Upper Missouri River Basin
September 2016 Calendar Year Runoff Forecast
September 2, 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.

August 2016 Runoff

August 2016 Missouri River Basin above Sioux City, IA (upper Basin) runoff was 1.0 MAF (76% of average). August runoff was 72% of average in the Fort Peck reach, 40% of average in the Garrison reach, 231% of average in the Oahe reach, 127% of average in the Fort Randall reach, 87% of average in the Gavins Point reach, and 128% of average in the Sioux City reach. Dry antecedent soil moisture conditions coupled with significantly below-normal precipitation led to below-average 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-average runoff for Oahe. Runoff in the Sioux City reach was largely due to higher-than-average baseflow that carried over from above-average May through July runoff and tributary streamflow coupled with areas of high precipitation across portions of North Dakota and South Dakota.

2016 Calendar Year Forecast Synopsis

The September 1 forecast for 2016 upper Basin runoff is **22.4 MAF (89% of average)**. Runoff for the basin above Gavins Point Dam is forecast to be **19.0 MAF (82% 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 23.3 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 4 months are being forecasted for this September 1 forecast (8 months observed/4 months forecast), the range of wetter than normal (upper basic) and drier than normal (lower basic) conditions is attributed to all 6 reaches for 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 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 August 30, 2016 (**Figure 1**), when compared to the drought monitor for July 26, 2016 (**Figure 2**), shows a mix of increase and decrease in severity and areal extent of drought conditions in the upper Basin. There has been some worsening in drought conditions in the basin, including an increase in the areal extent of Abnormally Dry through Severe Drought (D0-D2) conditions from north-central Wyoming to western Montana. A decrease in severity and areal extent in Abnormally Dry through Extreme Drought (D0-D3) conditions have occurred in northeastern Wyoming, southeastern Montana and western South Dakota, with decrease in areal extent of Abnormally Dry (D0) conditions in isolated areas of Nebraska, Iowa, Kansas and Missouri. The U.S. Seasonal Drought Outlook in **Figure 3** indicates that drought conditions are expected to persist in portions of western Montana, but drought conditions are expected to improve in the Black Hills region of Wyoming and South Dakota, as well as south-central Montana and north-central Wyoming.

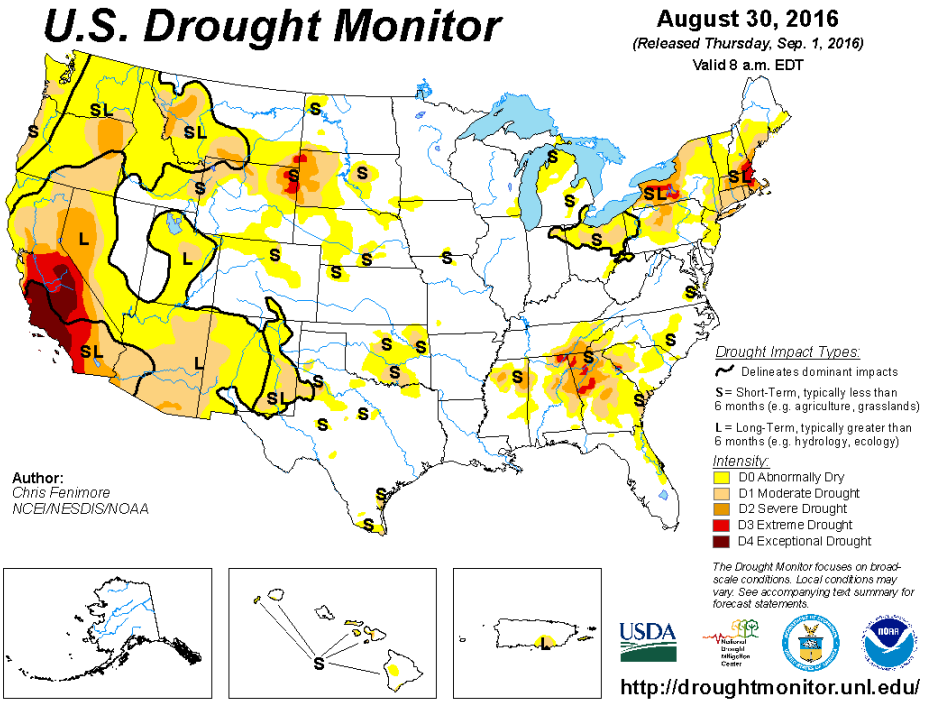

Figure 1. National Drought Mitigation Center U.S. Drought Monitor for August 30, 2016

