Upper Missouri River Basin
August 2016 Calendar Year Runoff Forecast
August 4, 2016

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.

July 2016 Runoff

July 2016 Missouri River Basin above Sioux City, IA (upper Basin) runoff was 2.3 MAF (69% of average). July runoff was 58% of average in the Fort Peck reach, 60% of average in the Garrison reach, 125% of average in the Oahe reach, 53% of average in the Fort Randall reach, 85% of average in the Gavins Point reach, and 117% of average in the Sioux City reach. Mountain snowpack had melted by the end of June, a couple weeks earlier than normal. The absence of any remaining mountain snowpack in early July coupled with significantly below-normal precipitation led to below-normal runoff in the Fort Peck and Fort Peck to Garrison reaches. Above normal rainfall in the northern portion of the Oahe reach contributed to above normal runoff for Oahe. Runoff in the Sioux City reaches was largely due to higher-than-average baseflow that carried over from above average May and June runoff and tributary streamflow.

2017 Calendar Year Forecast Synopsis

The August 1 forecast for 2016 upper Basin runoff is **22.7 MAF (89% of average)**. Runoff for the basin above Gavins Point Dam is forecast to be **19.3 MAF (83% 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 23.9 MAF upper basic forecast to the 21.5 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 5 months are being forecasted for this August 1 forecast (7 months observed/5 months forecast), the range of wetter than normal (upper basic) and drier than normal (lower basic) conditions is attributed to all 6 reaches for 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 continue to 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 July 26, 2016 (**Figure 1**), when compared to the drought monitor for June 28, 2016 (**Figure 2**), shows an increase in severity and areal extent of drought conditions in the upper Basin. There has been some worsening in drought conditions in the basin. This includes an increase in the areal extent of Extreme Drought (D3) conditions from northeast Wyoming to western South Dakota, and expansion of Moderate Drought (D0) conditions in western and southern Montana and northern Wyoming. The U.S. Seasonal Drought Outlook in **Figure 3** indicates that drought conditions are expected to persist in portions of Montana and Wyoming, but drought conditions are expected to improve in the Black Hills region of Wyoming and South Dakota.

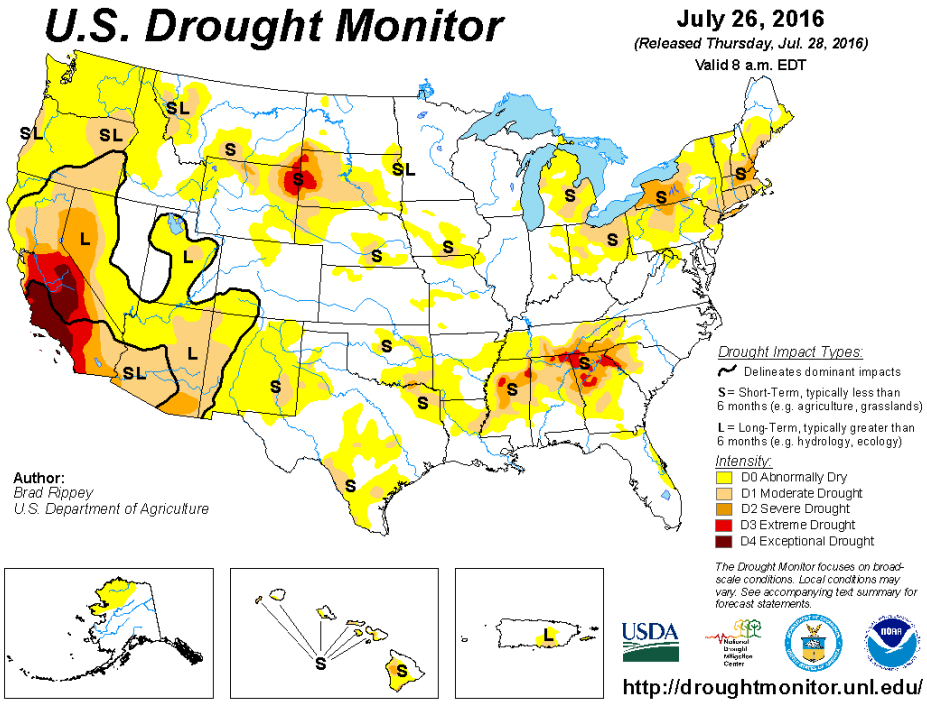

Figure 1. National Drought Mitigation Center U.S. Drought Monitor for July 26, 2016

