)	183	143	194	195	167	51	113	34	88	111	82	(-)
Fisher Creek (09D06S)		7.2	5.7	10.2	8.1	6.6	3.3	1.2	0.8	0.8	5.1	6.8	4.6	60.4
	% of 30-yr avg.	124	124	208	172	132	79	46	38	32	142	124	78	118
Moose (486428)		3.84	1.55	3.47	3.64	4.04	2.17	0.81	1.06	0.43	1.41	1.25	2.56	26.23
	% of 30-yr avg.	149	85	214	244	215	134	63	82	30	96	47	96	120
Moran5WN W (486440)		2.06	1.7	(-)	5.09	4.61	2.2	0.34	0.32	1.14	1.84	2.63	2.08	(-)
	% of 30-yr avg.	72	80	(-)	250	197	128	27	26	81	104	90	72	(-)
Lake Yellowstone (485345)		2.19	2.02	2.78	(-)	(-)	(-)	1.05	(-)	0.82	2	2.11	1.75	(-)
	% of 30-yr avg.	132	125	154	(-)	(-)	(-)	65	(-)	56	170	114	107	(-)

Table B1. Total monthly precipitation in inches and percent of average monthly precipitation compared to 1981-2010 averages for select climate stations in or near Yellowstone and Grand Teton National Parks and John D. Rockefeller Jr. Memorial Parkway during 2011 (*continued*).

Station Name (ID)		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual Total
Old Faithful (486845)		1.51	2.48	3.01	3.19	4.32	2.91	1.49	0.66	0.76	3.48	3.07	1.9	28.78
	% of 30-yr avg.	71	125	136	144	154	118	96	45	52	210	134	60	113
Parker Peak (09E07S)		3.8	2.7	5.3	8.2	7.9	2.2	1.3	1	0.8	4.5	4.6	3	45.3
	% of 30-yr avg.	136	104	183	256	208	69	76	77	44	173	153	103	142
Snake River (488315)		3.51	2.11	4.06	(-)	(-)	2.19	0.61	2.19	0.3	2.94	4.31	2.2	(-)
	% of 30-yr avg.	99	78	159	(-)	(-)	93	38	146	18	144	139	56	(-)
Sylvan Lake (10E06S)		4.7	3.4	5.9	8	5.5	3.3	1.3	1.2	0.7	4.4	4.7	4	47.1
	% of 30-yr avg.	127	113	174	216	128	97	72	80	33	142	112	100	123
Sylvan Road (10E20S)		3.3	2.8	4	5.9	4.3	2.6	1.1	0.2	0.2	2.3	4.1	3.5	34.3
	% of 30-yr avg.	114	140	182	236	159	100	85	14	12	100	114	113	121
Yellowstone Pk Mammoth (489905)		1.22	0.65	1.14	1.17	2.54	1.05	0.67	0.43	0.15	1.23	1.02	0.3	11.57
	% of 30-yr avg.	167	102	120	90	123	54	46	41	13	96	99	36	80

Note: Percentages of average monthly precipitation compared to 1981-2010 averages are given in the second line of data for each station. Station IDs are from NWS Cooperative Observer Program (COOP) stations and NRCS Snowpack Telemetry (SNOTEL) stations. Monthly statistics are not reported if more than three days of data are missing. Individual months are not used for calculating annual statistics if more than five days of data are missing.
(-) Indicates missing data.

Table B2. Average daily maximum temperatures (degrees Fahrenheit) and departure from 1981-2010 averages (± degrees Fahrenheit) in or near Grand Teton and Yellowstone National Parks and John D. Rockefeller Jr. Memorial Parkway.