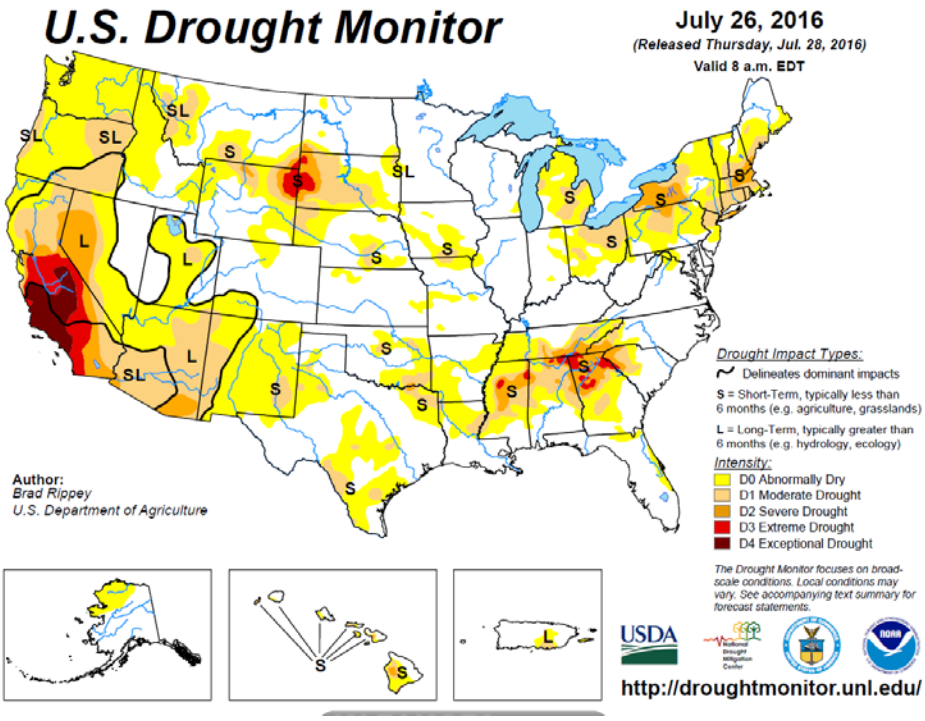

Figure 2. National Drought Mitigation Center U.S. Drought Monitor for July 26, 2016

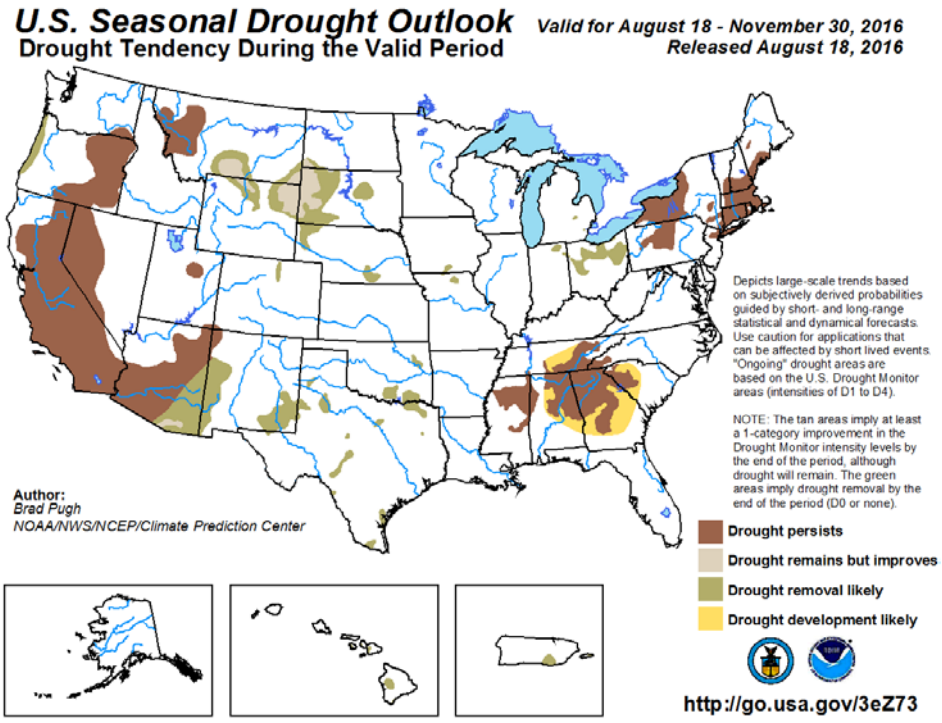

Figure 3. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

August precipitation accumulations are shown in **Figure 4** as both inches of precipitation (left) and percent of normal monthly precipitation (right). August precipitation was above average in a large area from south central Montana into southwestern South Dakota and northwestern Nebraska, portions of eastern North Dakota and South Dakota, southeastern Nebraska, eastern Kansas, and much of Iowa and Missouri. Precipitation was well below average across most of western North Dakota, northwestern and southeastern Wyoming, eastern Colorado and central Nebraska.