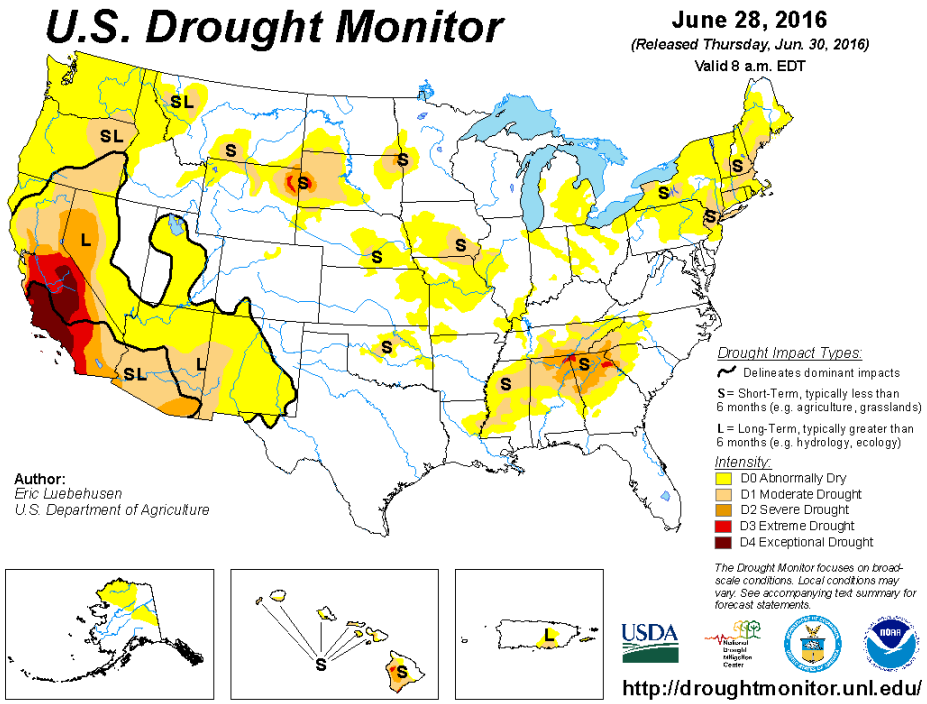

Figure 2. National Drought Mitigation Center U.S. Drought Monitor for June 28, 2016

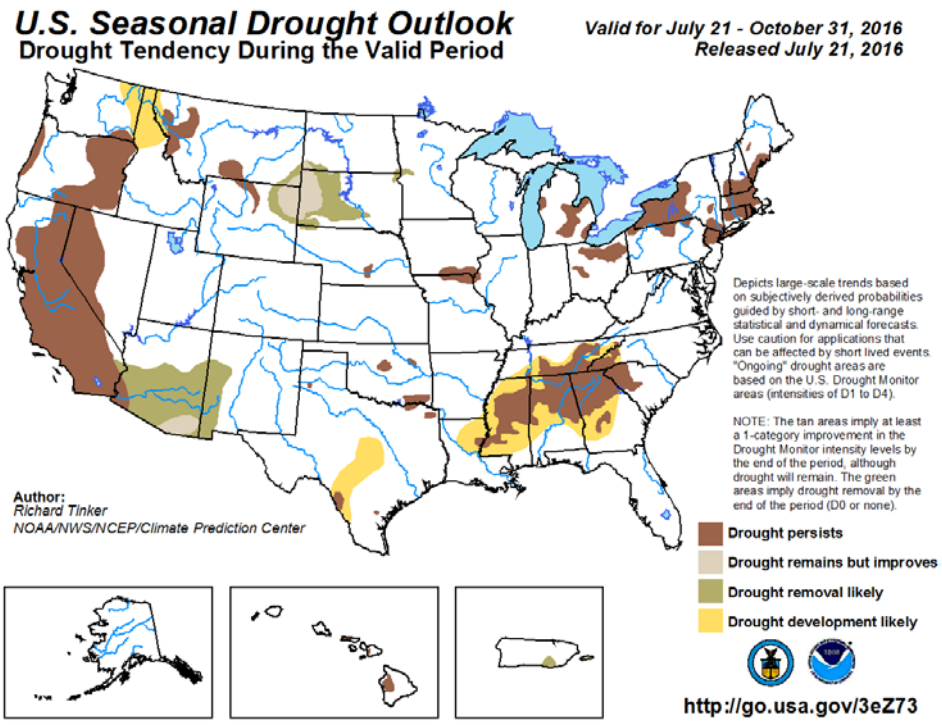

Figure 3. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

July precipitation accumulations are shown in **Figure 4** as both inches of precipitation (left) and percent of normal monthly precipitation (right). July precipitation was above average in large areas of northern Montana and North Dakota, and in smaller areas of South Dakota, and north central Nebraska. In the lower Basin, precipitation was above average in a small area of eastern Nebraska, southwest Iowa, eastern Kansas and central Missouri. Precipitation was well below average across most of Wyoming and several smaller regions of southern Montana, northwest South Dakota, and eastern South Dakota.

