Upper Missouri River Basin
January 2017 Calendar Year Runoff Forecast
January 10, 2017

U.S. Army Corps of Engineers, Northwestern Division
Missouri River Basin Water Management
Omaha, NE

Calendar Year Runoff Forecast

Explanation and Purpose of Forecast

The long-range runoff forecast is presented as the Calendar Year Runoff Forecast. This forecast is developed shortly after the beginning of each calendar year and is updated at the beginning of each month to show the actual runoff for historic months of that year and the updated forecast for the remaining months of the year. This forecast presents monthly inflows in million acre-feet (MAF) from five incremental drainage areas, as defined by the individual System projects, plus the incremental drainage area between Gavins Point Dam and Sioux City. Due to their close proximity, the Big Bend and Fort Randall drainage areas are combined. Summations are provided for the total Missouri River reach above Gavins Point Dam and for the total Missouri River reach above Sioux City. The Calendar Year Runoff Forecast is used in the Monthly Study simulation model to plan future system regulation in order to meet the authorized project purposes throughout the calendar year.

December 2016 Calendar Year Runoff

December 2016 Missouri River runoff was 0.9 MAF (114% of average) in the Missouri Basin above Sioux City and 0.6 MAF (85% of average) in the Missouri Basin above Gavins Point. The (preliminary, with no holdouts) calendar year 2016 runoff summation above Sioux City, IA was 24.2 MAF (96% of average), while it was 20.2 MAF (87% of average) above Gavins Point. These preliminary runoff volumes will be finalized within the first few months of 2017.

2017 Calendar Year Forecast Synopsis

The January 1 forecast for the 2017 Missouri River runoff above Sioux City, IA is **25.4 MAF (100% of average)**. Runoff above Gavins Point Dam is forecast to be **23.0 MAF (99% of average)**. Due to the amount of variability in precipitation and other hydrologic factors that can occur over the next 12 months, the range of expected inflow is quite large and ranges from the 35.4 MAF upper basic forecast to the 16.7 MAF lower basic forecast. The upper and lower basic forecasts are used in long-term regulation planning models to “bracket” the range of expected runoff given much wetter or drier conditions, respectively. Given that 12 months are being forecasted for this January 1 forecast (0 months observed/12 months forecast), the range of wetter than normal (upper basic) and lower than normal (lower basic) is attributed to all 6 reaches for all 12 months. The result is a large range or “bracket” for each reach, and thus, for the total runoff forecast. As the year progresses, the range will lessen as the number of observed months increases and number of forecast months decreases.

Current Conditions

Drought Analysis

The latest National Drought Mitigation Center’s drought monitor for December 27, 2016 (**Figure 1**), is compared to the drought monitor for November 29, 2015 (**Figure 2**). The U.S. Drought Monitor indicates there are some areas of Moderate Drought (D1) and Severe Drought (D2) in northeastern Wyoming, southeastern Montana, and western South Dakota. There are also some areas of D1 drought in western Montana. Abnormally Dry (D0) conditions persist in the remainder of eastern Wyoming, western Nebraska, and some portions of the lower Basin including eastern Kansas and Missouri. The Seasonal Drought Outlook in **Figure 3** indicates drought conditions will persist, especially in northeastern Wyoming, southeastern Montana, and western South Dakota through the end of March; however, some improvement is likely in these areas.

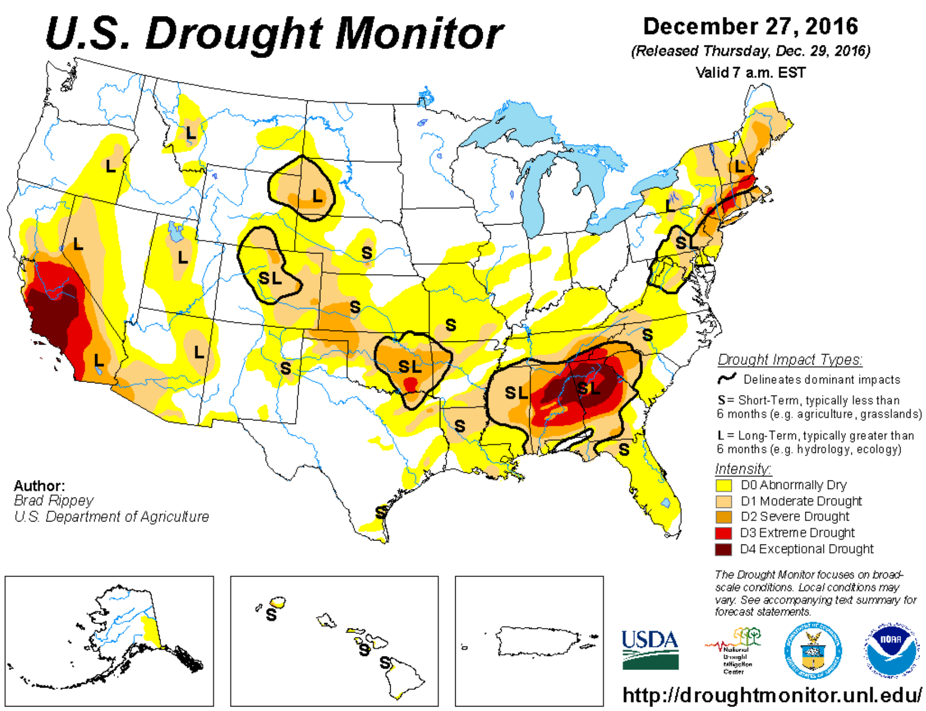


Figure 1. National Drought Mitigation Center U.S. Drought Monitor for December 27, 2016.

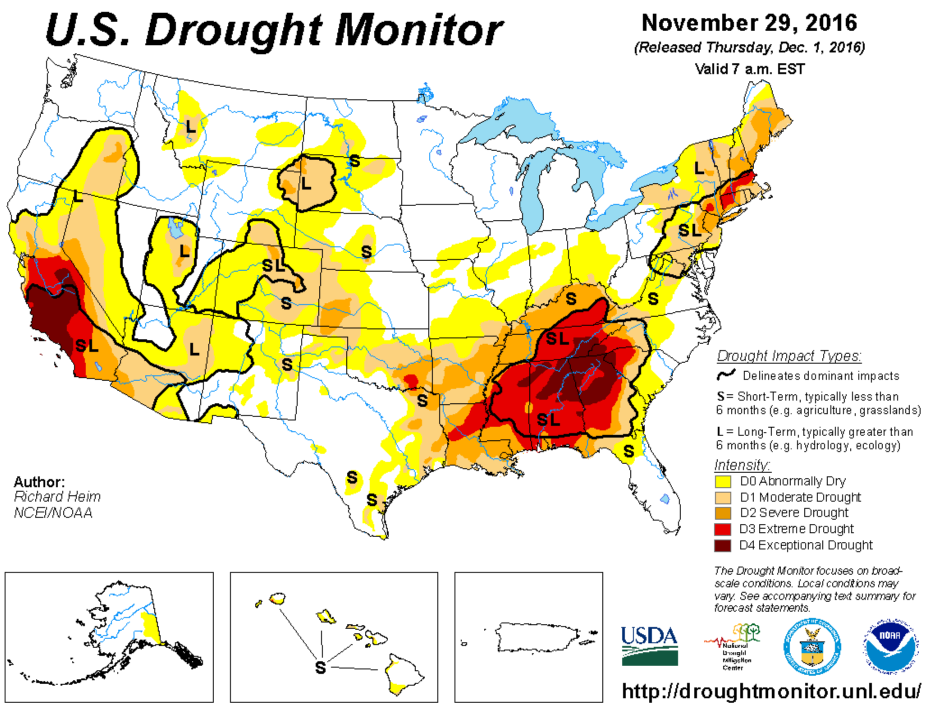


Figure 2. National Drought Mitigation Center U.S. Drought Monitor for November 29, 2016.

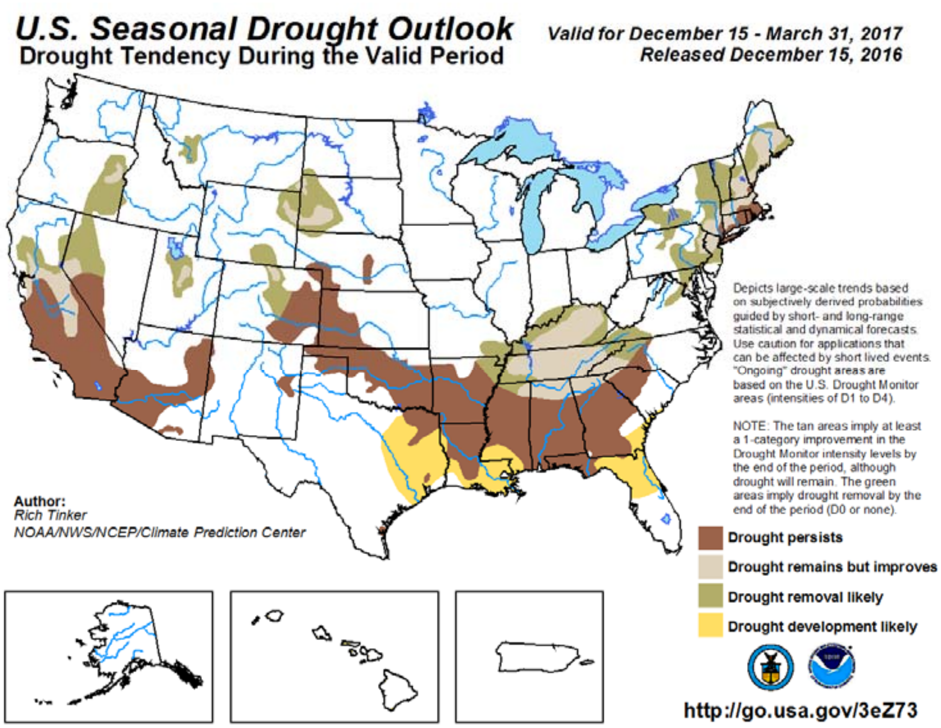


Figure 3. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

Monthly precipitation accumulations are described using High Plains Regional Climate Center images available at http://www.hprcc.unl.edu/. The December precipitation accumulations are shown in **Figure 4** as inches of precipitation (left) and percent of normal precipitation (right). Areas in the upper Basin received significant winter precipitation in excess of 200% of normal. Those areas include western and southern Montana, Wyoming, eastern Montana, North Dakota and South Dakota. While most of this precipitation has fallen as snow, rain and freezing rain was the dominant precipitation form that fell over central and eastern South Dakota on December 25. October-November-December precipitation accumulations are shown in **Figure 5**. The three-month accumulations reflect a relatively wet pattern across northwestern Wyoming, central and northern Montana, North Dakota and central and eastern South Dakota. Below-normal precipitation occurred in portions of eastern Montana, eastern Wyoming and the lower Basin.

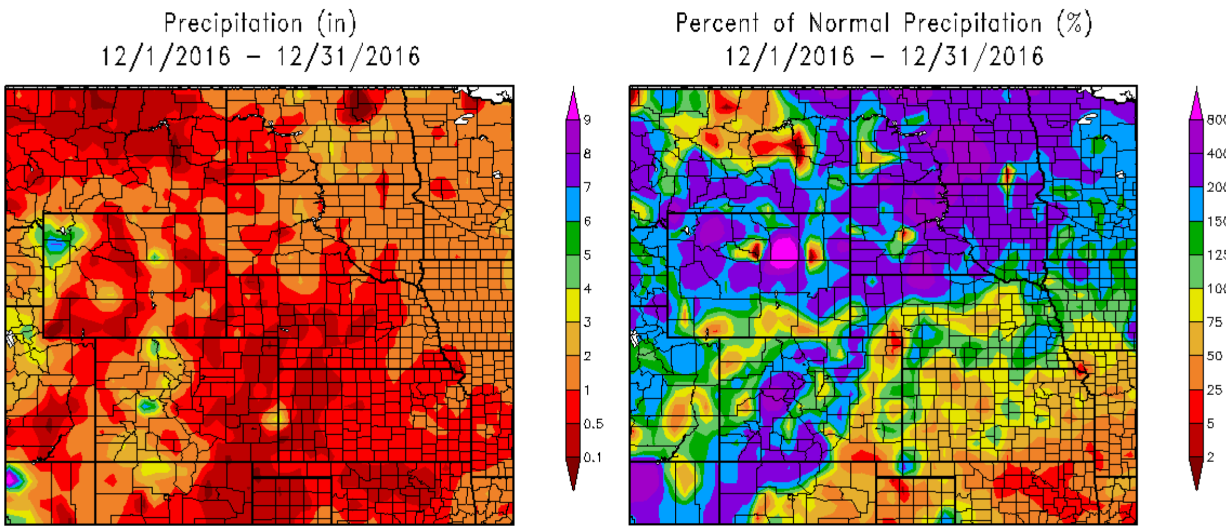


Figure 4. December 2016 Precipitation (inches) and Percent of Normal Precipitation.

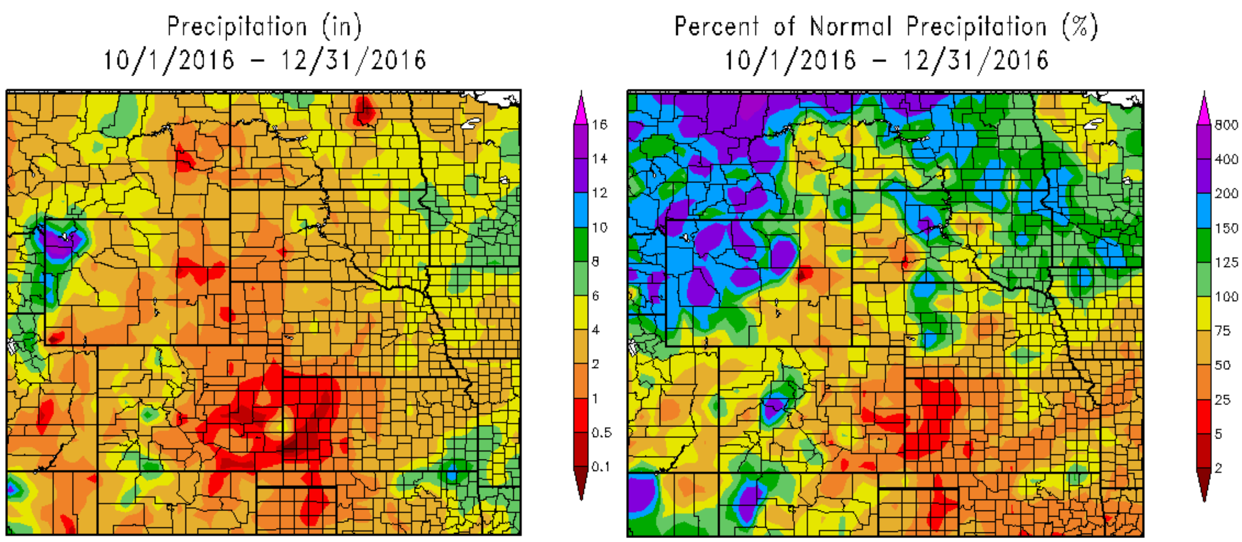


Figure 5. October-November-December 2017 Precipitation (inches) and Percent of Normal Precipitation.

Temperature

December temperature departures from normal in degrees Fahrenheit (deg F) in the left image of **Figure 6** have been predominantly below normal. Departures ranged from 4 to 10 deg F below normal over significant portions of Montana, Wyoming and the western Dakotas. Temperatures over much of the lower Basin were within 2 deg F of normal. October-November-December temperatures, in the right image of **Figure 6**, were within 2 deg F of normal in Montana and northern Wyoming, while temperatures were 2 to 4 deg F above normal throughout the remainder of the upper Basin. In the lower Basin, temperatures were 2 to 6 deg F above normal.

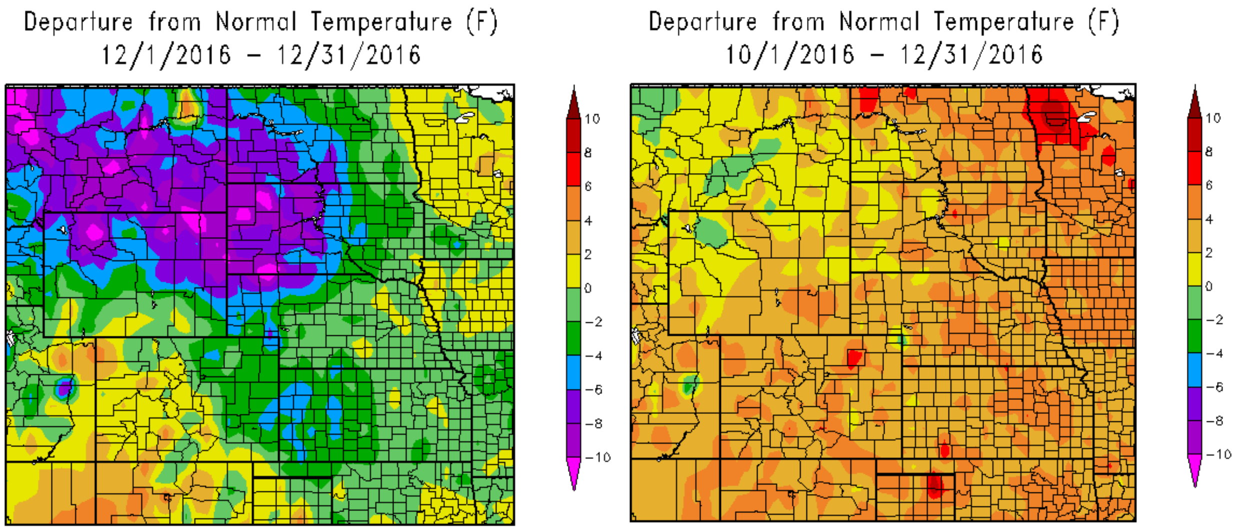
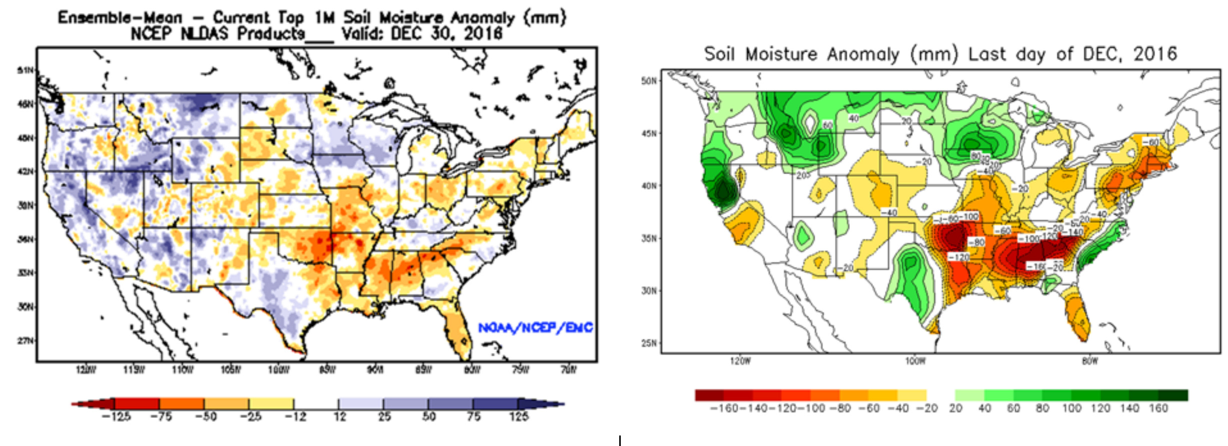


Figure 6. December 2016 and October-November-December 2016 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Soil Moisture

Soil moisture is factored into the forecast as an indicator of wet or dry hydrologic basin conditions. Typically when soil moisture conditions are wet or greater than normal, rainfall and snowmelt runoff is greater than when soil moisture is dry or less than normal. Not only is soil moisture a physical parameter that influences runoff, it can be used as an indicator of future runoff. As the calendar year approaches winter, the wet and dry soil moisture conditions will provide some insight into late winter and early spring runoff potential.

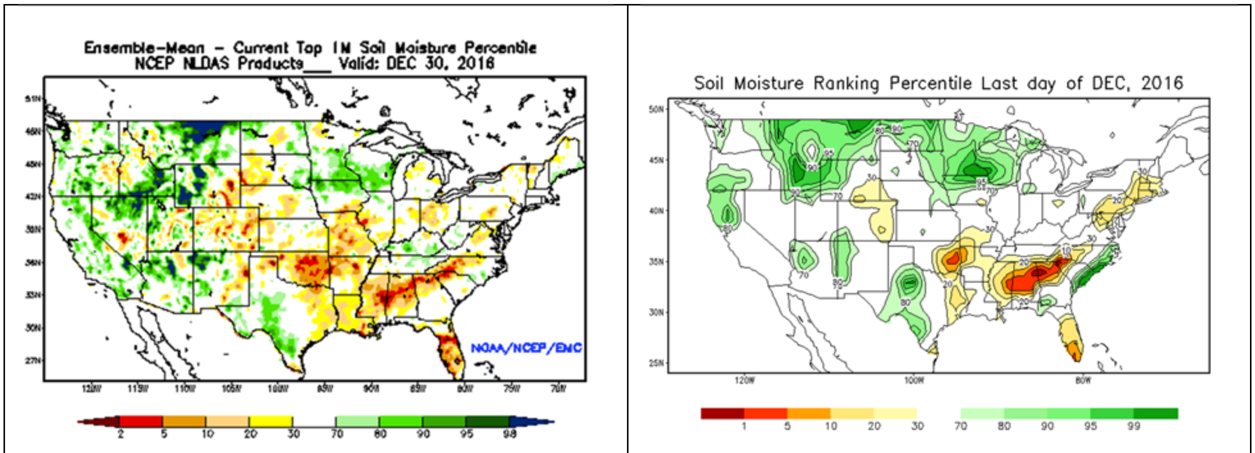
The left image of **Figure 7** shows the NOAA NLDAS ensemble top one-meter soil moisture anomaly on December 30, 2016. The NLDAS soil moisture depiction is an average value for the one-meter soil moisture column. The NLDAS image shows wetter-than-normal conditions across Montana, northwestern North Dakota, central and western Wyoming, eastern South Dakota and northwestern Iowa. Drier-than-normal conditions are present in central North Dakota, eastern Wyoming, western South Dakota, Nebraska and Missouri. Similarly, the CPC Soil Moisture Anomaly, in the right image of **Figure 7**, indicates wetter-than-normal soil moisture conditions in Montana, northwestern Wyoming, northern North Dakota and northwestern Iowa.



NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/	CPC Soil Moisture. http://www.cpc.ncep.noaa.gov/products/Soilmst_Monitoring/US/Soilmst/Soilmst.shtml#

Figure 7. NOAA NLDAS and CPC Soil Moisture Anomalies (mm).

Soil moisture conditions expressed as a percentile ranking, in addition to showing wetter-than-normal and drier-than-normal conditions, can show the severity and rarity of the soil moisture conditions through the percentile ranking probability. Soil moisture percentile rankings from NOAA NLDAS and the CPC are shown in **Figure 8**. The NLDAS percentile ranking, in the left image of **Figure 8**, indicates very wet soil moisture conditions in the areas categorized by the 95^{th} percentile rank including north central Montana and localized regions of central Wyoming. A 95^{th} percentile ranking soil moisture conditions indicates soil moisture is wetter than 95 out of 100 soil moisture samples or years for the indicated date. The CPC percentile ranking, in the right image of **Figure 8**, indicates very wet soil moisture conditions (95^{th} percentile ranking) in areas of north central and northeastern Montana, northern North Dakota, and northwestern Wyoming.



NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/	CPC Soil Moisture. http://www.cpc.ncep.noaa.gov/products/Soilmst_Monitoring/US/Soilmst/Soilmst.shtml#

Figure 8. NOAA NLDAS and CPC Soil Moisture Percentile Rankings.

Frost Conditions

Figure 9 shows the depth of frost penetration at NWS Warning Forecast Office (WFO) locations in the Missouri Basin as of January 2, 2017. Moderately deep soil frost was reported at Great Fall, MT (16 inches); Glasgow, MT (32 inches); Bismarck, ND (20 inches); Riverton, WY (34 inches); Rapid City, SD (14 inches); and, Aberdeen, SD (19 inches). Shallow soil frost was reported at Sioux Falls, SD (4 inches); and Omaha, NE (2 inches); while 0 inches of soil frost was reported near Kansas City, MO

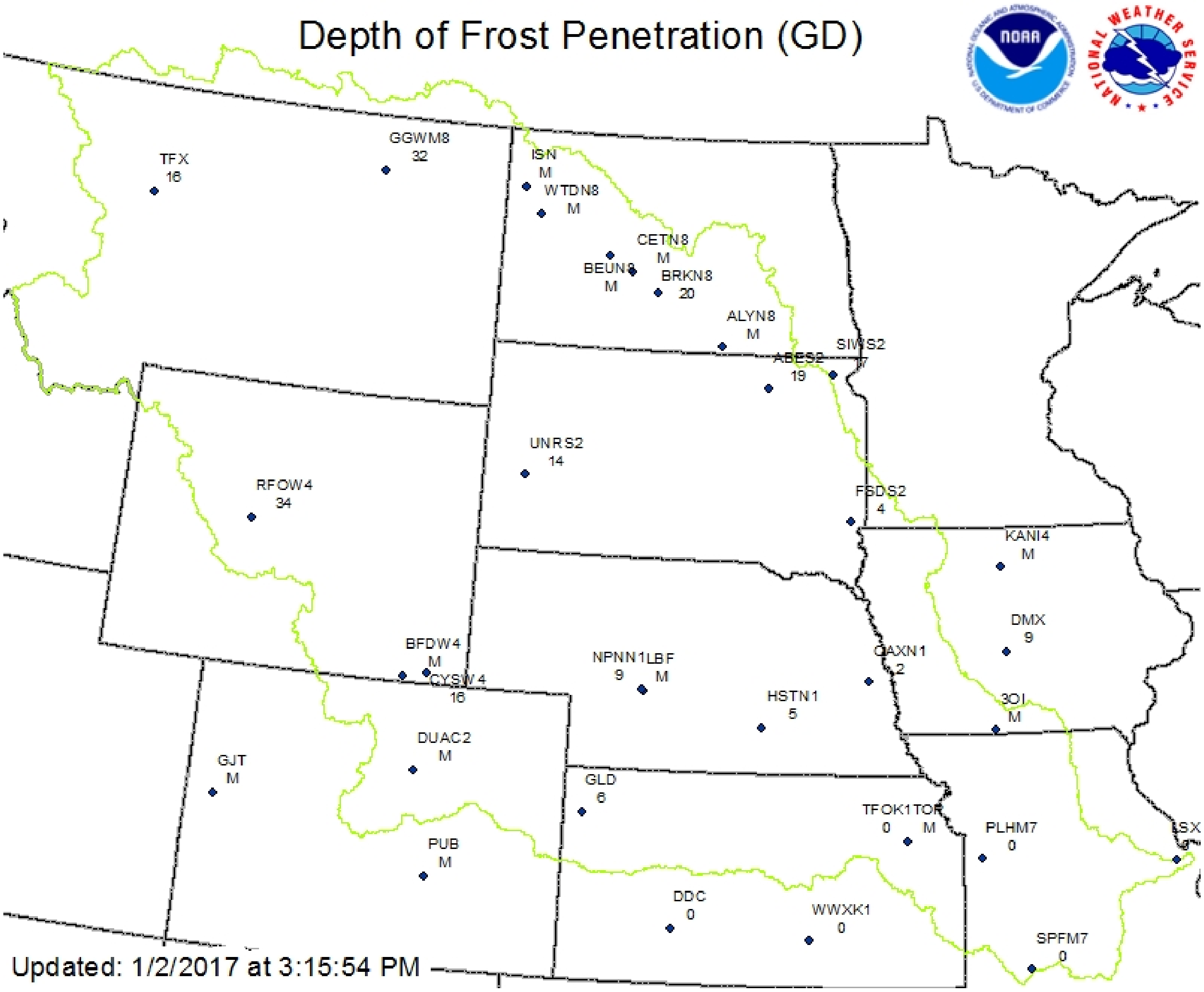


Figure 9. Measured frost depth (inches) at NWS WFO offices as of January 2, 2017. Source: NWS MBRFC. http://www.crh.noaa.gov/mbrfc

Plains Snowpack

Plains snowpack is an important parameter that influences the volume of runoff occurring in the basin during the months of March and April. A common misperception is that the March-April runoff is a result of plains snowmelt only. Historically, about 25% of annual runoff occurs in March and April, during the time when plains snow is melting, due to both melting snowpack and rainfall runoff. Runoff occurs in March and April whether or not there is any plains snow to melt. Determining exact rainfall amounts and locations are nearly impossible to predict more than a week in advance. Thus, the March-April runoff forecast is formulated based on existing plains snowpack and existing basin conditions and hydrologic forecasts, which for this year primarily includes long-term precipitation outlooks.

At this time of year, plains snowpack provides some indication of March-April runoff; however, as the snowpack reaches its ultimate peak accumulation, better forecasts of future runoff can be made. Some areas of North Dakota have received a significant amount of plains snowmelt so far this winter. The NWS at Bismarck, which normally receives about 20 inches of snowfall by early January, has received 53 inches of snow to date during this winter season.

The National Weather Service's National Operational Hydrologic Remote Sensing Center (NOHRSC), modeled snow assessment, shown in **Figure 10**, indicates 3 to 5 inches of snow water equivalent (SWE) have accumulated in central North Dakota, while 1 to 3 inches have accumulated in surrounding areas of eastern Montana, and western and northern South Dakota.

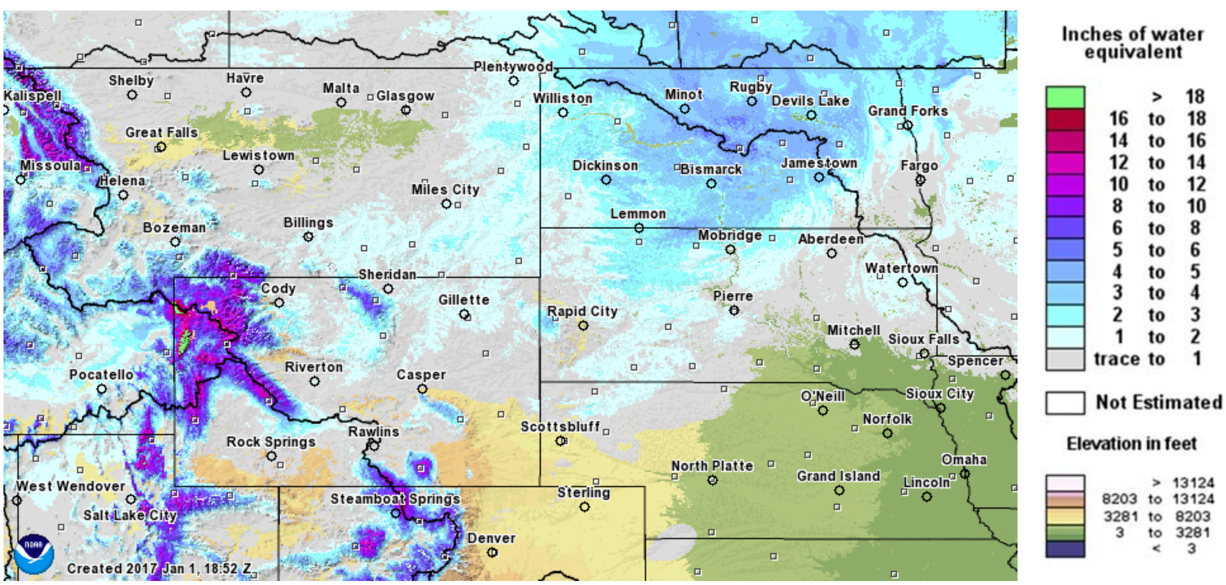


Figure 10. January 1, 2017 NOHRSC modeled plains snow water equivalent. Source: NOAA National Operational Hydrologic Remote Sensing Center. http://www.nohrsc.nws.gov/interactive/html/map.html

Less than 1 inch of SWE covers the remainder of the upper Basin, while the lower Basin has very little snowpack. Cooperative snow survey measurements indicate 3 inches of SWE have accumulated in Bismarck, ND; and 2.7 inches have accumulated near Jamestown, ND. Additional measurements during the week of January 2 indicated 4.2 inches of SWE near New Salem, ND; 5 inches of SWE near McIntosh, SD; and 2 inches of SWE near Wessington Springs, SD. These measurements were provided to NOHRSC and MBRFC, and a full report is available at http://www.nwd-mr.usace.army.mil/rcc/snowsurvey/snowsurvey.html.

MRBWMD and the USACE Cold Regions Research and Engineering Laboratory (CRREL) has developed an application to estimate plains snowpack in the upper Missouri Basin using SSM/I satellite-based estimates of SWE. This application can estimate HUC-8 and reservoir reach basin-average SWE on a weekly basis. **Figure 11** includes maps depicting basin-averaged SWE and percentile rank for the season in the upper Missouri Basin for the week ending on December 31, 2016. The values depicted by the SWE and percentile rank color scales are averaged over each System reservoir reach. **Figure 11** indicates that the greatest average reach SWE and percentile rank is present in the Fort Randall reach; however, it also indicates a moderate snowpack over the Garrison and Oahe reaches.

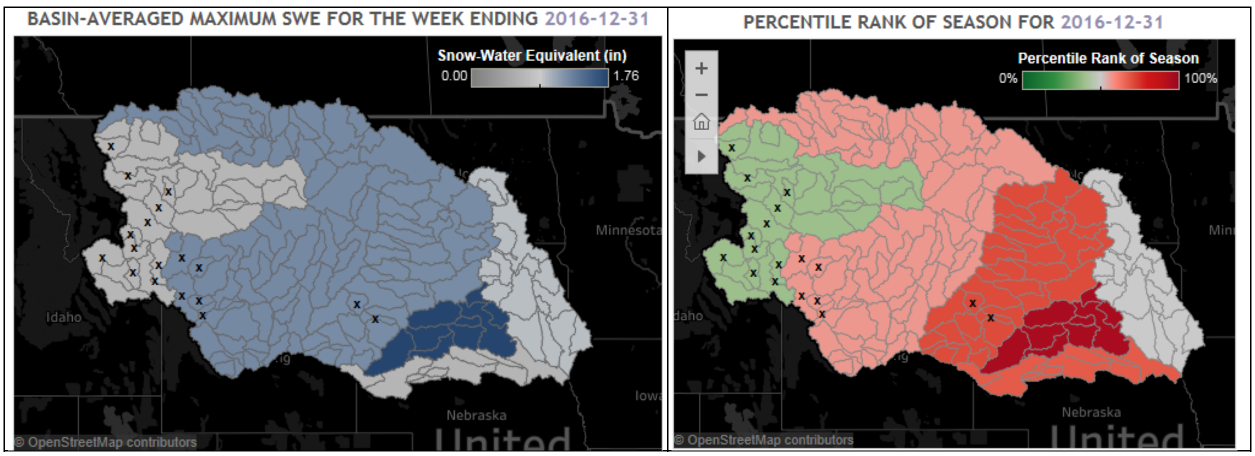


Figure 11. Experimental SSM/I Satellite-Based Plains Snowpack Estimate for the Mainstem Reservoir System.

Table 1 lists the basin-average SWE values, the percentile rank of the season for December 31, the historical median and the percent of median. In all basins, the December 31 SWE was greater than the historical median, and the percentile rankings were between the 50th and 75th percentile, with the exception of the high Fort Randall SWE and the 39th percentile above Fort Peck. This experimental product indicates the overall upper Basin plains snowpack is above average for the 2016-2017 winter.

Table 1. Detailed data SWE data for the Mainstem Reservoir System reaches calculated by the Experimental SSM/I Satellite-Based Plains Snowpack tool for December 31, 2016.

DETAILED DATA FOR 2016-12-31

Region	Basin-Averaged SWE (in)	Percentile Rank of Season	Historical Median SWE (in)	% of Median SWE
Above Fort Peck	0.66	39%	0.62	106%
Fort Peck to Garrison	1.25	57%	0.53	238%
Garrison to Oahe	1.24	71%	0.19	647%
Oahe to Fort Randall	1.76	96%	0.57	311%
Fort Randall to Gavins Point	0.64	68%	0.29	222%
Gavins Point to Sioux City	0.95	50%	0.90	105%

Mountain Snow Pack

Mountain snowpack is the primary factor used to predict May-July runoff volumes in the Fort Peck and Fort Peck to Garrison reaches. During the 3-month May-July runoff period, about 50% of the annual runoff enters the Mainstem System as a result of mountain snowmelt and rainfall runoff. Greater-than-average mountain snow accumulations are usually associated with greater-than-average May-July runoff volumes, especially when mountain soil moisture conditions have been wetter than normal as in the past three years. For example, we would expect to see higher-than-average runoff from an average mountain snowpack this year due to wetter-than-normal soil moisture conditions.

Figure 12 includes time series plots of the average mountain SWE beginning on October 1, 2015 based on the NRCS SNOTEL gages for the headwater basin above Fort Peck and the incremental basin from Fort Peck to Garrison. The current average SWE values (shaded blue area) are plotted against the 1981-2010 basin average SWE (bold red line), a recent low SWE year in 2001 (green line), and two historic high SWE years occurring in 1997 (purple) and 2011 (dark blue).

As of **January 1, 2017**, the Corps of Engineers computed an average mountain SWE in the **Fort Peck reservoir reach of 5.6 inches, which is 78% of average for January 1** based on the 1981-2010 average SWE for the Fort Peck reach. In the **reservoir reach between Fort Peck Dam and Garrison Dam**, the Corps computed an average mountain SWE of **6.6 inches, which is 105% of average for January 1** based on the 1981-2010 average SWE for the Garrison reach. Normally, 44% or less than half of the peak snow accumulation has occurred in the mountains by January 1, with slightly more than half of the snow accumulation season remaining.

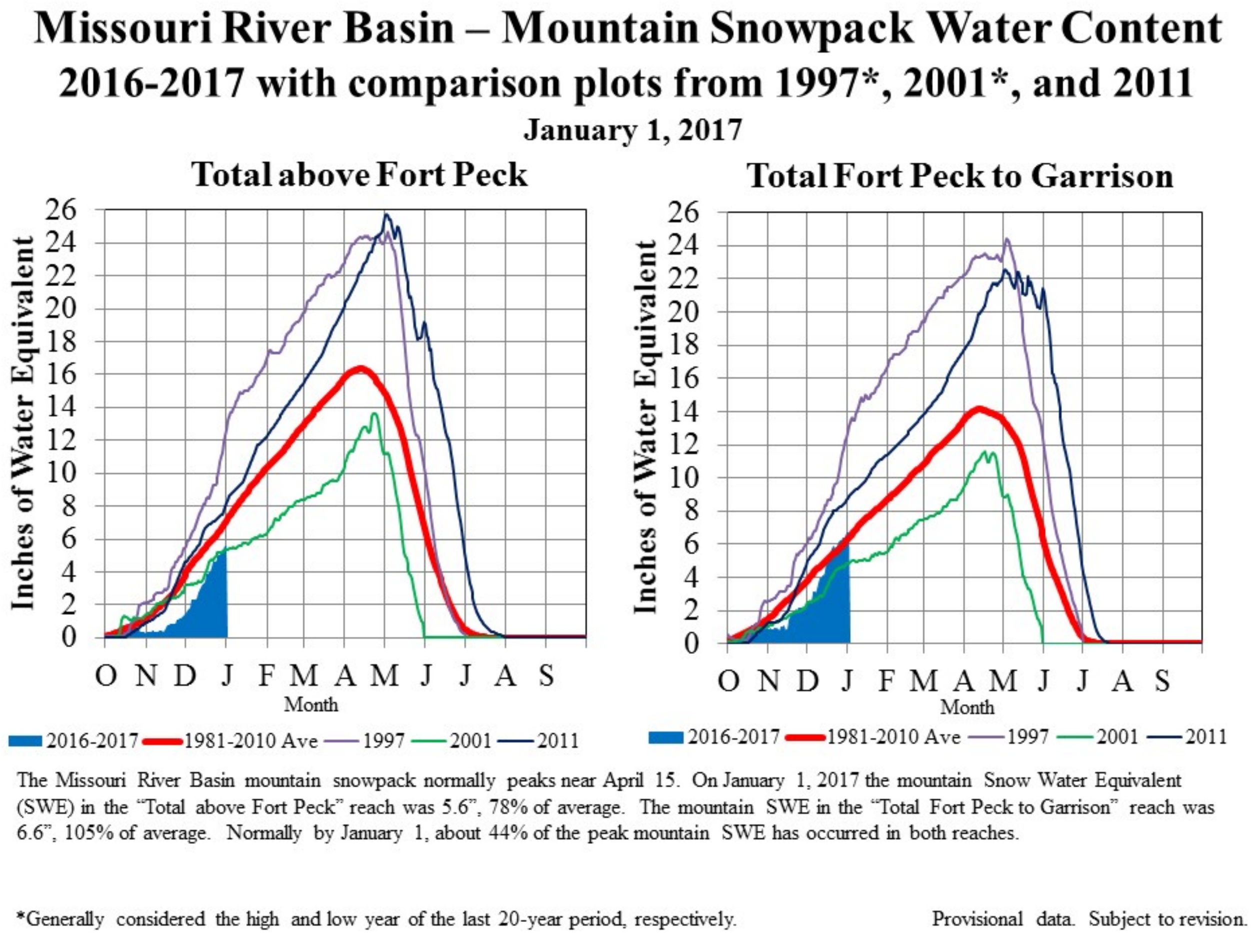


Figure 12. Mountain snowpack water content on January 1, 2017 compared to normal and historic conditions. Corps of Engineers - Missouri River Basin Water Management.

Climate Outlook

MRBWMD participates in the monthly North Central U.S. Climate/Drought Outlook Webinar coordinated through NOAA, the regional climate centers, and the American Association of State Climatologists (AASC). These webinars provide updates on near-term climate outlooks and impacts including the ENSO climate pattern and its implications on winter temperature and precipitation patterns in the Missouri River Basin.

During the first week of January, MRBWM requested the first round of cooperative snow survey measurements in the upper Missouri River Basin to help assess the depth and water equivalent of plains snowpack during the 2016-2017 winter. These measurements are used by MRBWM to adjust the March-April runoff forecast, and the measurements are shared with NWS to help verify modeled snow estimates used in spring streamflow forecasts. In addition to this snow information, anecdotal basin conditions information noted by the observers such as soil moisture content and frost depth improves situational awareness among federal, state and local agencies.

ENSO (El Niño Southern Oscillation)

The latest ENSO update indicates that weak La Niña condition are present and a transition to ENSO-neutral conditions are favored during January-March 2017. The impact of La Niña on Missouri Basin climate is reflected in the one-month and three-month CPC temperature and precipitation outlooks.

Temperature and Precipitation Outlooks

The NOAA Climate Prediction Center climate outlook for January 2017 (**Figure 13**) indicates there could be an increased probability for below-normal temperatures in most of the upper Basin with equal chances for temperatures in the lower Basin. With regard to precipitation, there could be an increased probability that precipitation will be above normal in Montana and Wyoming, while there could be equal chances for above-normal, normal and below-normal precipitation in the Dakotas and the lower Basin.

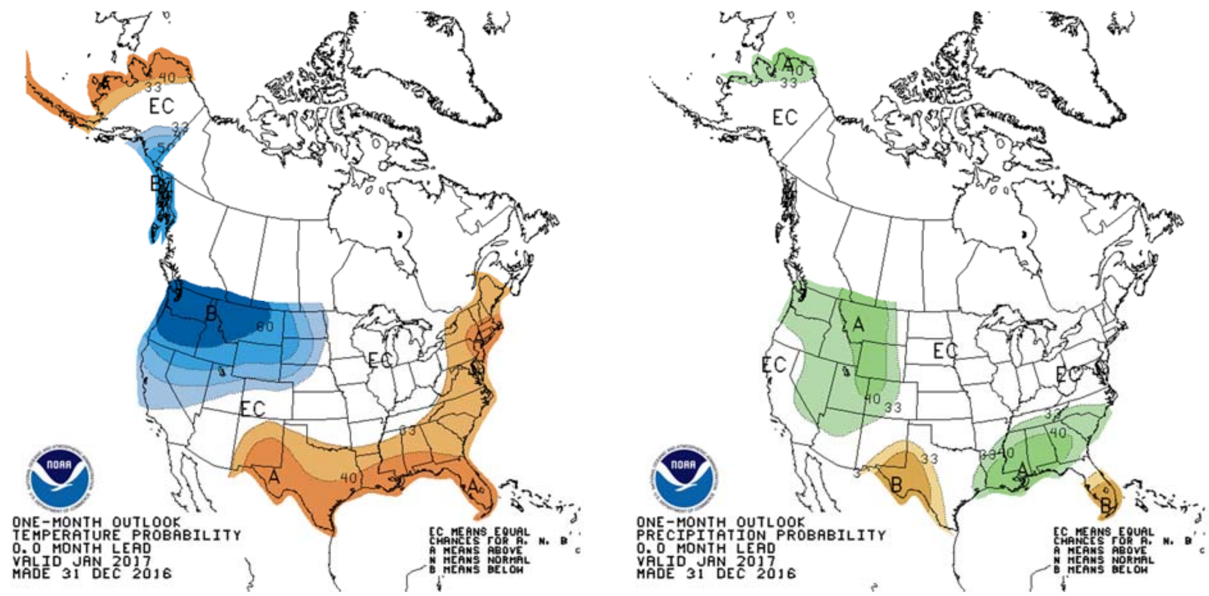


Figure 13. CPC January 2017 temperature and precipitation outlooks.

The winter (January-February-March) temperature outlook (**Figure 14**) indicates there could be increased chances for below-normal temperatures in Montana, North Dakota and South Dakota, where there could be equal chances in all other areas of the Missouri Basin. The January-February-March precipitation outlook shows increased chances for above-normal precipitation over Montana, Wyoming, much of North Dakota and western South Dakota. There are equal chances for above-normal, normal and below-normal precipitation in all other areas of the Missouri Basin.

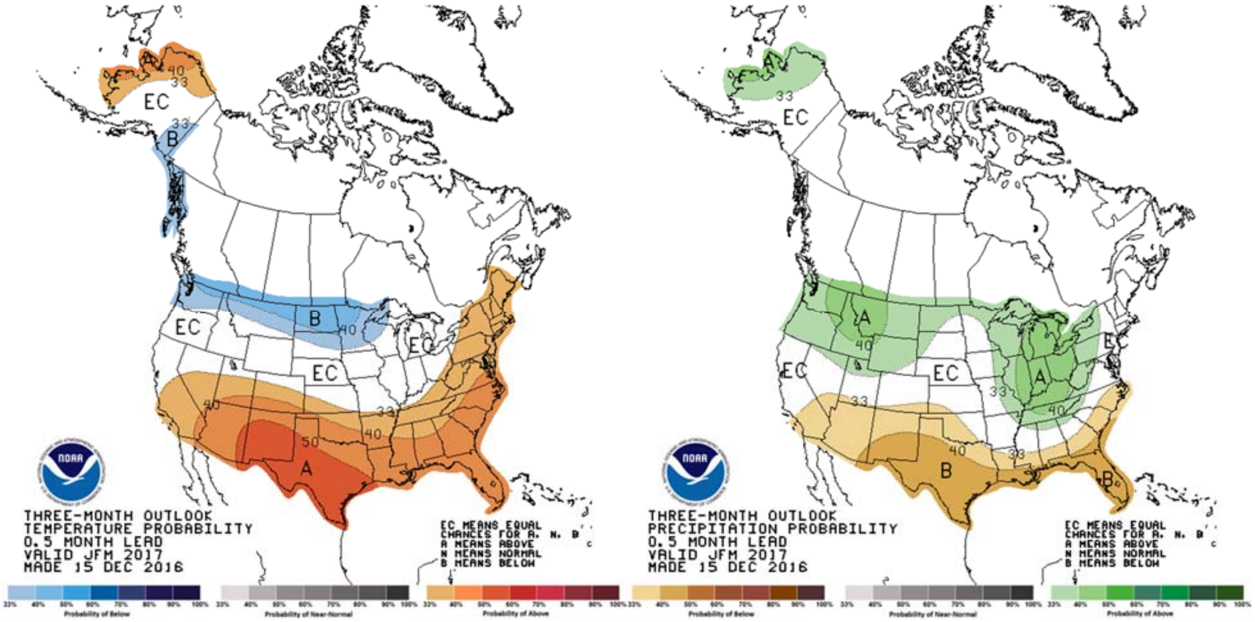


Figure 14. CPC January-February-March 2017 temperature and precipitation outlooks.

The April-May-June CPC temperature outlook (**Figure 15**) indicates there could be equal chances for above-normal, normal, and below-normal temperatures over much of the upper Basin, and increased chances for above-normal temperatures in the lower Basin. With regard to precipitation, there could be equal chances for above-normal, normal and below-normal precipitation in most of the Missouri Basin, with the exception of increased chances for above-normal precipitation in North Dakota and northeastern South Dakota

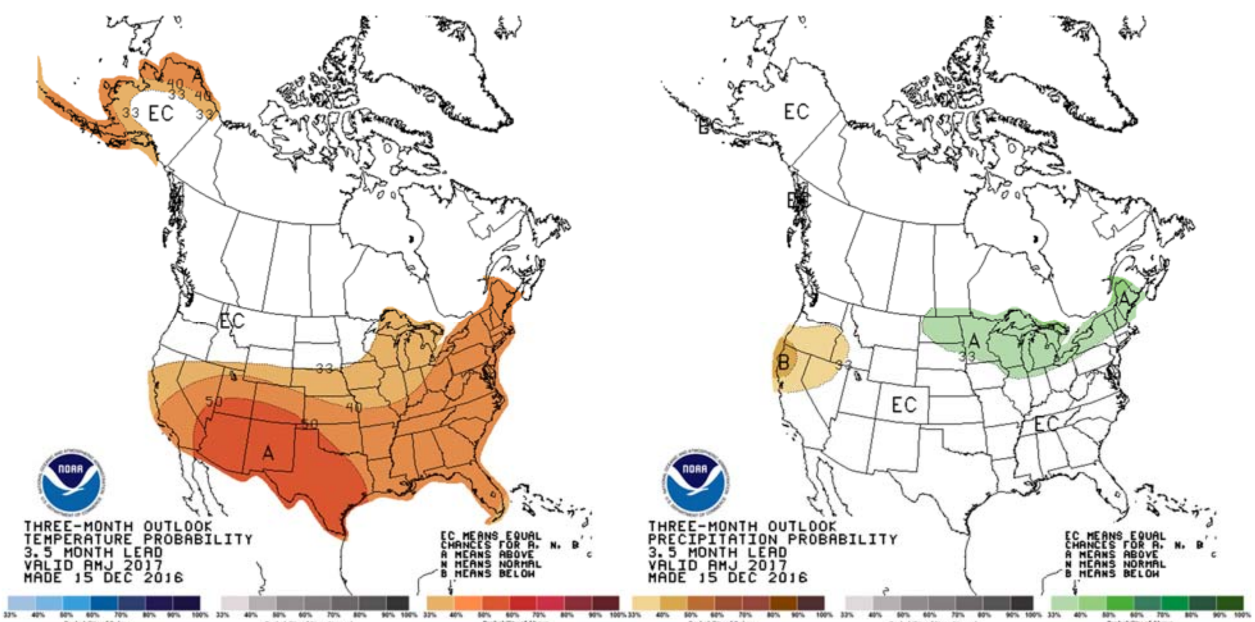


Figure 15. CPC April-May-June 2017 temperature and precipitation outlooks.

During the July-August-September period (**Figure 16**) and the October-November-December period (**Figure 17**) outlooks indicate similar increased chances for above-normal temperatures over the entire Missouri Basin. With regard to the precipitation outlooks, the CPC indicates equal chances for above-normal, normal and below-normal precipitation from July through December.

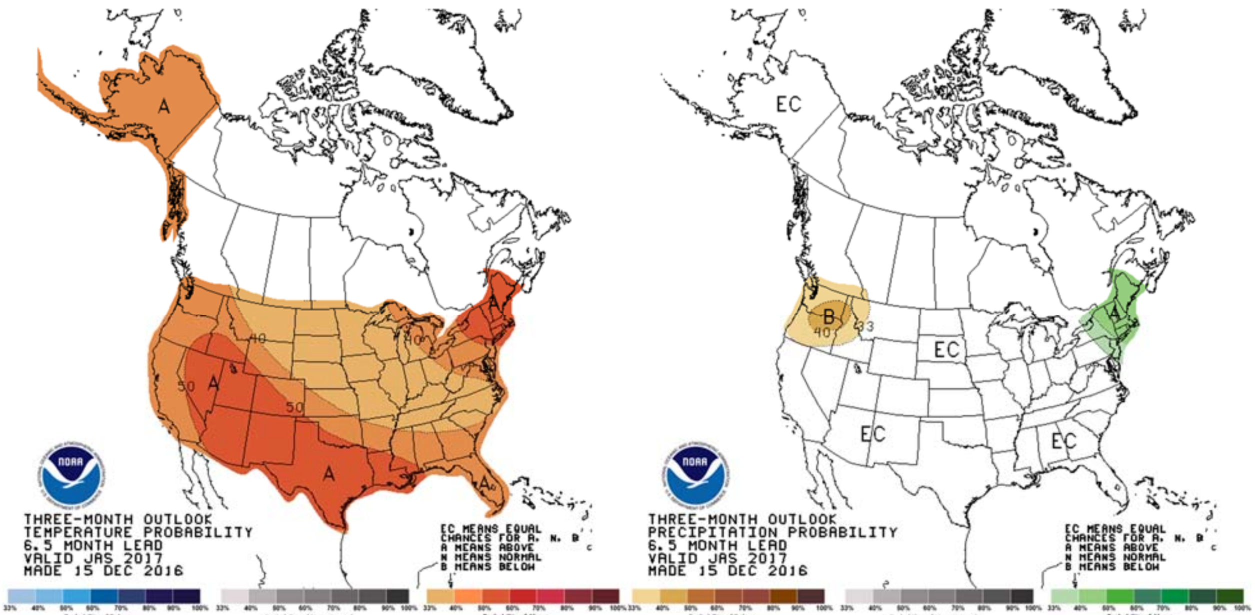


Figure 16. CPC July-August-September 2017 temperature and precipitation outlooks.

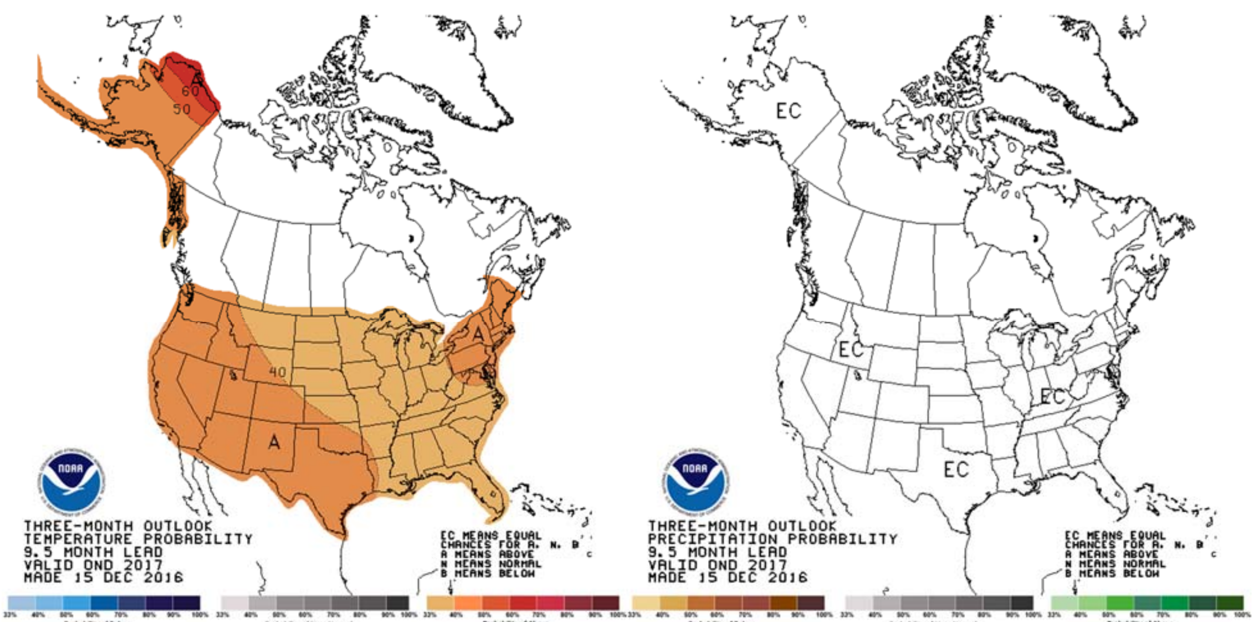
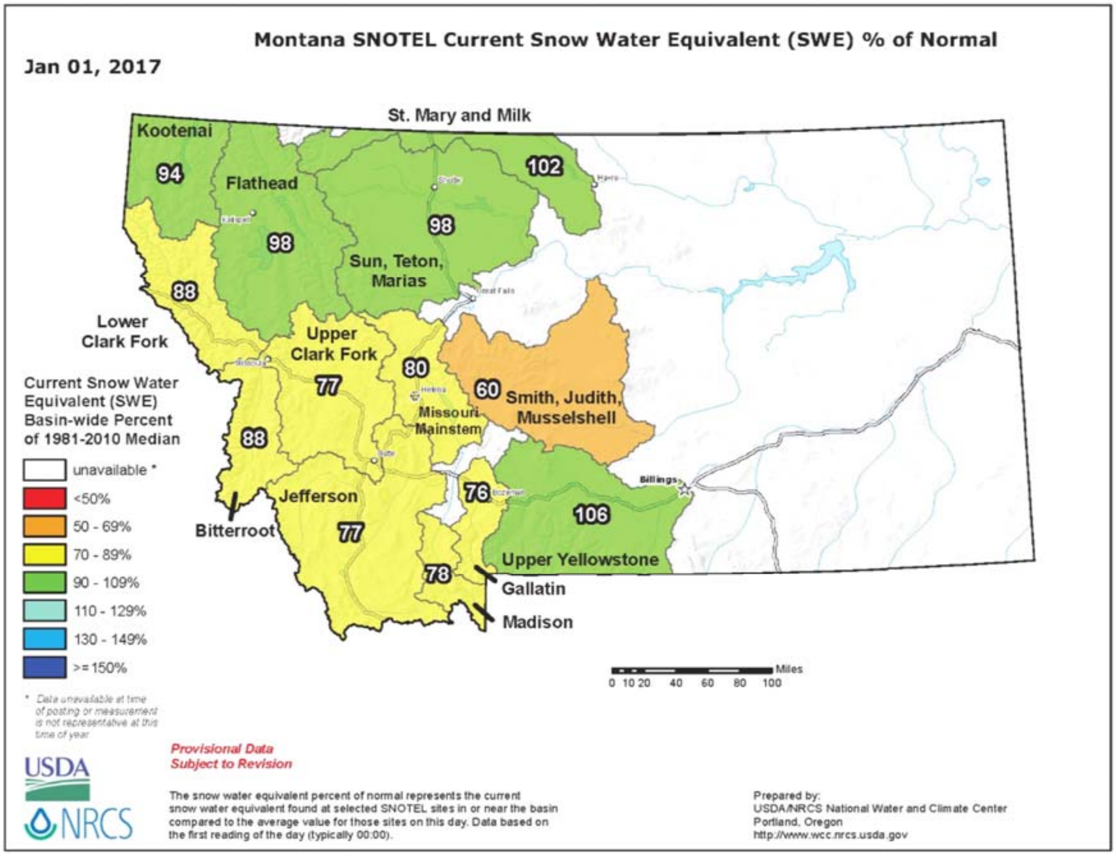


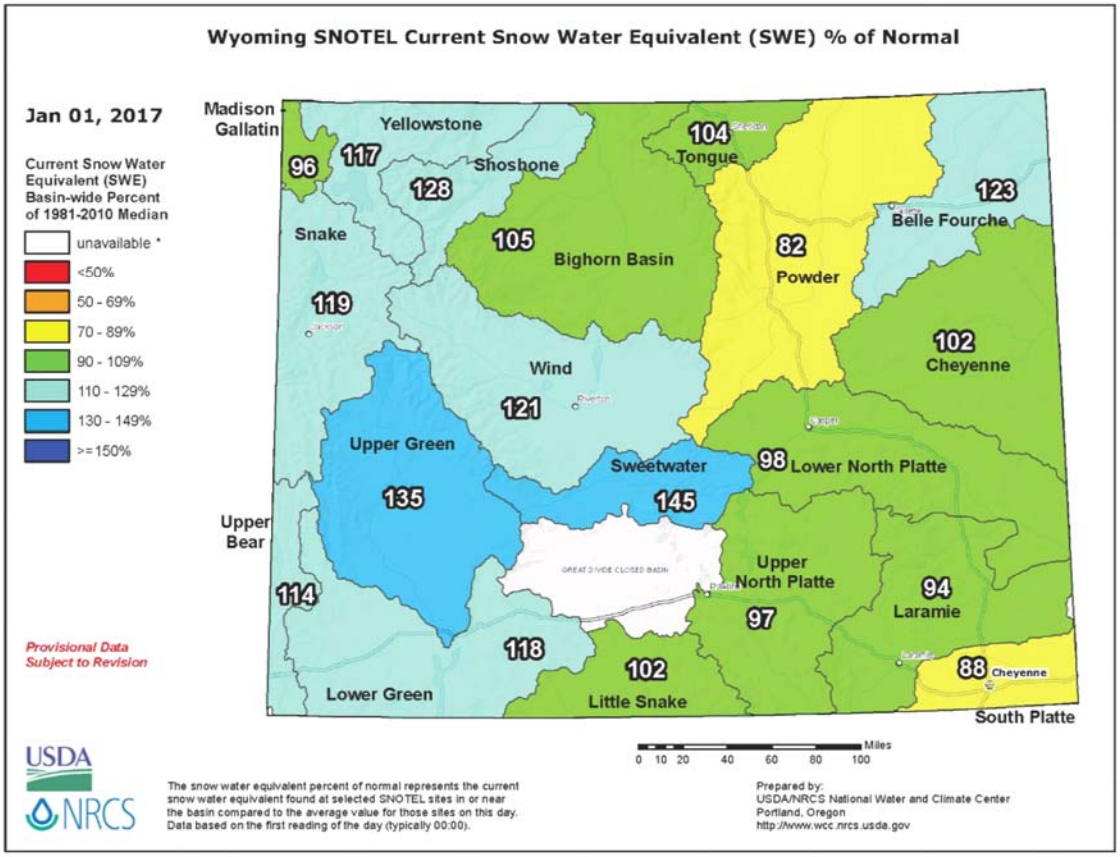
Figure 17. CPC October-November-December 2017 temperature and precipitation outlooks.

January 2017 Calendar Year Runoff Forecast

In summary, the 2017 calendar year runoff forecast is **25.4 MAF**, **100% of average**. Below-average runoff is forecast to continue in January and February; however, the moderate plains snowpack could cause above-average runoff during March and April, especially into Garrison and Oahe. May through July runoff in the Fort Peck and Garrison reaches will be influenced by the below-average mountain snowpack above Fort Peck and the slightly above-average mountain snowpack from Fort Peck to Garrison. Average runoff is forecast for the last half of the runoff season.

Additional Figures




Wyoming SNOTEL Current Snow Water Equivalent (SWE) % of Normal
Jan 01, 2017
Current Snow Water Equivalent (SWE) Basin-wide Percent of 1981-2010 Median
unavailable *
<50%
50 - 69%
70 - 89%
90 - 109%
110 - 129%
130 - 149%
>=150%
Provisional Data Subject to Revision
Madison Gallatin
96
Yellowstone
117
Shoshone
128
Snake
119
105
Bighorn Basin
104
Tongue
82
Powder
123
Belle Fourche
102
Cheyenne
Wind
121
Upper Green
135
Sweetwater
145
98
Lower North Platte
Upper Bear
114
118
Lower Green
102
Little Snake
Upper North Platte
97
94
Laramie
88
Cheyenne
South Platte
Miles
0 10 20 40 60 80 100
The snow water equivalent percent of normal represents the current snow water equivalent found at selected SNOTEL sites in or near the basin compared to the average value for those sites on this day. Data based on the first reading of the day (typically 00:00).
Prepared by:
USDA/NRCS National Water and Climate Center
Portland, Oregon
http://www.wcc.nrcs.usda.gov

USDA NRCS National Water & Climate Center
*** - DATA CURRENT AS OF: January 06, 2017 05:48:13 PM**
- Based on January 01, 2017 forecast values

PRELIMINARY MISSOURI RIVER BASIN FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
Lake Sherburne Inflow	APR-JUL	104	107	128	113	94	79	97
	APR-SEP	119	106	145	130	109	93	112
St Mary R At International Boundary	APR-JUL	470	108	600	525	420	340	435
	APR-SEP	545	108	685	600	490	405	505
Red Rock R Nr Monida (Lima Res Inflow)	APR-JUL	73	97	111	89	58	35	75
	APR-SEP	80	100	122	97	63	38	80
Beaverhead R Nr Grant (Clark Canyon Res I	APR-JUL	85	84	147	110	60	23	101
	APR-SEP	105	88	175	133	77	35	120
Jefferson R Nr Three Forks	APR-JUL	635	86	1070	810	460	200	740
	APR-SEP	685	86	1170	880	490	205	800
Madison R Nr Grayling (Hebgen Lake Inflow	APR-JUL	390	105	485	425	350	290	370
	APR-SEP	495	105	610	540	445	375	470
Madison R Nr Mcallister (Ennis Res Inflow	APR-JUL	640	102	805	705	570	470	625
	APR-SEP	790	102	990	870	710	595	775
Missouri R At Toston	APR-JUL	1640	92	2360	1930	1350	925	1790
	APR-SEP	1910	92	2730	2240	1580	1090	2070
Smith R bl Eagle Ck (2)	APR-JUL	83	78	138	105	60	28	106
	APR-SEP	94	81	157	120	68	30	116
Sun R At Gibson Dam Nr Augusta	APR-JUL	385	97	505	435	335	265	395
	APR-SEP	425	97	550	475	370	295	440
Marias R Nr Shelby	APR-JUL	315	88	490	385	245	145	360
	APR-SEP	330	88	500	400	260	157	375

PRELIMINARY YELLOWSTONE RIVER BASIN FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
West Rosebud Ck Nr Roscoe (Mystic Lake In	APR-JUL	60	102	70	64	56	50	59
	APR-SEP	77	104	90	82	72	64	74
Wind R Ab Bull Lake Ck	APR-JUL	570	125	735	635	500	400	455
	APR-SEP	615	126	800	690	540	435	490
Bull Lake Ck Nr Lenore	APR-JUL	156	112	191	170	141	120	139
	APR-SEP	189	112	230	205	172	146	169
Wind R Blw Boysen Resv (adj)	APR-JUL	775	127	1120	915	635	425	610
	APR-SEP	835	126	1210	985	685	465	665
Greybull R At Meeteetse	APR-JUL	161	123	215	183	139	106	131
	APR-SEP	215	121	285	245	191	152	177
Shell Ck Nr Shell	APR-JUL	57	104	73	64	50	41	55
	APR-SEP	69	105	86	76	61	51	66
Bighorn R At Kane, Wy	APR-JUL	1090	130	1580	1290	890	595	840
	APR-SEP	1160	128	1700	1380	950	635	905
NF Shoshone R at Wapiti	APR-JUL	635	138	735	675	595	535	460
	APR-SEP	705	137	810	750	665	605	515
SF Shoshone R nr Valley	APR-JUL	275	128	325	295	255	230	215
	APR-SEP	320	131	375	345	300	265	245
Shoshone R Blw Buffalo Bill Resv (adj)	APR-JUL	985	146	1200	1070	900	770	675
	APR-SEP	1090	146	1320	1180	995	855	745
Bighorn R Nr St Xavier	APR-JUL	1930	140	2560	2180	1670	1300	1380
	APR-SEP	2050	140	2740	2330	1770	1360	1460
Little Bighorn R Nr Hardin	APR-JUL	94	96	156	119	69	33	98

	APR-SEP	106	95	174	134	79	39	111
Tongue R nr Dayton (2)	APR-JUL	78	91	112	92	64	44	86
	APR-SEP	89	91	126	104	75	53	98
Tongue R At State Line Nr Decker	APR-JUL	189	98	295	230	146	82	193
	APR-SEP	210	98	325	255	164	97	215
NF Powder R nr Hazelton	APR-JUL	7.9	87	11.2	9.3	6.6	4.7	9.1
	APR-SEP	8.6	87	12.0	10.0	7.2	5.2	9.9
Powder R At Moorhead	APR-JUL	160	90	300	215	102	17.3	177
	APR-SEP	176	90	320	235	118	31	196
Powder R Nr Locate	APR-JUL	181	91	340	245	118	25	199
	APR-SEP	198	90	365	265	131	32	220

Max (10%), 30%, 50%, 70% and Min (90%) chance that actual volume will exceed forecast.
Averages are for the 1981-2010 period.
All volumes are in thousands of acre-feet.

footnotes:
1) Max and Min are 5% and 95% chance that actual volume will exceed forecast
2) streamflow is adjusted for upstream storage
3) median value used in place of average

Upper Missouri River Basin
February 2017 Calendar Year Runoff Forecast
February 6, 2017

U.S. Army Corps of Engineers, Northwestern Division
Missouri River Basin Water Management
Omaha, NE

Calendar Year Runoff Forecast

Explanation and Purpose of Forecast

The long-range runoff forecast is presented as the Calendar Year Runoff Forecast. This forecast is developed shortly after the beginning of each calendar year and is updated at the beginning of each month to show the actual runoff for historic months of that year and the updated forecast for the remaining months of the year. This forecast presents monthly inflows in million acre-feet (MAF) from five incremental drainage areas, as defined by the individual System projects, plus the incremental drainage area between Gavins Point Dam and Sioux City. Due to their close proximity, the Big Bend and Fort Randall drainage areas are combined. Summations are provided for the total Missouri River reach above Gavins Point Dam and for the total Missouri River Basin above Sioux City (upper Basin). The Calendar Year Runoff Forecast is used in the Monthly Study simulation model to plan future system regulation in order to meet the authorized project purposes throughout the calendar year.

Observed Runoff

The final calendar year 2016 runoff summation for the upper Basin was 24.1 MAF (95% of average), while it was 19.8 MAF (85% of average) for the Missouri Basin above Gavins Point.

January 2017 runoff was 151% of average for the upper Basin due to snowmelt in the upper Basin caused by warmer than normal temperatures during the past two weeks. Runoff was below average in the Fort Peck reach, but above average in all other reaches.

2017 Calendar Year Forecast Synopsis

The February 1 forecast for the 2017 Missouri River runoff above Sioux City, IA is **26.2 MAF (103% of average)**. Runoff above Gavins Point Dam is forecast to be **23.6 MAF (102% of average)**. Due to the amount of variability in precipitation and other hydrologic factors that can occur over the next 11 months, the range of expected inflow is quite large and ranges from the 36.0 MAF upper basic forecast to the 17.5 MAF lower basic forecast. The upper and lower basic forecasts are used in long-term regulation planning models to “bracket” the range of expected runoff given much wetter or drier conditions, respectively. Given that 11 months are being forecasted for this February 1 forecast (1 months observed/11 months forecast), the range of wetter than normal (upper basic) and lower than normal (lower basic) is attributed to all 6 reaches for all 11 months. The result is a large range or "bracket" for each reach, and thus, for the total runoff forecast. As the year progresses, the range will lessen as the number of observed months increases and number of forecast months decreases.

Current Conditions

Drought Analysis

The latest National Drought Mitigation Center's drought monitor for January 31, 2017 (**Figure 1**), is compared to the drought monitor for December 27, 2016 (**Figure 2**). The U.S. Drought Monitor indicates there are some areas of Moderate Drought (D1) in northeastern Wyoming, southeastern Montana, and western South Dakota. Abnormally Dry (D0) conditions persist in areas surrounding the D1 Drought and in small areas of western and eastern Montana. The Seasonal Drought Outlook in **Figure 3** indicates drought conditions will persist, especially in northeastern Wyoming and western South Dakota through the end of April 2017; however, some improvement is likely in these areas.

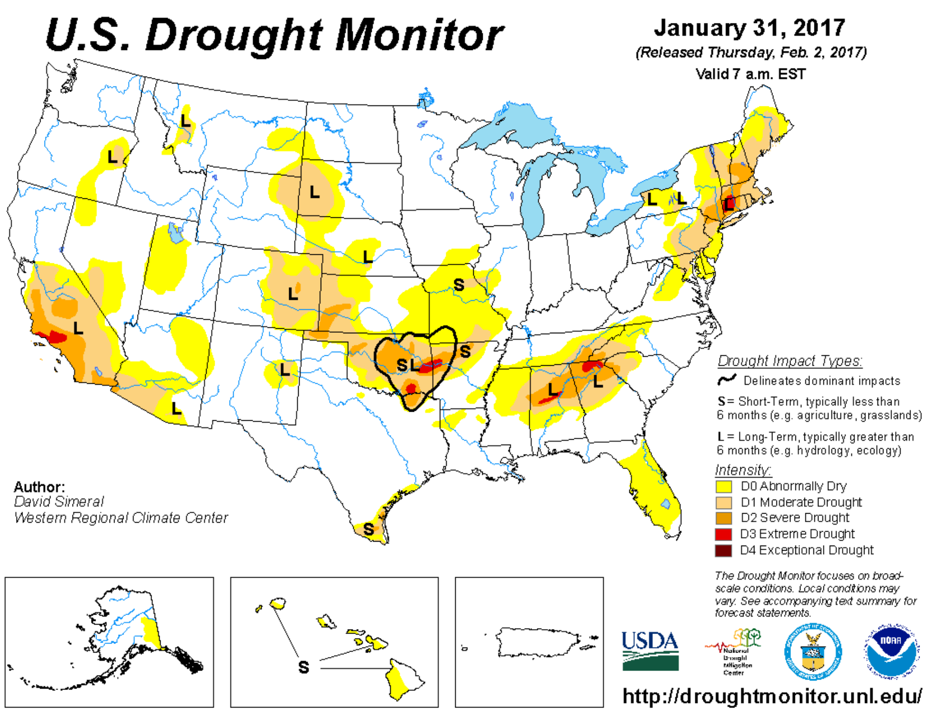


Figure 1. National Drought Mitigation Center U.S. Drought Monitor for January 31, 2017.

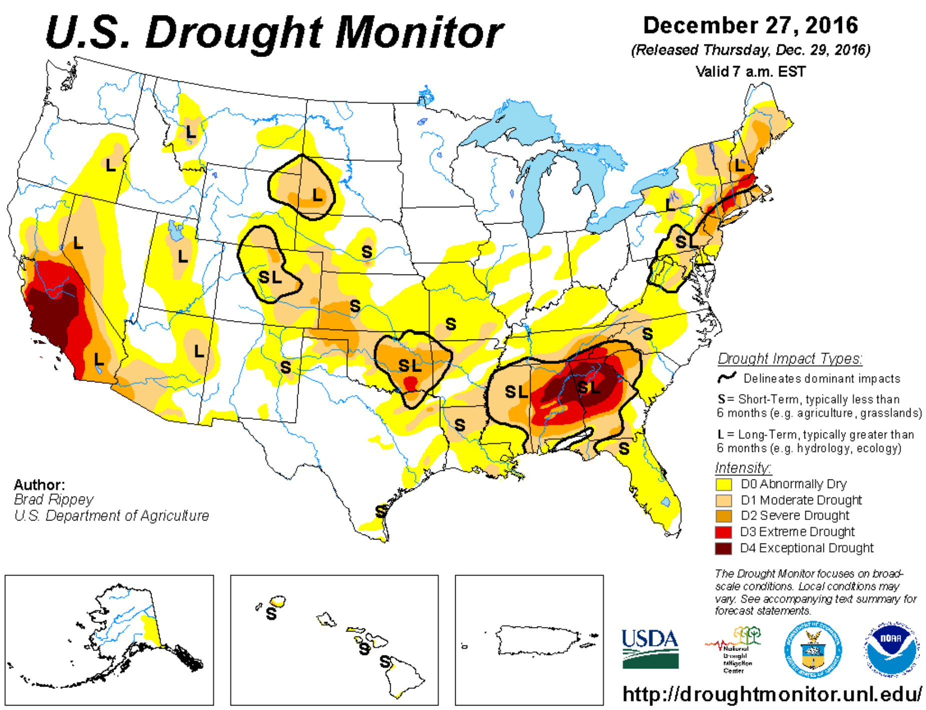


Figure 2. National Drought Mitigation Center U.S. Drought Monitor for December 27, 2016.

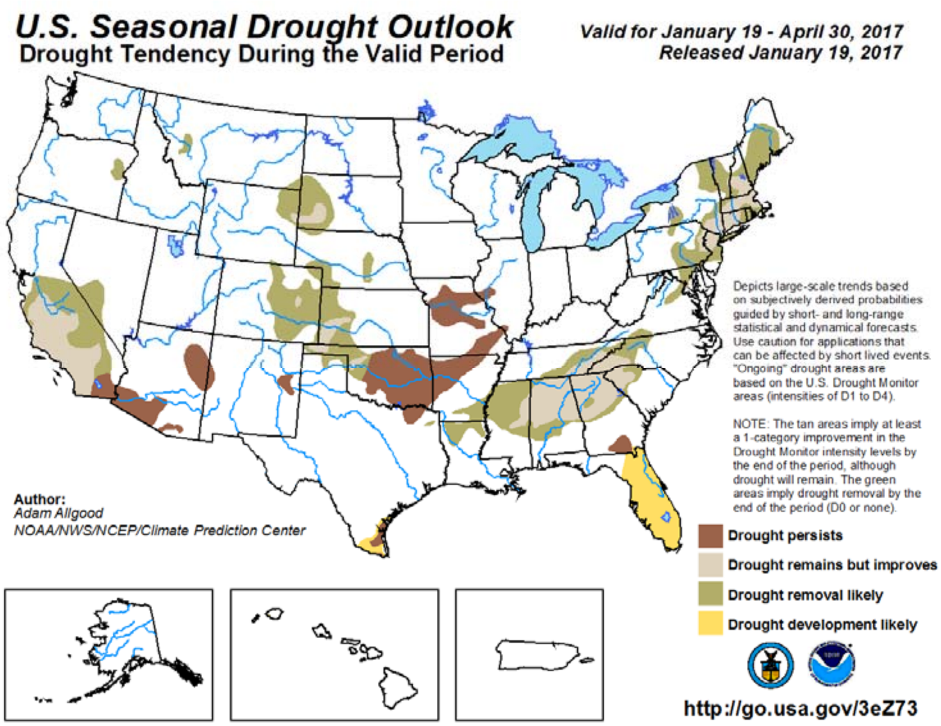


Figure 3. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

Monthly precipitation accumulations are shown using High Plains Regional Climate Center images available at http://www.hprcc.unl.edu/. The January precipitation accumulations are shown in **Figure 4** as inches of precipitation (left) and percent of normal precipitation (right). Precipitation was about average in Montana and North Dakota, while precipitation was more than 200% of normal over large areas of Wyoming, central and southern South Dakota and Nebraska. A significant portion of the precipitation in the eastern Dakotas, Nebraska and Iowa occurred as rain or freezing rain during January; therefore, snowfall was below normal in these regions. November-December-January precipitation accumulations are shown in **Figure 5**. The three-month accumulations reflect a relatively wet pattern across Wyoming, North Dakota, South Dakota and northern Nebraska. Below-normal precipitation occurred in much of Montana and the lower basin including eastern Kansas and Missouri.