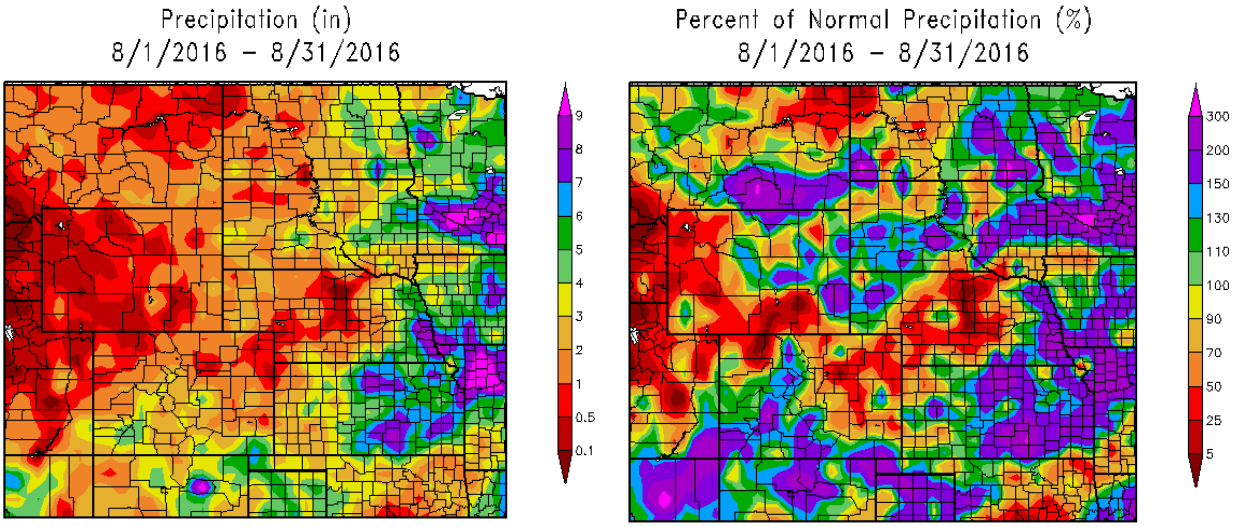

Figure 4. August 2016 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

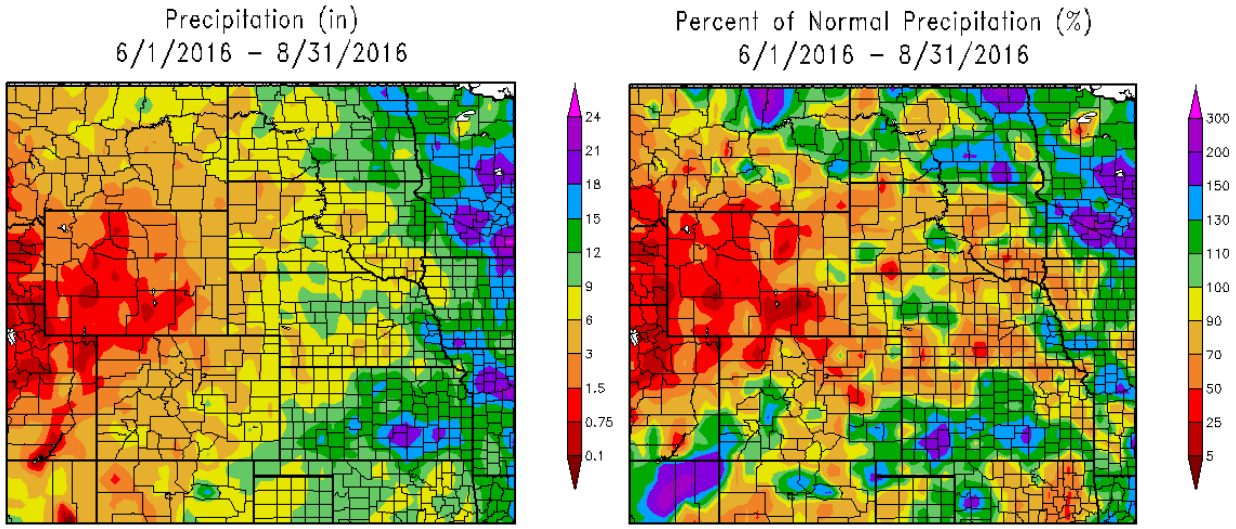

Figure 5. June-July-August 2016 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Table 1 contains notable August 2016 precipitation amounts and precipitation departures in many locations in the Missouri Basin. Low August precipitation totals occurred in many locations including Dillon, MT (0.12 inches); Denver, CO (0.22 inches); Lake Yellowstone, WY (0.31 inches); and Williston, ND (0.45 inches). In contrast high precipitation totals occurred in numerous places including Billings, MT (1.67 inches / 223%); Sheridan, WY (1.44 inches / 200%); Jamestown, ND (4.59 inches / 219%); Watertown, SD (6.98 inches / 251%); and Kansas City, MO (9.16 inches / 235%). Despite the very heavy rainfall, high volumes of runoff did not occur in many areas of the Missouri Basin in August.

