Upper Missouri River Basin
January 2015 Calendar Year Runoff Forecast
January 12, 2015

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 2014 and 2014 Calendar Year Runoff

December 2014 Missouri River runoff was 1.3 MAF (175% of normal) above Sioux City, and 1.2 MAF (176% of normal) above Gavins Point. The (preliminary, with no holdouts) calendar year 2014 runoff summation above Sioux City, IA was 35.0 MAF (139% of average), while it was 32.0 MAF (139% of average) above Gavins Point. These preliminary runoff volumes will be finalized within the first few months of 2015.

2015 Calendar Year Forecast Synopsis

The January 1 forecast for the 2015 Missouri River runoff above Sioux City, IA is **25.6 MAF** (101% of normal). Runoff above Gavins Point Dam is forecast to be **23.4 MAF** (102% of normal). 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 35.5 MAF upper basic forecast to the 16.8 MAF lower basic forecast. The upper basic 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 forecast 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 30, 2014 (**Figure 1**), when compared to the drought monitor for November 25, 2014 (**Figure 2**), shows a slight expansion of Abnormally Dry (D0) conditions in the Northern Plains and Upper Midwest. D0 conditions expanded west to the Missouri River in north central South Dakota and into northwest North Dakota since November 25. The U.S. Seasonal Drought Outlook in **Figure 3** indicates that very little change is expected to drought conditions through March 31, 2015 with the exception of a small area in northeast South Dakota where drought conditions are expected to persist or intensify.

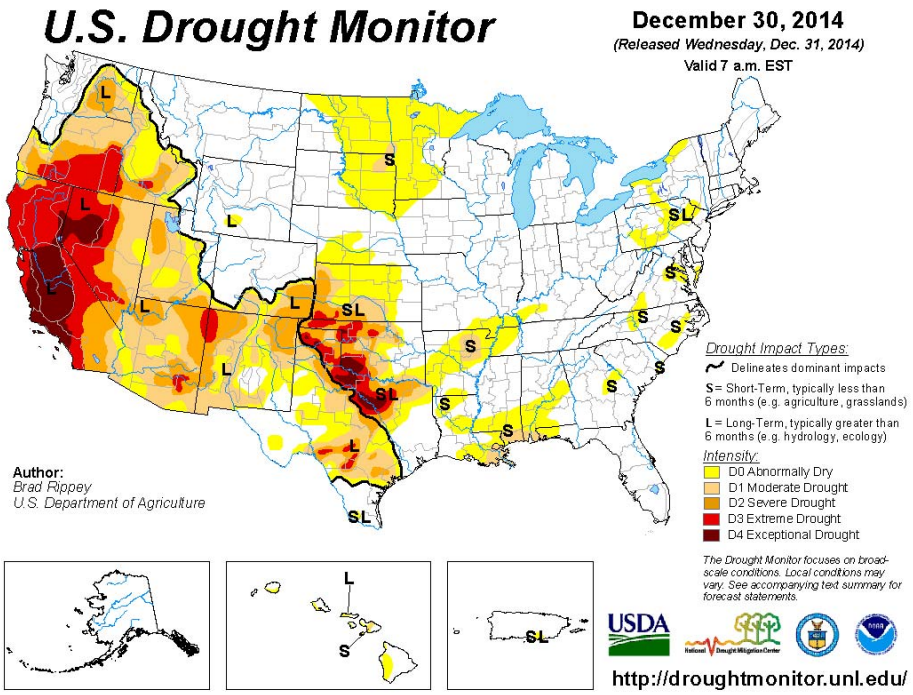

Figure 1. National Drought Mitigation Center U.S. Drought Monitor for December 30, 2015.

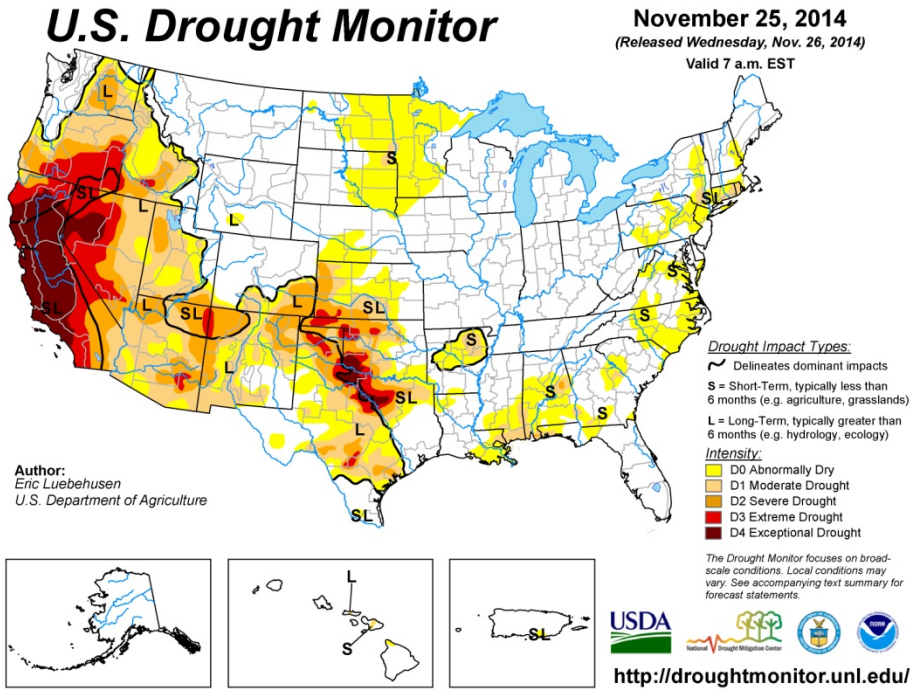

Figure 2. National Drought Mitigation Center U.S. Drought Monitor for November 25, 2014.

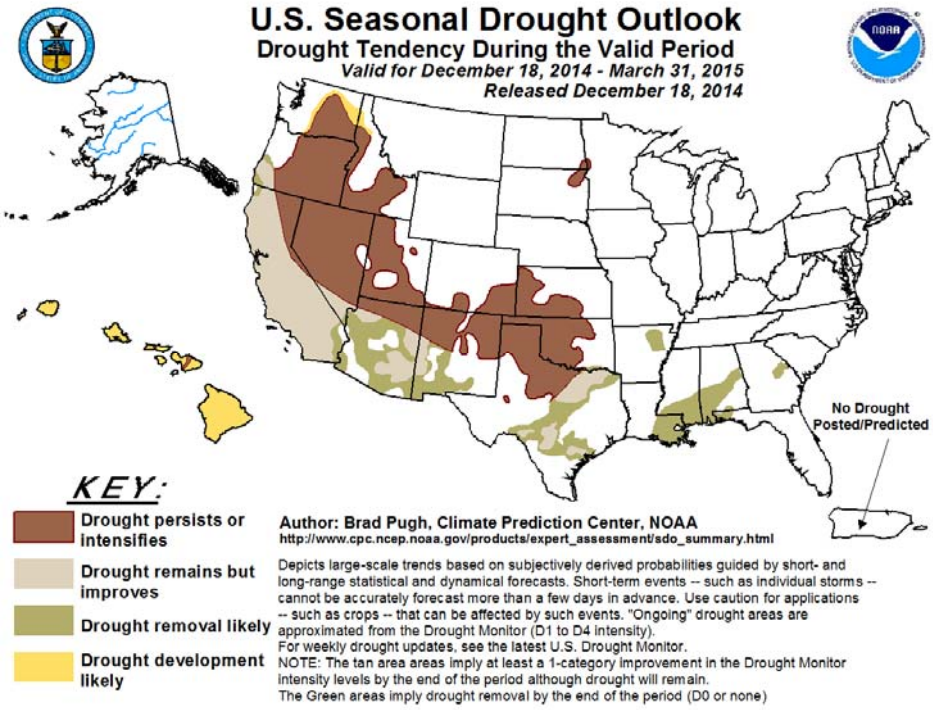

Figure 3. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

December precipitation accumulations are shown in **Figure 4** as both inches of rain and percent of normal monthly rain. From a climatological perspective, December is historically a dry month in the upper Basin. In December 2014, precipitation amounts ranged from less than 0.5 inches to 1 inch in North Dakota, most of South Dakota, most of Montana and much of Wyoming. As a percent of normal, the eastern half of Montana and North Dakota were generally much drier than normal, while the Rocky Mountains in western Montana and northwest and central Wyoming received greater than 150% of normal precipitation. Also above normal precipitation occurred over the southern half of South Dakota into Nebraska. Precipitation accumulations in southern South Dakota were 150% of normal or greater.

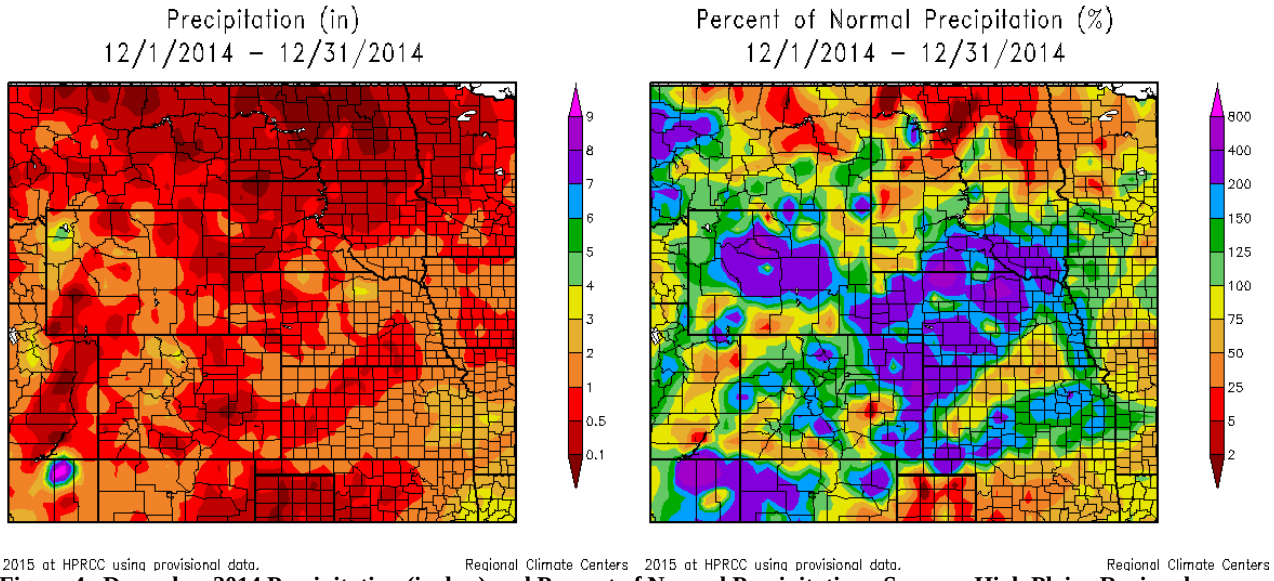

Figure 4. December 2014 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

October-November-December precipitation accumulations are shown in **Figure 5** as both inches of rain and percent of normal monthly rain. The three-month period accumulation reveals that precipitation accumulations were less than 70% of normal over eastern Montana, eastern Wyoming, much of the Dakotas and central and northeastern Nebraska. Above normal precipitation accumulations occurred over western Montana and northwest Wyoming along with a few regions of above normal precipitation scattered throughout the Basin.

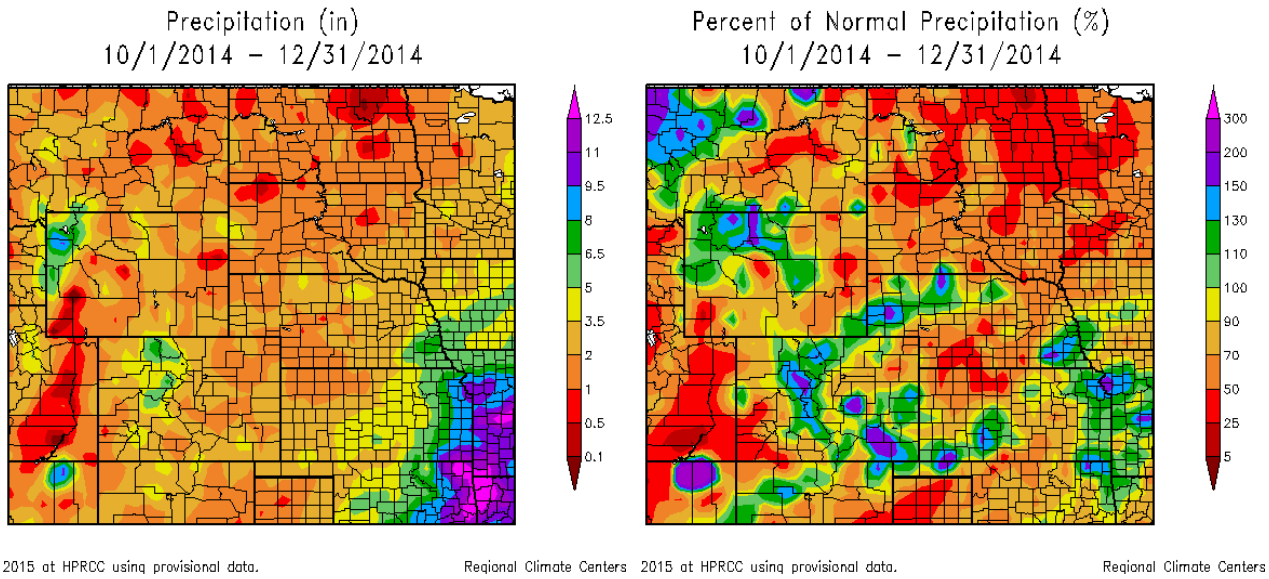

Figure 5. October 1 – December 31, 2014 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Temperature

December temperature departures from normal in degrees Fahrenheit (deg F) are shown in **Figure 6**. December temperatures in the Basin ranged from 2 to 6 deg F above normal. The warmest temperatures occurred over eastern Montana, central Wyoming and the Dakotas. Three-month (October-November-December) temperature departures are shown in **Figure 7**. The map indicates temperatures were slightly below normal in the eastern Dakotas, but they were above normal western of the Missouri River and about 2 to 4 deg F above normal in the Rocky Mountains.