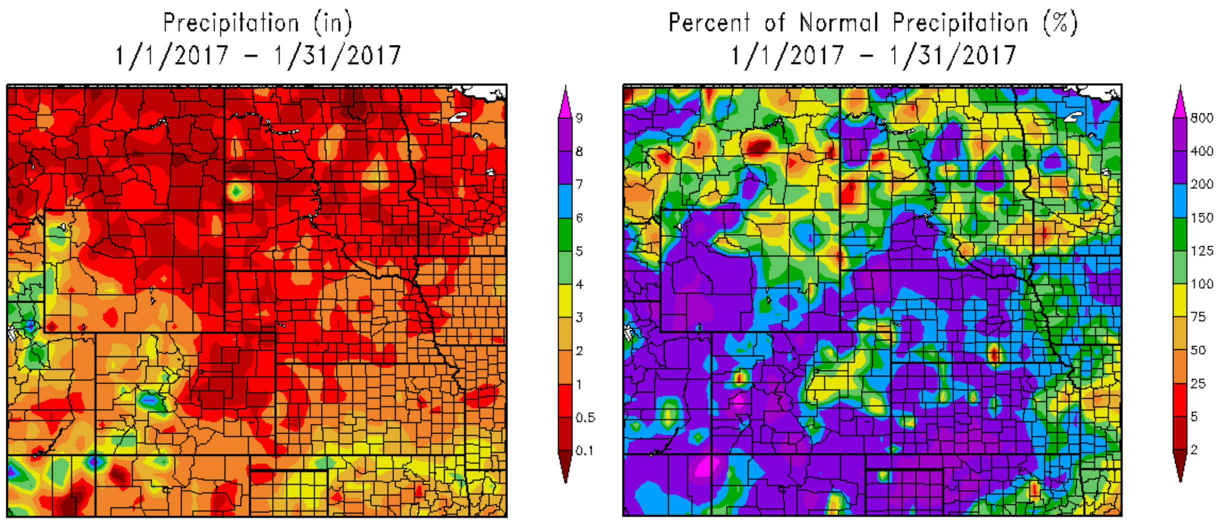


Figure 4. January 2017 Precipitation (inches) and Percent of Normal Precipitation.

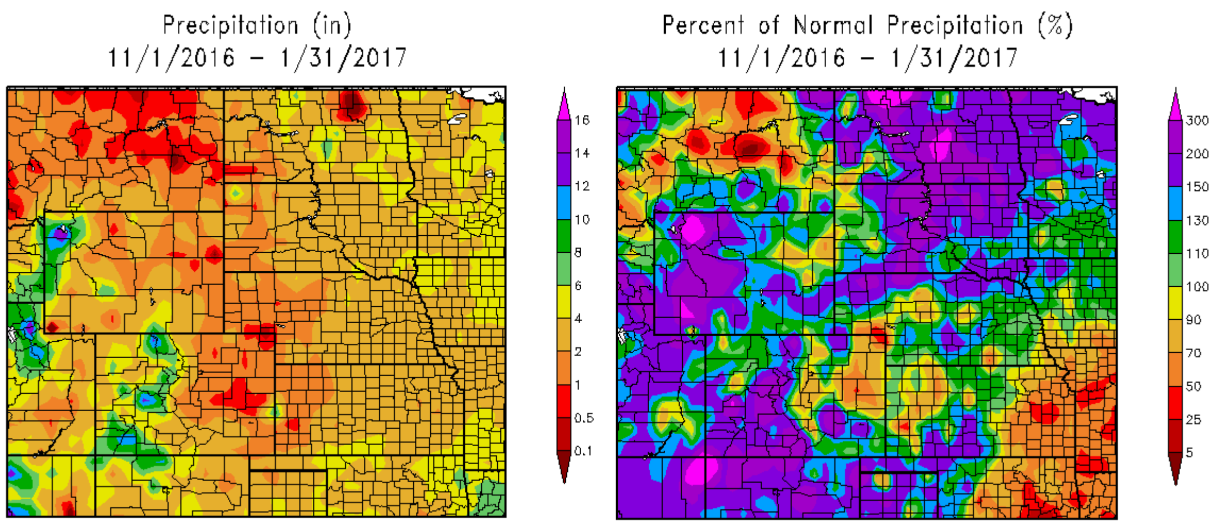


Figure 5. November-December 2016–January 2017 Precipitation (inches) and Percent of Normal Precipitation.

Temperature

January temperature departures in degrees Fahrenheit (deg F) in the left image of **Figure 6** were predominantly below normal, especially in Montana, Wyoming and the western Dakotas. Departures ranged from 3 to 12 deg F below normal; however, warmer-than-normal temperatures prevailed in the upper Basin during the last two weeks of January. Temperatures in the eastern Dakotas, Nebraska, and Iowa ranged from near normal to 6 deg F above normal in January. November-December-January temperatures, in the right image of **Figure 6**, were 0 to 6 deg F below normal over much of Montana and Wyoming, while temperatures were normal to 6 deg F above normal in the remainder of the Missouri Basin.

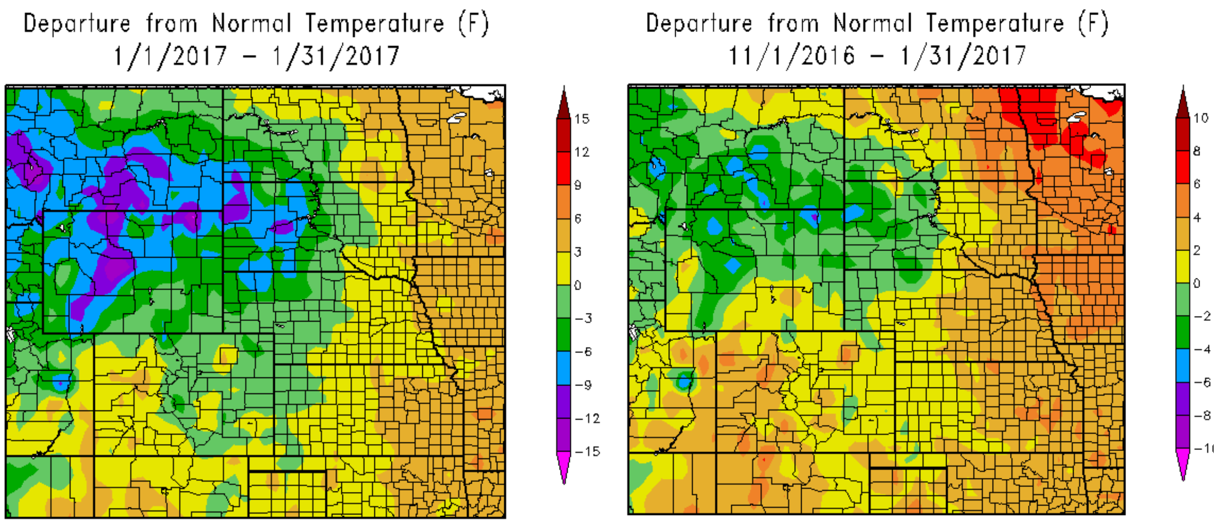
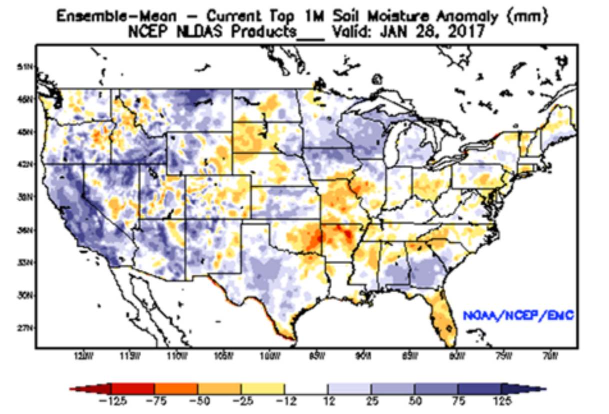


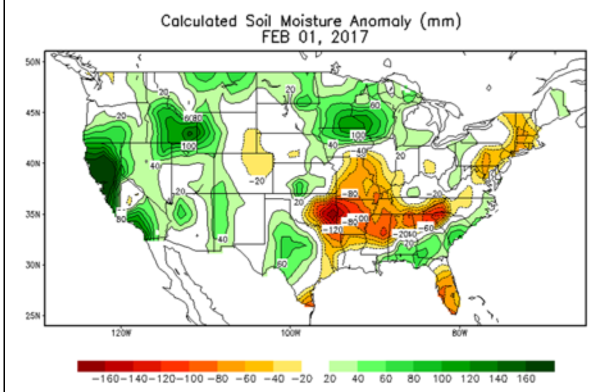
Figure 6. January 2017 and November-December 2016-January 2017 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Soil Moisture

Soil moisture is factored into the forecast as an indicator of wet or dry hydrologic basin conditions. Typically when soil moisture conditions are wet or greater than normal, rainfall and snowmelt runoff is greater than when soil moisture is dry or less than normal. Not only is soil moisture a physical parameter that influences runoff, it can be used as an indicator of future runoff. As the calendar year approaches winter, the wet and dry soil moisture conditions will provide some insight into late winter and early spring runoff potential.

The left image of **Figure 7** shows the NOAA NLDAS ensemble top one-meter soil moisture anomaly on January 28, 2017. The NLDAS image shows wetter-than-normal conditions across Montana, northwestern North Dakota, central and western Wyoming, eastern South Dakota and northwestern Iowa. Drier-than-normal conditions are present in central North Dakota, eastern Wyoming, western South Dakota, Nebraska and Missouri. Similarly, the CPC Soil Moisture Anomaly, in the right image of **Figure 7**, indicates wetter-than-normal soil moisture conditions in Montana, western Wyoming, North Dakota, eastern South Dakota, eastern Nebraska and northern Iowa.

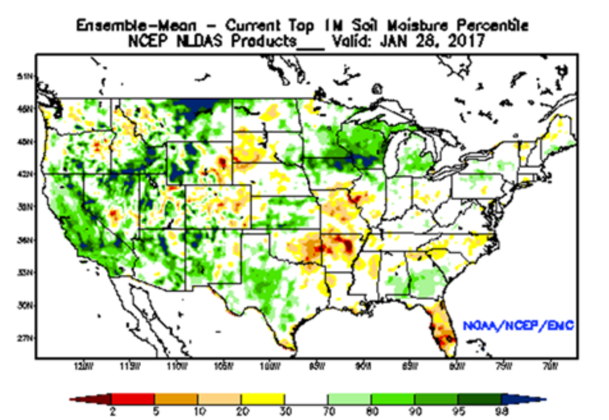


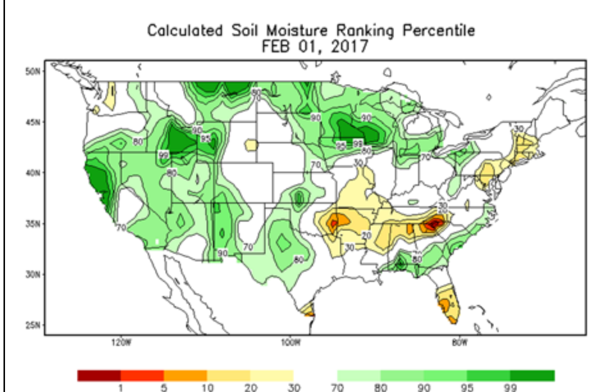


NOAA NLDAS Drought Monitor Soil Moisture.	CPC Soil Moisture.
http://www.emc.ncep.noaa.gov/mmb/nldas/drought/	http://www.cpc.ncep.noaa.gov/products/Soilmst_Monitoring/US/Soilmst/Soilmst.shtml#

Figure 7. NOAA NLDAS and CPC Soil Moisture Anomalies (mm).

Soil moisture conditions expressed as a percentile ranking can show the severity and rarity of the soil moisture conditions through the percentile ranking probability. Soil moisture percentile rankings from NOAA NLDAS and the CPC are shown in **Figure 8**. The NLDAS percentile ranking, in the left image of **Figure 8**, indicates very wet soil moisture conditions (95th percentile rank) in north central Montana and localized regions of central Wyoming. A 95th percentile ranking soil moisture conditions indicates soil moisture is wetter than 95 out of 100 soil moisture samples or years for the indicated date. The CPC percentile ranking, in the right image of **Figure 8**, indicates very wet soil moisture conditions (95th percentile ranking) in areas of north central Montana and western Wyoming. The percentile rankings of drier-than-normal areas in western South Dakota and eastern Wyoming differ somewhat between the models. The NLDAS map shows that dry soils rank between the 2nd and 30th percentile rankings for moisture, while the CPC ranking indicates a small region between the 20th and 40th percentile ranking.





NOAA NLDAS Drought Monitor Soil Moisture.	CPC Soil Moisture.
http://www.emc.ncep.noaa.gov/mmb/nldas/drought/	http://www.cpc.ncep.noaa.gov/products/Soilmst_Monitoring/US/Soilmst/Soilmst.shtml#

Figure 8. NOAA NLDAS and CPC Soil Moisture Percentile Rankings.

Frost Conditions

Figure 9 shows the depth of frost penetration at NWS Warning Forecast Office (WFO) locations in the Missouri Basin as of January 30, 2017. Moderately deep soil frost was reported at Great Fall, MT (22 inches); Glasgow, MT (44 inches); Bismarck, ND (28 inches); Riverton, WY (35 inches); Rapid City, SD (16 inches); and, Aberdeen, SD (30 inches). Local reports of ground conditions indicate the soil surface is partially thawed in many areas of Montana and the Dakotas on top of the frost layer.

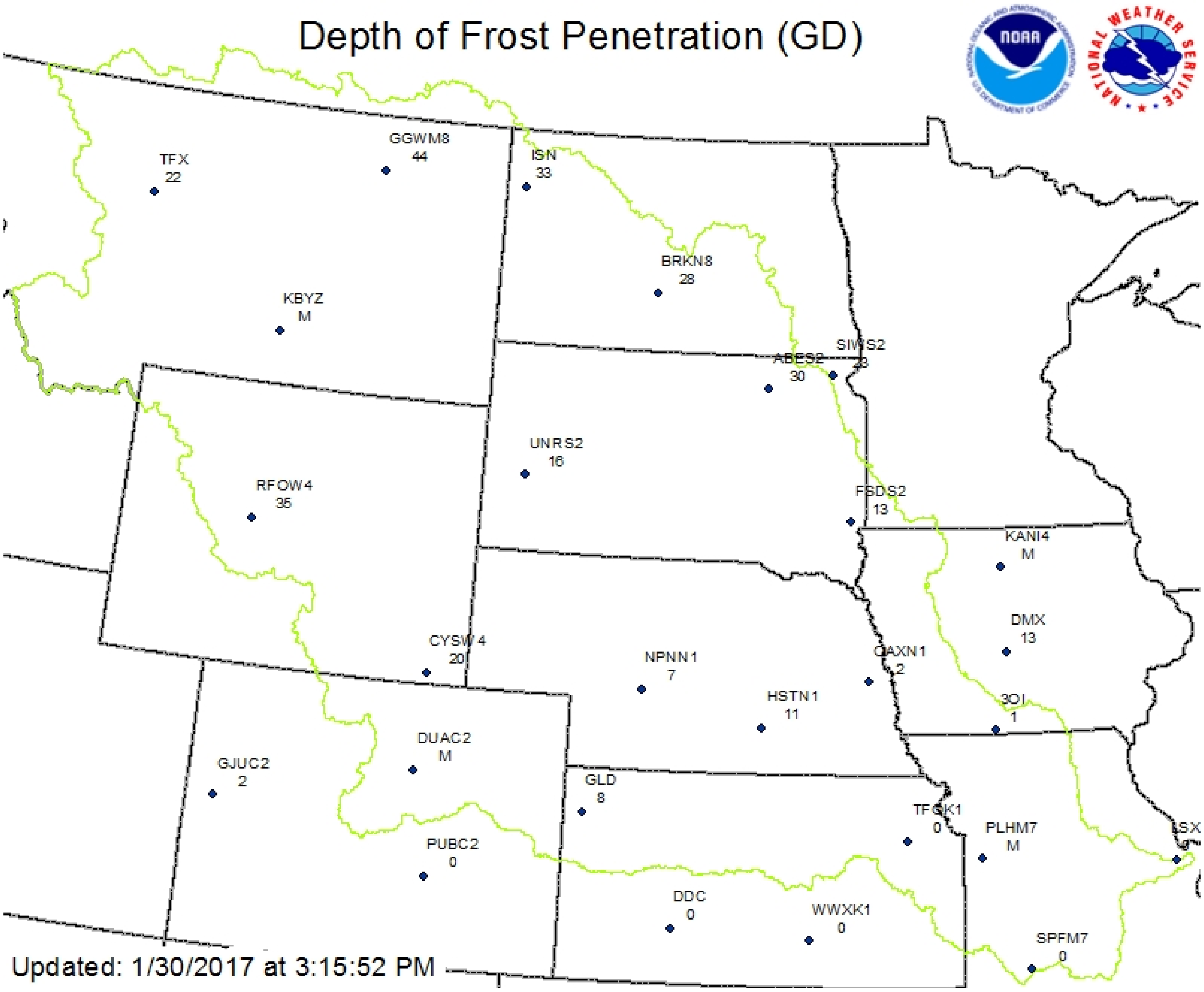


Figure 9. Measured frost depth (inches) at NWS WFO offices as of January 30, 2017. Source: NWS MBRFC. http://www.crh.noaa.gov/mbrfc

Plains Snowpack

Plains snowpack is an important parameter that influences the volume of runoff occurring in the basin during the months of March and April. A common misperception is that the March-April runoff is a result of plains snowmelt only. Historically, about 25% of annual runoff occurs in March and April, during the time when plains snow is melting, due to both melting snowpack and rainfall runoff. Runoff occurs in March and April whether or not there is any plains snow to melt. Determining exact rainfall amounts and locations are nearly impossible to predict more than a week in advance. Thus, the March-April runoff forecast is formulated based on existing plains snowpack and existing basin conditions and hydrologic forecasts, which for this year primarily includes long-term precipitation outlooks. At this time of year, plains snowpack provides some indication of March-April runoff; however, as the snowpack reaches its ultimate peak accumulation, better forecasts of future runoff can be made. Some areas of North Dakota have received a significant amount of snowfall so far this winter. The NWS at Bismarck, which normally receives about 29 inches of snowfall by the end of January, has received 58.7 inches of snow as of February 1.

The National Weather Service's National Operational Hydrologic Remote Sensing Center (NOHRSC), modeled snow assessment, shown in **Figure 10**, indicates 3 to 5 inches of snow water equivalent (SWE) have accumulated in central North Dakota and north central South Dakota, with some pockets of heavier snow. In eastern Montana and areas surrounding the heavier snowpack, 1 to 3 inches have accumulated. The plains SWE as of January 1, 2017 is shown in **Figure 11**. Since January 1, plains water equivalent has increased some in central North Dakota and north central South Dakota as a result of January precipitation. The extent of the plains snowpack has decreased slightly as a result of warmer-than-normal temperatures at the end of January. Less than 1 inch of SWE covers the remainder of the upper Basin, while the lower Basin has very little snowpack.

Cooperative snow survey measurements indicate 3.6 inches of SWE have accumulated in Bismarck, ND; and 3.9 inches is present near Jamestown, ND. Additional measurements during the week of January 30 indicated 2.0 to 4.0 inches of SWE throughout central North Dakota and north central South Dakota. The greatest amounts of SWE in North Dakota were measured near Beulah (7.3 inches) and in the Cannonball River basin near McIntosh, SD (4.9 inches). In central South Dakota, 2.0 to 3.0 inches of SWE were measured near Oahe Dam and Onida, respectively. A full report of snow depth and SWE measurements is available at http://www.nwd-mr.usace.army.mil/rcc/snowsurvey/snowsurvey.html.

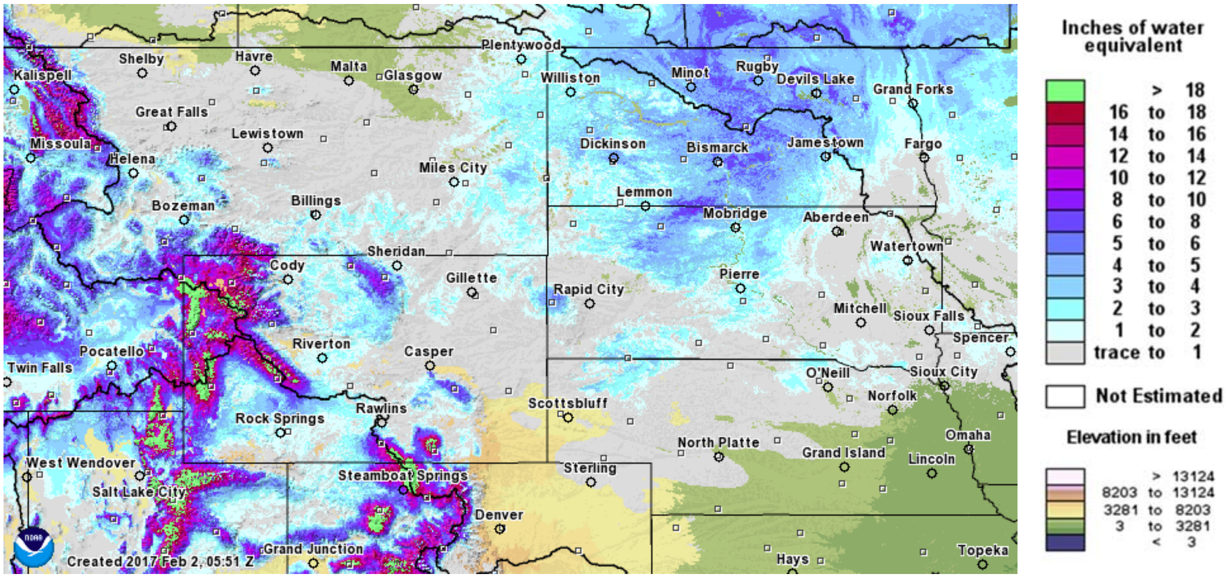


Figure 10. February 1, 2017 NOHRSC modeled plains snow water equivalent. Source: NOAA National Operational Hydrologic Remote Sensing Center. http://www.nohrsc.nws.gov/interactive/html/map.html

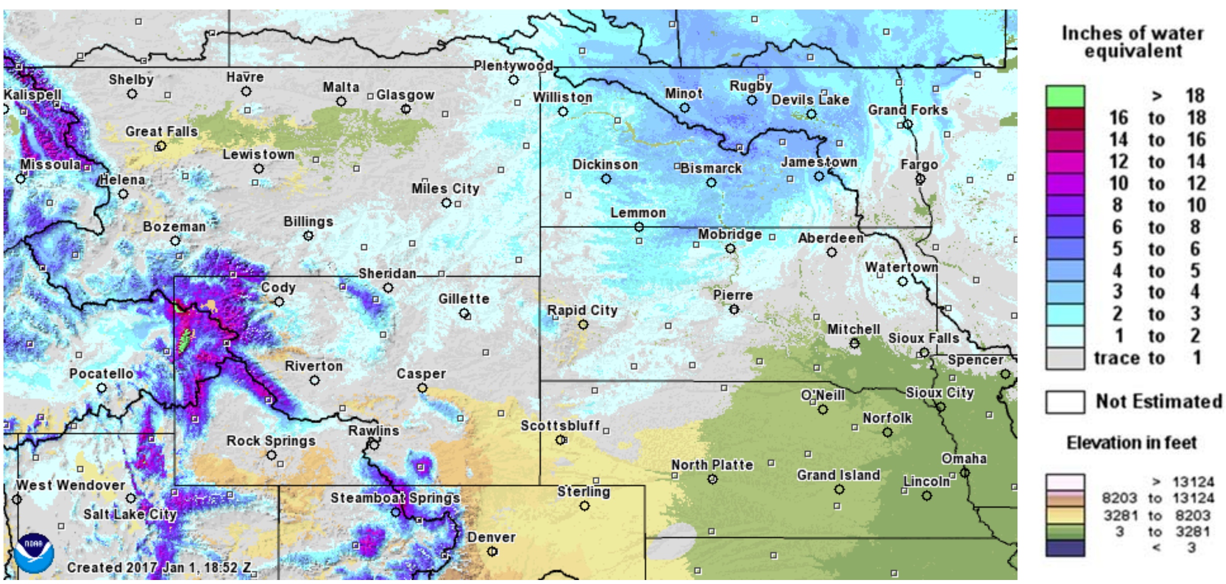


Figure 11. January 1, 2017 NOHRSC modeled plains snow water equivalent. Source: NOAA National Operational Hydrologic Remote Sensing Center. http://www.nohrsc.nws.gov/interactive/html/map.html

Mountain Snow Pack

Mountain snowpack is the primary factor used to predict May-July runoff volumes in the Fort Peck and Fort Peck to Garrison reaches. During the 3-month May-July runoff period, about 50% of the annual runoff enters the Mainstem System as a result of mountain snowmelt and rainfall runoff. Greater-than-average mountain snow accumulations are usually associated with greater-than-average May-July runoff volumes, especially when mountain soil moisture conditions have been wetter than normal as in the past three years. For example, we would expect to see higher-than-average runoff from an average mountain snowpack this year due to wetter-than-normal soil moisture conditions.

Figure 12 includes time series plots of the average mountain SWE beginning on October 1, 2016 based on the NRCS SNOTEL gages for the headwater basin above Fort Peck and the incremental basin from Fort Peck to Garrison. The current average SWE values (shaded blue area) are plotted against the 1981-2010 basin average SWE (bold red line), a recent low SWE year in 2001 (green line), and two historic high SWE years occurring in 1997 (purple) and 2011 (dark blue).

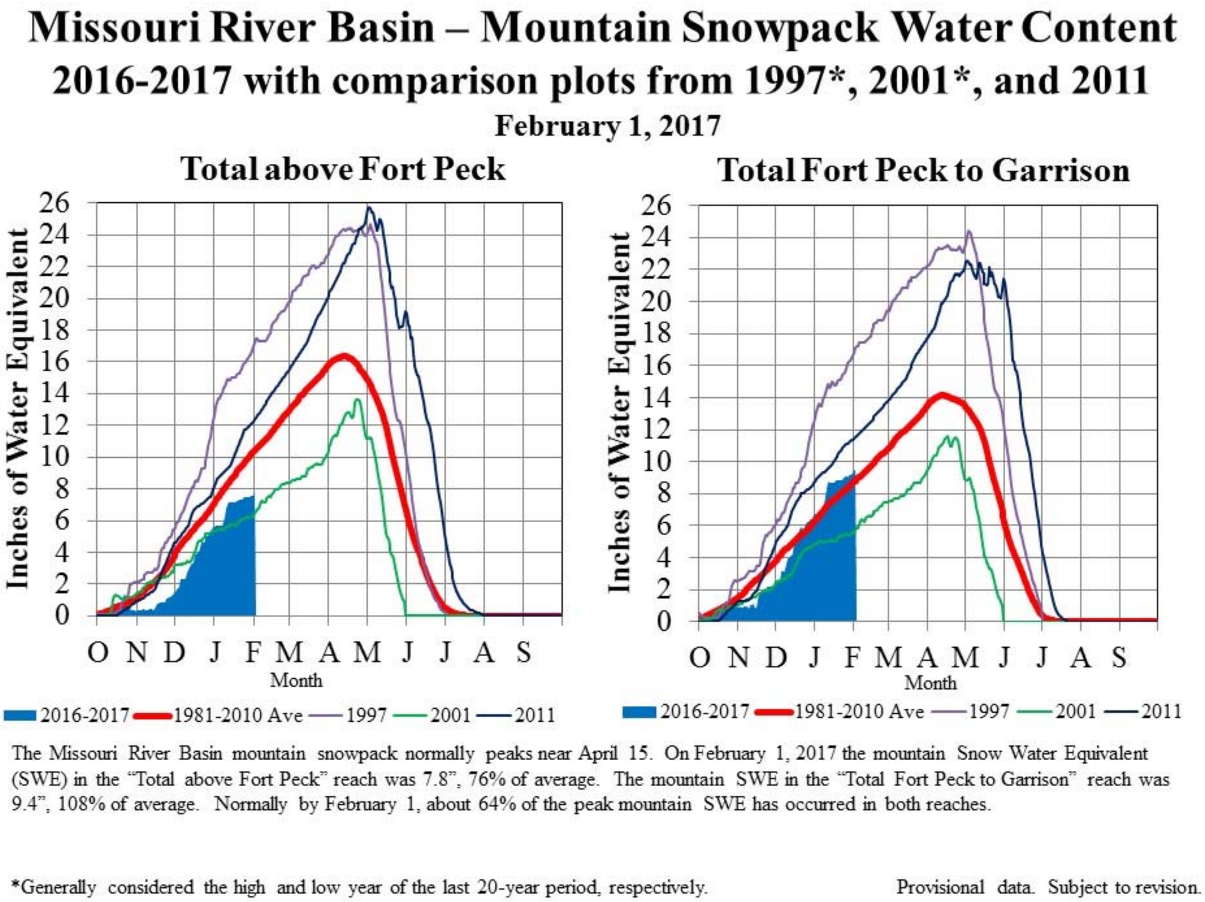


Figure 12. Mountain snowpack water content on February 1, 2017 compared to normal and historic conditions. Corps of Engineers - Missouri River Basin Water Management.

As of **February 1, 2017**, the Corps of Engineers computed an average mountain SWE in the **Fort Peck reservoir reach of 7.8 inches, which is 76% of average for February 1** based on the 1981-2010 average SWE for the Fort Peck reach. In the **reservoir reach between Fort Peck Dam and Garrison Dam**, the Corps computed an average mountain SWE of **9.4 inches, which is 108% of average for February 1** based on the 1981-2010 average SWE for the Garrison reach. Normally, 64% or less than half of the peak snow accumulation has occurred in the mountains by February 1, with slightly more than half of the snow accumulation season remaining.

In the **Additional Figures** section at the end of this document, basin maps of the mountain snowpack as a percent of median are provided for Montana, Wyoming and Colorado. These maps show that mountain snowpack is below median in much of Montana, but well-above median in many Wyoming basins and all Colorado basins.

Climate Outlook

MRBWMD participates in the monthly North Central U.S. Climate/Drought Outlook Webinar coordinated through NOAA, the regional climate centers, and the American Association of State Climatologists (AASC). These webinars provide updates on near-term climate outlooks and impacts including the ENSO climate pattern and its implications on winter temperature and precipitation patterns in the Missouri River Basin.

During the week of January 30, 2017, MRBWM requested the third round of cooperative snow survey measurements in the upper Missouri River Basin to help assess the depth and water equivalent of plains snowpack during the 2016-2017 winter. These measurements are used by MRBWM to adjust the March-April runoff forecast, and the measurements are shared with NWS NOHRSC to help verify modeled snow estimates used in spring streamflow forecasts. In addition to this snow information, anecdotal basin condition information such as soil moisture content and frost depth improves situational awareness among federal, state and local agencies.

ENSO (El Niño Southern Oscillation)

The latest ENSO update indicates that weak La Niña condition are present and a transition to ENSO-neutral conditions are favored during February 2017. The impacts of La Niña on Missouri Basin climate could continue into the spring, and these impacts are reflected in the one-month and three-month climate periods CPC temperature and precipitation outlooks.

Temperature and Precipitation Outlooks

The NOAA Climate Prediction Center climate outlook for January 2017 (**Figure 13**) indicates there could be an increased probability for above-normal temperatures in most of the Missouri Basin. With regard to precipitation, there could be an increased probability that precipitation will be above normal over much of the upper Basin, especially in western Montana, while there could be equal chances for above-normal, normal and below-normal precipitation in the lower Basin.

The February-March-April temperature outlook (**Figure 14**) indicates there could be increased chances for below-normal temperatures in Montana, North Dakota and northern South Dakota. There are equal chances for above-normal, normal and below-normal temperatures in the remainder of the Missouri Basin. The February-March-April precipitation outlook shows increased chances for above-normal precipitation over Montana, northern Wyoming, North Dakota and much of South Dakota. There are equal chances for above-normal, normal and below-normal precipitation in all other areas of the Missouri Basin.

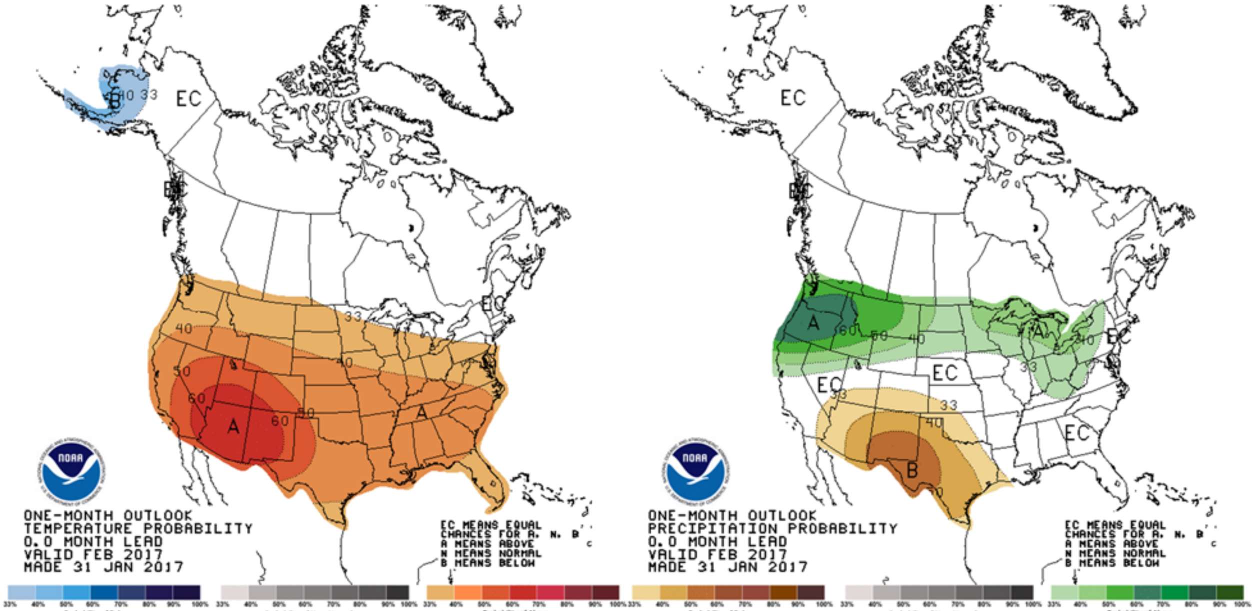


Figure 13. CPC February 2017 temperature and precipitation outlooks.

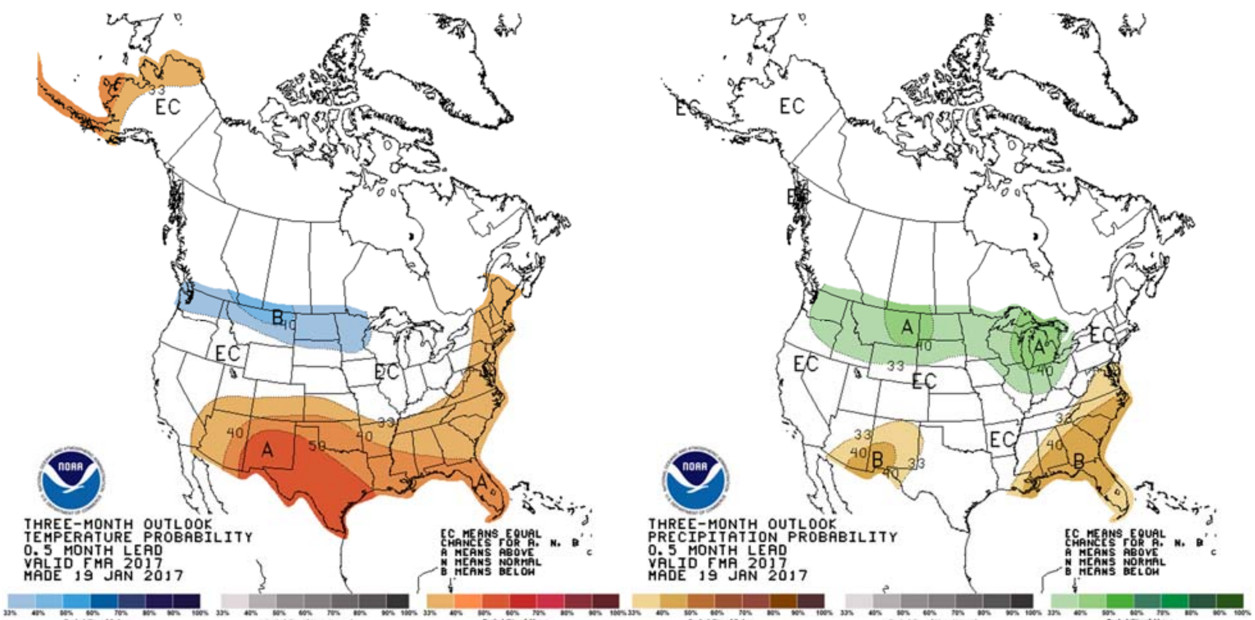


Figure 14. CPC February-March-April 2017 temperature and precipitation outlooks.

The May-June-July CPC temperature outlook (**Figure 15**) indicates there could be equal chances for above-normal, normal, and below-normal temperatures over the north central U.S. including central and eastern Montana, northeastern Wyoming and the Dakotas. There could be increased chances for above normal temperatures in western Montana, much of Wyoming and the lower Basin. With regard to precipitation, there could be equal chances for above-normal, normal and below-normal precipitation in most of the Missouri Basin, reflecting possible ENSO-neutral conditions.

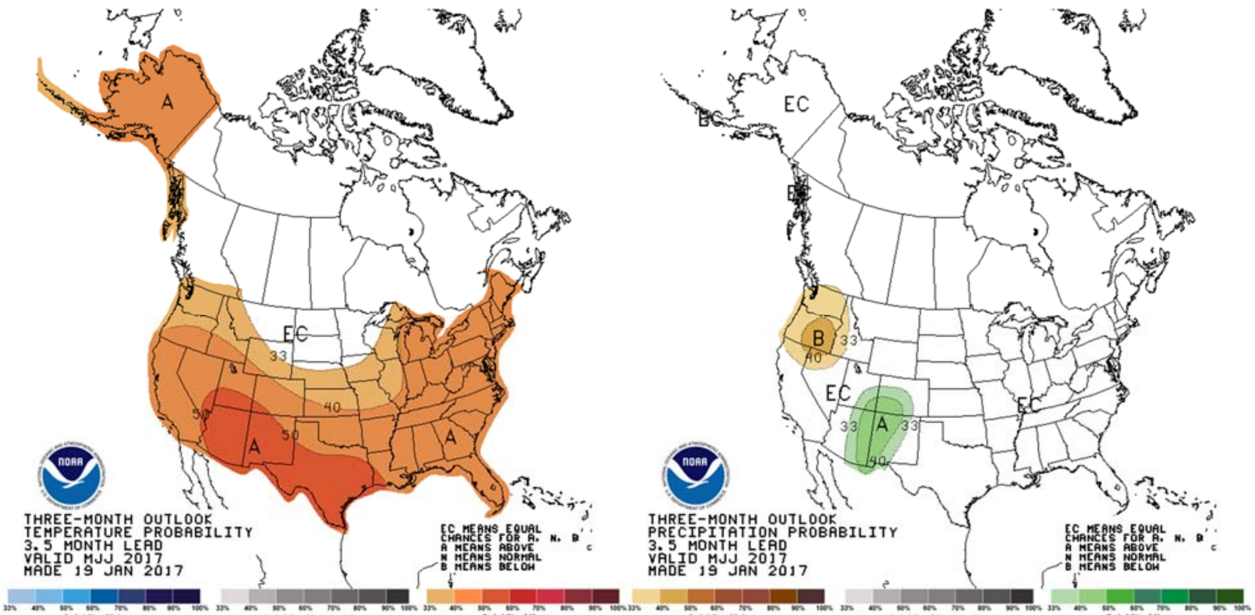


Figure 15. CPC May-June-July 2017 temperature and precipitation outlooks.

During the August-September-October period (**Figure 16**) and the November-December 2017-January 2018 period (**Figure 17**) outlooks indicate increased chances for above-normal temperatures over the entire Missouri Basin. With regard to the precipitation outlooks, the CPC indicates equal chances for above-normal, normal and below-normal precipitation from August through January 2018.

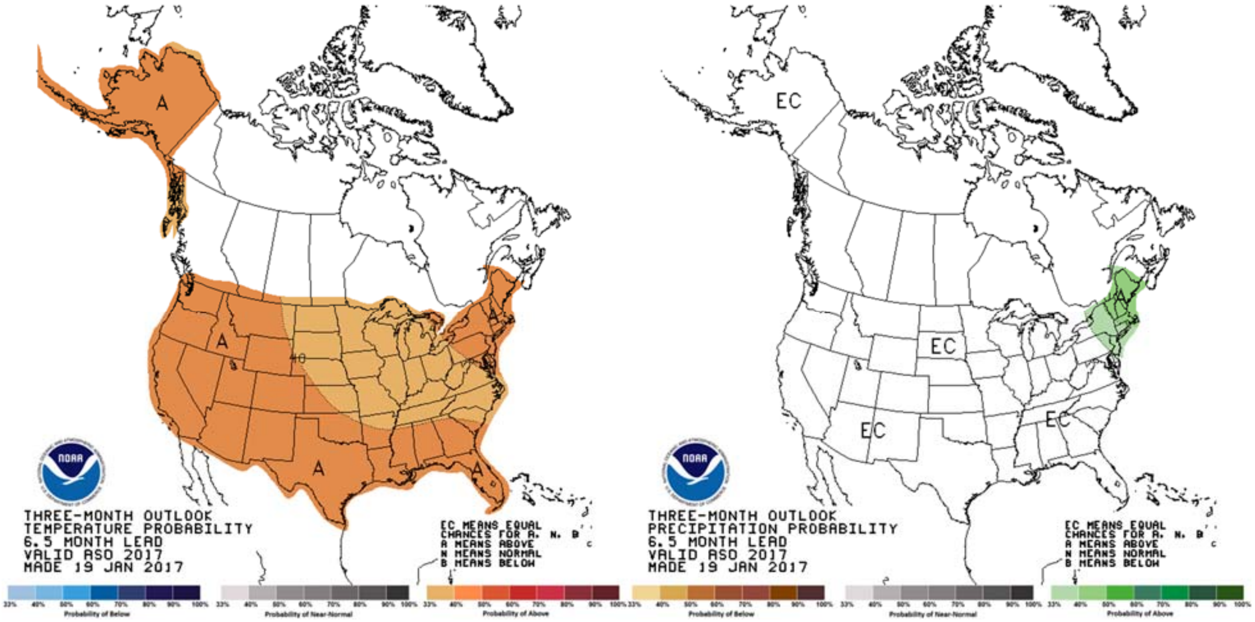


Figure 16. CPC August-September-October 2017 temperature and precipitation outlooks.

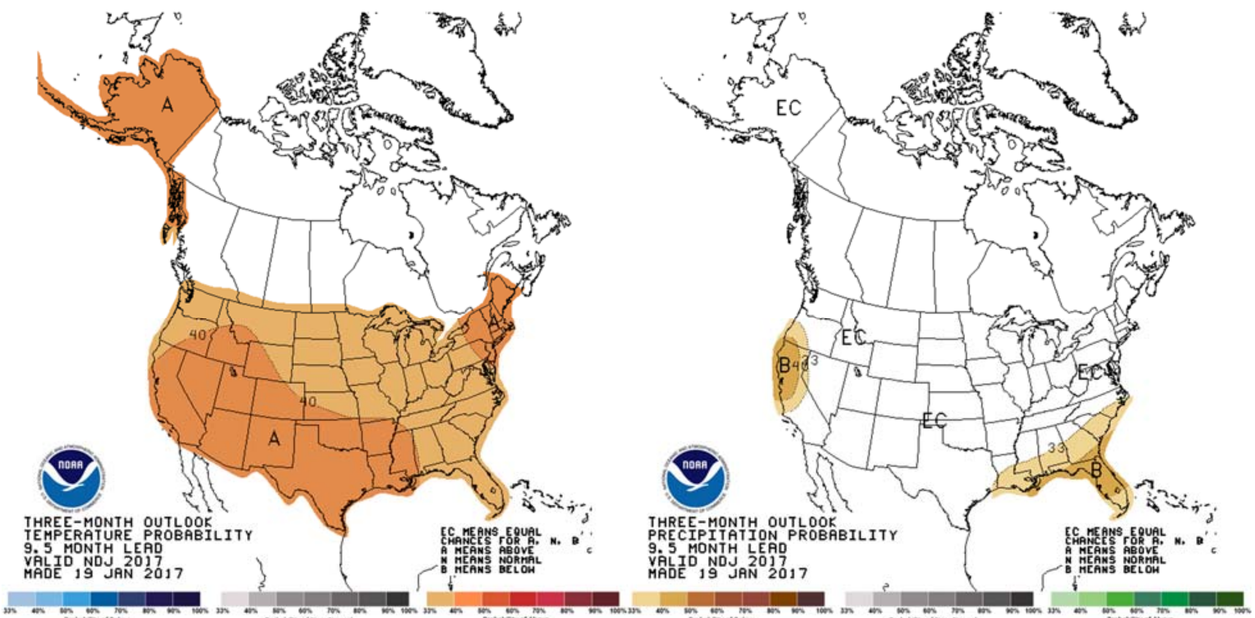
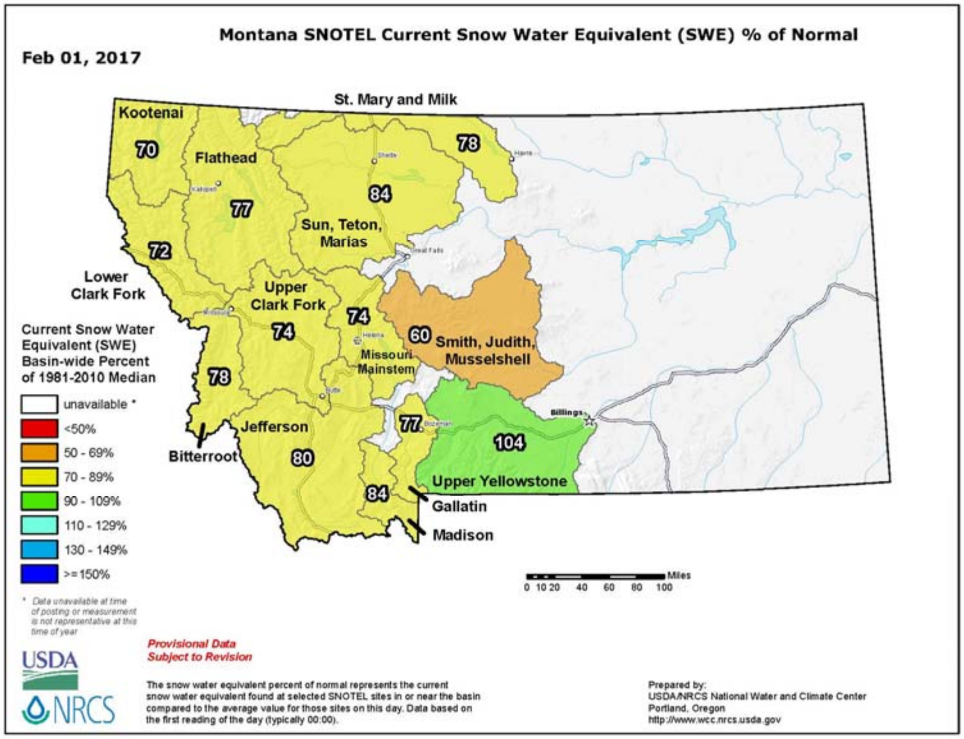


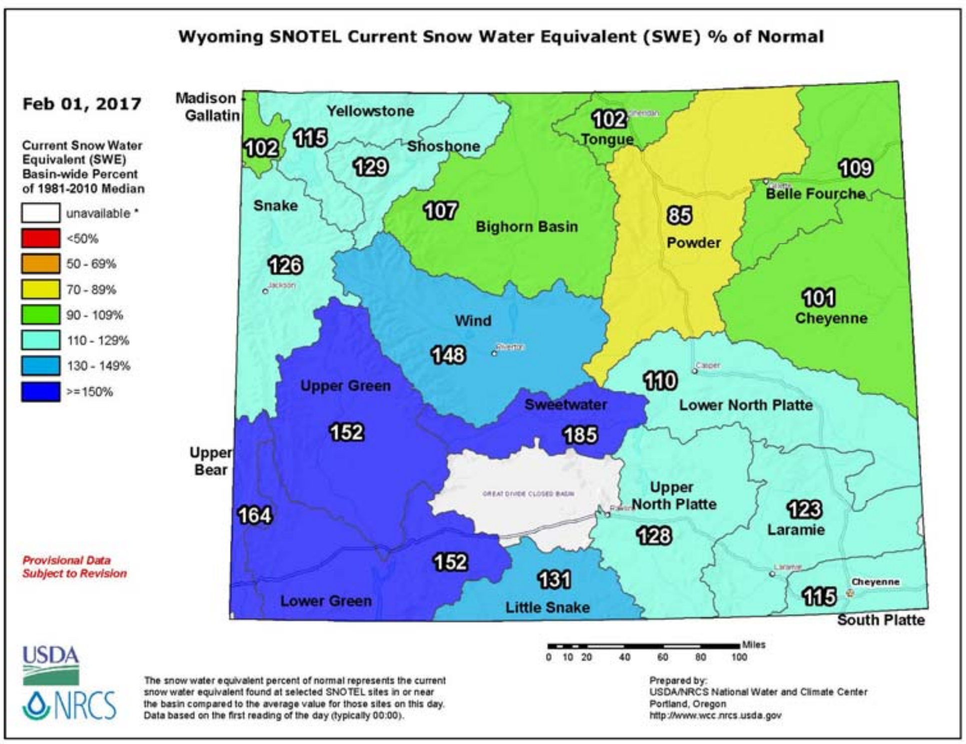
Figure 17. CPC -November-December 2017-January 2018 temperature and precipitation outlooks.

February 2017 Calendar Year Runoff Forecast

In summary, the 2017 calendar year runoff forecast is **26.2 MAF**, **103% of average**. Due to the forecast for warmer-than-normal temperatures, February runoff is forecast to be above average; and the moderate plains snowpack could cause above-average runoff during March and April, especially into Garrison and Oahe. With the ENSO-neutral conditions, our forecast for May through July runoff in the Fort Peck and Garrison reaches is mostly influenced by the below-average mountain snowpack above Fort Peck and the slightly above-average mountain snowpack from Fort Peck to Garrison.

Additional Figures





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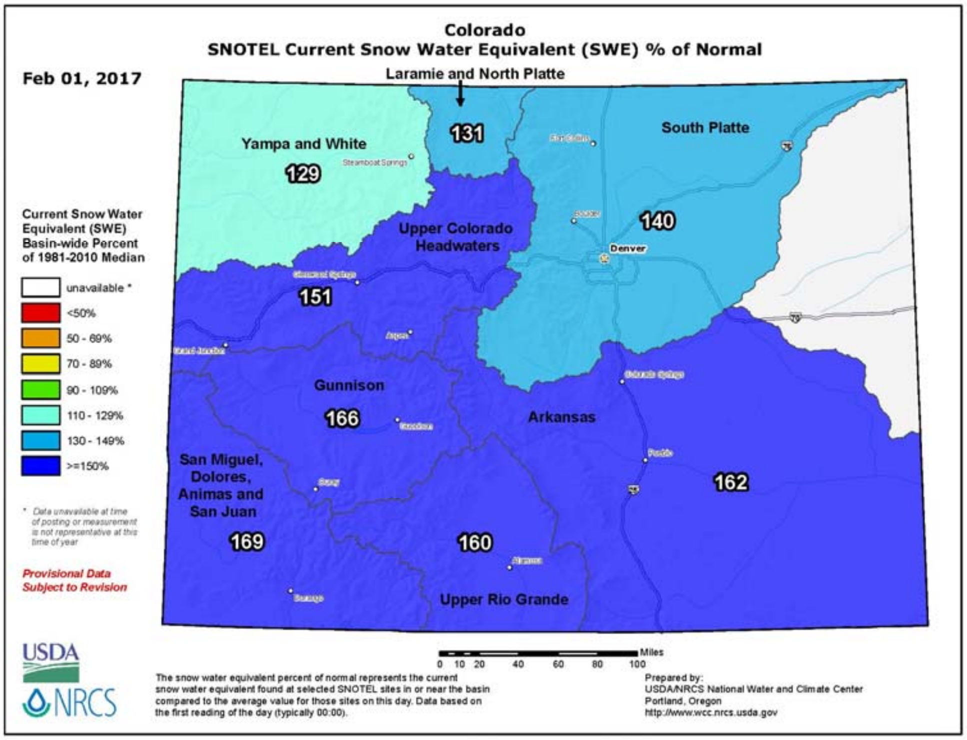


Colorado
SNOTEL Current Snow Water Equivalent (SWE) % of Normal
Feb 01, 2017
Laramie and North Platte
131
Yampa and White
129
Steamboat Springs
South Platte
140
Denver
Upper Colorado Headwaters
151
Gunnison
166
Arkansas
162
San Miguel, Dolores, Animas and San Juan
169
160
Upper Rio Grande
Current Snow Water Equivalent (SWE) Basin-wide Percent of 1981-2010 Median
unavailable *
<50%
50 - 69%
70 - 89%
90 - 109%
110 - 129%
130 - 149%
>=150%
* Data unavailable at time of posting or measurement is not representative at this time of year
Provisional Data Subject to Revision
USDA
NRCS
Miles
0 10 20 40 60 80 100
The snow water equivalent percent of normal represents the current snow water equivalent found at selected SNOTEL sites in or near the basin compared to the average value for those sites on this day. Data based on the first reading of the day (typically 00:00).
Prepared by:
USDA/NRCS National Water and Climate Center
Portland, Oregon
http://www.wcc.nrcs.usda.gov

USDA NRCS Water Supply Forecasts

USDA NRCS National Water & Climate Center
*** - DATA CURRENT AS OF: February 02, 2017 07:30:05 PM**
- Based on February 01, 2017 forecast values

PRELIMINARY MISSOURI RIVER BASIN FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
Lake Sherburne Inflow (2)	APR-JUL	89	92	110	98	80	68	97
	APR-SEP	102	91	125	111	93	79	112
St. Mary R at Intl Boundary (2)	APR-JUL	405	93	520	450	360	290	435
	APR-SEP	470	93	595	520	420	345	505
Lima Reservoir Inflow (2)	APR-JUL	71	95	107	85	57	36	75
	APR-SEP	77	96	116	93	61	38	80
Clark Canyon Reservoir Inflow (2)	APR-JUL	81	80	141	105	56	20	101
	APR-SEP	100	83	169	128	72	30	120
Jefferson R nr Three Forks (2)	APR-JUL	560	76	930	710	410	192	740
	APR-SEP	605	76	1020	775	435	188	800
Hebgen Lake Inflow (2)	APR-JUL	365	99	445	395	335	285	370
	APR-SEP	465	99	565	505	425	365	470
Ennis Lake Inflow (2)	APR-JUL	570	91	710	625	515	430	625
	APR-SEP	705	91	875	775	635	535	775
Missouri R at Toston (2)	APR-JUL	1430	80	2040	1680	1180	815	1790
	APR-SEP	1660	80	2380	1950	1370	940	2070
Smith R bl Eagle Ck (2)	APR-JUL	70	66	123	91	49	17.3	106
	APR-SEP	79	68	140	103	54	17.4	116
Gibson Reservoir Inflow (2)	APR-JUL	330	84	430	370	290	230	395
	APR-SEP	365	83	470	405	320	255	440
Marias R nr Shelby (2)	APR-JUL	280	78	435	345	220	129	360
	APR-SEP	290	77	450	355	225	133	375

PRELIMINARY YELLOWSTONE RIVER BASIN FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
West Rosebud Ck nr Roscoe (2)	APR-JUL	57	97	67	61	53	47	59
	APR-SEP	72	97	84	77	67	60	74
Wind R ab Bull Lake Ck	APR-JUL	625	137	780	690	560	470	455
	APR-SEP	680	139	850	750	615	515	490
Bull Lake Ck nr Lenore (2)	APR-JUL	184	132	215	197	170	150	139
	APR-SEP	225	133	265	240	205	183	169
Boysen Reservoir Inflow (2)	APR-JUL	950	156	1310	1090	800	585	610
	APR-SEP	1040	156	1420	1190	885	660	665
Greybull R at Meeteetse	APR-JUL	178	136	235	200	155	121	131
	APR-SEP	240	136	305	270	215	176	177
Shell Ck nr Shell	APR-JUL	55	100	70	61	49	40	55
	APR-SEP	66	100	83	73	59	49	66
Bighorn R at Kane (2)	APR-JUL	1300	155	1800	1500	1090	795	840
	APR-SEP	1420	157	1960	1640	1200	875	905
NF Shoshone R at Wapiti	APR-JUL	610	133	695	645	575	525	460
	APR-SEP	680	132	770	715	645	590	515
SF Shoshone R nr Valley	APR-JUL	280	130	320	295	260	235	215
	APR-SEP	325	133	370	345	305	275	245
Buffalo Bill Reservoir Inflow (2)	APR-JUL	1000	148	1170	1070	930	825	675
	APR-SEP	1100	148	1290	1180	1020	910	745
Bighorn R nr St. Xavier (2)	APR-JUL	2160	157	2780	2410	1910	1530	1380
	APR-SEP	2330	160	3020	2610	2060	1650	1460
Little Bighorn R nr Hardin	APR-JUL	91	93	148	114	68	34	98
	APR-SEP	103	93	165	128	78	40	111

Tongue R nr Dayton (2)	APR-JUL	74	86	105	87	62	43	86
	APR-SEP	85	87	119	99	72	52	98
Tongue R at State Line nr Decker (2)	APR-JUL	184	95	290	225	142	80	193
	APR-SEP	205	95	315	250	160	95	215
NF Powder R nr Hazelton	APR-JUL	7.4	81	9.9	8.4	6.4	4.9	9.1
	APR-SEP	8.1	82	10.7	9.2	7.0	5.5	9.9
Powder R at Moorhead	APR-JUL	176	99	310	230	122	43	177
	APR-SEP	194	99	330	250	139	59	196
Powder R nr Locate	APR-JUL	199	100	350	260	138	49	199
	APR-SEP	220	100	375	280	154	60	220

PRELIMINARY RAPID VALLEY UNIT FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
Deerfield Reservoir Inflow (2)	MAR-JUL	6.1	98	10.2	7.8	4.4	2.0	6.2
	APR-JUL	4.9	94	8.3	6.2	3.7	2.3	5.2
Pactola Reservoir Inflow (2)	MAR-JUL	23	92	42	31	15.8	4.6	25
	APR-JUL	19.6	89	39	27	13.7	7.0	22

PRELIMINARY PLATTE RIVER BASIN FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
North Platte R nr Northgate (2)	APR-JUL	305	136	435	360	250	175	225
	APR-SEP	335	134	475	390	280	194	250
Encampment R nr Encampment (2)	APR-JUL	185	143	245	210	161	126	129
	APR-SEP	197	143	260	220	172	135	138
Rock Ck ab King Canyon Cnl nr Arlington	APR-JUL	57	116	75	64	50	39	49
	APR-SEP	60	115	79	68	52	41	52
Seminoe Reservoir Inflow (2)	APR-JUL	970	136	1350	1130	815	585	715
	APR-SEP	1050	136	1520	1280	960	720	770
Sweetwater R nr Alcova	APR-JUL	108	183	144	122	94	72	59
	APR-SEP	115	180	153	131	100	78	64
La Prele Ck nr Douglas	APR-JUL	17.5	88	35	25	10.3	0.50	19.9
	APR-SEP	17.5	88	36	25	10.2	0.70	19.9
North Platte R bl Glendo Reservoir (2)	APR-JUL	1230	150	1830	1520	1090	770	820
	APR-SEP	1290	152	1910	1580	1140	810	850
North Platte R bl Guernsey Res (2)	APR-JUL	1270	155	1670	1480	1210	1020	820
	APR-SEP	1410	166	1750	1550	1280	1070	850
Laramie R and Pioneer Cnl nr Woods Ln (2)	APR-JUL	156	136	215	180	132	97	115
	APR-SEP	171	136	235	197	146	108	126
Little Laramie R nr Filmore	APR-JUL	62	122	83	70	53	40	51
	APR-SEP	67	122	90	76	57	43	55

Max (10%), 30%, 50%, 70% and Min (90%) chance that actual volume will exceed forecast.
Averages are for the 1981-2010 period.
All volumes are in thousands of acre-feet.

footnotes:
1) Max and Min are 5% and 95% chance that actual volume will exceed forecast
2) streamflow is adjusted for upstream storage
3) median value used in place of average

Upper Missouri River Basin
March 2017 Calendar Year Runoff Forecast
March 6, 2017

U.S. Army Corps of Engineers, Northwestern Division
Missouri River Basin Water Management
Omaha, NE

Calendar Year Runoff Forecast

Explanation and Purpose of Forecast

The long-range runoff forecast is presented as the Calendar Year Runoff Forecast. The Calendar Year Runoff Forecast is available at http://www.nwd-mr.usace.army.mil/rcc/reports/runoff.pdf. This forecast is developed shortly after the beginning of each calendar year and is updated at the beginning of each month to show the actual runoff for historic months of that year and the updated forecast for the remaining months of the year. This forecast presents monthly inflows in million acre-feet (MAF) from five incremental drainage areas, as defined by the individual System projects, plus the incremental drainage area between Gavins Point Dam and Sioux City. Due to their close proximity, the Big Bend and Fort Randall drainage areas are combined. Summations are provided for the total Missouri River reach above Gavins Point Dam and for the total Missouri River Basin above Sioux City (upper Basin). The Calendar Year Runoff Forecast is used in the Monthly Study simulation model to plan future system regulation in order to meet the authorized project purposes throughout the calendar year.

Observed Runoff

February 2017 runoff was 218% of average for the upper Basin due to warmer-than-normal temperatures during the past month, which melted most of the plains snowpack in the upper Basin and caused river ice to melt. Runoff was well-above average in all reaches of the upper Basin.

2017 Calendar Year Forecast Synopsis

The March 1 forecast for the 2017 Missouri River runoff above Sioux City, IA is **29.1 MAF (115% of average)**. Runoff above Gavins Point Dam is forecast to be **26.1 MAF (113% of average)**. Due to the amount of variability in precipitation and other hydrologic factors that can occur over the next 10 months, the range of expected inflow is quite large and ranges from the 39.3 MAF upper basic forecast to the 20.1 MAF lower basic forecast. The upper and lower basic forecasts are used in long-term regulation planning models to "bracket" the range of expected runoff given much wetter or drier conditions, respectively. Given that 10 months are being forecasted for this March 1 forecast (2 months observed/10 months forecast), the range of wetter than normal (upper basic) and drier than normal (lower basic) is attributed to all 6 reaches for all

10 months. The result is a large range or "bracket" for each reach, and thus, for the total runoff forecast. As the year progresses, the range will lessen as the number of observed months increases and number of forecast months decreases.

Current Conditions

Drought Analysis

The latest National Drought Mitigation Center's drought monitor for February 28, 2017 (**Figure 1**), is compared to the drought monitor for January 31, 2017 (**Figure 2**). The drought monitor is available at http://droughtmonitor.unl.edu/. The U.S. Drought Monitor indicates there are some areas of Moderate Drought (D1) in northeastern Wyoming, southeastern Montana, and western South Dakota. Abnormally Dry (D0) conditions persist in areas surrounding the D1 Drought and in small areas of western and eastern Montana. The Seasonal Drought Outlook in **Figure 3** indicates drought conditions may be removed if northeastern Wyoming and western South Dakota continue to receive precipitation through the end of April 2017.

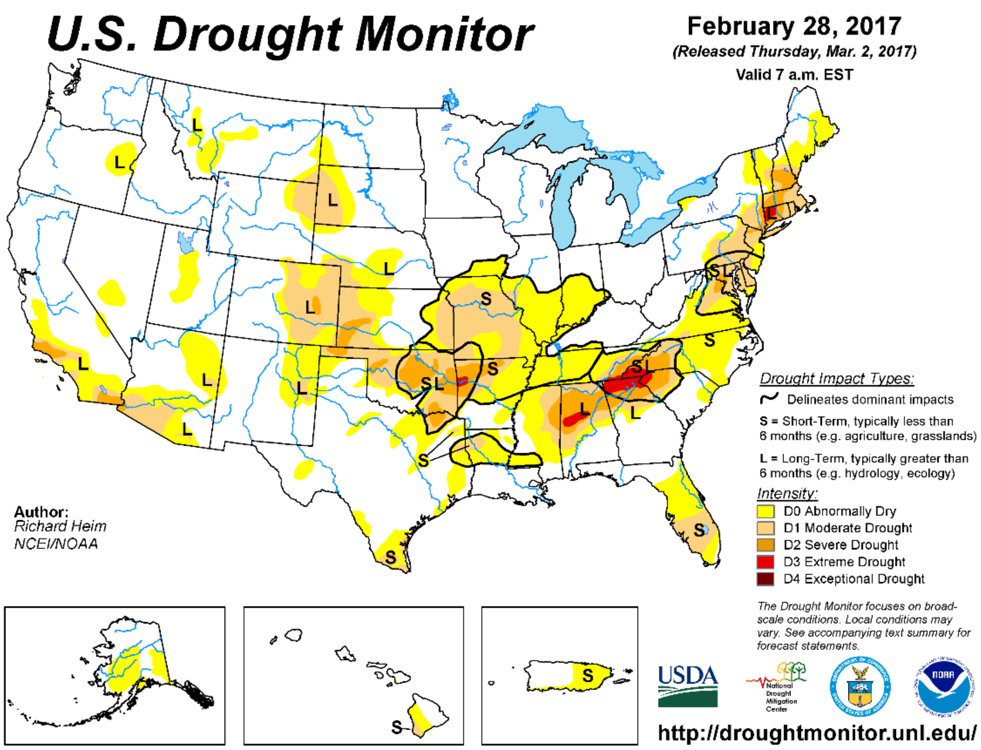


Figure 1. National Drought Mitigation Center U.S. Drought Monitor for February 28, 2017.

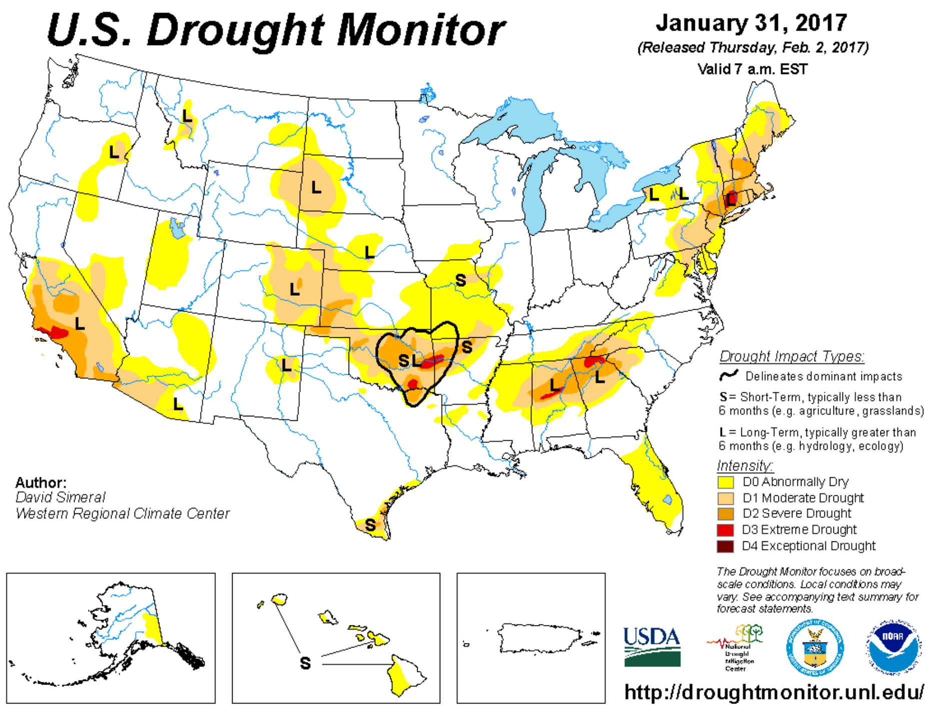


Figure 2. National Drought Mitigation Center U.S. Drought Monitor for January 31, 2017.

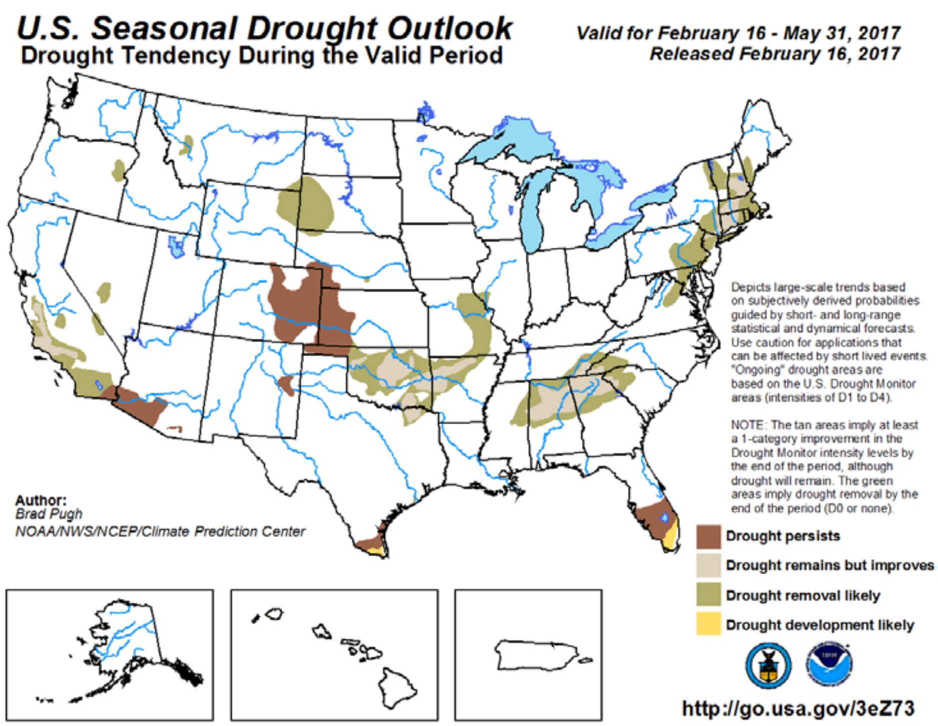


Figure 3. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

Monthly precipitation accumulations are shown using High Plains Regional Climate Center images available at http://www.hprcc.unl.edu/. The February precipitation accumulations are shown in **Figure 4** as inches of precipitation (left) and percent of normal precipitation (right). Precipitation was above average in Montana, Wyoming, and northern Nebraska, while precipitation was below average in Kansas, southern Nebraska, and South Dakota. Precipitation was about average in North Dakota. December-January-February precipitation accumulations are shown in **Figure 5**. The three-month accumulations reflect a relatively wet pattern across most of the basin, with areas more than 200% of normal in portions of Montana, Wyoming, Colorado, the Dakotas, and Nebraska.

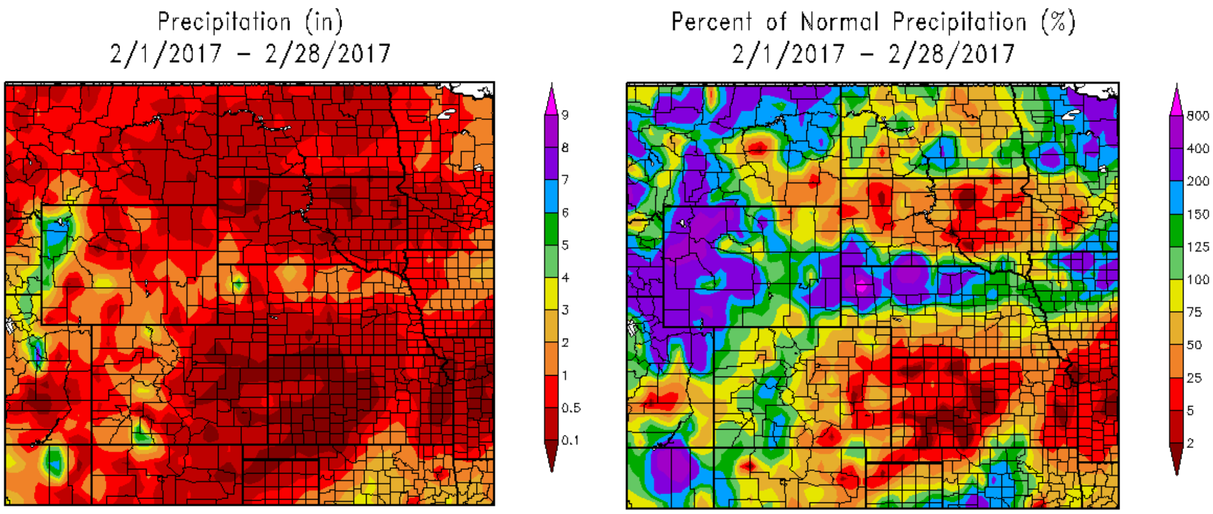


Figure 4. February 2017 Precipitation (inches) and Percent of Normal Precipitation.

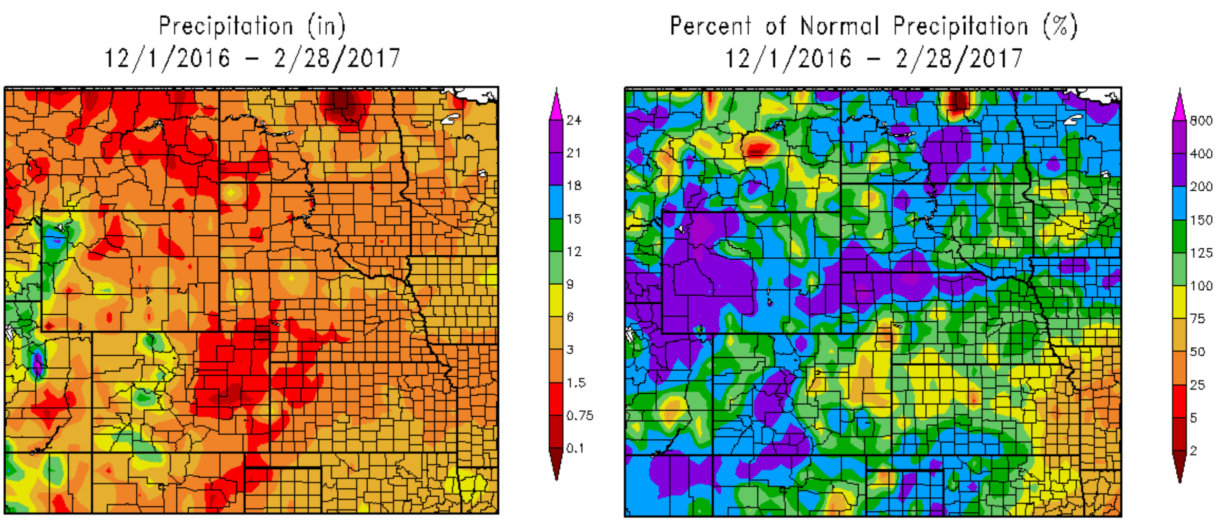


Figure 5. December 2016–January 2017-February 2017 Precipitation (inches) and Percent of Normal Precipitation.

Temperature

February temperature departures in degrees Fahrenheit (deg F) in the left image of **Figure 6** were predominantly above normal, especially in eastern Montana, Wyoming, the Dakotas, Nebraska, and Kansas. Departures ranged from 4 deg F below normal in western Montana to greater than 10 deg F above normal in southern and eastern areas of the Missouri Basin. December-January-February temperatures, in the right image of **Figure 6**, were 0 to 8 deg F below normal over much of Montana, Wyoming, and the western Dakotas, while temperatures were normal to 6 deg F above normal in the remainder of the Missouri Basin.

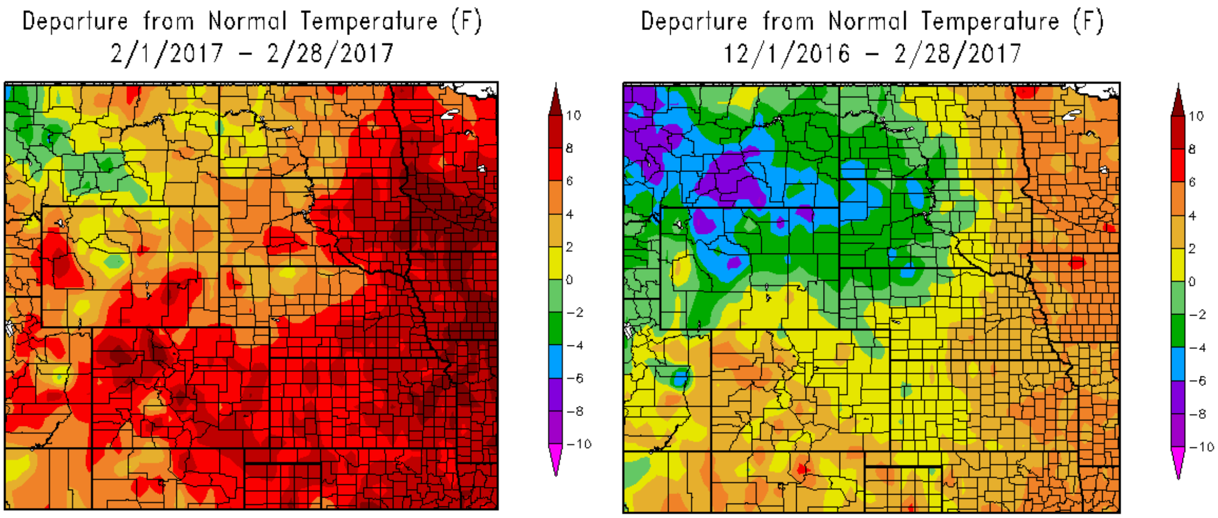


Figure 6. February 2017 and December 2016-January 2017-February 2017 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Soil Moisture

Soil moisture is factored into the forecast as an indicator of wet or dry hydrologic basin conditions. Typically when soil moisture conditions are wet or greater than normal, rainfall and snowmelt runoff is greater than when soil moisture is dry or less than normal. Not only is soil moisture a physical parameter that influences runoff, it can be used as an indicator of future runoff. As the calendar year approaches winter, the soil moisture conditions will provide some insight into late winter and early spring runoff potential.