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

Table 1. August 2016 precipitation and precipitation departures.

City, State	Precipitation inches	Precipitation Departure inches	Percent of Normal
Dillon, MT	0.12	-0.93	11%
Great Falls, MT	1.12	-0.45	71%
Billings, MT	1.67	0.92	223%
Glasgow, MT	0.52	-0.72	43%
Wolf Point, MT	0.73	-0.55	57%
Casper, WY	1.30	0.45	153%
Lake Yellowstone, WY	0.31	-1.21	20%
Sheridan, WY	1.44	0.72	200%
Jamestown, ND	4.59	2.49	219%
Williston, ND	0.45	-1.00	31%
Rapid City Arpt, SD	2.28	0.72	146%
Watertown, SD	6.98	4.20	251%
Sioux Falls, SD	2.32	-0.73	76%
Mitchell, SD	3.31	0.93	139%
Sioux City, IA	5.05	1.82	156%
Cheyenne, WY	1.05	-0.90	54%
Denver, CO	0.22	-1.47	13%
North Platte, NE	0.88	-1.41	38%
Kearney, NE	1.16	-1.92	38%
Grand Island, NE	0.57	-2.55	18%
Lincoln, NE	3.83	0.34	110%
Omaha, NE	5.78	1.96	151%
Topeka, KS	5.83	1.59	138%
Manhattan, KS	6.92	2.64	162%
St. Joseph, MO	6.74	2.76	169%
Kansas City Intl Arpt, MO	9.16	5.27	235%
Columbia, MO	5.84	1.48	134%
Jefferson City, MO	6.40	2.14	150%

Temperature

August temperature departures from normal are shown in the left image of **Figure 6** in degrees Fahrenheit (deg F). June-July-August 2016 temperature departures from normal are also shown in the right image of **Figure 6**. August temperature departures (left image) have varied across the upper Basin and lower Basin. Temperatures were generally cooler than normal in areas west of the Missouri River and warmer east of the Missouri River. Temperature departures during June-July-August in the right image of **Figure 6** have been generally above normal across the entire Missouri Basin with the exception of north-central Montana and eastern North Dakota.

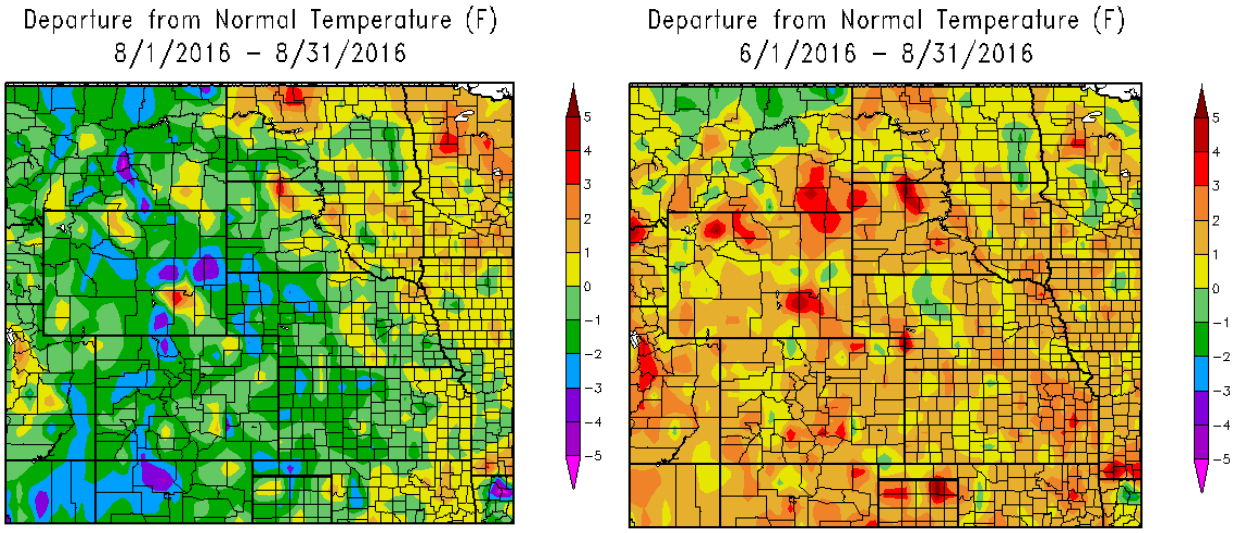

Figure 6. August 2016 and June-July-August 2016 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

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 August 27, 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 western Montana, northern and southeastern Wyoming, North Dakota, South Dakota, central Nebraska and northwestern Iowa. Soil moisture is above normal in northeastern Montana, western Nebraska, eastern Nebraska and southwestern Iowa and much of Kansas and Missouri.