Station Name (ID)		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Alta 1 NNW (480140)		26.83	26.39	37.55	39.85	52.1	66.63	78.59	78.95	72.49	53.52	35.64	26.17	49.56
	Departure (± °F)	-1.97	-5.41	-1.55	-8.35	-7.1	-1.47	0.99	2.05	4.99	0.32	-1.76	-1.63	-1.84
Ashton 1 N (100470)		(-)	(-)	(-)	45.93	57.77	69.08	81.68	83.54	76.65	57.17	(-)	28.89	(-)
	Departure (± °F)	(-)	(-)	(-)	-7.37	-6.53	-3.42	-0.02	2.14	5.15	-0.23	(-)	0.69	(-)
Cody (481840)		36.56	31.04	47.77	49.92	57.22	73.81	89.29	85.7	75.76	60.17	42.7	35.94	57.16
	Departure (± °F)	-0.84	-9.26	-1.33	-7.28	-8.88	-1.39	5.49	3.4	3.66	0.67	-2.5	-0.06	-1.64
Cooke City 2 W (241995)		22.98	23.78	33.99	37.59	45.03	60.73	74.23	73.38	67.68	48.78	31.24	23.47	45.24
	Departure (± °F)	-3.02	-7.42	-4.91	-8.81	-10.67	-4.47	-0.37	-0.12	4.48	-0.02	-1.16	-0.43	-3.16
Driggs (102676)		(-)	27.1	37.51	42.44	52.6	66.46	79.3	78.96	71.63	54.22	36.74	25.18	(-)
	Departure (± °F)	(-)	-5.6	-3.19	-8.86	-8.7	-3.84	0.4	0.46	2.73	-0.78	-2.66	-3.52	(-)
Lake Yellowstone (485345)		23.73	24.06	33.45	(-)	(-)	(-)	73.08	(-)	65.37	47.2	30.15	23.59	(-)
	Departure (± °F)	-0.67	-3.94	-2.75	(-)	(-)	(-)	1.48	(-)	3.77	-0.6	-3.35	-0.71	(-)
Moose (486428)		30.96	28.79	39.92	43.73	52.4	67.27	81.89	81.18	74.88	57	36.88	26.5	51.78
	Departure (± °F)	4.46	-2.51	-0.78	-6.57	-8.8	-3.73	1.29	1.68	5.38	1.6	-1.32	-0.1	-0.92
Moran 5 WNW (486440)		25.35	29.03	(-)	42.81	53.45	66.7	79.61	79.16	70.84	54.56	34.41	25.68	(-)
	Departure (± °F)	-0.95	-2.57	(-)	-6.09	-5.45	-2.7	0.61	0.96	2.94	1.06	-1.59	0.18	(-)

Table B2. Average daily maximum temperatures (degrees Fahrenheit) and departure from 1981-2010 averages (± degrees Fahrenheit) in or near Grand Teton and Yellowstone National Parks and John D. Rockefeller Jr. Memorial Parkway (*continued*).

Station Name (ID)		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Old Faithful (486845)		24.4	24.58	33.15	39.3	47.41	59.52	73.91	75.84	69	49.77	33.18	28.57	46.55
	Departure (±°F)	-3.8	-7.32	-5.95	-6.6	-7.39	-5.18	-0.99	1.84	5.3	-0.43	-1.82	2.27	-2.65
Snake River (488315)		24.08	25.28	35.65	(-)	(-)	61.97	77.52	77.98	70.47	52.19	31.95	25.73	(-)
	Departure (± °F)	-2.92	-5.52	-3.35	(-)	(-)	-4.93	0.62	1.58	4.37	0.59	-3.25	-0.07	(-)
Yellowstone Pk Mammoth (489905)		29.09	26.45	41.38	44.98	53.13	65.94	80.26	81.16	72.91	56.51	38.89	31.29	51.83
	Departure (± °F)	-1.11	-6.95	0.58	-3.92	-5.87	-2.66	0.96	2.56	5.51	3.71	1.19	2.59	-0.37

Note: Monthly average maximum daily temperature departures from 1981-2010 averages are given in the second line of data for each station in degrees Fahrenheit. Station IDs are from National Weather Service Cooperative Observer stations. Monthly statistics are not reported if more than five days of data are missing. Individual months are not used for calculating annual statistics if more than five days of data are missing.
(-) Indicates missing data.

Table B3. Average minimum daily temperatures in degrees Fahrenheit for select climate stations in or near Grand Teton and Yellowstone National Parks and John D. Rockefeller Jr. Memorial Parkway during 2011. Departures from 1981-2010 averages are given in the second line of data for each station expressed as ± ºF.