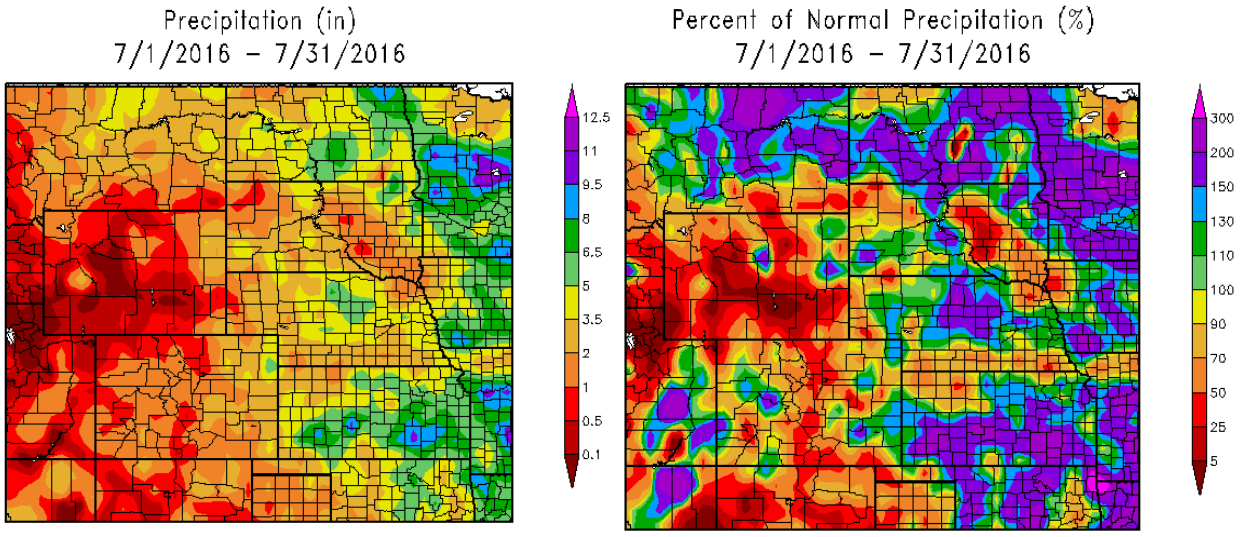

Figure 4. July 2016 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

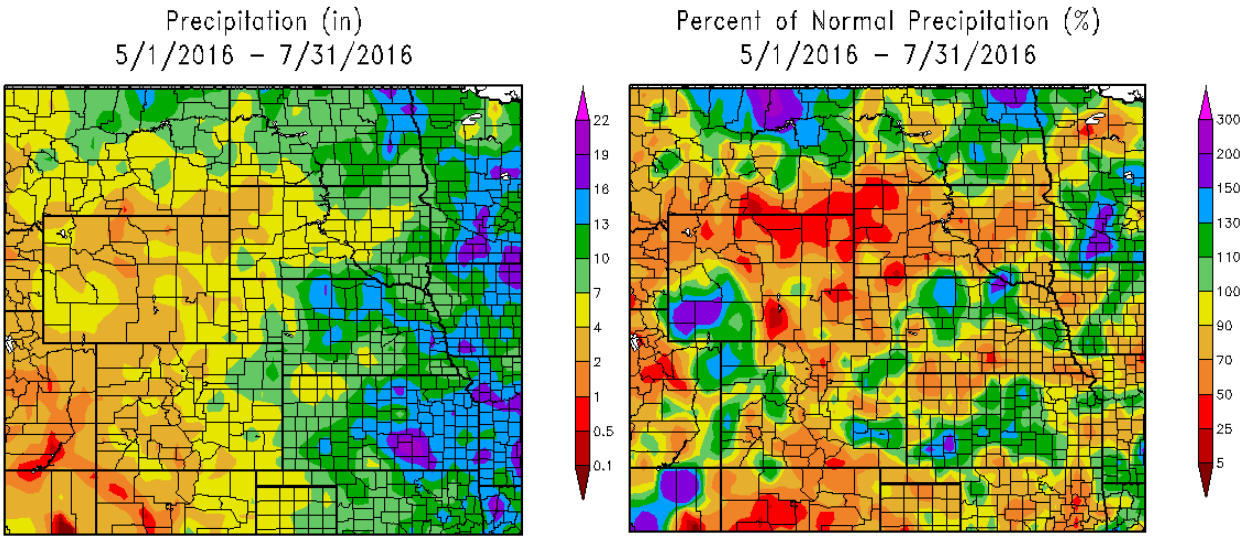

Figure 5. May-June-July 2016 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Table 1 contains notable July 2016 precipitation amounts and precipitation departures in many locations in the Missouri Basin. Low July precipitation totals occurred in Billings, MT (0.45 inches); Lander, WY (trace); and Sheridan, WY (0.22 inches). In contrast high precipitation totals occurred in Glasgow, MT (3.42 inches / 192%); Bismarck, ND (5.1 inches / 176%); and Pierre, SD (4.31 inches / 165%). High precipitation totals also occurred at many locations in the lower Basin including Omaha, NE (6.61 inches / 173%); Kansas City, MO (8.76 inches / 197%); and Columbia, MO (10.91 inches / 250%). Despite the very heavy rainfall, high volumes of runoff did not occur in the Missouri Basin in July.

May-June-July 2016 precipitation accumulations and percent of normal (average) precipitation are shown in **Figure 5**. The precipitation pattern since May 1 has been very dry in southern Montana, much of Wyoming, South Dakota, northwest Iowa, and southeast Nebraska. Areas that have received above average precipitation include north central Montana, eastern North Dakota, and portions of eastern Kansas and central Missouri.

Table 1. July 2016 precipitation and precipitation departures.

City, State	Precipitation inches	Precipitation Departure inches	Percent of Normal
Lewistown, MT	3.41	1.48	177%
Great Falls, MT	1.20	-0.30	80%
Havre, MT	2.43	0.79	148%
Miles City, MT	1.34	-0.30	82%
Billings, MT	0.45	-0.87	34%
Glasgow, MT	3.42	1.64	192%
Wolf Point, MT	2.43	0.45	123%
Lander, WY	Trace	-0.78	
Lake Yellowstone, WY	0.91	-0.56	62%
Sheridan, WY	0.22	-0.96	19%
Jamestown, ND	5.88	2.53	176%
Bismarck, ND	5.10	2.21	176%
Williston, ND	2.39	-0.15	94%
Rapid City Arpt, SD	2.83	0.98	153%
Aberdeen, SD	3.69	0.67	122%
Watertown, SD	2.48	-0.54	82%
Pierre, SD	4.31	1.70	165%
Mobridge, SD	2.33	-0.37	86%
Sioux Falls, SD	2.32	-0.77	75%
Sioux City, IA	2.19	-1.25	64%
North Platte, NE	3.84	0.77	126%
Grand Island, NE	4.10	0.70	121%
Lincoln, NE	4.67	1.27	137%
Omaha, NE	6.61	2.78	173%
Topeka, KS	5.36	1.54	140%
St. Joseph, MO	8.54	3.35	165%
Kansas City Intl Arpt, MO	8.76	4.31	197%
Columbia, MO	10.91	6.54	250%
Jefferson City, MO	7.99	3.71	187%

Temperature

July temperature departures from normal are shown in the left image of **Figure 6** in degrees Fahrenheit (deg F). May-June-July 2016 temperature departures from normal are also shown in the right image of **Figure 6**. July temperature departures (left image) have varied across the upper Basin and lower Basin. Temperatures were generally cooler than normal in areas that received above-normal precipitation, and temperatures were generally warmer than normal in the below-normal precipitation areas. Temperature departures during May-June-July in the right image of **Figure 6** have been generally above normal across the entire Missouri Basin.