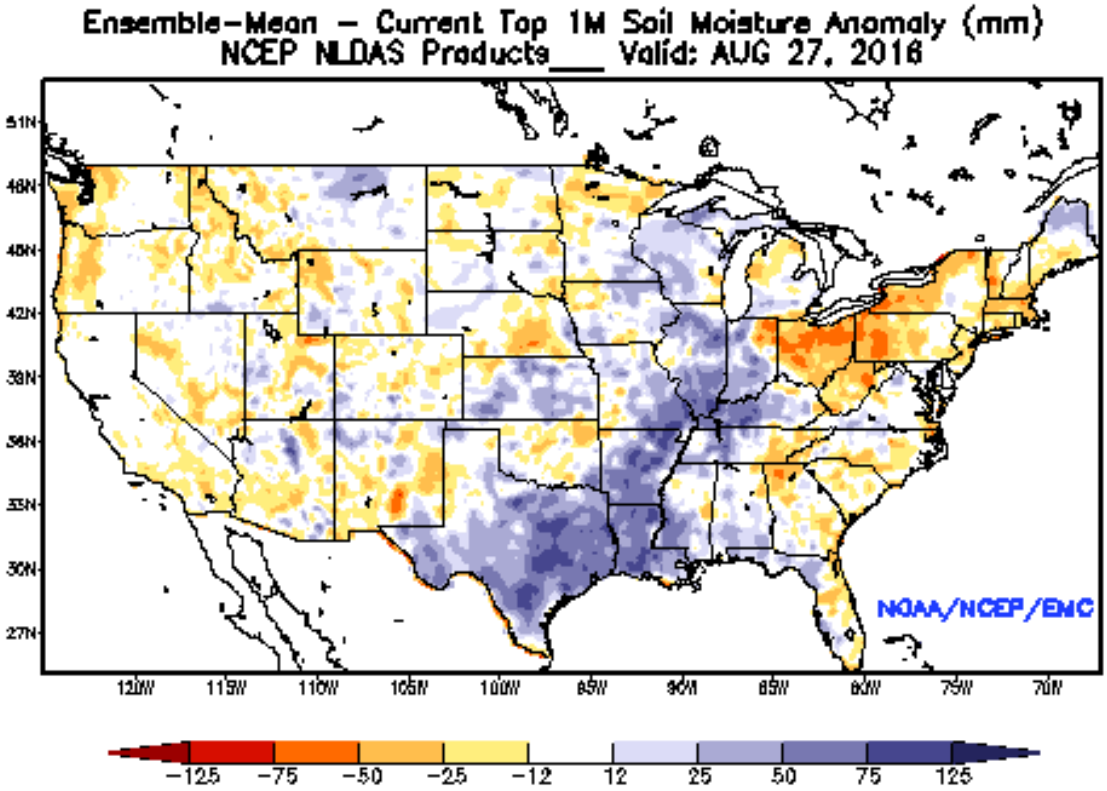

Figure 7. Top 1-Meter Soil Moisture Anomaly on August 27, 2016. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

Streamflow Conditions

Missouri Basin streamflow conditions are shown in **Figure 8**. These conditions are based on the ranking of the September 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 antecedent dry conditions and low precipitation accumulations in August. Streamflow between Garrison Dam and Sioux City, IA is generally in the "Normal" (25th – 75th percentile), while most of the lower Basin is in the "Above Normal" (75th – 90th percentile) to "Much Above Normal" (above 90th percentile) due to wetter than normal soil moisture and above average precipitation across much of the lower Basin.