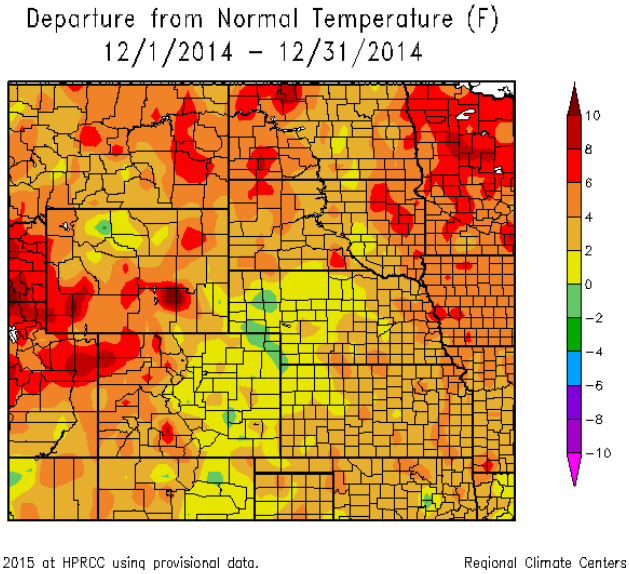

Figure 6. December 2014 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

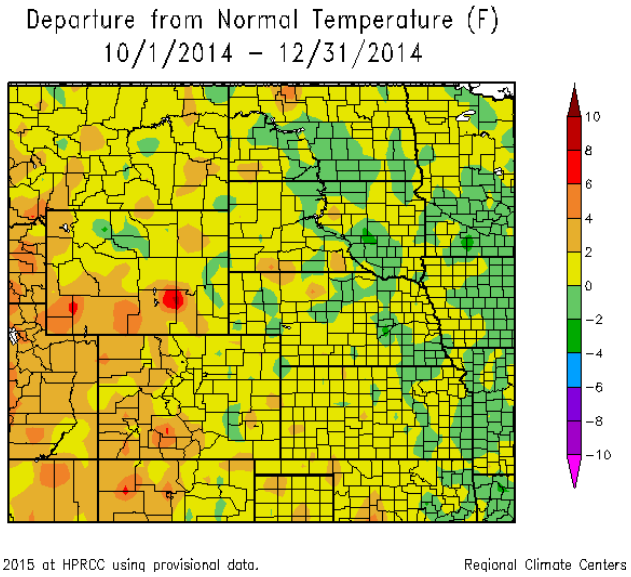

Figure 7. October-November-December 2014 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

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 monthly runoff.

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Figure 8 shows the NOAA NLDAS ensemble mean soil moisture percentiles on December 26, 2014 for the total modeled soil column, which is about 2 meters. The NLDAS soil moisture depiction is an average value for the soil moisture column. The average soil moisture in **Figure 8** indicates well above normal soil moisture conditions throughout Montana, Wyoming, western North Dakota and western South Dakota. Soil moisture is greater than the 70th percentile in the aforementioned areas and greater than the 98th percentile in north central Montana. These high soil moisture conditions developed as a result of the record August rainfall; however drying has occurred at the soil surface resulting in less soil moisture in surface layers compared to deeper soil layers. This difference in soil moisture by depth is discussed a later paragraph. Total column soil moisture in the eastern Dakotas is drier than normal with some conditions ranging from the 5th to 20th percentile.

The Ensemble Mean current total column soil moisture anomaly for the contiguous U.S. on December 26, 2014 is shown in **Figure 9**. These anomalies represent soil moisture averaged over the entire 2-meter soil column, so they do not reflect differences in soil moisture content at various depths. According to the modeled estimate, soil moisture anomalies in the western Dakotas, Montana and western Wyoming range from at least 25 – 50 mm (0.98 – 1.96 inches) above normal with some of north central Montana achieving 100 – 150 mm anomalies (3.95 – 5.91 inches). In contrast, anomalies in the eastern Dakotas range from 25 – 100 mm (0.98 – 3.94 inches) below normal. As stated in the previous paragraph, soil moisture in the surface layer is less than the average soil moisture content in the plains.

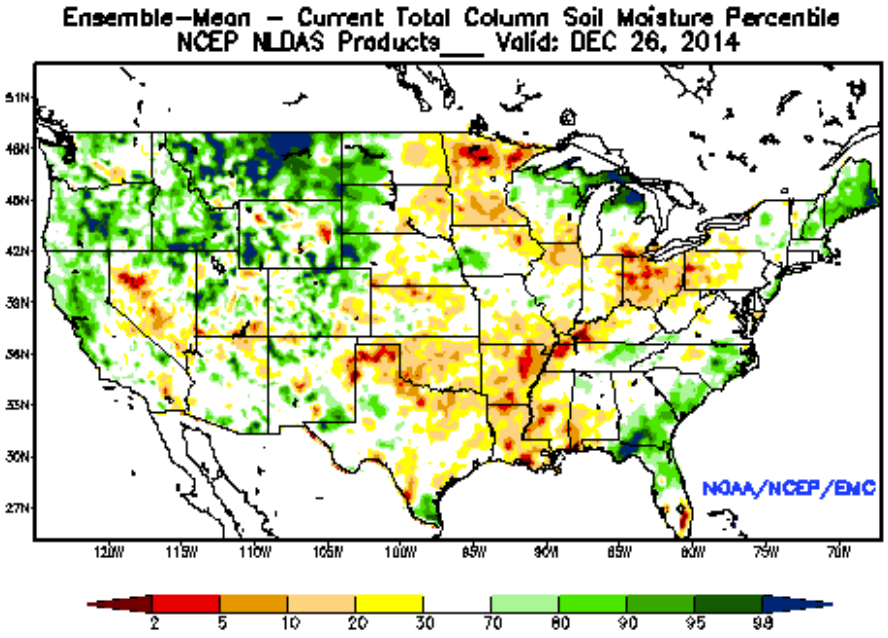


Figure 8. Total Column Soil Moisture Percentile on December 26, 2014. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

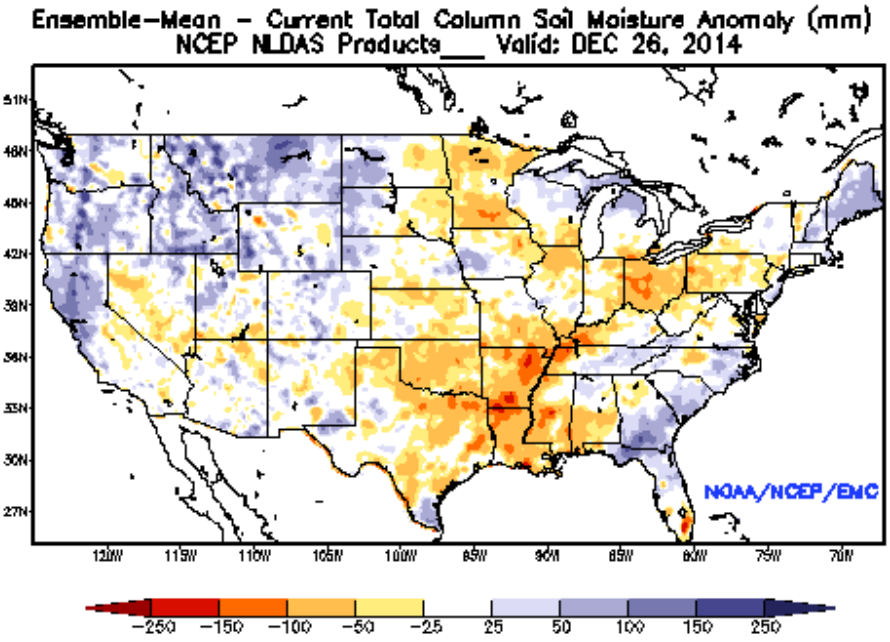


Figure 9. Calculated Soil Moisture Anomaly (mm) on December 26, 2014. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

The difference in soil moisture by depth is illustrated in **Table 1** and **Table 2**, percent soil moisture by depth at two USDA Soil Climate Analysis Network (SCAN) locations in the upper Basin. Over the last seven days in December, soil moisture declined rapidly in the top 2 to 8 inches of the soil profile near Dell Rapids, SD and Sidney, MT, while no soil moisture decline has been observed at 20 and 40 inches. By depth soil moisture is much less at 2- to 8-inch depths than at 20-inch and 40-inch depths at both locations. The high total column soil moisture percentiles and anomalies shown in **Figures 8** and **9** are due to the large contribution of subsoil moisture; however, the surface layer soil moisture is dry compared to subsoil moisture, providing additional capacity to absorb moisture from precipitation and snowmelt.

Table 1. Percent soil moisture by depth at the EROS Data Center USDA SCAN Site near Dell Rapids, SD.

USDA SCAN Site - EROS Data Center, Dell Rapids, SD					
Date	Percent Soil Moisture By Depth				
	2-inch	4-inch	8-inch	20-inch	40-inch
12/25/2014	24.8	32.7	28.1	25.8	28.3
12/26/2014	25.1	33.1	27.7	26	28.5
12/27/2014	25.1	33.4	27.8	26.1	28.4
12/28/2014	20.2	32.4	27.7	26.3	28.2
12/29/2014	19.3	21.4	26.3	26.2	27.9
12/30/2014	17.2	18.5	25.1	26.1	27.6
12/31/2014	16.1	17.3	17.8	25.3	27.6

Table 2. Percent soil moisture by depth at the USDA SCAN Site near Sidney, MT.

USDA SCAN Site – Sidney, MT					
Date	Percent Soil Moisture By Depth				
	2-inch	4-inch	8-inch	20-inch	40-inch
12/25/2014	11.1	13.1	16.7	26.2	25.2
12/26/2014	10.9	12.6	16.4	26.4	25.1
12/27/2014	10.8	12.4	16.5	26.3	25
12/28/2014	10.1	12	16.7	25.9	25.1
12/29/2014	9.6	11	17.1	24.7	25
12/30/2014	8.1	9.7	15.8	21.8	24.8
12/31/2014	7.7	9.4	14.9	19	24.9

Frost Conditions

In early November when the initial wave of very cold air entered the Missouri Basin, surface soils froze across the upper Basin, though soils experienced some thawing with warmer weather during the first half of December. At the end of December, colder temperatures refroze surface soils and allowed soil frost to develop at greater soil depths. **Figure 10** shows depth of frost penetration at National Weather Service (NWS) Warning Forecast Office (WFO) locations in the Missouri Basin as of January 1, 2015. While some frost depth measurements are missing, measurements indicate soils refroze at 14 to 18 inch depths extending from Glasgow, MT (GGWM8) to Aberdeen, SD (ABES2). As of January 1, 2015 frost had not developed at the reporting locations in western and south central Montana and central Wyoming, due to the warmer than normal temperatures experienced in those areas. Soil frost acts as a semi-impervious layer to snowmelt or precipitation infiltration into the soil.

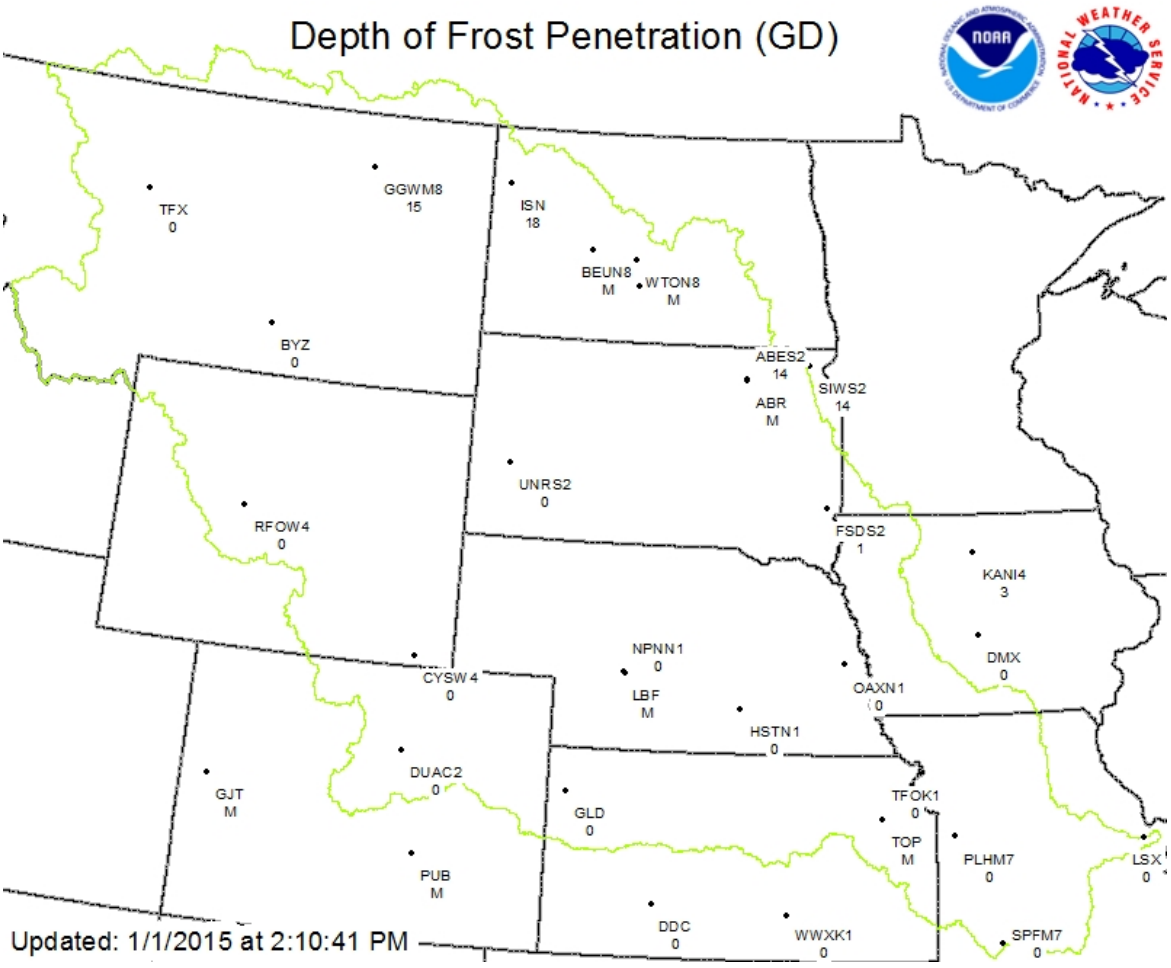


Figure 10. Measured frost depth (inches) at NWS WFO offices as of January 1, 2015. Source: NWS MBRFC. http://www.crh.noaa.gov/mbrfc