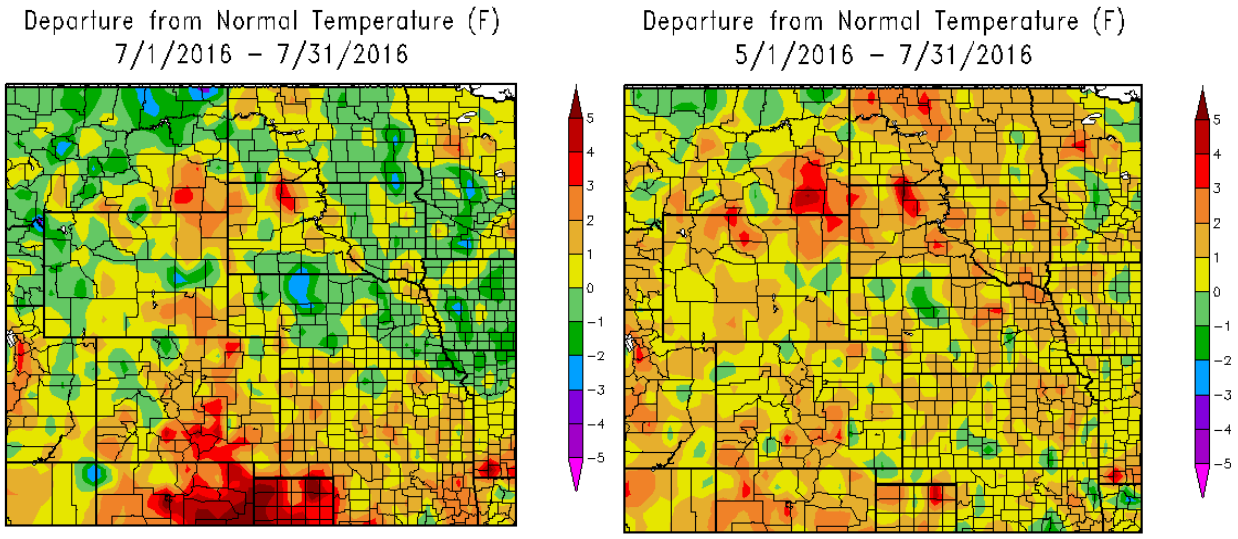

Figure 6. July 2016 and May-June-July 2016 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

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.

Figure 7 shows the NOAA NLDAS ensemble top one-meter soil moisture anomaly on July 29, 2016. The NLDAS soil moisture depiction is an average value for the one-meter soil moisture column. **Figure 7** indicates that soil moisture is predominantly drier than normal (below normal anomalies) over large portions of the Missouri Basin including southern and western Montana, Wyoming, southern North Dakota, South Dakota, southeast Nebraska and northern Missouri. Soil moisture is above normal in north central Montana, western Nebraska, western and central Kansas,and much of central Missouri.

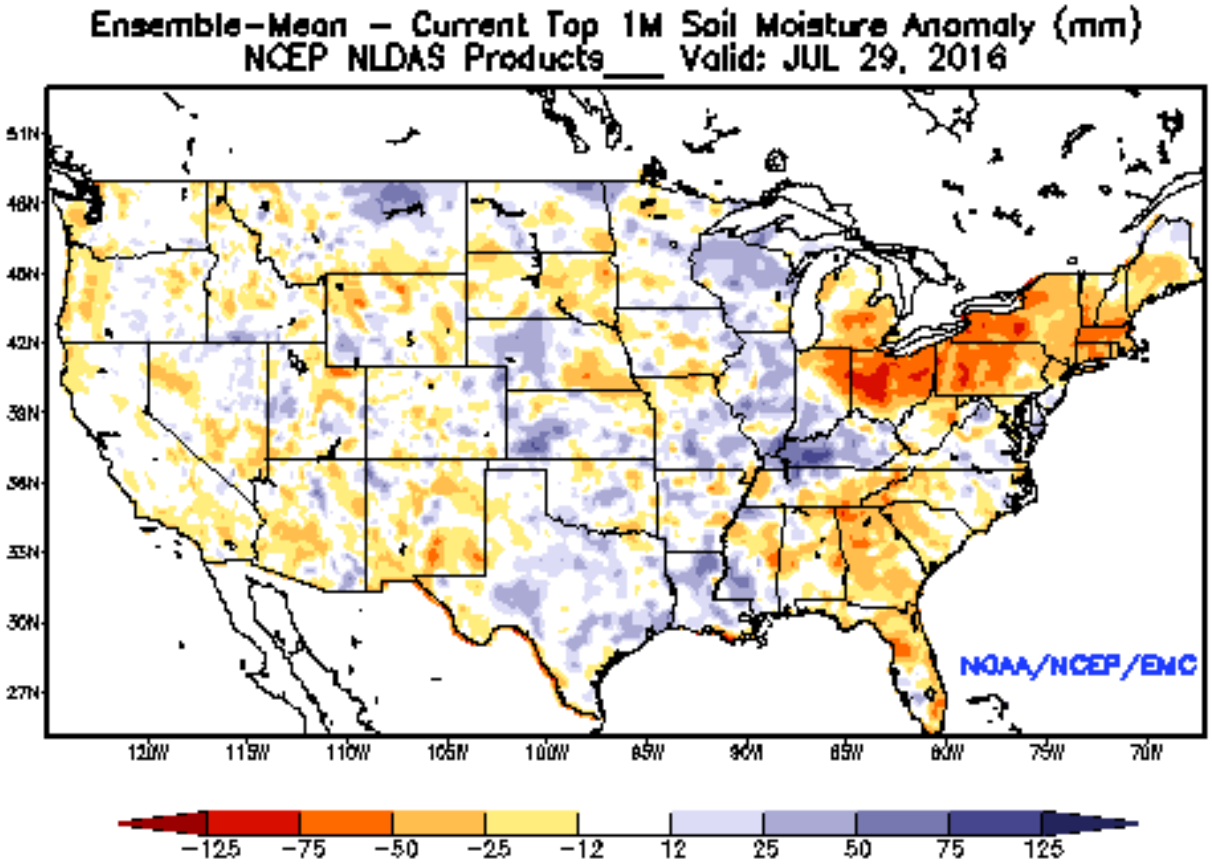

Figure 7. Top 1-Meter Soil Moisture Anomaly on July 29, 2016. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