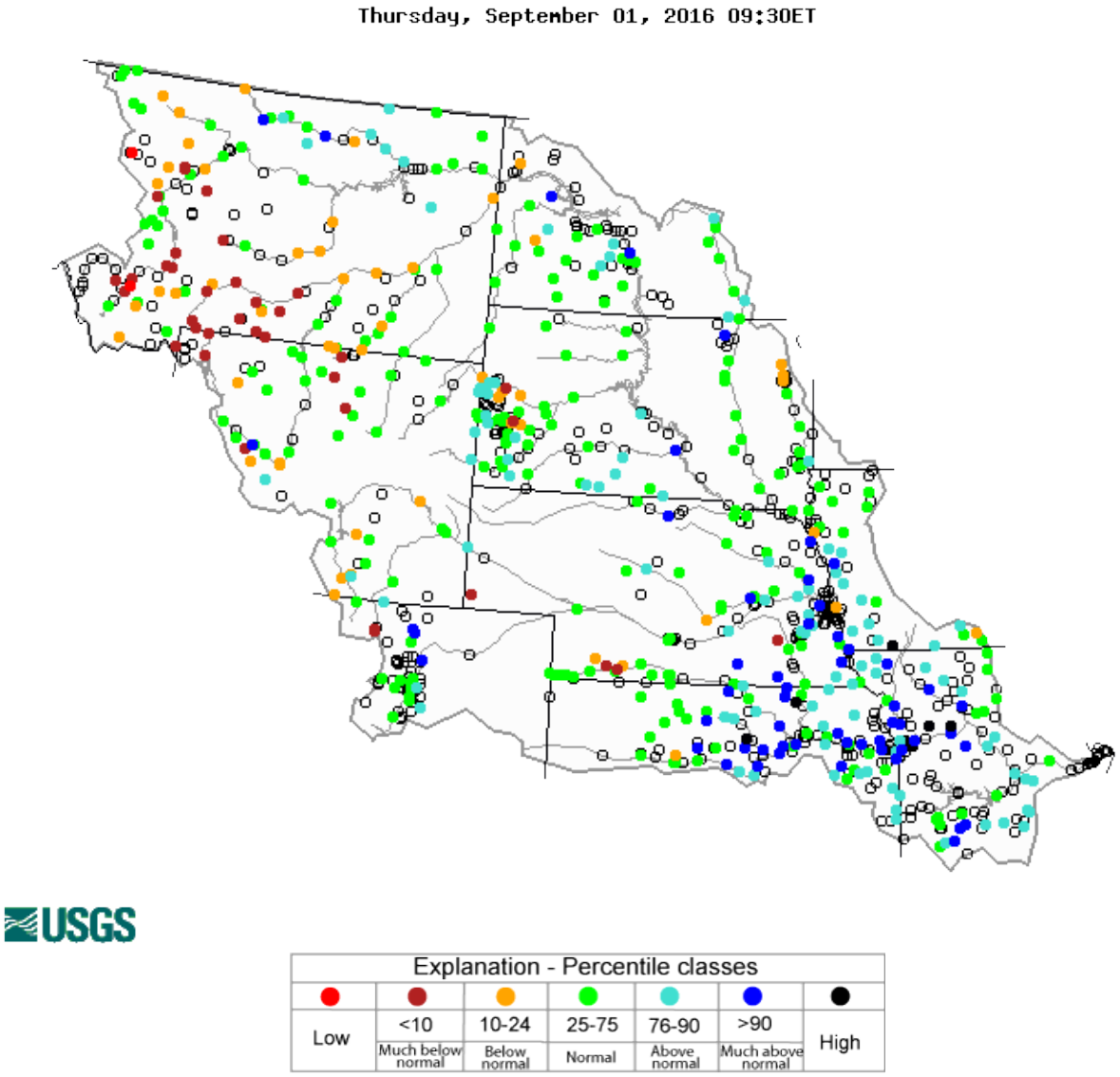

Figure 8. USGS Streamflow Conditions as a Percentile of Normal in the Missouri River Basin as of September 1, 2016. Source: USGS. http://waterwatch.usgs.gov/index.php

Climate Outlook

ENSO (El Niño Southern Oscillation)

According to the CPC's latest monthly updated[1] on August 29, 2016, "***ENSO-neutral conditions are present. La Niña is slightly 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 September 2016 (**Figure 9)** indicates there are equal chances for above-normal, normal and below-normal temperatures throughout the entire Basin. With regard to precipitation, there are increased chances for above-normal precipitation in eastern North Dakota and South Dakota, much of eastern Nebraska, and nearly all of Iowa, and equal chances for above-normal, normal and below-normal precipitation in the remainder of the Missouri Basin.

The September-October-November 2016 temperature outlook (**Figure 10**) indicates there are increased chances for above-normal temperatures throughout the entire Missouri Basin. With regard to precipitation, the September-October-November outlook indicates there are increased chances of above-normal precipitation in nearly all of Montana and North Dakota, extreme northern Wyoming, and most of northern South Dakota, 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