Streamflow Conditions

Missouri Basin streamflow conditions represented as percentile classes on November 10, 2014 are shown in **Figure 11**. These conditions are based on the ranking of the November 10, 2014 streamflow versus the historical record of streamflow for that date. Streamflow conditions on November 10, 2014 were normal (25^{th} – 75^{th} percentile) in the eastern Dakotas within the Missouri Basin, and in portions of north central Wyoming and western Montana. Much above normal streamflow conditions (> 90^{th} percentile) stand out as the blue and black gage locations on the map in many areas of Montana, Wyoming and the western Dakotas in the upper Basin, and in eastern Nebraska and western Iowa in the lower Basin.

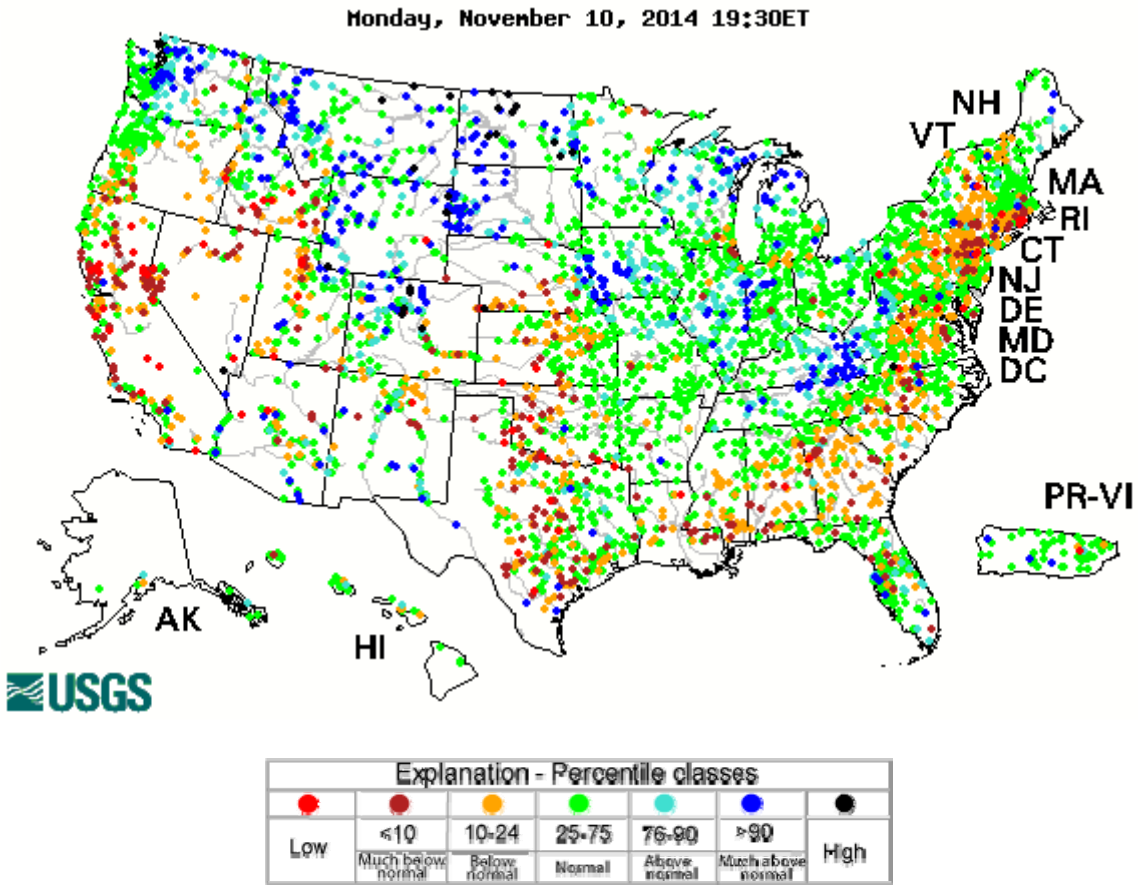


Figure 11. USGS Streamflow Conditions as a Percentile of Normal in the Missouri River Basin as of November 10, 2014.
Source: USGS. http://waterwatch.usgs.gov/index.php

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.

Based on the National Operational Hydrologic Remote Sensing Center (NOHRSC) assessment (**Figure 12**) as of January 1, 2015 most plains snow water equivalent (SWE) amounts ranged from trace to 1-inch amounts throughout the upper Basin. Amounts ranging from 1 to 2 inches covered portions of south central South Dakota and regions in the vicinity of the Rocky Mountains in Montana and Wyoming. Compared to January 1, 2014 (**Figure 13**) plains SWE, January 1, 2015 SWE is much less. On January 1, 2014, plains SWE generally ranged from 1 to 2 inches of SWE across large portions of the upper Basin including much of eastern Montana, North Dakota, and northern and eastern South Dakota.

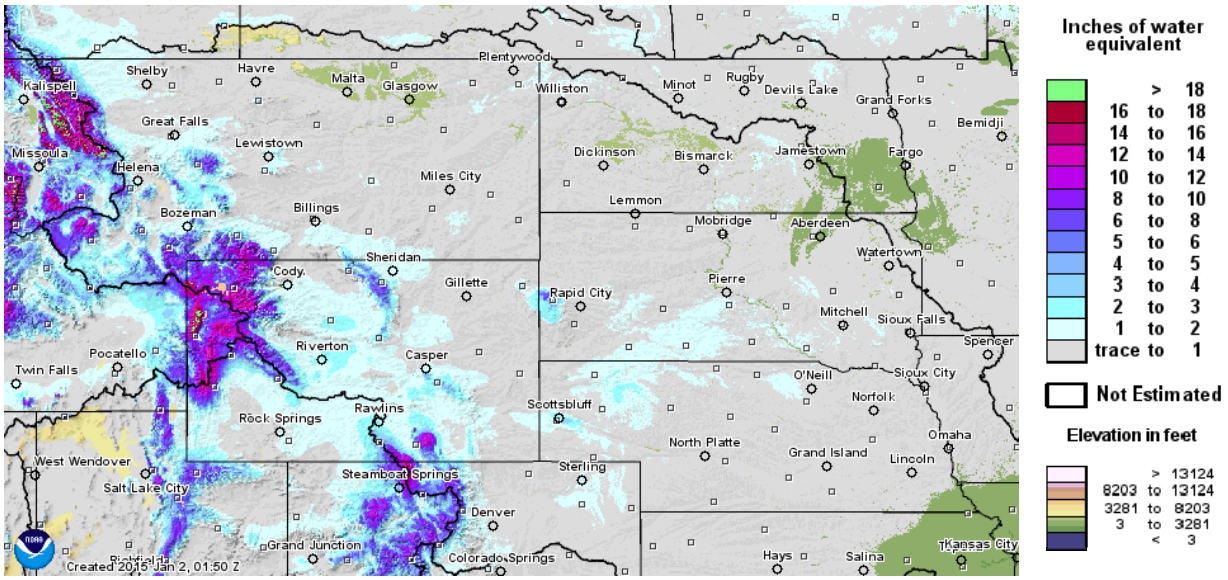


Figure 12. January 1, 2015 NOHRSC modeled plains snow water equivalent. Source: NOAA National Operational Hydrologic Remote Sensing Center. http://www.nohrsc.nws.gov/interactive/html/map.html

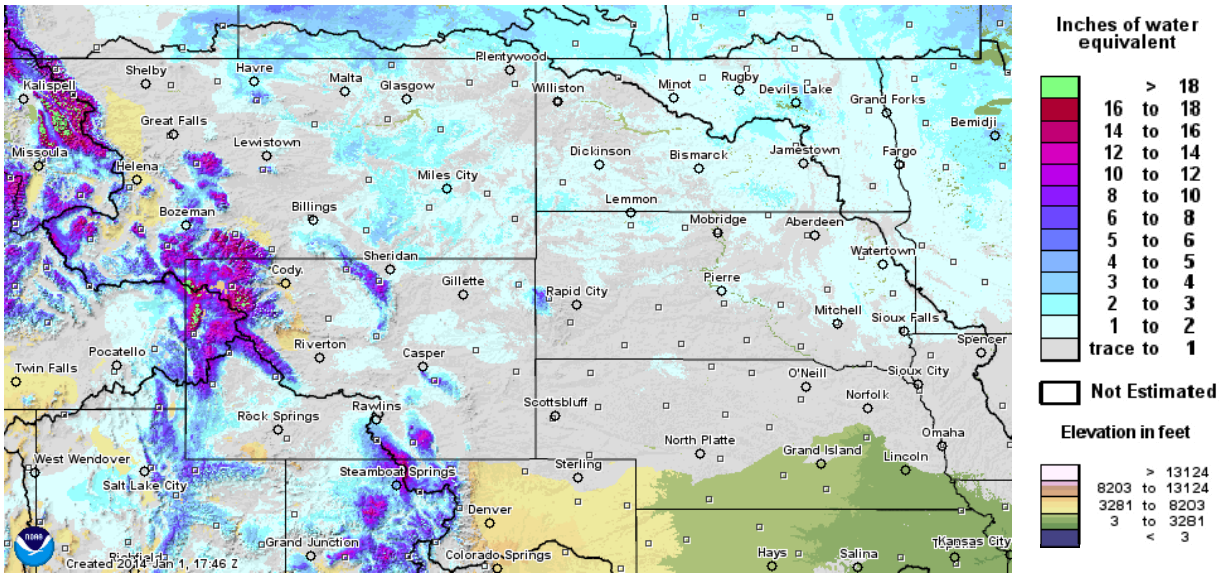


Figure 13. January 1, 2014 NOHRSC modeled plains snow water equivalent. Source: NOAA National Operational Hydrologic Remote Sensing Center. http://www.nohrsc.nws.gov/interactive/html/map.html

Using the MRBWM snowpack classification method, plains snowpack as of January 1, 2015 was classified as Light across the upper Basin in all reservoir reaches (**Table 3**). This classification includes plains snowpack accumulations that fall between the range of 0 to 1 inch of SWE in the Fort Peck, Oahe, Fort Randall and Gavins Point subbasins and 0 to 2 inches in the Fort Peck to Garrison and Gavins Point to Sioux City reaches.

Table 3. January 1, 2015 plains snowpack classification for runoff forecasting.

Reservoir Reach	Plains Snowpack Classification
Above Fort Peck	Light (0 – 1 inch SWE)
Fort Peck to Garrison	Light (0 – 2 inch SWE)
Garrison to Oahe	Light (0 – 1 inch SWE)
Oahe to Fort Randall	Light (0 – 1 inch SWE)
Fort Randall to Gavins Point	Light (0 – 1 inch SWE)
Gavins Point to Sioux City	Light (0 – 2 inch SWE)

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 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 greater than average runoff from an average mountain snowpack this year due to wetter than normal soil moisture conditions.

Figure 14 includes time series plots of the average mountain SWE beginning on October 1, 2014 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, 2015**, the Corps of Engineers computed an average mountain SWE in the headwater basin **above Fort Peck Dam of 7.3 inches, which is 101% of normal** based on the 1981-2010 average SWE for the Fort Peck basin. In the **subbasin between Fort Peck Dam and Garrison Dam**, the Corps computed an average mountain SWE of **6.4 inches, which is 101% of normal** based on the 1981-2010 average SWE for the Fort Peck to Garrison subbasin. Normally by January 1, 44% of the peak snow accumulation has occurred in the mountains. In comparison, January 1, 2014 mountain snowpack was 7.9 inches (110% of normal) in the Fort Peck subbasin and 7.2 inches (113% of normal) in the Fort Peck to Garrison subbasin.