The left image of **Figure 7** shows the NOAA NLDAS ensemble top one-meter soil moisture anomaly on March 2, 2017. The NLDAS image shows wetter-than-normal conditions across Montana, most of North Dakota, central and western Wyoming, eastern South Dakota and northwestern Iowa. Drier-than-normal conditions are present in central North Dakota, eastern Wyoming, western South Dakota, Nebraska, Kansas and Missouri. Similarly, the CPC Soil Moisture Anomaly, in the right image of **Figure 7**, indicates wetter-than-normal soil moisture conditions in Montana, western Wyoming, North Dakota, eastern South Dakota, eastern Nebraska and northern Iowa.

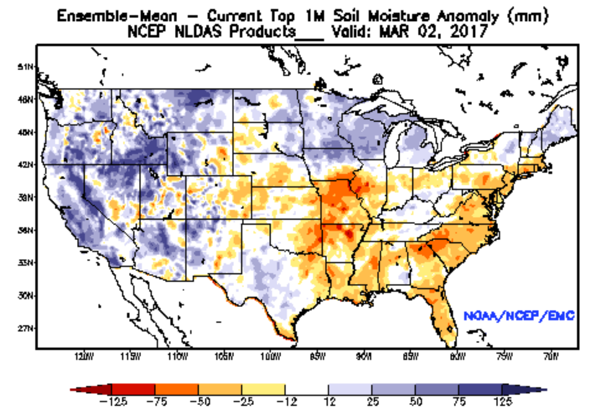
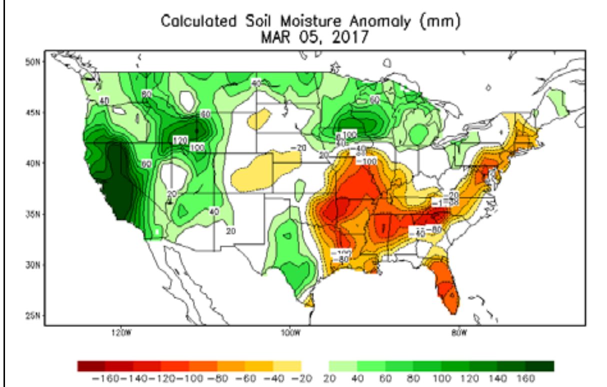
	
NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/	CPC Soil Moisture. http://www.cpc.ncep.noaa.gov/products/Soilmst_Monitoring/US/Soilmst/Soilmst.shtml#

Figure 7. NOAA NLDAS and CPC Soil Moisture Anomalies (mm).

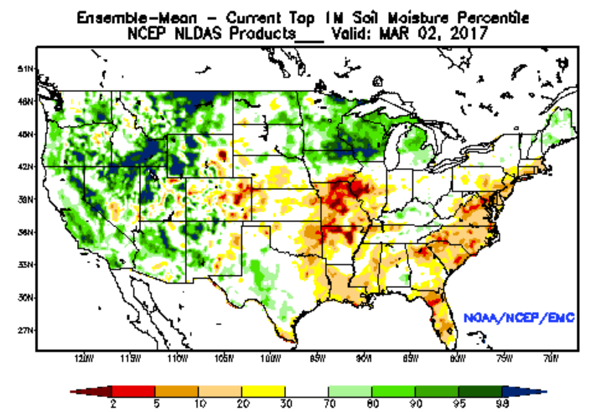
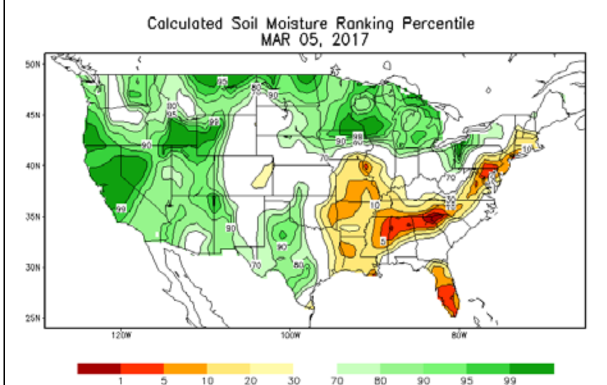
	
NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/	CPC Soil Moisture. http://www.cpc.ncep.noaa.gov/products/Soilmst_Monitoring/US/Soilmst/Soilmst.shtml#

Figure 8. NOAA NLDAS and CPC Soil Moisture Percentile Rankings.

Soil moisture conditions expressed as a percentile ranking can show the severity and rarity of the soil moisture conditions through the percentile ranking probability. Soil moisture percentile rankings from NOAA NLDAS and the CPC are shown in **Figure 8**. The NLDAS percentile ranking, in the left image of **Figure 8**, indicates very wet soil moisture conditions (greater than 98^{th} percentile rank) in north central Montana and localized regions of central and western Wyoming. A greater than 98^{th} percentile ranking soil moisture conditions indicates soil moisture is wetter than 98 out of 100 soil moisture samples or years for the indicated date. The CPC percentile ranking, in the right image of **Figure 8**, indicates very wet soil moisture conditions (99^{th} percentile ranking) in areas of north central Montana and western Wyoming. The percentile rankings of drier-than-normal areas in western South Dakota and eastern Wyoming differ somewhat between the models. The NLDAS map shows that dry soils rank between the

2nd and 30th percentile rankings for moisture, while the CPC ranking indicates a small region between the 20th and 30th percentile ranking in Colorado.

Frost Conditions

Figure 9 shows the depth of frost penetration at NWS Warning Forecast Office (WFO) locations in the Missouri Basin as of March 2, 2017. Frost penetration depths have generally decreased in the past month, but vary across the basin with the following depths being reported: Great Falls, MT (6 inches); Glasgow, MT (24 inches); Bismarck, ND (30 inches); Riverton, WY (8 inches); Rapid City, SD (4 inches); and, Aberdeen, SD (30 inches). Local reports of ground conditions indicate the soil surface is partially thawed in many areas of Montana and the Dakotas on top of the frost layer.

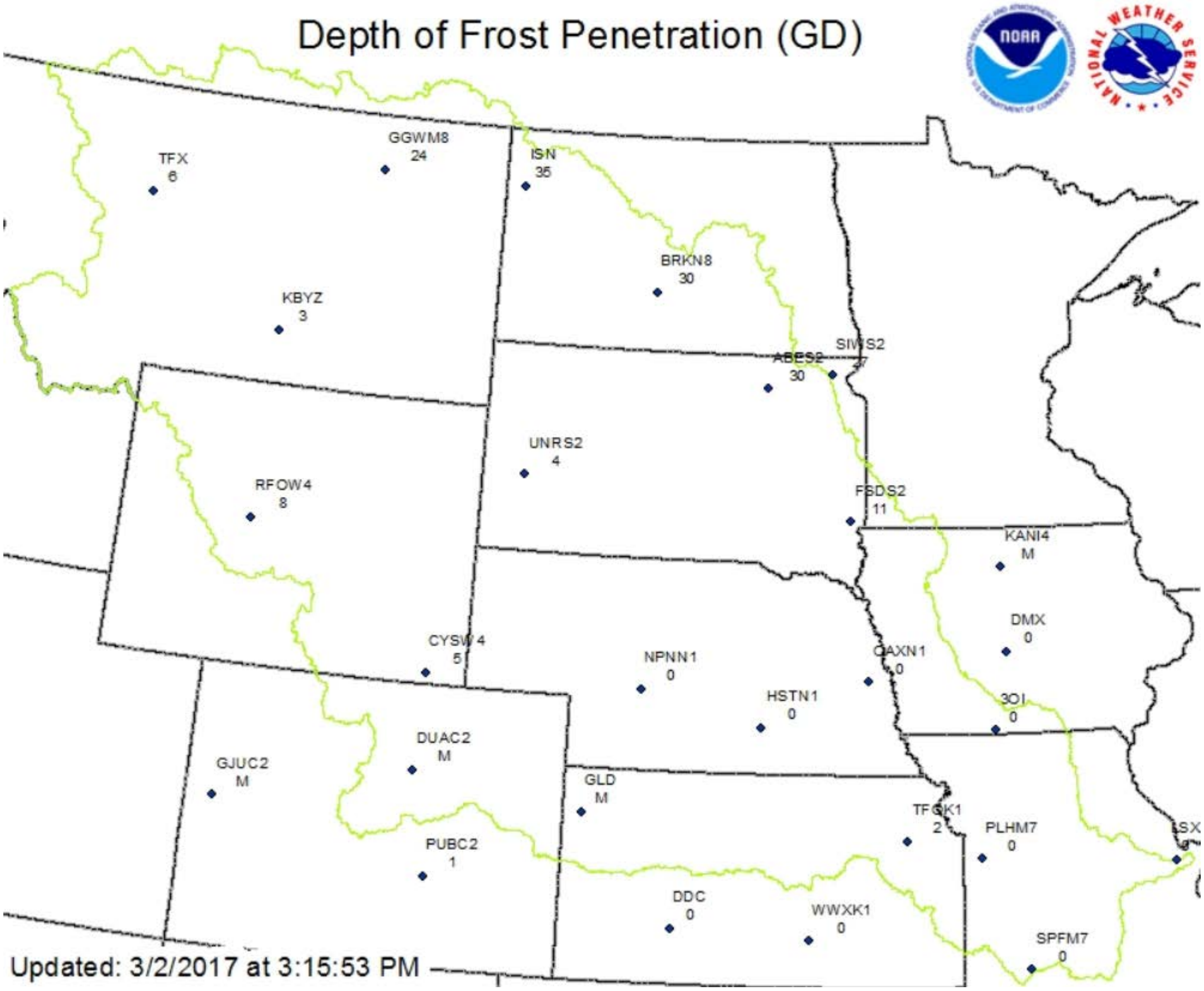


Figure 9. Measured frost depth (inches) at NWS WFO offices as of March 2, 2017. Source: NWS MBRFC. http://www.crh.noaa.gov/mbrfc

Plains Snowpack

Plains snowpack is an important parameter that influences the volume of runoff occurring in the basin during the months of March and April. A common misperception is that the March-April runoff is a result of plains snowmelt only. Historically, about 25% of annual runoff occurs in March and April, during the time when plains snow is melting, due to both melting snowpack and rainfall runoff. Runoff occurs in March and April whether or not there is any plains snow to melt. Determining exact rainfall amounts and locations are nearly impossible to predict more than a week in advance. Thus, the March-April runoff forecast is formulated based on existing plains snowpack and existing basin conditions and hydrologic forecasts, which for this year primarily includes long-term precipitation outlooks. At this time of year, plains snowpack provides some indication of March-April runoff; however, as the snowpack reaches its ultimate peak accumulation, better forecasts of future runoff can be made.

The National Weather Service's National Operational Hydrologic Remote Sensing Center (NOHRSC), modeled snow assessment, shown in **Figure 10**, indicates 2 to 4 inches of snow water equivalent (SWE) were present in localized areas of central North Dakota on March 6, 2017. Trace to zero inches of plains SWE remain in the rest of the basin. The plains SWE as of February 1, 2017 is shown in **Figure 11**. Since February 1, plains snow liquid content has decreased significantly as a result of warmer-than-normal temperatures in February.

During the week of February 27, 2017, MRBWMD requested the fifth round of cooperative snow survey measurements in the upper Missouri River Basin to help assess the depth and water equivalent of plains snowpack during the 2016-2017 winter. These measurements are used by MRBWMD to adjust the March-April runoff forecast, and the measurements are shared with NWS NOHRSC to help verify modeled snow estimates used in spring streamflow forecasts. In addition to this snow information, anecdotal basin condition information such as soil moisture content and frost depth improves situational awareness among federal, state and local agencies.

Cooperative snow survey measurements indicated 2.4 inches of SWE were present near Beulah, ND on February 27, 2017; and 3.1 inches were present near Jamestown, ND on February 27, 2017. Additional measurements during the week of February 27th indicated 0 to 3.0 inches of SWE at locations in central North Dakota. The greatest amounts of SWE in North Dakota were measured near Jamestown (3.1 inches). In South Dakota, zero to trace amounts of SWE remain. Since the end of February, additional snowmelt has occurred at these locations. A full report of snow depth and SWE measurements is available at http://www.nwd-mr.usace.army.mil/rcc/snowsurvey/snowsurvey.html.

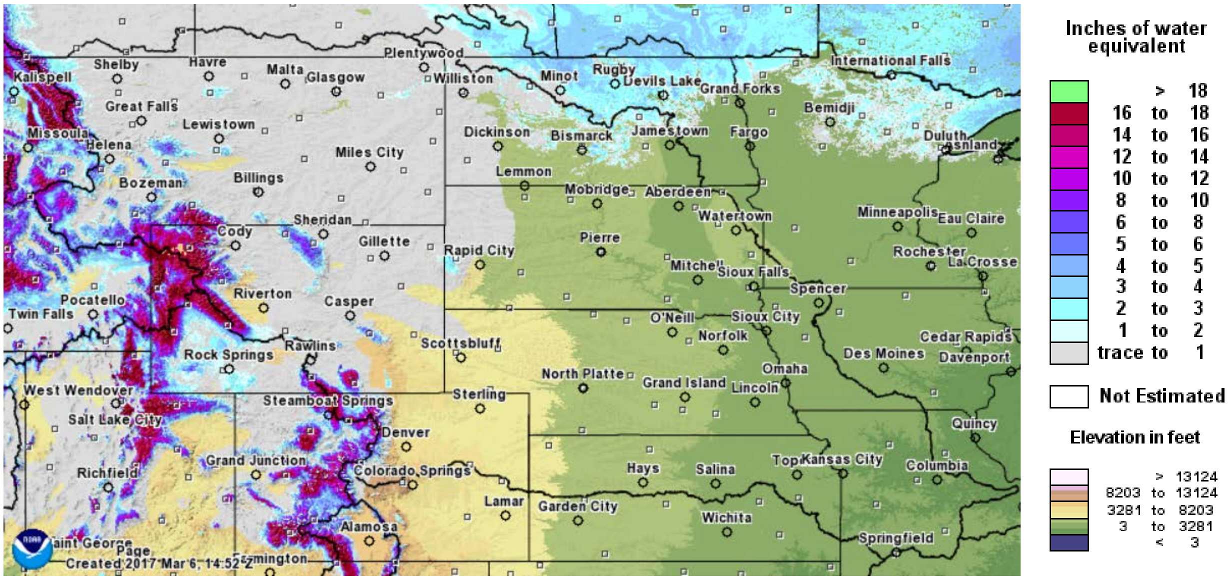


Figure 10. March 6, 2017 NOHRSC modeled plains snow water equivalent. Source: NOAA National Operational Hydrologic Remote Sensing Center. http://www.nohrsc.nws.gov/interactive/html/map.html

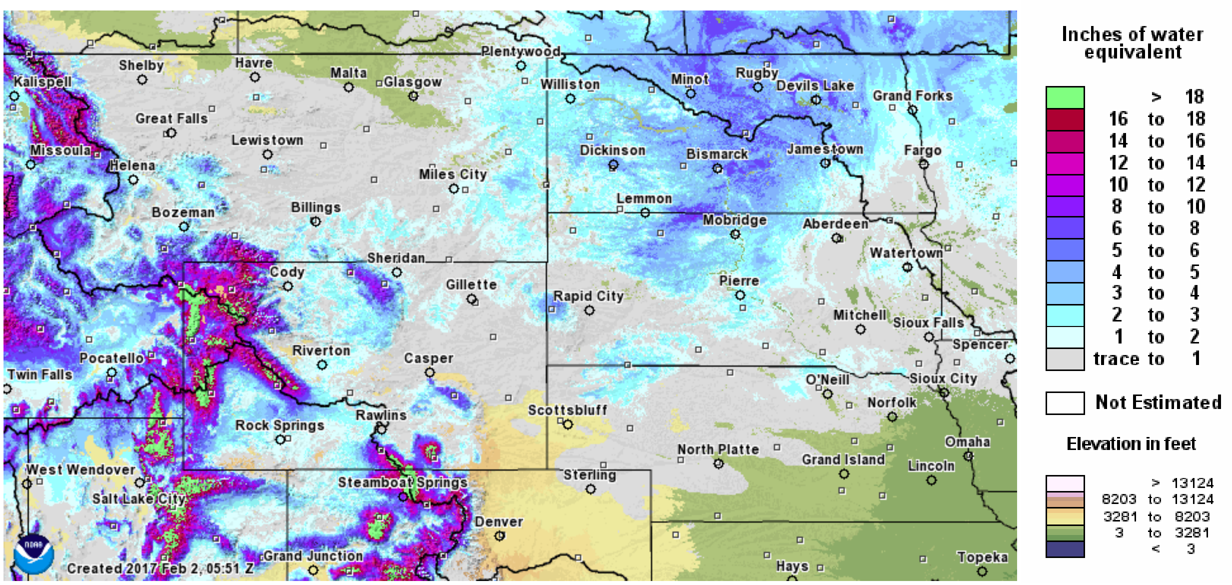


Figure 11. February 1, 2017 NOHRSC modeled plains snow water equivalent. Source: NOAA National Operational Hydrologic Remote Sensing Center. http://www.nohrsc.nws.gov/interactive/html/map.html

Mountain Snow Pack

Mountain snowpack is the primary factor used to predict May-July runoff volumes in the Fort Peck and Fort Peck to Garrison reaches. During the 3-month May-July runoff period, about 50% of the annual runoff in the upper Basin enters the Mainstem System as a result of mountain snowmelt and rainfall runoff. Greater-than-average mountain snow accumulations are usually associated with greater-than-average May-July runoff volumes, especially when mountain soil moisture conditions have been wetter than normal as in the past three years. For example, we would expect to see higher-than-average runoff from an average mountain snowpack this year due to wetter-than-normal soil moisture conditions.

Figure 12 includes time series plots of the average mountain SWE beginning on October 1, 2016 based on the NRCS SNOTEL gages for the headwater basin above Fort Peck and the incremental basin from Fort Peck to Garrison. The current average SWE values (shaded blue area) are plotted against the 1981-2010 basin average SWE (bold red line), a recent low SWE year in 2001 (green line), and two historic high SWE years occurring in 1997 (purple) and 2011 (dark blue).

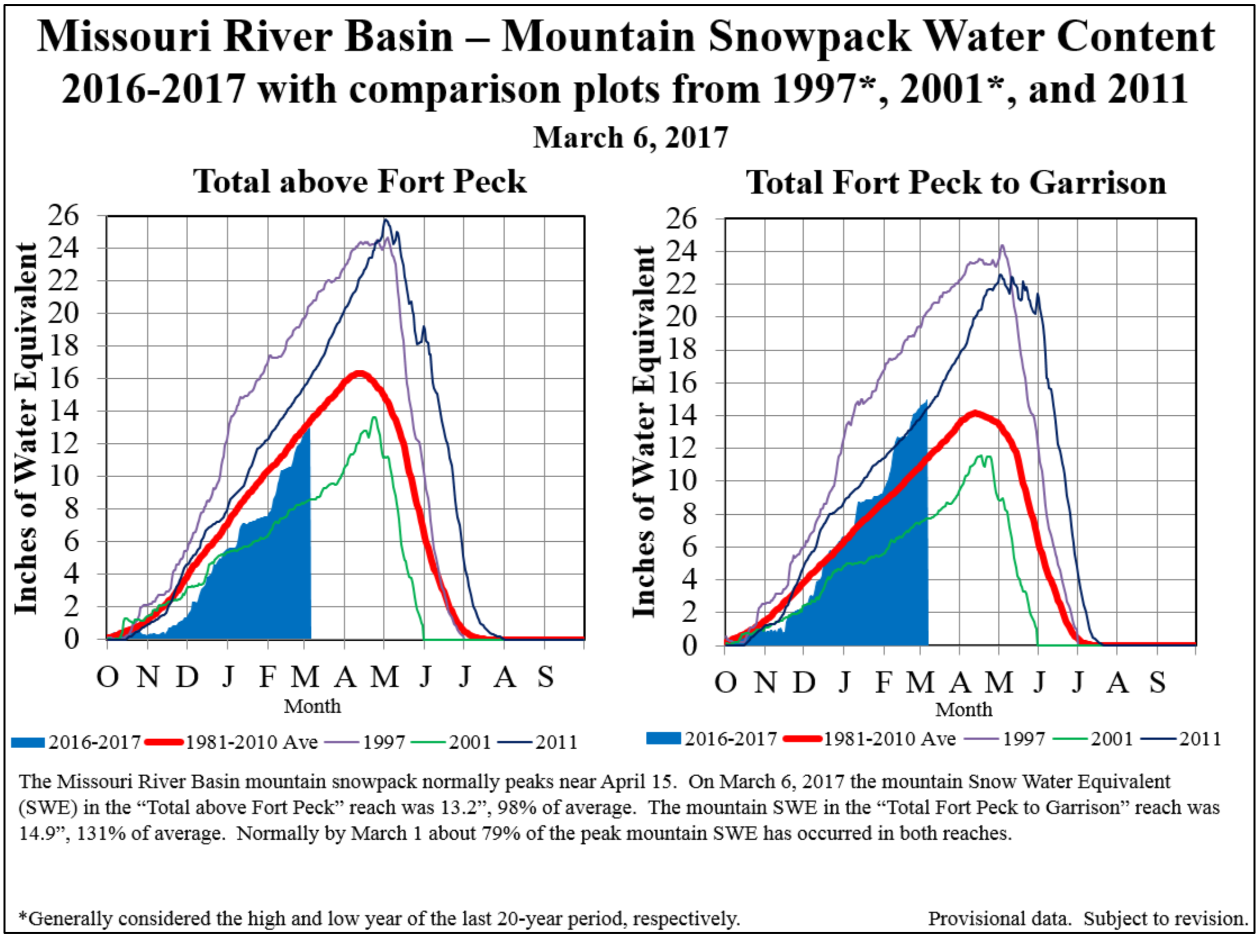


Figure 12. Mountain snowpack water content on March 6, 2017 compared to normal and historic conditions. Corps of Engineers - Missouri River Basin Water Management. Available at http://www.nwd-mr.usace.army.mil/rcc/reports/snow.pdf.

As of **March 6, 2017**, the Corps of Engineers computed an average mountain SWE in the Fort Peck reservoir reach of 13.2 inches, which is 98% of average for March 6 based on the 1981-2010 average SWE for the Fort Peck reach. In the reservoir reach between Fort Peck Dam and Garrison Dam, the Corps computed an average mountain SWE of 14.9 inches, which is 131% of average for March 6 based on the 1981-2010 average SWE for the Garrison reach. Normally, 79% of the peak snow accumulation has occurred in the mountains by March 1.

In the **Additional Figures** section at the end of this document, basin maps of the mountain snowpack as a percent of median are provided for Montana, Wyoming and Colorado. These maps are a product of the USDA/NRCS National Water and Climate Center and are available at http://www.wcc.nrcs.usda.gov. These maps show that mountain snowpack is about median to slightly above median in Montana, but well-above median in many Wyoming basins and all Colorado basins.

Climate Outlook

MRBWMD participates in the monthly North Central U.S. Climate/Drought Outlook Webinar coordinated through NOAA, the regional climate centers, and the American Association of State Climatologists (AASC). These webinars provide updates on near-term climate outlooks and impacts including the ENSO climate pattern and its implications on winter temperature and precipitation patterns in the Missouri River Basin.

ENSO (El Niño Southern Oscillation)

The latest ENSO update indicates that ENSO-neutral conditions are now present, and expected to continue through at least spring. With ENSO-neutral conditions, chances are equal for spring precipitation to be above normal, normal or below normal.

Temperature and Precipitation Outlooks

The NOAA Climate Prediction Center (CPC) outlooks are used to depict forecast future weather conditions during future outlook periods ranging from one to 12 months in the future. The CPC outlooks are available at http://www.cpc.ncep.noaa.gov/. The CPC climate outlook for March 2017 (**Figure 13**) indicates there could be an increased probability for above-normal temperatures in most of the southern states in the upper Missouri Basin, with equal chances in Montana, northern Wyoming, and North Dakota. There is a slight increase in the chance for below normal temperatures in northwestern Montana. With regard to precipitation, there could be an increased probability that precipitation will be above normal in Montana and North Dakota, while there could be below-normal precipitation in the lower Basin, including southern Wyoming, Nebraska, Colorado, Kansas, southwestern Iowa and western Missouri.

The March-April-May temperature outlook (**Figure 14**) indicates there could be increased chances for above-normal temperatures in the lower Basin, and equal chances for above normal, normal, and below normal temperatures in the upper Basin. The March-April-May precipitation outlook shows increased chances for above-normal precipitation over Montana, northern Wyoming, North Dakota, and South Dakota with equal chances in the remainder of the Missouri Basin.

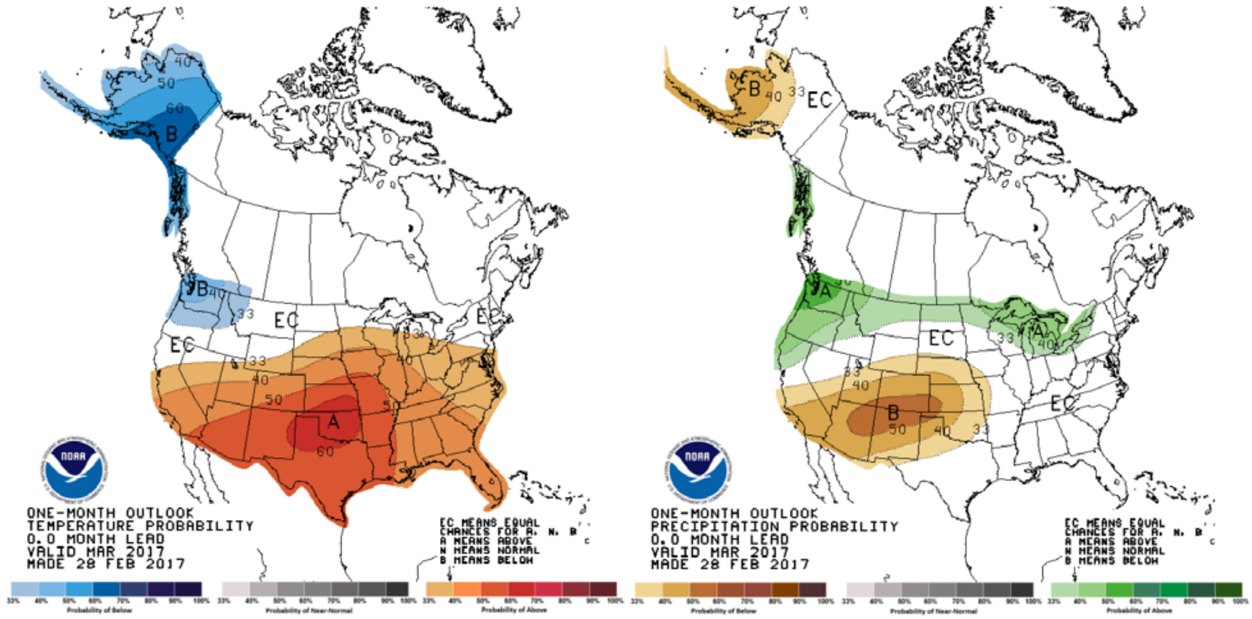


Figure 13. CPC March 2017 temperature and precipitation outlooks.

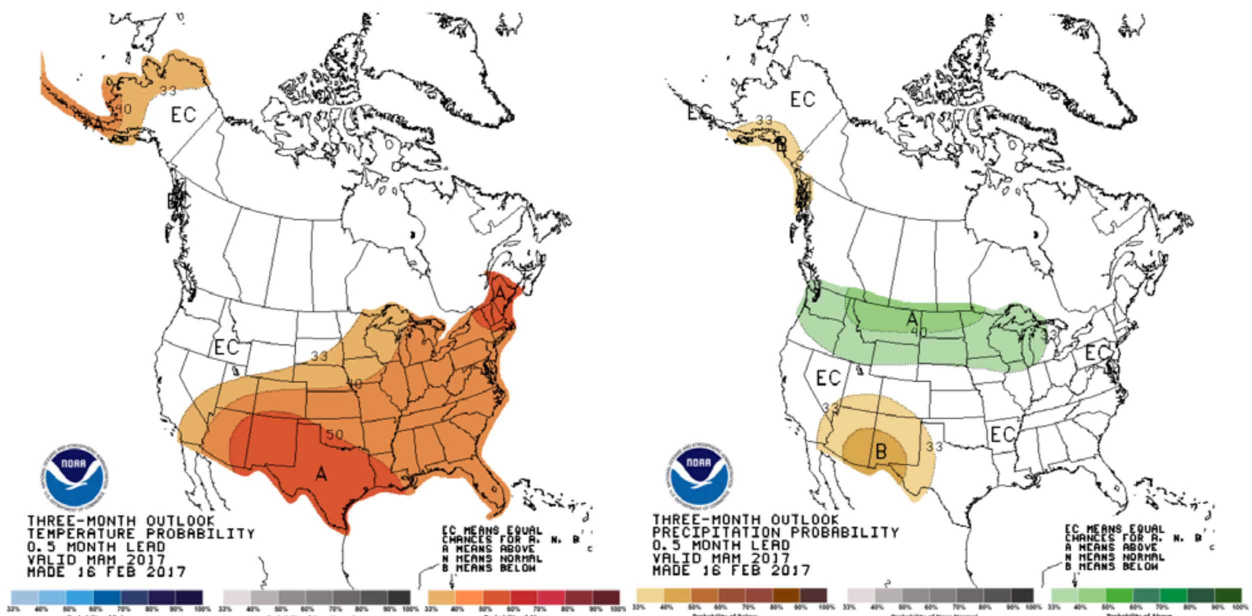


Figure 14. CPC March-April-May 2017 temperature and precipitation outlooks.

The June-July-August CPC temperature outlook (**Figure 15**) indicates there could be equal chances for above-normal, normal, and below-normal temperatures over the north central U.S. including central and eastern Montana, northeastern Wyoming and the Dakotas. There could be increased chances for above normal temperatures in western Montana, Wyoming, Colorado, western Nebraska and much of Kansas. With regard to precipitation, there could be equal chances for above-normal, normal and below-normal precipitation in all of the Missouri Basin, reflecting possible ENSO-neutral conditions.

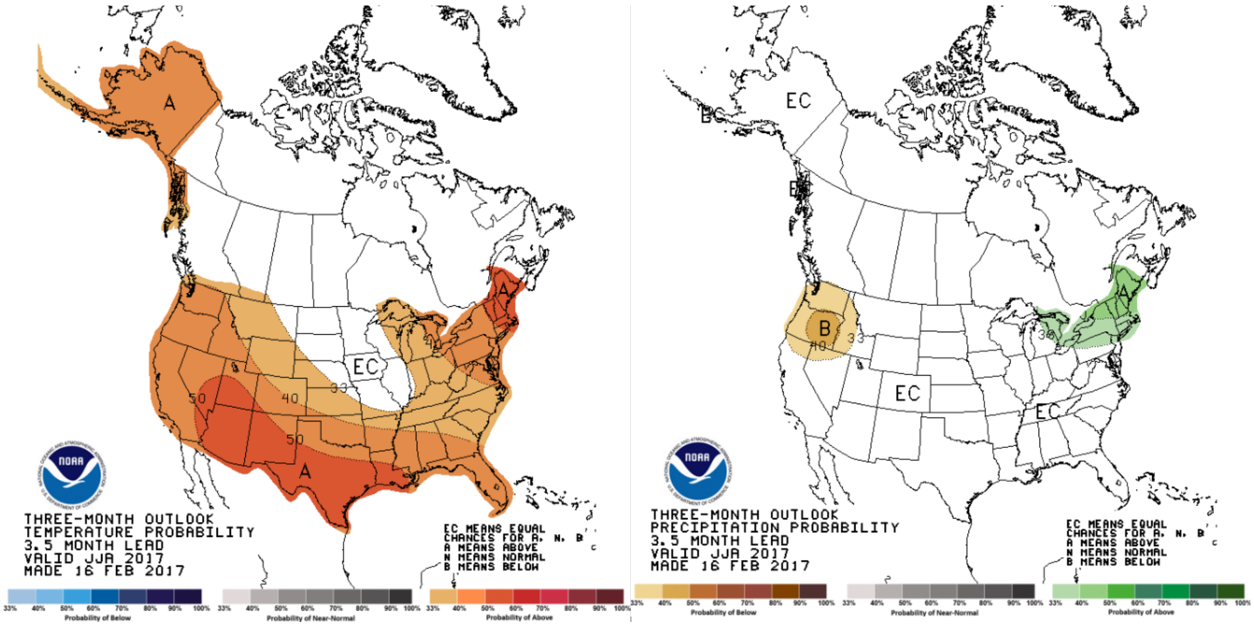


Figure 15. CPC June-July-August 2017 temperature and precipitation outlooks.

During the September-October-November period (**Figure 16**) and the December 2017-January 2018-February 2018 period (**Figure 17**), outlooks indicate increased chances for above-normal temperatures over the entire Missouri Basin. With regard to the precipitation outlooks, the CPC indicates equal chances for above-normal, normal and below-normal precipitation from September through February 2018.

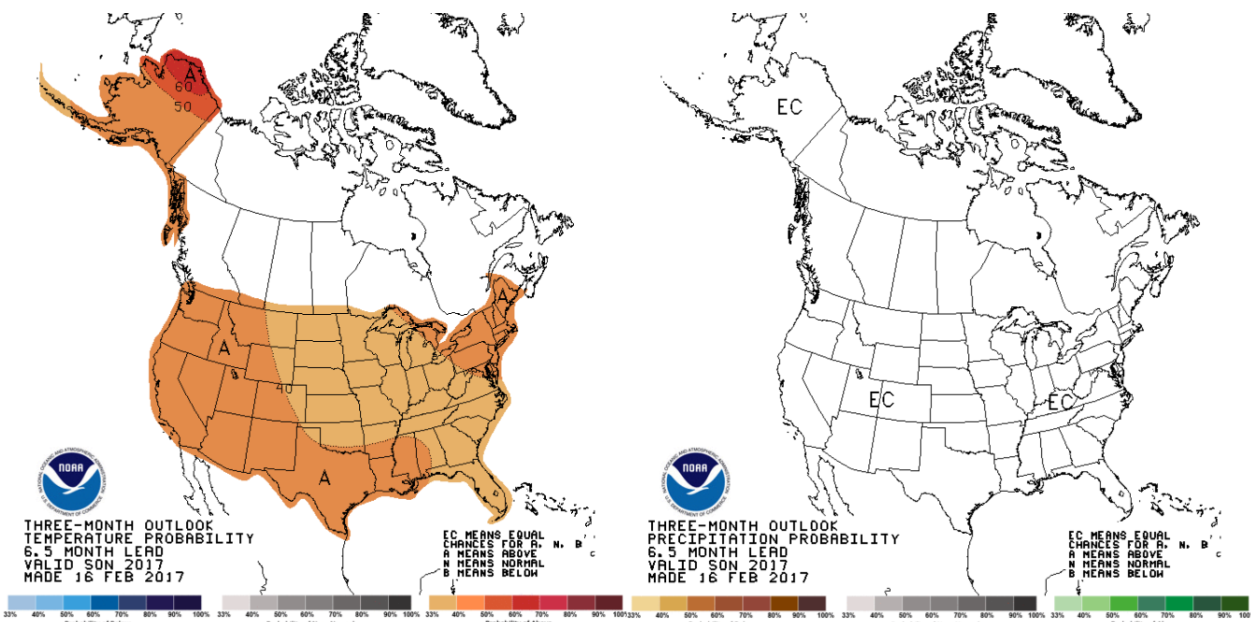


Figure 16. CPC September-October-November 2017 temperature and precipitation outlooks.

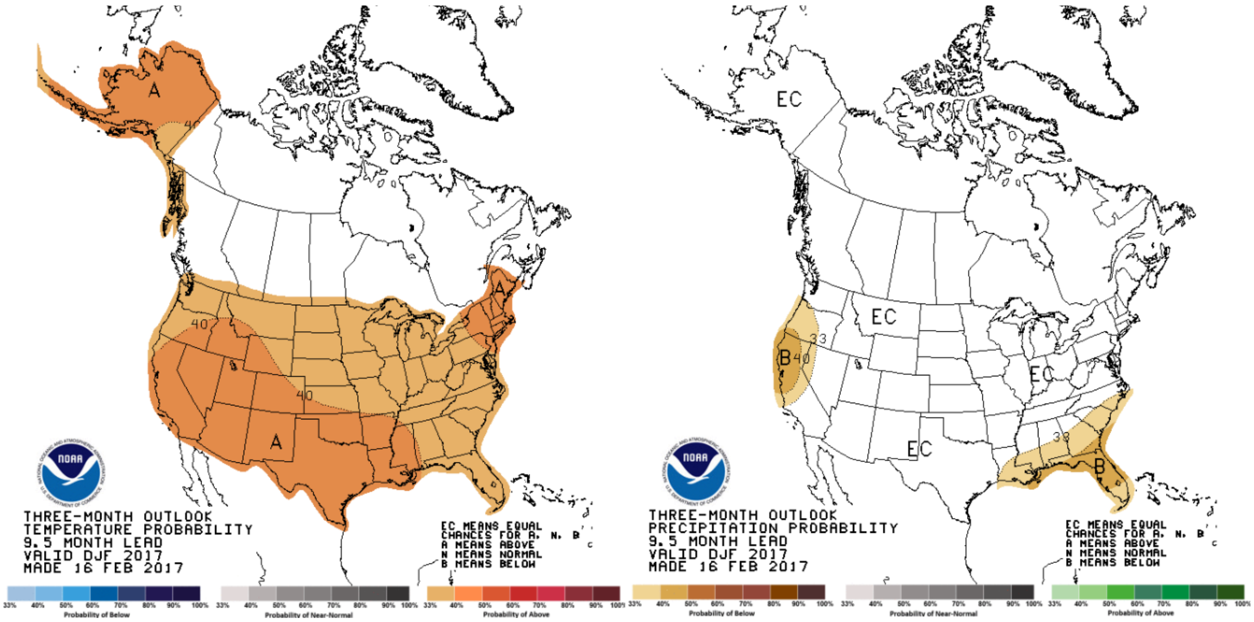
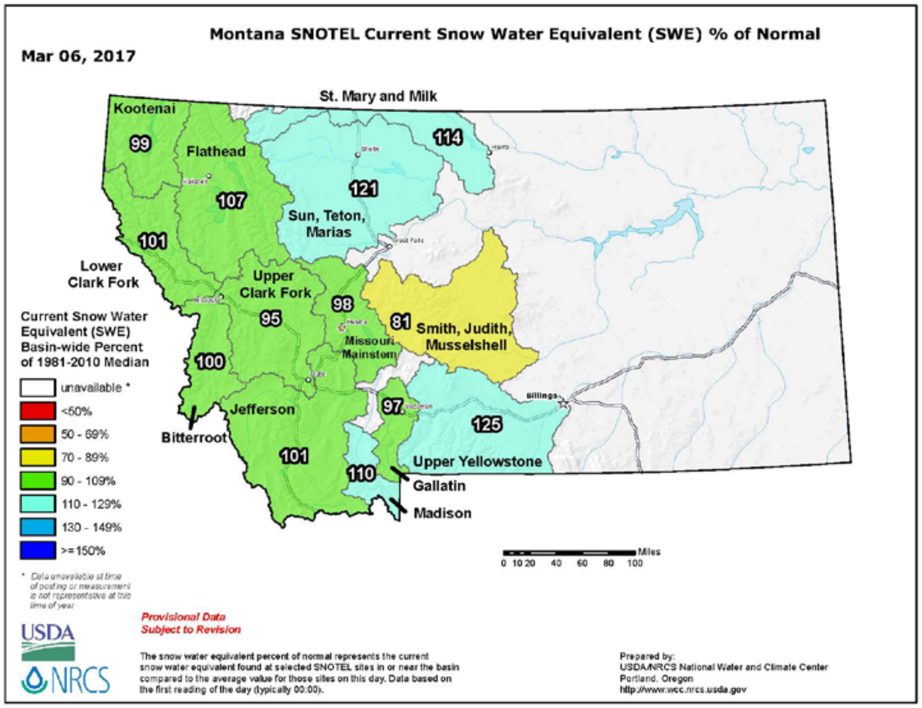


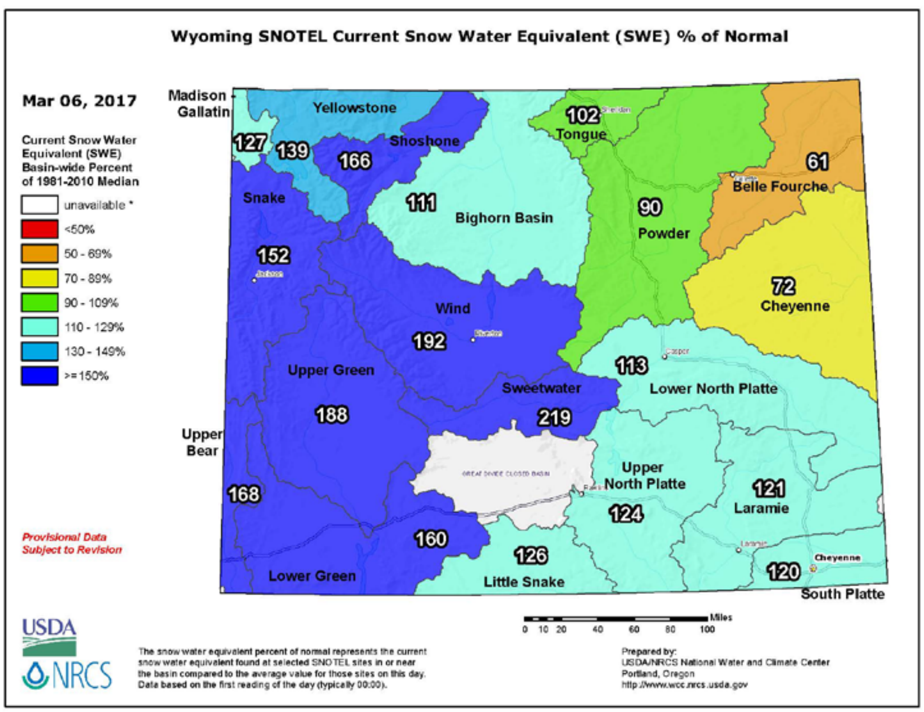
Figure 17. CPC December 2017-January 2018-February 2018 temperature and precipitation outlooks.

February 2017 Calendar Year Runoff Forecast

In summary, the 2017 calendar year runoff forecast is **29.1 MAF**, **115% of average**. Due to the limited remaining plains snow pack, March runoff is forecast to be about average. April runoff into Fort Peck and Garrison is forecasted to be slightly above normal, due to the overall above-average mountains snowpack and the possibility of early mountain snowmelt from warmer-than-normal temperatures. The forecast for May-June-July runoff in the Fort Peck and Garrison reaches is influenced by the average mountain snowpack above Fort Peck and the above-average mountain snowpack from Fort Peck to Garrison, the above-normal precipitation outlook for Montana, and the high soil moisture content in Montana and Wyoming. With the ENSO-neutral conditions, runoff is forecast to be near average for the four lower reaches from May through the end of 2017.

Additional Figures





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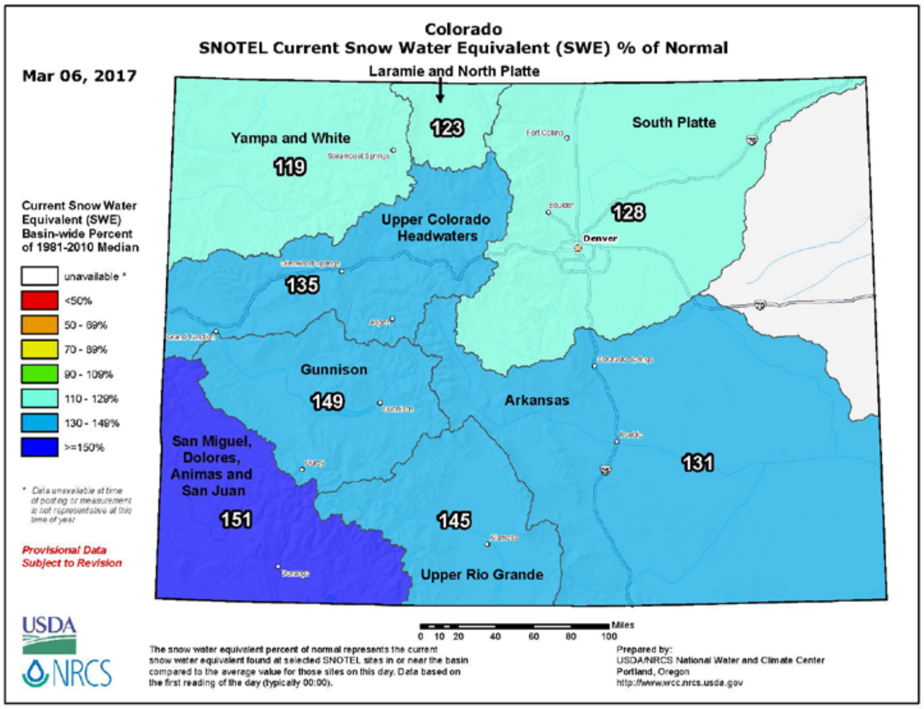

Colorado
SNOTEL Current Snow Water Equivalent (SWE) % of Normal
Mar 06, 2017
Laramie and North Platte
123
Yampa and White
119
South Platte
128
Denver
Upper Colorado Headwaters
135
Gunnison
149
Arkansas
131
San Miguel, Dolores, Animas and San Juan
151
145
Upper Rio Grande
Current Snow Water Equivalent (SWE) Basin-wide Percent of 1981-2010 Median
unavailable *
<50%
50 - 69%
70 - 89%
90 - 109%
110 - 129%
130 - 149%
>=150%
* Data unavailable at time of posting or measurement is not representative at this time of year
Provisional Data Subject to Revision
Miles
0 10 20 40 60 80 100
The snow water equivalent percent of normal represents the current snow water equivalent found at selected SNOTEL sites in or near the basin compared to the average value for those sites on this day. Data based on the first reading of the day (typically 00:00).
Prepared by:
USDA/NRCS National Water and Climate Center
Portland, Oregon
http://www.wcc.nrcs.usda.gov

USDA NRCS Water Supply Forecasts

USDA NRCS National Water & Climate Center
*** - DATA CURRENT AS OF: March 03, 2017 03:27:58 PM**
- Based on March 01, 2017 forecast values

PRELIMINARY MISSOURI RIVER BASIN FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
Lake Sherburne Inflow (2)	APR-JUL	107	110	128	115	99	86	97
	APR-SEP	123	110	146	132	113	100	112
St. Mary R at Intl Boundary (2)	APR-JUL	490	113	600	535	445	375	435
	APR-SEP	560	111	685	610	510	440	505
Lima Reservoir Inflow (2)	APR-JUL	90	120	123	103	76	56	75
	APR-SEP	99	124	136	114	83	61	80
Clark Canyon Reservoir Inflow (2)	APR-JUL	130	129	187	153	107	73	101
	APR-SEP	156	130	225	184	129	89	120
Jefferson R nr Three Forks (2)	APR-JUL	780	105	1160	935	630	405	740
	APR-SEP	845	106	1270	1020	675	425	800
Hebgen Lake Inflow (2)	APR-JUL	450	122	525	480	420	375	370
	APR-SEP	570	121	660	605	535	480	470
Ennis Lake Inflow (2)	APR-JUL	675	108	820	735	615	530	625
	APR-SEP	830	107	1000	900	760	655	775
Missouri R at Toston (2)	APR-JUL	1840	103	2480	2100	1580	1200	1790
	APR-SEP	2120	102	2860	2420	1820	1380	2070
Smith R bl Eagle Ck (2)	APR-JUL	94	89	150	116	71	38	106
	APR-SEP	107	92	173	133	80	41	116
Gibson Reservoir Inflow (2)	APR-JUL	440	111	540	480	400	340	395
	APR-SEP	485	110	595	530	440	375	440
Marias R nr Shelby (2)	APR-JUL	385	107	535	445	320	230	360
	APR-SEP	400	107	565	465	335	240	375

PRELIMINARY YELLOWSTONE RIVER BASIN FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
West Rosebud Ck nr Roscoe (2)	APR-JUL	64	108	74	68	60	54	59
	APR-SEP	81	109	93	86	76	69	74
Wind R ab Bull Lake Ck	APR-JUL	820	180	965	880	765	680	455
	APR-SEP	900	184	1060	965	840	745	490
Bull Lake Ck nr Lenore (2)	APR-JUL	220	158	255	235	205	186	139
	APR-SEP	265	157	310	285	250	225	169
Boysen Reservoir Inflow (2)	APR-JUL	1280	210	1640	1420	1130	910	610
	APR-SEP	1400	211	1790	1560	1250	1010	665
Greybull R at Meeteetse	APR-JUL	195	149	255	220	170	134	131
	APR-SEP	265	150	340	295	235	194	177
Shell Ck nr Shell	APR-JUL	56	102	72	62	50	40	55
	APR-SEP	68	103	85	75	61	51	66
Bighorn R at Kane (2)	APR-JUL	1680	200	2230	1900	1460	1140	840
	APR-SEP	1860	206	2450	2100	1620	1270	905
NF Shoshone R at Wapiti	APR-JUL	710	154	815	755	670	610	460
	APR-SEP	790	153	900	835	745	680	515
SF Shoshone R nr Valley	APR-JUL	350	163	395	370	330	305	215
	APR-SEP	405	165	455	425	385	355	245
Buffalo Bill Reservoir Inflow (2)	APR-JUL	1190	176	1360	1260	1120	1020	675
	APR-SEP	1310	176	1490	1380	1230	1120	745
Bighorn R nr St. Xavier (2)	APR-JUL	2740	199	3410	3010	2460	2060	1380

	APR-SEP	3000	205	3750	3310	2700	2260	1460
Little Bighorn R nr Hardin	APR-JUL	88	90	146	112	65	31	98
	APR-SEP	100	90	164	126	74	36	111
Tongue R nr Dayton (2)	APR-JUL	81	94	111	93	68	50	86
	APR-SEP	93	95	126	106	79	59	98
Tongue River Reservoir Inflow (2)	APR-JUL	181	94	290	225	137	72	193
	APR-SEP	205	95	320	250	156	88	215
NF Powder R nr Hazelton	APR-JUL	8.4	92	12.3	10.0	6.8	4.5	9.1
	APR-SEP	9.1	92	13.1	10.7	7.5	5.1	9.9
Powder R at Moorhead	APR-JUL	190	107	335	250	131	45	177
	APR-SEP	210	107	360	270	149	60	196
Powder R nr Locate	APR-JUL	215	108	375	280	150	55	199
	APR-SEP	235	107	405	305	168	68	220

PRELIMINARY RAPID VALLEY UNIT FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
Deerfield Reservoir Inflow	MAR-JUL	4.4	71	8.2	5.9	2.8	0.54	6.2
	APR-JUL	4.0	77	6.8	5.0	3.0	1.90	5.2
Pactola Reservoir Inflow	MAR-JUL	12.9	52	31	20	5.7	2.0	25
	APR-JUL	10.5	48	23	15.0	6.8	2.8	22

PRELIMINARY PLATTE RIVER BASIN FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
North Platte R nr Northgate (2)	APR-JUL	285	127	410	335	235	158	225
	APR-SEP	310	124	450	365	255	169	250
Encampment R nr Encampment (2)	APR-JUL	190	147	245	215	167	133	129
	APR-SEP	205	149	265	225	179	143	138
Rock Ck ab King Canyon Cnl nr Arlington	APR-JUL	57	116	74	64	50	40	49
	APR-SEP	61	117	80	69	54	43	52
Seminoe Reservoir Inflow (2)	APR-JUL	960	134	1330	1110	815	595	715
	APR-SEP	1050	136	1430	1200	890	665	770
Sweetwater R nr Alcova	APR-JUL	129	219	162	142	116	96	59
	APR-SEP	141	220	176	155	127	106	64
La Prele Ck nr Douglas	APR-JUL	21	106	39	28	13.9	3.4	19.9
	APR-SEP	21	106	39	28	13.8	3.3	19.9
North Platte R bl Glendo Reservoir (2)	APR-JUL	1280	156	1790	1490	1070	770	820
	APR-SEP	1360	160	1880	1570	1150	835	850
North Platte R bl Guernsey Reservoir (2)	APR-JUL	1300	159	1820	1510	1090	775	820
	APR-SEP	1380	162	1920	1600	1160	840	850
Laramie R and Pioneer Cnl nr Woods Lg (2)	APR-JUL	154	134	210	177	131	97	115
	APR-SEP	168	133	230	194	143	106	126
Little Laramie R nr Filmore	APR-JUL	63	124	85	72	54	41	51
	APR-SEP	68	124	92	78	58	44	55

Max (10%), 30%, 50%, 70% and Min (90%) chance that actual volume will exceed forecast.
Averages are for the 1981-2010 period.
All volumes are in thousands of acre-feet.

footnotes:
1) Max and Min are 5% and 95% chance that actual volume will exceed forecast
2) streamflow is adjusted for upstream storage
3) median value used in place of average

Upper Missouri River Basin
April 2017 Calendar Year Runoff Forecast
April 7, 2017

U.S. Army Corps of Engineers, Northwestern Division
Missouri River Basin Water Management
Omaha, NE

Calendar Year Runoff Forecast

Explanation and Purpose of Forecast

The long-range runoff forecast is presented as the Calendar Year Runoff Forecast. The Calendar Year Runoff Forecast is available at http://www.nwd-mr.usace.army.mil/rcc/reports/runoff.pdf. This forecast is developed shortly after the beginning of each calendar year and is updated at the beginning of each month to show the actual runoff for historic months of that year and the updated forecast for the remaining months of the year. This forecast presents monthly inflows in million acre-feet (MAF) from five incremental drainage areas, as defined by the individual System projects, plus the incremental drainage area between Gavins Point Dam and Sioux City. Due to their close proximity, the Big Bend and Fort Randall drainage areas are combined. Summations are provided for the total Missouri River reach above Gavins Point Dam and for the total Missouri River Basin above Sioux City (upper Basin). The Calendar Year Runoff Forecast is used in the Monthly Study simulation model to plan future system regulation in order to meet the authorized project purposes throughout the calendar year.

Observed Runoff

March 2017 runoff was 111% of average for the upper Basin. All of the seasonal plains snowpack and river ice melted in March. March runoff was above average in the Fort Peck reach (124% of average) and the Garrison reach (155% of average). Runoff was below average in the Oahe reach (60% of average), Fort Randall reach (32% of average) and the Gavins Point reach (68% of average).

2017 Calendar Year Forecast Synopsis

The April 1 forecast for the 2017 Missouri River runoff above Sioux City, IA is **29.4 MAF (116% of average)**. Runoff above Gavins Point Dam is forecast to be **26.5 MAF (115% of average)**. Due to the amount of variability in precipitation and other hydrologic factors that can occur over the next 9 months, the range of expected inflow is quite large and ranges from the 38.3 MAF upper basic forecast to the 21.7 MAF lower basic forecast. The upper and lower basic forecasts are used in long-term regulation planning models to "bracket" the range of expected runoff given much wetter or drier conditions, respectively. Given that 9 months are being forecasted for this April 1 forecast (3 months observed/9 months forecast), the range of wetter-than-normal (upper basic) and drier-than-normal (lower basic) is attributed to all 6 reaches for all 9 months. The result is a large range or "bracket" for each reach, and thus, for the total runoff forecast. As the year progresses, the range will lessen as the number of observed months increases and the number of forecast months decreases.

Current Conditions

Drought Analysis

The latest National Drought Mitigation Center's drought monitor for March 28, 2017 (**Figure 1**), is compared to the drought monitor for February 28, 2017 (**Figure 2**). The drought monitor is available at http://droughtmonitor.unl.edu/. The U.S. Drought Monitor indicates there are some areas of Moderate Drought (D1) in northeastern Wyoming, southeastern Montana, and western South Dakota. Abnormally Dry (D0) conditions persist in areas surrounding the D1 Drought and in small areas of western and eastern Montana. D1 conditions as well as pockets of Severe Drought (D2) are present in Colorado, southwestern Nebraska, Kansas, Missouri and southern Iowa. The Seasonal Drought Outlook in **Figure 3** indicates drought conditions may be removed if northeastern Wyoming and western South Dakota continue to receive precipitation through the end of June 2017.

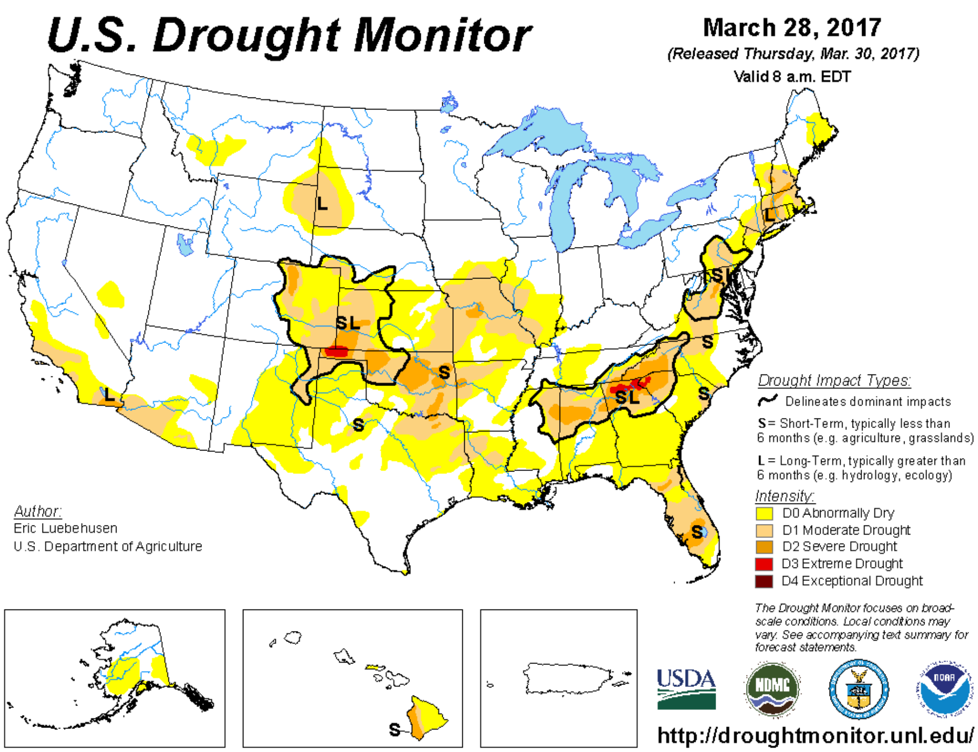


Figure 1. National Drought Mitigation Center U.S. Drought Monitor for March 28, 2017.

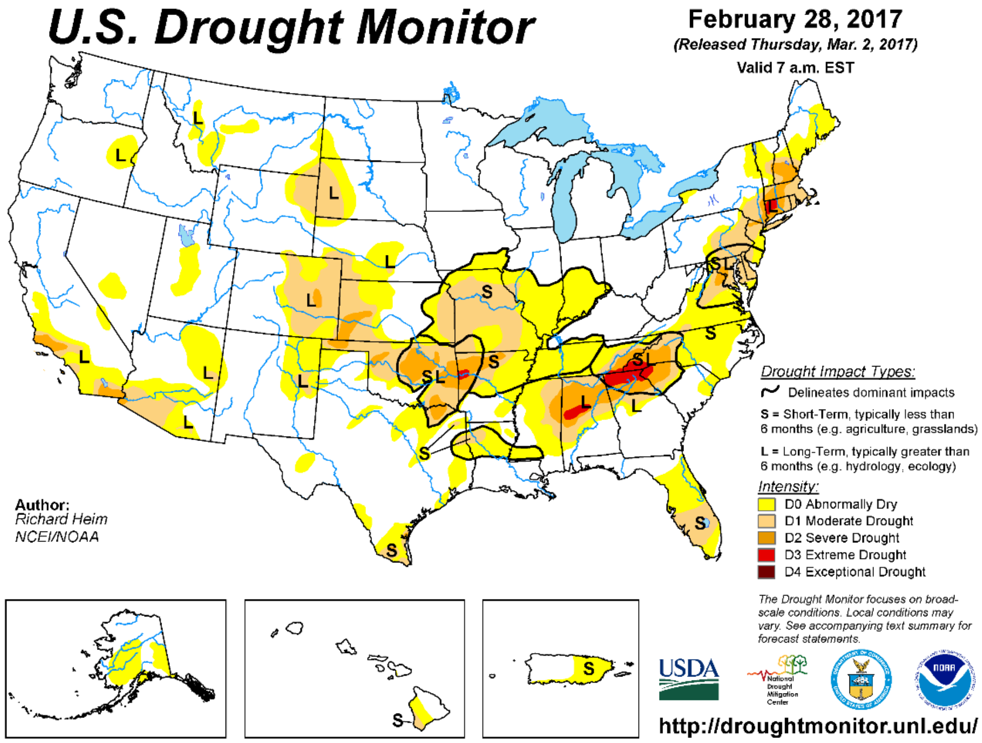


Figure 2. National Drought Mitigation Center U.S. Drought Monitor for February 28, 2017.

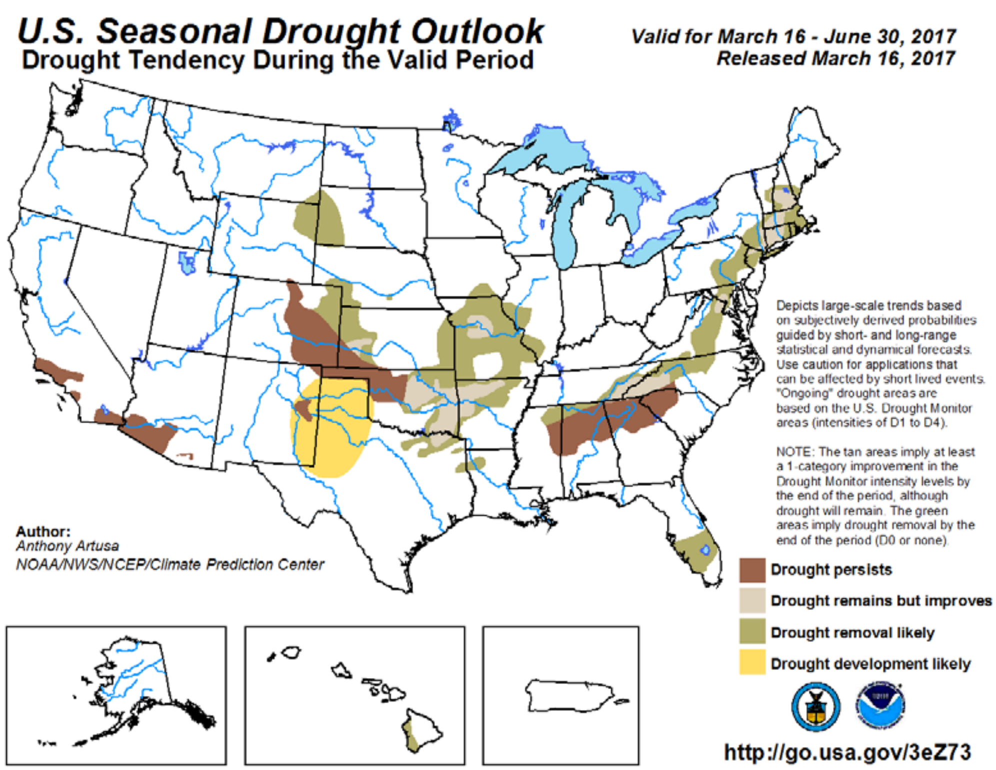


Figure 3. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

Monthly precipitation accumulations are shown using High Plains Regional Climate Center images available at http://www.hprcc.unl.edu/. The March precipitation accumulations are shown in **Figure 4** as inches of precipitation (left) and percent of normal precipitation (right). Precipitation was well-above average in southern Montana, Wyoming, and western Nebraska. March precipitation was well-below average in northern Montana, the Dakotas and portions of Nebraska. January-February-March precipitation accumulations are shown in **Figure 5**. The three-month accumulations reflect the continuing wet pattern across western and southern Montana, Wyoming, and western Nebraska.

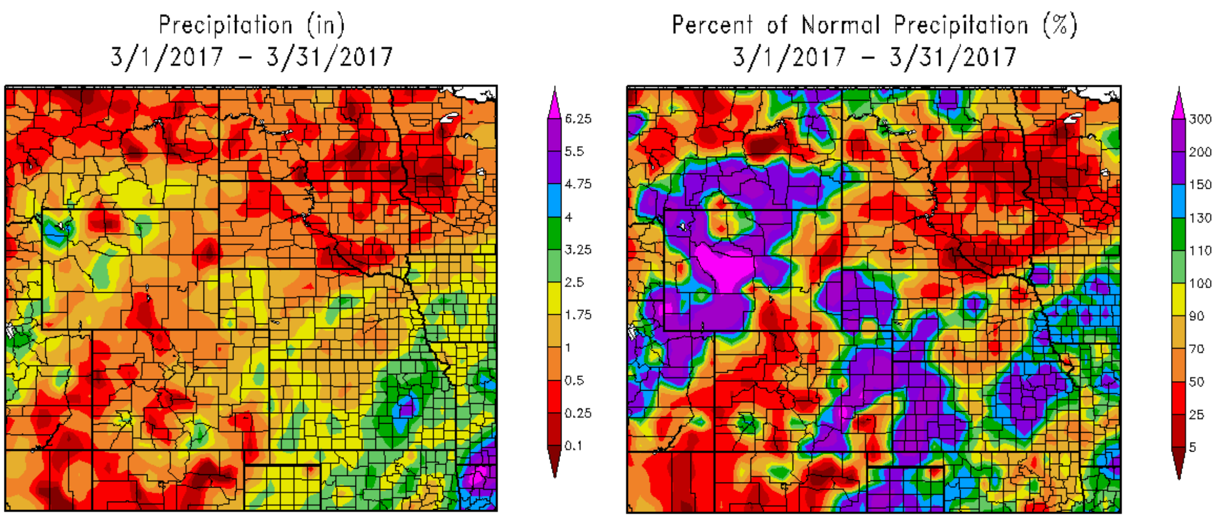


Figure 4. March 2017 Precipitation (inches) and Percent of Normal Precipitation.

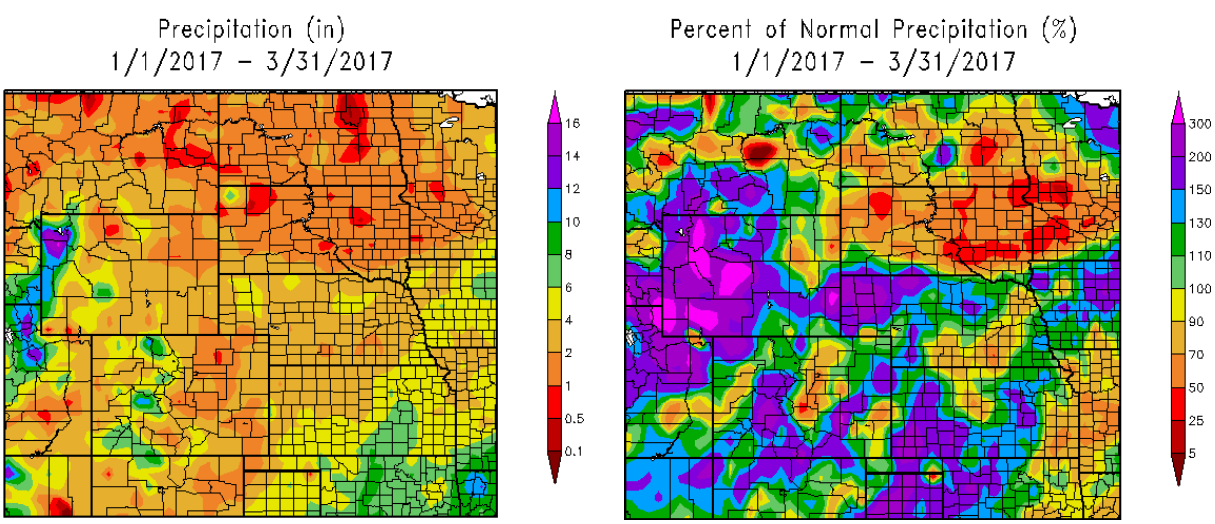


Figure 5. January-February-March 2017 Precipitation (inches) and Percent of Normal Precipitation.

Temperature

March temperature departures in degrees Fahrenheit (deg F) in the left image of **Figure 6** were predominantly above normal, especially in southern Montana, Wyoming, western South Dakota, Nebraska, and Kansas. Departures ranged from 2 to 8 deg F above normal in these areas. March temperatures were near normal in northern Montana, below normal in North Dakota, and near to below normal in eastern South Dakota. January-February-March temperatures, in the right image of **Figure 6**, were 0 to 4 deg F below normal over much of Montana, northern Wyoming, and the western Dakotas. Temperatures have been 2 to 6 deg F above normal in the eastern Dakotas, much of Nebraska, Iowa, Kansas and Missouri.

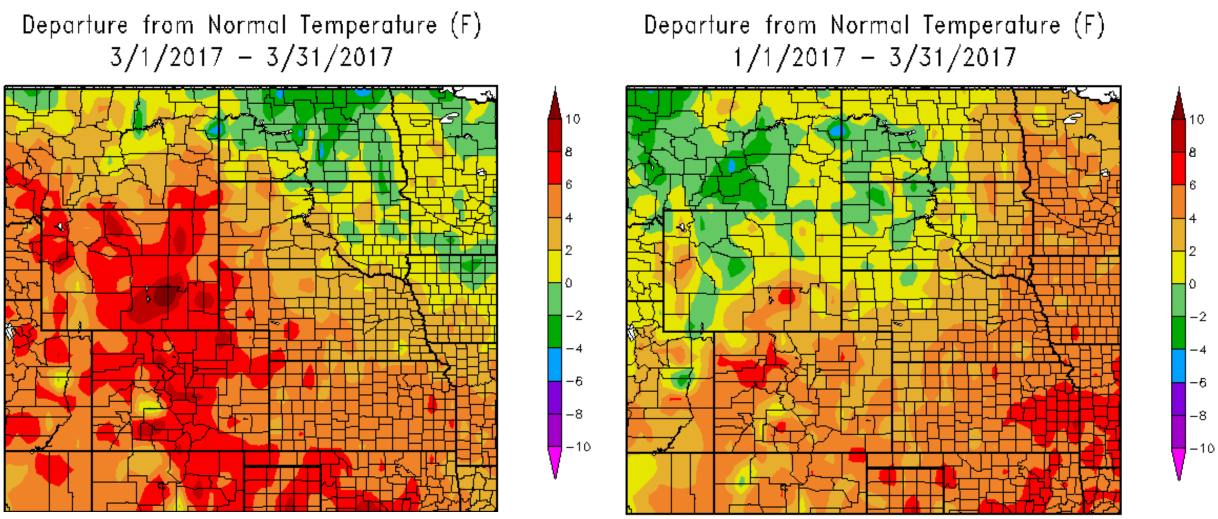
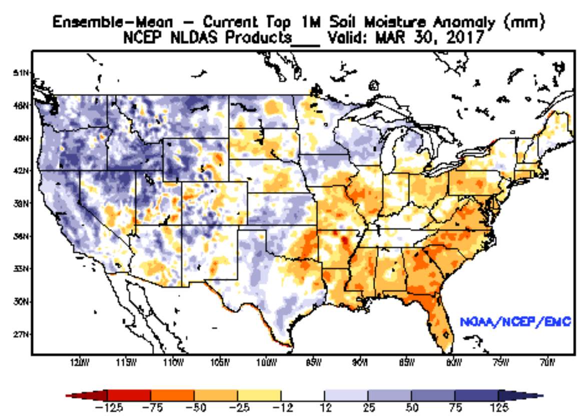


Figure 6. March 2017 and January-February-March 2017 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

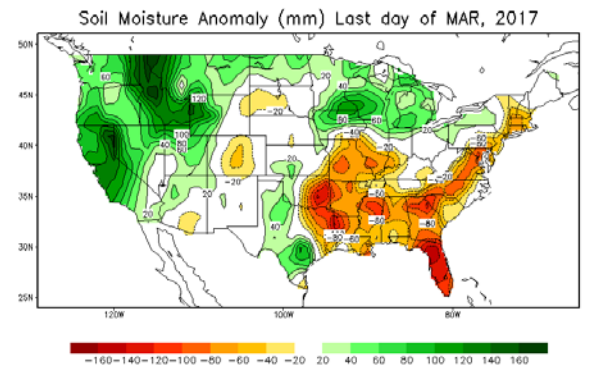
Soil Moisture

Soil moisture is factored into the forecast as an indicator of wet or dry hydrologic basin conditions. Typically when soil moisture conditions are wet or greater than normal, rainfall and snowmelt runoff is greater than when soil moisture is dry or less than normal. Not only is soil moisture a physical parameter that influences runoff, it can be used as an indicator of future runoff. As the calendar year approaches winter, the soil moisture conditions will provide some insight into late winter and early spring runoff potential.

The left image of **Figure 7** shows the NOAA NLDAS ensemble top one-meter soil moisture anomaly on March 30, 2017. The NLDAS image shows wetter-than-normal conditions across Montana, much of North Dakota, central and western Wyoming, southeastern South Dakota, western Iowa, eastern Nebraska and Kansas. Drier-than-normal conditions are present in eastern Wyoming, South Dakota, central Nebraska and Missouri. Similarly, the CPC Soil Moisture Anomaly, in the right image of **Figure 7**, indicates wetter-than-normal soil moisture conditions in Montana, western Wyoming, North Dakota, and Iowa. The CPC anomaly indicates slightly drier-than-normal conditions in South Dakota, eastern Nebraska and northern Iowa.   Soils have high anomalies in western Montana and western Wyoming.

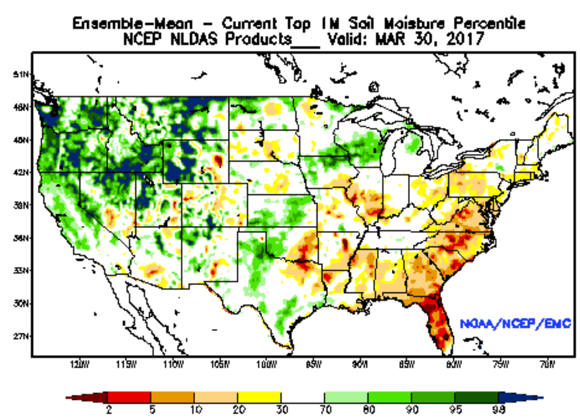


NOAA NLDAS Drought Monitor Soil Moisture.
http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

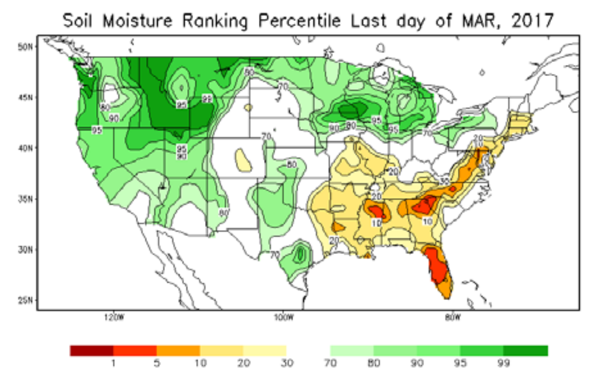


CPC Soil Moisture.
http://www.cpc.ncep.noaa.gov/products/Soilmst_Monitoring/US/Soilmst/Soilmst.shtml#

Figure 7. NOAA NLDAS and CPC Soil Moisture Anomalies (mm).



NOAA NLDAS Drought Monitor Soil Moisture.
http://www.emc.ncep.noaa.gov/mmb/nldas/drought/



CPC Soil Moisture.
http://www.cpc.ncep.noaa.gov/products/Soilmst_Monitoring/US/Soilmst/Soilmst.shtml#

Figure 8. NOAA NLDAS and CPC Soil Moisture Percentile Rankings.

Soil moisture conditions expressed as a percentile ranking can show the severity of the soil moisture conditions through the percentile ranking probability. Soil moisture percentile rankings from NOAA NLDAS and the CPC are shown in **Figure 8**. The NLDAS percentile ranking, in the left image of **Figure 8**, indicates very wet soil moisture conditions (greater than 98th percentile rank) throughout many areas of Montana and Wyoming. A greater than 98th percentile ranking soil moisture conditions indicates soil moisture is wetter than 98 out of 100 soil moisture samples or years for the indicated date. The CPC percentile ranking, in the right image of **Figure 8**, indicates very wet soil moisture conditions (99th percentile ranking) in western Montana, northeastern Montana and western Wyoming. Slightly drier-than-normal areas are present over eastern Colorado, a small area in northeastern Wyoming and western South Dakota, and Missouri.

Frost Conditions

Figure 9 shows the depth of frost penetration at NWS Warning Forecast Office (WFO) locations in the Missouri River basin as of April 3, 2017. All soil frost has thawed at the measured NWS locations near the soil surface; however, frost layers that developed deep within the soil profile may still be present. **Figure 9** indicates one such area could be in the vicinity of Williston, ND, which has a frost layer present at 32 inches below the soil surface.