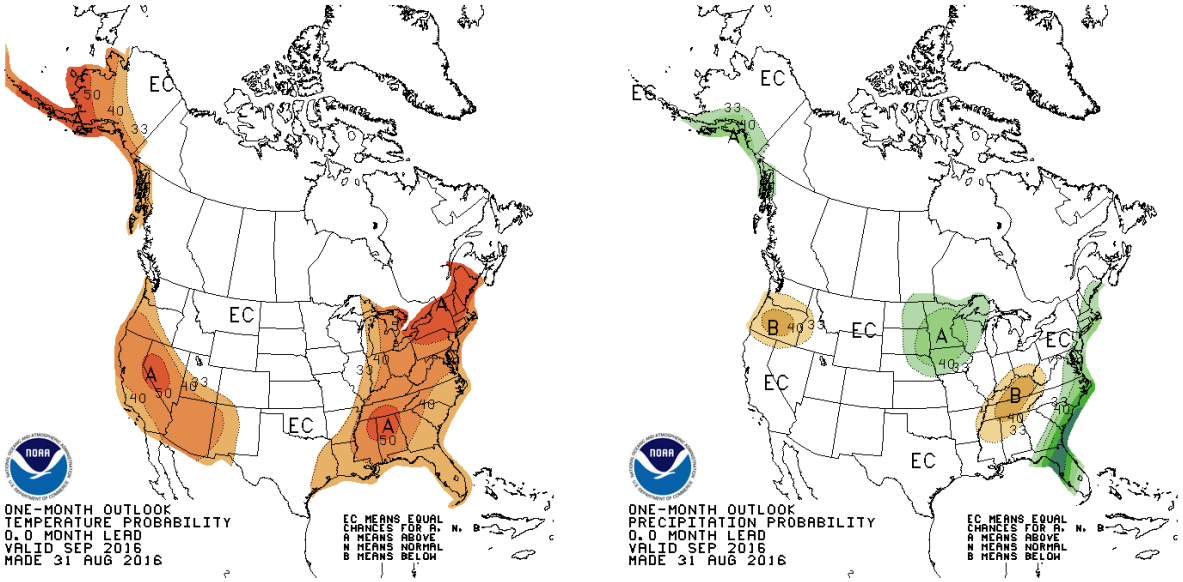

Figure 9. CPC September 2016 temperature and precipitation outlooks.

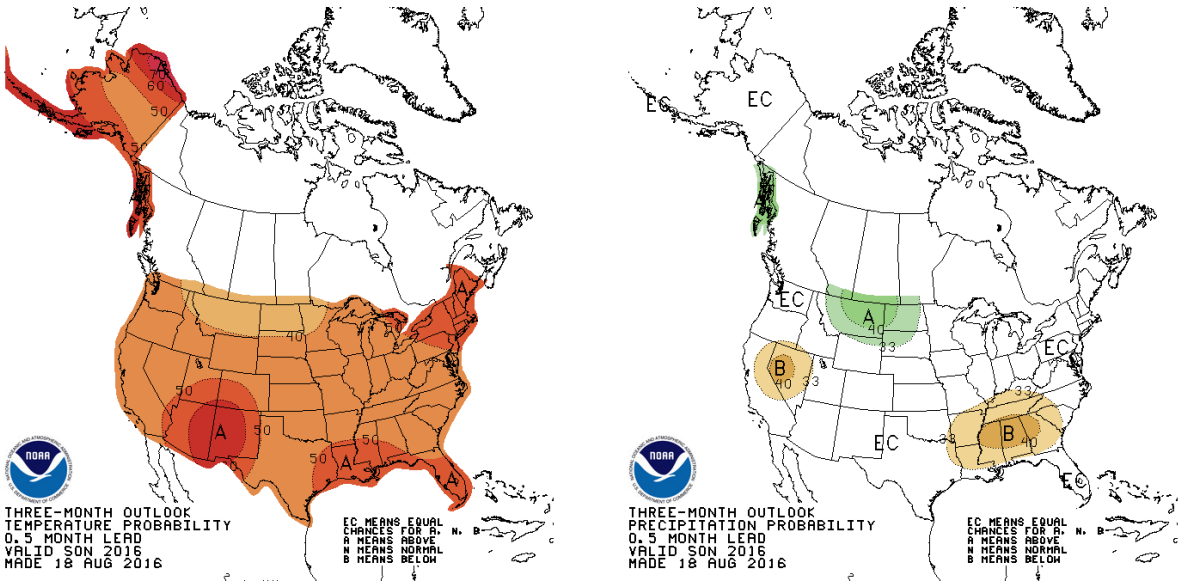

Figure 10. CPC September-October-November 2016 temperature and precipitation outlooks.

The December 2016-January-February 2017 CPC temperature outlook (**Figure 11**) indicates there are increased chances for below-normal temperatures across the northern plains into the northern Rockies, with equal chances for above-normal, normal or below-normal temperatures across nearly the rest of the Basin. 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 December 2016 to February 2017. During the March-April-May 2017 period (**Figure 12**) CPC outlooks indicate increased chances for below-normal temperatures in most of the upper Basin as

a result of La Niña, increased chances for above-normal temperatures for Colorado, Kansas and Missouri, and equal chances in the remainder of the Missouri Basin. There are equal chances for above-normal, normal or below-normal precipitation across the entire Basin.