Streamflow Conditions

Missouri Basin streamflow conditions are shown in **Figure 8**. These conditions are based on the ranking of the August 1, 2016 daily streamflow versus the historical record of streamflow for that date. Streamflow conditions are generally "Normal" (25th-75th percentile) and "Below Normal) (10th to 24th percentile) in Montana and Wyoming, though there are a number of tributaries that have fallen into the "Much Below Normal" (below 10th percentile) class as a result of the absence of remaining snowpack and low precipitation accumulations in July. Streamflow on the lower Platte River Basin and on the Missouri River from Sioux City to Nebraska City was "Above Normal" (76th – 90th percentile) to "Much Above Normal" (above 90th percentile). Also some Missouri tributaries in Missouri were "Much Above Normal" (above 90th percentile).

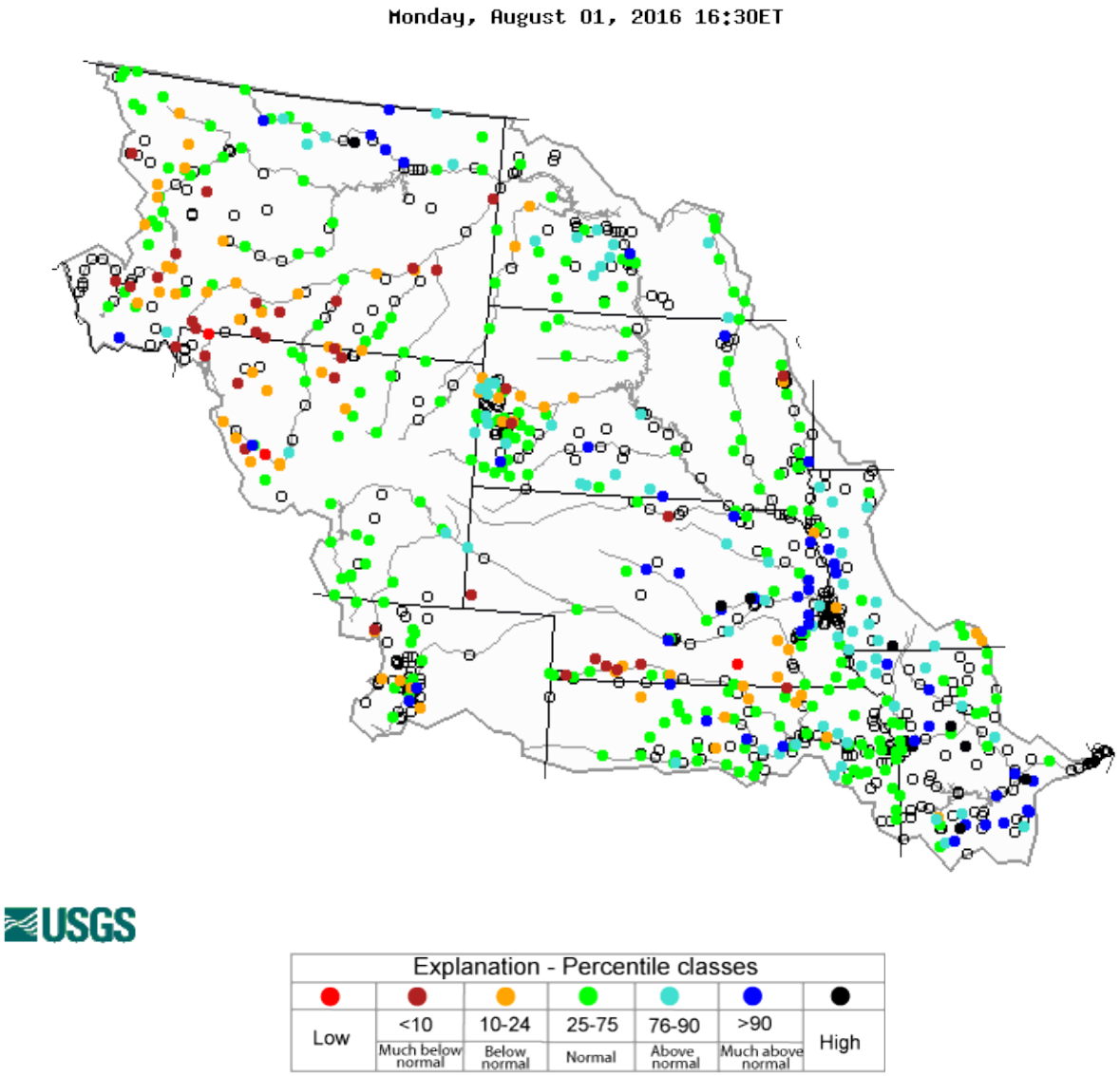

Figure 8. USGS Streamflow Conditions as a Percentile of Normal in the Missouri River Basin as of August 1, 2016. Source: USGS. http://waterwatch.usgs.gov/index.php

Mountain Snowpack

Mountain snowpack is the primary factor used to predict June-July runoff volumes in the Fort Peck and Fort Peck to Garrison mainstem reaches. During the 3-month May-June-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 June-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 below-average runoff from a below-average mountain snowpack this year due to soil moisture conditions ranging from drier than normal to wetter than normal.