Station Name (ID)		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Alta 1 NNW (480140)		10.3	8.66	21.3	24.49	32.35	41.17	50.06	48.69	40.93	32.67	16.64	7.8	27.92
	Departure (± °F)	-0.9	-3.84	1.2	-2.91	-2.65	-1.33	1.56	1.89	2.13	2.57	-2.56	-3	-0.78
Ashton 1 N (100470)		(-)	(-)	(-)	27.76	36.24	41.65	49.83	49.24	42.43	33.47	20.36	12.23	(-)
	Departure (± °F)	(-)	(-)	(-)	-2.24	-1.66	-2.35	0.93	2.14	2.73	2.77	-1.04	0.33	(-)
Cody (481840)		16.44	10.42	26.33	30.52	39.1	48.54	58.84	57.24	50.32	39.54	23.26	15.28	34.65
	Departure (± °F)	0.04	-7.78	0.43	-2.28	-2.2	-0.66	2.74	2.74	4.72	4.24	-1.64	-0.52	-0.05
Cooke City 2 W (241995)		7.76	2.28	16.76	19.23	27.44	31.93	38.33	38.45	30.72	28.92	12.09	1.92	21.32
	Departure (± °F)	2.56	-3.52	3.46	-1.67	-0.96	-2.47	-0.47	1.15	-0.18	5.32	-0.91	-1.68	0.02
Driggs (102676)		(-)	7.19	21.16	26	33.13	40.33	47.71	46.75	38.33	32.7	16.26	3.16	(-)
	Departure (± °F)	(-)	-3.91	1.66	-0.9	-1.07	-0.57	1.31	1.45	1.13	4.1	-2.34	-6.04	(-)
Moose (486428)		1.29	0.22	14.55	21.51	30.36	36.25	40.87	40.34	32.93	27.98	6.39	-4.59	20.68
	Departure (± °F)	0.39	-3.38	0.55	-2.29	-2.04	-2.15	-2.23	-0.76	-0.37	3.78	-7.71	-6.99	-2.02
Moran 5 WNW (486440)		3.48	2.18	(-)	19.89	27.02	33.72	38.9	41.82	32.5	26.41	10.75	-2.14	(-)
	Departure (± °F)	2.58	-0.32	(-)	-1.11	-2.58	-2.98	-2.6	2.22	0.1	2.11	-3.35	-5.64	(-)
Lake Yellowstone (485345)		4.11	-2.29	11.42	(-)	(-)	(-)	42.38	(-)	34.54	26.7	10.65	2.32	(-)
	Departure (± °F)	2.91	-3.49	2.22	(-)	(-)	(-)	0.78	(-)	2.74	3	-3.15	-2.68	(-)

Table B3. Average minimum daily temperatures in degrees Fahrenheit for select climate stations in or near Grand Teton and Yellowstone National Parks and John D. Rockefeller Jr. Memorial Parkway during 2011. Departures from 1981-2010 averages are given in the second line of data for each station expressed as ± ºF (*continued*).

Station Name (ID)		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Old Faithful (486845)		2.4	-0.02	10.75	16.49	27.25	33.31	40	37.2	30.21	27.61	6.33	-5.24	18.86
	Departure (± °F)	2.1	-1.42	0.95	-2.31	-1.05	-1.69	0.4	0.2	0.91	6.01	-3.27	-5.44	-0.44
Snake River (488315)		4.08	-2.06	12.72	(-)	(-)	31.25	33.81	34.24	27.05	23.21	5.76	-2.43	(-)
	Departure (± °F)	4.48	-2.86	2.62	(-)	(-)	-3.05	-4.39	-1.26	-0.65	2.91	-4.44	-2.63	(-)
Yellowstone Pk Mammoth (489905)		13.03	5.57	21.82	24.62	33.95	41.07	49.58	48.61	41.1	34.39	18.19	11.22	28.59
	Departure (± °F)	1.03	-7.43	1.72	-2.08	-0.85	-1.23	1.28	1.91	2.7	4.99	-1.61	-0.08	-0.01

Note: Monthly average minimum daily temperature departures from 1981-2010 averages are given in the second line of data for each station in degrees Fahrenheit. Station IDs are from National Weather Service Cooperative Observer stations. Monthly statistics are not reported if more than five days of data are missing. Individual months are not used for calculating annual statistics if more than five days of data are missing.

(-) Indicates missing data

Table B4. First and last freeze and frost dates, spring and fall onset dates, accumulated growing degree days, and days above or below critical temperature thresholds for key stations in or near Grand Teton and Yellowstone National Parks and John D. Rockefeller Jr. Memorial Parkway during 2011. Values for 2011 are shown in the first line for each station and averages on the second line. Averages are published by the Western Region Climate Center in General Climate Summary Tables and reference period may differ from 1981-2010.