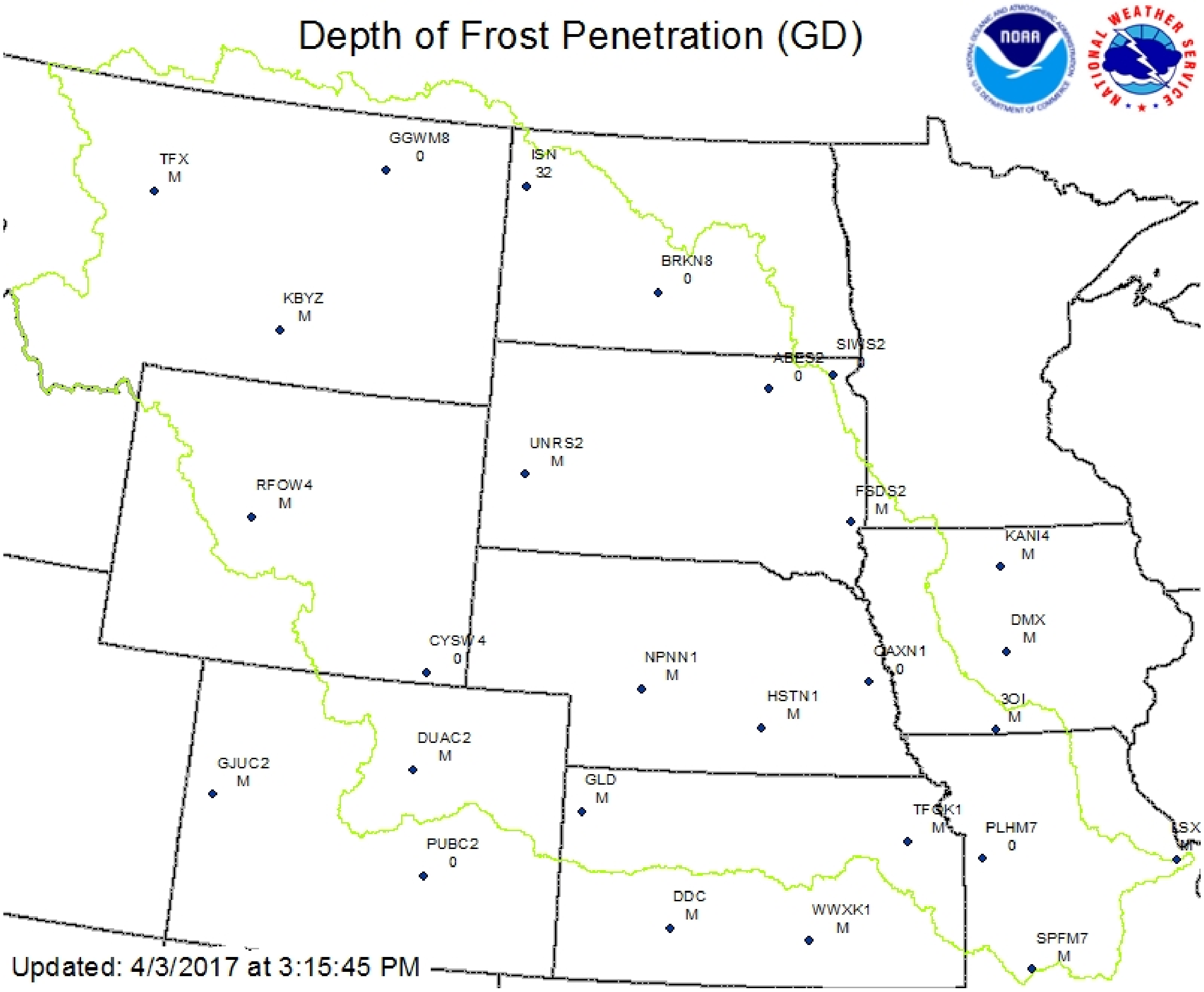


Figure 9. Measured frost depth (inches) at NWS WFO offices as of April 3, 2017. Source: NWS MBRFC. http://www.crh.noaa.gov/mbrfc

Plains Snowpack

Plains snowpack is an important parameter that influences the volume of runoff occurring in the basin during the months of March and April. A common misperception is that the March-April runoff is a result of plains snowmelt only. Historically, about 25% of annual runoff occurs in March and April, during the time when plains snow is melting, due to both melting snowpack and rainfall runoff. Runoff occurs in March and April whether or not there is any plains snow to melt. Determining exact rainfall amounts and locations are nearly impossible to predict more than a week in advance. Thus, the March-April runoff forecast can be formulated based on existing plains snowpack and existing basin conditions and hydrologic forecasts, which for this year primarily includes long-term precipitation outlooks.

The National Weather Service's National Operational Hydrologic Remote Sensing Center (NOHRSC), modeled snow assessment, shown in **Figure 10**, indicates all seasonal plains snow water equivalent (SWE) had melted in the upper Basin. As of April 1, 2017, trace to one-inch amounts of SWE had recently accumulated in southeastern Wyoming, northeastern Colorado, western Nebraska, and southwestern South Dakota.

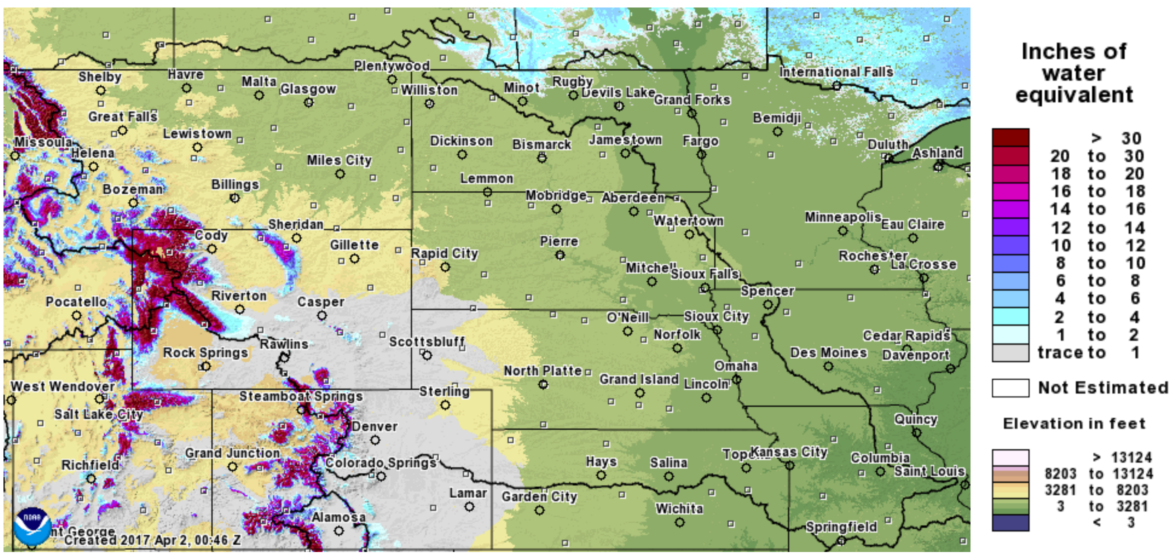


Figure 10. April 1, 2017 NOHRSC modeled plains snow water equivalent. Source: NOAA National Operational Hydrologic Remote Sensing Center. http://www.nohrsc.nws.gov/interactive/html/map.html

During January, February and March 2017, MRBWMD coordinated cooperative snow survey measurements in the upper Missouri River basin to help assess the depth and water equivalent of plains snowpack. These measurements are used by MRBWMD to adjust the March-April runoff forecast, and the measurements are shared with NWS to help verify modeled snow estimates used in spring streamflow forecasts. In addition to this information, anecdotal basin condition information such as soil moisture content and frost depth improves situational awareness among federal, state and local agencies. A full report of snow depth and SWE measurements are available at http://www.nwd-mr.usace.army.mil/rcc/snowsurvey/snowsurvey.html.

Mountain Snow Pack

Mountain snowpack is the primary factor used to predict May-July runoff volumes in the Fort Peck and Fort Peck to Garrison reaches. During the 3-month May-July runoff period, about 50% of the annual runoff in the upper Basin enters the Mainstem System as a result of mountain snowmelt and rainfall runoff. Greater-than-average mountain snow accumulations are usually associated with greater-than-average May-July runoff volumes, especially when mountain soil moisture conditions have been wetter-than-normal. For example, we would expect to see greater-than-average runoff from an average mountain snowpack this year due to wetter-than-normal soil moisture conditions.

Figure 12 includes time series plots of the average mountain SWE beginning on October 1, 2016 based on the NRCS SNOTEL gages for the headwater basin above Fort Peck and the incremental basin from Fort Peck to Garrison. The current average SWE values (shaded blue area) are plotted against the 1981-2010 basin average SWE (bold red line), a recent low SWE year in 2001 (green line), and two historic high SWE years occurring in 1997 (purple) and 2011 (dark blue).

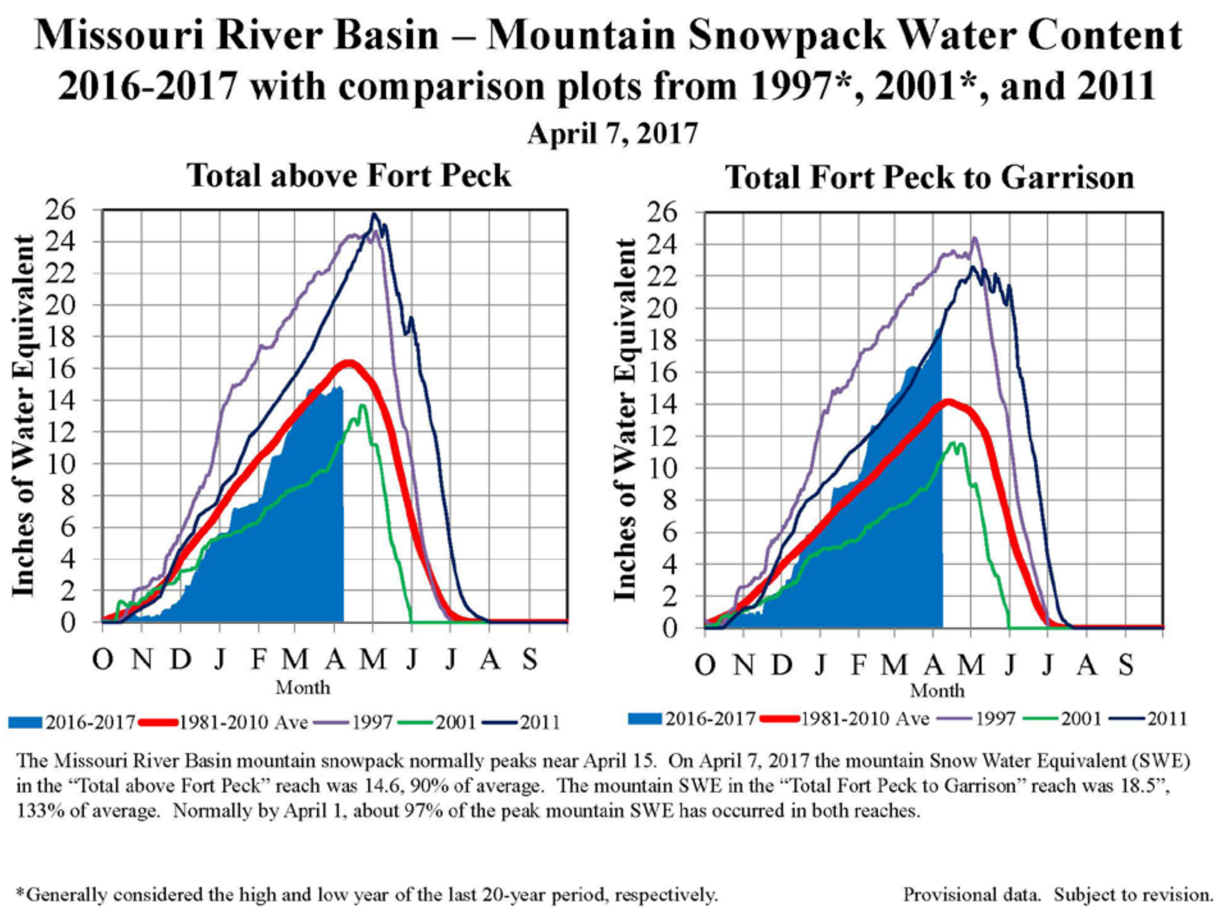


Figure 11. Mountain snowpack water content on April7, 2017 compared to normal and historic conditions. Corps of Engineers - Missouri River Basin Water Management. Available at http://www.nwd-mr.usace.army.mil/rcc/reports/snow.pdf.

As of **April 1, 2017**, the Corps of Engineers computed an average mountain SWE in the Fort Peck reservoir reach of 14.8 inches, which is 93% of average for April 1 based on the 1981-2010 average SWE for the Fort Peck reach. In the reservoir reach between Fort Peck Dam and Garrison Dam, the Corps computed an average mountain SWE of 18.0 inches, which is 133% of average for April 1 based on the 1981-2010 average SWE for the Garrison reach. As of **April 7, 2017**, the Fort Peck SWE was 14.6 inches, 90% of average, and the Garrison SWE was 18.5 inches, 133% of average. Normally, 97% of the peak snow accumulation has occurred in the mountains by April 1, and the mountain snowpack normally peaks around April 15.

In the **Additional Figures** section at the end of this document, basin maps of the mountain snowpack as a percent of median are provided for Montana, Wyoming and Colorado. These maps are a product of the USDA-NRCS National Water and Climate Center and are available at http://www.wcc.nrcs.usda.gov. These maps show that mountain snowpack is about median to slightly above median in Montana, but well-above median in many Wyoming basins and all Colorado basins.

Climate Outlook

MRBWMD participates in the monthly North Central U.S. Climate/Drought Outlook Webinar coordinated through NOAA, the regional climate centers, and the American Association of State Climatologists (AASC). These webinars provide updates on near-term climate outlooks and impacts including the ENSO climate pattern and its implications on winter temperature and precipitation patterns in the Missouri River Basin.

ENSO (El Niño Southern Oscillation)

The latest ENSO update indicates that ENSO-neutral conditions are present, and expected to continue through Spring 2017. ENSO-neutral conditions typically do not influence the chances for spring precipitation and temperatures in the upper Basin.

Temperature and Precipitation Outlooks

The NOAA Climate Prediction Center (CPC) outlooks provide the forecasted probability (or chance) of occurrence of future weather conditions during periods ranging from one to 12 months into the future. The CPC outlooks are available at http://www.cpc.ncep.noaa.gov/.

The CPC outlooks through mid-April indicate increased chances for cooler and wetter conditions in the mountains, and wetter conditions in the plains with mixed temperatures. During the second half of April, the CPC indicates an increased chance for warmer-than-average temperatures in the mountains and plains. The warmer temperatures may lead to increased runoff in April due to increased mountain snowmelt. The overall outlook for April 2017 (**Figure 13**) indicates there are equal chances for above-normal, normal and below-normal temperatures in the upper Basin, and there are increased chance for above-normal temperatures in the lower

Basin. With regard to precipitation, CPC indicates there are increased chances for above-normal precipitation in northeastern Montana, North Dakota, and northern South Dakota.

The April-May-June temperature outlook (**Figure 14**) indicates equal chances for temperatures in the upper Basin and increased chances for above-normal temperatures in the lower Basin. The April-May-June precipitation outlook indicates increased chances for above-normal precipitation over Montana, Wyoming, North Dakota, South Dakota, northern Nebraska, and northwestern Iowa with equal chances in the remainder of the Missouri River basin.

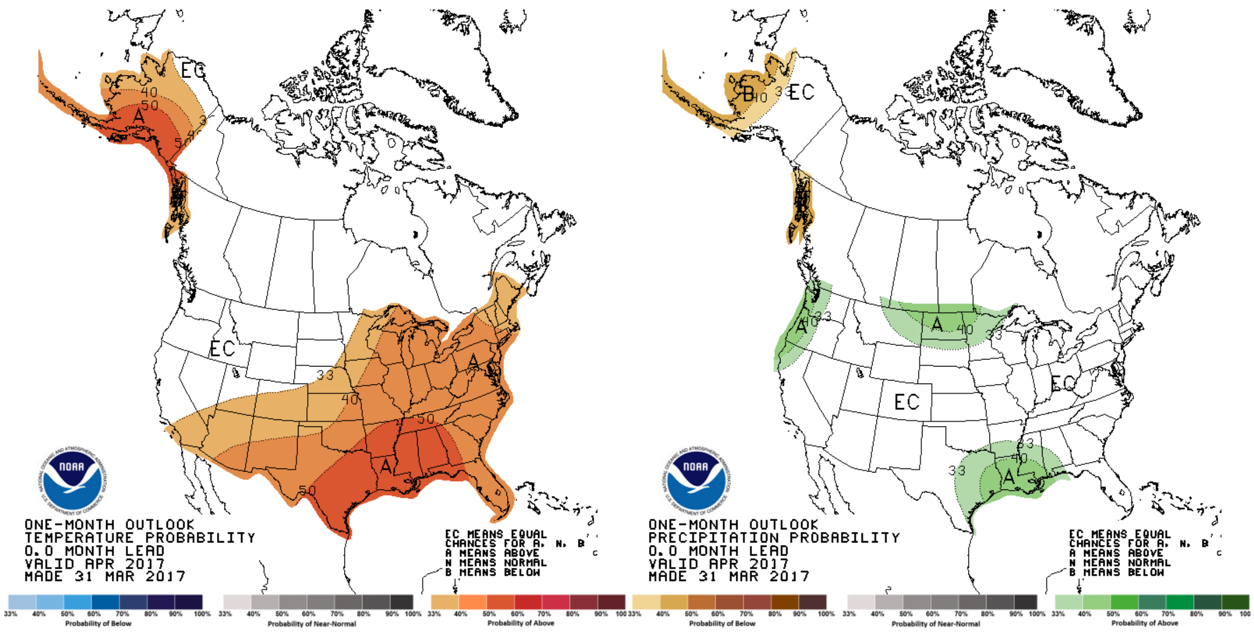


Figure 12. CPC April 2017 temperature and precipitation outlooks.

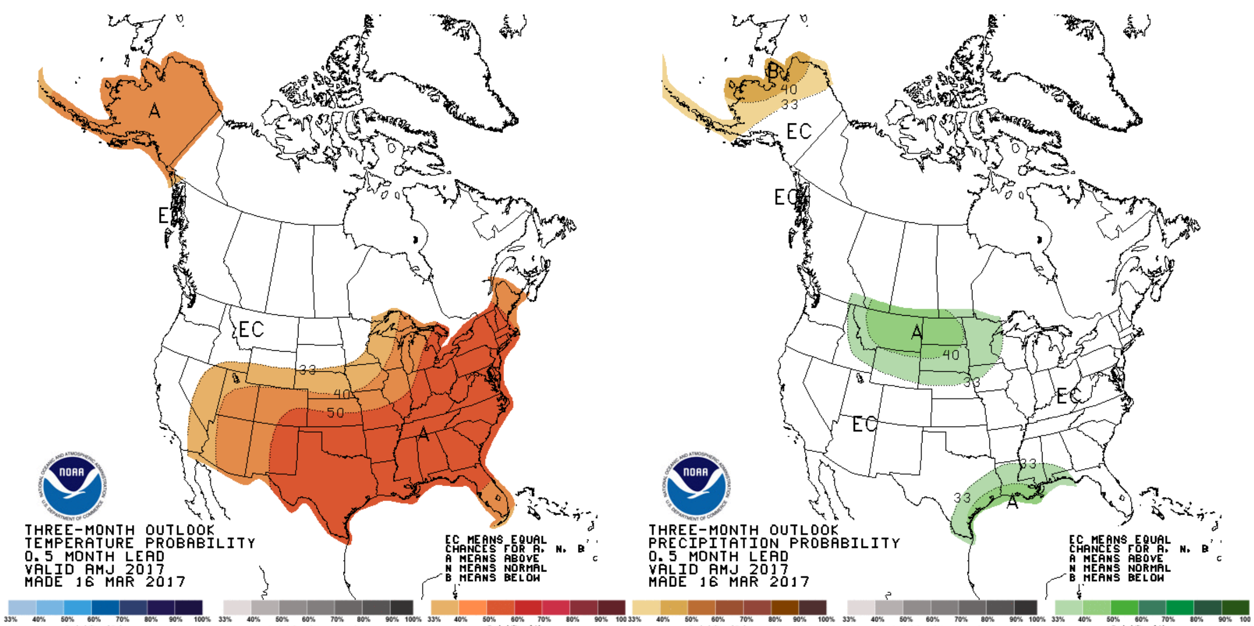


Figure 13. CPC April-May-June 2017 temperature and precipitation outlooks.

The July-August-September CPC temperature outlook (**Figure 15**) indicates there could be increased chances for above-normal temperatures over the Missouri River basin. With regard to precipitation, there could be increased chances for above-normal precipitation in Montana, Wyoming, the western Dakotas and northwestern Nebraska. During the October-November-December period (**Figure 16**), the temperature outlook indicates increased chances for above-normal temperatures over the entire Missouri River basin. With regard to the precipitation outlooks, CPC indicates equal chances for precipitation. Based on these outlooks, the runoff for the August-December period is forecasted to be average for all six reaches.

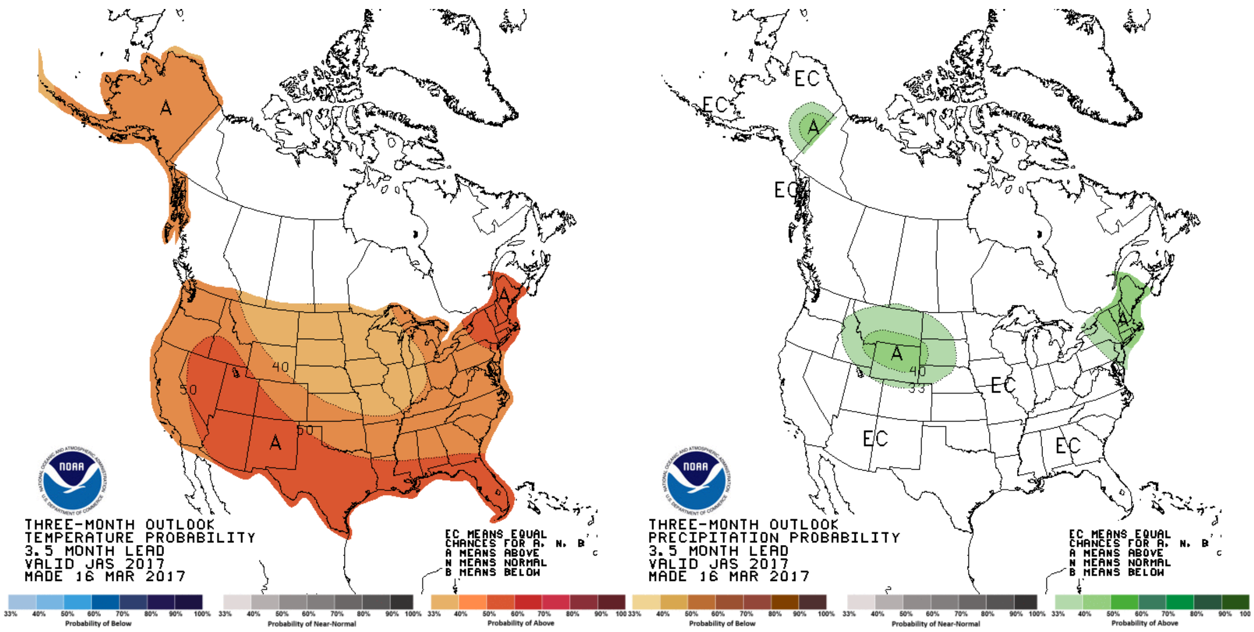


Figure 14. CPC July-August-September 2017 temperature and precipitation outlooks.

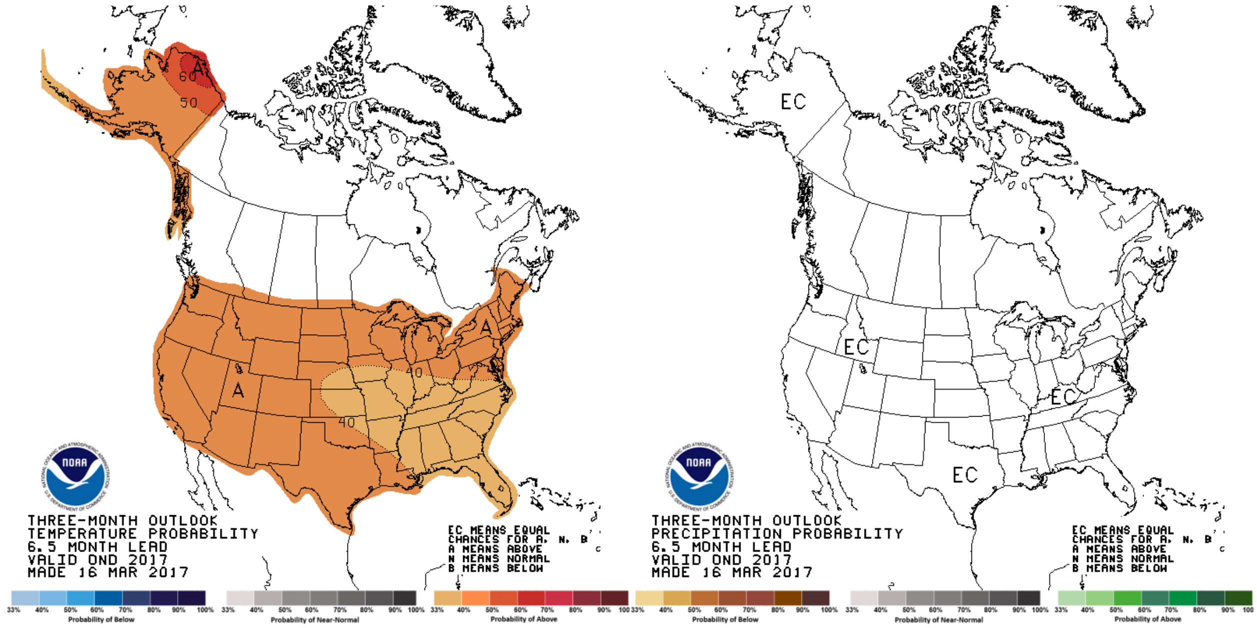
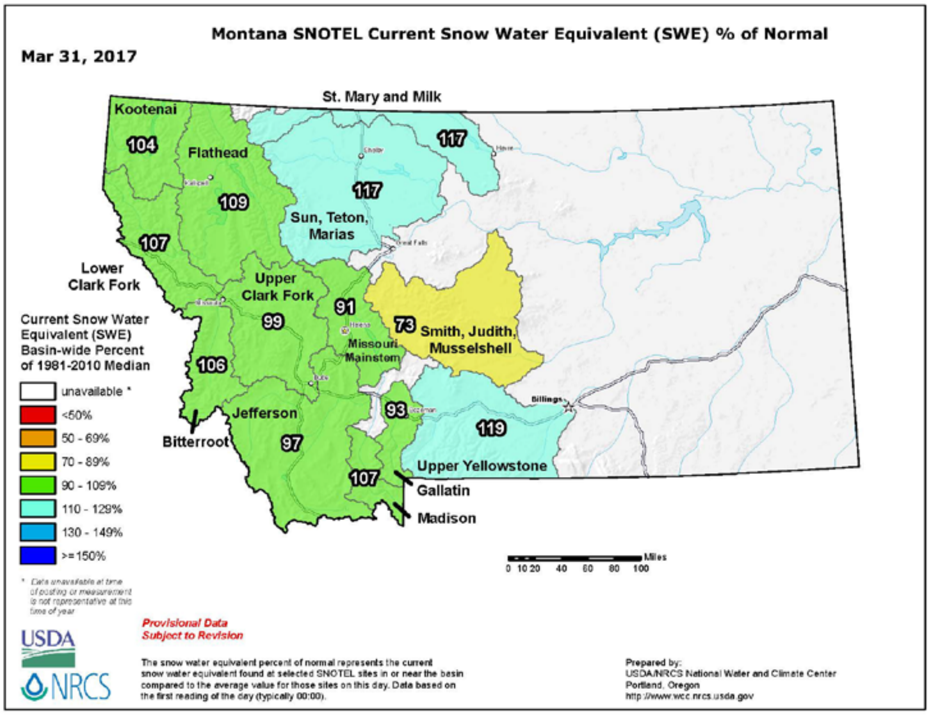


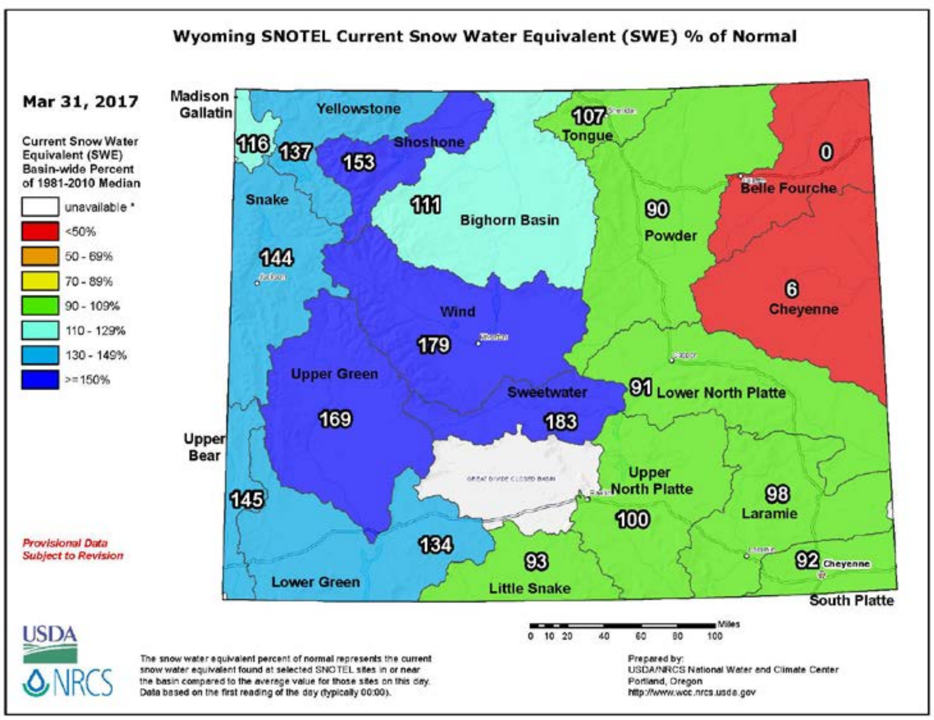
Figure 15. CPC October-November-December 2017 temperature and precipitation outlooks.

April 2017 Calendar Year Runoff Forecast

In summary, the 2017 calendar year runoff forecast is **29.4 MAF**, **116% of average**. Seasonal plains snowpack and river ice melted in the upper Missouri River basin and ran off in March. Wet soil moisture conditions in Montana and Wyoming are factored into the above-average runoff forecast in the Fort Peck and Garrison reaches in April. In contrast, dry soil moisture conditions are present in eastern Wyoming, central North Dakota, and South Dakota. Following below-average runoff in March, April runoff is forecast to be below average from Oahe to Gavins Point and could continue through late-spring (June). Mountain snowpack was 93% of average in the Fort Peck reach and 133% of average in the Garrison reach as of April 1. Considering both the mountain snowpack and wet soil moisture conditions, May-June-July runoff is forecast to be 95% of average in the Fort Peck reach and 135% of average in the Garrison reach. The CPC outlooks through mid-April indicate increased chances for cooler and wetter conditions in the mountains, and wetter conditions in the plains with mixed temperatures. During the second half of April, the CPC indicates an increased chance for warmer-than-average temperatures in the mountains and plains. The warmer temperatures at the end of April may lead to increased runoff due to increased mountain snowmelt. The climate outlooks through May-June-July indicate equal chances for forecast temperature and a slight increase in the chances for precipitation throughout the upper Basin.

Additional Figures





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USDA NRCS Water Supply Forecasts

USDA NRCS National Water & Climate Center
*** - DATA CURRENT AS OF: April 06, 2017 03:19:40 PM**
- Based on April 01, 2017 forecast values

PRELIMINARY MISSOURI RIVER BASIN FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
Lake Sherburne Inflow (2)	APR-JUL	112	115	130	119	105	94	97
	APR-SEP	128	114	148	136	120	108	112
St. Mary R at Intl Boundary (2)	APR-JUL	510	117	605	550	470	415	435
	APR-SEP	580	115	690	625	535	470	505
Lima Reservoir Inflow (2)	APR-JUL	59	79	85	70	48	33	75
	APR-SEP	63	79	91	75	51	35	80
Clark Canyon Reservoir Inflow (2)	APR-JUL	93	92	140	112	74	46	101
	APR-SEP	114	95	169	136	92	59	120
Jefferson R nr Three Forks (2)	APR-JUL	685	93	1000	815	555	370	740
	APR-SEP	735	92	1090	880	590	375	800
Hebgen Lake Inflow (2)	APR-JUL	400	108	470	430	370	330	370
	APR-SEP	505	107	590	540	470	420	470
Ennis Lake Inflow (2)	APR-JUL	605	97	735	660	550	475	625
	APR-SEP	750	97	905	815	685	595	775
Missouri R at Toston (2)	APR-JUL	1660	93	2200	1880	1440	1120	1790
	APR-SEP	1920	93	2560	2180	1660	1270	2070
Smith R bl Eagle Ck (2)	APR-JUL	85	80	137	106	64	33	106
	APR-SEP	98	84	161	124	72	35	116
Gibson Reservoir Inflow (2)	APR-JUL	460	116	540	495	425	380	395
	APR-SEP	505	115	595	540	470	415	440
Marias R nr Shelby (2)	APR-JUL	420	117	550	475	370	295	360
	APR-SEP	440	117	580	495	385	305	375

PRELIMINARY YELLOWSTONE RIVER BASIN FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
West Rosebud Ck nr Roscoe (2)	APR-JUL	66	112	74	69	63	58	59
	APR-SEP	85	115	96	89	81	74	74
Wind R ab Bull Lake Ck	APR-JUL	885	195	1030	940	830	745	455
	APR-SEP	970	198	1130	1030	905	815	490
Bull Lake Ck nr Lenore (2)	APR-JUL	250	180	285	265	235	215	139
	APR-SEP	300	178	340	315	285	260	169
Boysen Reservoir Inflow (2)	APR-JUL	1500	246	1860	1640	1360	1140	610
	APR-SEP	1650	248	2030	1800	1500	1270	665
Greybull R at Meeteetse	APR-JUL	215	164	275	240	189	152	131
	APR-SEP	295	167	370	325	270	225	177
Shell Ck nr Shell	APR-JUL	61	111	76	67	55	46	55
	APR-SEP	73	111	89	79	66	56	66
Bighorn R at Kane (2)	APR-JUL	1980	236	2510	2200	1760	1450	840
	APR-SEP	2200	243	2770	2430	1970	1630	905
NF Shoshone R at Wapiti	APR-JUL	750	163	835	785	715	665	460
	APR-SEP	830	161	930	870	790	730	515
SF Shoshone R nr Valley	APR-JUL	380	177	410	385	345	320	215
	APR-SEP	440	180	475	440	400	365	245
Buffalo Bill Reservoir Inflow	APR-JUL	1200	178	1360	1260	1140	1040	675
	APR-SEP	1320	177	1490	1390	1250	1150	745
Bighorn R nr St. Xavier (2)	APR-JUL	3060	222	3700	3320	2800	2420	1380
	APR-SEP	3370	231	4070	3650	3090	2670	1460

Little Bighorn R nr Hardin	APR-JUL	103	105	153	123	83	53	98
	APR-SEP	116	105	172	139	93	60	111
Tongue R nr Dayton (2)	APR-JUL	88	102	115	99	77	61	86
	APR-SEP	100	102	130	112	88	70	98
Tongue River Reservoir Inflow (2)	APR-JUL	215	111	315	255	175	115	193
	APR-SEP	235	109	340	280	192	129	215
NF Powder R nr Hazelton	APR-JUL	8.1	89	11.6	9.5	6.7	4.6	9.1
	APR-SEP	8.7	88	12.4	10.2	7.2	5.0	9.9
Powder R at Moorhead	APR-JUL	220	124	360	275	163	78	177
	APR-SEP	240	122	385	300	182	97	196
Powder R nr Locate	APR-JUL	245	123	400	310	182	90	199
	APR-SEP	270	123	430	335	205	107	220

PRELIMINARY RAPID VALLEY UNIT FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
Deerfield Reservoir Inflow (2)	APR-JUL	2.0	38	5.0	3.2	1.30	0.80	5.2
Pactola Reservoir Inflow (2)	APR-JUL	3.6	16	16.3	8.7	2.0	1.00	22

Max (10%), 30%, 50%, 70% and Min (90%) chance that actual volume will exceed forecast.
Averages are for the 1981-2010 period.
All volumes are in thousands of acre-feet.

footnotes:
1) Max and Min are 5% and 95% chance that actual volume will exceed forecast
2) streamflow is adjusted for upstream storage
3) median value used in place of average

Upper Missouri River Basin
May 2017 Calendar Year Runoff Forecast
May 2, 2017

U.S. Army Corps of Engineers, Northwestern Division
Missouri River Basin Water Management
Omaha, NE

Calendar Year Runoff Forecast

Explanation and Purpose of Forecast

The long-range runoff forecast is presented as the Calendar Year Runoff Forecast. The Calendar Year Runoff Forecast is available at http://www.nwd-mr.usace.army.mil/rcc/reports/runoff.pdf. This forecast is developed shortly after the beginning of each calendar year and is updated at the beginning of each month to show the actual runoff for historic months of that year and the updated forecast for the remaining months of the year. This forecast presents monthly inflows in million acre-feet (MAF) from five incremental drainage areas, as defined by the individual System projects, plus the incremental drainage area between Gavins Point Dam and Sioux City. Due to their close proximity, the Big Bend and Fort Randall drainage areas are combined. Summations are provided for the total Missouri River reach above Gavins Point Dam and for the total Missouri River Basin above Sioux City (upper Basin). The Calendar Year Runoff Forecast is used in the Monthly Study simulation model to plan future system regulation in order to meet the authorized project purposes throughout the calendar year.

Observed Runoff

April 2017 runoff was 93% of average for the upper Basin. April runoff was above average in the Fort Peck reach (114% of average) and the Garrison reach (101% of average). Runoff was below average in the Oahe reach (47% of average), the Fort Randall reach (96% of average), the Gavins Point reach (81% of average), and the Sioux City reach (96% of average).

2017 Calendar Year Forecast Synopsis

The May 1 forecast for the 2017 Missouri River runoff above Sioux City, IA is **29.7 MAF (117% of average)**. Runoff above Gavins Point Dam is forecast to be **26.9 MAF (117% of average)**. Due to the amount of variability in precipitation and other hydrologic factors that can occur over the next 8 months, the range of expected inflow is quite large and ranges from the 37.4 MAF upper basic forecast to the 23.1 MAF lower basic forecast. The upper and lower basic forecasts are used in long-term regulation planning models to "bracket" the range of expected runoff given much wetter or drier conditions, respectively. Given that 8 months are being forecasted for this May 1 forecast (4 months observed/8 months forecast), the range of wetter-than-normal (upper basic) and drier-than-normal (lower basic) is attributed to all 6 reaches for all

8 months. The result is a large range or "bracket" for each reach, and thus, for the total runoff forecast. As the year progresses, the range will lessen as the number of observed months increases and the number of forecast months decreases.

Current Conditions

Drought Analysis

The latest National Drought Mitigation Center's drought monitor for April 25, 2017 (**Figure 1**), is compared to the drought monitor for March 28, 2017 (**Figure 2**). The drought monitor is available at http://droughtmonitor.unl.edu/. The U.S. Drought Monitor indicates there is an area of Moderate Drought (D1) in northeastern Wyoming. Abnormally Dry (D0) conditions persist in areas surrounding the D1 Drought and in small areas of western and eastern Montana. Pockets of D1 conditions are also present in Colorado and southwestern Nebraska. The Seasonal Drought Outlook in **Figure 3** indicates all areas of drought in the Missouri River Basin may be removed by the end of July.

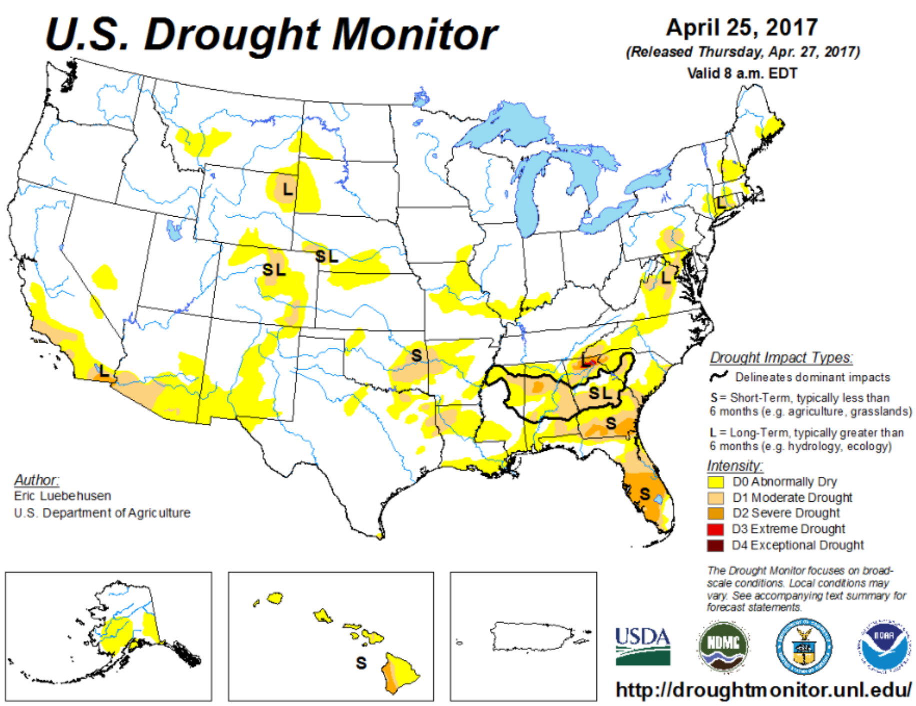


Figure 1. National Drought Mitigation Center U.S. Drought Monitor for April 25, 2017.

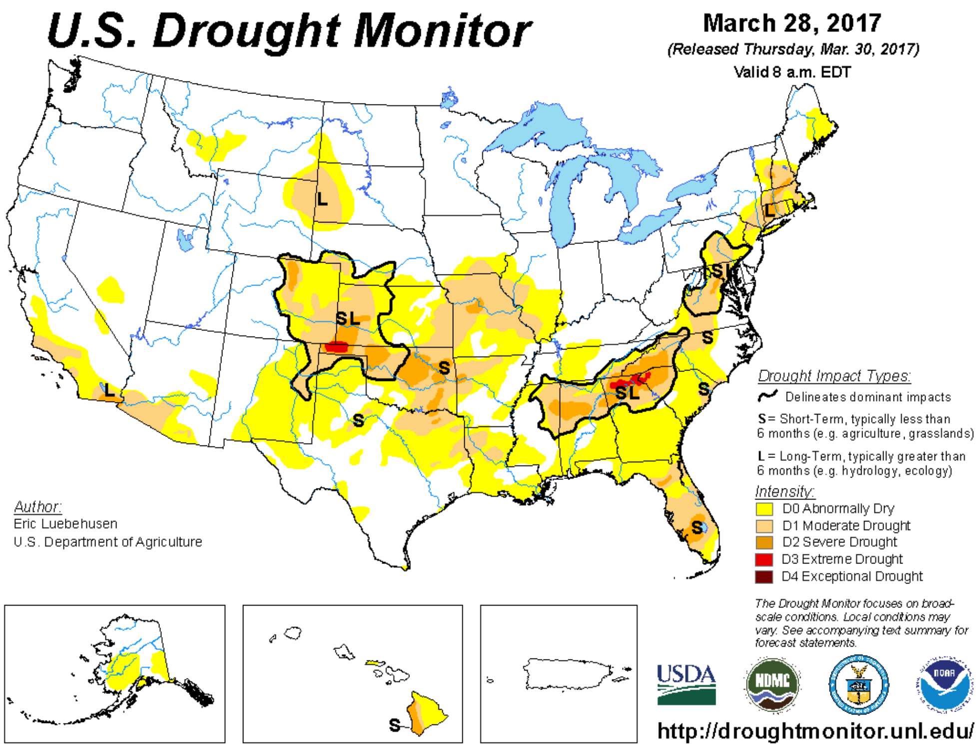


Figure 2. National Drought Mitigation Center U.S. Drought Monitor for March 28, 2017.

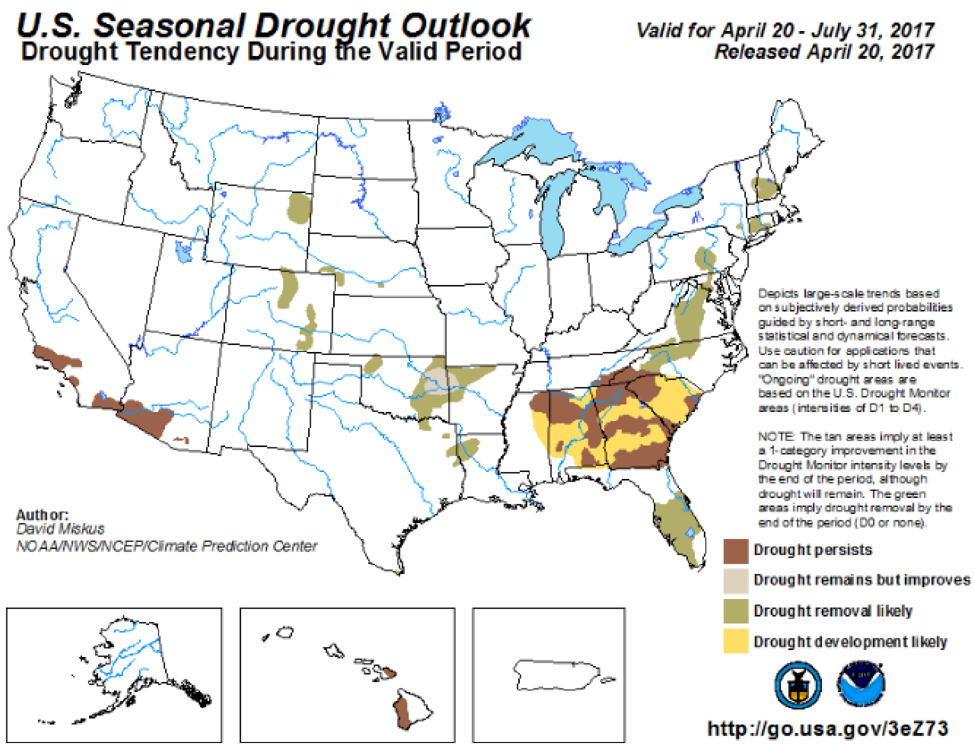


Figure 3. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

Monthly precipitation accumulations are shown using High Plains Regional Climate Center images available at http://www.hprcc.unl.edu/. The April precipitation accumulations are shown in **Figure 4** as inches of precipitation (left) and percent of normal precipitation (right). April precipitation was well-above average in southern Montana, Wyoming, Kansas, and Missouri. April precipitation was well-below average in northern Montana, the Dakotas and portions of Nebraska. February-March-April precipitation accumulations are shown in **Figure 5**. The three-month accumulations reflect the continuing wet pattern across western and southern Montana, Wyoming, western Nebraska, Kansas and Missouri.

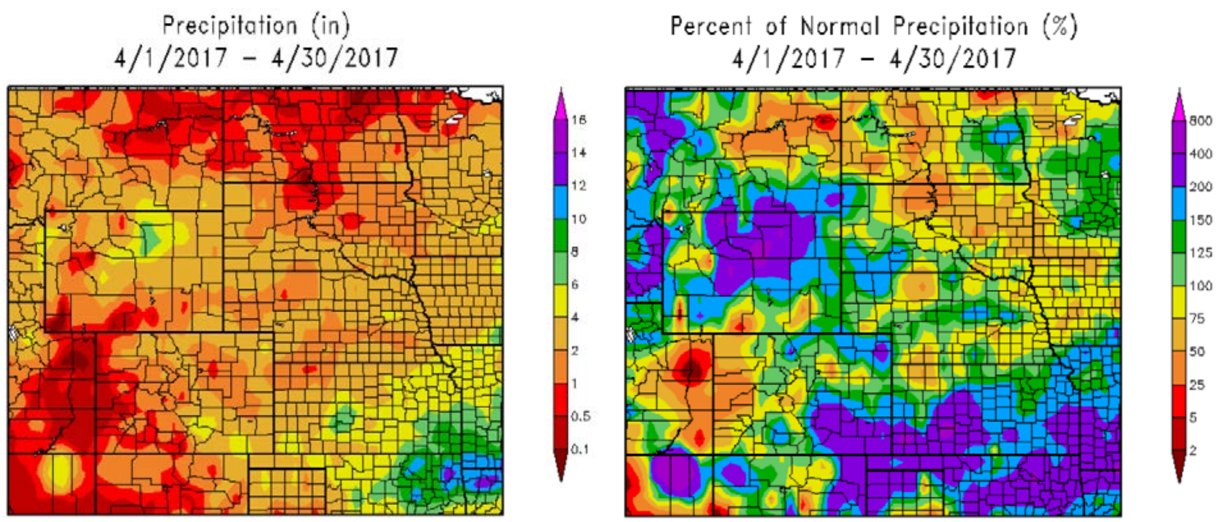


Figure 4. April 2017 Precipitation (inches) and Percent of Normal Precipitation.

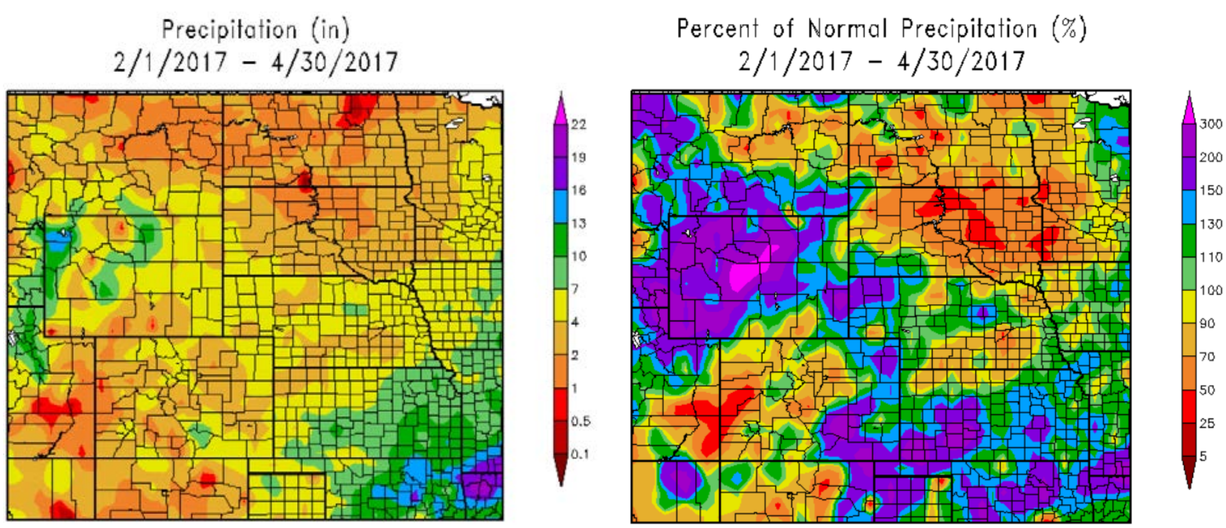


Figure 5. February-March-April 2017 Precipitation (inches) and Percent of Normal Precipitation.

Temperature

April temperature departures in degrees Fahrenheit (deg F) in the left image of **Figure 6** were predominantly normal, with slightly cooler temperatures in the upper Basin and slightly warmer temperatures in the lower Basin. Departures ranged from 2 deg F below normal in the upper Basin to 4 deg F above normal in the lower Basin. February-March-April temperatures, in the right image of **Figure 6**, were 0 to 2 deg F below normal over pockets of Montana and North Dakota. Temperatures have been 2 to 8 deg F above normal in Colorado, Wyoming, South Dakota, Nebraska, Iowa, Kansas, and Missouri.

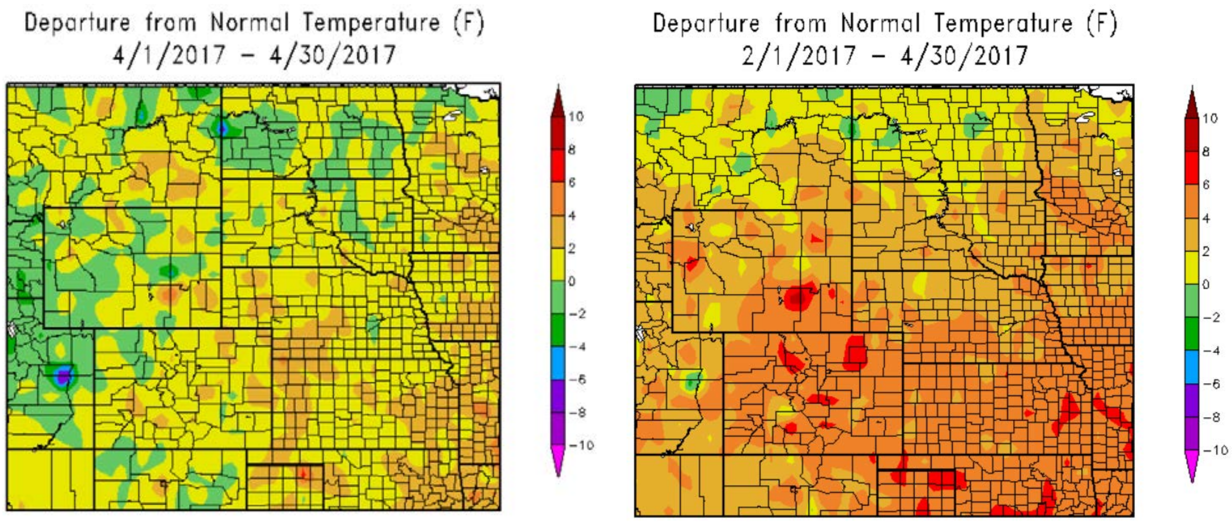
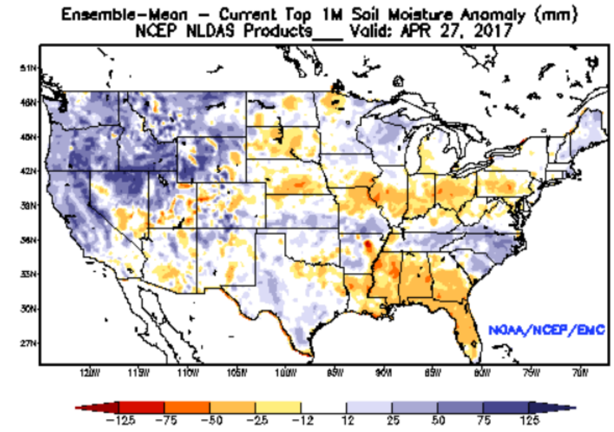


Figure 6. April 2017 and -February-March-April 2017 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

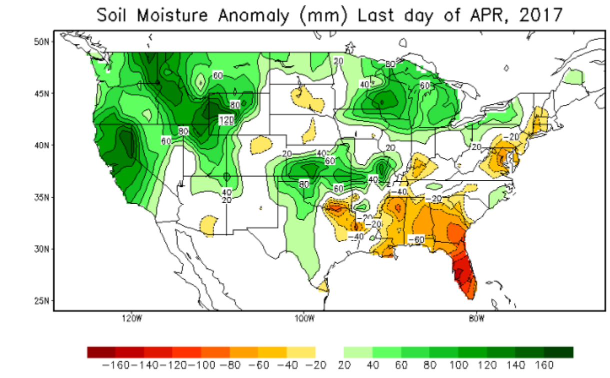
Soil Moisture

Soil moisture is factored into the forecast as an indicator of wet or dry hydrologic basin conditions. Typically when soil moisture conditions are wet or greater than normal, rainfall and snowmelt runoff is greater than when soil moisture is dry or less than normal. Not only is soil moisture a physical parameter that influences runoff, it can be used as an indicator of future runoff. As the calendar year approaches winter, the soil moisture conditions will provide some insight into late winter and early spring runoff potential.

The left image of **Figure 7** shows the NOAA NLDAS ensemble top one-meter soil moisture anomaly on April 27, 2017. The NLDAS image shows wetter-than-normal conditions across Montana, part of North Dakota, most of Wyoming, northern Iowa, southern Kansas, and southern Missouri. Drier-than-normal conditions are present in southeastern Wyoming, South Dakota, Nebraska and northern Missouri. Similarly, the CPC Soil Moisture Anomaly, in the right image of **Figure 7**, indicates wetter-than-normal soil moisture conditions in Montana, western Wyoming, North Dakota, Iowa, Missouri, and Kansas. The CPC anomaly indicates slightly drier-than-normal conditions in South Dakota, central Nebraska and Colorado. Soils have high positive anomalies in western Montana and western Wyoming.

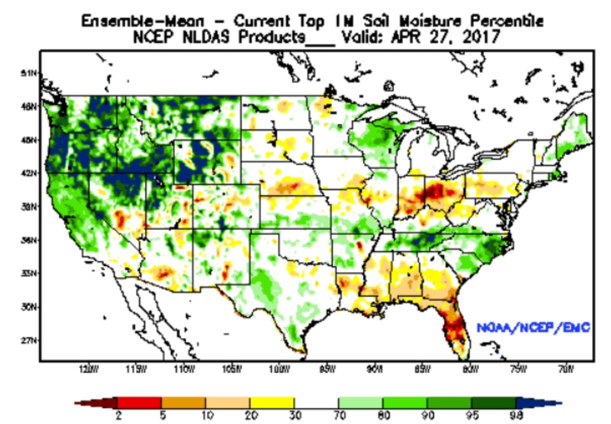


NOAA NLDAS Drought Monitor Soil Moisture.
http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

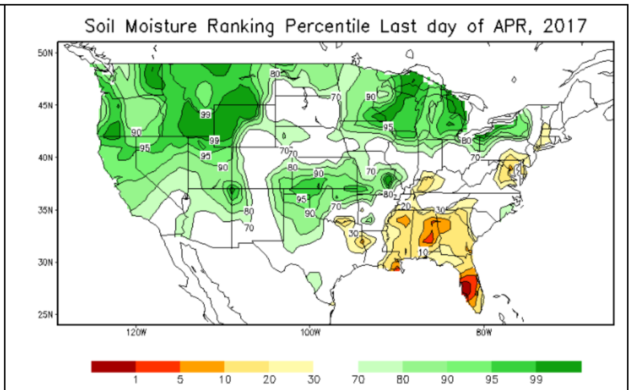


CPC Soil Moisture.
http://www.cpc.ncep.noaa.gov/products/Soilmst_Monitoring/US/Soilmst/Soilmst.shtml#

Figure 7. NOAA NLDAS and CPC Soil Moisture Anomalies (mm).



NOAA NLDAS Drought Monitor Soil Moisture.
http://www.emc.ncep.noaa.gov/mmb/nldas/drought/



CPC Soil Moisture.
http://www.cpc.ncep.noaa.gov/products/Soilmst_Monitoring/US/Soilmst/Soilmst.shtml#

Figure 8. NOAA NLDAS and CPC Soil Moisture Percentile Rankings.

Soil moisture conditions expressed as a percentile ranking can show the severity of the soil moisture conditions through the percentile ranking probability. Soil moisture percentile rankings from NOAA NLDAS and the CPC are shown in **Figure 8**. The NLDAS percentile ranking, in the left image of **Figure 8**, indicates very wet soil moisture conditions (greater than 98^{th} percentile rank) throughout many areas of Montana and Wyoming. A greater than 98^{th} percentile ranking soil moisture conditions indicates soil moisture is wetter than 98 out of 100 soil moisture samples or years for the indicated date. The CPC percentile ranking, in the right image of **Figure 8**, indicates very wet soil moisture conditions (greater than 99^{th} percentile ranking) in parts of Montana and Wyoming. The rest of the Basin has average (30^{th} to 70^{th} percentile ranking) to wet (70^{th} to 99^{th} percentile ranking) soil moisture conditions.

Plains Snowpack

Plains snowpack is an important parameter that influences the volume of runoff occurring in the basin during the months of March and April. A common misperception is that the March-April runoff is a result of plains snowmelt only. Historically, about 25% of annual runoff occurs in March and April, during the time when plains snow is melting, due to both melting snowpack and rainfall runoff. Runoff occurs in March and April whether or not there is any plains snow to melt. Determining exact rainfall amounts and locations are nearly impossible to predict more than a week in advance. Thus, the March-April runoff forecast can be formulated based on existing plains snowpack and existing basin conditions and hydrologic forecasts, which for this year primarily includes long-term precipitation outlooks.

The National Weather Service's National Operational Hydrologic Remote Sensing Center (NOHRSC), modeled snow assessment, shown in **Figure 9**, indicates all seasonal plains snow water equivalent (SWE) had melted in the upper Basin. As of May 2, 2017, only trace amounts of plains SWE remain in very small areas Wyoming and Montana. All other plains snow has melted.

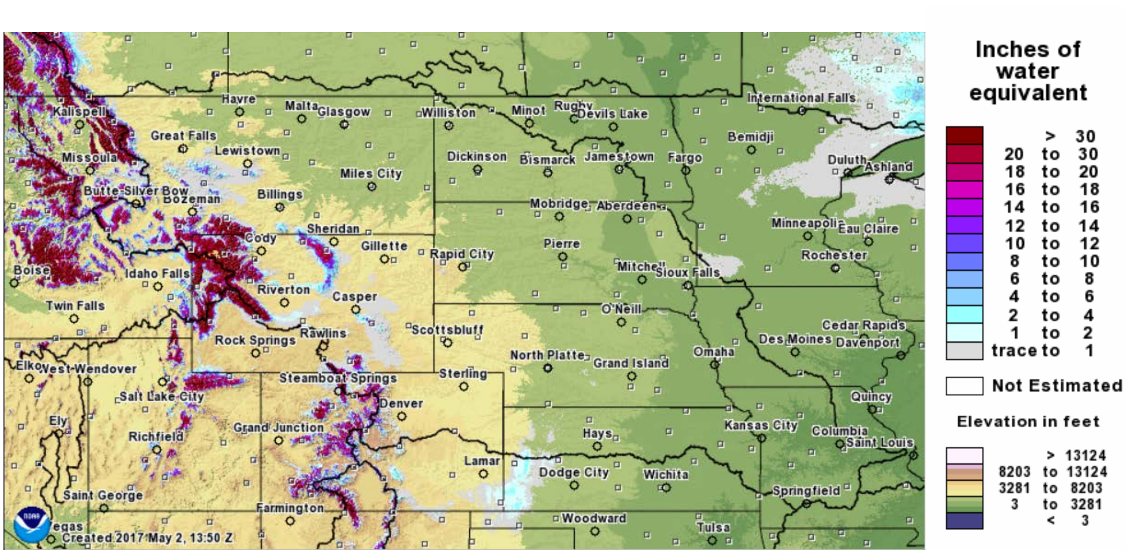
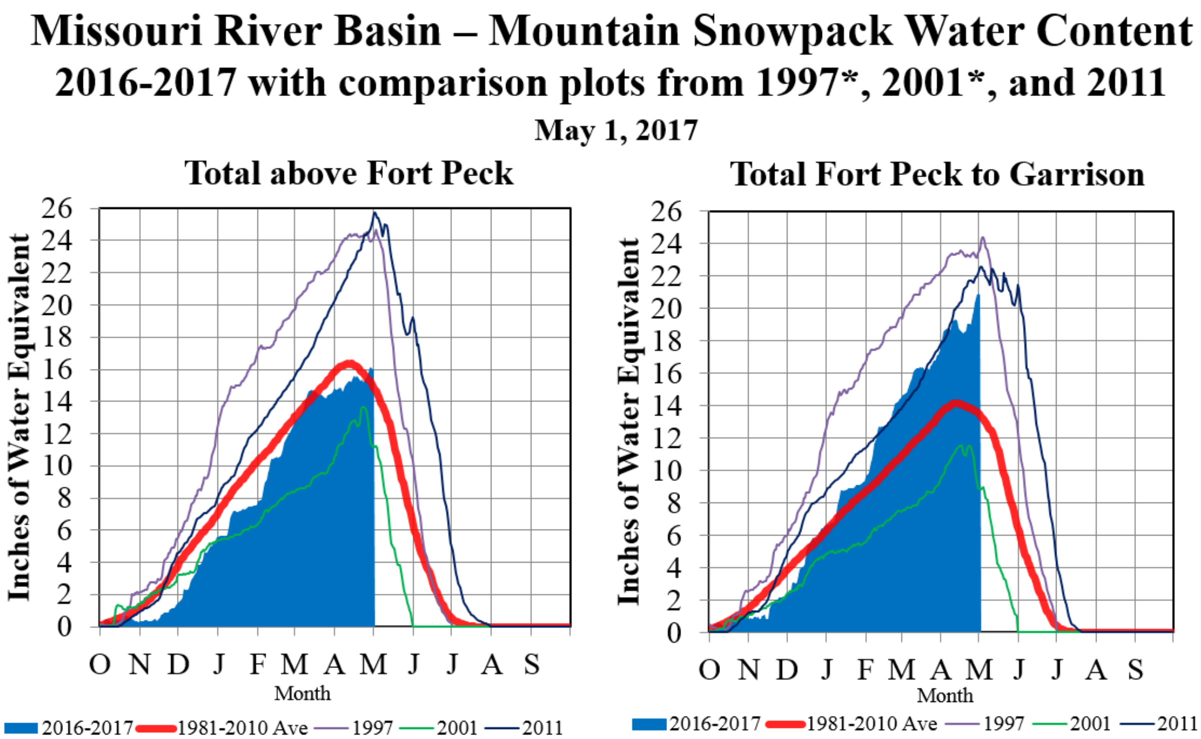


Figure 9. May 2, 2017 NOHRSC modeled plains snow water equivalent. Source: NOAA National Operational Hydrologic Remote Sensing Center. http://www.nohrsc.nws.gov/interactive/html/map.html

Mountain Snowpack

Mountain snowpack is the primary factor used to predict May-July runoff volumes in the Fort Peck and Fort Peck to Garrison reaches. During the 3-month May-July runoff period, about 50% of the annual runoff in the upper Basin enters the Mainstem System as a result of mountain snowmelt and rainfall runoff. Greater-than-average mountain snow accumulations are usually associated with greater-than-average May-July runoff volumes, especially when mountain soil moisture conditions have been wetter-than-normal. For example, we would expect to see greater-than-average runoff from an average mountain snowpack this year due to wetter-than-normal soil moisture conditions.

Figure 10 includes time series plots of the average mountain SWE beginning on October 1, 2016 based on the NRCS SNOTEL gages for the headwater basin above Fort Peck and the incremental basin from Fort Peck to Garrison. The current average SWE values (shaded blue area) are plotted against the 1981-2010 basin average SWE (bold red line), a recent low SWE year in 2001 (green line), and two historic high SWE years occurring in 1997 (purple) and 2011 (dark blue).



The Missouri River Basin mountain snowpack normally peaks near April 15. On May 1, 2017 the mountain Snow Water Equivalent (SWE) in the "Total above Fort Peck" reach was 16.0", 107% of the May 1 average and 98% of the normal peak SWE. The mountain SWE in the "Total Fort Peck to Garrison" reach was 20.8", 155% of the May 1 average and 147% of the normal peak SWE.

*Generally considered the high and low year of the last 20-year period, respectively. Provisional data. Subject to revision.

Figure 10. Mountain snowpack water content on May 1, 2017 compared to normal and historic conditions. Corps of Engineers - Missouri River Basin Water Management. Available at http://www.nwd-mr.usace.army.mil/rcc/reports/snow.pdf.

As of **May 1, 2017**, the Corps of Engineers computed an average mountain SWE in the reach above Fort Peck reservoir of 16.0 inches, which is 107% of average for May 1 based on the 1981-2010 average SWE for the Fort Peck reach. In the reservoir reach between Fort Peck Dam and Garrison Dam, the Corps computed an average mountain SWE of 20.8 inches, which is 155% of average for May 1 based on the 1981-2010 average SWE for the Garrison reach. The mountain snowpack normally peaks around April 15. The reach above Fort Peck appears to have peaked at 16.1" on April 29th. The reach between Fort Peck and Garrison appears to still be accumulating SWE, with 20.9" recorded on May 2nd.

In the **Additional Figures** section at the end of this document, basin maps of the mountain snowpack as a percent of median are provided for Montana, Wyoming and Colorado. These maps are a product of the USDA-NRCS National Water and Climate Center and are available at http://www.wcc.nrcs.usda.gov. These maps show that mountain snowpack is about median to slightly above median in Montana and Colorado, but well-above median in many Wyoming basins.

The USDA NRCS Water Supply Forecast is also included at the end of this document. Per the USDA, Snowpack conditions since April 1 have remained high in the Wind and Shoshone Basins and increased in the Bighorns, resulting in increased Powder and Tongue forecasts. **Figure 11** highlights Water Year Precipitation Records at sites throughout the above noted area. The period of record varies at each location, from approximately 20 years to 110 years. The majority of the sites in these basins are reporting either the highest or second highest precipitation on record.

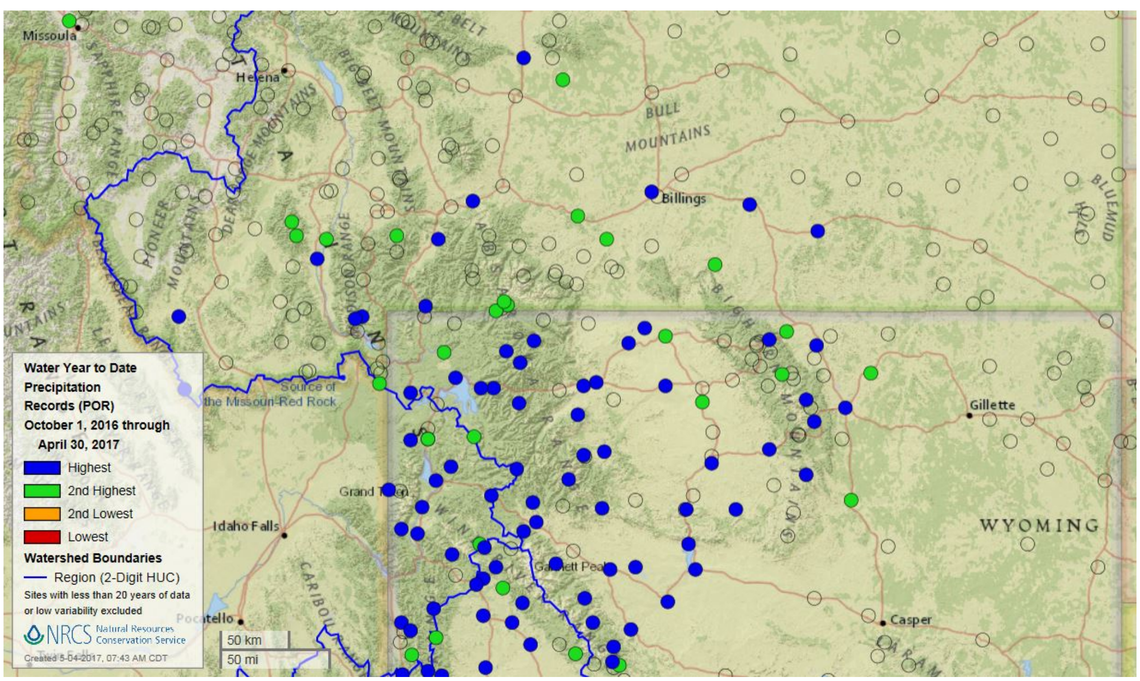


Figure 9. Water Year to Date Precipitation Records from October 1, 2016 through April 30, 2016 for Sites in Wyoming and Montana. Source: USDA NRCS. https://www.wcc.nrcs.usda.gov.

Climate Outlook

MRBWMD participates in the monthly North Central U.S. Climate/Drought Outlook Webinar coordinated through NOAA, the regional climate centers, and the American Association of State Climatologists (AASC). These webinars provide updates on near-term climate outlooks and impacts including the ENSO climate pattern and its implications on winter temperature and precipitation patterns in the Missouri River Basin.

ENSO (El Niño Southern Oscillation)

The latest ENSO update indicates that ENSO-neutral conditions are present, and expected to continue through spring and early summer 2017. ENSO-neutral conditions typically do not influence the chances for precipitation and temperatures in the upper Basin.

Temperature and Precipitation Outlooks

The NOAA Climate Prediction Center (CPC) outlooks provide the forecasted probability (or chance) of occurrence of future weather conditions during periods ranging from one to 12 months into the future. The CPC outlooks are available at http://www.cpc.ncep.noaa.gov/.

The CPC outlooks through mid-May indicate increased chances for warmer temperatures throughout the Basin, wetter conditions west of the Missouri River, and drier conditions east of the Missouri River. During the second half of May, the CPC indicates increased chances for below normal temperatures in Montana, Wyoming, the western Dakotas, western Nebraska and western Kansas; and, increased chances for above normal temperatures in the eastern Dakotas, eastern Nebraska, eastern Kansas, Iowa and Missouri. The warmer temperatures at the beginning of May could lead to increased runoff due to increased mountain snowmelt. The outlook for May 2017 (**Figure 12**) indicates there are equal chances for above-normal, normal and below-normal temperatures in the upper Basin, and there are increased chances for below-normal temperatures in the lower Basin. With regard to precipitation, CPC indicates there are increased chances for above-normal precipitation in Montana, Wyoming, western North Dakota, and Colorado. CPC indicates there are increased chances for below-normal precipitation in the lower Basin.

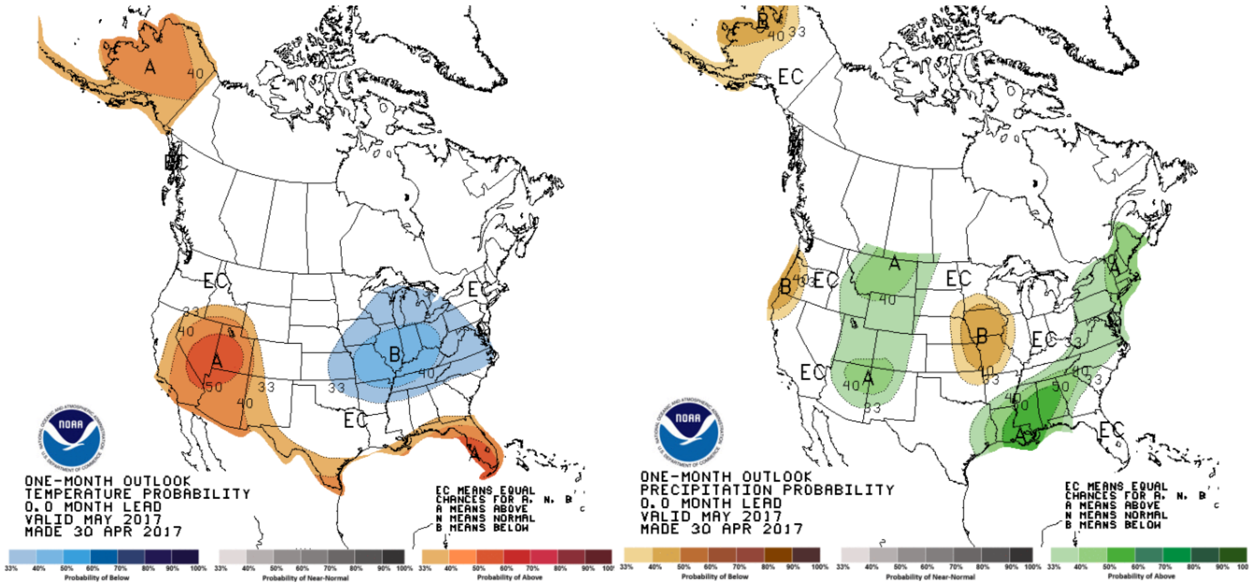


Figure 10. CPC May 2017 temperature and precipitation outlooks.

The May-June-July temperature outlook (**Figure 13**) indicates equal chances for temperatures in Montana and North Dakota, and increased chances for above-normal temperatures elsewhere in the Basin. The May-June-July precipitation outlook indicates increased chances for above-normal precipitation over Montana, Wyoming, and Colorado, and equal chances for the remainder of the Basin.

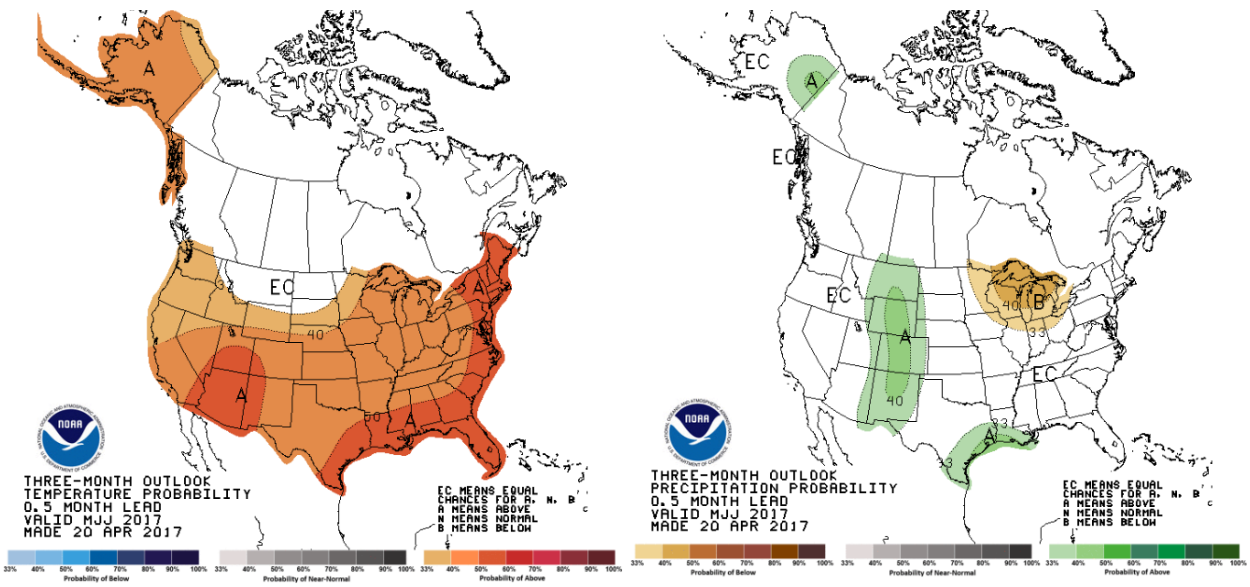


Figure 11. CPC May-June-July 2017 temperature and precipitation outlooks.