Figure 9 includes time series plots of the average mountain snow water equivalent (SWE) beginning on October 1, 2015 based on the NRCS SNOTEL gages for the 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), 2001 (green line), and two historic high SWE years occurring in 1997 (purple) and 2011 (dark blue). On average, mountain SWE normally peaks around April 15, and about 39% of the peak SWE accumulation remains by June 1.

The Fort Peck reach peaked at 15.0 inches of SWE on April 1, while Fort Peck to Garrison peaked at 12.2 inches of SWE on April 2, or 95% and 89% of average annual peak SWE, respectively. As of July 1, the mountain snowpack in both the Fort Peck and the Fort Peck to Garrison reaches had melted.

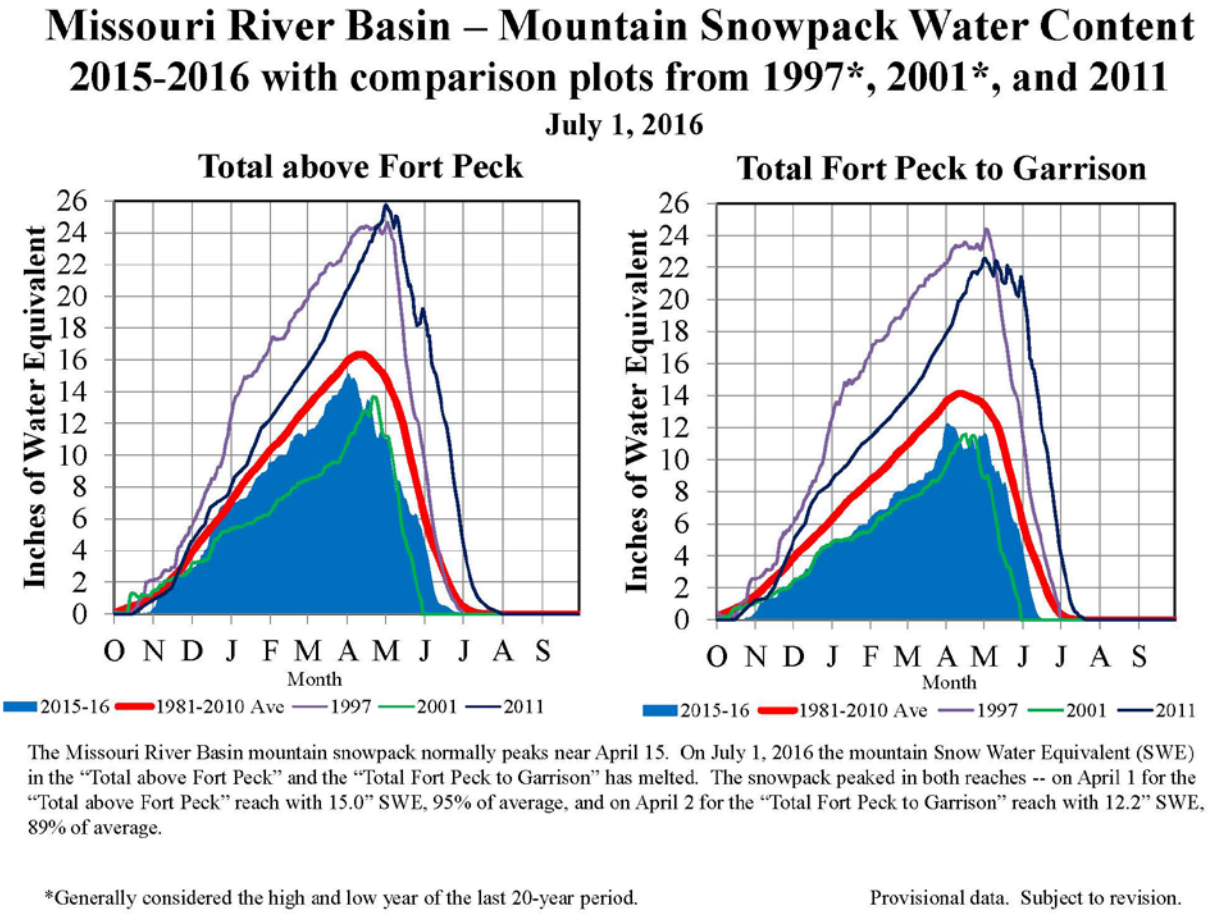

Figure 9. Mountain snowpack water content on July 1, 2016 compared to normal and historic conditions. Corps of Engineers - Missouri River Basin Water Management.

Climate Outlook

ENSO (El Niño Southern Oscillation)

According to the CPC's latest monthly updated[1] on August 1, 2016, "***ENSO-neutral conditions are present. La Niña is favored to develop during August-October 2016, with about a 55-60% chance of La Niña during the fall and winter 2016-2017.***"

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 La Niña climate pattern and its implications on winter temperature and precipitation patterns in the Missouri River Basin. During La Niña winters, the probability for a colder-than-normal and slightly wetter-than-normal weather pattern in the Northern Rockies and Northern Plains is higher. The possible impacts of La Niña have been factored into the CPC climate outlooks described below.

Temperature and Precipitation Outlooks

The NOAA Climate Prediction Center climate outlook for August 2016 (**Figure 10)** indicates there are equal chances for above-normal, normal and below-normal temperatures throughout the upper Basin and most of the lower Basin. The August outlook indicates increased chances for above-normal temperatures in eastern Kansas and most of Missouri. With regard to precipitation, there are increased chances for below-normal precipitation in western Montana, increased chances for above-normal precipitation in South Dakota, Nebraska, Iowa and northern Missouri, and equal chances for above-normal, normal and below-normal precipitation in the remainder of the Missouri Basin.

The August-September-October 2016 temperature outlook (**Figure 11**) indicates there are increased chances for above-normal temperatures throughout the entire Missouri Basin. With regard to precipitation, the August-September-October outlook indicates there are increased chances of below-normal precipitation in western Montana, an increased probability of above-normal precipitation in eastern Montana, northeast Wyoming, the Dakotas and northern Nebraska, and equal chances for above-normal, normal or below-normal precipitation over the remainder of the Basin.