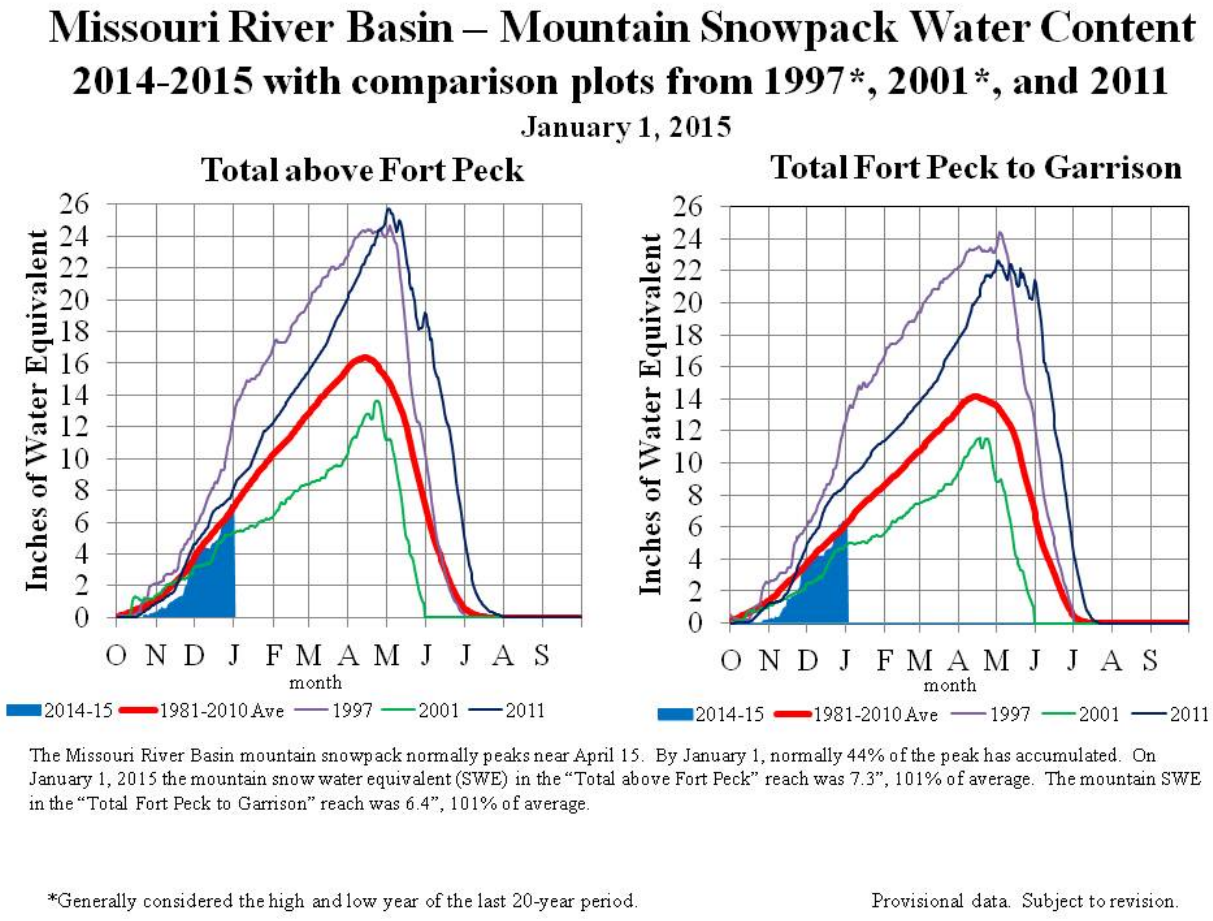


Figure 14. Mountain snowpack water content snow accumulation compared to normal and historic conditions. Corps of Engineers - Missouri River Basin Water Management.

Climate Outlook

ENSO (El Niño Southern Oscillation)

Based on the CPC analysis of equatorial sea surface temperatures (SST), positive anomalies continue across the Pacific Ocean, yet an ENSO-neutral phase continues. There is a 65% chance that El Niño conditions will be present during the Northern Hemisphere winter and last into the Northern Hemisphere spring 2015. During the winter, El Niño conditions can increase chances for warmer and drier conditions in the Northern Plains. If El Niño has an impact on temperature and precipitation during the winter, the impact to upper Basin runoff is not realized until the spring and summer following an El Niño winter since most winter precipitation is snowfall. In some years El Niño has reduced the amount of mountain snowpack due to the warmer-than-normal temperatures, therefore reducing the volume of May-June-July runoff. The influence of a potential winter El Niño has been factored into the CPC's temperature and precipitation outlooks, and is discussed in the following section.

Temperature and Precipitation Outlooks

The NOAA Climate Prediction Center climate outlook for January 215 (**Figure 15**) indicates an increased probability for above normal temperatures in western Montana and western Wyoming; however, there is an increased probability for below normal temperatures primarily over the Dakotas, Nebraska and northwest Iowa. Probabilities for below normal temperatures in these areas range from 33.3% to over 40%, complimented by a 33.3% chance that temperatures will be in the normal range, and a 26.7% to 33.3% chance temperatures will be above normal. Stated simply, there is only a slight increase in the chance for below normal temperatures. With regard to precipitation, there are equal chances that precipitation will be above normal, normal and below normal in January throughout the entire upper Basin.

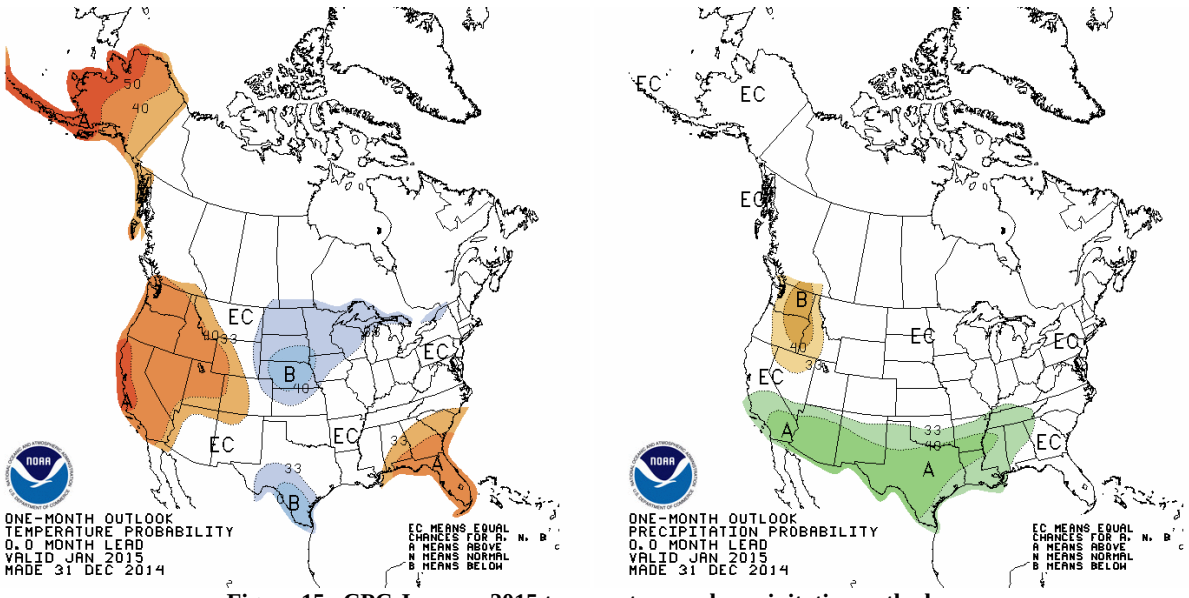


Figure 15. CPC January 2015 temperature and precipitation outlooks.

The winter (January-February-March) temperature outlook (**Figure 16**) indicates a slightly higher probability (33.3% to 40%) that temperatures will be above normal in western Montana and western Wyoming, while there are equal chances for below normal, normal and above normal temperatures in the remainder of the upper Basin. The January-February-March precipitation outlook indicates a slight increase in the probability for below normal precipitation in northwest Montana and equal chances for above normal, normal and below normal precipitation in the remainder of the upper Basin. Both temperature and precipitation outlooks reflect the influences of El Niño conditions.

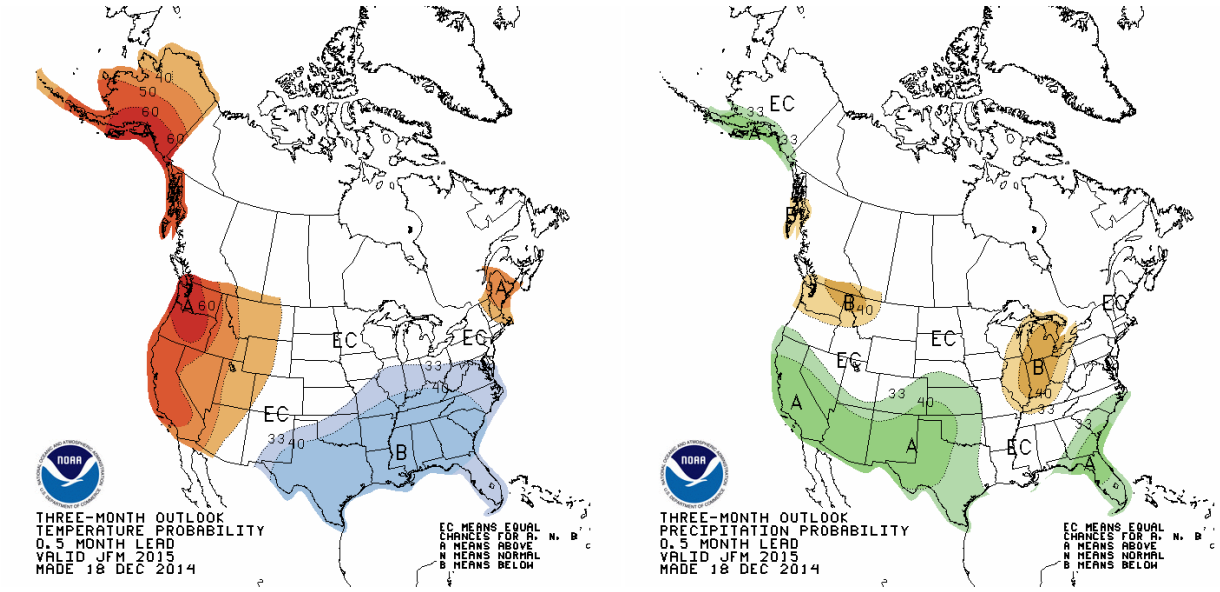


Figure 16. CPC January-February-March 2015 temperature and precipitation outlooks.

The April-May-June 2015 CPC temperature outlook (**Figure 17**) indicates there are equal chances for above normal, normal, and below normal temperatures throughout the upper Basin; however, in the western U.S. there is a slightly higher probability that temperatures will be above normal during the period. With regard to precipitation there is a slightly higher probability for above normal precipitation in western Montana and western Wyoming. The probability ranges from 33.3% to over 40% that precipitation will be above normal, compared to a 33.3% probability that precipitation will be above normal in an equal chances scenario.

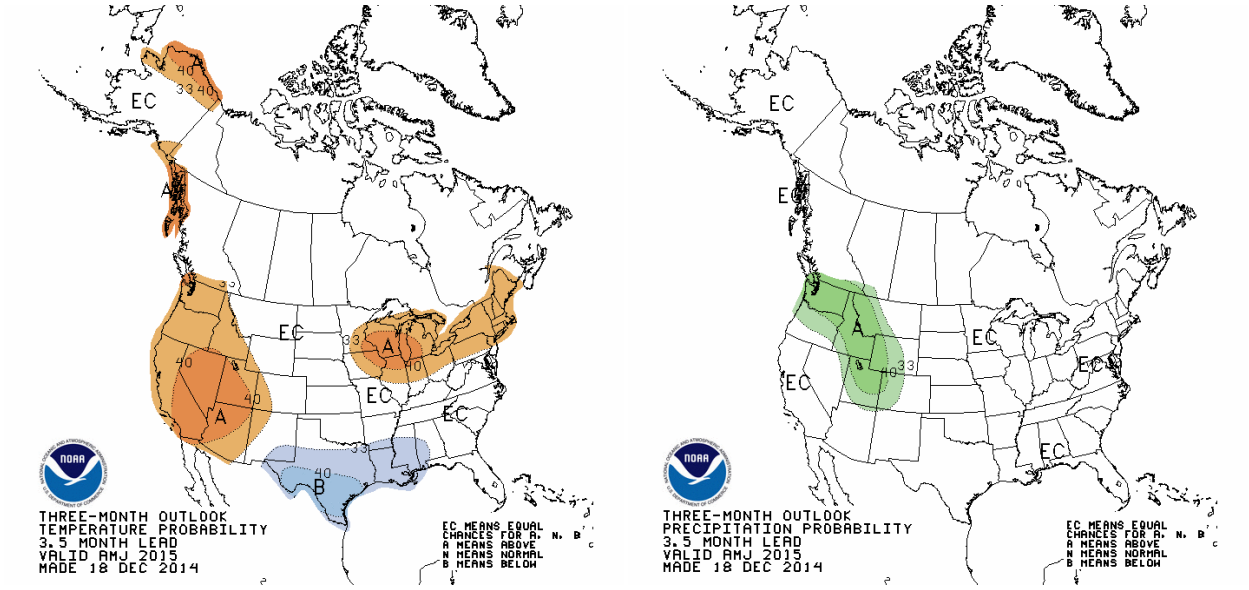


Figure 17. CPC April-May-June 2015 temperature and precipitation outlooks.

During the remainder of the calendar year, the CPC temperature outlooks for the July-August-September period (**Figure 18**) and the October-November-December period (**Figure 19**) indicate slightly higher probabilities that temperatures will be above normal in Montana and Wyoming, while there are equal chances temperatures will be above normal, normal or below normal in the remainder of the upper Basin. With regard to precipitation, there are equal chances precipitation will be above normal, normal or below normal during the July-August-September period (**Figure 18**) and the October-November-December period (**Figure 19**).