The August-September-October CPC temperature outlook (**Figure 14**) indicates there could be increased chances for above-normal temperatures over the Basin. With regard to precipitation, there could be increased chances for above-normal precipitation in Wyoming and Colorado. During the November-December-January period (**Figure 15**), the temperature outlook indicates increased chances for above-normal temperatures over the entire Basin. With regard to the precipitation outlooks, CPC indicates equal chances for precipitation. Based on these outlooks, the runoff for the August-December period is forecasted to be about average for most reaches.

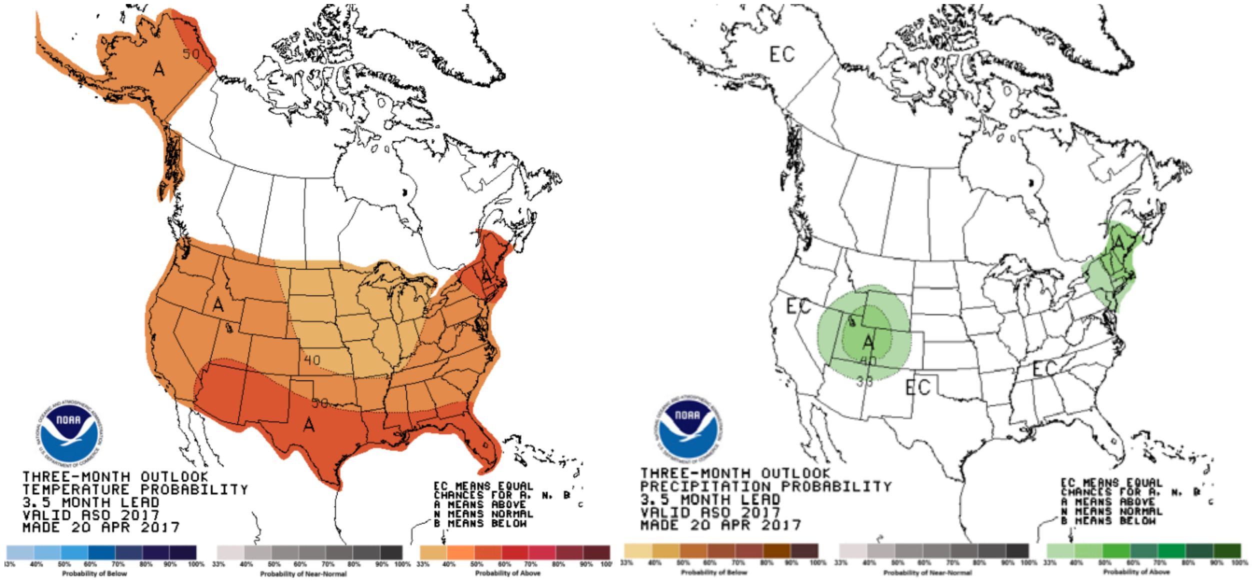


Figure 12. CPC August-September-October 2017 temperature and precipitation outlooks.

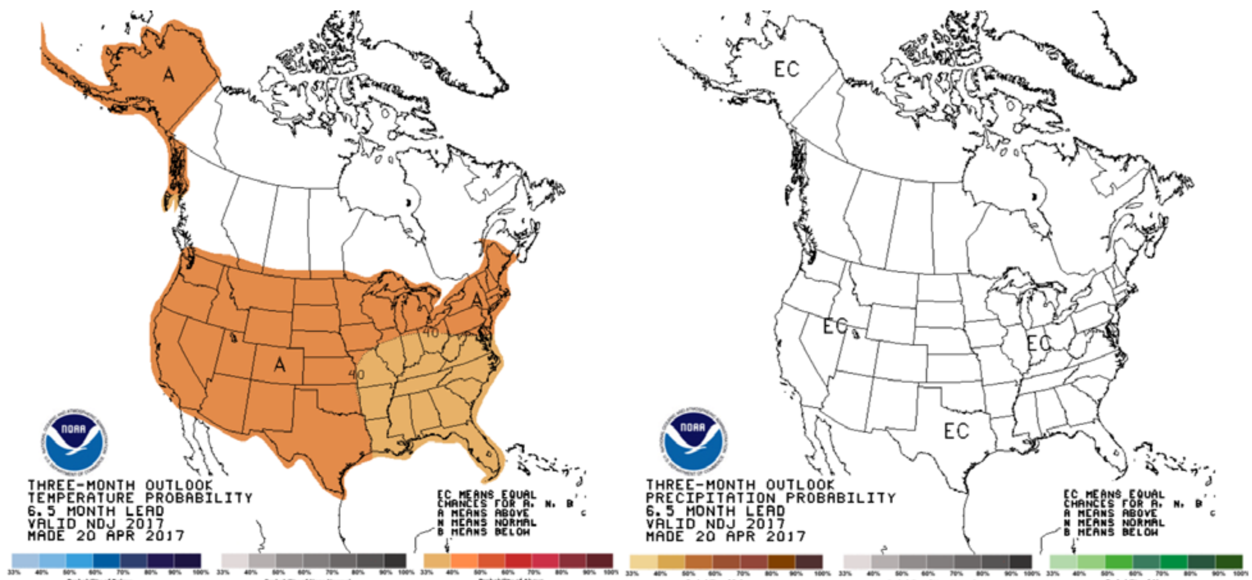
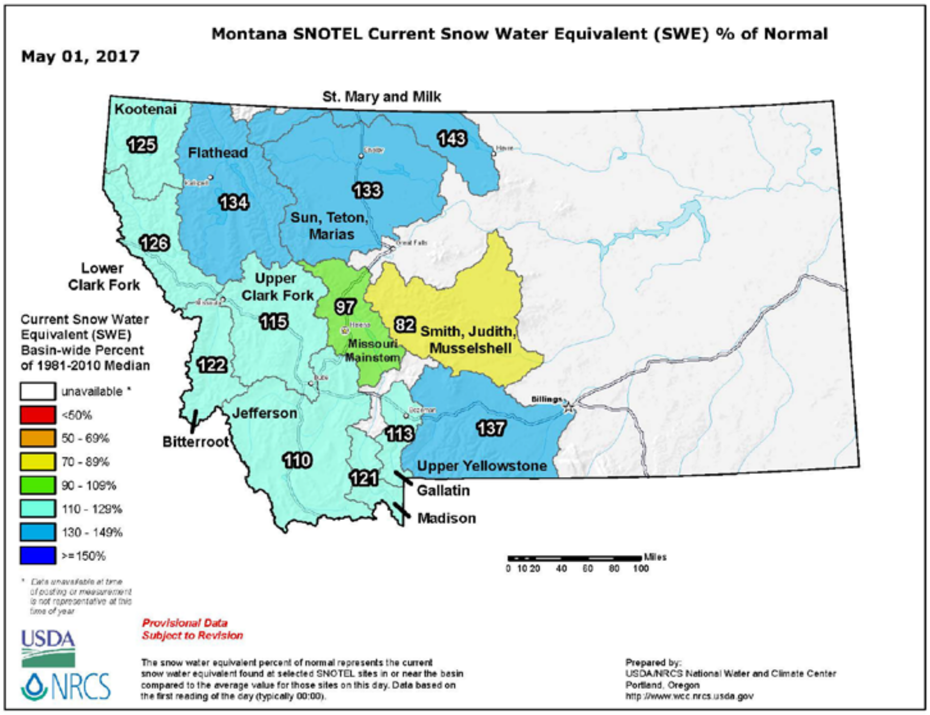


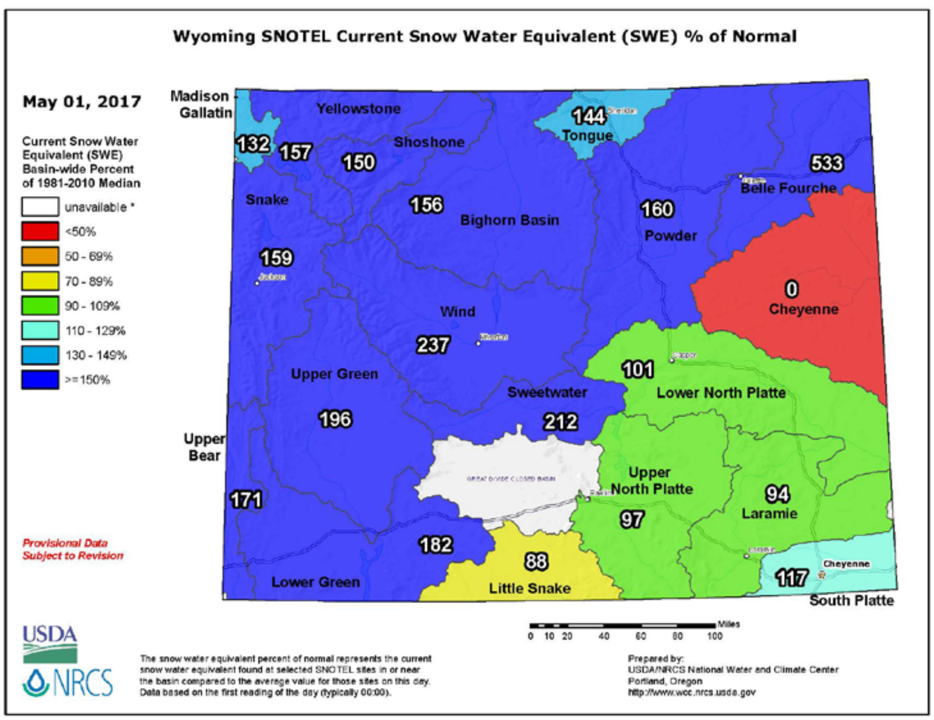
Figure 13. CPC November-December-January 2017 temperature and precipitation outlooks.

May 2017 Calendar Year Runoff Forecast

In summary, the 2017 calendar year runoff forecast is **29.7 MAF**, **117% of average**. Wet soil moisture conditions in Montana and Wyoming are factored into the above-average runoff forecast in the Fort Peck and Garrison reaches in May. In contrast, dry soil moisture conditions are present in eastern Wyoming, central North Dakota, and South Dakota. Following below-average runoff in April, May runoff is forecast to be below average from Oahe to Gavins Point and could continue through late-spring (June). Mountain snowpack was 107% of average in the Fort Peck reach and 155% of average in the Garrison reach as of May 1. Considering both the mountain snowpack and wet soil moisture conditions, May-June-July runoff is forecast to be 100% of average in the Fort Peck reach and 147% of average in the Garrison reach. The CPC outlooks through mid-May indicate increased chances for warmer temperatures throughout the Basin, wetter conditions west of the Missouri River, and drier conditions east of the Missouri River. During the second half of May, the CPC shows below normal temperatures in the mountains, with normal temperatures in the lower Basin. The warmer temperatures at the beginning of May could lead to increased runoff due to increased mountain snowmelt.

Additional Figures





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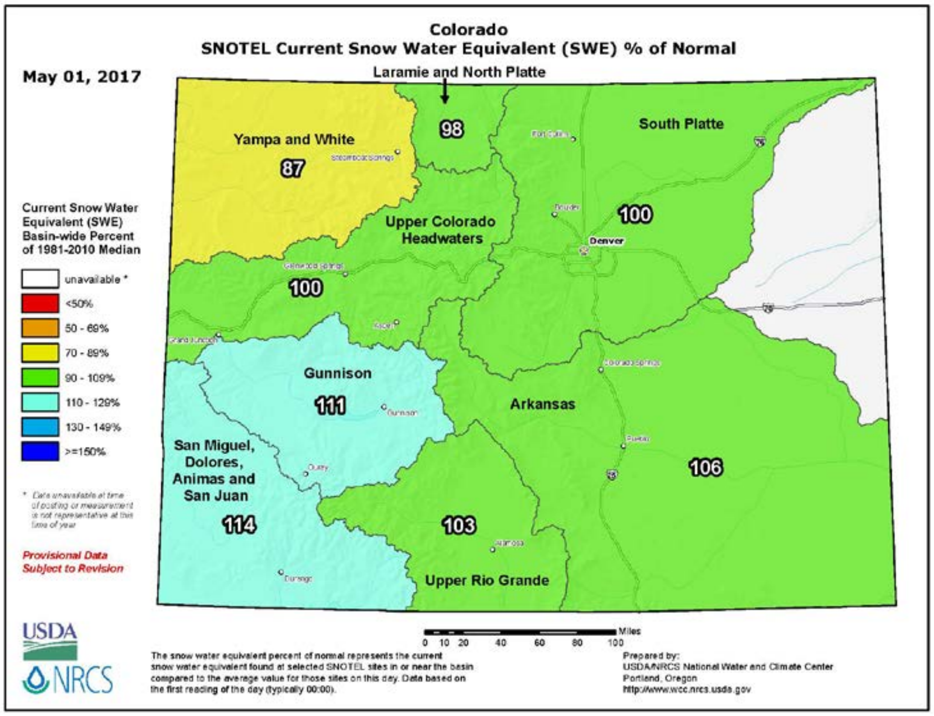

Colorado
SNOTEL Current Snow Water Equivalent (SWE) % of Normal
May 01, 2017
Laramie and North Platte
98
Yampa and White
87
South Platte
100
Upper Colorado Headwaters
Denver
100
Gunnison
111
Arkansas
106
San Miguel, Dolores, Animas and San Juan
114
103
Upper Rio Grande
Current Snow Water Equivalent (SWE) Basin-wide Percent of 1981-2010 Median
unavailable *
<50%
50 - 69%
70 - 89%
90 - 109%
110 - 129%
130 - 149%
>=150%
Provisional Data Subject to Revision
Miles
0 10 20 40 60 80 100
The snow water equivalent percent of normal represents the current snow water equivalent found at selected SNOTEL sites in or near the basin compared to the average value for those sites on this day. Data based on the first reading of the day (typically 00:00).
Prepared by:
USDA/NRCS National Water and Climate Center
Portland, Oregon
http://www.wcc.nrcs.usda.gov

USDA NRCS Water Supply Forecasts

USDA NRCS National Water & Climate Center
*** - DATA CURRENT AS OF: May 03, 2017 12:39:54 PM**
- Based on May 01, 2017 forecast values

PRELIMINARY MISSOURI RIVER BASIN FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
Lake Sherburne Inflow (2)	MAY-JUL	107	124	124	114	100	90	86
	MAY-SEP	123	122	142	131	115	104	101
St. Mary R at Intl Boundary (2)	MAY-JUL	495	124	590	535	455	400	400
	MAY-SEP	565	120	670	610	525	460	470
Lima Reservoir Inflow (2)	MAY-JUL	48	96	71	57	39	25	50
	MAY-SEP	54	96	80	64	44	28	56
Clark Canyon Reservoir Inflow (2)	MAY-JUL	76	119	121	94	58	31	64
	MAY-SEP	100	120	155	122	78	45	83
Jefferson R nr Three Forks (2)	MAY-JUL	620	108	890	730	510	350	575
	MAY-SEP	680	107	995	810	550	365	635
Hebgen Lake Inflow (2)	MAY-JUL	355	116	420	380	330	290	305
	MAY-SEP	465	115	550	500	430	380	405
Ennis Lake Inflow (2)	MAY-JUL	590	111	700	635	545	480	530
	MAY-SEP	750	110	890	805	695	610	680
Missouri R at Toston (2)	MAY-JUL	1600	108	2040	1780	1420	1160	1480
	MAY-SEP	1890	107	2450	2110	1660	1330	1760
Smith R bl Eagle Ck (2)	MAY-JUL	84	94	130	103	65	38	89
	MAY-SEP	94	95	150	116	71	38	99
Gibson Reservoir Inflow (2)	MAY-JUL	415	117	480	440	390	350	355
	MAY-SEP	460	116	530	490	430	385	395
Marias R nr Shelby (2)	MAY-JUL	345	115	460	390	300	230	300
	MAY-SEP	365	116	490	415	315	240	315

PRELIMINARY YELLOWSTONE RIVER BASIN FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
West Rosebud Ck nr Roscoe (2)	MAY-JUL	67	118	74	70	64	60	57
	MAY-SEP	87	121	96	91	83	78	72
Wind R ab Bull Lake Ck	MAY-JUL	845	197	950	890	805	740	430
	MAY-SEP	935	201	1050	980	890	820	465
Bull Lake Ck nr Lenore (2)	MAY-JUL	240	178	265	250	230	220	135
	MAY-SEP	295	178	320	305	285	270	166
Boysen Reservoir Inflow (2)	MAY-JUL	1470	263	1690	1560	1380	1250	560
	MAY-SEP	1620	263	1850	1710	1520	1380	615
Greybull R at Meeteetse	MAY-JUL	245	198	290	260	225	196	124
	MAY-SEP	325	191	380	350	305	270	170
Shell Ck nr Shell	MAY-JUL	63	121	77	69	57	49	52
	MAY-SEP	75	119	91	81	69	59	63
Bighorn R at Kane (2)	MAY-JUL	2010	261	2380	2160	1870	1650	770
	MAY-SEP	2220	267	2600	2370	2070	1840	830
NF Shoshone R at Wapiti	MAY-JUL	735	171	820	770	705	655	430
	MAY-SEP	820	169	915	860	785	725	485
SF Shoshone R nr Valley	MAY-JUL	385	193	425	400	370	345	200
	MAY-SEP	450	191	495	470	430	405	235
Buffalo Bill Reservoir Inflow	MAY-JUL	1190	189	1320	1240	1140	1060	630
	MAY-SEP	1310	187	1460	1370	1250	1160	700
Bighorn R nr St. Xavier (2)	MAY-JUL	3080	244	3540	3270	2890	2620	1260

	MAY-SEP	3390	253	3880	3590	3190	2900	1340
Little Bighorn R nr Hardin	MAY-JUL	112	132	155	129	94	69	85
	MAY-SEP	126	130	175	146	107	78	97
Tongue R nr Dayton (2)	MAY-JUL	100	125	124	110	90	75	80
	MAY-SEP	114	124	141	125	103	86	92
Tongue River Reservoir Inflow (2)	MAY-JUL	250	143	340	290	215	164	175
	MAY-SEP	280	141	375	315	240	185	198
NF Powder R nr Hazelton	MAY-JUL	12.6	152	15.7	13.9	11.3	9.5	8.3
	MAY-SEP	13.4	149	16.7	14.7	12.1	10.1	9.0
Powder R at Moorhead	MAY-JUL	335	222	460	385	285	215	151
	MAY-SEP	370	218	495	420	320	245	170
Powder R nr Locate	MAY-JUL	365	223	505	420	310	225	164
	MAY-SEP	410	222	555	465	350	260	185

PRELIMINARY RAPID VALLEY UNIT FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
Deerfield Reservoir Inflow (2)	MAY-JUL	2.6	67	5.0	3.6	1.56	0.100	3.9
Pactola Reservoir Inflow (2)	MAY-JUL	9.1	52	20	13.7	4.5	1.00	17.5

PRELIMINARY PLATTE RIVER BASIN FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
North Platte R nr Northgate (2)	MAY-JUL	210	112	305	250	172	117	187
	MAY-SEP	235	112	340	280	194	132	210
Encampment R nr Encampment (2)	MAY-JUL	138	117	179	155	121	97	118
	MAY-SEP	148	117	191	165	131	105	127
Rock Ck ab King Canyon Cnl nr Arlington	MAY-JUL	48	100	60	53	44	37	48
	MAY-SEP	51	102	63	56	46	39	50
Seminoe Reservoir Inflow (2)	MAY-JUL	675	110	915	770	580	435	615
	MAY-SEP	735	110	985	835	635	485	670
Sweetwater R nr Alcova	MAY-JUL	122	265	145	131	113	99	46
	MAY-SEP	131	262	156	141	121	106	50
La Prele Ck nr Douglas	MAY-JUL	13.6	91	21	16.8	10.4	5.7	14.9
	MAY-SEP	14.0	95	22	17.2	10.8	6.1	14.8
North Platte R bl Glendo Reservoir (2)	MAY-JUL	805	120	1140	940	675	480	670
	MAY-SEP	840	120	1180	975	705	500	700
North Platte R bl Guernsey Reservoir (2)	MAY-JUL	810	121	1150	950	670	470	670
	MAY-SEP	845	121	1200	985	705	495	700
Laramie R and Pioneer Cnl nr Woods Lg (2)	MAY-JUL	119	110	157	135	103	81	108
	MAY-SEP	130	109	172	147	113	88	119
Little Laramie R nr Filmore	MAY-JUL	46	96	61	52	40	31	48
	MAY-SEP	50	96	67	57	43	33	52

Max (10%), 30%, 50%, 70% and Min (90%) chance that actual volume will exceed forecast.
Averages are for the 1981-2010 period.
All volumes are in thousands of acre-feet.

footnotes:
1) Max and Min are 5% and 95% chance that actual volume will exceed forecast
2) streamflow is adjusted for upstream storage
3) median value used in place of average

Upper Missouri River Basin
June 2017 Calendar Year Runoff Forecast
June 7, 2017

U.S. Army Corps of Engineers, Northwestern Division
Missouri River Basin Water Management
Omaha, NE

Calendar Year Runoff Forecast

Explanation and Purpose of Forecast

The long-range runoff forecast is presented as the Calendar Year Runoff Forecast. The Calendar Year Runoff Forecast is available at http://www.nwd-mr.usace.army.mil/rcc/reports/runoff.pdf. This forecast is developed shortly after the beginning of each calendar year and is updated at the beginning of each month to show the actual runoff for historic months of that year and the updated forecast for the remaining months of the year. This forecast presents monthly inflows in million acre-feet (MAF) from five incremental drainage areas, as defined by the individual System projects, plus the incremental drainage area between Gavins Point Dam and Sioux City. Due to their close proximity, the Big Bend and Fort Randall drainage areas are combined. Summations are provided for the total Missouri River reach above Gavins Point Dam and for the total Missouri Basin above Sioux City (upper Basin). The Calendar Year Runoff Forecast is used in the Monthly Study simulation model to plan future system regulation in order to meet the authorized project purposes throughout the calendar year.

Observed Runoff

May runoff in the upper Basin was 129% of average. Runoff was 112% of average in the Fort Peck reach and 160% of average in the Garrison due to some early, rapid mountain snowmelt. Precipitation in much of the upper Basin was less than 50% of average resulting in well-below average runoff in the Oahe and Fort Randall reaches. In contrast, precipitation was above average in the Sioux City reach and in many areas of the lower Basin. As a result, the Sioux City reach runoff was more than 200% of average.

2017 Calendar Year Forecast Synopsis

The 2017 calendar year runoff forecast for the upper Missouri Basin above Sioux City, IA, updated on June 1, is **29.9 MAF (118% of average).** The 2017 calendar year runoff forecast above Gavins Point Dam is **26.5 MAF (115% of average)**.

Due to the amount of variability in precipitation and other hydrologic factors that can occur over the next 7 months, the range of expected inflow is quite large and ranges from the 35.9 MAF upper basic forecast to the 24.6 MAF lower basic forecast. The upper and lower basic forecasts are used in long-term regulation planning models to “bracket” the range of expected runoff given much wetter or drier conditions, respectively. Given that 7 months are being forecasted for this June 1 forecast (5 months observed/7 months forecast), the range of wetter-than-expected (upper basic) and drier-than-expected (lower basic) conditions is attributed to all 6 reaches for all 7 months. The result is a large range or "bracket" for each reach, and thus, for the total runoff forecast. As the year progresses, the range will lessen as the number of observed months increases and the number of forecast months decreases.

Current Conditions

Drought Analysis

The latest National Drought Mitigation Center's drought monitor for May 30, 2017 (**Figure 1**), is compared to the drought monitor for April 25, 2017 (**Figure 2**). The drought monitor is available at http://droughtmonitor.unl.edu/. The U.S. Drought Monitor indicates there is a large area of Abnormally Dry (D0) conditions in eastern Montana, North Dakota, northeastern Wyoming, and much of South Dakota. Furthermore an area of Moderate Drought (D1) developed since April 25 in central and southern North Dakota, and northern South Dakota. The Seasonal Drought Outlook in **Figure 3** indicates there will likely be no changes to drought conditions in the Missouri Basin through August 31, 2017.

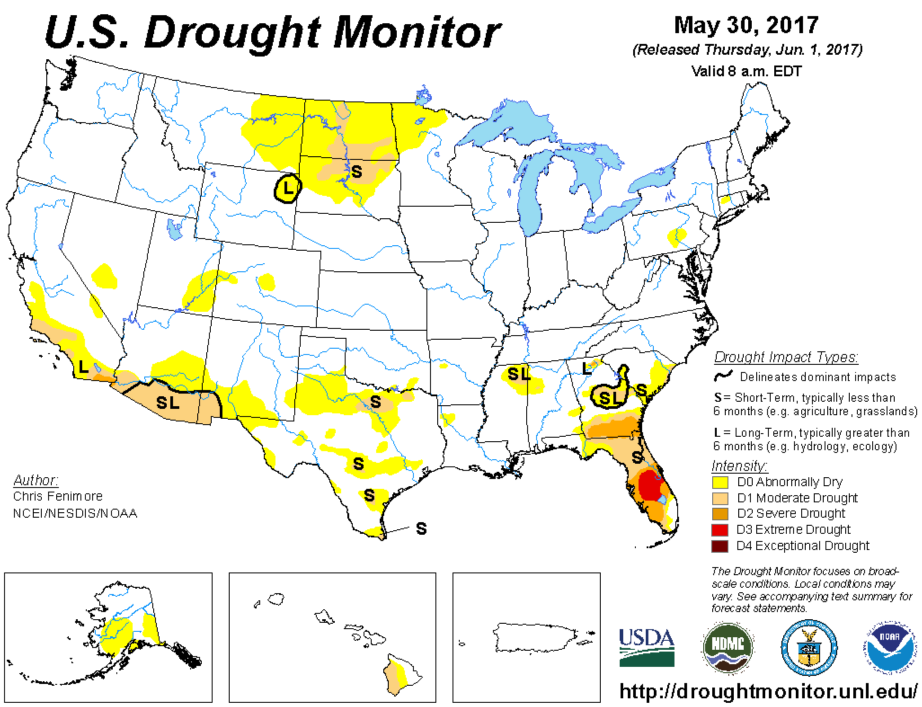


Figure 1. National Drought Mitigation Center U.S. Drought Monitor for May 30, 2017.

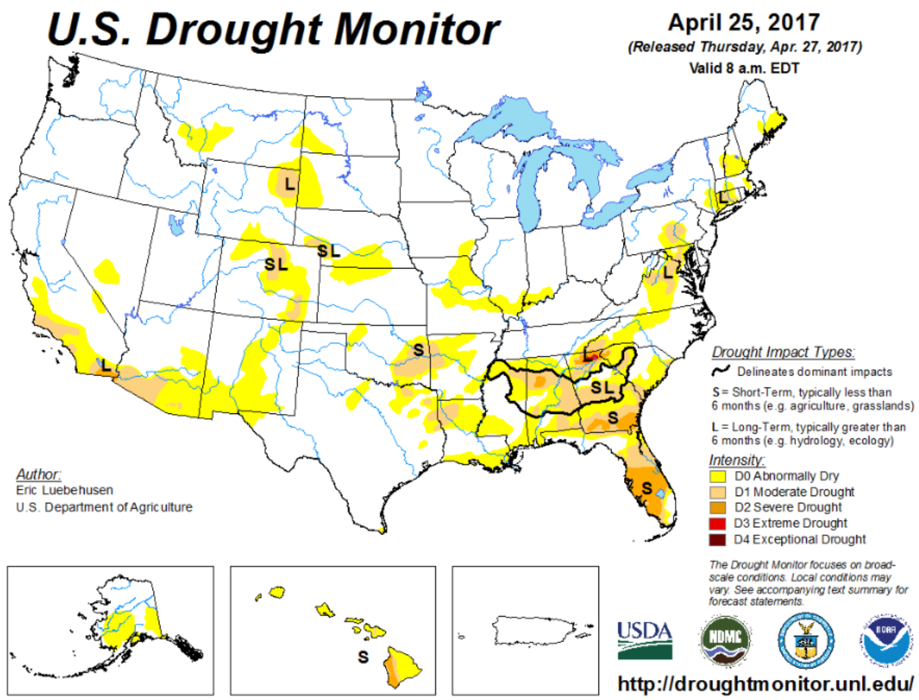


Figure 2. National Drought Mitigation Center U.S. Drought Monitor for April 25, 2017.

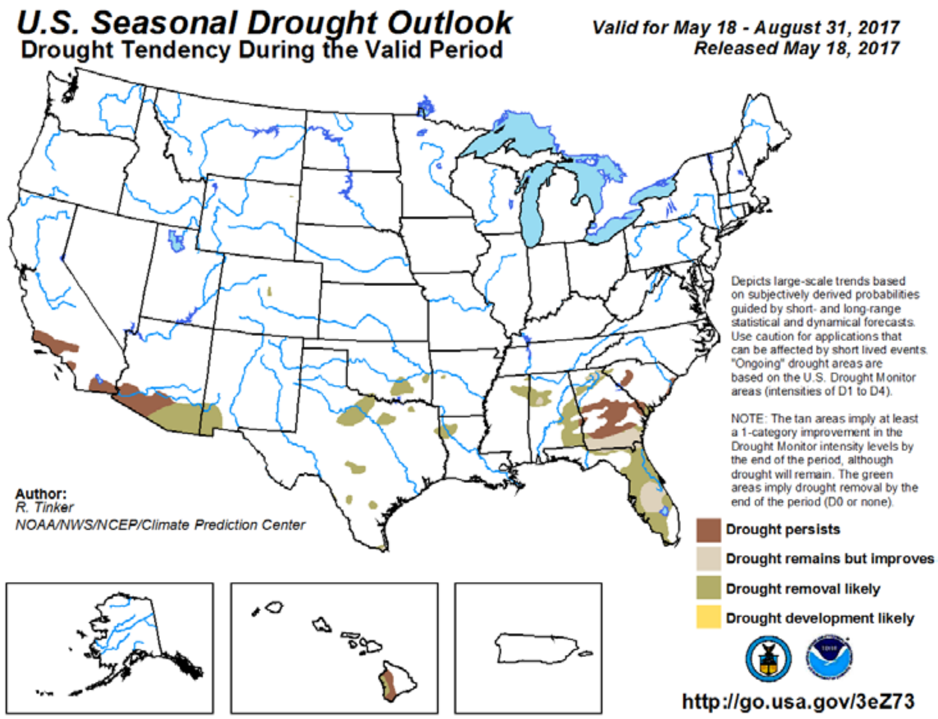


Figure 3. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

Monthly precipitation accumulations are shown using High Plains Regional Climate Center images available at http://www.hprcc.unl.edu/. The May precipitation accumulations are shown in **Figure 4** as inches of precipitation (left) and percent of normal precipitation (right). May precipitation was well-below average (less than 50% of average) in much of Montana, western Wyoming and the Dakotas. Below average precipitation in the Dakotas resulted in below-average May runoff in the Oahe and Fort Randall reaches. May precipitation was above average in southeastern Wyoming, western, southern and eastern Nebraska, eastern Colorado, central and western Kansas, far eastern South Dakota, and western Iowa. This resulted in above-average streamflow in the Nebraska, Kansas and Iowa tributaries to the Missouri River. March-April-May precipitation accumulations are shown in **Figure 5**. The three-month accumulations reflect a seasonally wet precipitation pattern across western and southern Montana, Wyoming, eastern Colorado, Nebraska, Kansas and Missouri.

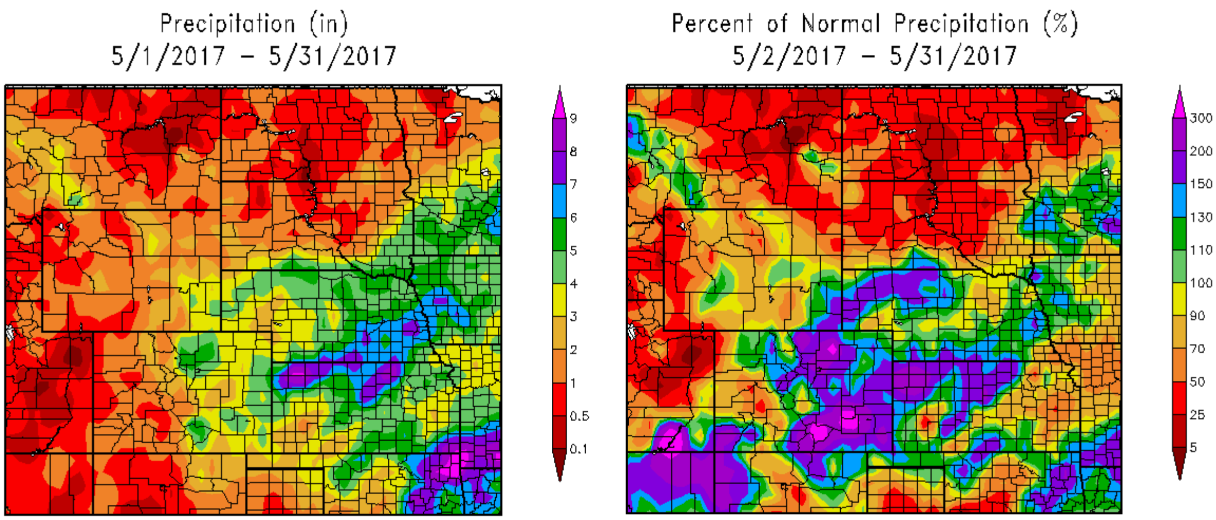


Figure 4. May 2017 Precipitation (inches) and Percent of Normal Precipitation.

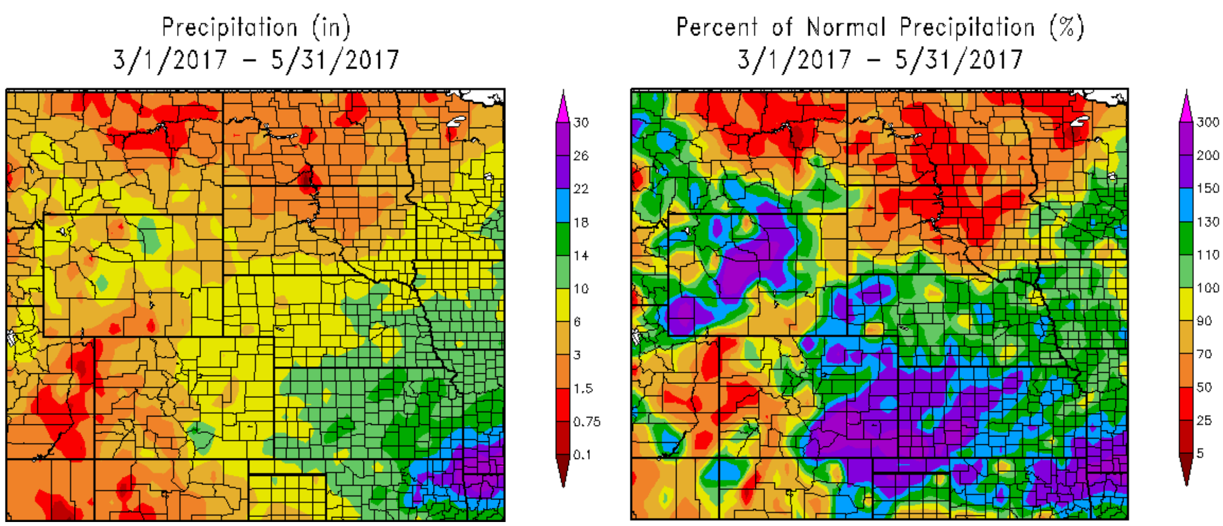


Figure 5. March-April-May 2017 Precipitation (inches) and Percent of Normal Precipitation.

Temperature

May temperature departures in degrees Fahrenheit (deg F) in the left image of **Figure 6** were mostly 0 to 2 deg F in Montana, North Dakota, northwestern South Dakota, western Wyoming. Temperature departures were 0 to -2 deg F in many other areas of the Missouri Basin, with some areas in western Nebraska, southeastern South Dakota and western Iowa experiencing -2 to -4 deg F temperature departures. March-April-May temperature departures, in the right image of **Figure 6**, were 0 to 4 deg F over Montana, Wyoming, eastern Kansas and Missouri. Temperature departures in western South Dakota, Nebraska and central Kansas were generally 0 to 2 deg F.

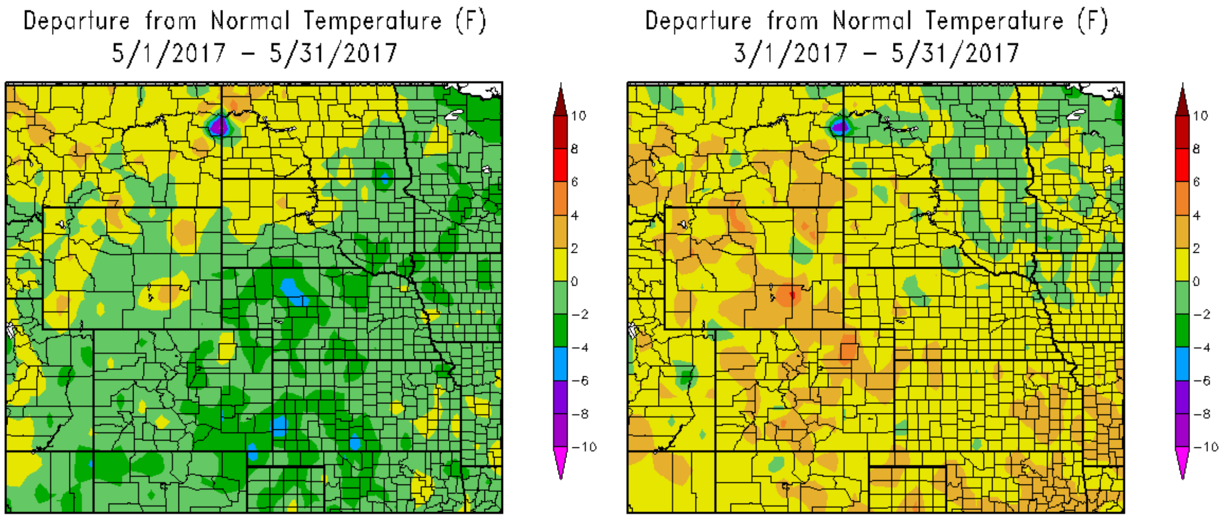
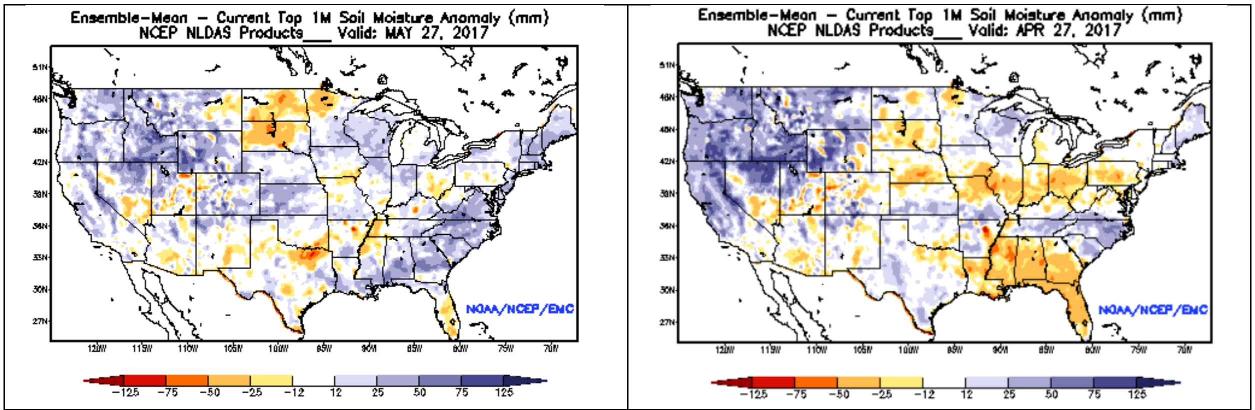


Figure 6. May 2017 and March-April-May 2017 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Soil Moisture

Soil moisture is factored into the forecast as an indicator of wet or dry hydrologic basin conditions. Typically when soil moisture conditions are wet or greater than normal, rainfall and snowmelt runoff is greater than when soil moisture is dry or less than normal. Not only is soil moisture a physical parameter that influences runoff, it can be used as an indicator of future runoff. As the calendar year approaches winter, the soil moisture conditions will provide some insight into late winter and early spring runoff potential.

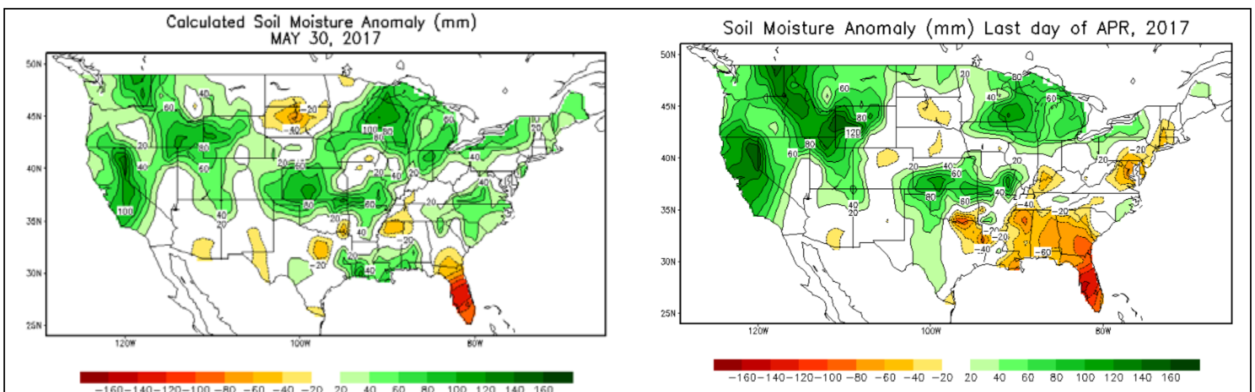
The left image of **Figure 7** shows the NOAA NLDAS ensemble top one-meter soil moisture anomaly on May 27, 2017 compared to the soil moisture anomaly on April 27, 2017. The NLDAS image continues to show wetter-than-normal conditions across western and central Montana and Wyoming; however, drier-than-normal anomalies have developed in eastern Montana and intensified in the Dakotas. In the lower Basin, soil moisture anomalies have become increasingly wetter-than-normal since April 27.



May 27, 2017	April 27, 2017

Figure 7. NOAA NLDAS and CPC Soil Moisture Anomalies (mm). Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

Similarly, the CPC Soil Moisture Anomaly, in the right image of **Figure 8**, indicates wetter-than-normal soil moisture conditions in Montana and Wyoming; however, soil conditions are drier-than-normal in southern North Dakota and South Dakota. Positive soil moisture anomalies have increased in eastern Colorado, Kansas, western Nebraska, eastern Nebraska and western Iowa since the end of April 2017.



May 30, 2017	April 30, 2017

Figure 8. NOAA NLDAS and CPC Soil Moisture Anomalies (mm). Source: CPC Soil Moisture. http://www.cpc.ncep.noaa.gov/products/Soilmst_Monitoring/US/Soilmst/Soilmst.shtml#

Soil moisture conditions expressed as a percentile ranking can show the severity of the soil moisture conditions through the percentile ranking probability. Soil moisture percentile rankings from NOAA NLDAS and the CPC are shown in **Figure 9**. The NLDAS percentile ranking, in the left image of **Figure 9**, indicates wet soil moisture conditions (greater than 70th percentile rank) throughout many areas of Montana, Wyoming, eastern Colorado, western Nebraska and western Kansas. Some locally wet areas, having 95th percentile rankings or greater, are present in Montana, Wyoming and Colorado. The CPC percentile rankings, in the right image of **Figure 9**, indicate similar wet soil moisture conditions in parts of Montana, Wyoming as well as central Kansas.

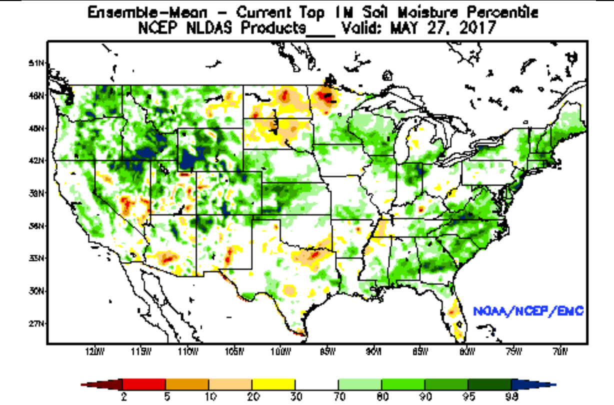
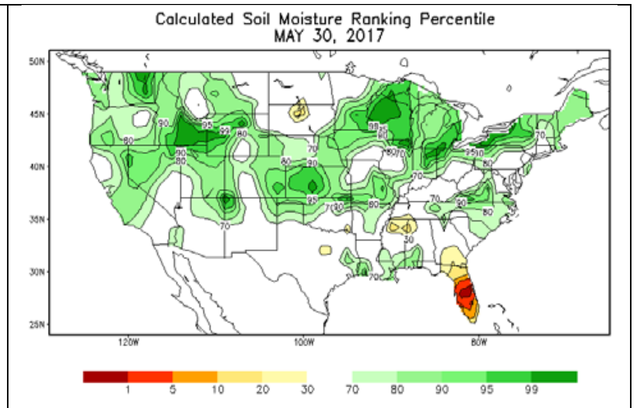
	
NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/	CPC Soil Moisture. http://www.cpc.ncep.noaa.gov/products/Soilmst_Monitoring/US/Soilmst/Soilmst.shtml#

Figure 9. NOAA NLDAS and CPC Soil Moisture Percentile Rankings.

Mountain Snowpack

Mountain snowpack is the primary factor used to predict May-July runoff volumes in the Fort Peck and Fort Peck to Garrison reaches. During the 3-month May-July runoff period, about 50% of the annual runoff in the upper Basin enters the Mainstem System as a result of mountain snowmelt and rainfall runoff. Greater-than-average mountain snow accumulations are usually associated with greater-than-average May-July runoff volumes, especially when mountain soil moisture conditions have been wetter-than-normal. For example, we would expect to see greater-than-average runoff from an average mountain snowpack this year due to wetter-than-normal soil moisture conditions.

Figure 10 includes time series plots of the average mountain SWE beginning on October 1, 2016 based on the NRCS SNOTEL gages for the headwater basin above Fort Peck and the incremental basin from Fort Peck to Garrison. The current average SWE values (shaded blue area) are plotted against the 1981-2010 basin average SWE (bold red line), a recent low SWE year in 2001 (green line), and two historic high SWE years occurring in 1997 (purple) and 2011 (dark blue).

The average mountain SWE in the reach above Fort Peck peaked at 16.1 inches (99% of average) on April 29. The average mountain SWE in the reach between Fort Peck and Garrison peak at 20.9 inches (148% of average) on May 2. The average mountain SWE normally peaks around April 15.

As of **June 1, 2017**, the Corps of Engineers computed an average mountain SWE in the reach above Fort Peck reservoir of 6.5 inches, which is 104% of average for June 1 based on the 1981-2010 average SWE and 40% of the normal April 15 peak. In the reservoir reach between Fort Peck Dam and Garrison Dam, the Corps computed an average mountain SWE of 10.2 inches, which is 164% of average for June 1 based on the 1981-2010 average SWE, and 72% of the normal April 15 peak. As of June 1, about 40% of the peak SWE remained in the Fort Peck reach, and about 49% of the peak SWE remained in the Fort Peck to Garrison reach.

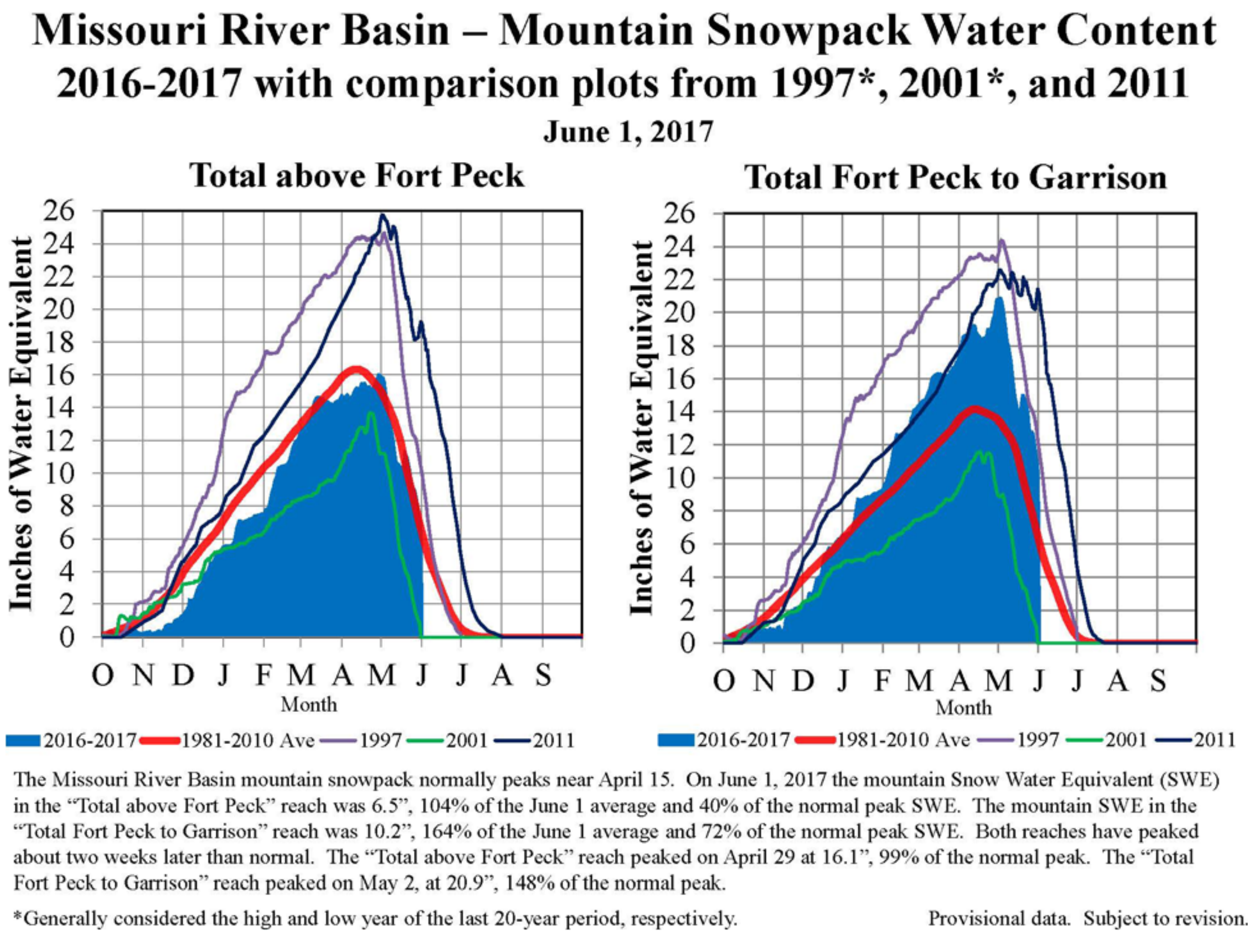


Figure 10. Mountain snowpack water content on June 1, 2017 compared to normal and historic conditions. Corps of Engineers - Missouri River Basin Water Management. Available at http://www.nwd-mr.usace.army.mil/rcc/reports/snow.pdf.

In the **Additional Figures** section at the end of this document, basin maps of the mountain snowpack as a percent of median are provided for Montana, Wyoming and Colorado. These maps are a product of the USDA-NRCS National Water and Climate Center and are available at http://www.wcc.nrcs.usda.gov. These maps show that mountain snowpack is about median to slightly above median in Montana and Colorado, but well-above median in many Wyoming basins.

Climate Outlook

MRBWMD participates in the monthly North Central U.S. Climate/Drought Outlook Webinar coordinated through NOAA, the regional climate centers, and the American Association of State Climatologists (AASC). These webinars provide updates on near-term climate outlooks and impacts including the ENSO climate pattern and its implications on winter temperature and precipitation patterns in the Missouri Basin.

ENSO (El Niño Southern Oscillation)

The latest ENSO update indicates that ENSO-neutral conditions are present, and expected to continue through the Northern Hemisphere summer 2017. During the fall, ENSO-neutral and El Niño conditions are nearly equally favored.

Temperature and Precipitation Outlooks

The NOAA Climate Prediction Center (CPC) outlooks provide the forecasted probability (or chance) of occurrence of future weather conditions during periods ranging from one to 12 months into the future. The CPC outlooks are available at http://www.cpc.ncep.noaa.gov/.

The CPC outlooks through mid-June (**Figure 11**) indicate increased chances for above-normal temperatures in the upper Basin and below-normal precipitation in western Montana and northwestern Wyoming. There are equal chances for precipitation throughout the remainder of the Missouri Basin. The June CPC outlooks (**Figure 12**) indicate a slight increase in the chance for above-normal precipitation in the Northern Rockies extending into Colorado, and equal chances for temperatures in the upper Basin with increased chances for below-normal temperatures in the lower Basin.

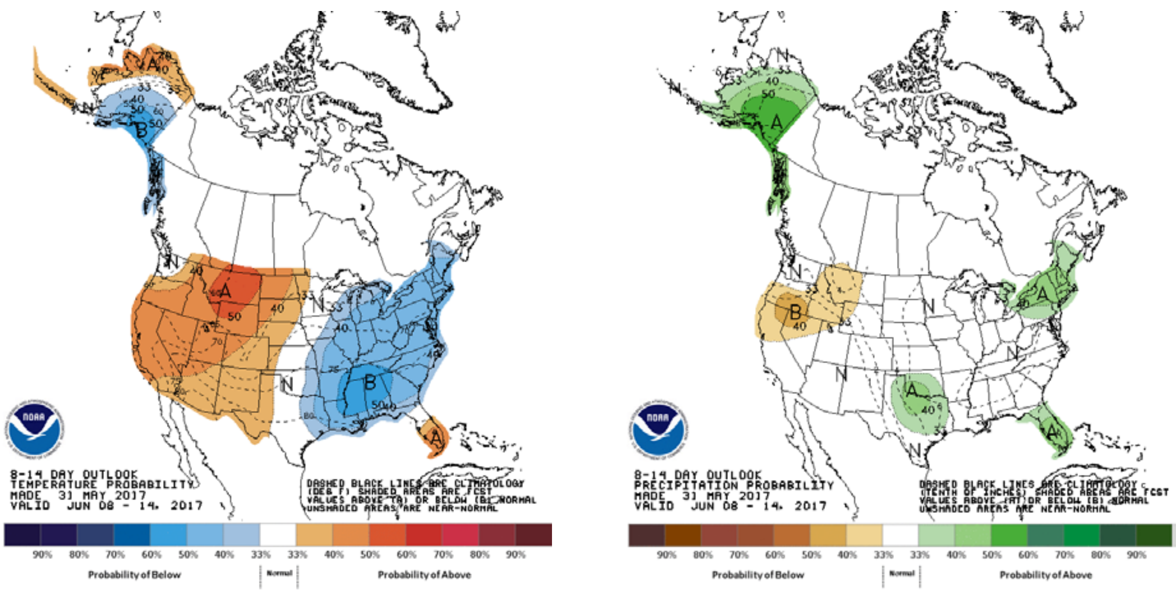


Figure 11. CPC 8-14 Day temperature and precipitation outlooks through June 14, 2017.

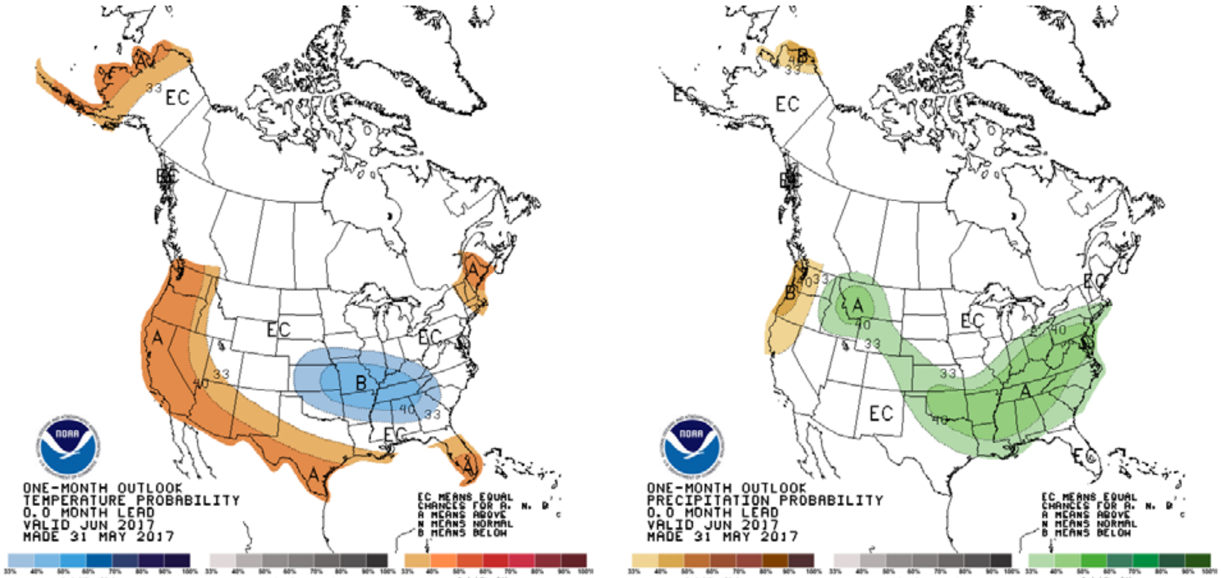


Figure 12. CPC June 2017 temperature and precipitation outlooks.

The June-July-August temperature outlook (**Figure 13**) indicates equal chances for temperatures in the Missouri Basin. With regard to precipitation the June-July-August outlook indicates increased chances for above-normal precipitation over most of the Missouri Basin, with the highest probability (greater than 40%) centered over eastern Wyoming.

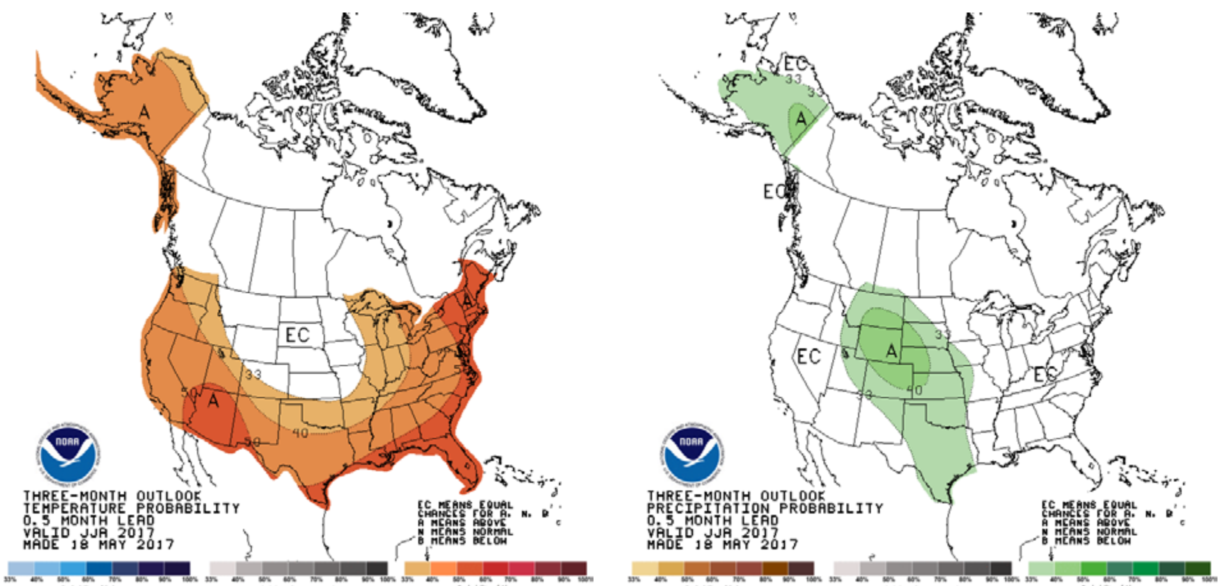


Figure 13. CPC June-July-August 2017 temperature and precipitation outlooks.

The September-October-November CPC temperature outlook (**Figure 14**) indicates there could be increased chances for above-normal temperatures over the Missouri Basin. With regard to precipitation, there are equal chances for above-normal, normal and below-normal precipitation in the Missouri Basin. During the December-January-February period (**Figure 15**), the temperature outlook indicates increased chances for above-normal temperatures over the Missouri Basin. With regard to the precipitation outlooks, CPC indicates a slight increase in the chance for below-normal precipitation in the Northern Rocky Mountains, and equal chances for precipitation in the remainder of the Missouri Basin.

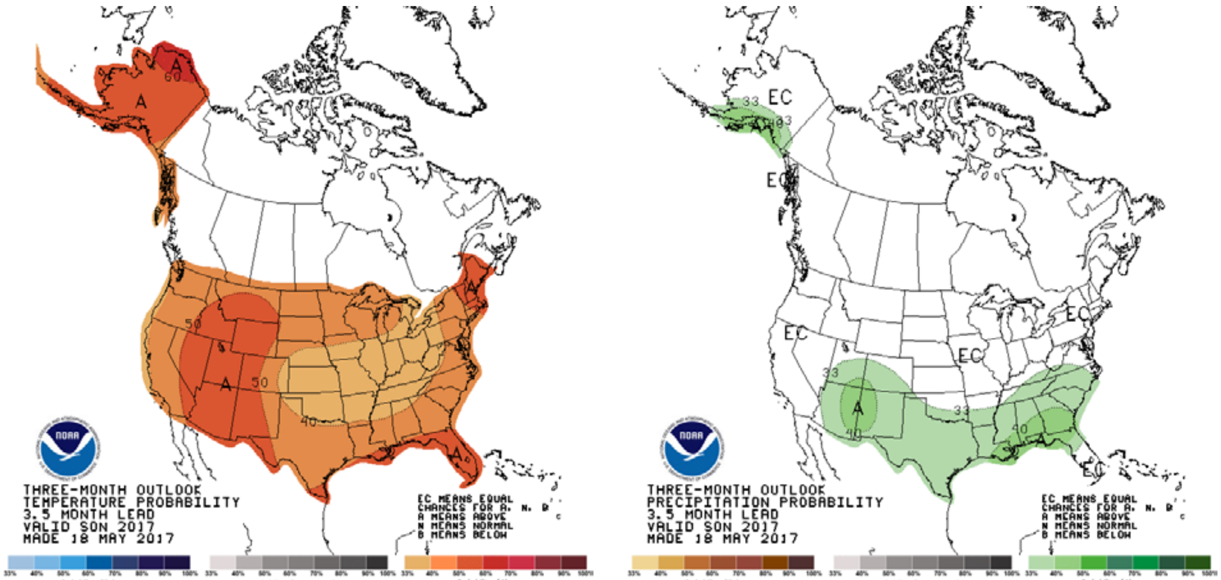


Figure 14. CPC September-October-November 2017 temperature and precipitation outlooks.

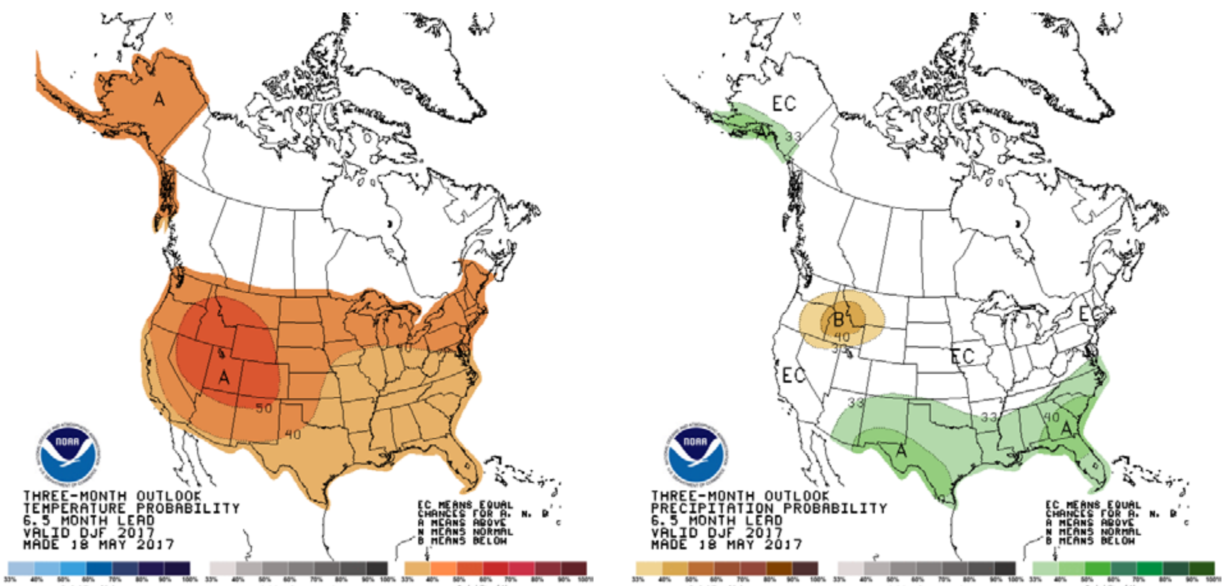


Figure 15. CPC December 2017-January-February 2018 temperature and precipitation outlooks.

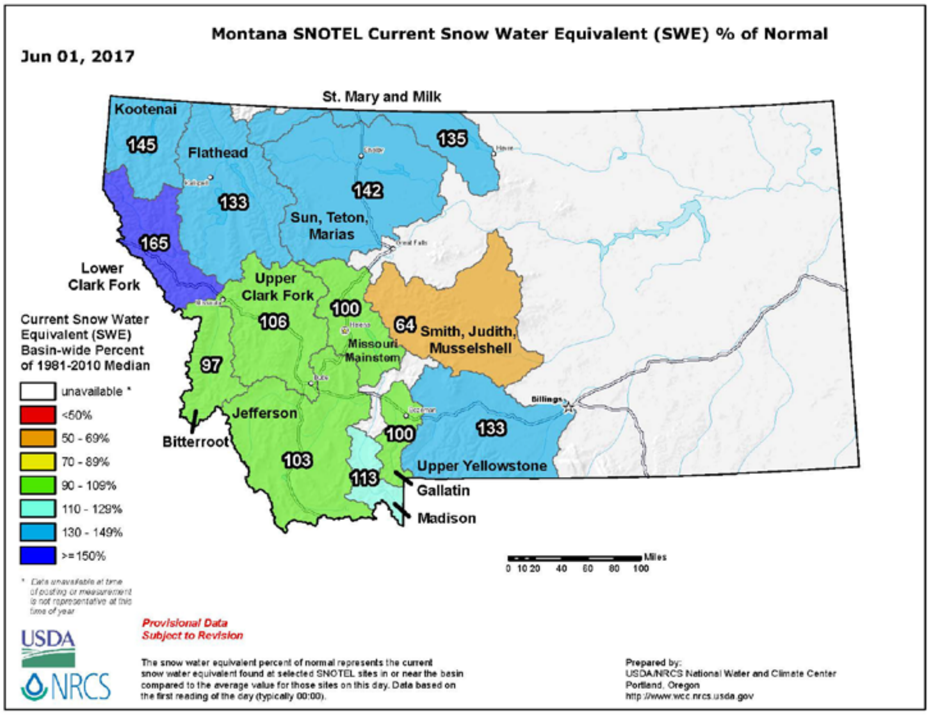
June 2017 Calendar Year Runoff Forecast

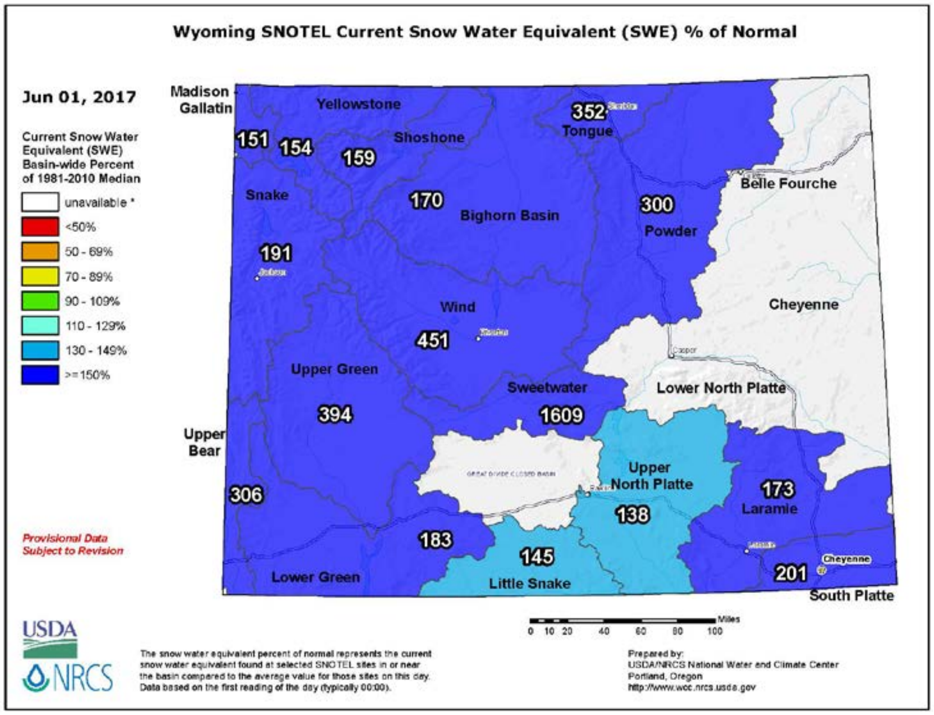
In summary, the 2017 calendar year runoff forecast is **29.9 MAF**, **118% of average**.

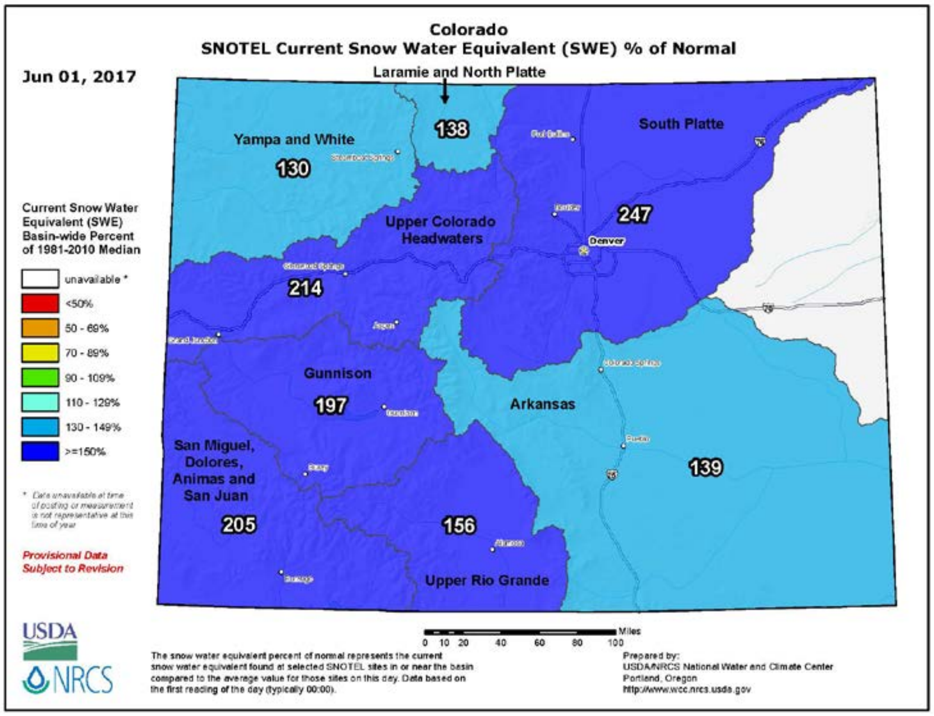
Mountain snowpack in the Fort Peck reach was 104% of the June 1 long-term average, and 40% of the 2017 peak SWE accumulation remained on June 1. In the Garrison reach the mountain snowpack was 164% of the June 1 long-term average, and 49% of the 2017 peak SWE accumulation remained on June 1. Temperatures through mid-June are forecast to be warmer-than-average in the upper Basin and will likely result in most of the remaining snowpack to melt. The June-July runoff in the Fort Peck reach is forecast to be slightly below average during June and July, while the June-July runoff in the Garrison reach is forecast to be 139% of average.

Soil moisture conditions are still wet in western Montana and Wyoming, but they are dry in the Dakotas. Since May 1 soil moisture conditions have become drier overall in the upper Basin. Below-normal May precipitation in the upper Basin was a major contributing factor to the developing dryness in eastern Montana and the Dakotas. As a result of the dry soil conditions and low May runoff in the Oahe and Fort Randall reaches, runoff during the next few months in the Oahe and Fort Randall reaches is forecast to be well-below average.

Additional Figures







Colorado
SNOTEL Current Snow Water Equivalent (SWE) % of Normal
Jun 01, 2017
Laramie and North Platte
138
Yampa and White
130
South Platte
247
Denver
Upper Colorado Headwaters
214
Gunnison
197
Arkansas
139
San Miguel, Dolores, Animas and San Juan
205
156
Upper Rio Grande
Current Snow Water Equivalent (SWE) Basin-wide Percent of 1981-2010 Median
unavailable *
<50%
50 - 69%
70 - 89%
90 - 109%
110 - 129%
130 - 149%
>=150%
* Data unavailable at time of posting or measurement is not representative at this time of year
Provisional Data Subject to Revision
USDA
NRCS
Miles
0 10 20 40 60 80 100
The snow water equivalent percent of normal represents the current snow water equivalent found at selected SNOTEL sites in or near the basin compared to the average value for those sites on this day. Data based on the first reading of the day (typically 00:00).
Prepared by:
USDA/NRCS National Water and Climate Center
Portland, Oregon
http://www.wcc.nrcs.usda.gov

USDA NRCS Water Supply Forecasts

USDA NRCS National Water & Climate Center
*** - DATA CURRENT AS OF: June 05, 2017 04:53:11 PM**
- Based on June 01, 2017 forecast values

PRELIMINARY MISSOURI RIVER BASIN FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
Lake Sherburne Inflow (2)	JUN-JUL	73	130	88	79	67	58	56
	JUN-SEP	90	127	108	97	83	72	71
St. Mary R at Intl Boundary (2)	JUN-JUL	345	125	435	380	310	255	275
	JUN-SEP	425	123	525	465	380	320	345
Lima Reservoir Inflow (2)	JUN-JUL	21	78	33	26	16.2	9.2	27
	JUN-SEP	26	79	41	32	20	11.4	33
Clark Canyon Reservoir Inflow (2)	JUN-JUL	32	91	64	45	19.9	1.45	35
	JUN-SEP	53	96	95	70	36	11.1	55
Jefferson R nr Three Forks (2)	JUN-JUL	395	111	610	480	310	184	355
	JUN-SEP	455	110	720	565	350	191	415
Hebgen Lake Inflow (2)	JUN-JUL	215	121	255	230	199	175	178
	JUN-SEP	325	116	385	350	300	265	280
Ennis Lake Inflow (2)	JUN-JUL	365	111	440	395	335	290	330
	JUN-SEP	525	108	625	565	485	425	485
Missouri R at Toston (2)	JUN-JUL	1000	106	1360	1150	855	645	940
	JUN-SEP	1280	105	1760	1480	1090	800	1220
Smith R bl Eagle Ck (2)	JUN-JUL	43	80	77	57	29	9.3	54
	JUN-SEP	52	80	98	70	34	6.3	65
Gibson Reservoir Inflow (2)	JUN-JUL	250	119	295	265	230	205	210
	JUN-SEP	290	116	345	310	270	240	250
Marias R nr Shelby (2)	JUN-JUL	190	122	275	225	156	105	156
	JUN-SEP	210	122	310	250	169	109	172

PRELIMINARY YELLOWSTONE RIVER BASIN FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
West Rosebud Ck nr Roscoe (2)	JUN-JUL	54	115	61	57	51	47	47
	JUN-SEP	72	114	82	76	68	62	63
Wind R ab Bull Lake Ck	JUN-JUL	705	214	790	740	675	625	330
	JUN-SEP	775	212	885	820	735	670	365
Bull Lake Ck nr Lenore (2)	JUN-JUL	205	190	220	210	198	188	108
	JUN-SEP	255	183	275	265	245	235	139
Boysen Reservoir Inflow (2)	JUN-JUL	1170	275	1310	1230	1110	1030	425
	JUN-SEP	1280	264	1460	1350	1210	1110	485
Greybull R at Meeteetse	JUN-JUL	180	188	215	194	165	144	96
	JUN-SEP	250	176	295	270	235	210	142
Shell Ck nr Shell	JUN-JUL	39	111	49	43	35	30	35
	JUN-SEP	51	111	62	56	46	40	46
Bighorn R at Kane (2)	JUN-JUL	1510	265	1760	1610	1410	1260	570
	JUN-SEP	1680	267	1980	1800	1560	1380	630
NF Shoshone R at Wapiti	JUN-JUL	525	172	590	550	500	460	305
	JUN-SEP	605	168	680	635	575	530	360
SF Shoshone R nr Valley	JUN-JUL	300	191	330	315	285	270	157
	JUN-SEP	355	188	395	370	340	315	189
Buffalo Bill Reservoir Inflow	JUN-JUL	880	189	990	925	835	770	465
	JUN-SEP	990	185	1110	1040	940	865	535

Bighorn R nr St. Xavier (2)	JUN-JUL	2270	247	2610	2410	2130	1920	920
	JUN-SEP	2520	250	2930	2690	2350	2110	1010
Little Bighorn R nr Hardin	JUN-JUL	66	125	94	77	55	38	53
	JUN-SEP	80	121	114	94	67	47	66
Tongue R nr Dayton (2)	JUN-JUL	59	120	75	65	53	43	49
	JUN-SEP	72	116	91	80	65	54	62
Tongue River Reservoir Inflow (2)	JUN-JUL	152	138	199	171	132	104	110
	JUN-SEP	176	131	235	199	153	119	134
NF Powder R nr Hazelton	JUN-JUL	5.8	129	7.9	6.6	5.0	3.7	4.5
	JUN-SEP	6.5	125	8.8	7.4	5.6	4.2	5.2
Powder R at Moorhead	JUN-JUL	215	234	270	240	192	158	92
	JUN-SEP	240	218	310	270	215	176	110
Powder R nr Locate	JUN-JUL	205	203	280	235	175	130	101
	JUN-SEP	230	189	320	265	195	142	122

Max (10%), 30%, 50%, 70% and Min (90%) chance that actual volume will exceed forecast.
Averages are for the 1981-2010 period.
All volumes are in thousands of acre-feet.

footnotes:
1) Max and Min are 5% and 95% chance that actual volume will exceed forecast
2) streamflow is adjusted for upstream storage
3) median value used in place of average

Upper Missouri River Basin
July 2017 Calendar Year Runoff Forecast
July 7, 2017

U.S. Army Corps of Engineers, Northwestern Division
Missouri River Basin Water Management
Omaha, NE

Calendar Year Runoff Forecast

Explanation and Purpose of Forecast

The long-range runoff forecast is presented as the Calendar Year Runoff Forecast. The Calendar Year Runoff Forecast is available at http://www.nwd-mr.usace.army.mil/rcc/reports/runoff.pdf. This forecast is developed shortly after the beginning of each calendar year and is updated at the beginning of each month to show the actual runoff for historic months of that year and the updated forecast for the remaining months of the year. This forecast presents monthly inflows in million acre-feet (MAF) from five incremental drainage areas, as defined by the individual System projects, plus the incremental drainage area between Gavins Point Dam and Sioux City. Due to their close proximity, the Big Bend and Fort Randall drainage areas are combined. Summations are provided for the total Missouri River reach above Gavins Point Dam and for the total Missouri Basin above Sioux City (upper Basin). The Calendar Year Runoff Forecast is used in the Monthly Study simulation model to plan future system regulation in order to meet the authorized project purposes throughout the calendar year.