Station Name (ID)		AGDD40	AGDD50	Last date in spring ≤28°F	Earliest date in fall ≤28°F	Last date in spring ≤32°F	Earliest date in fall ≤32°F	# of days Tmax		# of days Tmin	
								≥80°F	≥90°F	≤0°F	≤32°F
Alta 1 NNW (480140)		2678	1278	24-May	18-Oct	25-Jun	20-Sep	32	0	22	220
	avg.	2656	1152	30-May	12-Sep	28-Jun	2-Sep	(-)	2.2	27.4	222.7
Ashton 1 N (100470)		3073	1543	7-Jun	25-Oct	7-Jun	7-Oct	62	3	(-)	(-)
	avg.	3096	1422	18-May	18-Sep	14-Jun	8-Sep	(-)	7.4	23	206.1
Cody (481840)		4125	2288	30-Apr	26-Oct	2-May	9-Oct	77	21	20	157
	avg.	4048	2110	5-May	1-Oct	17-May	20-Sep	(-)	18.1	18.3	168.3
Cooke City 2 W (241995)		1563	443	20-Jun	2-Sep	11-Jul	12-Aug	6	0	41	275
	avg.	1604	470	26-Jun	30-Aug	12-Jul	9-Aug	(-)	0	46.3	275
Driggs (102676)		2583	1149	4-Jun	18-Oct	17-Jun	20-Sep	32	1	(-)	(-)
	avg.	2752	1193	31-May	11-Sep	27-Jun	1-Sep	(-)	2.8	33.9	221.2
Lake Yellowstone (485345)		(-)	(-)	28-May	20-Sep	31-May	19-Aug	(-)	(-)	(-)	(-)
	avg.	1427	390	29-Jun	24-Aug	21-Jul	9-Aug	(-)	0	61.8	279.7
Moose (486428)		2313	965	18-Jun	2-Sep	27-Jun	13-Aug	52	0	58	242
	avg.	2339	927	9-Jun	2-Sep	29-Jun	24-Aug	(-)	2.6	53.8	248.8
Moran 5 WNW (486440)		2040	764	18-Jun	20-Sep	27-Jun	2-Sep	35	0	(-)	(-)
	avg.	1971	675	17-Jun	2-Sep	9-Jul	15-Aug	(-)	0.5	59.9	265.2
Old Faithful (486845)		1632	511	4-Jun	3-Sep	2-Jul	12-Aug	14	0	64	268
	avg.	1713	540	27-Jun	17-Aug	18-Jul	3-Aug	(-)	0.5	57	276
Snake River (488315)		(-)	(-)	19-Jul	2-Sep	29-Jul	12-Aug	28	0	(-)	(-)
	avg.	1776	559	5-Jul	9-Aug	22-Jul	3-Aug	(-)	0.9	58.7	284.8
Yellowstone Pk Mammoth (489905)		2823	1327	2-May	18-Oct	28-May	21-Sep	47	1	21	199
	avg.	2733	1203	18-May	15-Sep	10-Jun	9-Sep	(-)	3.2	20.2	208

Note AGDD=Accumulated Growing Degree Days

(-) Indicates missing data

.

Table B5 Total monthly precipitation in inches and percent of average monthly precipitation versus 1981-2010 averages for select climate stations in or near Bighorn Canyon National Recreation Area during 2011.

Station Name (ID)	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual Total
Bald Mountain (07E21S)	4.3	2.4	3.5	6.5	8.5	3.6	0.4	0	0.7	3.8	2.9	1.4	38
	154	100	109	191	218	109	22	0	28	136	116	52	117
Lovell (485770)	0.12	0.72	0.3	0.96	2.42	1.56	0.04	0.26	0.05	2.37	0.3	0.11	9.2
	61	448	87	154	209	147	5	68	8	365	152	48	145
Shell 1 NE (488124)	0.87	0.64	1.87	2.03	4.24	2.3	0.1	(-)	0.16	3	0.75	0.22	(-)
	156	123	346	214	217	157	12	(-)	14	316	125	40	(-)
Shell Creek (07E23S)	4.2	1.7	4.2	5.7	7.5	2.5	1.1	0.6	0.5	3.9	2.9	1.1	35.9
	175	100	168	184	208	81	61	55	22	156	132	58	127
Yellowtail Dam (249240)	1.48	0.64	0.6	1.82	10.98	2.07	0.25	2.09	0.18	0.83	0.72	0.48	22.15
	211	86	46	101	385	81	18	268	11	46	91	64	129

Note: Percentages of average monthly precipitation versus 1981–2010 averages are given in the second line of data for each station. Station IDs are from NWS Cooperative Observer Program (COOP) stations and NRCS Snowpack Telemetry (SNOTEL) stations. Monthly statistics are not reported if more than three days of data are missing. Individual months are not used for calculating annual statistics if more than five days of data are missing.