[1] http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/lanina/enso_evolution-status-fcsts-web.pdf

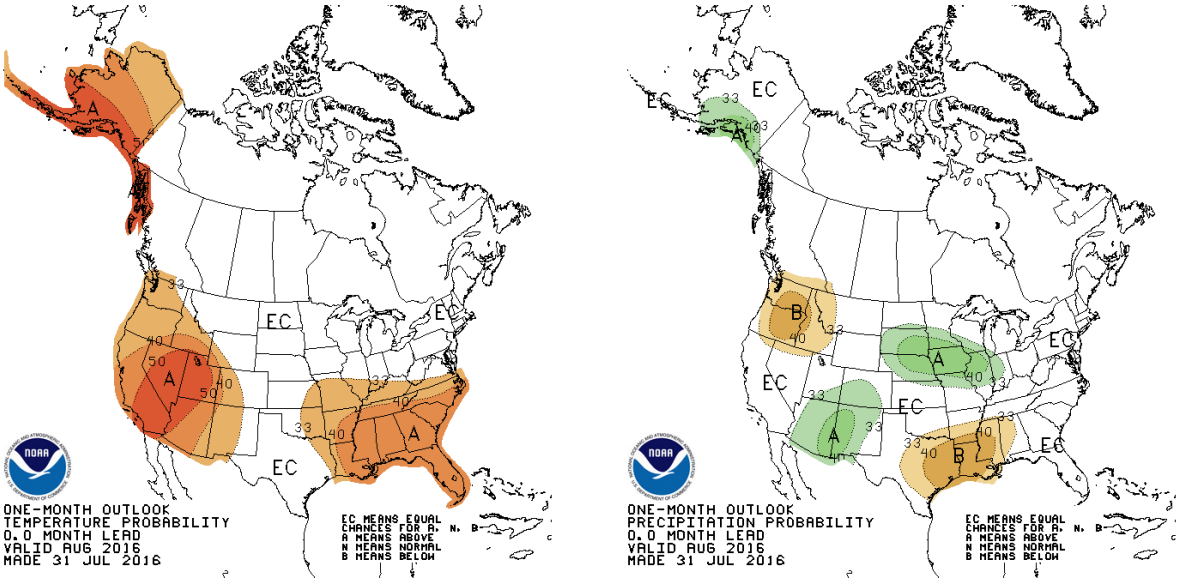

Figure 10. CPC August 2016 temperature and precipitation outlooks.

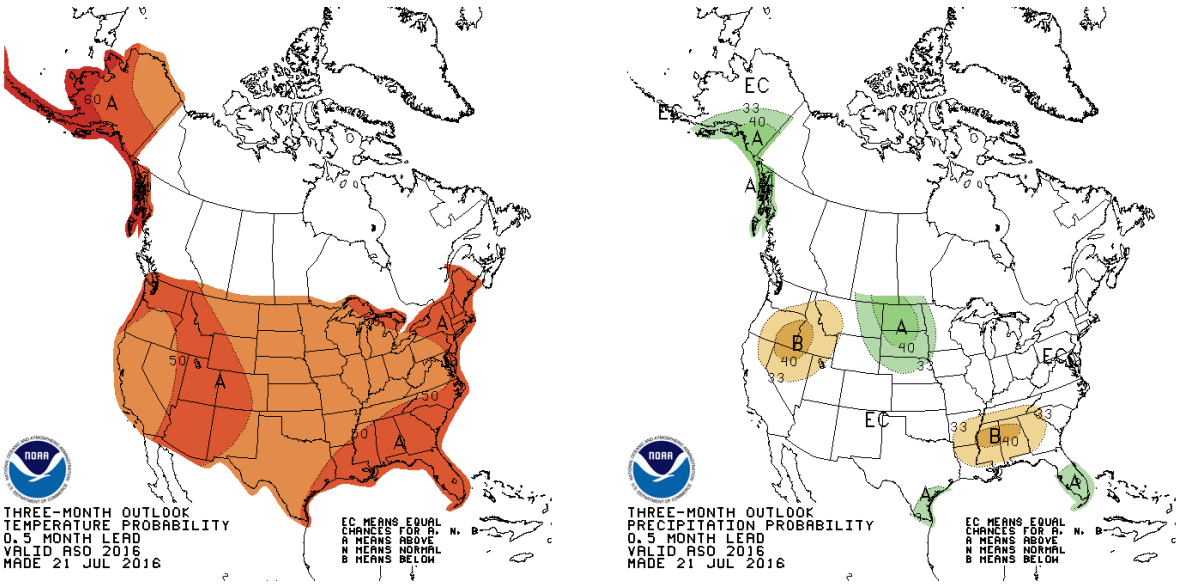

Figure 11. CPC August-September-October 2016 temperature and precipitation outlooks.

The November-December 2016-January 2017 CPC temperature outlook (**Figure 12**) indicates there are equal chances for above-normal, normal or below-normal temperatures across much of the upper Basin. There are increased chances for above-normal temperatures in western Montana, most of Wyoming, western Nebraska, Colorado and Kansas. With regard to precipitation, there are increased chances for above-normal precipitation across Montana, northern Wyoming, western North Dakota and northwest South Dakota because of the possibility of La Niña developing during the 2016 fall season. There are equal chances for precipitation in the remainder of the Missouri Basin from November 2016 to January 2017. During the February-March-April 2017 period (**Figure 13**) CPC outlooks indicate increased chances for

below-normal temperatures in most of the upper Basin as a result of La Niña, and equal chances in the remainder of the Missouri Basin. There are equal chances for precipitation in much of the upper Basin, and increased chances for precipitation in northwest Montana. There are increased chances for below normal precipitation in the southern half of Nebraska, Colorado and Kansas.