Observed Runoff

June runoff in the upper Basin was5.8 MAF, 106% of average. Mountain snowmelt was the primary source of runoff during June in the Fort Peck and Garrison reaches. Runoff was 86% of average in the Fort Peck reach and 138% of average in the Garrison reach. Precipitation in much of the upper Basin was less than 50% of average resulting in well-below average runoff in the Oahe, Fort Randall, and Gavins Point reaches. Precipitation and runoff were about average in the Sioux City reach.

2017 Calendar Year Forecast Synopsis

The 2017 calendar year runoff forecast for the upper Missouri Basin above Sioux City, IA, updated on July 1, is **28.5 MAF (113% of average).** The 2017 calendar year runoff forecast above Gavins Point Dam is **25.3 MAF (110% of average)**.

Due to the amount of variability in precipitation and other hydrologic factors that can occur over the next 6 months, the range of expected inflow ranges from the 31.4 MAF upper basic forecast to the 25.9 MAF lower basic forecast. The upper and lower basic forecasts are used in long-term regulation planning models to "bracket" the range of expected runoff given much wetter or drier conditions, respectively. Given that 6 months are being forecast for this July 1 forecast (6 months observed/6 months forecast), the range of wetter-than-expected (upper basic) and drier-than-expected (lower basic) conditions is attributed to all 6 reaches for all 6 months. The result is a range or "bracket" for each reach, and thus, for the total runoff forecast. As the year progresses, the range will lessen as the number of observed months increases and the number of forecast months decreases.

Current Conditions

Drought Analysis

The latest National Drought Mitigation Center's drought monitor for June 27, 2017 (**Figure 1**), is compared to the drought monitor for May 30, 2017 (**Figure 2**). The drought monitor is available at http://droughtmonitor.unl.edu/. The U.S. Drought Monitor indicates there is a large area of Abnormally Dry (D0) conditions in Montana, North Dakota, Wyoming, South Dakota, and Nebraska. Moderate Drought (D1) is present in Montana, North Dakota, and South Dakota. Since May 30, areas of Severe Drought (D2) and Extreme Drought (D3) have developed in eastern Montana, North Dakota, and South Dakota. The Seasonal Drought Outlook in **Figure 3** indicates that drought conditions will remain but improve, or drought removal is likely, for the entire area by September 30.

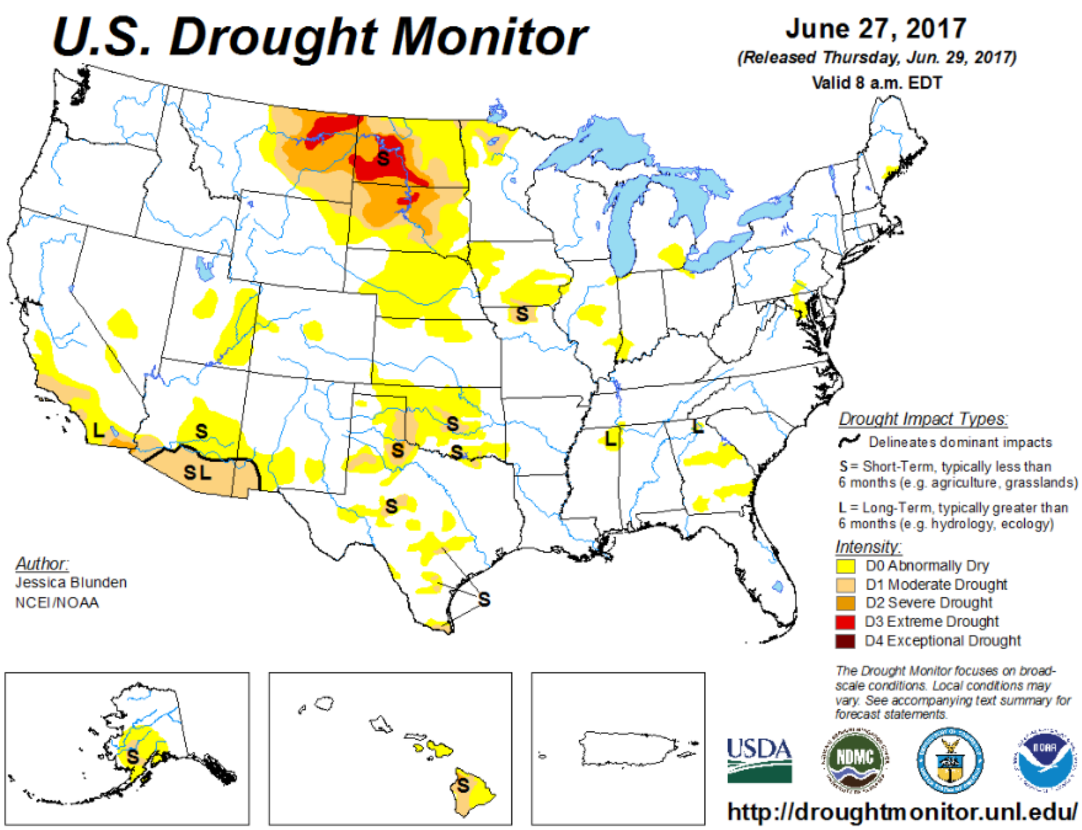


Figure 1. National Drought Mitigation Center U.S. Drought Monitor for June 27, 2017.

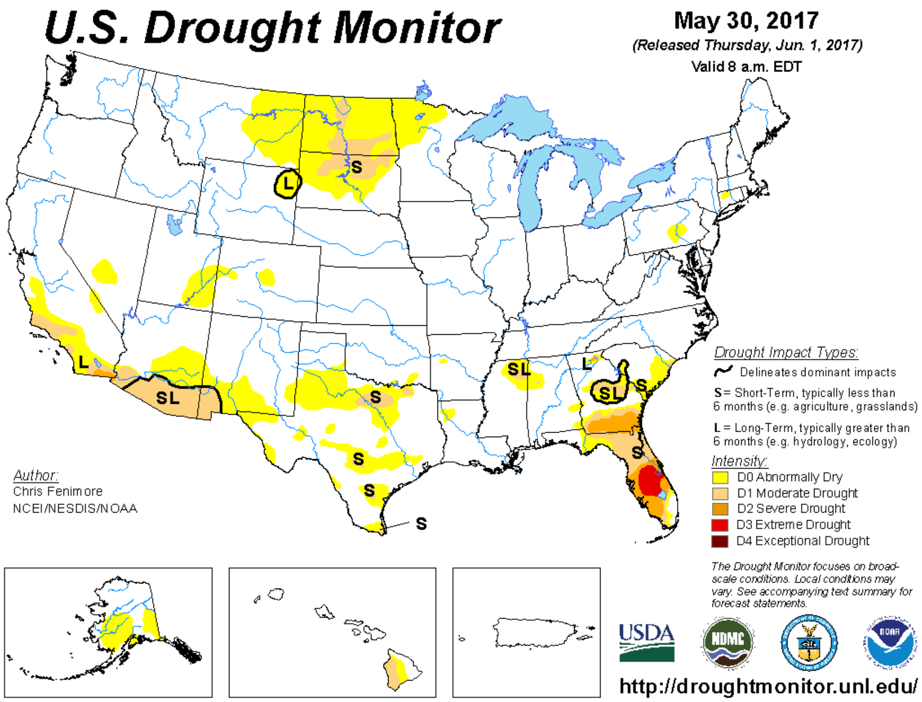


Figure 2. National Drought Mitigation Center U.S. Drought Monitor for May 30, 2017.

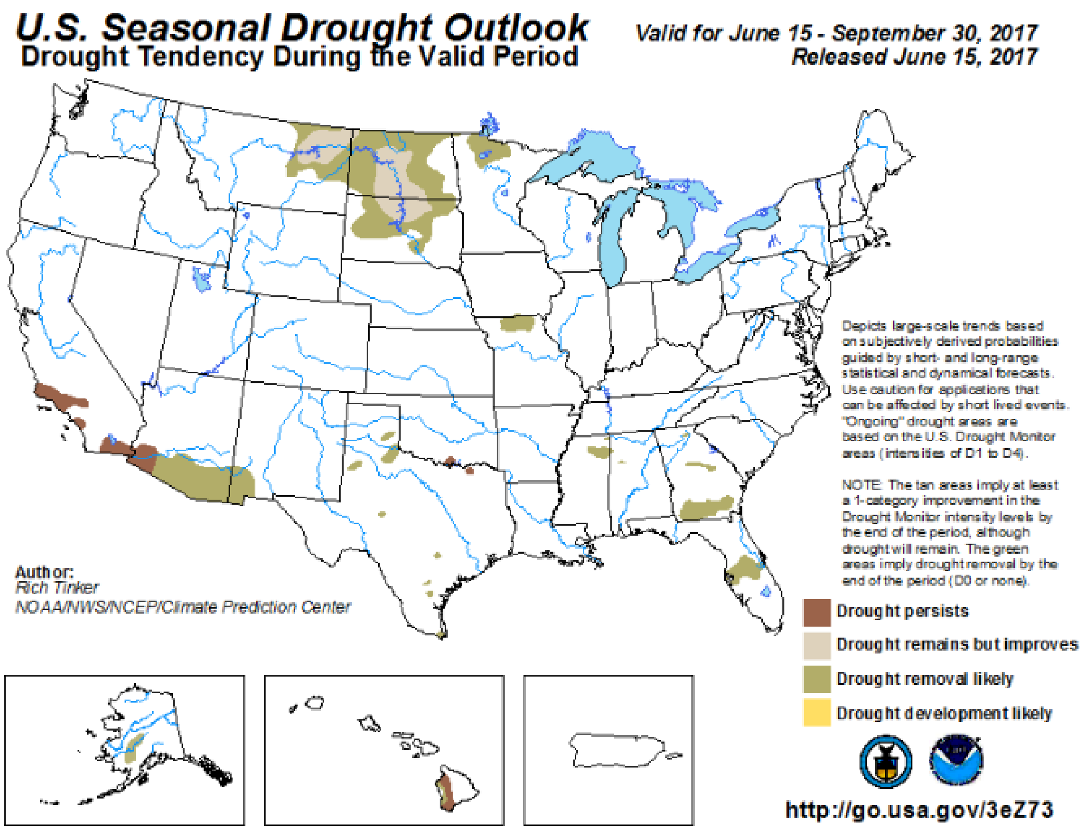


Figure 3. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

Monthly precipitation accumulations are shown using High Plains Regional Climate Center images available at http://www.hprcc.unl.edu/. The June precipitation accumulations are shown in **Figure 4** as inches of precipitation (left) and percent of normal precipitation (right). June precipitation was well-below average (less than 50% of average) in much of Montana, Wyoming, Nebraska and the Dakotas. This resulted in below-average June runoff in the Oahe, Fort Randall, and Gavins Point reaches. June precipitation was above average in western Wyoming, pockets of eastern and central North Dakota, pockets of Kansas, and northwestern Missouri. April-May-June precipitation accumulations are shown in **Figure 5**. The three-month accumulations reflect a seasonally wet precipitation pattern in areas of central Wyoming, southeastern Colorado, Kansas and Missouri. The upper basin generally experienced below normal precipitation over the last three months.

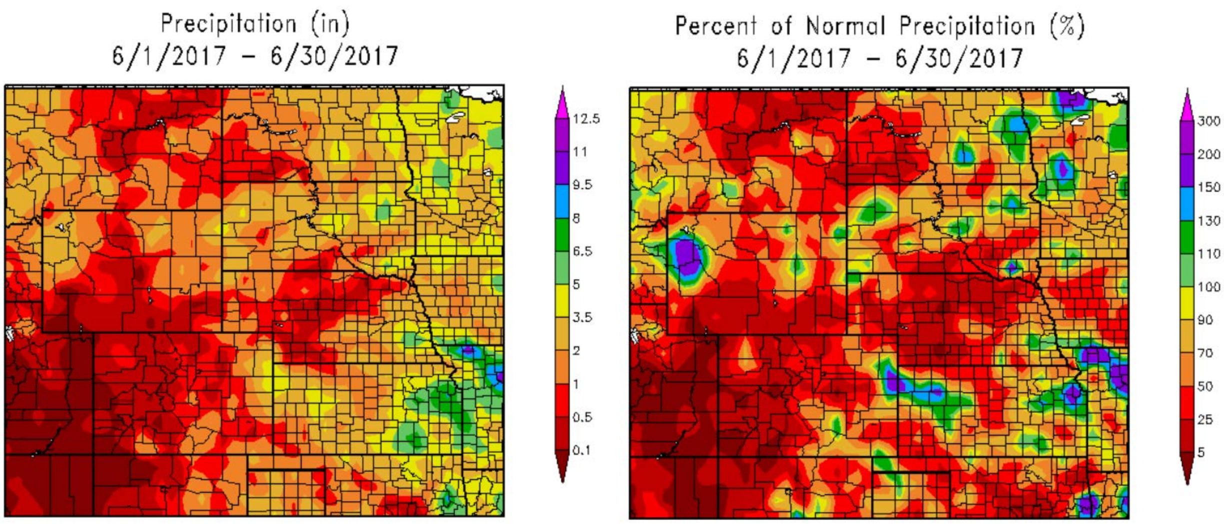


Figure 4. June 2017 Precipitation (inches) and Percent of Normal Precipitation.

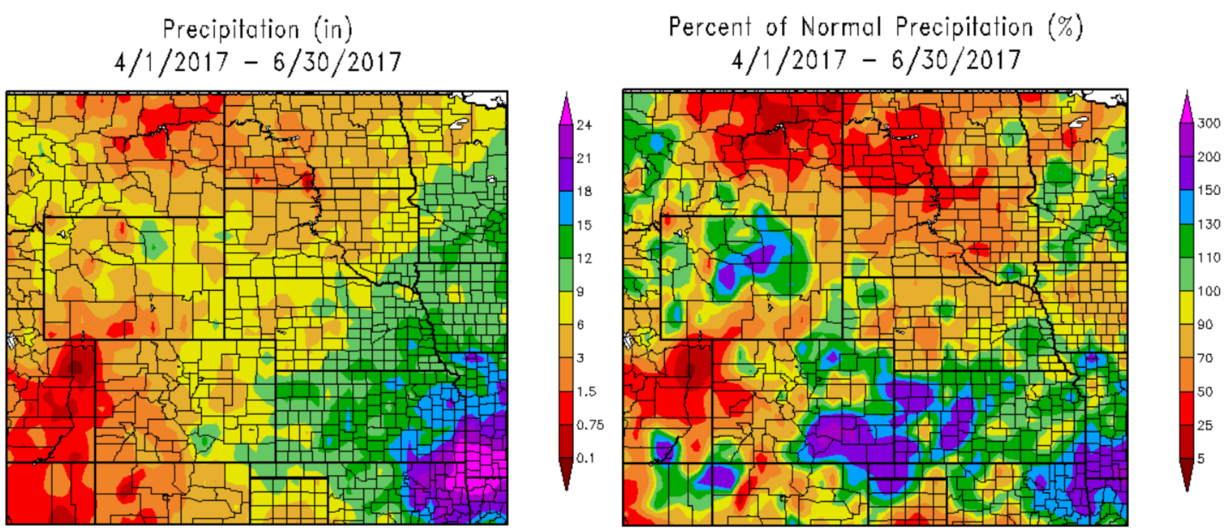


Figure 5. April-May-June 2017 Precipitation (inches) and Percent of Normal Precipitation.

Temperature

June temperature departures in degrees Fahrenheit (deg F) in the left image of **Figure 6** were mostly 0 to 4 deg F throughout the Basin, with small pockets of 4 to 8 and 0 to -2 deg F. April-May-June temperature departures, in the right image of **Figure 6**, ranged from areas of -4 to greater than 5 deg F throughout the Basin, with the bulk of the Basin falling in the -2 to 2 deg F range.

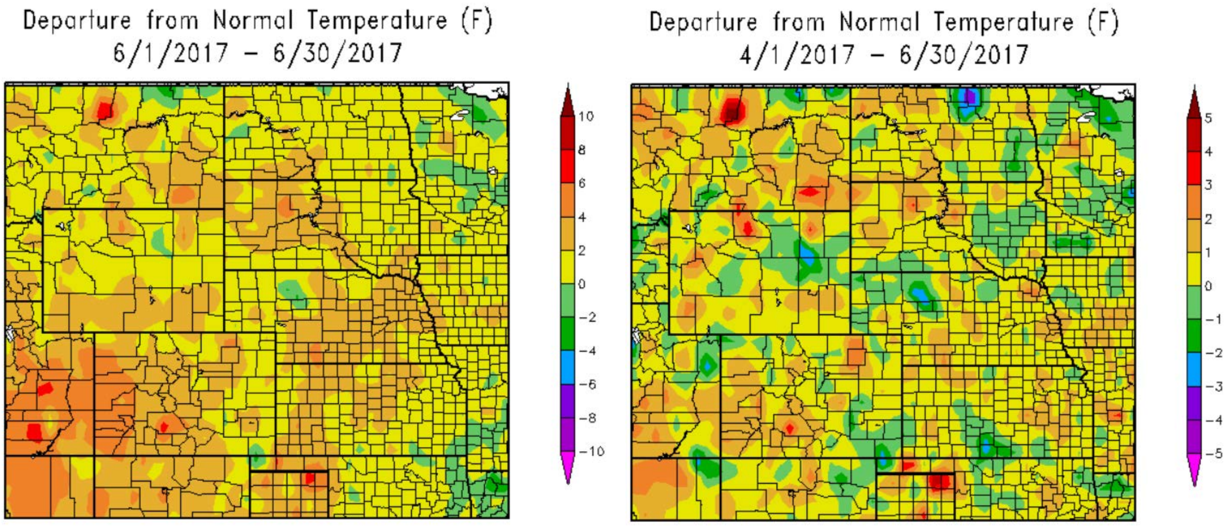
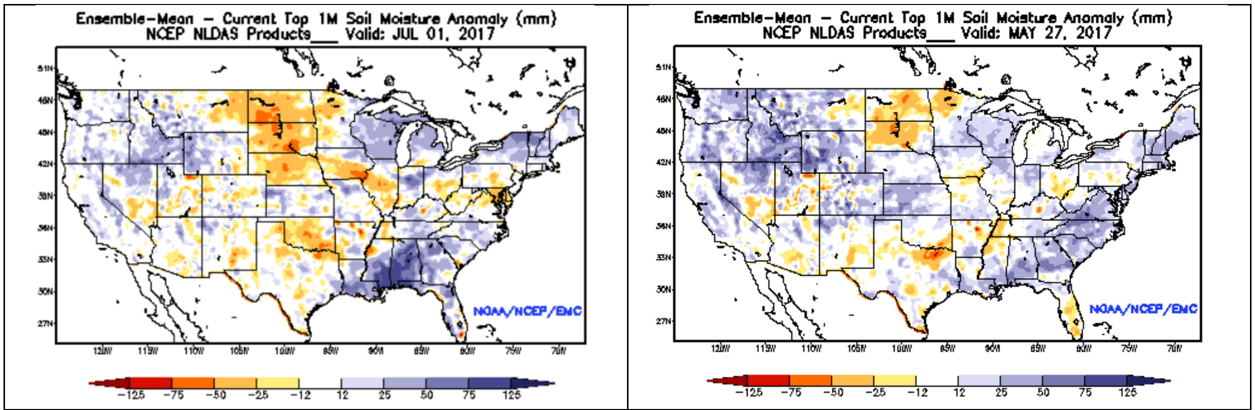


Figure 6. June 2017 and April-May-June 2017 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Soil Moisture

Soil moisture is factored into the forecast as an indicator of wet or dry hydrologic basin conditions. Typically when soil moisture conditions are wet or greater than normal, rainfall and snowmelt runoff is greater than when soil moisture is dry or less than normal. Not only is soil moisture a physical parameter that influences runoff, it can be used as an indicator of future runoff. As the calendar year approaches winter, the soil moisture conditions will provide some insight into late winter and early spring runoff potential.

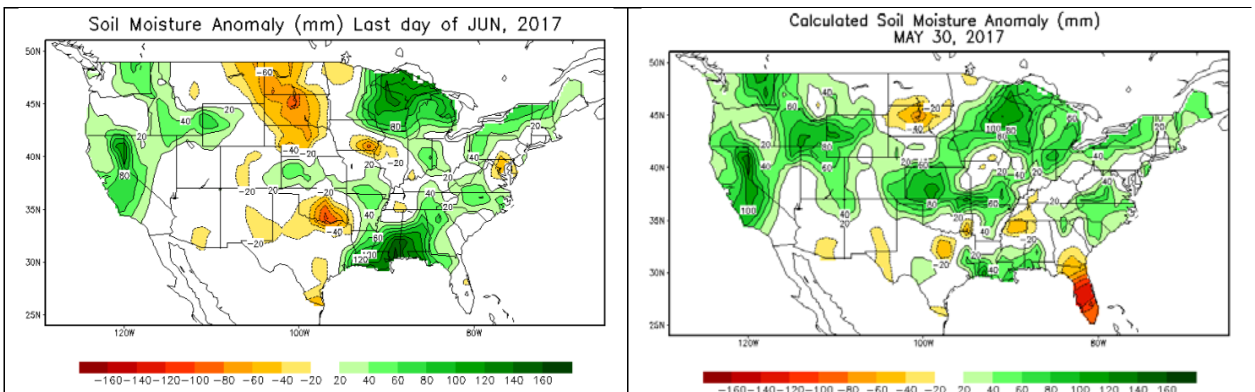
The left image of **Figure 7** shows the NOAA NLDAS ensemble top one-meter soil moisture anomaly on July 1, 2017 compared to the soil moisture anomaly on May 27, 2017. The NLDAS image shows the drier-than-normal conditions in the Dakotas spreading further into eastern Montana, Nebraska, and southern Iowa during June. Soil conditions are wetter than normal in Wyoming, Missouri, and parts of Kansas.



July 1, 2017	May 27, 2017

Figure 7. NOAA NLDAS and CPC Soil Moisture Anomalies (mm). Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

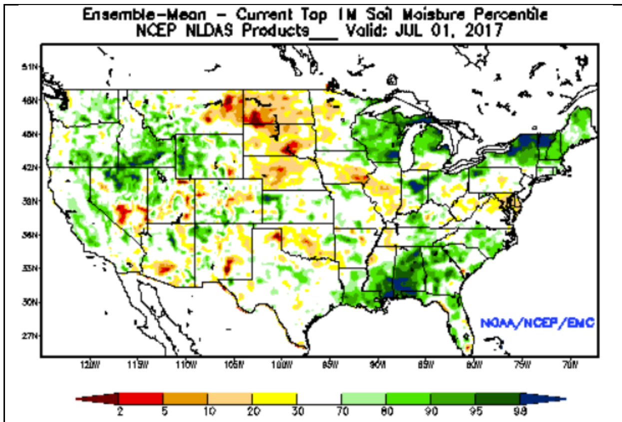
Similarly, the CPC Soil Moisture Anomaly, in the right image of **Figure 8**, indicates drier-than-normal conditions across the Dakotas, eastern Montana, Nebraska, and southern Iowa. Wetter-than-normal conditions are indicated for southern Missouri, Kansas, and western Wyoming.



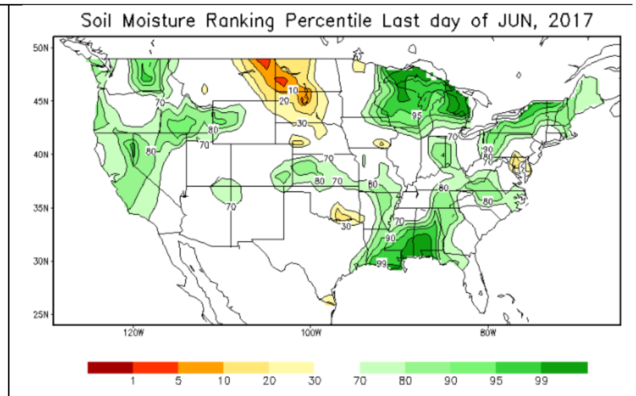
June 30, 2017	May 30, 2017

Figure 8. NOAA NLDAS and CPC Soil Moisture Anomalies (mm). Source: CPC Soil Moisture. http://www.cpc.ncep.noaa.gov/products/Soilmst_Monitoring/US/Soilmst/Soilmst.shtml#

Soil moisture conditions expressed as a percentile ranking can show the severity of the soil moisture conditions through the percentile ranking probability. Soil moisture percentile rankings from NOAA NLDAS and the CPC are shown in **Figure 9**. The NLDAS percentile ranking, in the left image of **Figure 9**, indicates wet soil moisture conditions (greater than 70th percentile rank) throughout many areas Wyoming, Kansas, and Missouri. Some locally wet areas, having 95th percentile rankings or greater, are present in western Wyoming and western Kansas. The CPC percentile rankings, in the right image of **Figure 9**, indicate similar wet soil moisture conditions in parts of Wyoming, Kansas, and Missouri. The NLDAS percentile ranking indicates very dry soil moisture conditions (less than 10th percentile rank) in areas of Montana, the Dakotas, Colorado, Nebraska, and Iowa. Overall, the Basin is much drier as of July 1 than it was on June 1.



NOAA NLDAS Drought Monitor Soil Moisture.
http://www.emc.ncep.noaa.gov/mmb/nldas/drought/



CPC Soil Moisture.
http://www.cpc.ncep.noaa.gov/products/Soilmst_Monitoring/US/Soilmst/Soilmst.shtml#

Figure 9. NOAA NLDAS and CPC Soil Moisture Percentile Rankings.

Mountain Snowpack

Mountain snowpack is the primary factor used to predict May-July runoff volumes in the Fort Peck and Garrison reaches. During the 3-month May-July runoff period, about 50% of the annual runoff in the upper Basin enters the Mainstem System as a result of mountain snowmelt and rainfall runoff. Greater-than-average mountain snow accumulations are usually associated with greater-than-average May-July runoff volumes, especially when mountain soil moisture conditions have been wetter-than-normal. For example, we would expect to see greater-than-average runoff from an average mountain snowpack this year due to wetter-than-normal soil moisture conditions.

Figure 10 includes time series plots of the average mountain SWE beginning on October 1, 2016 based on the NRCS SNOTEL gages for the headwater basin above Fort Peck and the incremental basin from Fort Peck to Garrison. The current average SWE values (shaded blue area) are plotted against the 1981-2010 basin average SWE (bold red line), a recent low SWE year in 2001 (green line), and two historic high SWE years occurring in 1997 (purple) and 2011 (dark blue).

The average mountain SWE in the reach above Fort Peck peaked at 16.1 inches (99% of average) on April 29. The average mountain SWE in the reach between Fort Peck and Garrison peak at 20.9 inches (148% of average) on May 2. The average mountain SWE normally peaks around April 15.

As of **July 1, 2017**, the Corps of Engineers computed an average mountain SWE in the reach above Fort Peck reservoir of 0.2 inches, which is 1% of the peak SWE remaining. In the reservoir reach between Fort Peck Dam and Garrison Dam, the Corps computed an average mountain SWE of 0.1 inches, which is less than 1% of the peak SWE remaining. All significant mountain SWE had melted by July 1.

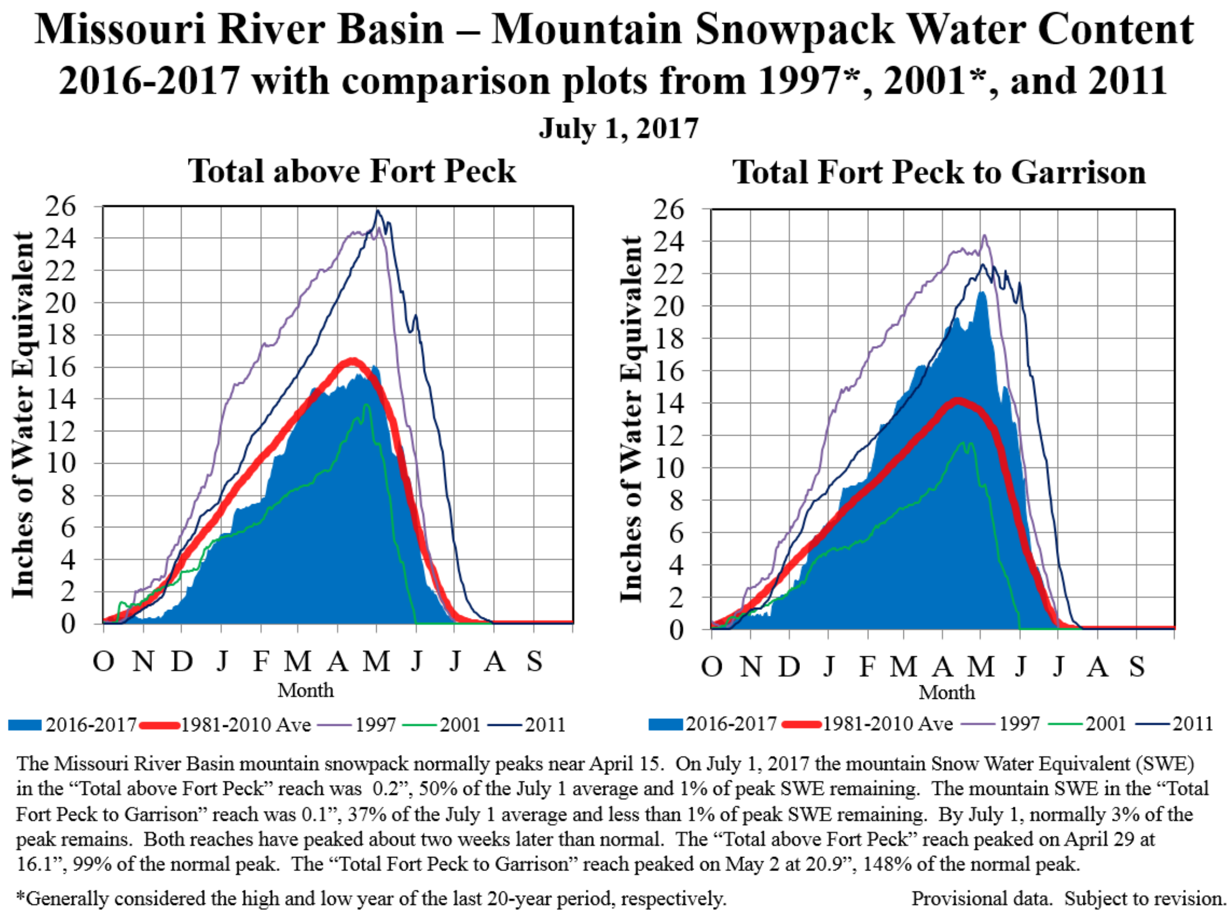


Figure 10. Mountain snowpack water content on July 1, 2017 compared to normal and historic conditions. Corps of Engineers - Missouri River Basin Water Management. Available at http://www.nwd-mr.usace.army.mil/rcc/reports/snow.pdf.

In the **Additional Figures** section at the end of this document, basin maps of the mountain snowpack as a percent of median are provided for Montana, Wyoming and Colorado. These maps are a product of the USDA-NRCS National Water and Climate Center and are available at http://www.wcc.nrcs.usda.gov. These maps show that all significant mountain snowpack has melted.

Climate Outlook

MRBWMD participates in the monthly North Central U.S. Climate/Drought Outlook Webinar coordinated through NOAA, the regional climate centers, and the American Association of State Climatologists (AASC). These webinars provide updates on near-term climate outlooks and impacts including the ENSO climate pattern and its implications on winter temperature and precipitation patterns in the Missouri Basin.

ENSO (El Niño Southern Oscillation)

The latest ENSO update indicates that ENSO-neutral conditions are present, and expected to continue through the Northern Hemisphere summer 2017. During the fall, ENSO-neutral and El Niño conditions are nearly equally favored.

Temperature and Precipitation Outlooks

The NOAA Climate Prediction Center (CPC) outlooks provide the forecasted probability (or chance) of occurrence of future weather conditions during periods ranging from one to 12 months into the future. The CPC outlooks are available at http://www.cpc.ncep.noaa.gov/.

The CPC outlooks through mid-July (**Figure 11**) indicate increased chances for above-normal temperatures and below-normal precipitation for most of the Basin. The July CPC outlooks (**Figure 12**) indicate a slight increase in the chance for above-normal precipitation in Missouri and Kansas, below-normal precipitation in Montana and the Dakotas, and equal chances elsewhere. There are increased chances for above-normal temperatures in the upper Basin and equal chances in the lower Basin.

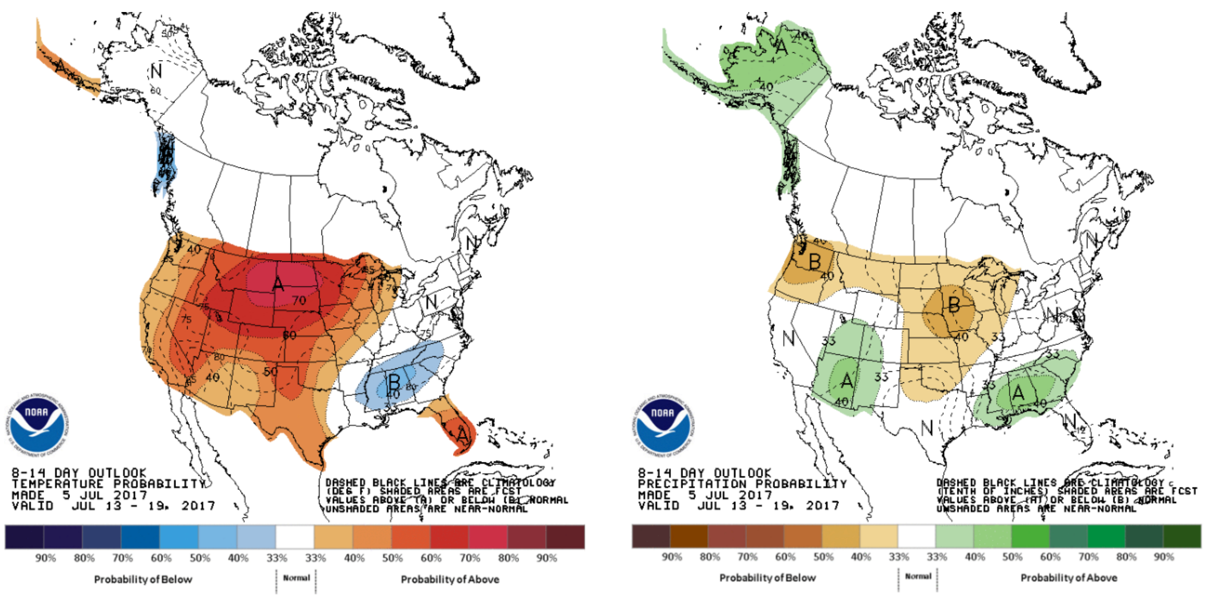


Figure 11. CPC 8-14 Day temperature and precipitation outlooks through July 19, 2017.

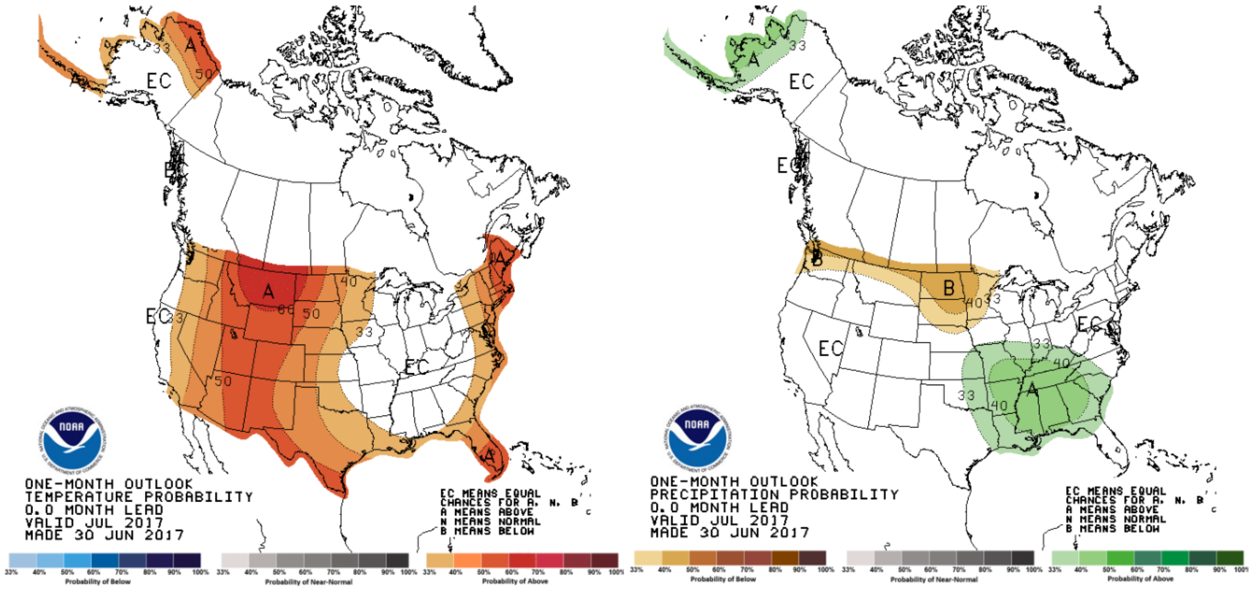


Figure 12. CPC July 2017 temperature and precipitation outlooks.

The July-August-September temperature outlook (**Figure 13**) indicates equal chances for temperatures in Montana and increased chances for above-normal temperatures in the rest of the Basin. With regard to precipitation, the July-August-September outlook indicates increased chances for above-normal precipitation in Montana and the Dakotas, with equal chances elsewhere.

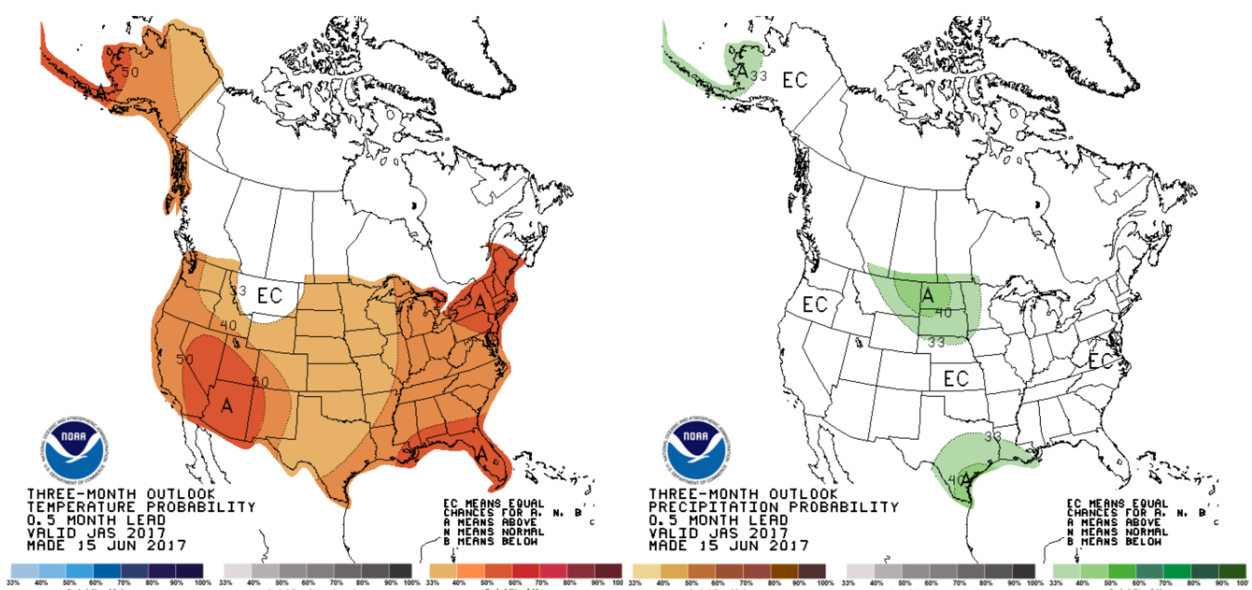


Figure 13. CPC July-August-September 2017 temperature and precipitation outlooks.

The October-November-December CPC temperature outlook (**Figure 14**) indicates there could be increased chances for above-normal temperatures over the Missouri Basin. With regard to precipitation, there are slightly increased chances for above-normal precipitation in the upper

Basin, and equal chances in the remainder of the Basin. During the January-February-March period (**Figure 15**), the temperature outlook indicates increased chances for above-normal temperatures in Montana, Colorado, Wyoming, and Kansas, with equal chances for the rest of the Basin. With regard to the precipitation outlooks, CPC indicates equal chances for above-normal, normal, and below-normal precipitation for the Missouri Basin.

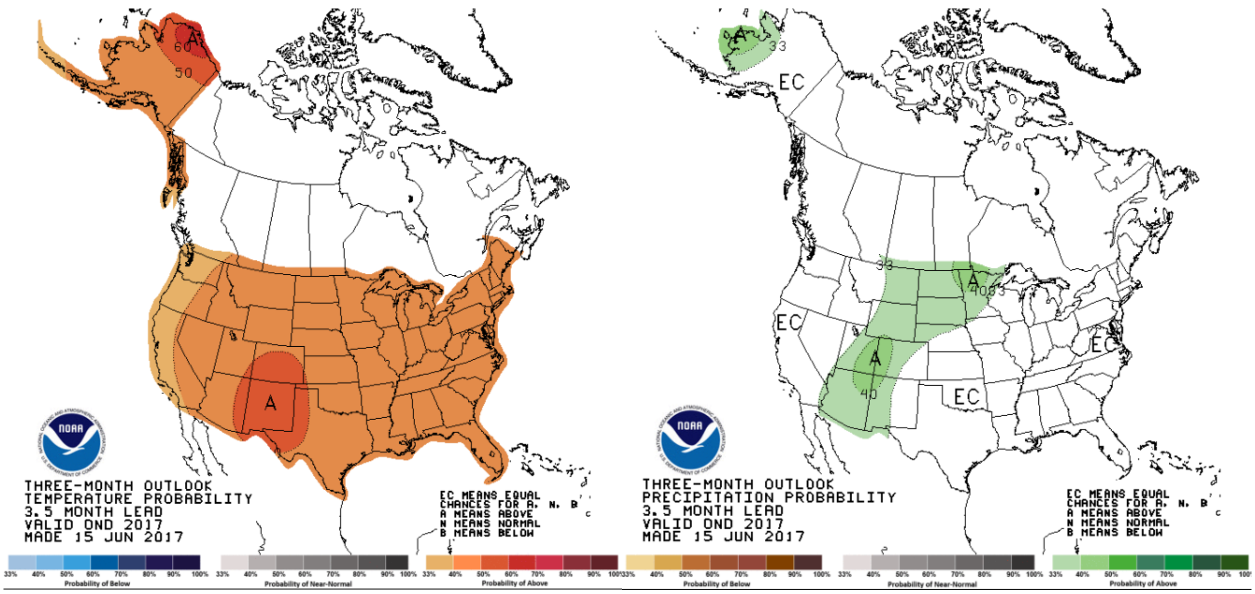


Figure 14. CPC October-November-December 2017 temperature and precipitation outlooks.

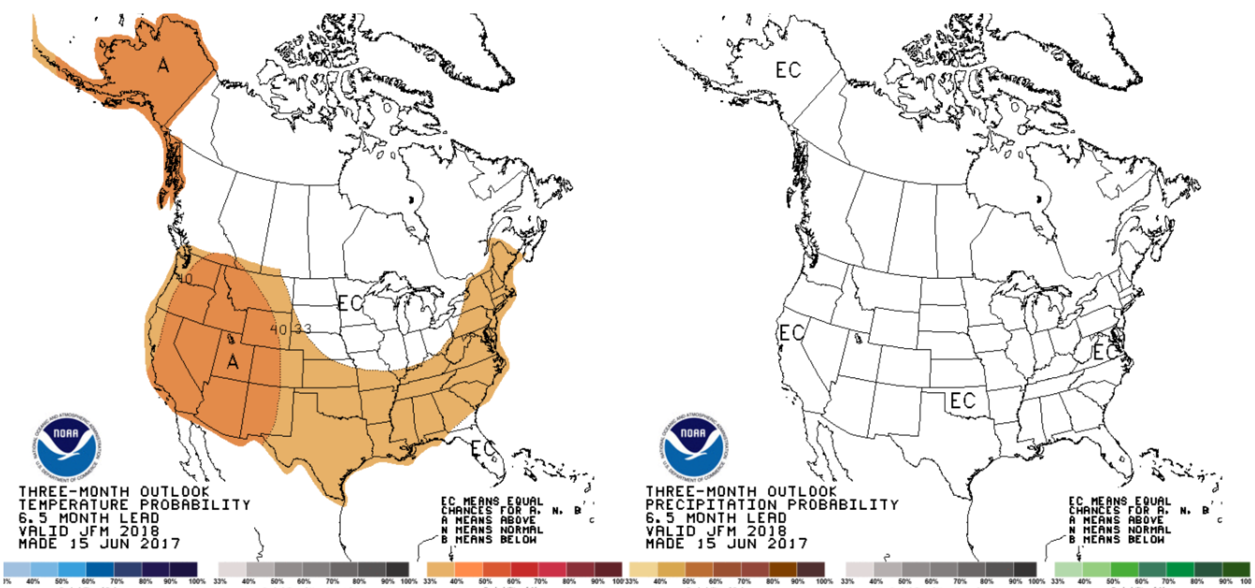


Figure 15. CPC January-February-March 2018 temperature and precipitation outlooks.

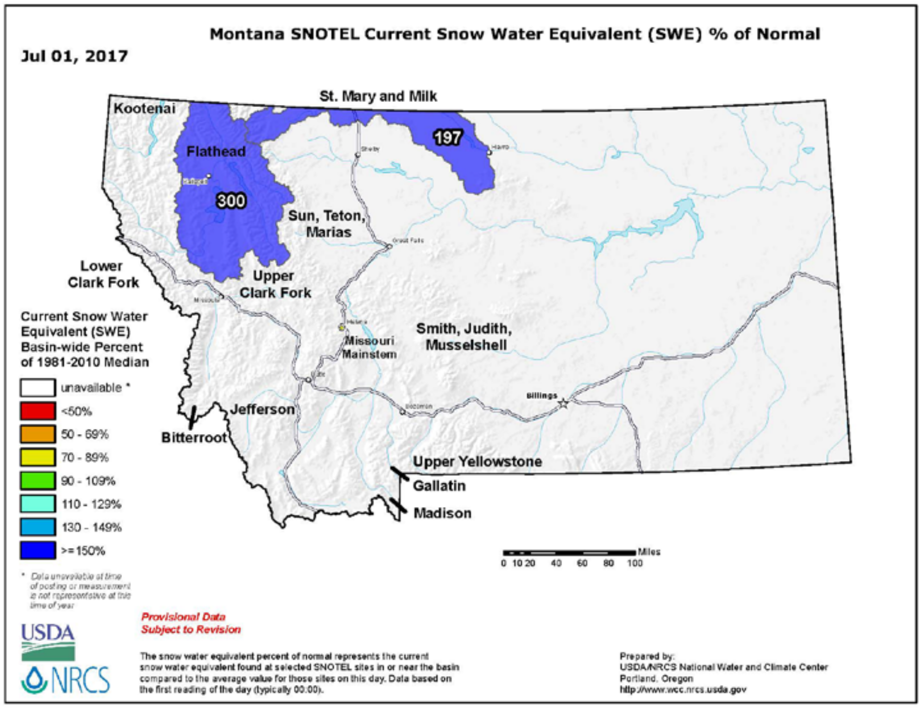
June 2017 Calendar Year Runoff Forecast

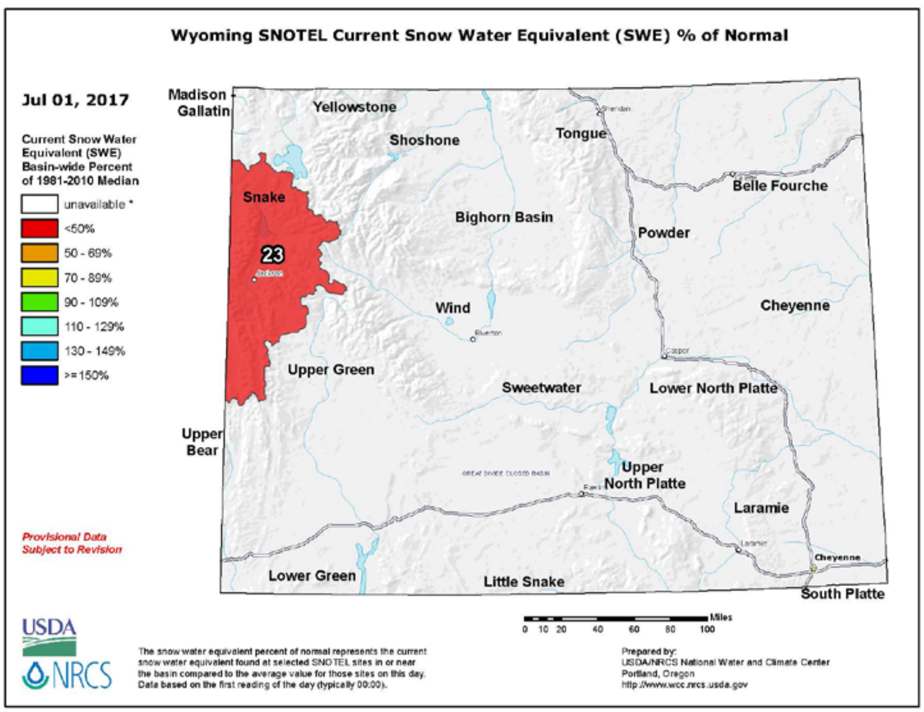
In summary, the 2017 calendar year runoff forecast is **28.5 MAF**, **113% of average**.

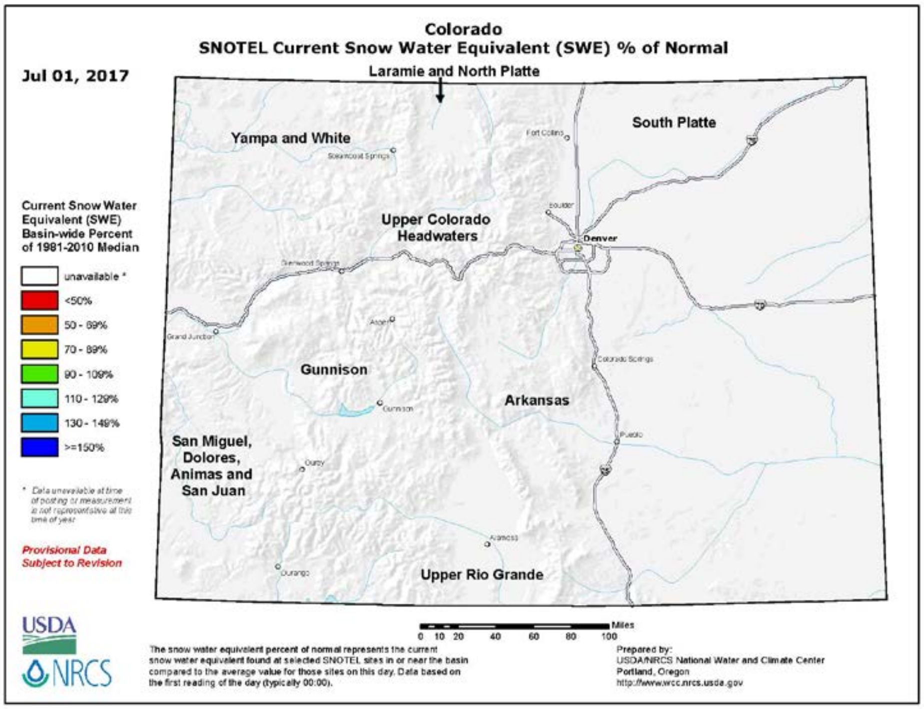
All significant mountain snowpack has melted. The July runoff in the Fort Peck reach is forecast to be slightly below average, while the runoff in the Garrison reach is forecast to be slightly above average.

Drought conditions have spread and worsened during the month of June. As a result of the dry soil conditions, below-average precipitation, and low June runoff in the Oahe, Fort Randall, and Gavins Point reaches, runoff during the next few months for these reaches is forecast to be below average. Runoff in the Sioux City reach is forecasted to follow current trends and remain above average.

Additional Figures






Colorado
SNOTEL Current Snow Water Equivalent (SWE) % of Normal
Jul 01, 2017
Laramie and North Platte
Yampa and White
South Platte
Upper Colorado Headwaters
Denver
Gunnison
Arkansas
San Miguel, Dolores, Animas and San Juan
Upper Rio Grande
Current Snow Water Equivalent (SWE) Basin-wide Percent of 1981-2010 Median
unavailable *
<50%
50 - 69%
70 - 89%
90 - 109%
110 - 129%
130 - 149%
>=150%
Provisional Data Subject to Revision
USDA
NRCS
Miles
0 10 20 40 60 80 100
The snow water equivalent percent of normal represents the current snow water equivalent found at selected SNOTEL sites in or near the basin compared to the average value for those sites on this day. Data based on the first reading of the day (typically 00:00).
Prepared by:
USDA/NRCS National Water and Climate Center
Portland, Oregon
http://www.wcc.nrcs.usda.gov

Upper Missouri River Basin
August 2017 Calendar Year Runoff Forecast
August 7, 2017

U.S. Army Corps of Engineers, Northwestern Division
Missouri River Basin Water Management
Omaha, NE

Calendar Year Runoff Forecast

Explanation and Purpose of Forecast

The long-range runoff forecast is presented as the Calendar Year Runoff Forecast. The Calendar Year Runoff Forecast is available at http://www.nwd-mr.usace.army.mil/rcc/reports/runoff.pdf. This forecast is developed shortly after the beginning of each calendar year and is updated at the beginning of each month to show the actual runoff for historic months of that year and the updated forecast for the remaining months of the year. This forecast presents monthly inflows in million acre-feet (MAF) from five incremental drainage areas, as defined by the individual System projects, plus the incremental drainage area between Gavins Point Dam and Sioux City. Due to their close proximity, the Big Bend and Fort Randall drainage areas are combined. Summations are provided for the total Missouri River reach above Gavins Point Dam and for the total Missouri Basin above Sioux City (upper Basin). The Calendar Year Runoff Forecast is used in the Monthly Study simulation model to plan future system regulation in order to meet the authorized project purposes throughout the calendar year.

Observed Runoff

July runoff in the upper Basin was 3.3 MAF, 101% of average. Runoff was 124% of average in the Garrison reach due to the runoff caused by the abundant mountain snowpack. In all other reaches, July runoff was well-below average.

2017 Calendar Year Forecast Synopsis

The 2017 calendar year runoff forecast for the upper Missouri Basin above Sioux City, IA, updated on August 1, is **27.9 MAF (110% of average).** The 2017 calendar year runoff forecast above Gavins Point Dam is **24.9 MAF (108% of average)**.

Due to the amount of variability in precipitation and other hydrologic factors that can occur over the next 5 months, the range of expected inflow ranges from the 29.2 MAF upper basic forecast to the 26.7 MAF lower basic forecast. The upper and lower basic forecasts are used in long-term regulation planning models to “bracket” the range of expected runoff given much wetter or drier conditions, respectively. Given that 5 months are being forecast for this August 1 forecast (7 months observed/5 months forecast), the range of wetter-than-expected (upper basic) and drier-than-expected (lower basic) conditions is attributed to all 6 reaches for all 5 months. The result is a range or "bracket" for each reach, and thus, for the total runoff forecast. As the year progresses, the range will lessen as the number of observed months increases and the number of forecast months decreases.

Current Conditions

Drought Analysis

The latest National Drought Mitigation Center's drought monitor for July 25, 2017 (**Figure 1**), is compared to the drought monitor for June 27, 2017 (**Figure 2**). The drought monitor is available at http://droughtmonitor.unl.edu/. The U.S. Drought Monitor shows drought conditions in all states of the Missouri Basin and over a majority of the upper Basin. In Montana, 82% of the state is impacted by drought, and 24% of the state is impacted by Extreme (D3) and Exceptional (D4) Drought. The most severe drought conditions in Montana are present over the northeastern quarter of the state. In North Dakota, 94% of the state is impacted by drought, and 46% is impacted by D3 and D4 Drought, most of which is in western North Dakota. In South Dakota, 100% of the state is impacted by drought, and 15% is impacted by D3 and D4 Drought. The most severe conditions are in north central South Dakota. Wyoming is mostly unaffected by the drought except for a small area in the northeastern corner of the state. The Seasonal Drought Outlook in **Figure 3** indicates that drought conditions will persist in eastern Montana and the western Dakotas through October 31. In the central Dakotas some improvement to conditions is likely, and drought removal is possible in the eastern Dakotas.

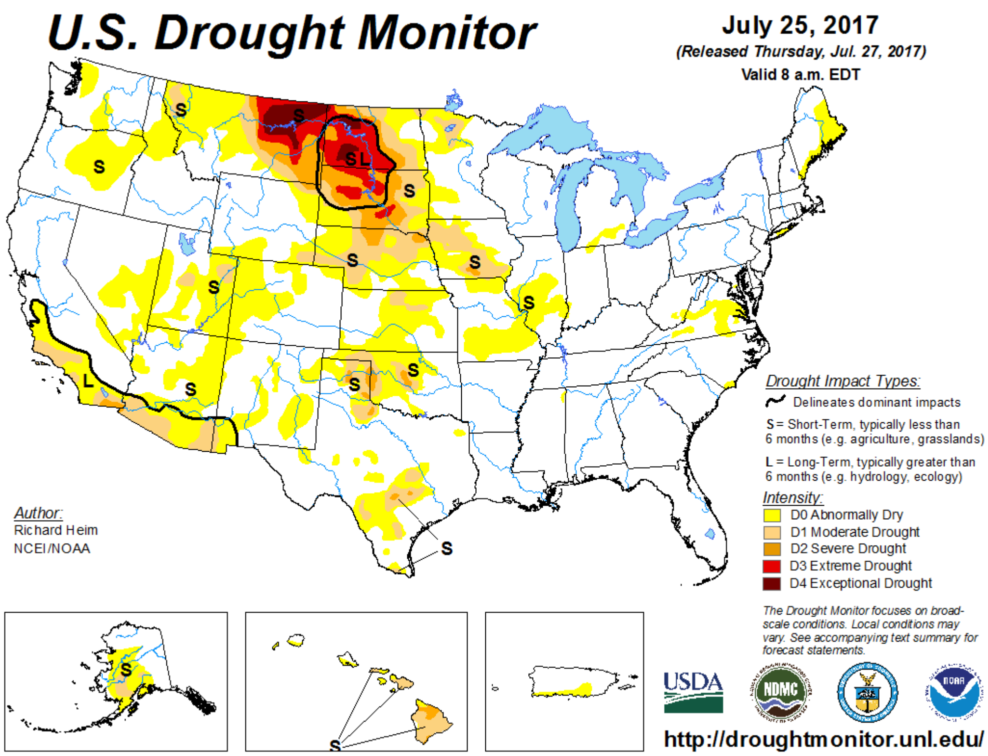


Figure 1. National Drought Mitigation Center U.S. Drought Monitor for July 25, 2017.

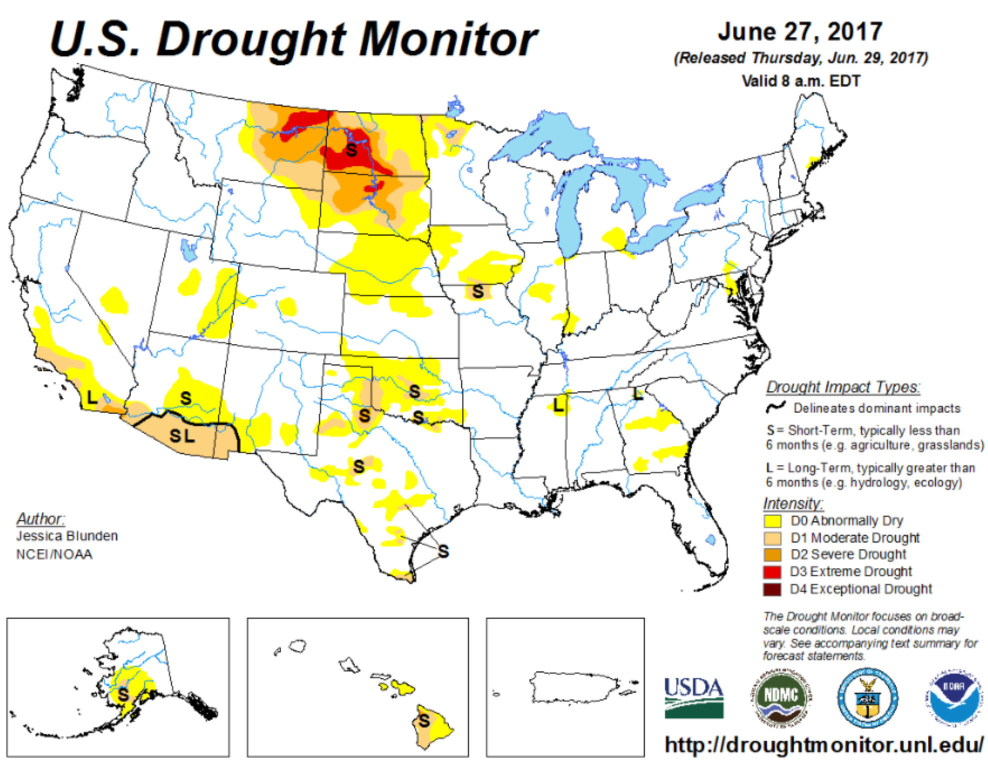


Figure 2. National Drought Mitigation Center U.S. Drought Monitor for June 27, 2017.

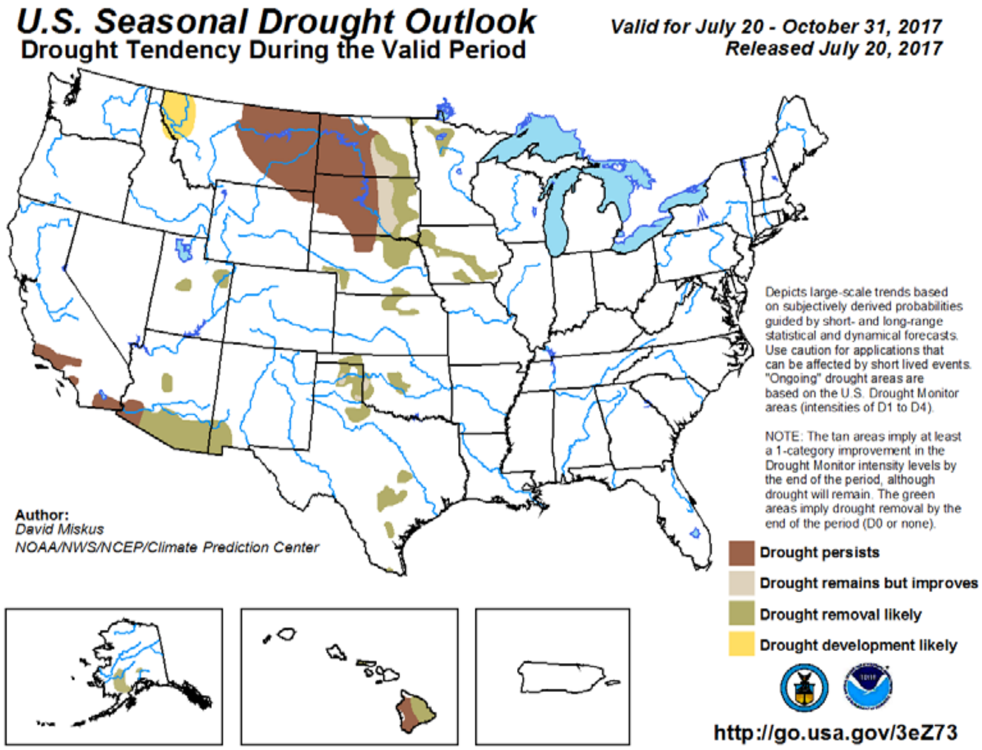


Figure 3. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

Monthly precipitation accumulations are shown using High Plains Regional Climate Center images available at http://www.hprcc.unl.edu/. The July precipitation accumulations are shown in **Figure 4** as inches of precipitation (left) and percent of normal precipitation (right). July precipitation was well-below average (less than 50% of average) in much of Montana, Wyoming, North Dakota, parts of South Dakota, and other large regions of the lower Basin. This resulted in well-below-average July runoff in the Fort Peck, Oahe, Fort Randall, Gavins Point and Sioux City reaches. July precipitation was above average in only a few localized areas of the Missouri Basin. May-June-July precipitation accumulations are shown in **Figure 5**. The three-month accumulations reflect a seasonally dry precipitation pattern in the upper Basin, particularly in eastern Montana and western North Dakota, where precipitation was less than 50% of normal. Much of the upper Basin received less than 70% of normal precipitation during the three-month period. The lower Basin received predominantly below-normal precipitation.

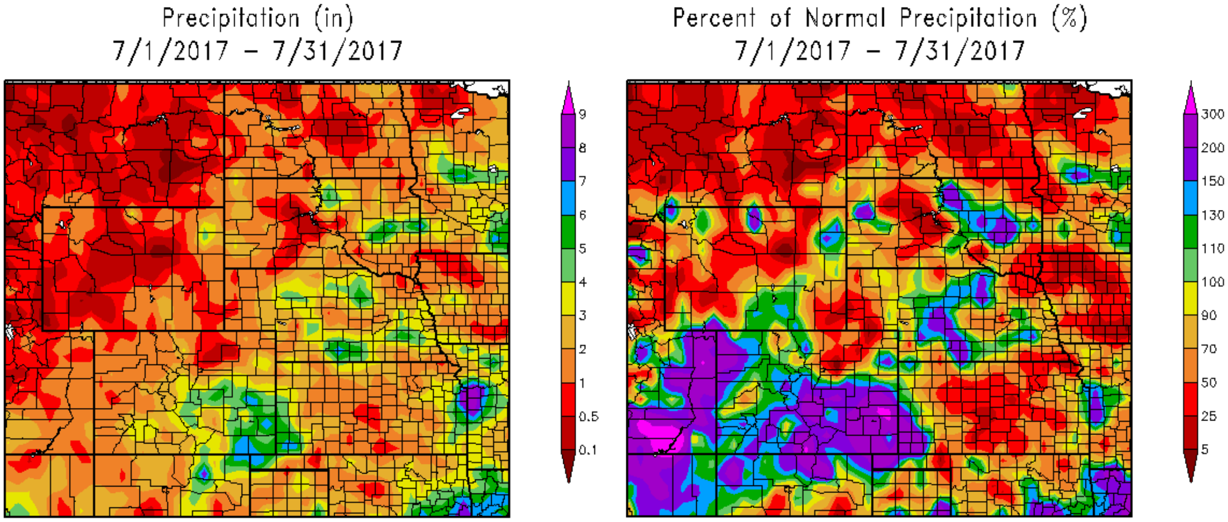


Figure 4. July 2017 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

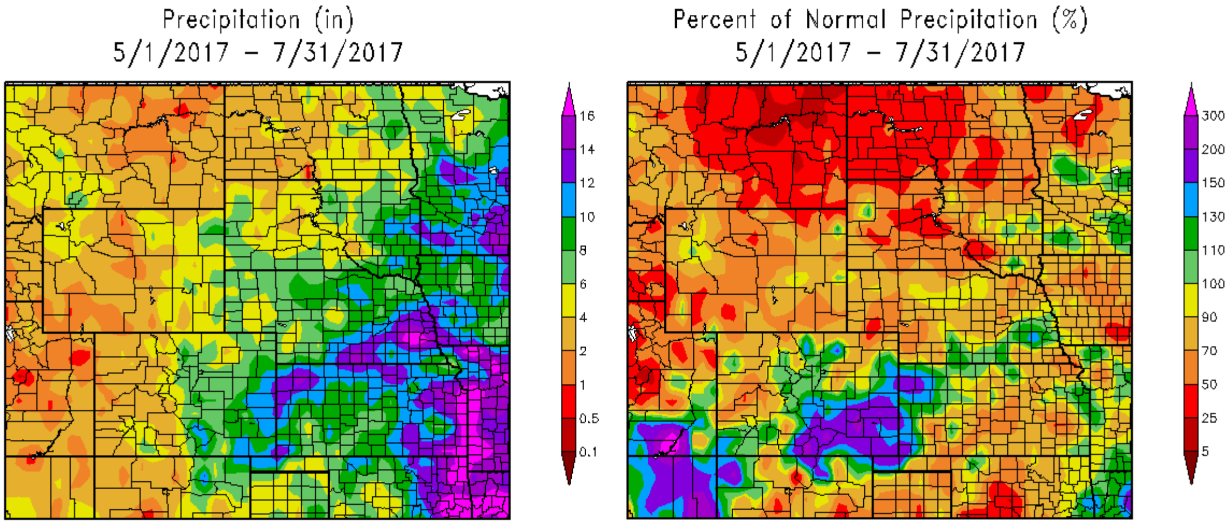


Figure 5. May-June-July 2017 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Temperature

July temperature departures in degrees Fahrenheit (deg F) in the left image of **Figure 6** were 4 – 8 deg F above normal over much of Montana and the western Dakotas, and 2 – 6 deg F above normal over the remainder of the upper Basin. May-June-July temperature departures, in the right image of **Figure 6**, ranged from 2 – 6 deg F above normal in Montana and the western Dakotas, to 0 – 2 deg F above normal in most other areas of the Missouri Basin.

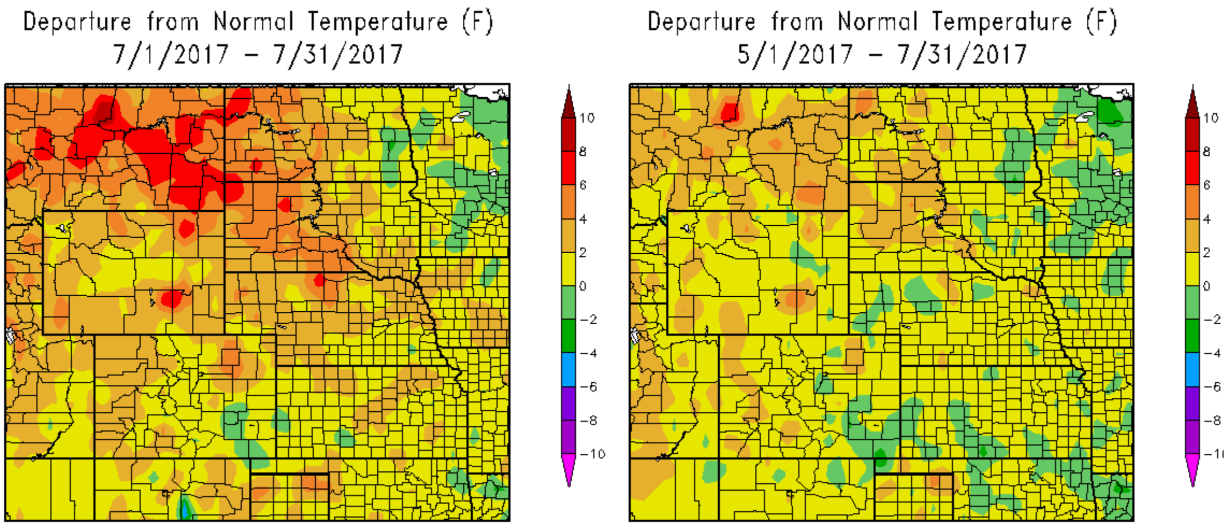
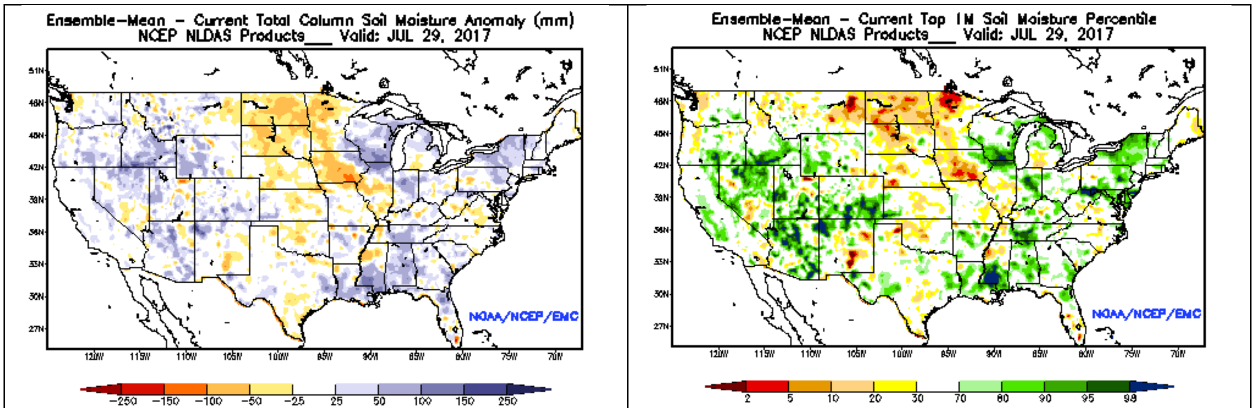


Figure 6. July 2017 and May-June-July 2017 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Soil Moisture

Soil moisture is factored into the forecast as an indicator of wet or dry hydrologic basin conditions. Typically when soil moisture conditions are wet or greater than normal, rainfall and snowmelt runoff is greater than when soil moisture is dry or less than normal. Not only is soil moisture a physical parameter that influences runoff, it can be used as an indicator of future runoff. As the calendar year approaches winter, the soil moisture conditions will provide some insight into late winter and early spring runoff potential.

The left image of **Figure 7** shows the current NOAA NLDAS ensemble top one-meter soil moisture anomaly and the right image of **Figure 7** shows the top one-meter soil moisture percentile on July 29, 2017. The NLDAS image shows the drier-than-normal conditions in the Dakotas spreading further into eastern Montana, Nebraska, and Iowa. Soil moisture anomalies range from -25 to -50 mm (-0.99 to -1.97 inches) over much of the aforementioned area, with more severe anomalies ranging from -50 to -100 mm (-1.97 to -3.94 inches) in eastern North Dakota, central South Dakota, and central Iowa. Soil moisture anomalies continue to be positive in much of western Montana and western Wyoming.



Soil Moisture Anomaly (mm)	Soil Moisture Percentile

Figure 7. NOAA NLDAS Soil Moisture Anomaly (mm) and Soil Moisture Percentile. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

Soil moisture conditions expressed as a percentile ranking can show the severity of the soil moisture conditions through the percentile ranking probability. The NOAA NLDAS soil moisture percentile is shown in the right image of **Figure 7**. The NLDAS percentile ranking, indicates dry soil moisture conditions (less than the 20^{th} percentile rank) throughout many areas of eastern Montana, North Dakota, South Dakota and Iowa. Very dry soil moisture conditions (less than 5^{th} percentile ranking) exist in northeastern Montana, and localized regions throughout North Dakota, South Dakota and south central Iowa.

Mountain Snowpack

Mountain snowpack is the primary factor used to predict May-July runoff volumes in the Fort Peck and Garrison reaches. During the 3-month May-July runoff period, about 50% of the annual runoff in the upper Basin enters the Mainstem System as a result of mountain snowmelt and rainfall runoff. Greater-than-average mountain snow accumulations are usually associated with greater-than-average May-July runoff volumes, especially when mountain soil moisture conditions have been wetter-than-normal. For example, we would expect to see greater-than-average runoff from an average mountain snowpack this year due to wetter-than-normal soil moisture conditions.

Figure 8 includes time series plots of the average mountain SWE beginning on October 1, 2016 based on the NRCS SNOTEL gages for the headwater basin above Fort Peck and the incremental basin from Fort Peck to Garrison. The current average SWE values (shaded blue area) are plotted against the 1981-2010 basin average SWE (bold red line), a recent low SWE year in 2001 (green line), and two historic high SWE years occurring in 1997 (purple) and 2011 (dark blue).

The average mountain SWE in the reach above Fort Peck peaked at 16.1 inches (99% of average) on April 29. The average mountain SWE in the reach between Fort Peck and Garrison peak at 20.9 inches (148% of average) on May 2. The average mountain SWE normally peaks around April 15. By early July, most of the measureable snowpack in both the Fort Peck and Garrison reservoir reaches had melted.