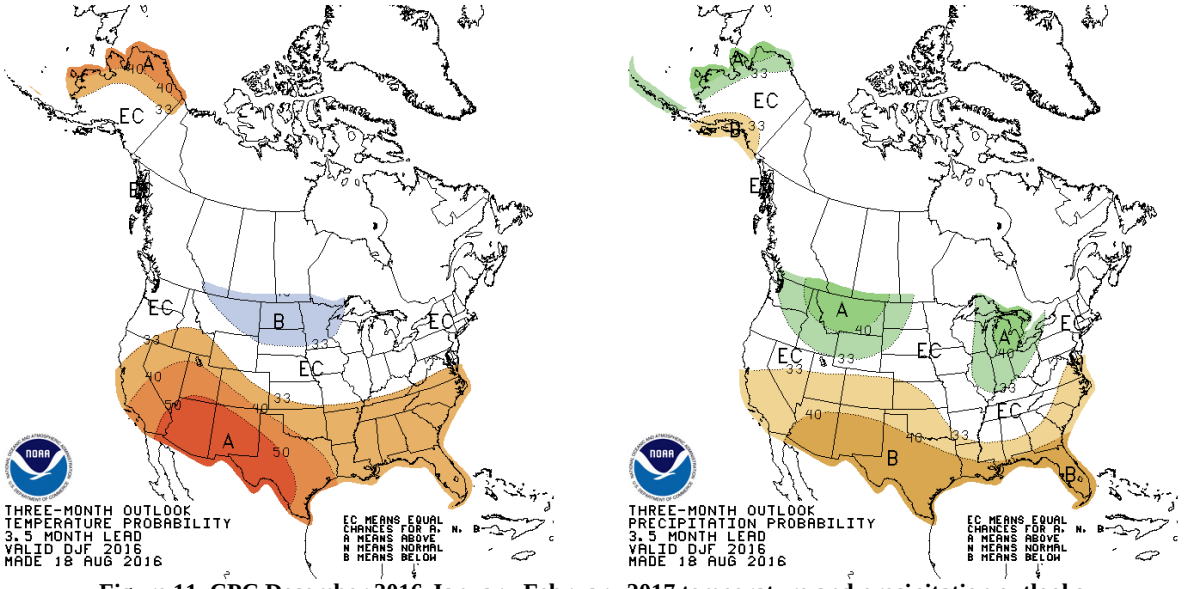

Figure 11. CPC December 2016-January-February 2017 temperature and precipitation outlooks.

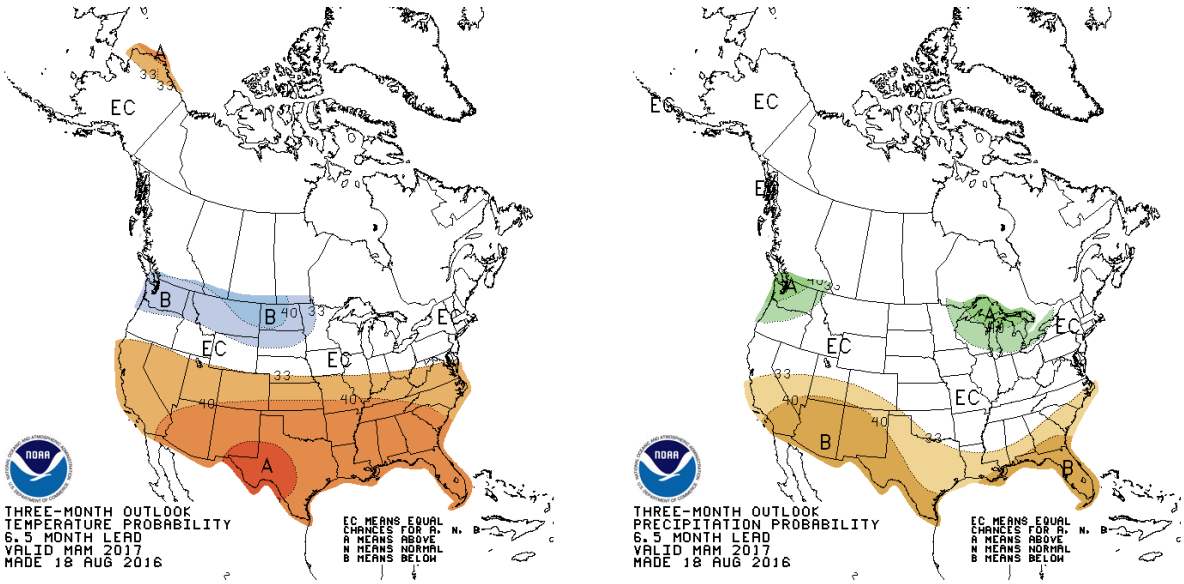

Figure 12. CPC March-April-May 2017 temperature and precipitation outlooks.

September 2016 Calendar Year Runoff Forecast

In summary, the 2016 calendar year runoff forecast is **22.4 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 **19.0 MAF (82% of average)**. August runoff was 1.0 MAF (76% of average). Runoff was 72% and 40% of average in the Fort Peck and Garrison reaches, respectively. These reaches generally received well-below normal rainfall in July, and no mountain snowpack has remained since the beginning of July. Current soil moisture and drought conditions indicate runoff in most of the upper Basin 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 and into winter. 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.