(-) Indicates missing data

Table B6. Average maximum daily temperatures in degrees Fahrenheit for select climate stations in or near Bighorn Canyon National Recreation Area during 2011. Departures from 1981-2010 averages are given in the second line of data for each station expressed as ± ºF.

Station Name (ID)		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Lovell (485770)		26.45	24.67	44.75	51.1	59.23	75	89.1	86.43	78.32	62.75	42.34	30.29	55.87
	Departure (± °F)	-4.35	-12.43	-4.15	-7.4	-8.07	-1.7	3	1.73	5.52	3.65	-1.36	-0.81	-2.33
Shell 1 NE (488124)		29.79	28.35	48.32	54.29	59.76	76.42	91.61	89.93	80.45	63.73	43.69	33.7	58.34
	Departure (± °F)	-2.71	-10.55	-2.28	-6.11	-9.44	-3.28	2.41	2.83	5.65	2.63	-1.11	1	-1.86
Yellowtail Dam (249240)		39.93	31.78	45.17	54.18	59.8	75.87	90.46	89.39	78.87	65.13	48.37	43.51	60.2
	Departure (± °F)	1.33	-9.62	-4.83	-4.82	-8.6	-2.33	2.26	1.79	3.47	3.93	1.47	5.61	-1

Note: Monthly average maximum daily temperature departures from 1981-2010 averages are given in the second line of data for each station in degrees Fahrenheit.

Station IDs are from NWS Cooperative Observer Program (COOP) stations. Monthly statistics are not reported if more than five days of data are missing. Individual months are not used for calculating annual statistics if more than five days of data are missing.

Table B7 Average minimum daily temperatures in degrees Fahrenheit for select climate stations in or near Bighorn Canyon National Recreation Area during 2011. Departures from 1981-2000 averages are given in the second line of data for each station expressed as ± ºF.

Station Name (ID)		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Lovell (485770)		6.31	2.12	22.16	30.57	40.55	47.63	56.26	53.19	41.83	34.93	18.24	8.19	30.16
	Departure (± °F)	-1.09	-10.98	-0.84	-1.23	-1.15	-2.37	0.66	0.69	-0.17	3.23	-1.86	-0.21	-1.34
Shell 1 NE (488124)		6.59	1.06	21.96	29.77	38.87	44.5	53.71	52.23	42.37	35.23	15.44	7.38	29.09
	Departure (± °F)	-0.31	-13.14	-2.14	-1.13	0.17	-3.8	-0.89	0.53	0.27	4.53	-3.46	-0.02	-1.71
Yellowtail Dam (249240)		21.17	14.17	24.93	34.22	43.18	51.58	61.42	60.05	49.34	44.17	28.84	23.13	38.02
	Departure (± °F)	1.97	-7.13	-2.17	-1.08	0.08	0.28	4.12	4.25	2.94	6.97	1.54	4.13	1.22

Note: Monthly average minimum daily temperature departures from 1981-2010 averages are given in the second line of data for each station in degrees Fahrenheit. Station IDs are from NWS Cooperative Observer Program (COOP) stations. Monthly statistics are not reported if more than five days of data are missing. Individual months are not used for calculating annual statistics if more than five days of data are missing.

Table B8. First and last freeze and frost dates, spring and fall onset dates, accumulated growing degree days, and days above or below critical temperature thresholds for key stations in or near Bighorn Canyon National Recreation Area during 2011. Values for 2011 are shown in the first line for each station and averages on the second line. Averages are published by the Western Regional Climate Center and the reference period may differ from 1981-2010.

Station Name		AGDD40	AGDD50	Last date in spring ≤28°F	Earliest date in fall ≤28°F	Last date in spring ≤32°F	Earliest date in fall ≤32°F	# of days Tmax		# of days Tmin	
								≥80°F	≥90°F	≤0°F	≤32°F
Lovell (485770)		3877	2121	25-Apr	26-Oct	5-May	21-Sep	82	22	27	187
	avg.	4077	2209	1-May	3-Oct	14-May	20-Sep	(-)	33.1	26.5	188.4
Shell 1 NE (488124)		(-)	(-)	1-May	20-Oct	15-May	20-Sep	(-)	(-)	27	187
	avg.	4083	2211	8-May	28-Sep	24-May	18-Sep	(-)	39.1	23.2	199.2
Yellowtail Dam (249240)		4872	2740	20-Apr	2-Nov	2-May	26-Oct	90	33	15	128
	avg.	5186	2930	18-Apr	16-Oct	6-May	5-Oct	(-)	46.1	14.6	130.6

Note: (-) temperature data or published averages are missing.

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