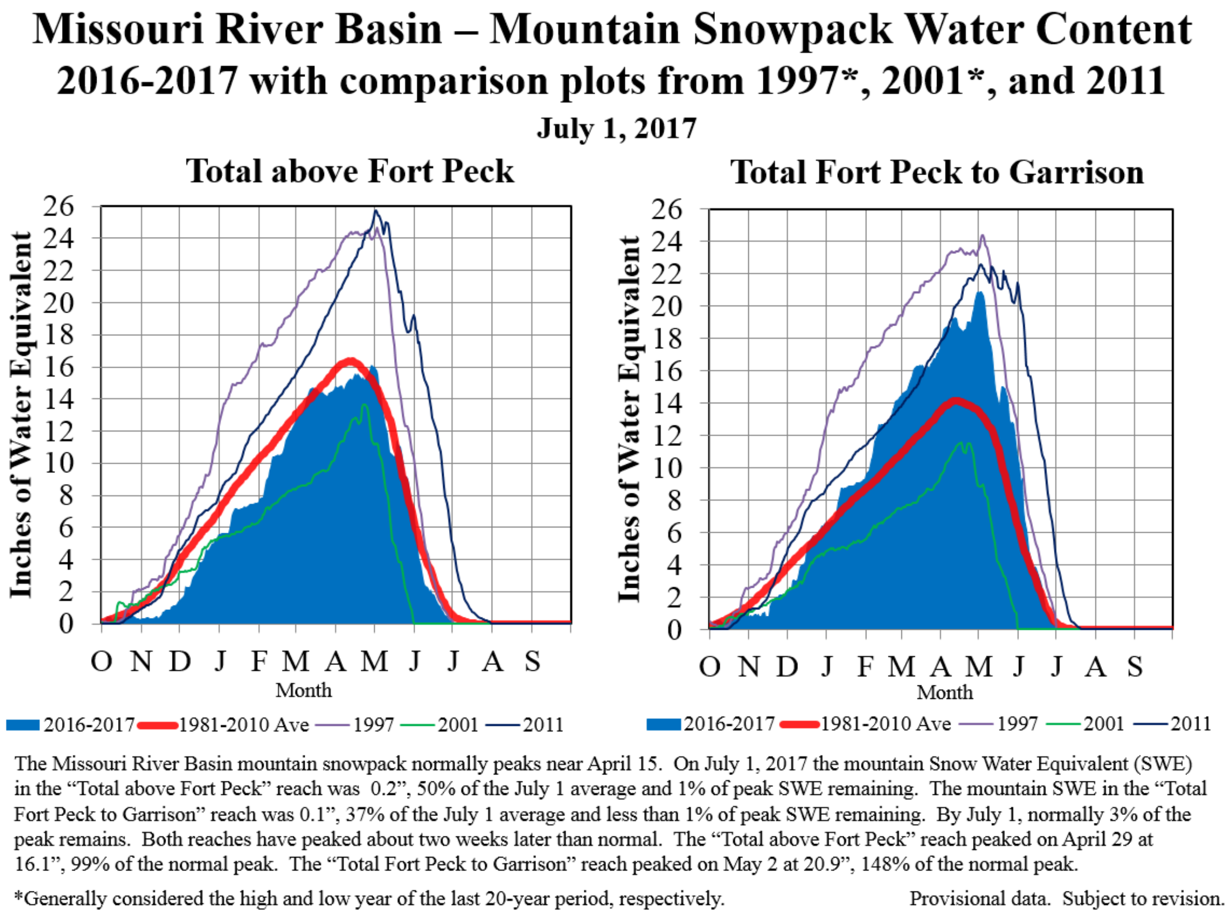


Figure 8. Mountain snowpack water content on July 1, 2017 compared to normal and historic conditions. Corps of Engineers - Missouri River Basin Water Management. Available at http://www.nwd-mr.usace.army.mil/rcc/reports/snow.pdf.

Climate Outlook

MRBWMD participates in the monthly North Central U.S. Climate/Drought Outlook Webinar coordinated through NOAA, the regional climate centers, and the American Association of State Climatologists (AASC). These webinars provide updates on near-term climate outlooks and impacts including the ENSO climate pattern and its implications on winter temperature and precipitation patterns in the Missouri Basin.

ENSO (El Niño Southern Oscillation)

The latest ENSO Outlook updated on July 31, 2017 indicates that ENSO-neutral conditions are present. ENSO-neutral conditions are favored to continue with a 50 to 55% chance into the Northern Hemisphere winter of 2017-2018.

Temperature and Precipitation Outlooks

The NOAA Climate Prediction Center (CPC) outlooks provide the forecasted probability (or chance) of occurrence of future weather conditions during periods ranging from one to 12 months into the future. The CPC outlooks are available at http://www.cpc.ncep.noaa.gov/.

The CPC temperature outlook through August 14 (**Figure 9**) indicate increased chances for above-normal temperatures in Montana, but increased chances for below normal temperatures in Wyoming, much of North Dakota, South Dakota and the lower Basin. The precipitation outlook through August 14 indicates a slight increase in the chance for below-normal precipitation across Montana and the Dakotas. There are increased chances for above-normal precipitation in Wyoming, Colorado, Nebraska, southern Iowa, Kansas and Missouri.

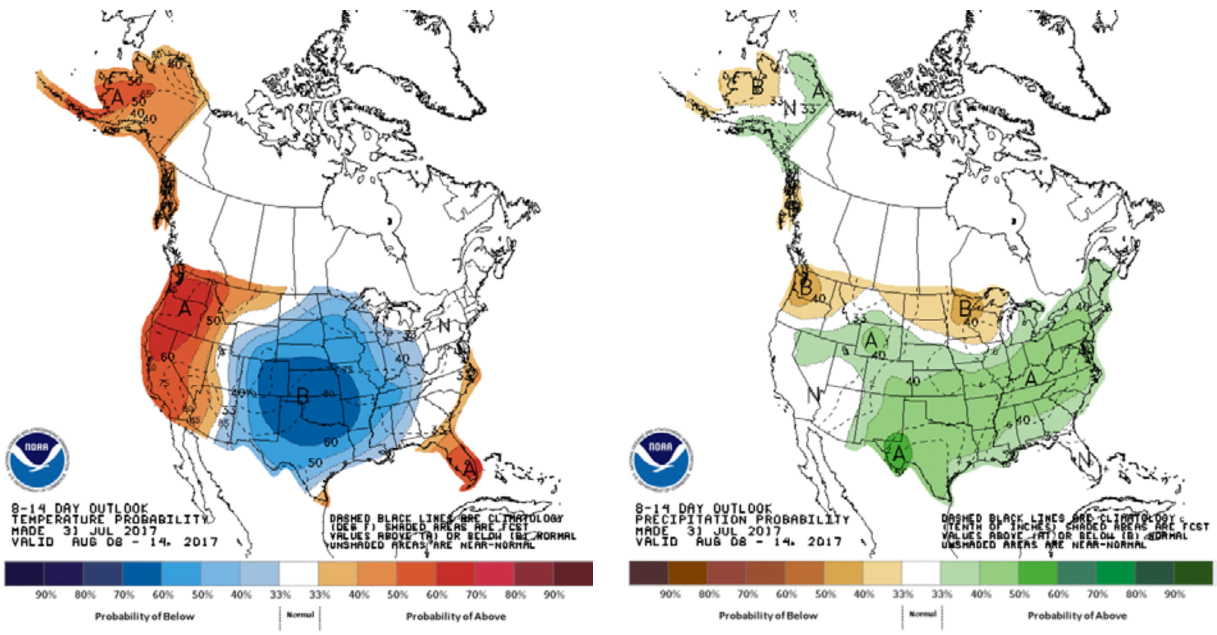


Figure 9. CPC 8-14 Day temperature and precipitation outlooks through August 14, 2017.

The August CPC outlooks in **Figure 10** indicate increased chances for above-normal temperatures and below-normal precipitation in Montana. For the remainder of the upper Basin, there are equal chances for above-normal, normal and below-normal temperatures and precipitation. In the lower Basin, there is an increased chance for below-normal temperatures and equal chances for precipitation.

During the August-September-October period, the CPC outlooks in **Figure 11** indicate increased chances for above-normal temperatures and equal chances for precipitation over the entire Missouri Basin. In the November-December 2017-January 2018 period shown in **Figure 12**, the CPC outlooks indicate similar above-normal temperature and normal precipitation patterns.

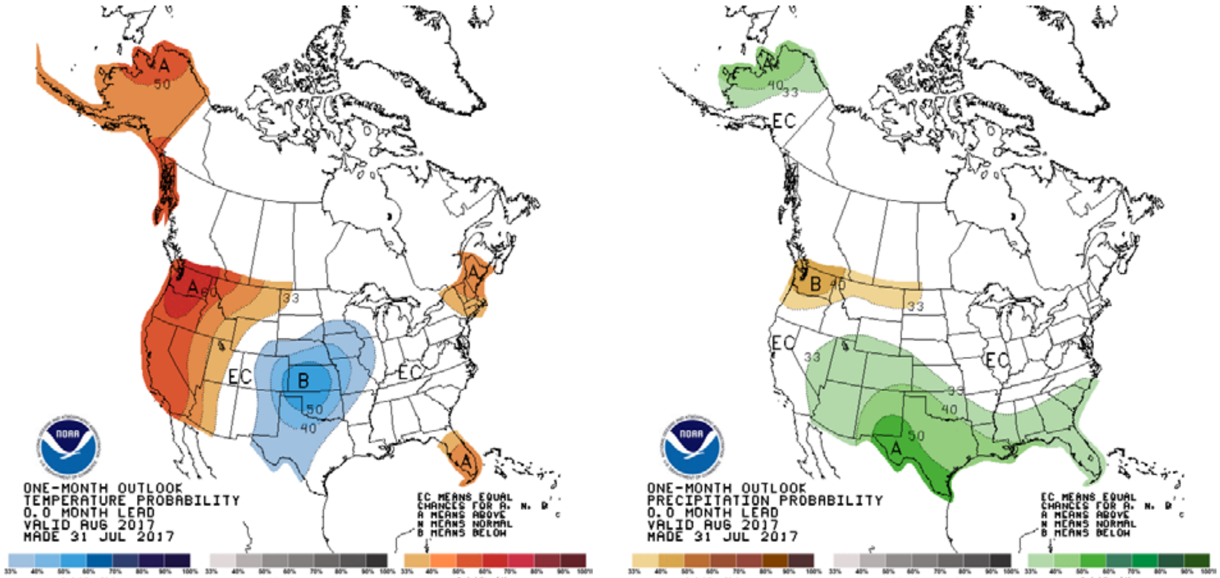


Figure 10. CPC August 2017 temperature and precipitation outlooks.

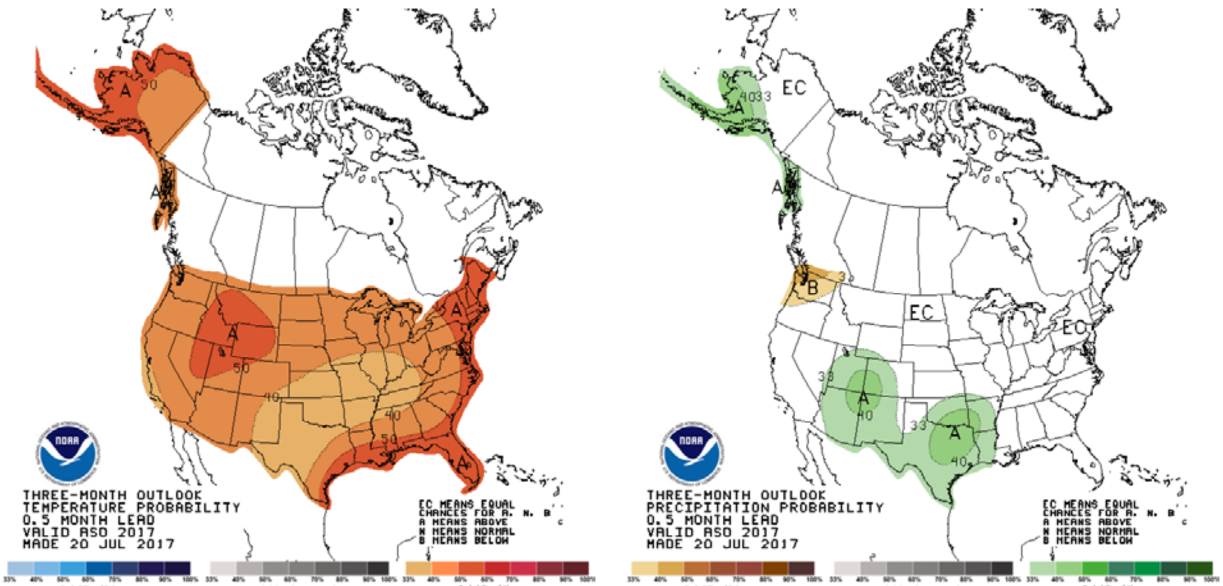


Figure 11. CPC August-September-October 2017 temperature and precipitation outlooks.

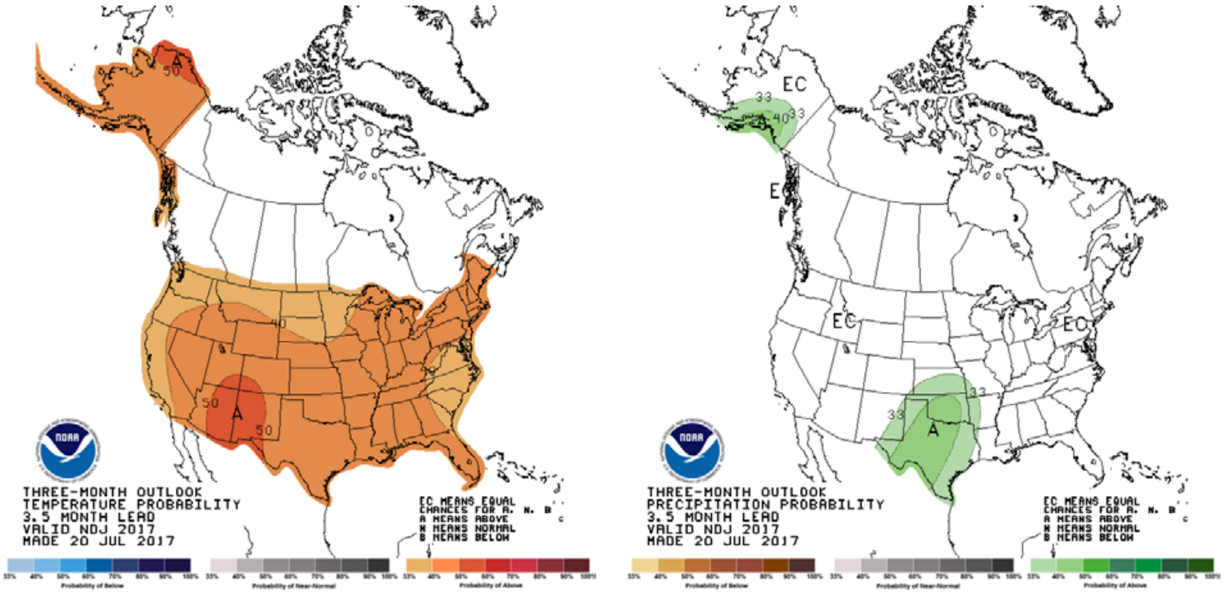


Figure 12. CPC November-December 2017–January 2018 temperature and precipitation outlooks.

Summary

In summary, the 2017 calendar year runoff forecast is **27.9 MAF**, **110% of average**. Considering the high likelihood that drought will continue in much of the upper Basin, well-below average runoff is forecast for all reservoir reaches except the Garrison reach.

Upper Missouri River Basin
September 2017 Calendar Year Runoff Forecast
September 5, 2017

U.S. Army Corps of Engineers, Northwestern Division
Missouri River Basin Water Management
Omaha, NE

Calendar Year Runoff Forecast

Explanation and Purpose of Forecast

The long-range runoff forecast is presented as the Calendar Year Runoff Forecast. The Calendar Year Runoff Forecast is available at http://www.nwd-mr.usace.army.mil/rcc/reports/runoff.pdf. This forecast is developed shortly after the beginning of each calendar year and is updated at the beginning of each month to show the actual runoff for historic months of that year and the updated forecast for the remaining months of the year. This forecast presents monthly inflows in million acre-feet (MAF) from five incremental drainage areas, as defined by the individual System projects, plus the incremental drainage area between Gavins Point Dam and Sioux City. Due to their close proximity, the Big Bend and Fort Randall drainage areas are combined. Summations are provided for the total Missouri River reach above Gavins Point Dam and for the total Missouri Basin above Sioux City (upper Basin). The Calendar Year Runoff Forecast is used in the Monthly Study simulation model to plan future system regulation in order to meet the authorized project purposes throughout the calendar year.

Observed Runoff

August runoff in the upper Basin was 129% of average. Runoff in the Fort Peck reach, which was 78% of average due to the drought conditions in Montana, was the only reach below normal. Runoff was more than 3 times the average in the Oahe and Fort Randall reaches. In the other 3 reaches, August runoff was slightly above average.

2017 Calendar Year Forecast Synopsis

The 2017 calendar year runoff forecast for the upper Missouri Basin above Sioux City, IA, updated on September 1, is **28.7 MAF (113% of average).** The 2017 calendar year runoff forecast above Gavins Point Dam is **25.5 MAF (111% of average)**.

Due to the amount of variability in precipitation and other hydrologic factors that can occur over the next 4 months, the range of expected inflow ranges from the 29.7 MAF upper basic forecast to the 27.8 MAF lower basic forecast. The upper and lower basic forecasts are used in long-term regulation planning models to “bracket” the range of expected runoff given much wetter or drier conditions, respectively. Given that 4 months are being forecast for this September 1 forecast (8 months observed/4 months forecast), the range of wetter-than-expected (upper basic) and drier-than-expected (lower basic) conditions is attributed to all 6 reaches for all 4 months. The result is a range or "bracket" for each reach, and thus, for the total runoff forecast. As the year progresses, the range will lessen as the number of observed months increases and the number of forecast months decreases.

Current Conditions

Drought Analysis

The latest National Drought Mitigation Center's drought monitor for August 29, 2017 (**Figure 1**), is compared to the drought monitor for July 25, 2017 (**Figure 2**). The drought monitor is available at http://droughtmonitor.unl.edu/. The U.S. Drought Monitor shows drought conditions in all states of the Missouri Basin and over a majority of the upper Basin. In Montana, 90% of the state is impacted by drought (D1 to D4), and 40% of the state is impacted by Extreme (D3) and Exceptional (D4) Drought. The most severe drought conditions in Montana are present over the northeastern quarter of the state. In North Dakota, 66% of the state is impacted by drought, and 22% is impacted by D3 and D4 Drought, most of which is in western North Dakota. In South Dakota, 69% of the state is impacted by drought, and 6% is impacted by D3 and D4 Drought. The most severe conditions are in north central South Dakota. Comparing **Figure 1** and **Figure 2**, drought conditions improved in the Dakotas and worsened in Montana between July 25 and August 29. The Seasonal Drought Outlook in **Figure 3** indicates that drought conditions will persist in Montana and the Dakotas through November 30. Some additional drought development is likely in Montana, and drought removal is likely for some areas of South Dakota.

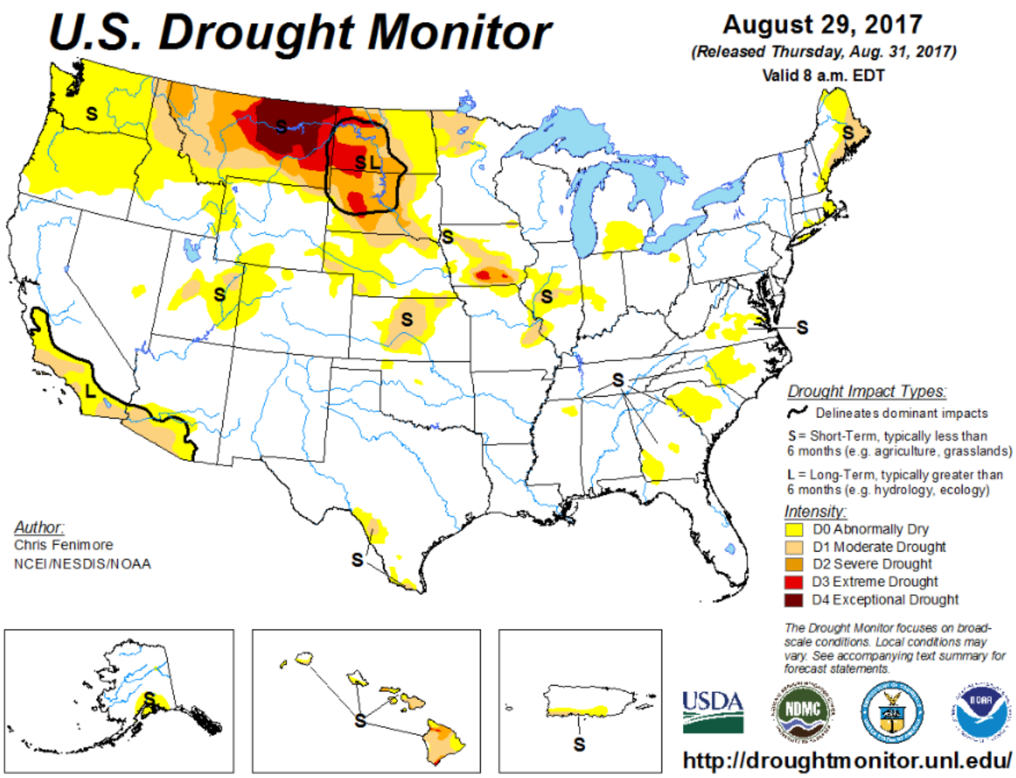


Figure 1. National Drought Mitigation Center U.S. Drought Monitor for July 25, 2017.

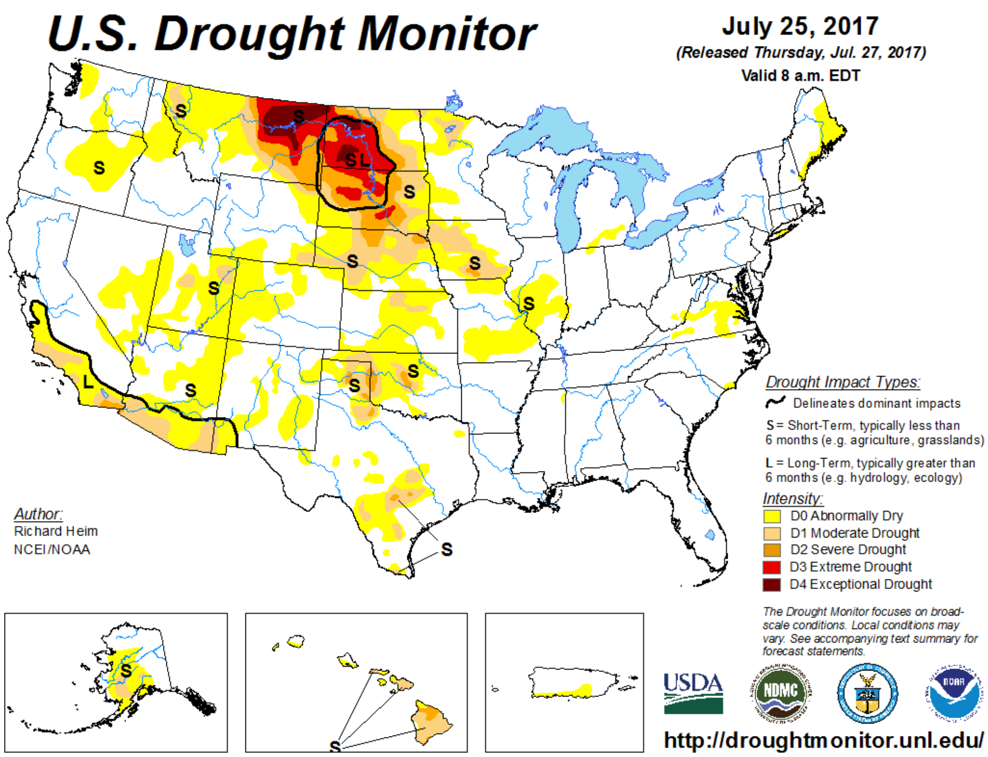


Figure 2. National Drought Mitigation Center U.S. Drought Monitor for July 25, 2017.

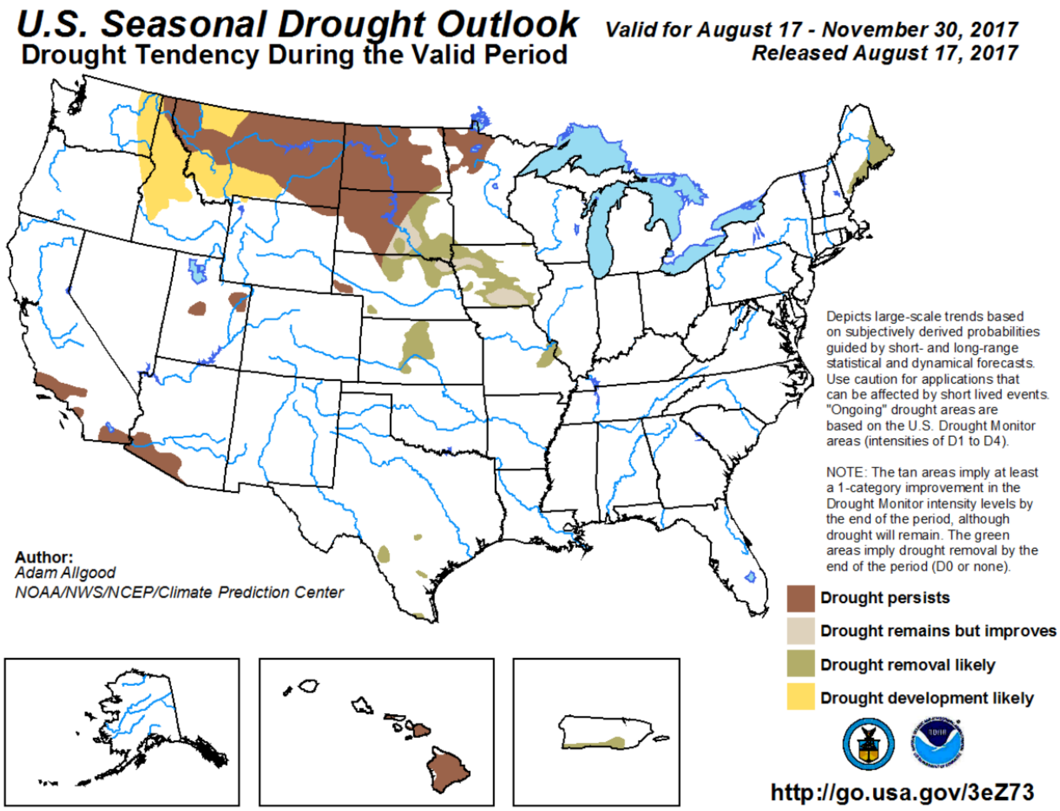


Figure 3. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

Monthly precipitation accumulations are shown using High Plains Regional Climate Center images available at http://www.hprcc.unl.edu/. The August precipitation accumulations are shown in **Figure 4** as inches of precipitation (left) and percent of normal precipitation (right). July precipitation was well-below average (less than 50% of average) in much of Montana. This resulted in below-average August runoff in the Fort Peck reach. July precipitation was well-above average (greater than 150% of average) in large areas of North Dakota, South Dakota, and Nebraska. This resulted in more than 3 times the average runoff for August in the Oahe and Fort Randall reaches. June-July-August precipitation accumulations are shown in **Figure 5**. The 3-month accumulations reflect a seasonally dry precipitation pattern in the upper Basin, particularly in Montana, where precipitation was less than 50% of normal.

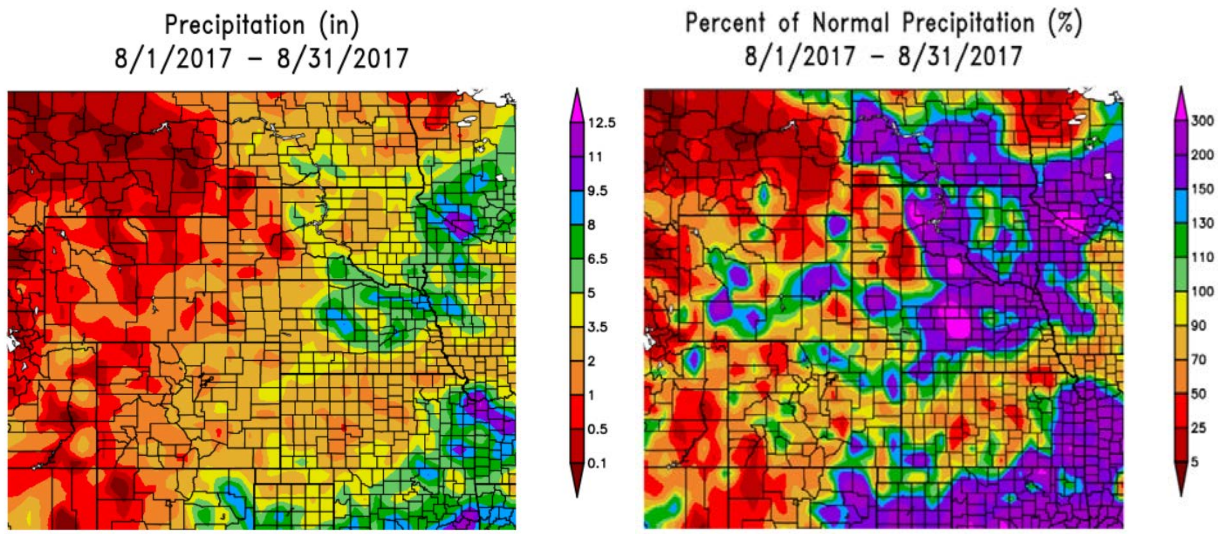


Figure 4. August 2017 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

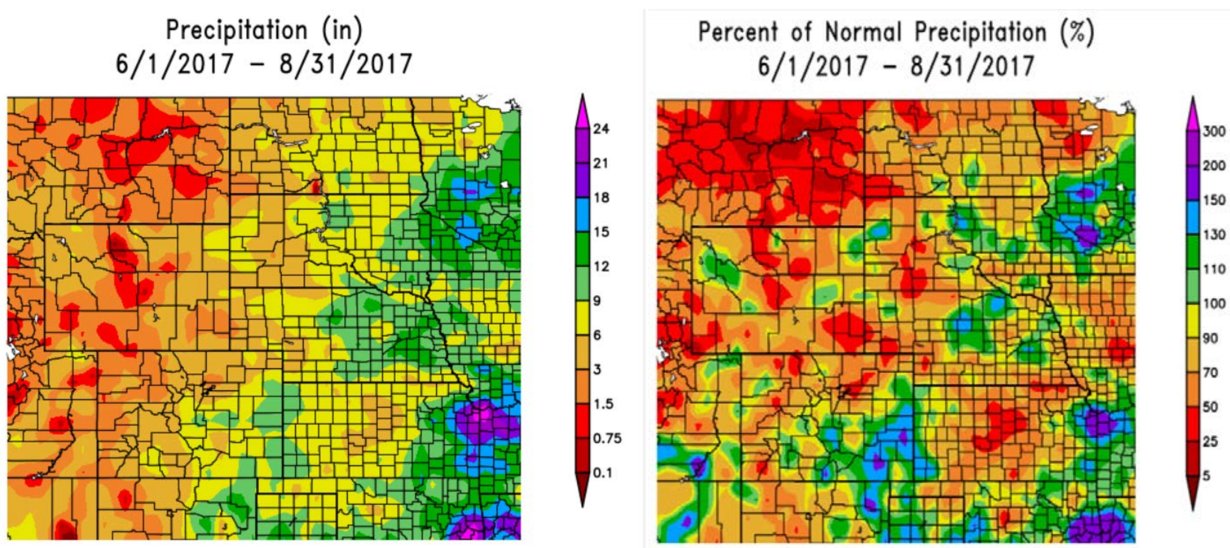


Figure 5. June-July-August 2017 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Temperature

August temperature departures in degrees Fahrenheit (deg F) in the left image of **Figure 6** were 0-2 deg F above normal over western Montana, dropping to 4-6 deg F below normal progressing southeast through the Basin. June-July-August temperature departures, in the right image of **Figure 6**, ranged from 4-5 deg F above normal in the northwestern portion of the Basin, to 1 – 2 deg F below normal in the southeastern portion of the Basin.

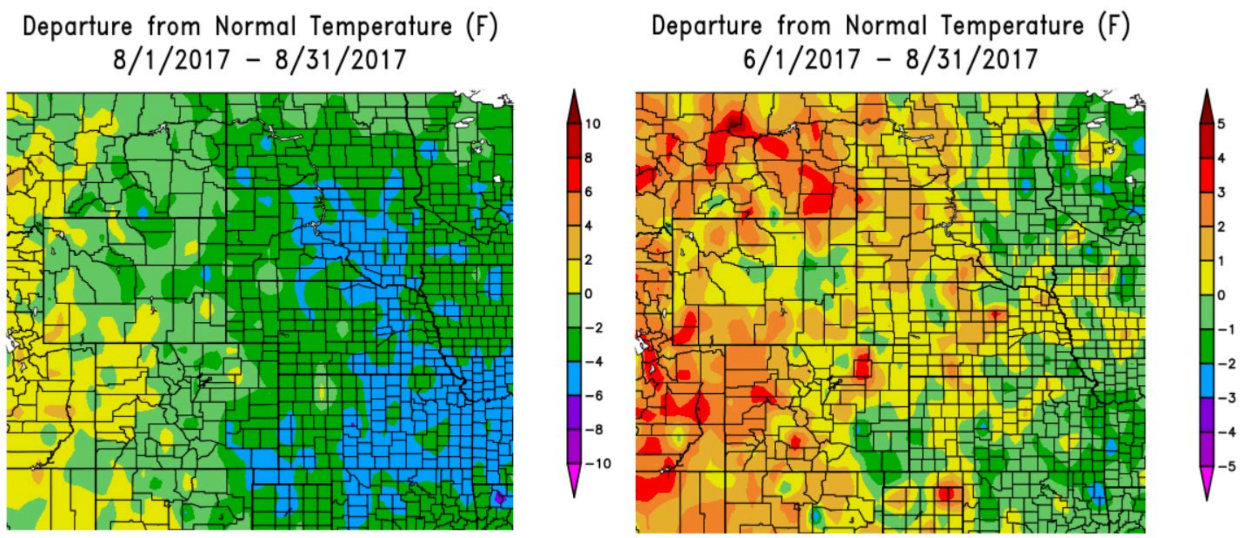
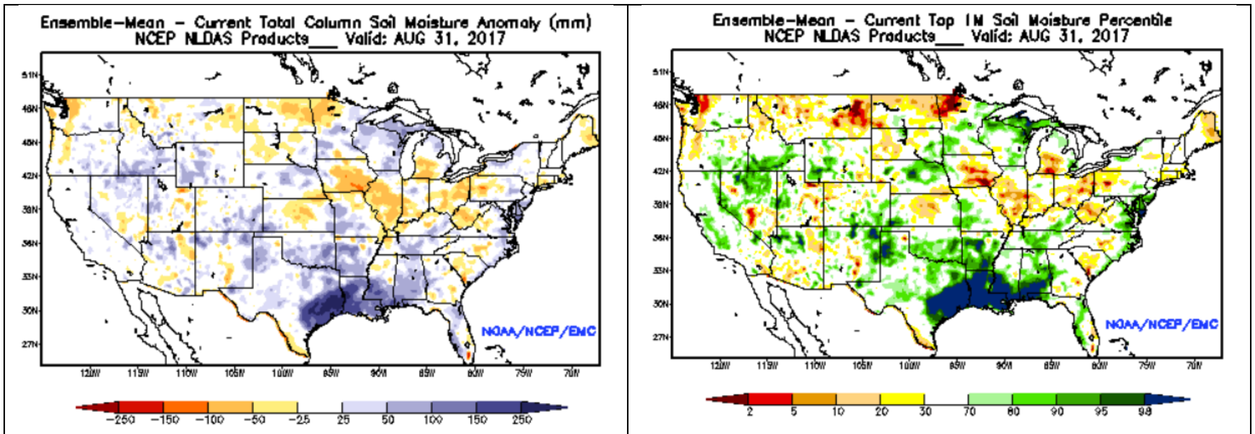


Figure 6. August 2017 and June-July-August 2017 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Soil Moisture

Soil moisture is factored into the forecast as an indicator of wet or dry hydrologic basin conditions. Typically when soil moisture conditions are wet or greater than normal, rainfall and snowmelt runoff is greater than when soil moisture is dry or less than normal. Not only is soil moisture a physical parameter that influences runoff, it can be used as an indicator of future runoff. As the calendar year approaches winter, the soil moisture conditions will provide some insight into late winter and early spring runoff potential.

The left image of **Figure 7** shows the current NOAA NLDAS ensemble top one-meter soil moisture anomaly and the right image of **Figure 7** shows the top one-meter soil moisture percentile on August 31, 2017. The NLDAS image shows the drier-than-normal conditions in the Dakotas spreading further into eastern Montana, Kansas, and Iowa. Soil moisture anomalies range from -25 to -50 mm (-0.99 to -1.97 inches) over much of the aforementioned area, with more severe anomalies ranging from -50 to -100 mm (-1.97 to -3.94 inches) in eastern North Dakota, areas of Montana, and central Iowa. Soil moisture anomalies are positive in most of Nebraska and Wyoming.



Soil Moisture Anomaly (mm)	Soil Moisture Percentile

Figure 7. NOAA NLDAS Soil Moisture Anomaly (mm) and Soil Moisture Percentile. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

Soil moisture conditions expressed as a percentile ranking can show the severity of the soil moisture conditions through the percentile ranking probability. The NOAA NLDAS soil moisture percentile is shown in the right image of **Figure 7**. The NLDAS percentile ranking indicates dry soil moisture conditions (less than the 20th percentile rank) throughout many areas of Montana, North Dakota, South Dakota and Iowa. Very dry soil moisture conditions (less than 5th percentile ranking) exist in northeastern Montana and localized regions throughout North Dakota and south central Iowa.

Mountain Snowpack

Mountain snowpack is the primary factor used to predict May-July runoff volumes in the Fort Peck and Garrison reaches. During the 3-month May-July runoff period, about 50% of the annual runoff in the upper Basin enters the Mainstem System as a result of mountain snowmelt and rainfall runoff. Greater-than-average mountain snow accumulations are usually associated with greater-than-average May-July runoff volumes, especially when mountain soil moisture conditions have been wetter-than-normal. For example, we would expect to see greater-than-average runoff from an average mountain snowpack this year due to wetter-than-normal soil moisture conditions.

Figure 8 includes time series plots of the average mountain SWE beginning on October 1, 2016 based on the NRCS SNOTEL gages for the headwater basin above Fort Peck and the incremental basin from Fort Peck to Garrison. The current average SWE values (shaded blue area) are plotted against the 1981-2010 basin average SWE (bold red line), a recent low SWE year in 2001 (green line), and two historic high SWE years occurring in 1997 (purple) and 2011 (dark blue).

The average mountain SWE in the reach above Fort Peck peaked at 16.1 inches (99% of average) on April 29. The average mountain SWE in the reach between Fort Peck and Garrison peak at 20.9 inches (148% of average) on May 2. The average mountain SWE normally peaks around April 15. By early July, most of the measureable snowpack in both the Fort Peck and Garrison reservoir reaches had melted.

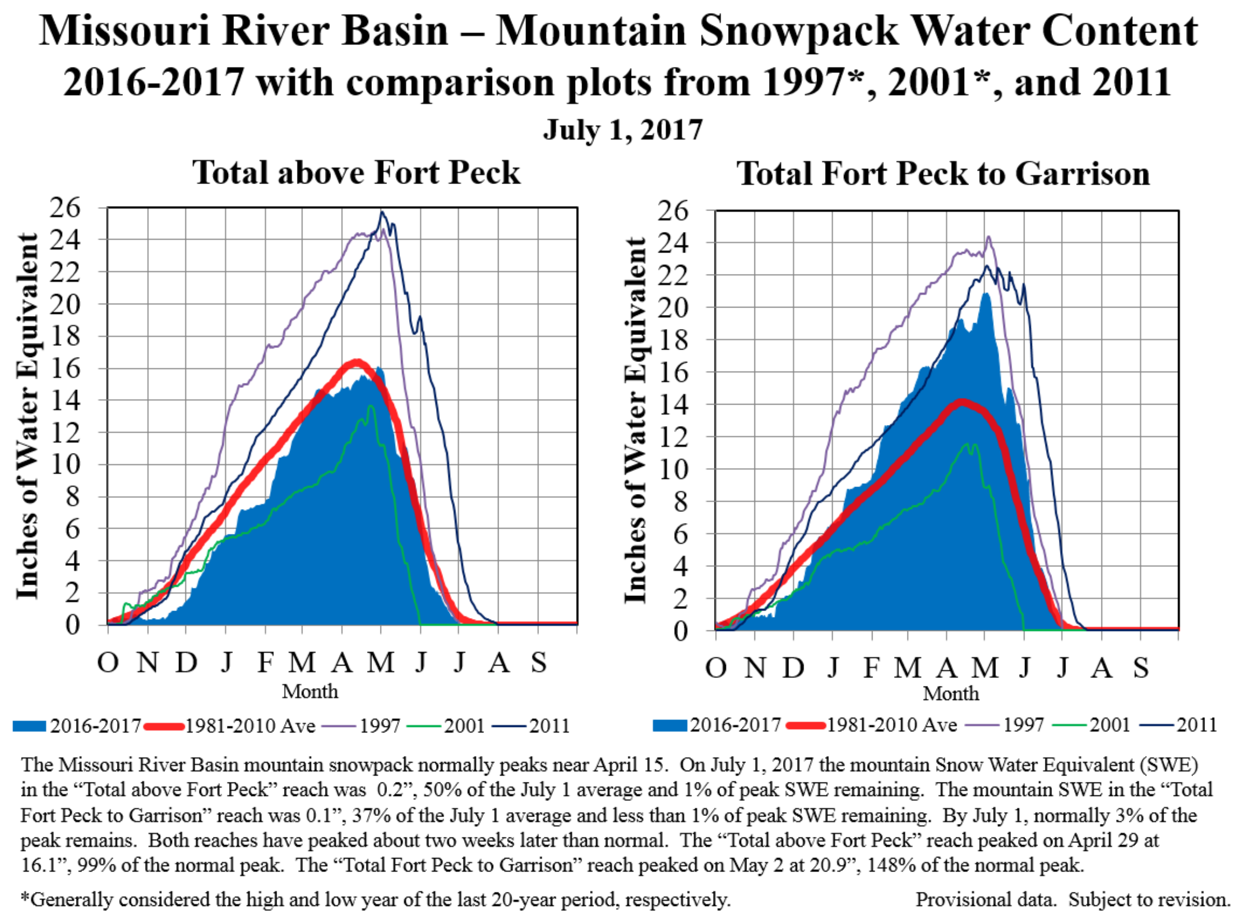


Figure 8. Mountain snowpack water content on July 1, 2017 compared to normal and historic conditions. Corps of Engineers - Missouri River Basin Water Management. Available at http://www.nwd-mr.usace.army.mil/rcc/reports/snow.pdf.

Climate Outlook

MRBWMD participates in the monthly North Central U.S. Climate/Drought Outlook Webinar coordinated through NOAA, the regional climate centers, and the American Association of State Climatologists (AASC). These webinars provide updates on near-term climate outlooks and impacts including the ENSO climate pattern and its implications on winter temperature and precipitation patterns in the Missouri Basin.

ENSO (El Niño Southern Oscillation)

The latest ENSO Outlook indicates that ENSO-neutral conditions are present. ENSO-neutral conditions are favored to continue into the Northern Hemisphere winter of 2017-2018.

Temperature and Precipitation Outlooks

The NOAA Climate Prediction Center (CPC) outlooks provide the forecasted probability (or chance) of occurrence of future weather conditions during periods ranging from 1 to 12 months into the future. The CPC outlooks are available at http://www.cpc.ncep.noaa.gov/.

The CPC temperature outlook through September 18 (**Figure 9**) indicates increased chances for above-normal temperatures in the upper Basin, but increased chances for below normal temperatures in the lower Basin. The precipitation outlook through September 18 indicates a increase in the chance for below-normal precipitation over most of the basin, with normal chances in Montana.

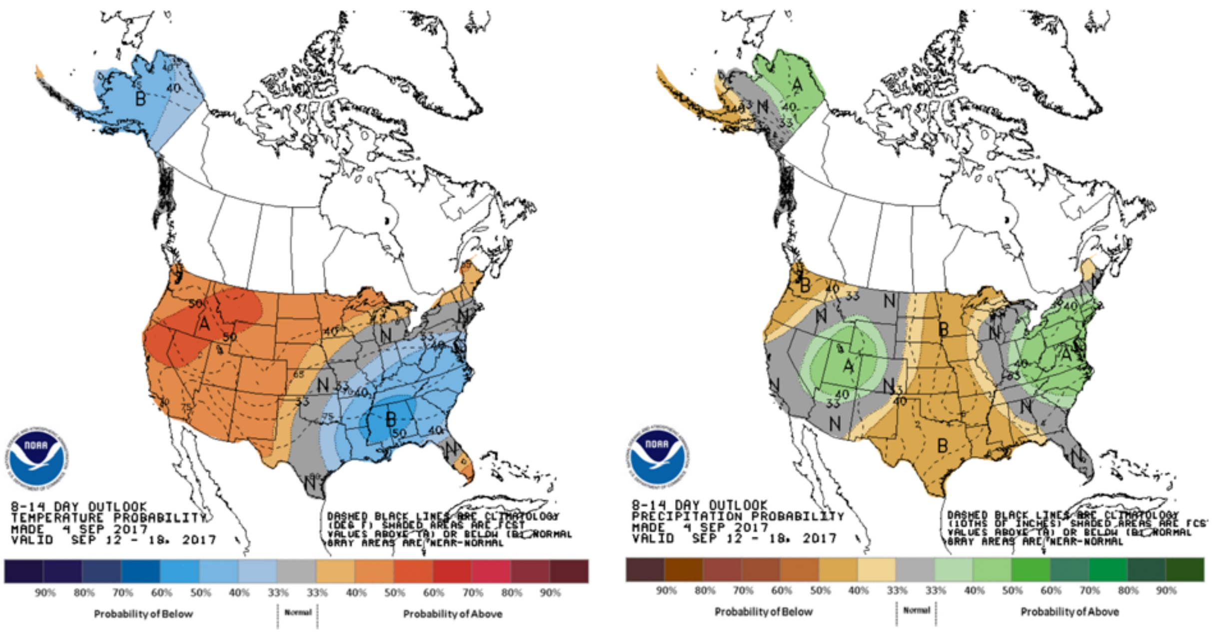


Figure 9. CPC 8-14 Day temperature and precipitation outlooks through September 18, 2017.

The September CPC outlooks in **Figure 10** indicate increased chances for above-normal temperatures in the upper Basin and below-normal temperatures in the lower Basin, with equal chances in between. Increased chances for below-normal precipitation are indicated for the entire Basin during September.

During the September-October-November period, the CPC outlooks in **Figure 11** indicate increased chances for above-normal temperatures and equal chances for precipitation over the entire Missouri Basin. In the December 2017-January 2018-February 2018 period shown in **Figure 12**, the CPC outlooks indicate similar above-normal to normal temperature and normal precipitation patterns.

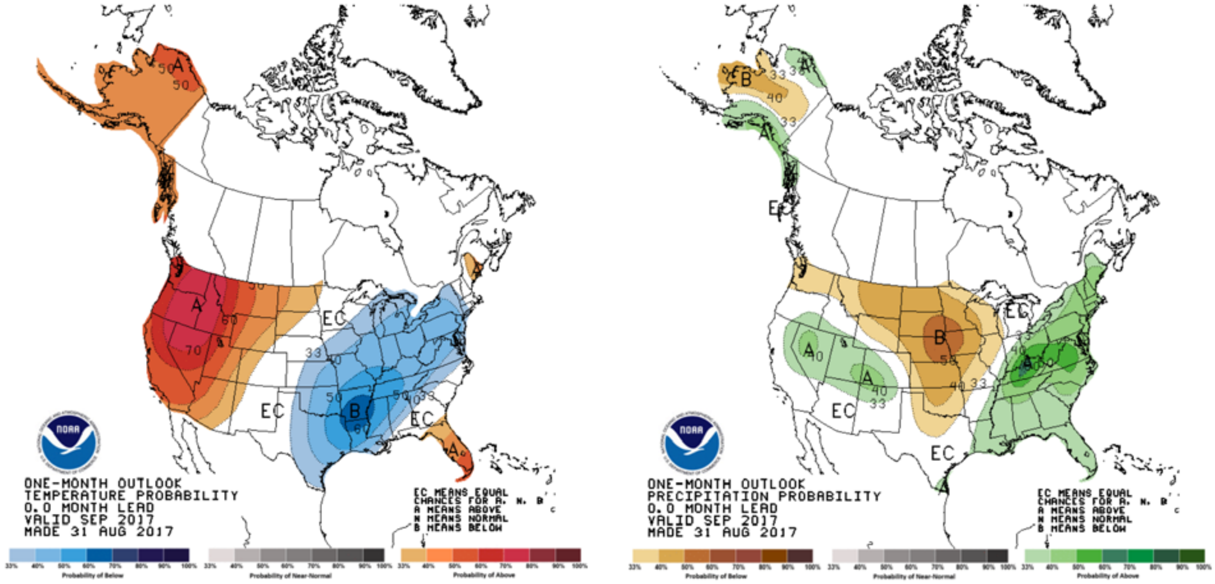


Figure 10. CPC September 2017 temperature and precipitation outlooks.

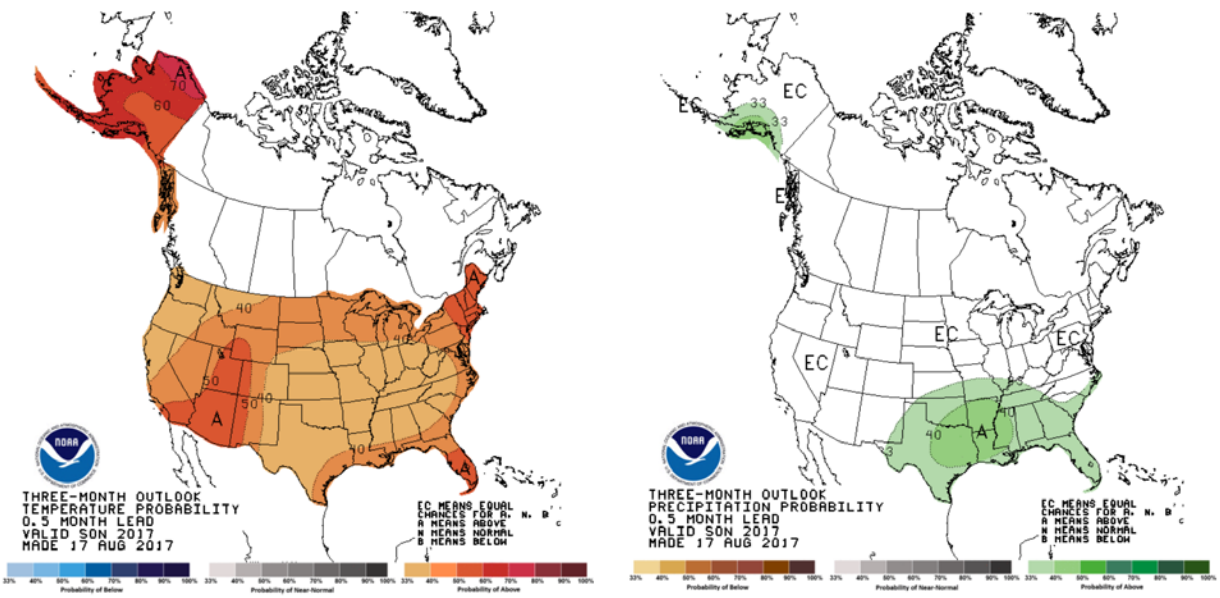


Figure 11. CPC September-October-November 2017 temperature and precipitation outlooks.

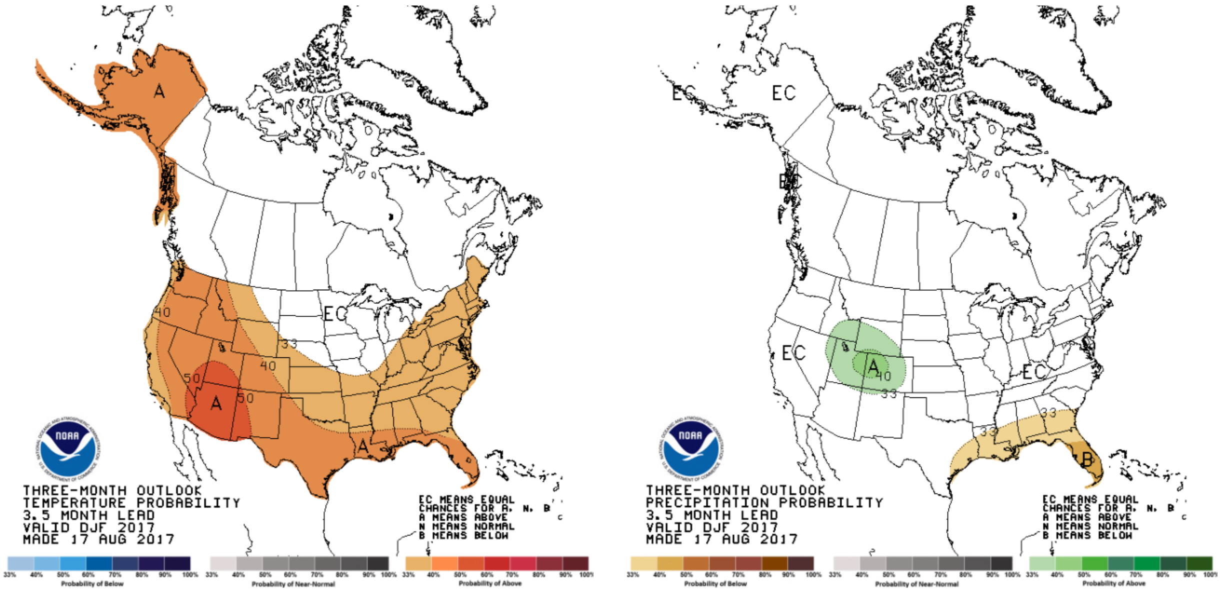


Figure 12. CPC December 2017–January 2018-February 2018 temperature and precipitation outlooks.

Summary

In summary, the 2017 calendar year runoff forecast is **28.7 MAF**, **113% of average**. Historically, the upper Basin runoff for the last 4 months of the calendar year has been about 4 million acre-feet. Similar runoff is forecast for the remaining 4 months of 2017.

Upper Missouri River Basin
October 2017 Calendar Year Runoff Forecast
October 3, 2017

U.S. Army Corps of Engineers, Northwestern Division
Missouri River Basin Water Management
Omaha, NE

Calendar Year Runoff Forecast

Explanation and Purpose of Forecast

The long-range runoff forecast is presented as the Calendar Year Runoff Forecast. The Calendar Year Runoff Forecast is available at http://www.nwd-mr.usace.army.mil/rcc/reports/runoff.pdf. This forecast is developed shortly after the beginning of each calendar year and is updated at the beginning of each month to show the actual runoff for historic months of that year and the updated forecast for the remaining months of the year. This forecast presents monthly inflows in million acre-feet (MAF) from five incremental drainage areas, as defined by the individual System projects, plus the incremental drainage area between Gavins Point Dam and Sioux City. Due to their close proximity, the Big Bend and Fort Randall drainage areas are combined. Summations are provided for the total Missouri River reach above Gavins Point Dam and for the total Missouri Basin above Sioux City (upper Basin). The Calendar Year Runoff Forecast is used in the Monthly Study simulation model to plan future system regulation in order to meet the authorized project purposes throughout the calendar year.

Observed Runoff

The September runoff summation for the upper Basin above Sioux City was 91% of average. The September runoff summation for the upper Basin above Gavins Point was 81% of average. Even though precipitation in many areas of the upper Basin was greater than 150% of normal, runoff in the Fort Peck and Garrison reaches was well-below average due to the current drought conditions. Runoff in the lower four reaches was average to above average due to above-normal precipitation in these reaches.

2017 Calendar Year Forecast Synopsis

The 2017 calendar year runoff forecast for the upper Missouri Basin above Sioux City, IA, updated on October 1, is **28.5 MAF (112% of average).** The 2017 calendar year runoff forecast above Gavins Point Dam is **25.1 MAF (109% of average)**.

Due to the amount of variability in precipitation and other hydrologic factors that can occur over the next 3 months, the range of expected inflow ranges from the 29.2 MAF upper basic forecast to the 27.9 MAF lower basic forecast. The upper and lower basic forecasts are used in long-term regulation planning models to “bracket” the range of expected runoff given much wetter or drier conditions, respectively. Given that 3 months are being forecast for this October 1 forecast (9 months observed/3 months forecast), the range of wetter-than-expected (upper basic) and drier-than-expected (lower basic) conditions is attributed to all 6 reaches for all 3 months. The result is a range or "bracket" for each reach, and thus, for the total runoff forecast. As the year progresses, the range will lessen as the number of observed months increases and the number of forecast months decreases.

Current Conditions

Drought Analysis

The latest National Drought Mitigation Center's drought monitor for September 26, 2017 (**Figure 1**), is compared to the drought monitor for August 29, 2017 (**Figure 2**). The drought monitor is available at http://droughtmonitor.unl.edu/. The U.S. Drought Monitor shows drought conditions in all states of the Missouri Basin and over a majority of the upper Basin. In Montana, about 86% of the state is impacted by drought (D1 to D4), and 43% of the state is impacted by Extreme (D3) and Exceptional (D4) Drought. The most severe drought conditions in Montana are present over the northeastern quarter of the state. In North Dakota, 63% of the state is impacted by drought, and only 3% is impacted by D3 and D4 Drought. In South Dakota, 59% of the state is impacted by drought, and 6% is impacted by D3 and D4 Drought. Comparing **Figure 1** and **Figure 2**, drought conditions improved between August 29 and September 26 in all areas, particularly western North Dakota due to above-normal rainfall. The Seasonal Drought Outlook in **Figure 3** indicates that drought conditions will persist in Montana and the Dakotas through December 31. Some drought improvement is possible in western Montana; however, drought conditions are expected to remain in all areas.

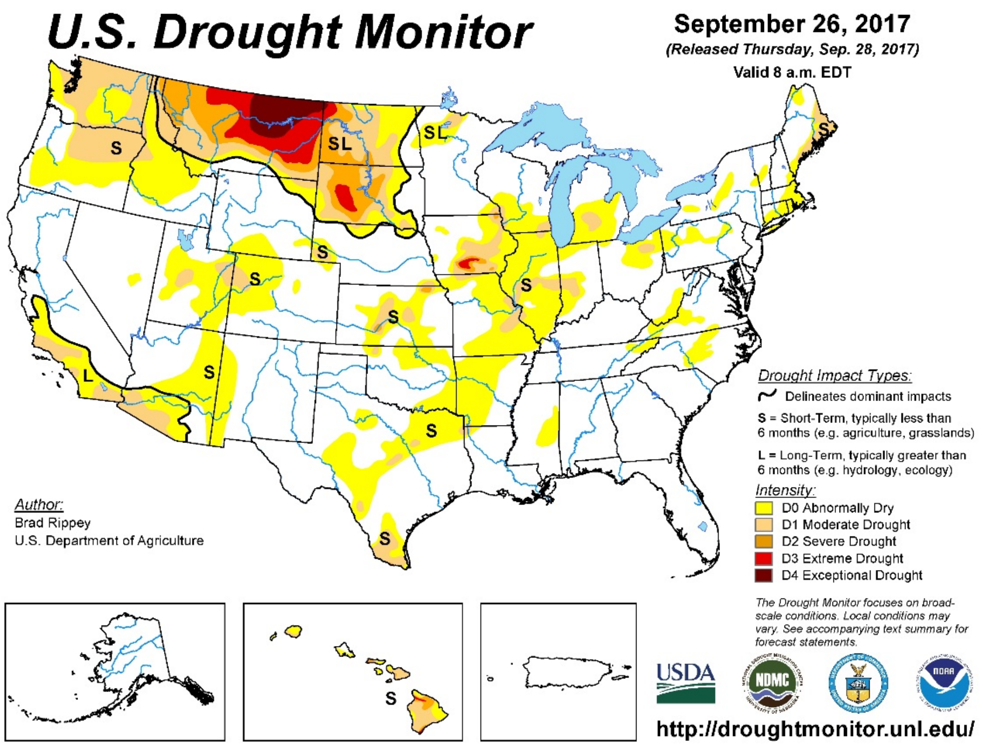


Figure 1. National Drought Mitigation Center U.S. Drought Monitor for September 26, 2017.

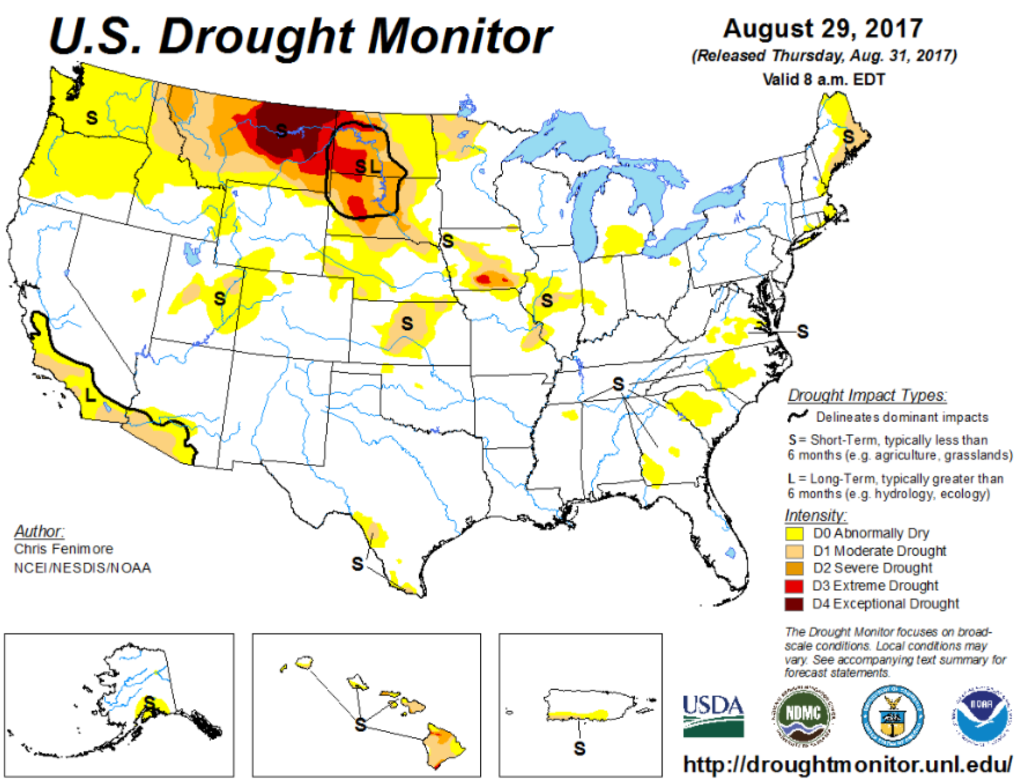


Figure 2. National Drought Mitigation Center U.S. Drought Monitor for August 29, 2017.

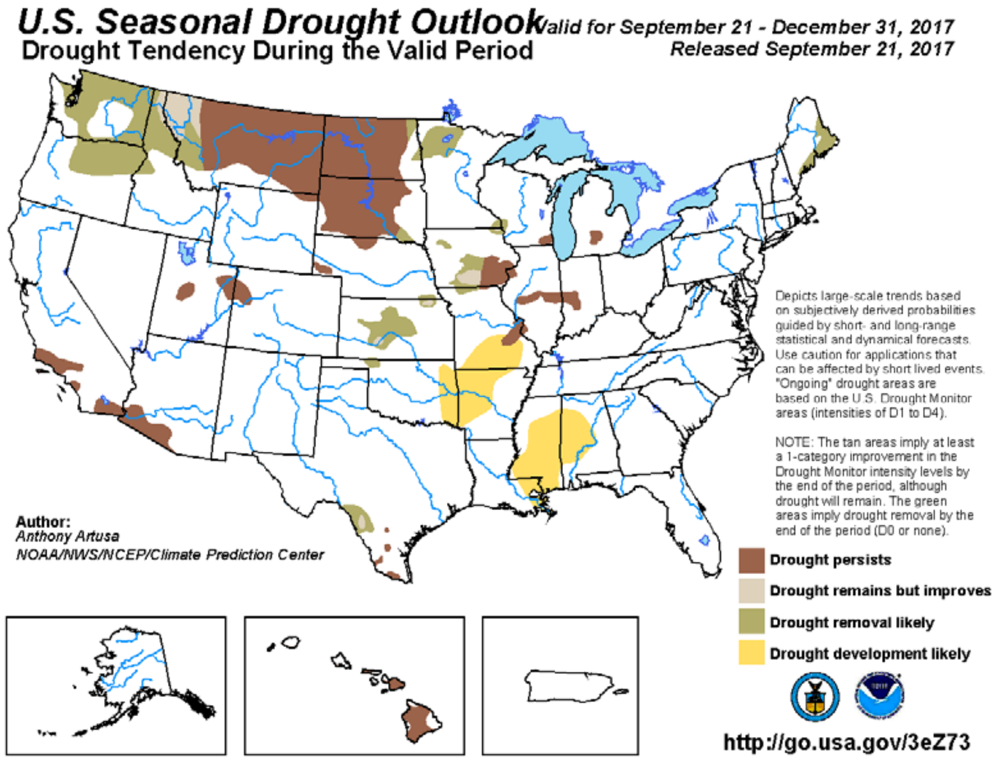


Figure 3. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

Monthly precipitation accumulations are shown using High Plains Regional Climate Center images available at http://www.hprcc.unl.edu/. The September precipitation accumulations are shown in **Figure 4** as inches of precipitation (left) and percent of normal precipitation (right). September precipitation was more than 150% of average in central and southern Montana, western and northern Wyoming, portions of the western Dakotas, western Nebraska and eastern South Dakota. Despite the above-normal precipitation in Montana, Wyoming and the western Dakotas, September runoff in Fort Peck and Garrison was below average. During the storms that produced the majority of this precipitation, the mountainous areas received moderate to heavy accumulating snowfall. In eastern Kansas and Missouri precipitation was less than 50% of normal. Precipitation was also below normal in central and southeastern South Dakota and most of Iowa.

July-August-September precipitation accumulations are shown in **Figure 5**. The three-month accumulations reflect a dry precipitation pattern in much of Montana; however, wetter-than-normal areas have emerged due to September precipitation. The three-month accumulations were above normal in southern Montana and northwestern Wyoming. Heavy September rainfall has also increased three-month percent-of-normal accumulations in central Nebraska and parts of eastern South Dakota.

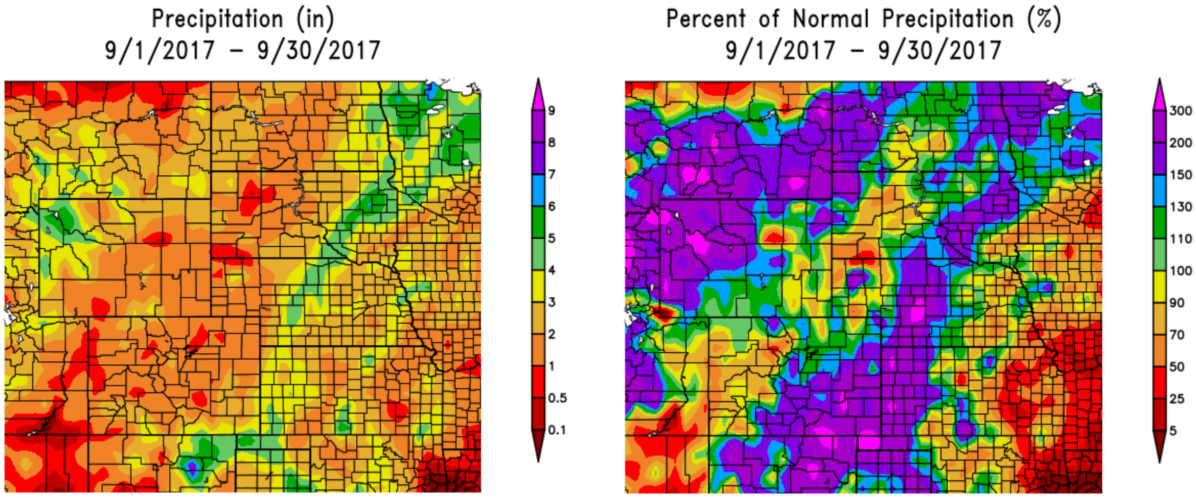


Figure 4. September 2017 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

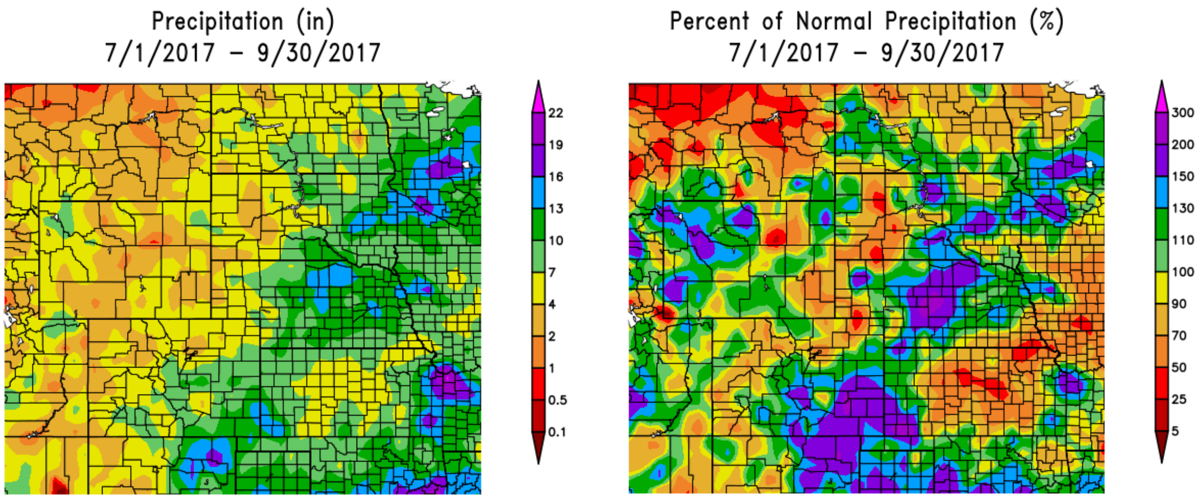


Figure 5. July-August-September 2017 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Temperature

September temperature departures in degrees Fahrenheit (deg F) in the left image of **Figure 6** were 0 to 2 deg F below normal over portions of southern and western Montana, central and northern Wyoming, and western North Dakota. Elsewhere in the upper Basin, temperatures generally ranged from near normal to 2 deg F above normal. Warmer-than-normal temperatures ranging from 2 to 5 deg F above normal were prevalent in eastern South Dakota, central and eastern Nebraska, Iowa, Kansas and northern Missouri. July-August-September temperature departures, in the right image of **Figure 6**, ranged from 1 to 4 deg F above normal in Montana, and 1 deg F below normal to 2 deg F above normal in other areas of the upper Basin. In the lower Basin, temperatures were normal to 1 deg F below normal.

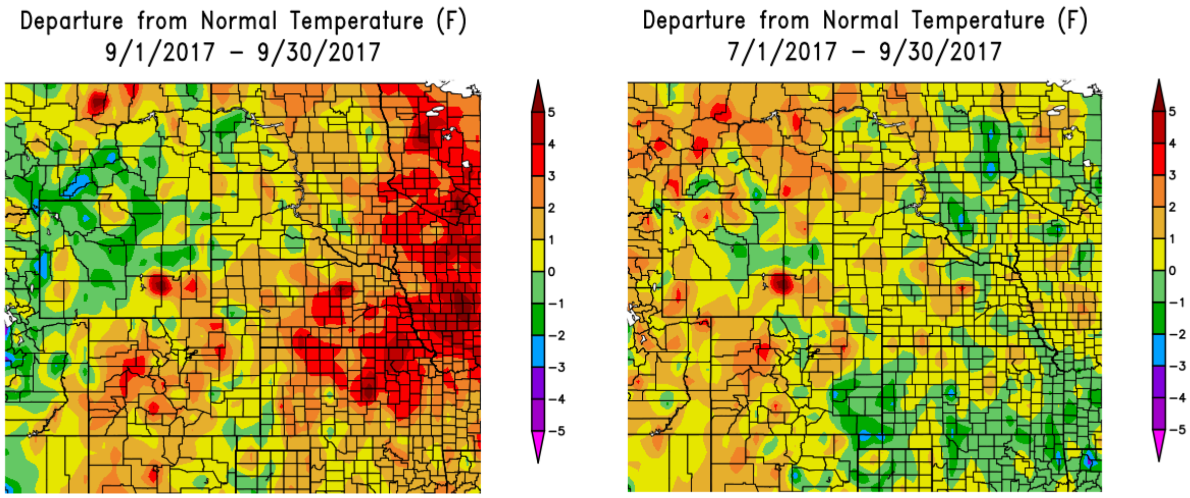
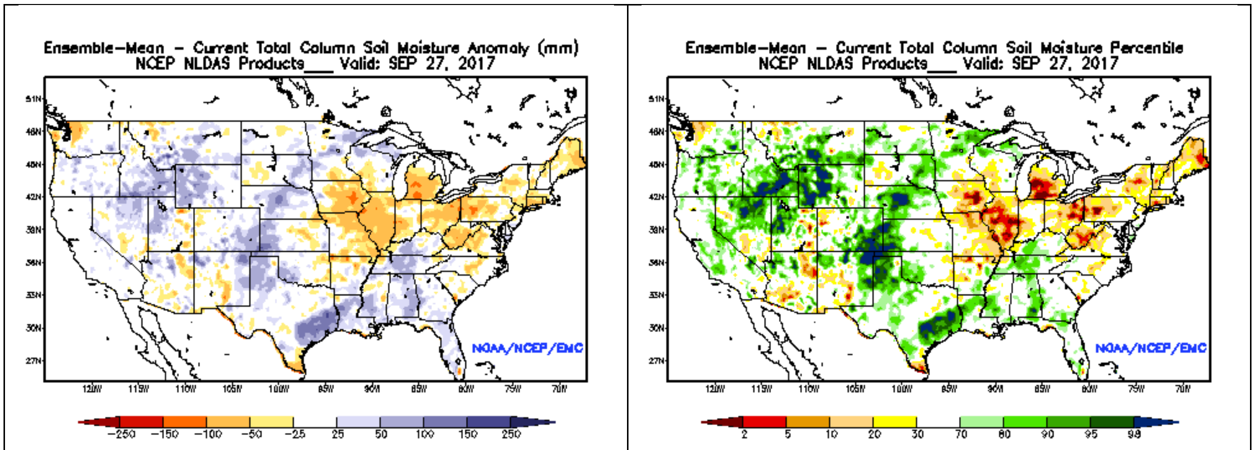


Figure 6. September 2017 and July-August-September 2017 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Soil Moisture

Soil moisture is factored into the forecast as an indicator of wet or dry hydrologic basin conditions. Typically when soil moisture conditions are wet or greater than normal, rainfall and snowmelt runoff is greater than when soil moisture is dry or less than normal. Not only is soil moisture a physical parameter that influences runoff, it can be used as an indicator of future runoff. As the calendar year approaches winter, the soil moisture conditions will provide some insight into late winter and early spring runoff potential.

The left image of **Figure 7** shows the current NOAA NLDAS ensemble soil moisture anomaly and the right image of **Figure 7** shows the soil moisture percentile on September 27, 2017. Both images show wetter-than-normal soil conditions in the upper Basin, particularly southern Montana, western Wyoming, western Nebraska and eastern South Dakota. Soil moisture anomalies in these areas are greater than 50 mm (1.97 inches). Drier-than-normal areas include northwestern Montana, western South Dakota, southeastern Nebraska, eastern Kansas, Iowa and Missouri, where soil moisture anomalies range from -25 to -100 mm (-0.98 to -3.94 inches).



Soil Moisture Anomaly (mm)	Soil Moisture Percentile

Figure 7. NOAA NLDAS Soil Moisture Anomaly (mm) and Soil Moisture Percentile. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

Climate Outlook

MRBWM participates in the monthly North Central U.S. Climate/Drought Outlook Webinar coordinated through NOAA, the regional climate centers, and the American Association of State Climatologists (AASC). These webinars provide updates on near-term climate outlooks and impacts including the ENSO climate pattern and its implications on winter temperature and precipitation patterns in the Missouri Basin.

ENSO (El Niño Southern Oscillation)

The latest ENSO Outlook indicates that ENSO-neutral conditions are present. Equatorial sea surface temperatures are near to below average across the central and eastern Pacific Ocean. Current temperature trends and model projections indicate there is a 55 to 60% chance that La Niña will develop during the Northern Hemisphere fall and winter 2017-2018. During a La Niña phase of ENSO, there are increased probabilities for above-normal precipitation and below-normal temperatures in the upper Missouri Basin during the winter season.

Temperature and Precipitation Outlooks

The NOAA Climate Prediction Center (CPC) outlooks provide the forecasted probability (or chance) of occurrence of future weather conditions during periods ranging from 1 to 12 months into the future. The CPC outlooks are available at http://www.cpc.ncep.noaa.gov/.

The CPC temperature outlook through October 15 (**Figure 8**) indicates increased chances for below-normal temperatures in the Missouri Basin. The precipitation outlook indicates an increased chance for below-normal precipitation over the Missouri Basin.

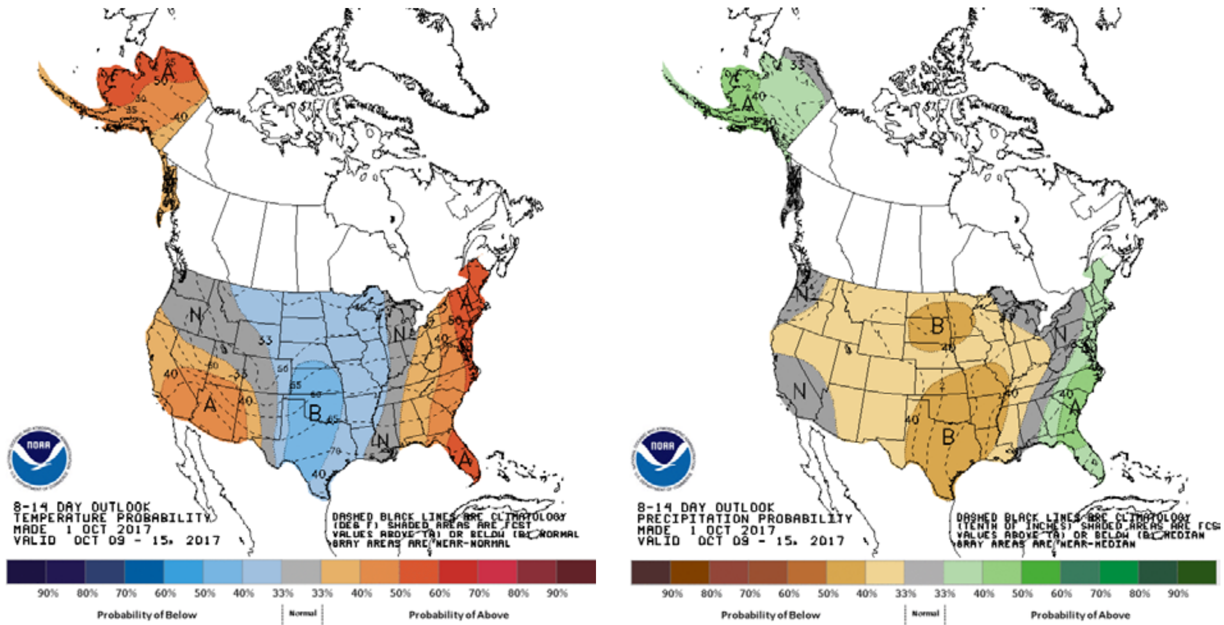


Figure 8. CPC 8-14 Day temperature and precipitation outlooks through October 15, 2017.