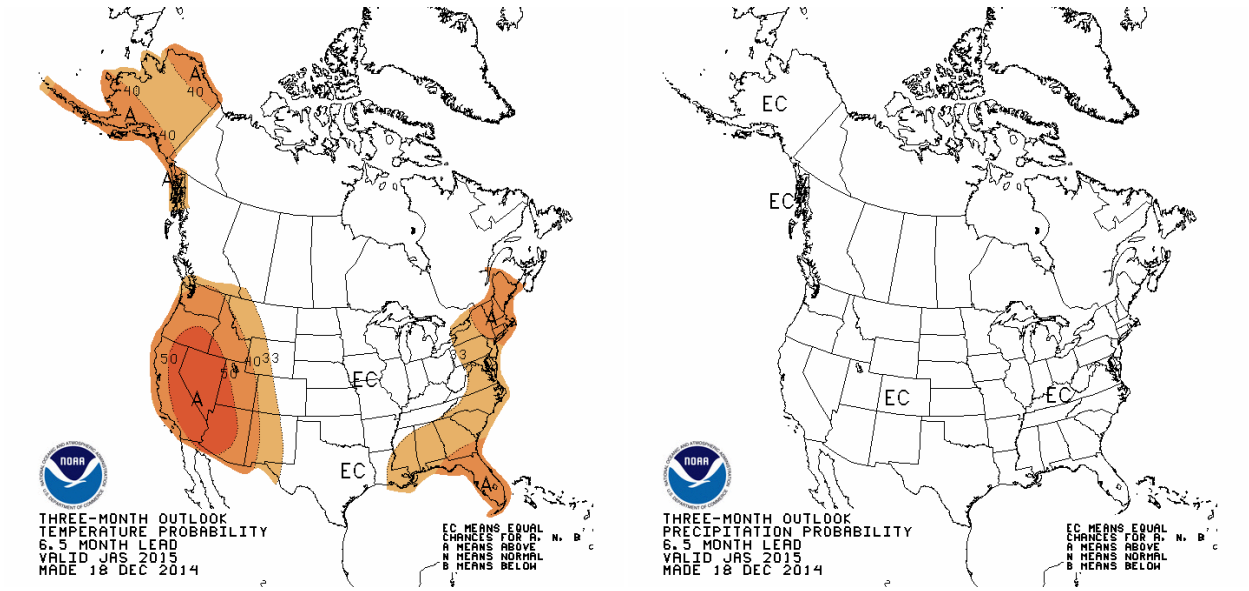


Figure 18. CPC July-August-September 2015 temperature and precipitation outlooks.

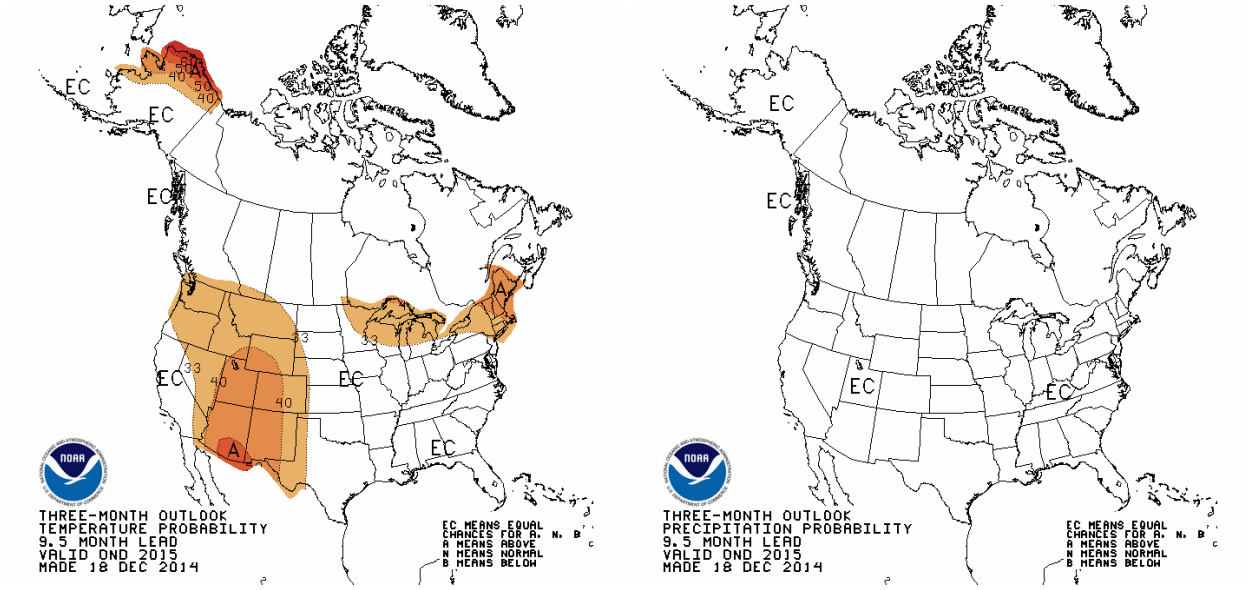


Figure 19. CPC October-November-December 2015 temperature and precipitation outlooks.

Expert Discussions

Prior to the December calendar year runoff forecast, MRBWM held a conference call on November 24 with Dr. Adnan Akyuz, North Dakota State Climatologist; Dr. Dennis Todey, South Dakota State Climatologist, and Mr. Scott Dummer, Missouri Basin River Forecast Center (MBRFC), to discuss the hydrologic state of the upper Missouri River Basin. These discussions were held in order to attain expert assessments of various hydrologic factors that the Corps considers in it runoff forecasts. A summary of the major points of this discussion follows.

Fall Precipitation and Streamflow

Fall precipitation is a very useful indicator of spring runoff in North Dakota, with the Red River Basin of the North being a prime example of the usefulness of fall precipitation as an indicator. Higher fall precipitation accumulations generally lead to higher fall streamflow, higher spring runoff and streamflow due to higher (wetter) soil moisture conditions, and higher levels of water in surface storage such as the prairie pothole lakes. At the onset of the winter freeze, much of this moisture is locked up in frozen soil moisture and will not be released until the spring thaw. Fall precipitation in 2014 has been well below normal over a large majority of the upper Missouri Basin (**Figure 5**), though there have been some regionally wet areas, especially west of the Missouri River near the Montana border. Compared to 2011, fall precipitation in 2014 has been much lower, and on the dry side of the fall precipitation spectrum.

At the start of river freeze-up streamflow conditions were near their 90th percentile rankings at many stream gages in the upper Missouri Basin. According to Scott Dummer of the MBRFC, higher streamflow conditions increase the potential for freeze-up jams in the winter.

Soil Moisture, Soil Frost and Surface Storage

The NLDAS product is a modeled total column soil moisture product that is highly regionalized and the soil depth representation is very generalized. Therefore, anecdotal information from local observers is only accurate at the location and not regionally. Soil moisture over the upper Missouri Basin is quite varied as represented by the NLDAS ensemble mean soil moisture maps shown in **Figure 8** and **Figure 9**. The eastern Dakotas are dry, while the western Dakotas have above normal soil moisture averaged over the soil profile. According to Dr. Todey, the top 3 feet of soil in most areas of South Dakota are fairly dry; however, there is good soil moisture at 3 to 4 foot depths due to low summer evapotranspiration demands. According to Dr. Akyuz, the state of the soil prior to snow accumulation is important. Frozen soils, somewhat independent of soil moisture content, act as an impervious surface to water. Prior to the first snow accumulation in early November, soil frost developed due to the very cold temperatures in the upper Basin. Since the soils are currently frozen, the amount of runoff will depend on the amount of accumulated plains snow, the rate of snowmelt in the spring and spring rainfall.

Furthermore, substantial surface or wetland storage in the prairie potholes region of North Dakota and South Dakota is available to store meltwater in the spring, rendering some of this region as non-contributing area to the Missouri River basin.

Winter Weather Forecast

The dominant factor influencing winter weather in the Missouri Basin is the Arctic oscillation, which describes the oscillation of cold air from the Canadian Arctic into the lower latitudes. The Arctic oscillation has typically brought cold air into the Missouri Basin during more severe winters. This factor is not typically predictable beyond a few weeks; therefore, no forecast can be made for the entire winter season based on this factor.

January 2015 Calendar Year Runoff Forecast

The calendar year runoff forecast is **25.6 MAF (101% of average) above Sioux City** and **23.4 MAF (101% of average) above Gavins Point**. Due to the amount of variability in precipitation that can occur over the next 12 months, the range of expected inflow is quite large and ranges from the 35.5 MAF upper basic forecast to the 16.8 MAF lower basic forecast. The upper and lower basic forecasts provide a likely range of runoff scenarios that could occur given much wetter conditions or much drier conditions. The upper and lower basic forecasts are used in long-term regulation planning models to “bracket” the range of expected runoff. It should be noted, however, that it is possible, due to either much higher or much lower than forecasted precipitation occurring, that these ranges may be exceeded on either end.

Factors taken into consideration while preparing the 2015 forecast include: continuing drought and soil moisture conditions in the upper Basin, antecedent fall precipitation and streamflow, plains snowpack, mountain snowpack, and the CPC's monthly and seasonal temperature and precipitation outlooks.

January-February

Runoff in December 2014 was 1.3 MAF (175% of normal) due to warmer than normal temperatures during much of the month which melted tributary and Missouri River mainstem ice. Over the October-November-December period, runoff was 115% of normal. With a January temperature outlook indicating above normal temperatures in the mountains, but below normal temperatures in the plains region, plus above normal soil moisture conditions in the upper Basin west of the Missouri River, we expect runoff will be slightly above normal. In January, runoff is forecast to be above normal in the Garrison, Oahe, Fort Randall and Sioux City reaches, while it is forecast to be below normal in the Fort Peck and Gavins Point reaches. February runoff will follow a similar trend. The runoff forecast for January and February is highly dependent on temperature because its influence on ice formation determines how much water is stored in the soil and as ice in tributaries, or how much water enters the reservoirs during the winter.

March-April

Plains snowpack is a significant factor influencing the volume of runoff in March and April; however, snow and rainfall precipitation during this time period are also very important factors that need consideration. Furthermore, antecedent accumulated precipitation and antecedent soil moisture conditions have a significant influence on March-April runoff.

Plains snowpack is Light in all reaches of the upper Basin with SWE ranging from trace to 1-inch amounts. Furthermore antecendent fall precipitation was less than 70% of normal in much of the upper Basin and less than 50% of normal in many parts of the Dakotas. Soil moisture is still well-above normal west of the Missouri River but below normal east of the Missouri River in the Dakotas. Considering these factors, the March-April runoff forecast is 102% of normal for the upper Basin. The March-April runoff forecast is above normal in the Fort Peck, Garrison and Oahe reaches and normal in the Fort Randall reach. The runoff forecast is below normal in the Gavins Point and Sioux City reaches.

May-June-July

During the May-June-July period, the mainstem system receives 50% of its annual runoff as a result of mountain snowmelt and spring and summer precipitation. This is the most active period for precipitation in the Missouri River Basin, so runoff can vary significantly as a result of the above or below normal rainfall.

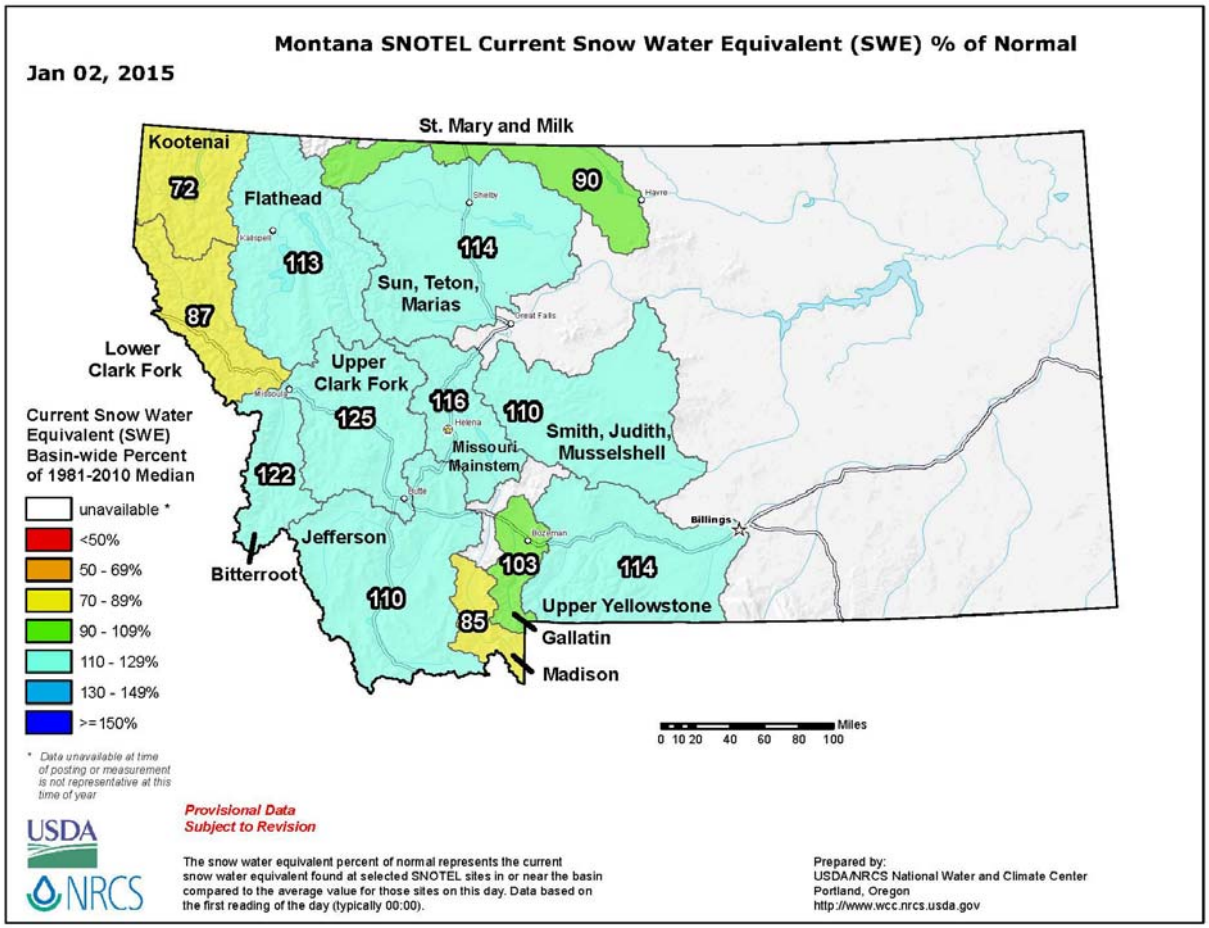
For this 3-month period, the most reliable method for predicting runoff into Fort Peck and Garrison reservoirs is through regression equations that relate mountain snowpack to runoff. The January 1, 2015 mountain snowpack was 101% of average in the reach above Fort Peck and 101% of average in the reach between Fort Peck and Garrison. The CPC 3-month outlooks of April-May-June precipitation indicates an increased probability for above normal precipitation in the Rocky Mountains of Montana and Wyoming. Taking into consideration these factors, 103% of normal runoff is forecast for the Fort Peck and Garrison reaches. Near normal runoff is forecast for the remaining reaches. The overall May-June-July runoff summation forecast is 102% of normal.