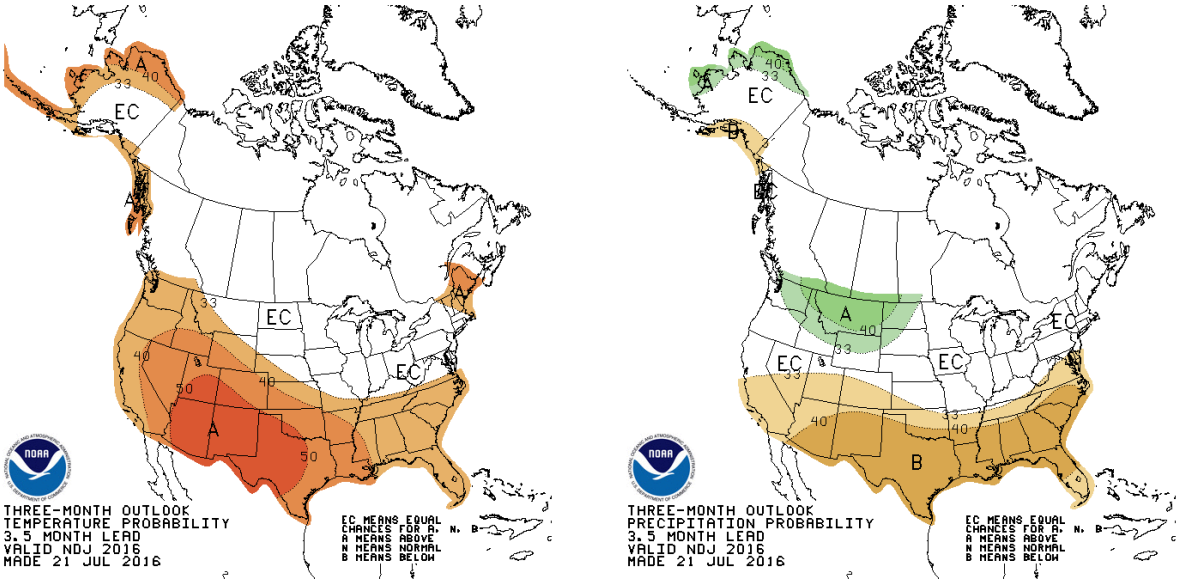

Figure 12. CPC November-December 2016-January 2017 temperature and precipitation outlooks.

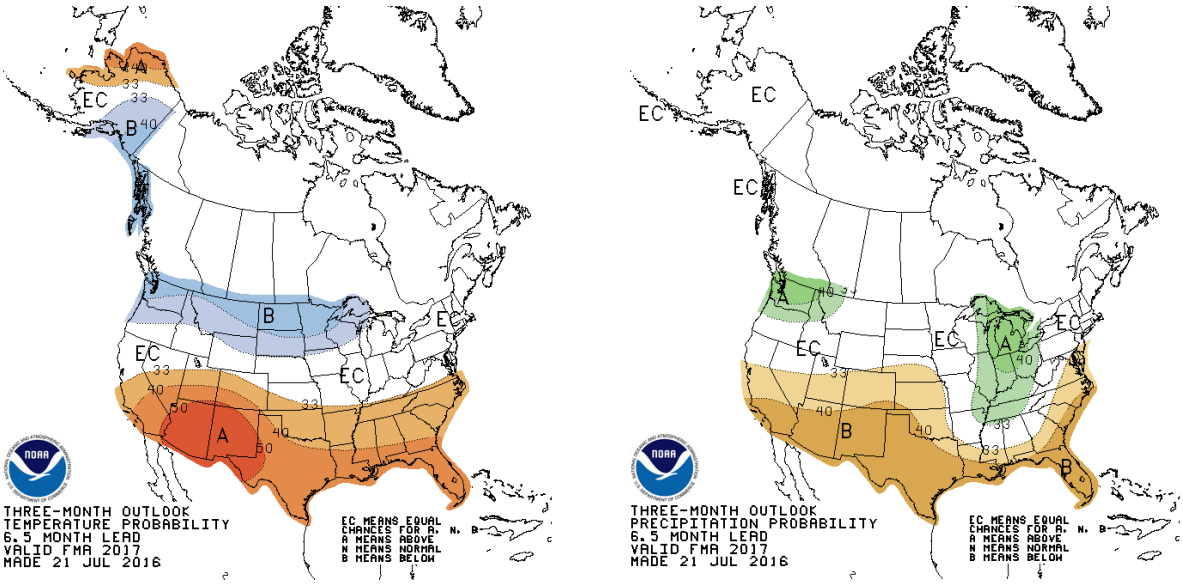

Figure 13. CPC February-March-April 2017 temperature and precipitation outlooks.

August 2016 Calendar Year Runoff Forecast

In summary, the 2016 calendar year runoff forecast is **22.7 MAF, 89% of average**. Runoff for the basin above Gavins Point Dam, excluding the contributing area between Gavins Point Dam and Sioux City, IA, is forecast to be **19.3 MAF (83% of average)**. July runoff was 2.3 MAF (69% of average). Runoff was 58% and 60% of average in the Fort Peck and Garrison reaches, respectively. These reaches generally received well-below normal rainfall in July, and no mountain snowpack remained at the beginning of July. Current soil moisture and drought conditions indicate runoff for the next few months will likely be below average even with normal precipitation conditions. Precipitation outlooks for the plains region of the upper Basin indicate increased probabilities for above normal precipitation through the fall, however, there are increased chances for below normal precipitation in western Montana. Winter precipitation, which normally comes in the form of mountain or plains snow, will have little impact on runoff during the 2016 calendar year. We will continue to monitor Missouri Basin conditions and make forecast adjustments as conditions change.