The October CPC outlooks in **Figure 9** indicate increased chances for below-normal temperatures in Montana and Wyoming, and equal chances in the Dakotas and Nebraska. There are increased chances for above-normal temperatures in the lower Basin. With regard to precipitation, there are increased chances for above-normal precipitation throughout the upper Basin, Colorado, Kansas, Nebraska and western Iowa during October.

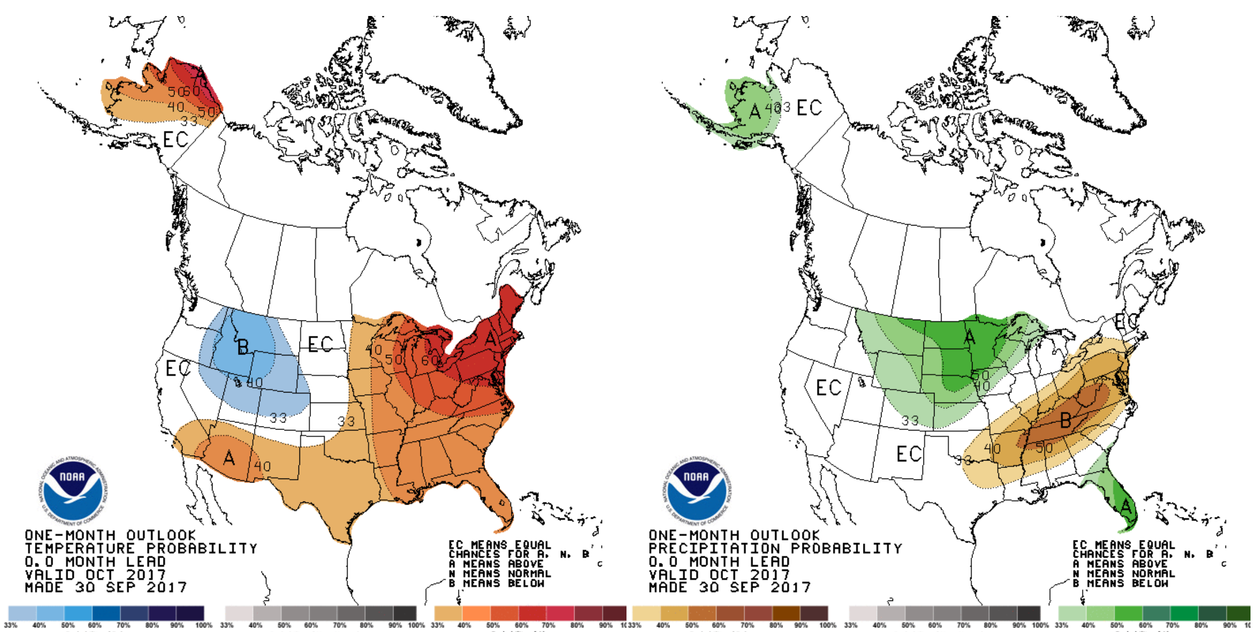


Figure 9. CPC October 2017 temperature and precipitation outlooks.

During the October-November-December period, the CPC outlooks in **Figure 10** indicate increased chances for above-normal temperatures throughout much of the Missouri Basin. With regard to precipitation, the outlook indicates increased chances for above-normal precipitation in western Montana and western Wyoming due to the increased probability that La Niña will develop this winter. There are equal chances for precipitation in the remainder of the upper Basin, and a slight increase in the chance for below-normal precipitation in Missouri and eastern Kansas.

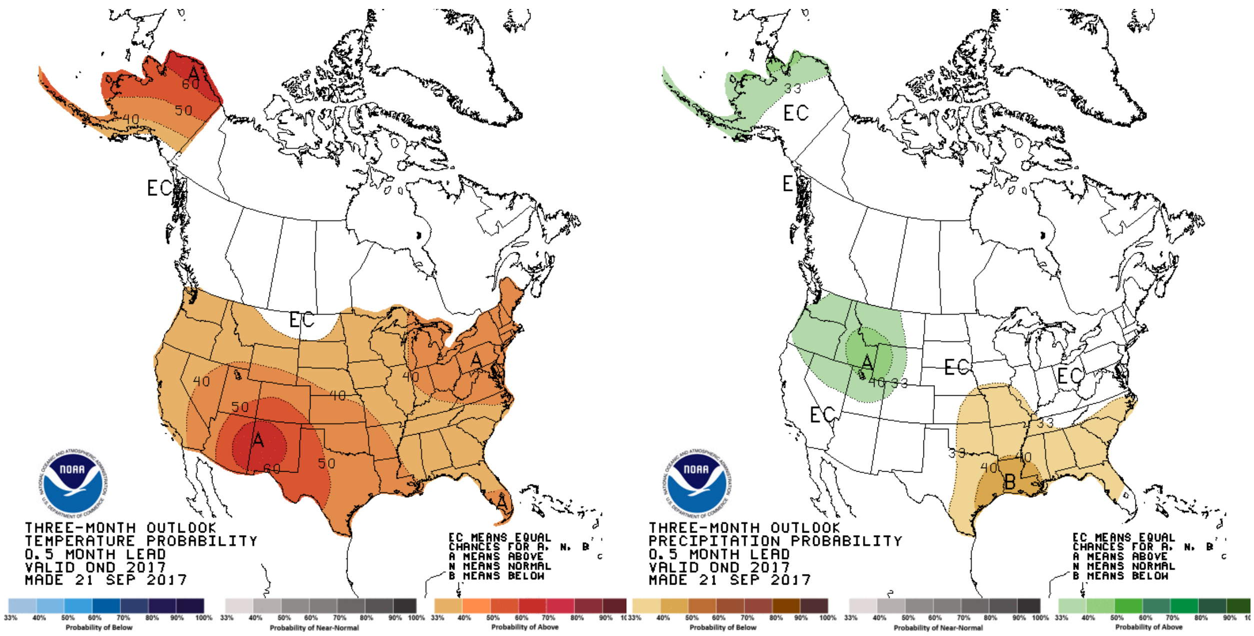


Figure 10. CPC October-November-December 2017 temperature and precipitation outlooks.

Summary

In summary, the 2017 calendar year runoff forecast is **28.5 MAF**, **112% of average**. Historically, the upper Basin runoff for the last three months of the calendar year has been about 3 MAF. About 90% of that, 2.7 MAF, is forecast because of the continuing drought conditions in the upper Basin.

Upper Missouri River Basin
November 2017 Calendar Year Runoff Forecast
November 2, 2017

U.S. Army Corps of Engineers, Northwestern Division
Missouri River Basin Water Management
Omaha, NE

Calendar Year Runoff Forecast

Explanation and Purpose of Forecast

The long-range runoff forecast is presented as the Calendar Year Runoff Forecast. The Calendar Year Runoff Forecast is available at http://www.nwd-mr.usace.army.mil/rcc/reports/runoff.pdf. This forecast is developed shortly after the beginning of each calendar year and is updated at the beginning of each month to show the actual runoff for historic months of that year and the updated forecast for the remaining months of the year. This forecast presents monthly inflows in million acre-feet (MAF) from five incremental drainage areas, as defined by the individual System projects, plus the incremental drainage area between Gavins Point Dam and Sioux City. Due to their close proximity, the Big Bend and Fort Randall drainage areas are combined. Summations are provided for the total Missouri River reach above Gavins Point Dam and for the total Missouri Basin above Sioux City (upper Basin). The Calendar Year Runoff Forecast is used in the Monthly Study simulation model to plan future system regulation in order to meet the authorized project purposes throughout the calendar year.

Observed Runoff

The October runoff summation for the upper Basin above Sioux City was 133% of average. The October runoff summation for the upper Basin above Gavins Point was 97% of average. October precipitation was more than 200% of normal in areas of South Dakota, Nebraska, and Iowa. Runoff in the Sioux City reach was 567% of average, while runoff was below average in the Fort Peck, Oahe, and Fort Randall reaches.

2017 Calendar Year Forecast Synopsis

The 2017 calendar year runoff forecast for the upper Missouri Basin above Sioux City, IA, updated on November 1, is **29.2 MAF (115% of average).** The 2017 calendar year runoff forecast above Gavins Point Dam is **25.3 MAF (110% of average)**.

Due to the amount of variability in precipitation and other hydrologic factors that can occur over the next 2 months, the range of expected inflow ranges from the 29.7 MAF upper basic forecast to the 28.8 MAF lower basic forecast. The upper and lower basic forecasts are used in long-term regulation planning models to "bracket" the range of expected runoff given much wetter or drier conditions, respectively. Given that 2 months are being forecast for this November 1 forecast

(10 months observed/2 months forecast), the range of wetter-than-expected (upper basic) and drier-than-expected (lower basic) conditions is attributed to all 6 reaches for both months. The result is a range or “bracket” for each reach, and thus, for the total runoff forecast.

Current Conditions

Drought Analysis

The latest National Drought Mitigation Center’s drought monitor for October 24, 2017 (**Figure 1**), is compared to the drought monitor for September 26, 2017 (**Figure 2**). The drought monitor is available at http://droughtmonitor.unl.edu/. The U.S. Drought Monitor shows drought conditions in all states of the Missouri Basin and over a majority of the upper Basin. Comparing **Figure 1** and **Figure 2**, drought conditions improved between September 26 and October 24 in all areas. In Montana, about 73% of the state is impacted by drought (D1 to D4), and 15% of the state is impacted by Extreme (D3) Drought. This is an improvement from last month, when 43% of the state was impacted by Extreme (D3) to Exceptional (D4) Drought. In North Dakota, 37% of the state is impacted by drought. In South Dakota, 49% of the state is impacted by drought, and 6% is impacted by D3 and D4 Drought. The Seasonal Drought Outlook in **Figure 3** indicates that drought conditions will persist in eastern Montana and the western half of the Dakotas through January 31, 2018. Some drought improvement and removal is forecast in western Montana and Iowa.

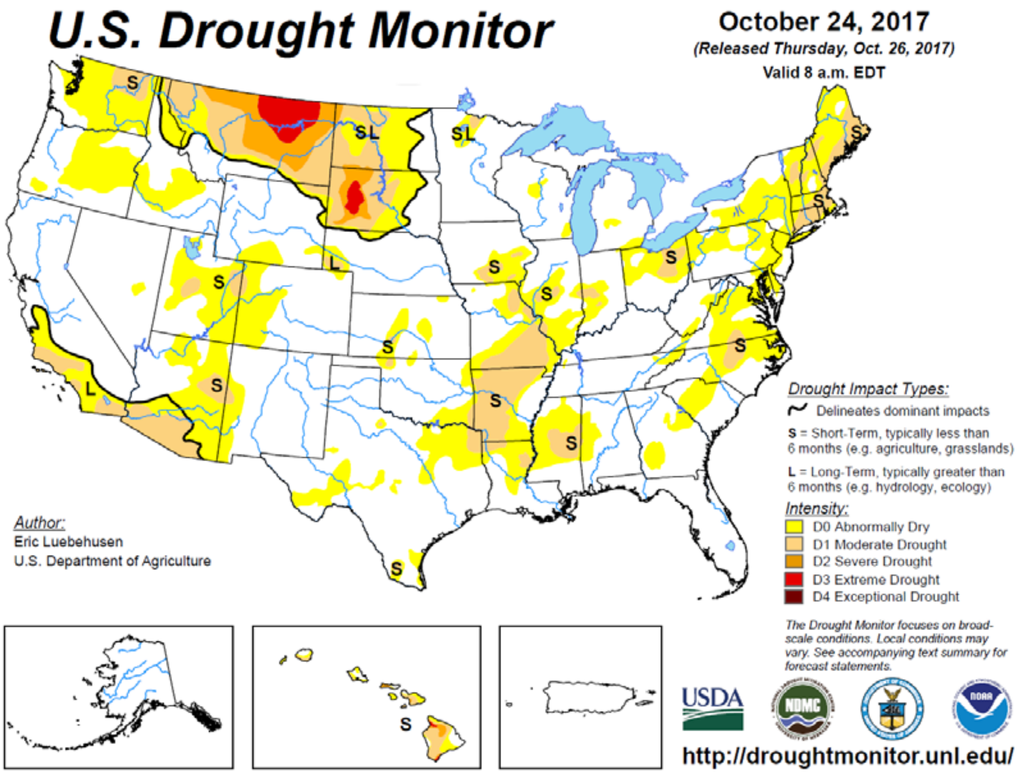


Figure 1. National Drought Mitigation Center U.S. Drought Monitor for October 24, 2017.

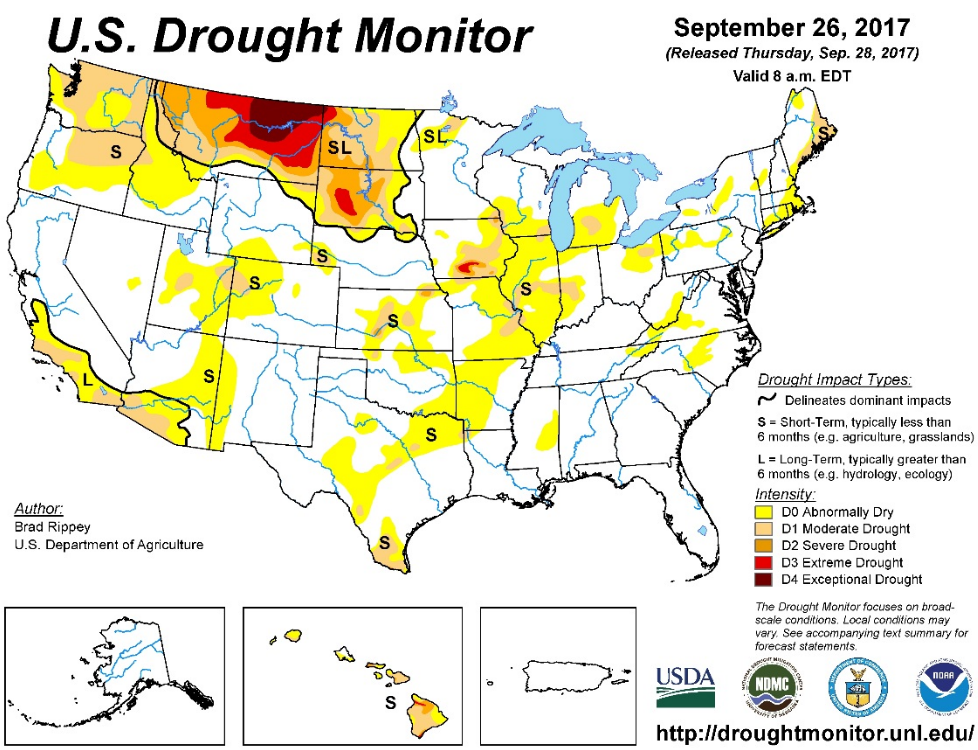


Figure 2. National Drought Mitigation Center U.S. Drought Monitor for September 26, 2017.

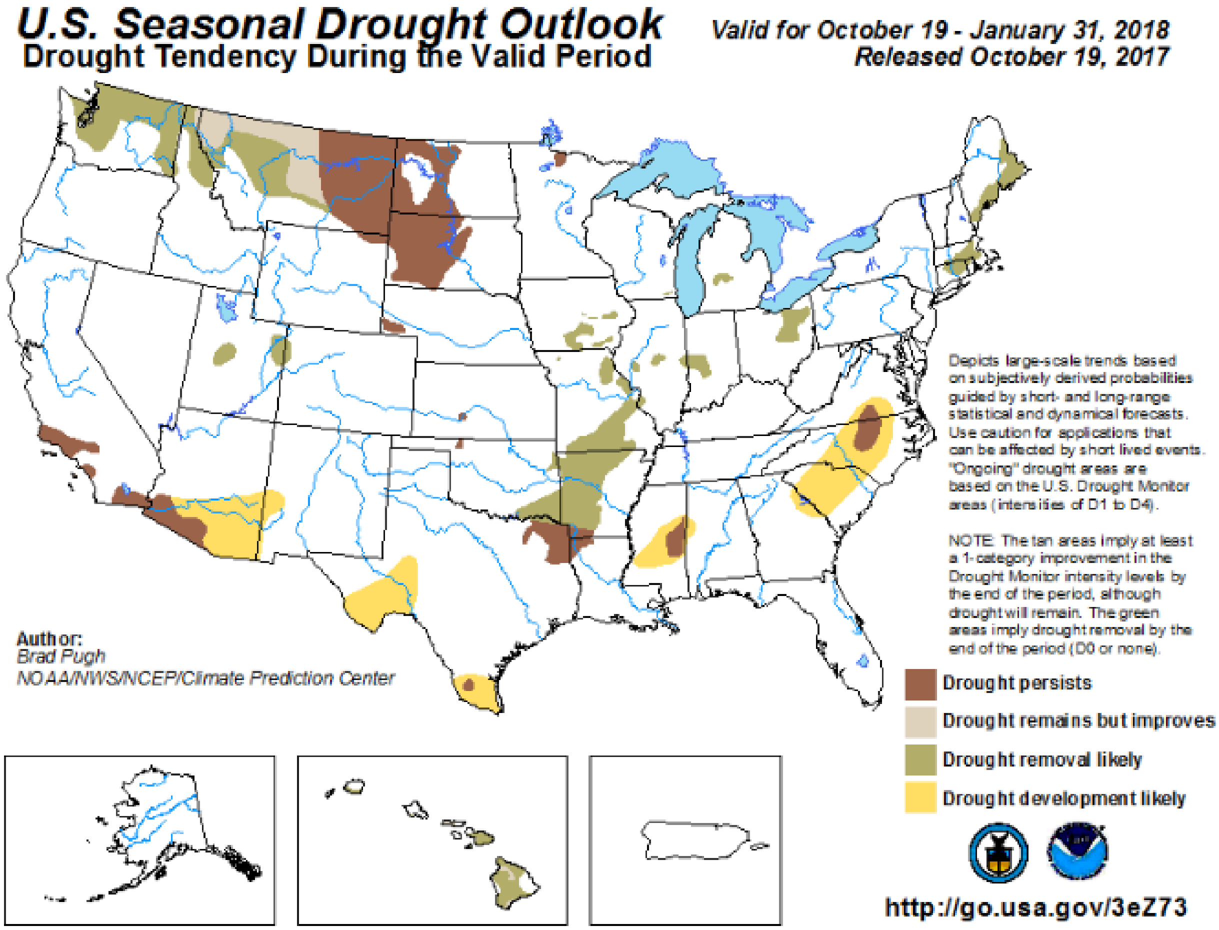


Figure 3. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

Monthly precipitation accumulations are shown using High Plains Regional Climate Center images available at http://www.hprcc.unl.edu/. The October precipitation accumulations are shown in **Figure 4** as inches of precipitation (left) and percent of normal precipitation (right). October precipitation was more than 200% of average in areas of Montana, South Dakota, Nebraska, Iowa, and Kansas. In contrast, some areas of North and South Dakota experienced precipitation that was less than 5% of normal.

August-September-October precipitation accumulations are shown in **Figure 5**. The three-month accumulations reflect a varied precipitation pattern, with areas of both above and below normal precipitation in every Basin state. The three-month accumulations were above normal along the Missouri River corridor in South Dakota, Nebraska, and Iowa; however, precipitation has been below normal in western South Dakota and much of Montana.

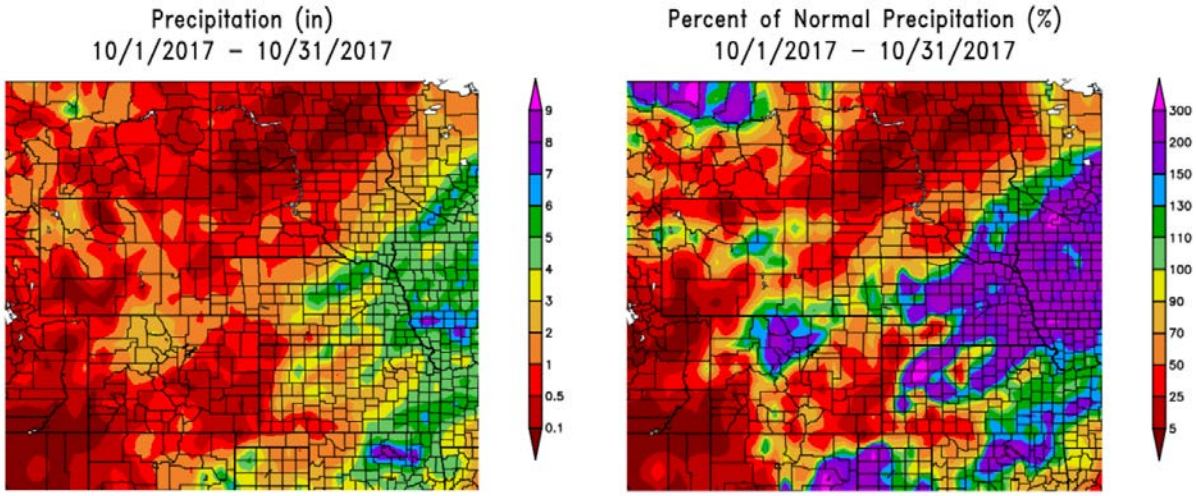


Figure 4. October 2017 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

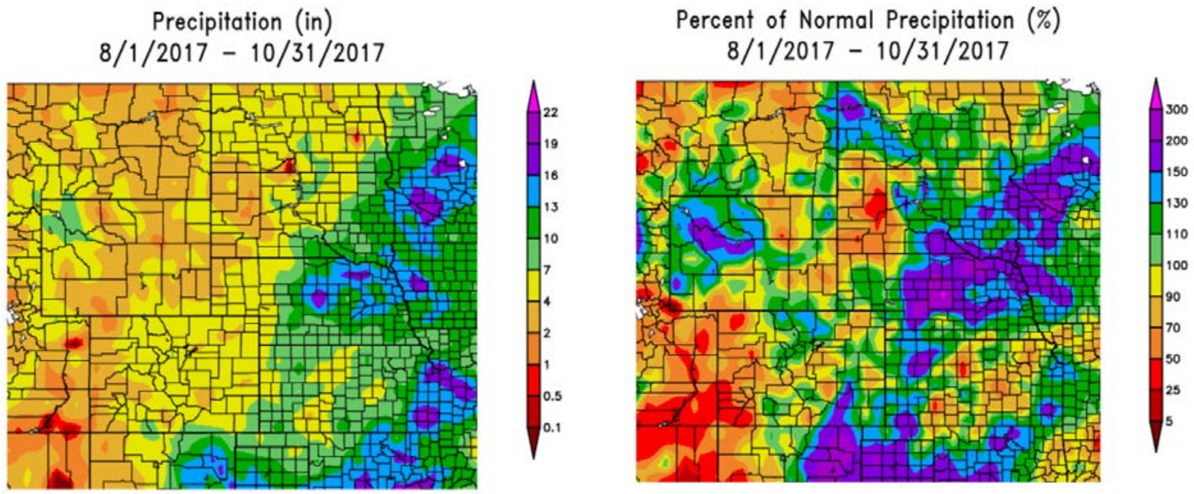


Figure 5. August-September-October 2017 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Temperature

October temperature departures in degrees Fahrenheit (deg F) in the left image of **Figure 6** were 0 to 4 deg F below normal over the western portion of the Basin, while temperatures were 0 to 4 deg F above normal in the eastern portion of the Basin. August-September-October temperature departures, in the right image of **Figure 6**, were close to normal for most of the Basin. The three-month temperatures in Wyoming have exhibited a below-normal pattern, ranging from 1 to 3 deg F below normal.

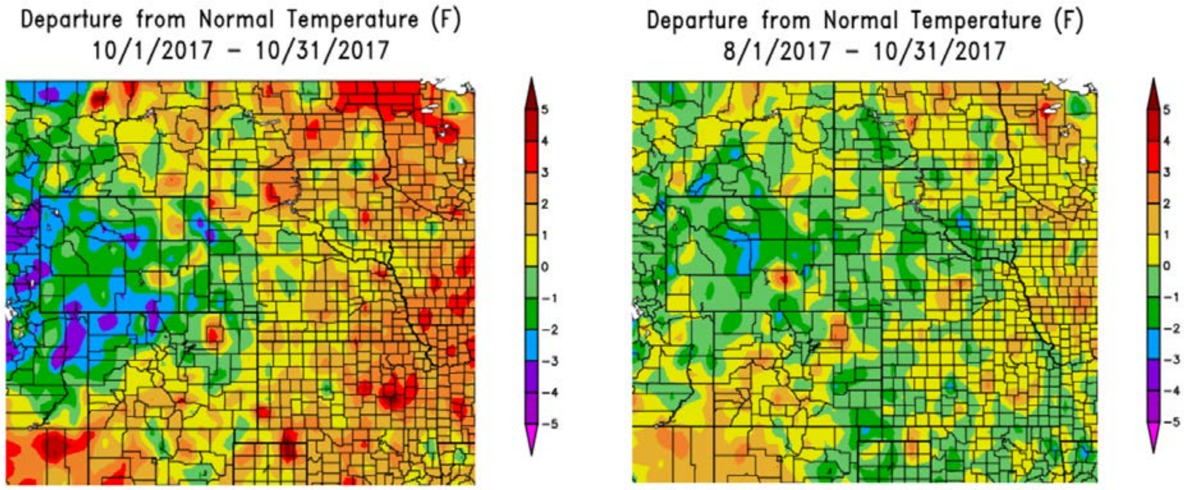
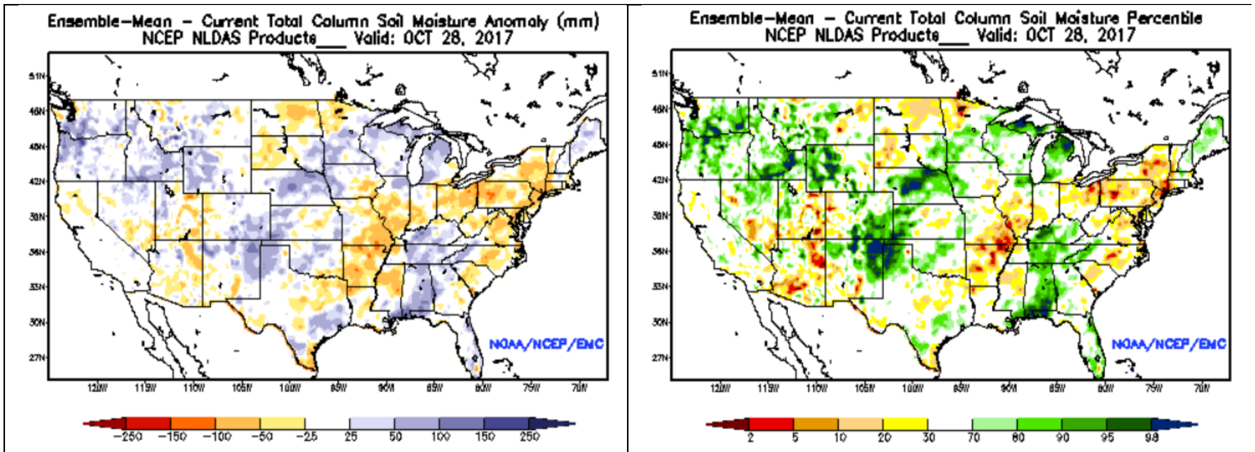


Figure 6. October 2017 and August-September-October 2017 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Soil Moisture

Soil moisture is factored into the forecast as an indicator of wet or dry hydrologic basin conditions. Typically when soil moisture conditions are wet or greater than normal, rainfall and snowmelt runoff is greater than when soil moisture is dry or less than normal. Not only is soil moisture a physical parameter that influences runoff, it can be used as an indicator of future runoff. As the calendar year approaches winter, the soil moisture conditions will provide some insight into late winter and early spring runoff potential.

The left image of **Figure 7** shows the current NOAA NLDAS ensemble soil moisture anomaly and the right image of **Figure 7** shows the soil moisture percentile on October 28, 2017. Both images show wetter-than-normal soil conditions in western Wyoming, eastern Colorado, Nebraska, eastern South Dakota, and western Iowa. Soil moisture anomalies in these areas are greater than 50 mm (1.97 inches). Drier-than-normal areas include eastern Montana, western South Dakota, North Dakota, central Kansas, eastern Iowa and Missouri, where soil moisture anomalies range from -25 to -100 mm (-0.98 to -3.94 inches).



Soil Moisture Anomaly (mm)	Soil Moisture Percentile

Figure 7. NOAA NLDAS Soil Moisture Anomaly (mm) and Soil Moisture Percentile. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

Mountain Snow Pack

Mountain snowpack is the primary factor used to predict May-July runoff volumes in the Fort Peck and Fort Peck to Garrison mainstem reservoir reaches. It is typically NOT a factor influencing runoff at the end of a calendar year.

Figure 8 includes time series plots of the average mountain SWE beginning on October 1, 2017 based on the NRCS SNOTEL data for the headwater basin above Fort Peck and the incremental basin from Fort Peck to Garrison. The current average SWE values (shaded blue area) are plotted against the 1981-2010 basin average SWE (bold red line), a recent low SWE year in 2001 (green line), and two historic high SWE years occurring in 1997 (purple) and 2011 (dark blue).

As of November 1, 2017, the Corps of Engineers computed an average mountain SWE in the Fort Peck reservoir reach of 1.5 inches, which is 119% of average based on the 1981-2010 average SWE for the Fort Peck reach. In the reservoir reach between Fort Peck Dam and Garrison Dam, the Corps computed an average mountain SWE of 1.7 inches, which is 110% of average based on the 1981-2010 average SWE for the Garrison reach. Typically by November 1, only 9% of the total accumulation occurs.

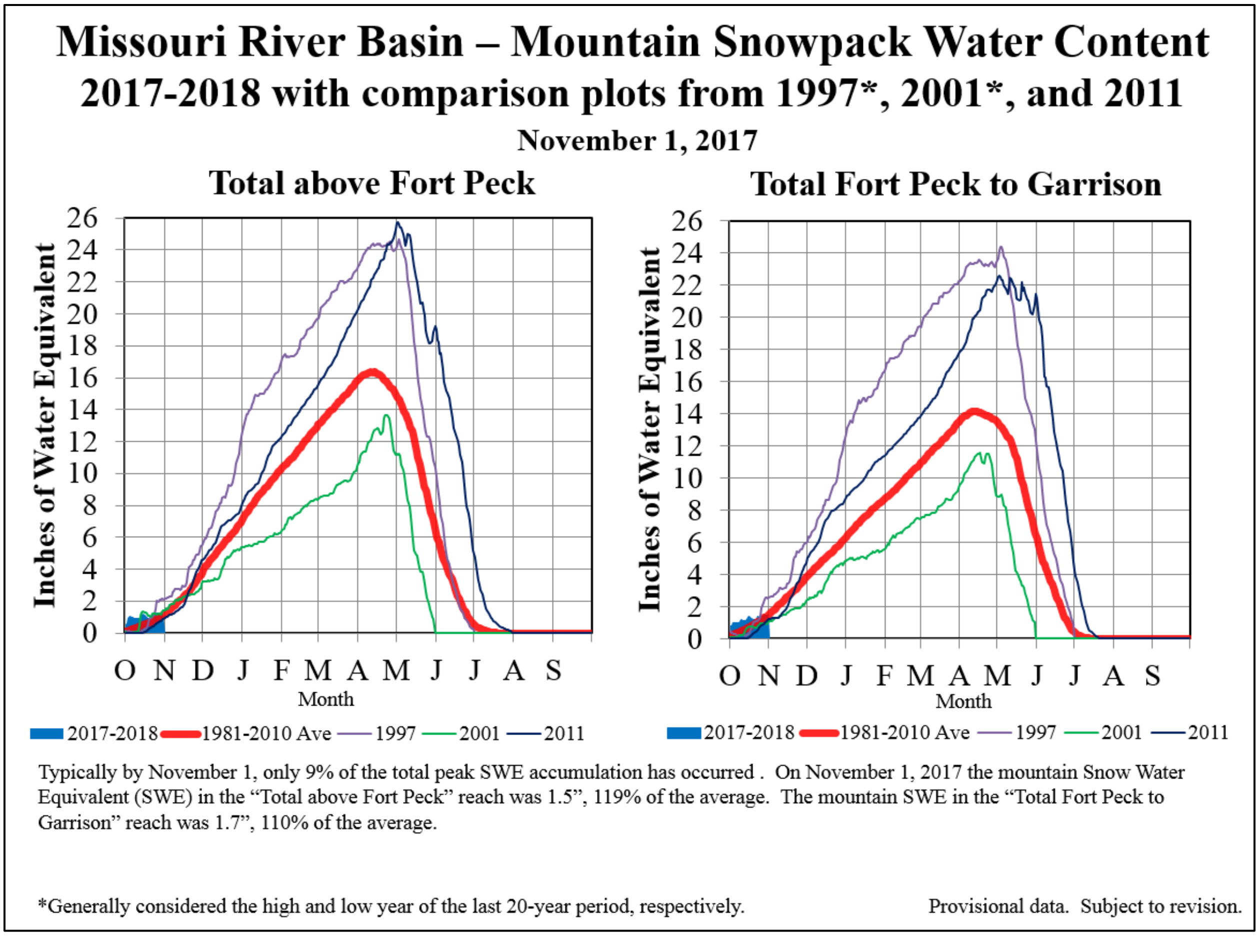


Figure 8. Mountain snowpack water content on November 1, 2017 compared to normal and historic conditions. Corps of Engineers - Missouri River Basin Water Management.

Climate Outlook

MRBWM participates in the monthly North Central U.S. Climate/Drought Outlook Webinar coordinated through NOAA, the regional climate centers, and the American Association of State Climatologists (AASC). These webinars provide updates on near-term climate outlooks and impacts including the ENSO climate pattern and its implications on winter temperature and precipitation patterns in the Missouri Basin.

ENSO (El Niño Southern Oscillation)

The latest ENSO Outlook indicates that ENSO-neutral conditions are present. Current temperature trends and model projections indicate there is a 55 to 65% chance that La Niña will develop during the Northern Hemisphere fall and winter 2017-2018. During a La Niña phase of ENSO, there are increased probabilities for above-normal precipitation and below-normal temperatures in the upper Missouri Basin during the winter season.

Temperature and Precipitation Outlooks

The NOAA Climate Prediction Center (CPC) outlooks provide the forecasted probability (or chance) of occurrence of future weather conditions during periods ranging from 1 to 12 months into the future. The CPC outlooks are available at http://www.cpc.ncep.noaa.gov/.

The CPC temperature outlook through October 15 (**Figure 9**) indicates increased chances for below-normal temperatures in the upper Missouri Basin, particularly in Montana, North Dakota and northern South Dakota. The precipitation outlook indicates an increased chance for below-normal precipitation over the southwestern portion of the Basin, and equal chances elsewhere.

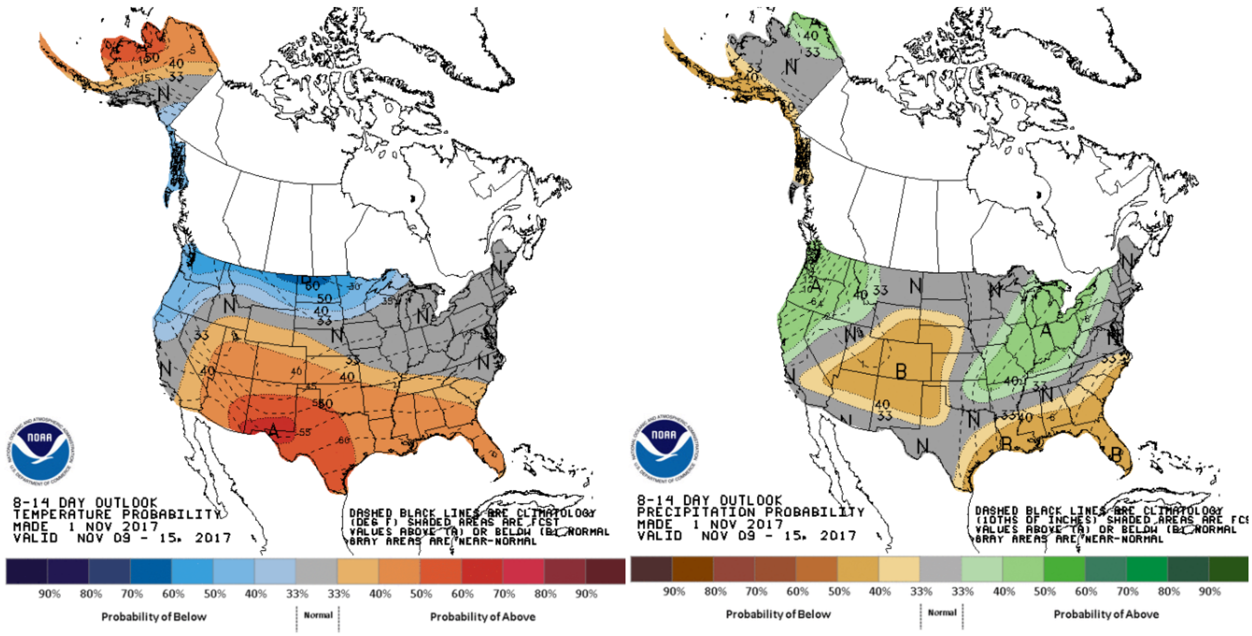


Figure 9. CPC 8-14 Day temperature and precipitation outlooks through November 15, 2017.

The November CPC outlooks in **Figure 10** indicate increased chances for below-normal temperatures in the upper Basin, with mostly equal chances in the lower Basin. With regard to precipitation, there are increased chances for above-normal precipitation in Wyoming, Montana, and North Dakota, and equal chances in the remainder of the upper Basin. In western and central Montana, there is a 60% chance that precipitation will be above normal.

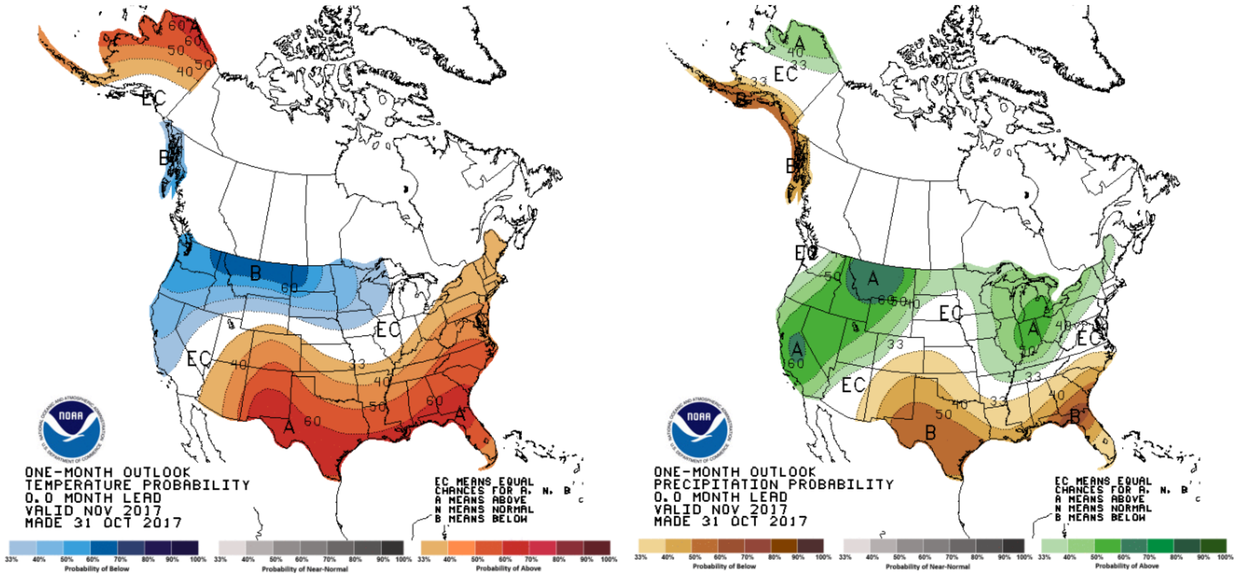


Figure 10. CPC November 2017 temperature and precipitation outlooks.

During the November-December 2017-January 2018 period, the CPC outlooks in **Figure 11** indicate increased chances for above-normal temperatures throughout much of the Missouri Basin, with equal chances in Montana and North Dakota. With regard to precipitation, the outlook indicates increased chances for above-normal precipitation in Montana and Wyoming due to the increased probability that La Niña will develop this winter. There are equal chances for precipitation in the remainder of the Basin.

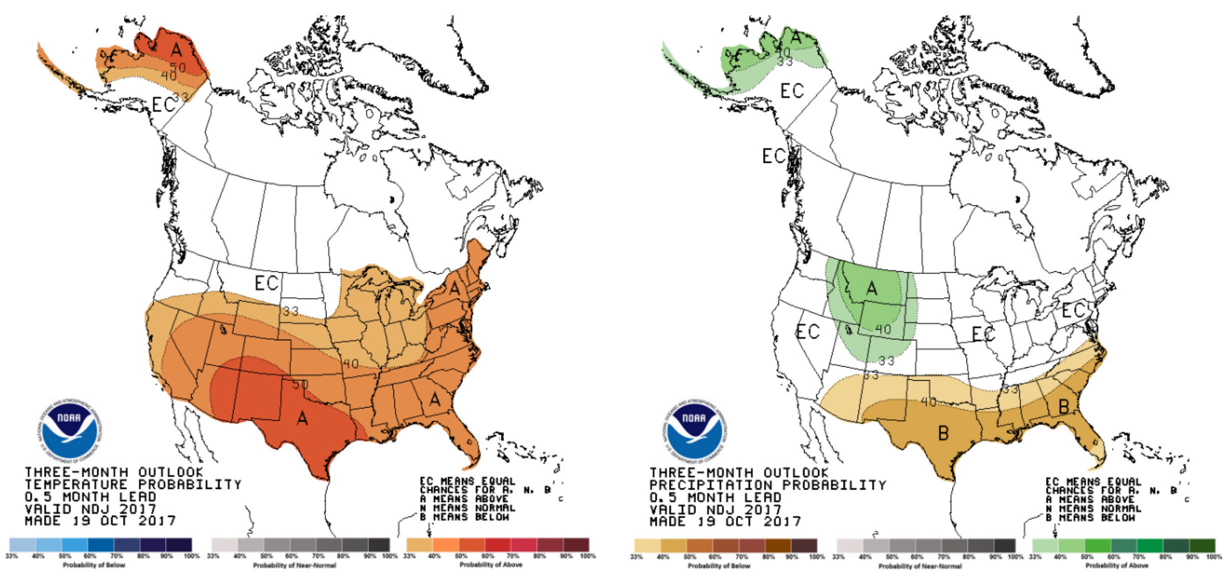


Figure 8. CPC November-December 2017-January 2018 temperature and precipitation outlooks.

Summary

In summary, the 2017 calendar year runoff forecast is **29.2 MAF**, **115% of average**. For the remaining two months of the year, slightly below normal runoff is forecasted for the portion of the basin above Gavins Point due to the continuing drought conditions. However, above normal runoff is forecasted for the Gavins Point to Sioux City reach due to current higher-than-normal streamflow in the Vermillion River and the Big Sioux River.

Upper Missouri River Basin
December 2017 Calendar Year Runoff Forecast
December 5, 2017

U.S. Army Corps of Engineers, Northwestern Division
Missouri River Basin Water Management
Omaha, NE

Calendar Year Runoff Forecast

Explanation and Purpose of Forecast

The long-range runoff forecast is presented as the Calendar Year Runoff Forecast. The Calendar Year Runoff Forecast is available at http://www.nwd-mr.usace.army.mil/rcc/reports/runoff.pdf. This forecast is developed shortly after the beginning of each calendar year and is updated at the beginning of each month to show the actual runoff for historic months of that year and the updated forecast for the remaining months of the year. This forecast presents monthly inflows in million acre-feet (MAF) from five incremental drainage areas, as defined by the individual System projects, plus the incremental drainage area between Gavins Point Dam and Sioux City. Due to their close proximity, the Big Bend and Fort Randall drainage areas are combined. Summations are provided for the total Missouri River reach above Gavins Point Dam and for the total Missouri Basin above Sioux City (upper Basin). The Calendar Year Runoff Forecast is used in the Monthly Study simulation model to plan future system regulation in order to meet the authorized project purposes throughout the calendar year.

Observed Runoff

The November runoff summation for the upper Basin above Sioux City was 110% of average. The November runoff summation for the upper Basin above Gavins Point was 96% of average. Runoff was near average in the Fort Peck and Garrison reaches, below average in the Fort Randall reach, and above average in the Oahe, Gavins Point and Sioux City reaches.

2017 Calendar Year Forecast Synopsis

The 2017 calendar year runoff forecast for the upper Missouri Basin above Sioux City, IA, updated on December 1, is **29.4 MAF (116% of average).** The 2017 calendar year runoff forecast above Gavins Point Dam is **25.4 MAF (110% of average)**.

Due to the amount of variability in precipitation and other hydrologic factors that can occur over the next month, expected inflow could range from the 29.6 MAF upper basic forecast to the 29.2 MAF lower basic forecast. The upper and lower basic forecasts are used in long-term regulation planning models to "bracket" the range of expected runoff given much wetter or drier conditions, respectively. Given that one month is being forecast for this December 1 forecast (11 months observed/1 month forecast), the range of wetter-than-expected (upper basic) and drier-than-expected (lower basic) conditions is attributed to all 6 reaches for December. The result is a range or "bracket" for each reach, and thus, for the total runoff forecast.

Current Conditions

Drought Analysis

The National Drought Mitigation Center's drought monitor for November 28, 2017 is shown in **Figure 1**. The drought monitor is available at http://droughtmonitor.unl.edu/. The U.S. Drought Monitor shows drought conditions in all states of the Missouri Basin and over a majority of the upper Basin. Extreme Drought (D3) conditions are present in northeastern Montana and western South Dakota, while there are Moderate (D1) and Severe (D2) Drought conditions over a broader area of the upper Basin. The Seasonal Drought Outlook in **Figure 2**, which extends through the end of February, indicates that drought conditions could improve in central and western Montana, but will likely persist in eastern Montana, western North Dakota, and western South Dakota.

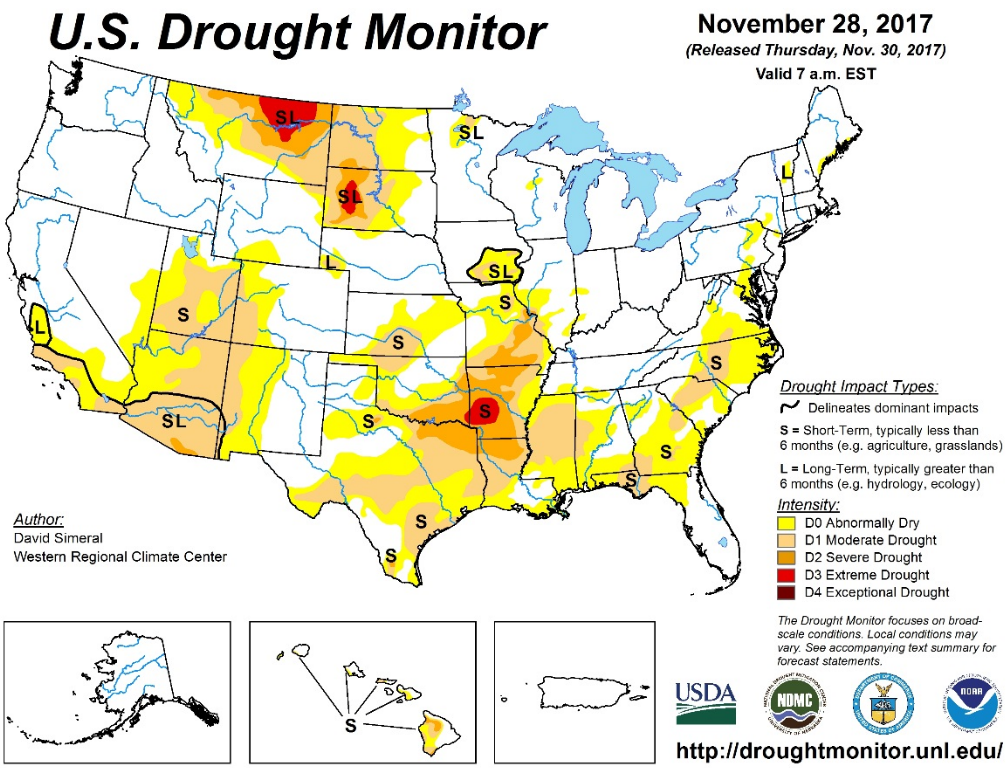


Figure 1. National Drought Mitigation Center U.S. Drought Monitor for November 28, 2017.

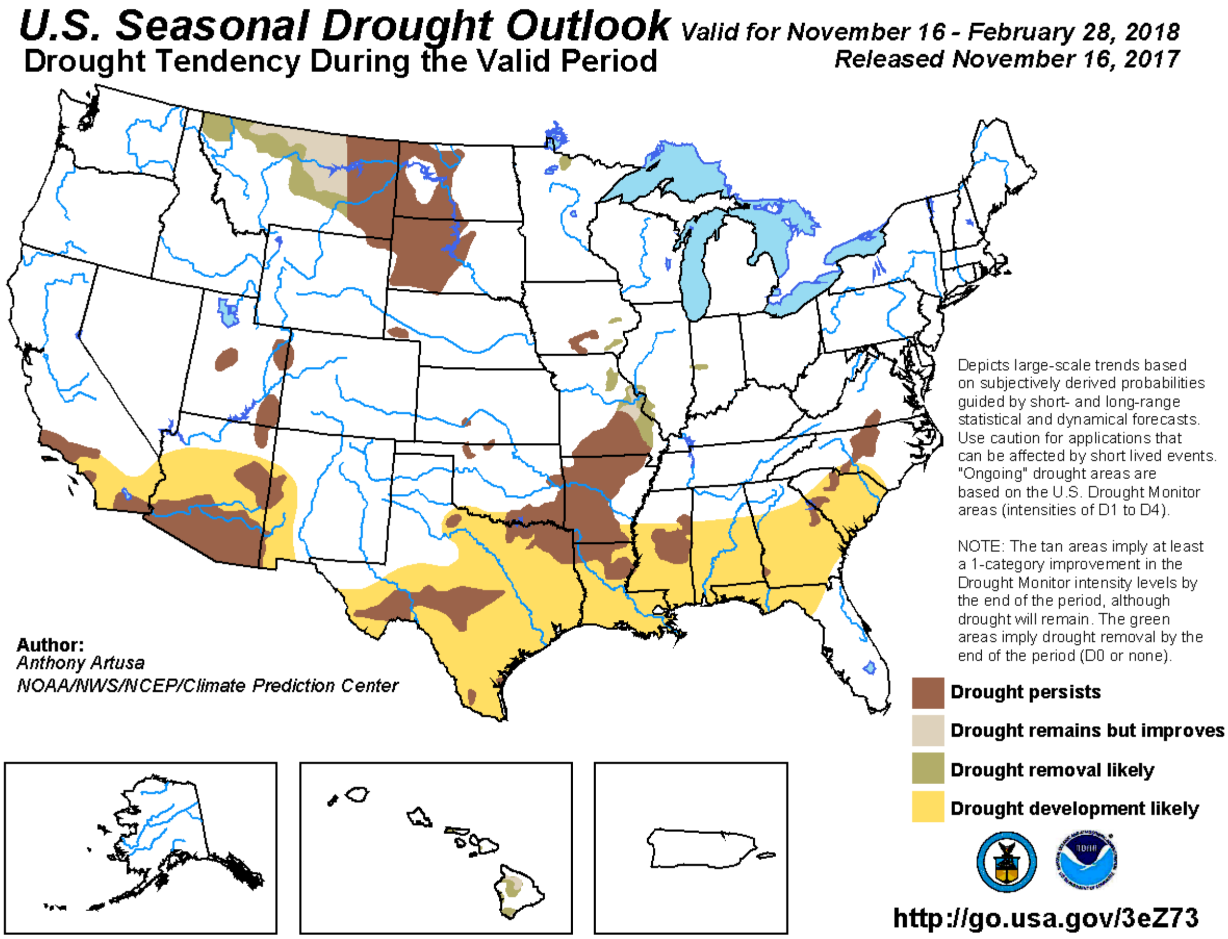


Figure 2. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

Monthly precipitation accumulations are shown using High Plains Regional Climate Center images available at http://www.hprcc.unl.edu/. The November precipitation accumulations are shown in **Figure 3** as inches of precipitation (left) and percent of normal precipitation (right). November precipitation was more than 150% of average in areas of western and southern Montana, and northwestern Wyoming. In contrast, November precipitation was less than 50% of average over northeastern Montana, much of North Dakota, South Dakota, and the lower Basin.

September-October-November precipitation accumulations are shown in **Figure 4**. The three-month accumulations reflect the ongoing above-normal precipitation pattern in the Rocky Mountains of Montana and Wyoming. Precipitation accumulations greater than 150% of normal have led to above-average mountain snowpack in the Fort Peck and Garrison reaches this year. An above-normal precipitation pattern has also covered much of Montana, eastern South Dakota, Nebraska and Iowa. In contrast, North Dakota, western South Dakota and western Nebraska have experienced below-normal precipitation.

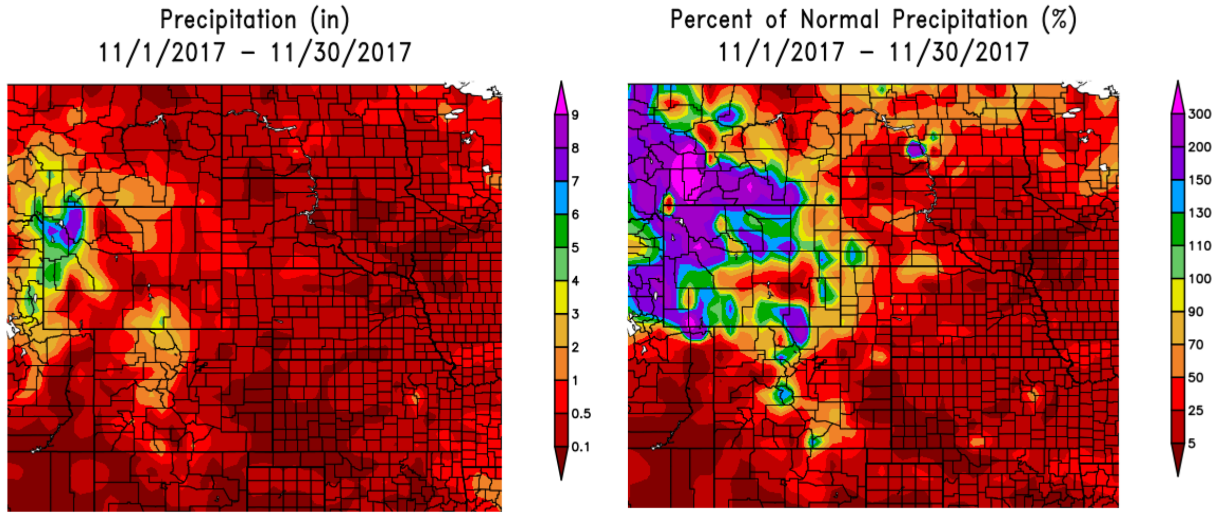


Figure 3. November 2017 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

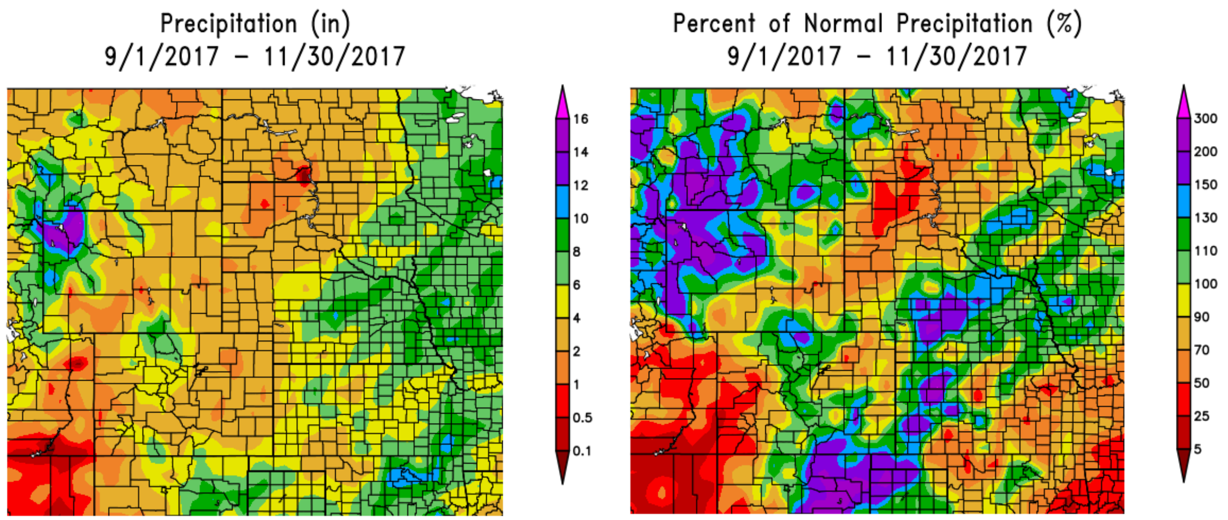


Figure 4. September-October-November 2017 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Temperature

November temperature departures in degrees Fahrenheit (deg F) in the left image of **Figure 5** indicate normal to below-normal temperatures in northern Montana and North Dakota. In contrast the November image indicates above-normal temperatures in Wyoming, South Dakota and Nebraska. The above-normal temperatures in Wyoming have limited the accumulation of mountain snowpack in that state. September-October-November temperature departures, in the right image of **Figure 5**, were close to normal in Montana, northern Wyoming and North Dakota, with a slight leaning toward below-normal temperatures in the Rocky Mountains. Three-month temperatures were above normal in all other areas of the Basin.

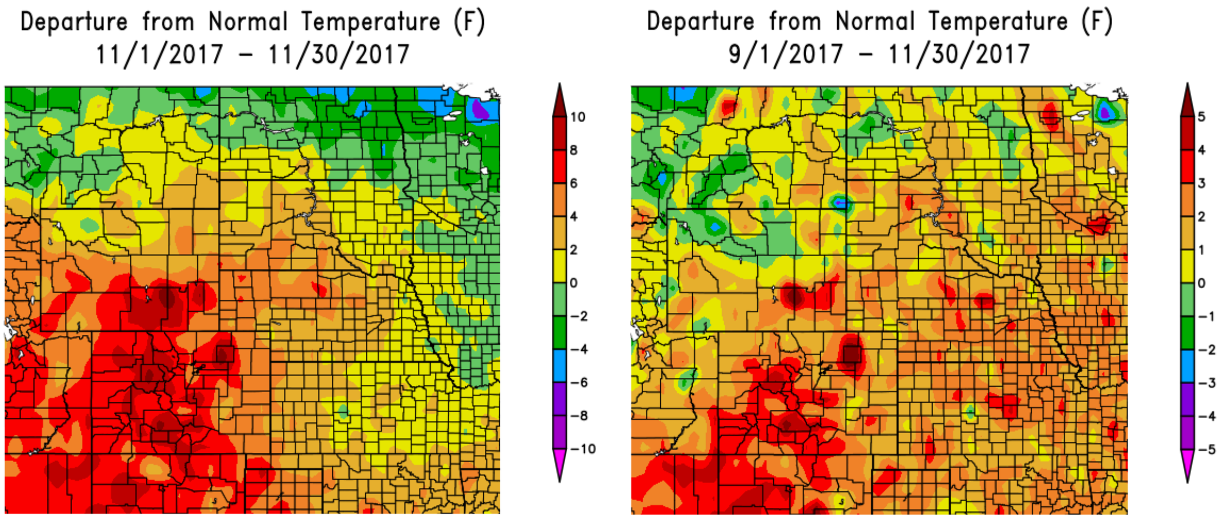
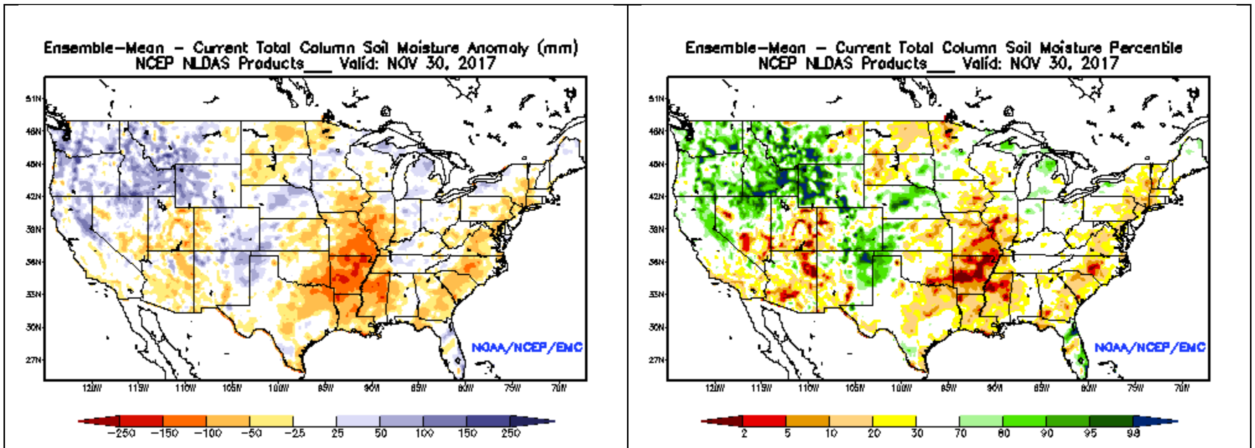


Figure 5. November 2017 and September-October-November 2017 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Soil Moisture

Soil moisture is factored into the forecast as an indicator of wet or dry hydrologic basin conditions. Typically when soil moisture conditions are wet or greater than normal, rainfall and snowmelt runoff is greater than when soil moisture is dry or less than normal. Not only is soil moisture a physical parameter that influences runoff, it can be used as an indicator of future runoff. As the calendar year approaches winter, the soil moisture conditions will provide some insight into late winter and early spring runoff potential.

The left image of **Figure 6** shows the current NOAA NLDAS ensemble soil moisture anomaly and the right image of **Figure 6** shows the soil moisture percentile on November 30, 2017. Soil moisture conditions have been a reflection of the precipitation patterns over the past three months. Soil moisture anomalies and percentiles are above normal in western and central Montana, Wyoming, eastern South Dakota and central Nebraska. Since soil moisture conditions in these areas are above normal, runoff has continued to be near normal in the fall with the below-normal precipitation previously discussed. Spring runoff could potentially be above normal under normal winter precipitation and snowfall accumulations due to the above-normal soil moisture conditions in western Montana and Wyoming. In contrast, soil moisture anomalies and percentiles are below normal in North and South Dakota, Kansas and much of Missouri. As a result, spring runoff could potentially be below normal under normal winter precipitation and snowfall accumulations in eastern Montana and the Dakotas.



Soil Moisture Anomaly (mm)	Soil Moisture Percentile

Figure 6. NOAA NLDAS Soil Moisture Anomaly (mm) and Soil Moisture Percentile. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

Mountain Snow Pack

Mountain snowpack is the primary factor used to predict May-July runoff volumes in the Fort Peck and Fort Peck to Garrison mainstem reservoir reaches. It is typically NOT a factor influencing runoff at the end of a calendar year.

Figure 7 includes time series plots of the average mountain SWE beginning on October 1, 2017 based on the NRCS SNOTEL data for the headwater basin above Fort Peck and the incremental basin from Fort Peck to Garrison. The current average SWE values (shaded blue area) are plotted against the 1981-2010 basin average SWE (bold red line), a recent low SWE year in 2001 (green line), and two historic high SWE years occurring in 1997 (purple) and 2011 (dark blue).

As of December 1, 2017, the Corps of Engineers computed an average mountain SWE in the Fort Peck reservoir reach of 4.5 inches, which is 113% of average based on the 1981-2010 average SWE for the Fort Peck reach. In the reservoir reach between Fort Peck Dam and Garrison Dam, the Corps computed an average mountain SWE of 5.8 inches, which is 147% of average based on the 1981-2010 average SWE for the Garrison reach. Typically by December 1, 26% of the total accumulation has occurred.

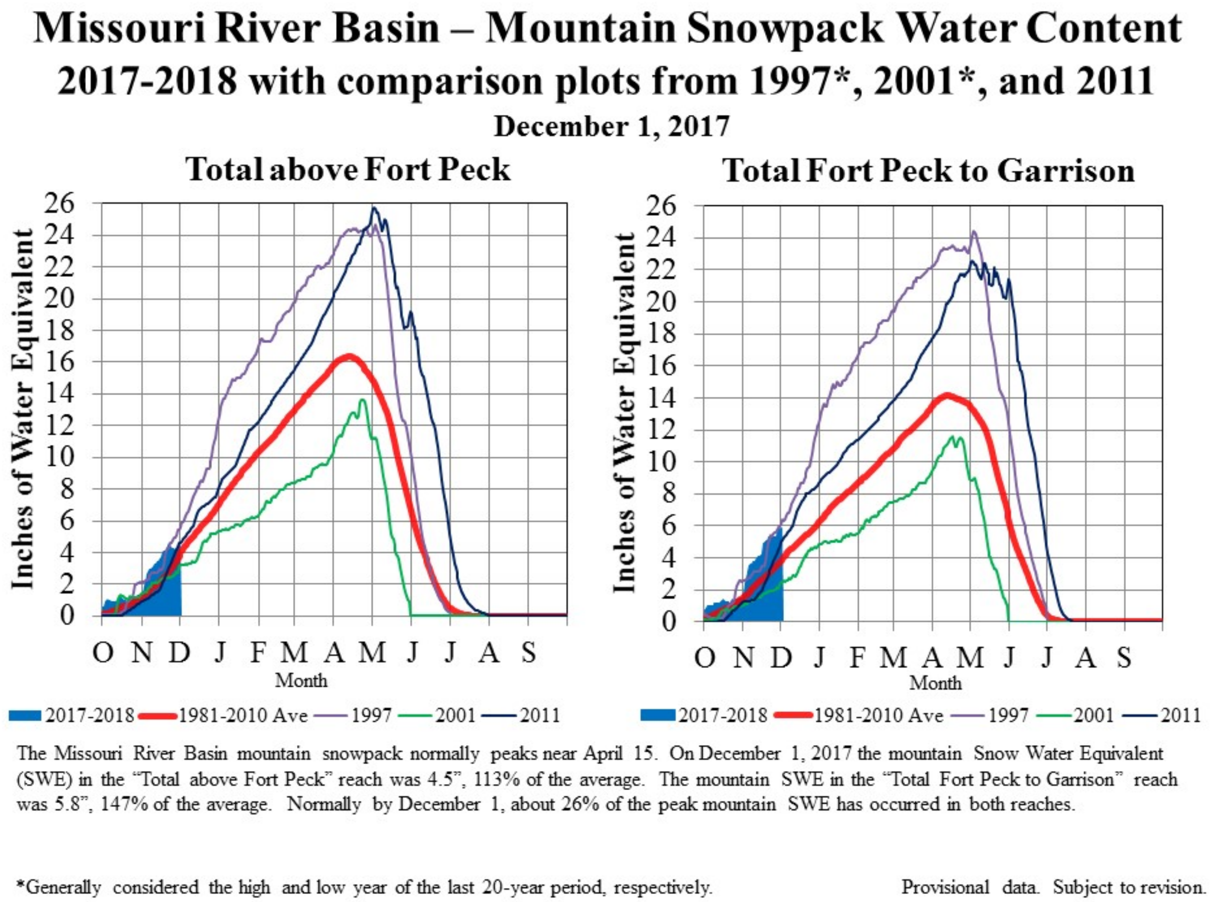


Figure 7. Mountain snowpack water content on December 1, 2017 compared to normal and historic conditions. Corps of Engineers - Missouri River Basin Water Management.

Climate Outlook

MRBWM participates in the monthly North Central U.S. Climate/Drought Outlook Webinar coordinated through NOAA, the regional climate centers, and the American Association of State Climatologists (AASC). These webinars provide updates on near-term climate outlooks and impacts including the ENSO climate pattern and its implications on winter temperature and precipitation patterns in the Missouri Basin.

ENSO (El Niño Southern Oscillation)

The latest ENSO Outlook indicates that La Niña conditions are present. Current temperature trends and model projections indicate there is a 65% to 75% chance that La Niña conditions will continue through the Northern Hemisphere winter 2017-2018. During a La Niña phase of ENSO, there are increased probabilities for above-normal precipitation and below-normal temperatures in the upper Missouri Basin during the winter season.

Temperature and Precipitation Outlooks

The NOAA Climate Prediction Center (CPC) outlooks provide the forecasted probability (or chance) of occurrence of future weather conditions during periods ranging from 1 to 12 months into the future. The CPC outlooks are available at http://www.cpc.ncep.noaa.gov/.

The CPC temperature outlook through December 14 (**Figure 8**) indicates increased chances for below-normal temperatures in portions of the lower Basin; however, there are increased chances for above-normal temperatures in much of the upper Basin, potentially inhibiting formation of mountain and plains snowpack. The precipitation outlook indicates increased chances for below-normal precipitation in the lower Basin and the Rocky Mountains. There is a slight increase in the chances for above-normal precipitation over North Dakota.

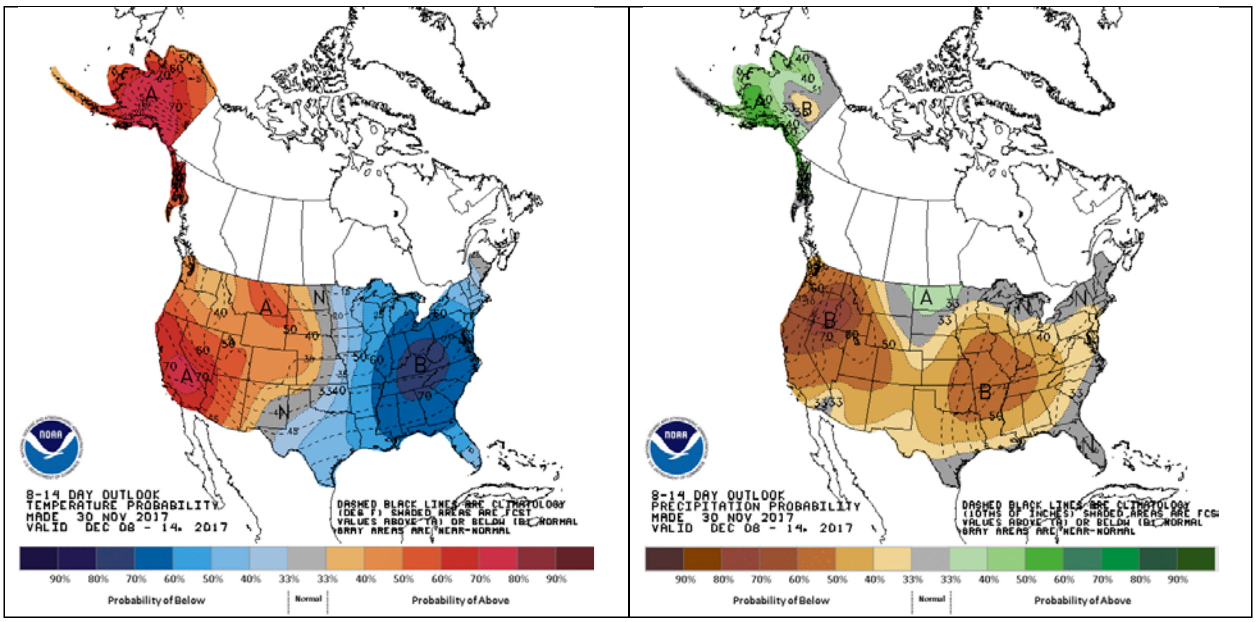


Figure 8. CPC 8-14 Day temperature and precipitation outlooks through December 14, 2017.

The December CPC outlooks in **Figure 9** indicate equal chances for above-normal, normal or below-normal temperatures in most of the Missouri Basin. However, the outlook does indicate increased chances for above-normal temperatures in the Rocky Mountains and below-normal temperatures in Iowa and Missouri. With regard to precipitation, there are mostly equal chances for above-normal, normal or below-normal precipitation in the upper Basin; however, there is a slight increase in the chance for below-normal precipitation in western Montana and western Wyoming. There are also increased chances for below-normal precipitation in much of the lower Basin.

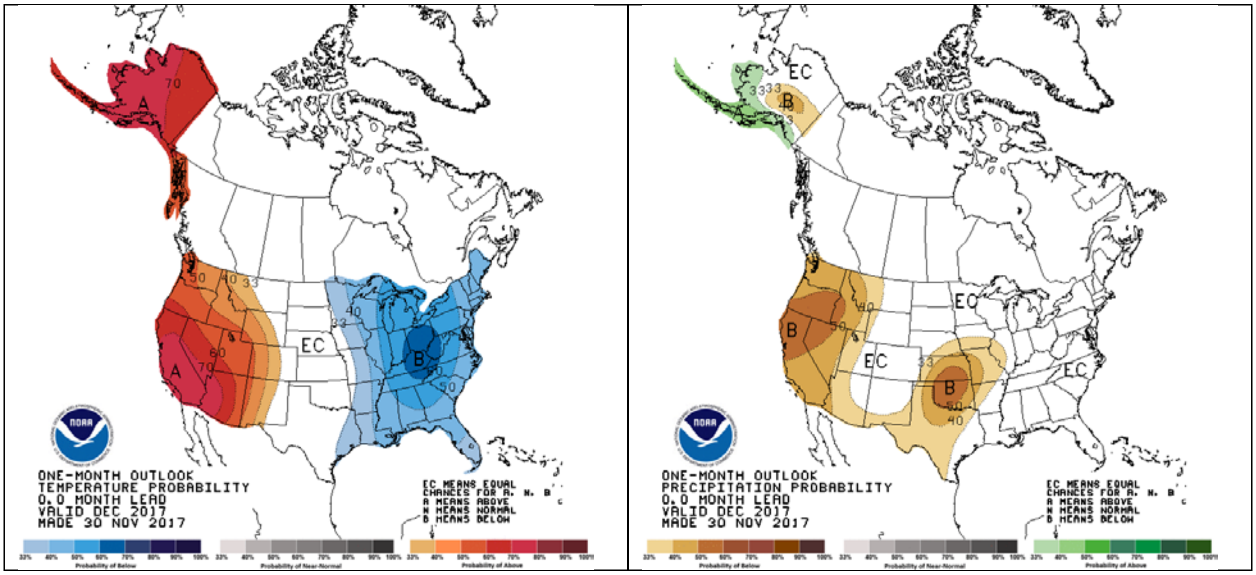


Figure 9. CPC December 2017 temperature and precipitation outlooks.

During the January-February-March 2018 period, the CPC outlooks in **Figure 10** indicate increased chances for below-normal temperatures in northern Montana, North Dakota, much of South Dakota and Iowa based on the projected weak La Niña. With regard to the precipitation outlook, the weak La Niña could increase chances for above-normal precipitation in the upper Basin, particularly in Montana and Wyoming. There are equal chances for precipitation in eastern South Dakota, Nebraska and Kansas.

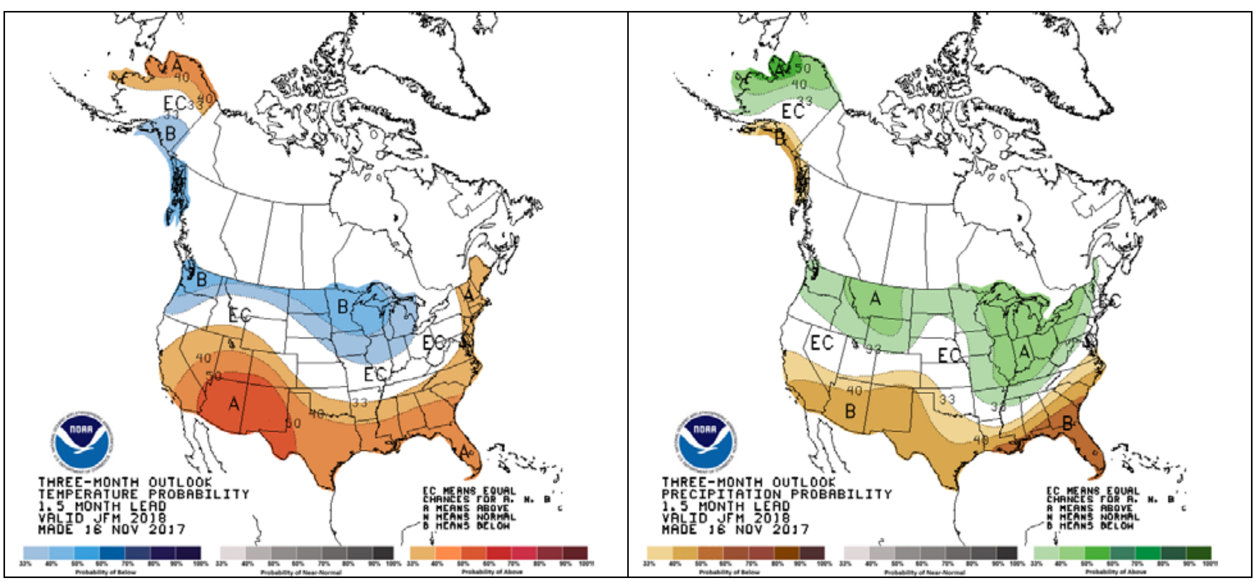


Figure 10. CPC January-February-March 2018 temperature and precipitation outlooks.

Summary

In summary, the 2017 calendar year runoff forecast is 29.4 MAF, 116% of average. For the remaining month of the year, the runoff summation above Gavins Point is forecast to be about average; however, above-average runoff is expected in the Sioux City reach. At the end of the calendar year and beginning of the winter low-flow season, Missouri River ice monitoring will become a major focus. As temperatures begin to fall at the start of winter, very cold temperatures can cause rapid development of river ice, causing immediate changes to river stages. Furthermore, plains snowpack monitoring will become an important activity in order to begin forecasting spring snowmelt runoff.