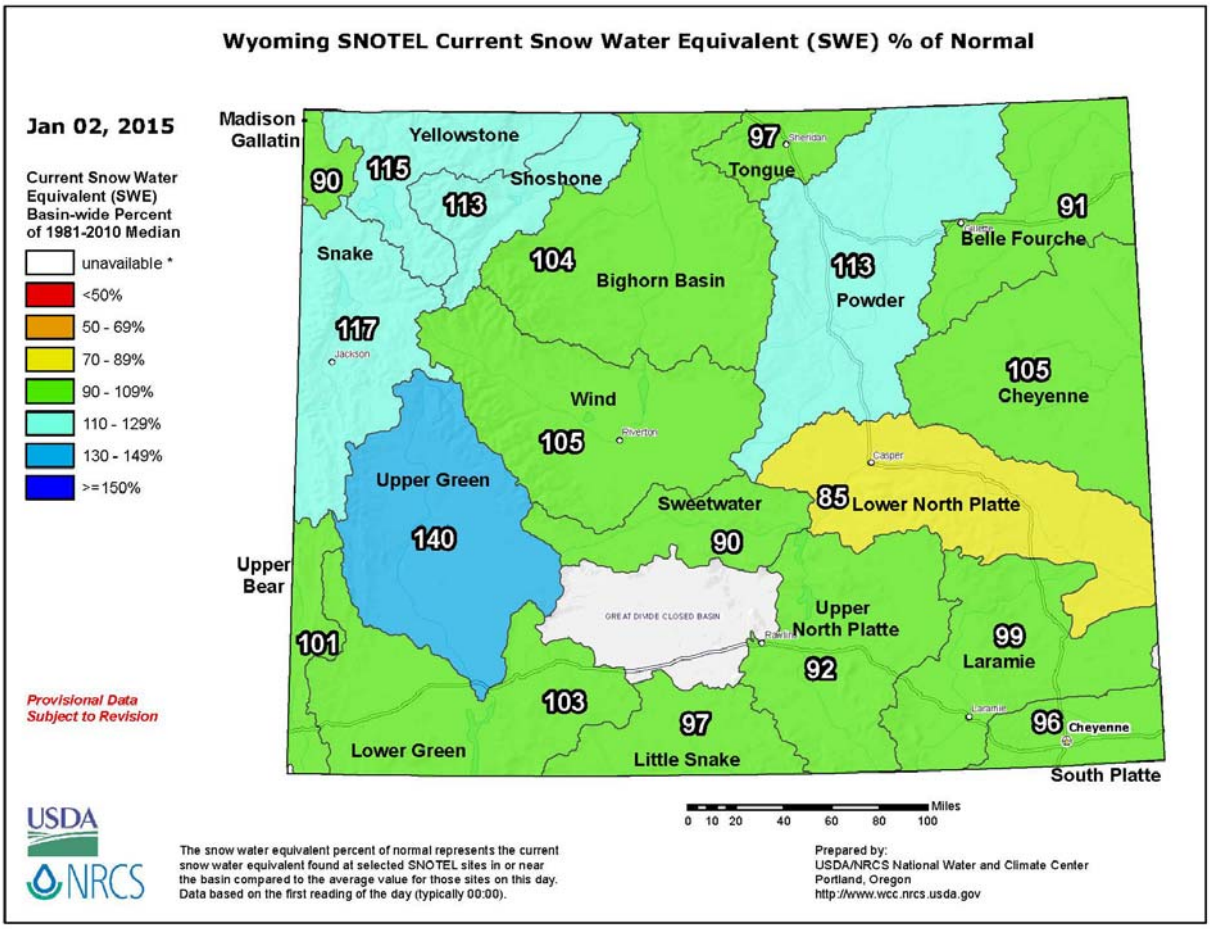
The significance of accurately forecasting May-June-July runoff for the Fort Peck and Garrison reaches is based on the fact that, historically, an average of 9.2 MAF of runoff occurs during these 3 months into these 2 projects. That is 37% of the total annual runoff into the system.

August through December

For the latter half of 2015, NOAA's climate outlook indicates increased chances for above normal temperatures throughout the basin and equal chances for above, below and normal precipitation. Very little information is known at this time which can indicate how much runoff will occur during that time period because summer and fall runoff is determined by precipitation; therefore, normal runoff is forecast from August through December.

Additional Figures and Information




Wyoming SNOTEL Current Snow Water Equivalent (SWE) % of Normal
Jan 02, 2015
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
Yellowstone
Shoshone
Tongue
Belle Fourche
Snake
Bighorn Basin
Powder
Wind
Cheyenne
Upper Green
Sweetwater
Lower North Platte
Upper Bear
GREAT DIVIDE CLOSED BASIN
Upper North Platte
Laramie
Lower Green
Little Snake
Cheyenne
South Platte
90
115
113
97
91
104
113
117
105
105
85
140
90
101
92
99
103
97
96
Jackson
Riverton
Casper
Rawlins
Laramie
Miles
0 10 20 40 60 80 100
USDA NRCS
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, 2015 03:19:37 PM
  - Based on January 01, 2015 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	90	93	110	98	82	70	97
	APR-SEP	105	94	125	113	96	84	112
St. Mary R at Int'l Boundary (2)	APR-JUL	385	89	505	435	340	270	435
	APR-SEP	450	89	570	500	400	330	505
Lima Reservoir Inflow (2)	APR-JUL	65	79	101	80	50	29	82
	APR-SEP	69	78	110	86	52	28	89
Clark Canyon Reservoir Inflow (2)	APR-JUL	79	78	178	119	39	-15.0	101
	APR-SEP	96	80	205	140	52	-4.0	120
Jefferson R nr Three Forks (2)	APR-JUL	775	105	1240	960	590	315	740
	APR-SEP	845	106	1360	1050	640	335	800
Hebgen Reservoir Inflow (2)	APR-JUL	330	89	415	365	295	245	370
	APR-SEP	425	90	525	465	380	320	470
Ennis Reservoir Inflow (2)	APR-JUL	545	87	700	610	480	390	625
	APR-SEP	690	89	870	760	615	505	775
Missouri R at Toston (2)	APR-JUL	1730	97	2500	2040	1420	965	1790
	APR-SEP	2010	97	2900	2370	1650	1120	2070
Smith R bl Eagle Ck (2)	APR-JUL	128	121	183	150	106	73	106
	APR-SEP	145	125	210	171	120	82	116
Gibson Reservoir Inflow (2)	APR-JUL	425	108	545	475	375	305	395
	APR-SEP	470	107	595	520	420	345	440
Marias R nr Shelby (2)	APR-JUL	380	110	580	460	300	181	345
	APR-SEP	390	108	595	475	305	185	360
Milk R at Western Crossing	MAR-SEP	35	107	61	46	27	20	33*
Milk R at Eastern Crossing	MAR-SEP	84	103	155	105	63	44	82*

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	61	103	71	65	57	51	59
	APR-SEP	78	105	91	83	73	65	74
Wind R ab Bull Lake Ck (2)	APR-JUL	465	102	625	530	400	305	455
	APR-SEP	495	101	675	565	420	315	490
Bull Lake Ck nr Lenore	APR-JUL	137	99	172	151	123	103	139
	APR-SEP	168	99	210	185	151	125	169
Boysen Reservoir Inflow (2)	APR-JUL	530	87	910	685	375	148	610
	APR-SEP	585	88	1020	760	410	153	665
Greybull R nr Meeteetse	APR-JUL	149	114	185	163	134	113	131
	APR-SEP	200	113	250	220	183	156	177
Shell Ck nr Shell	APR-JUL	50	91	66	57	44	35	55
	APR-SEP	62	94	78	69	55	46	66
Bighorn R at Kane (2)	APR-JUL	800	95	1270	990	615	335	840
	APR-SEP	865	96	1380	1070	655	350	905
NF Shoshone R at Wapiti	APR-JUL	485	105	585	525	445	385	460
	APR-SEP	540	105	645	580	500	435	515
SF Shoshone R nr Valley	APR-JUL	235	109	280	255	215	184	215
	APR-SEP	265	108	320	285	245	210	245
Buffalo Bill Reservoir Inflow (2)	APR-JUL	730	108	890	795	665	570	675
	APR-SEP	795	107	965	865	725	625	745
Bighorn R nr St. Xavier (2)	APR-JUL	1400	101	1970	1630	1160	825	1380
	APR-SEP	1480	101	2130	1740	1220	835	1460
Little Bighorn R nr Hardin	APR-JUL	88	90	140	109	67	36	98
	APR-SEP	100	90	157	123	77	43	111
Tongue R nr Dayton (2)	APR-JUL	80	93	114	93	66	45	86
	APR-SEP	91	93	128	106	76	54	98
Tongue River Reservoir Inflow (2)	APR-JUL	178	92	290	225	132	65	193

	APR-SEP	199	93	315	245	151	81	215
NF Powder R nr Hazelton	APR-JUL	10.1	111	13.3	11.4	8.8	6.8	9.1
	APR-SEP	10.9	110	14.3	12.3	9.6	7.5	9.9
Powder R at Moorhead	APR-JUL	189	107	305	235	142	73	177
	APR-SEP	210	107	330	260	160	88	196
Powder R nr Locate	APR-JUL	215	108	355	270	157	74	199
	APR-SEP	235	107	390	300	176	86	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	6.4	103	11.1	8.3	4.5	1.66	6.2
	APR-JUL	5.2	100	9.5	6.8	3.9	2.3	5.2
Pactola Reservoir Inflow (2)	MAR-JUL	24	96	46	33	14.3	4.5	25
	APR-JUL	21	95	45	30	13.9	3.5	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.
Milk forecasts provided by Alberta, medians are for the 1980-2008 period, there is no max (90%), the 30% column is 25% exceedance, and the 70% column is 75% exceedance.

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 2015 Calendar Year Runoff Forecast
February 6, 2015

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.

January 2015 Runoff

January 2015 runoff was 1.4 MAF (178% of normal) above Sioux City, and 1.2 MAF (174% of normal) above Gavins Point Dam. Warmer-than-normal temperatures melted most of the plains snowpack and thawed most Missouri River tributaries during January. The additional runoff that occurred in January is runoff that normally would occur from late February to March during the normal time of the spring thaw.

2015 Calendar Year Forecast Synopsis

The January 1 forecast for the 2015 Missouri River runoff above Sioux City, IA is **25.5 MAF (101% of normal)**. Runoff above Gavins Point Dam is forecast to be **23.3 MAF (101% of normal)**. 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 35.0 MAF upper basic forecast to the 17.2 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 11 months are being forecasted for this February 1 forecast (1 month 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 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 National Drought Mitigation Center's drought monitor for January 27, 2015 (**Figure 1**), when compared to the drought monitor for December 30, 2014 (**Figure 2**), shows a slight expansion of Abnormally Dry (D0) conditions in the Northern Plains and Upper Midwest. Since December 30, D0 conditions expanded in eastern Nebraska and Kansas, southern Iowa, and northern Missouri. The U.S. Seasonal Drought Outlook in **Figure 3** indicates that very little change is expected to drought conditions through April 30, 2015 with the exception of a small area in northeast South Dakota where drought conditions are expected to persist or intensify.

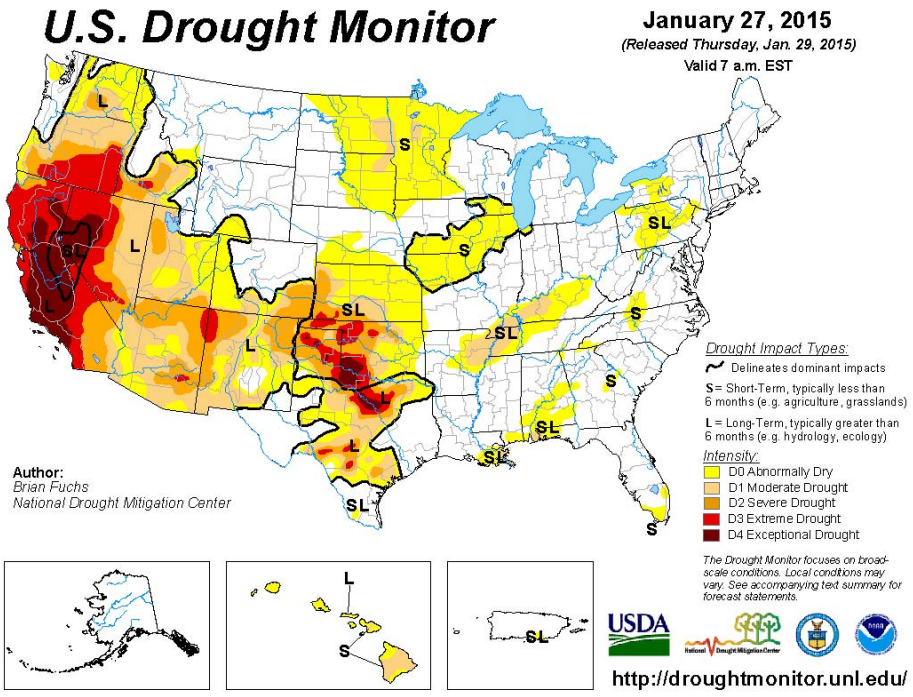


Figure 1. National Drought Mitigation Center U.S. Drought Monitor for January 27, 2015.

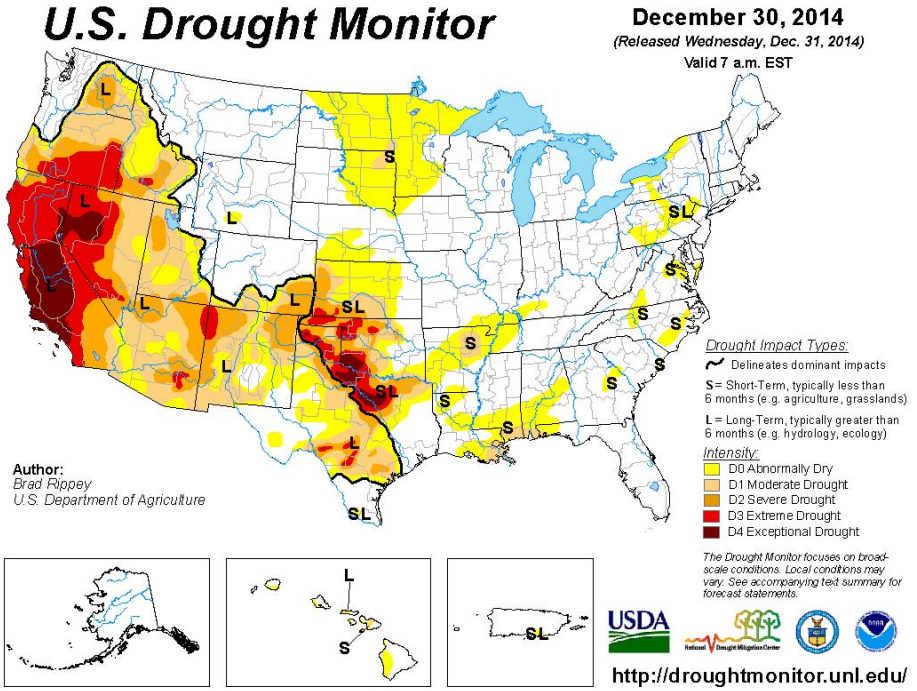


Figure 2. National Drought Mitigation Center U.S. Drought Monitor for December 30, 2014.

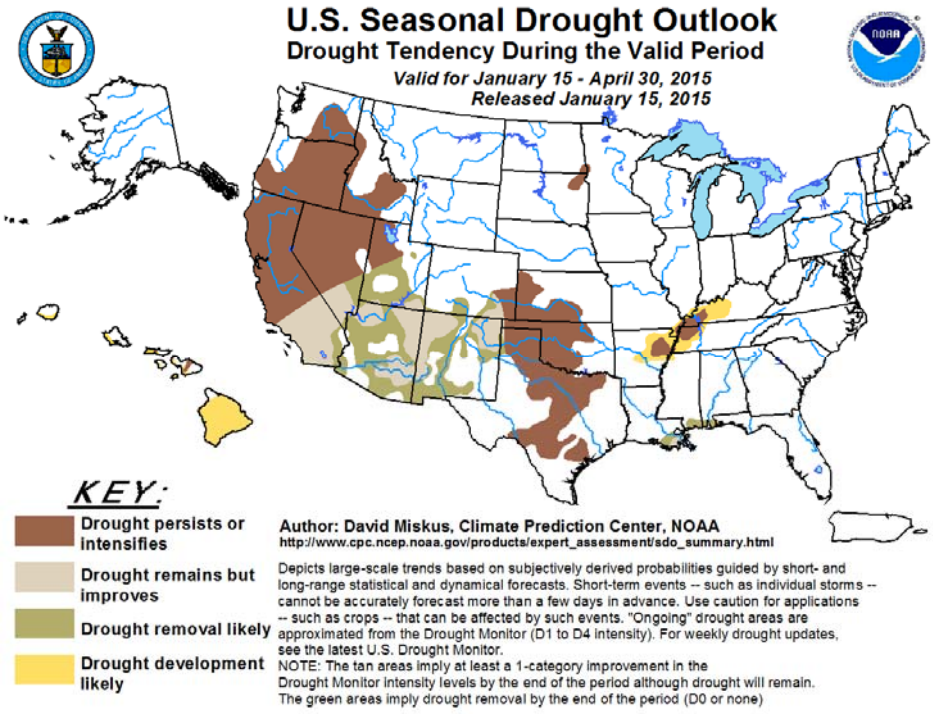


Figure 3. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

January precipitation accumulations are shown in **Figure 4** as both inches of precipitation and percent of normal monthly precipitation. From a climatological perspective, January is historically a dry month in the upper Basin. In January 2015, precipitation amounts ranged from less than 0.1 inch to 0.5 inch in most of Nebraska, South Dakota, and Wyoming. Parts of Montana and North Dakota received up to 1.75 inches. As a percent of normal, Montana and south central North Dakota were generally much wetter than normal with over 150% of normal precipitation, while most of Wyoming, South Dakota and Nebraska were well below normal.

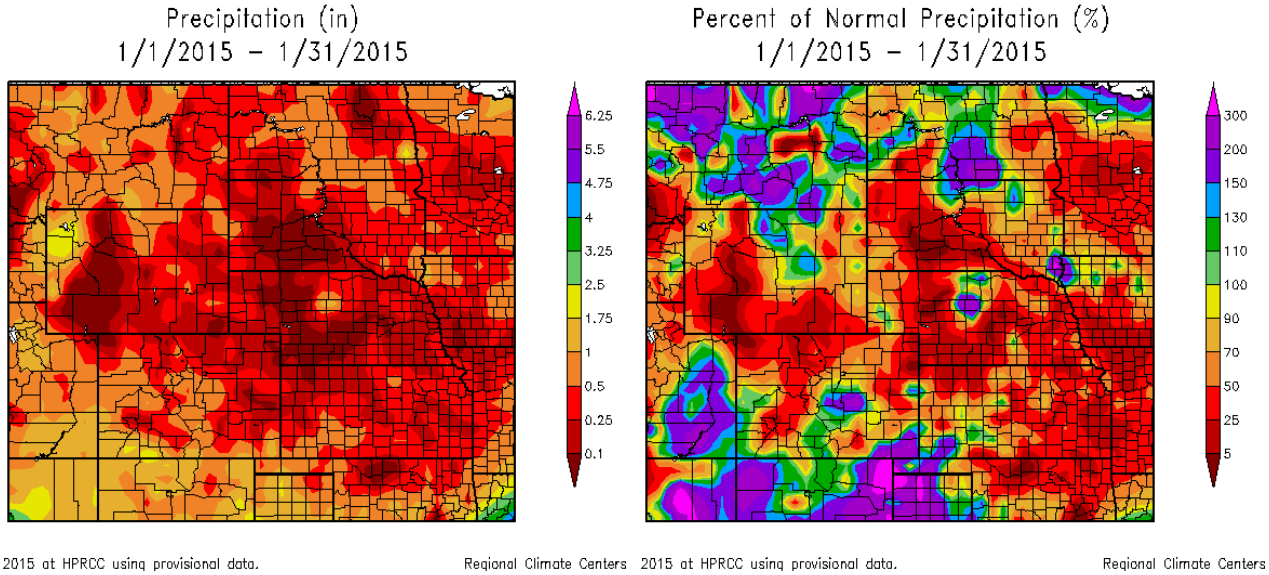


Figure 4. January 2015 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

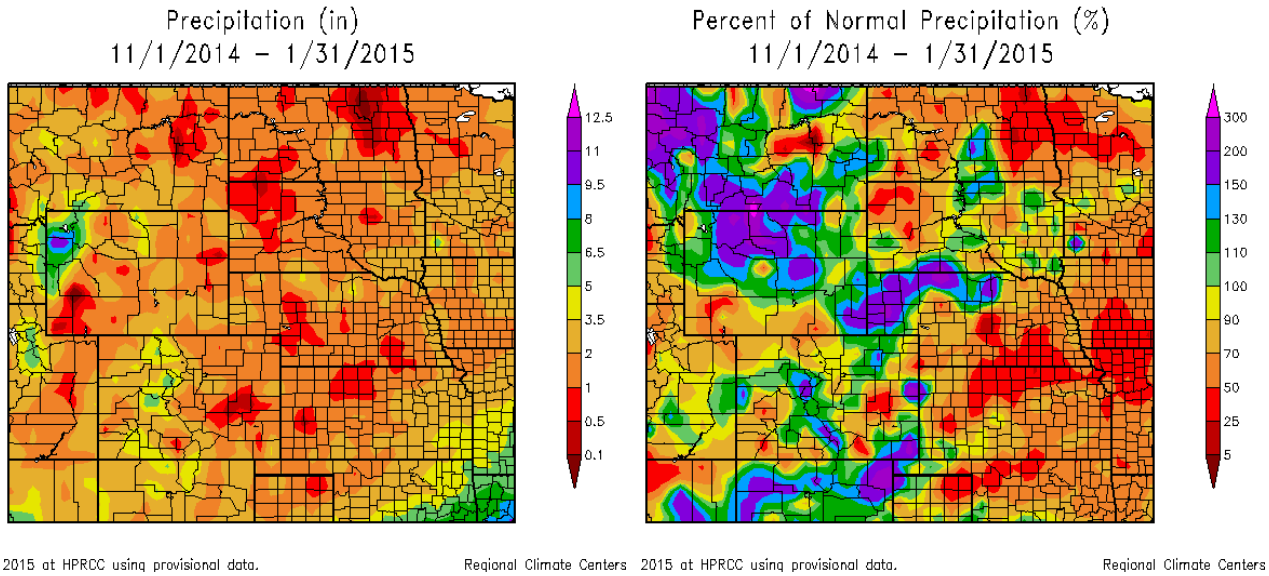


Figure 5. November 1 – January 31, 2015 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

November-December-January precipitation accumulations are shown in **Figure 5** as both inches and percent of normal precipitation. The three-month accumulation reveals that precipitation accumulations were less than 70% of normal over much of the Dakotas and central and eastern Nebraska. Above normal precipitation accumulations occurred over western and southern Montana and northern Wyoming along with a few regions of above normal precipitation scattered throughout the Basin. One area in particular, which has received 130% to 150% of normal precipitation, extends from central North Dakota into north central South Dakota.

Temperature

January temperature departures from normal in degrees Fahrenheit (deg F) are shown in **Figure 6**. January temperatures in the Basin generally ranged from 2 to 8 deg F above normal. The Dakotas had the largest departures from normal generally ranging from 4 to 8 deg F above normal. Three-month (November-December-January) temperature departures are also shown in **Figure 6**. The Missouri River basin is mostly either 2 degrees above normal or 2 degrees below normal with the exception of some localized locations.

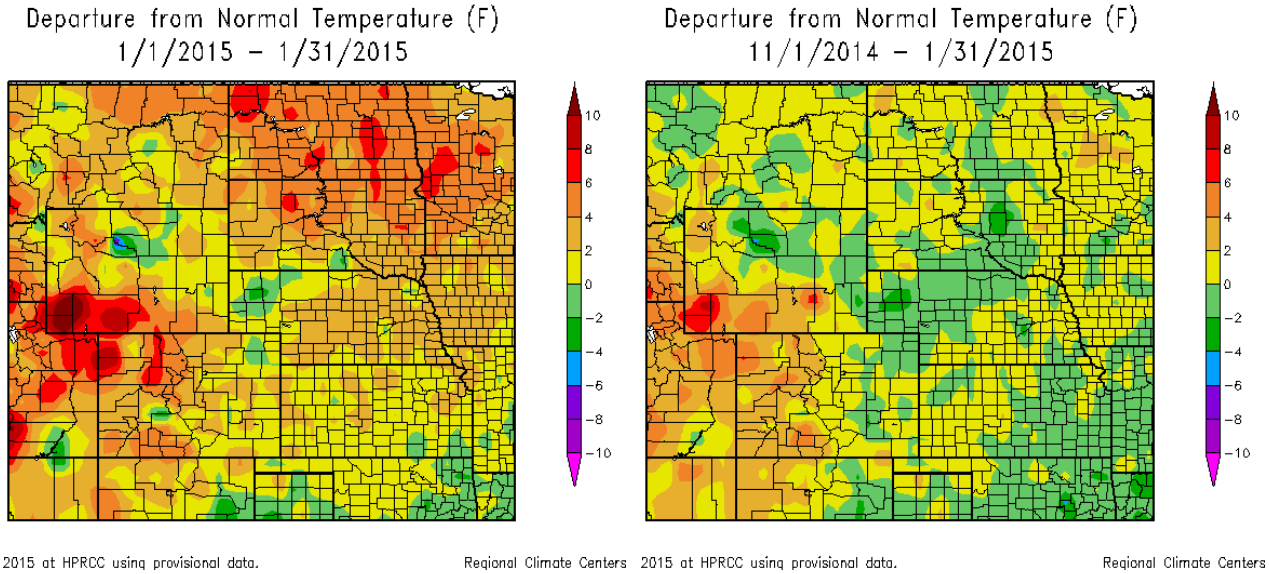


Figure 6. January 2015 and November-December 2014-January 2015 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

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 monthly runoff.

Figure 7 shows the NOAA NLDAS ensemble mean soil moisture percentiles on January 29, 2015 for the total modeled soil column, which is about 2 meters. The NLDAS soil moisture

depiction is an average value for the soil moisture column. The average soil moisture in **Figure 7** indicates well above normal soil moisture conditions throughout Montana, Wyoming, western North Dakota and western South Dakota. Soil moisture is greater than the 70th percentile in the aforementioned areas and greater than the 98th percentile in north central Montana. These high soil moisture conditions developed as a result of the record August rainfall; however drying has occurred at the soil surface resulting in less soil moisture in surface layers compared to deeper soil layers. This difference in soil moisture by depth is discussed in a later paragraph. Total column soil moisture in the eastern Dakotas is drier than normal with some conditions ranging from the 10th to 20th percentile.

The Ensemble Mean current total column soil moisture anomaly for the contiguous U.S. on January 29, 2015 is shown in **Figure 8**. These anomalies represent soil moisture averaged over the entire 2-meter soil column, so they do not reflect differences in soil moisture content at various depths. According to the modeled estimate, soil moisture anomalies in the western Dakotas, Montana and western Wyoming range from at least 25 – 50 mm (0.98 – 1.96 inches) above normal with some of north central Montana achieving 100 – 150 mm anomalies (3.95 – 5.91 inches). In contrast, anomalies in the eastern Dakotas range from 25 – 100 mm (0.98 – 3.94 inches) below normal. As stated in the previous paragraph, soil moisture in the surface layer is less than the average soil moisture content in the plains.

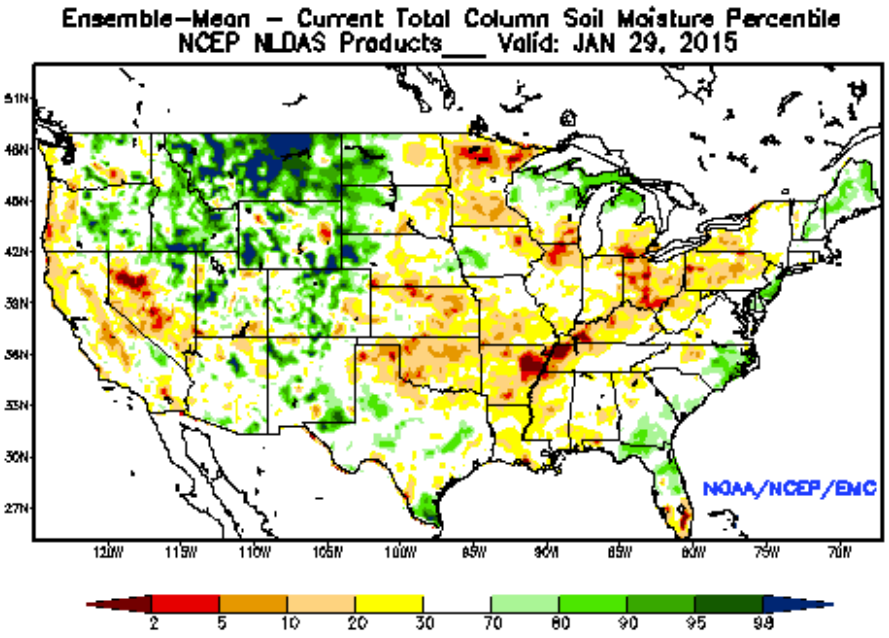


Figure 7. Total Column Soil Moisture Percentile on January 29, 2015. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

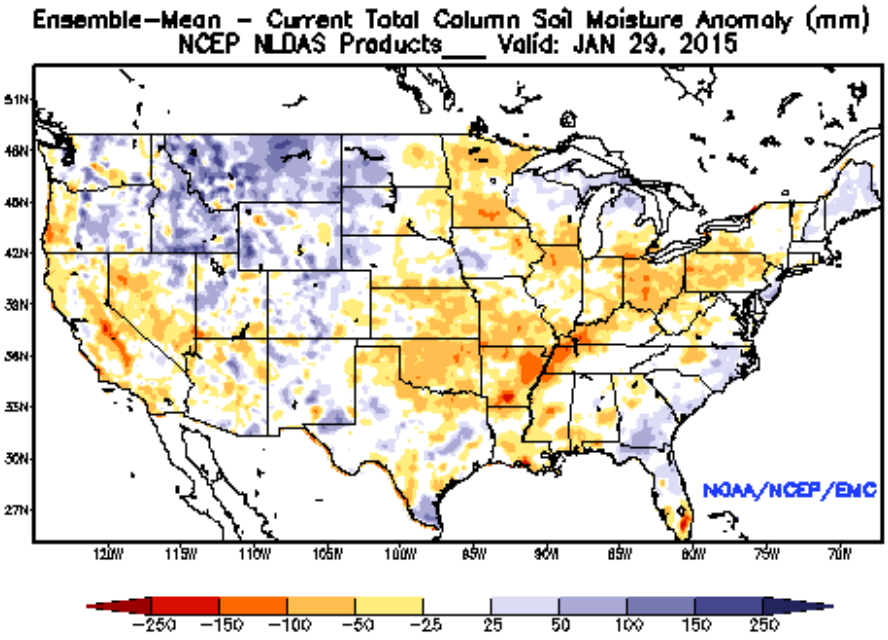


Figure 8. Calculated Soil Moisture Anomaly (mm) on January 29, 2015. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

The difference in soil moisture by depth is illustrated in **Table 1** and **Table 2**, percent soil moisture by depth at two USDA Soil Climate Analysis Network (SCAN) locations in the upper Basin. Over the last seven days in January, soil moisture declined rapidly in the top 2 to 4 inches of the soil profile near Dell Rapids, SD, but the surface conditions remained steady at Sidney, MT. No soil moisture decline has been observed at the 8-, 20- and 40-inch depths at either location. At Dell Rapids, SD, soil moisture is driest in the 8-inch depth showing some wetting near the surface during the past month. At Sidney, MT soil moisture is much less at 2- to 4-inch depths than at 16-inch, 20-inch and 40-inch depths. Soil moisture amounts are greatest in the 20- to 40-inch range at both locations. The high total column soil moisture percentiles and anomalies shown in **Figures 7** and **8** are primarily due to the higher contribution of subsoil moisture; however, the surface layer soil moisture is dry compared to subsoil moisture, providing additional capacity to absorb moisture from precipitation and snowmelt.

Table 1. Percent soil moisture by depth at the EROS Data Center USDA SCAN Site near Dell Rapids, SD.

USDA SCAN Site - EROS Data Center, Dell Rapids, SD					
Date	Percent Soil Moisture By Depth				
	2-inch	4-inch	8-inch	20-inch	40-inch
1/25/2015	19.8	20.1	15.7	25.1	27.3
1/26/2015	20.3	20.5	15.9	25.1	27.3
1/27/2015	20.3	20.7	16.2	25.1	27.2
1/28/2015	20.4	20.8	16.3	25.1	27.3
1/29/2015	20.5	21.0	16.5	25.1	27.2
1/30/2015	18.5	19.6	16.3	25.2	27.3
1/31/2015	18.0	18.9	15.7	25.3	27.2

Table 2. Percent soil moisture by depth at the USDA SCAN Site near Sidney, MT.

USDA SCAN Site – Sidney, MT					
Date	Percent Soil Moisture By Depth				
	2-inch	4-inch	8-inch	20-inch	40-inch
12/25/2014	11.6	13.3	16.9	15.7	21.1
12/26/2014	11.7	13.3	16.8	16.0	21.2
12/27/2014	11.7	13.3	16.9	16.2	21.2
12/28/2014	11.7	13.3	17.0	16.3	21.2
12/29/2014	11.8	13.3	16.8	16.3	21.0
12/30/2014	11.5	13.3	16.9	16.6	21.2
12/31/2014	11.1	13.2	16.9	16.8	21.2

Frost Conditions

In late December and early January, cold temperatures froze surface soils and allowed soil frost to develop at the greatest soil depths of the season. Soils experienced some thawing with the warmer weather conditions in January. **Figure 9** shows depth of frost penetration at National Weather Service (NWS) Weather Forecast Office (WFO) locations in the Missouri Basin as of February 2, 2015. While several frost depth measurements are missing, measurements indicate soil frost exists across the basin, but is shallow in the western and southern portion of the basin. Substantial frost exists in northern Montana and the Dakotas. Soil frost acts as a semi-impervious layer to snowmelt or precipitation infiltration into the soil.

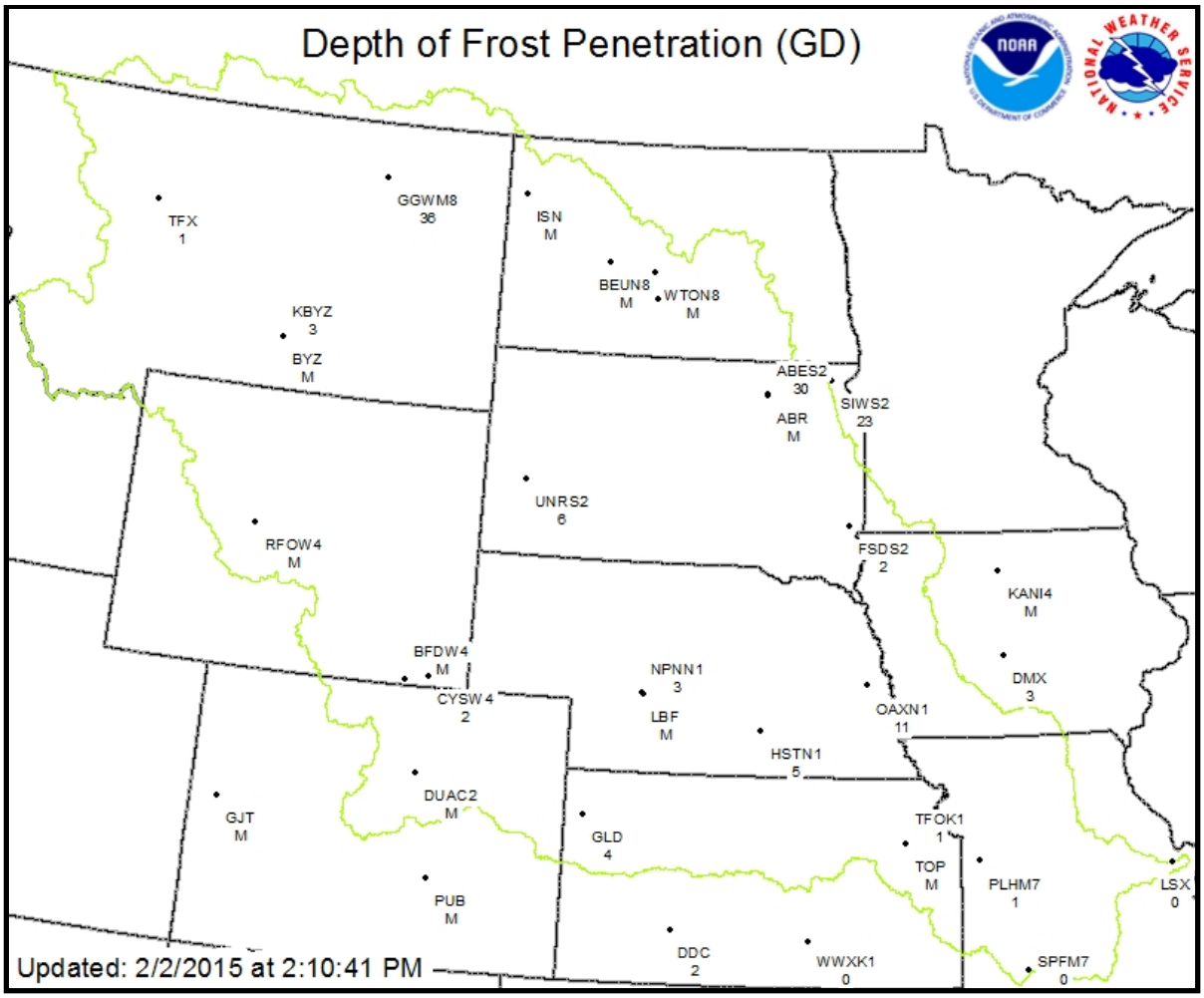


Figure 9. Measured frost depth (inches) at NWS WFO offices as of February 2, 2015. Source: NWS MBRFC.
http://www.crh.noaa.gov/mbrfc

Streamflow Conditions

Missouri Basin streamflow conditions represented as percentile classes on November 10, 2014 are shown in **Figure 10**. These conditions are based on the ranking of the November 10, 2014 streamflow versus the historical record of streamflow for that date. Streamflow conditions on November 10, 2014 were normal (25^{th} – 75^{th} percentile) in the eastern Dakotas within the Missouri Basin, and in portions of north central Wyoming and western Montana. Much-above normal streamflow conditions (> 90^{th} percentile) stand out as the blue and black gage locations on the map in many areas of Montana, Wyoming and the western Dakotas in the upper Basin, and in eastern Nebraska and western Iowa in the lower Basin.

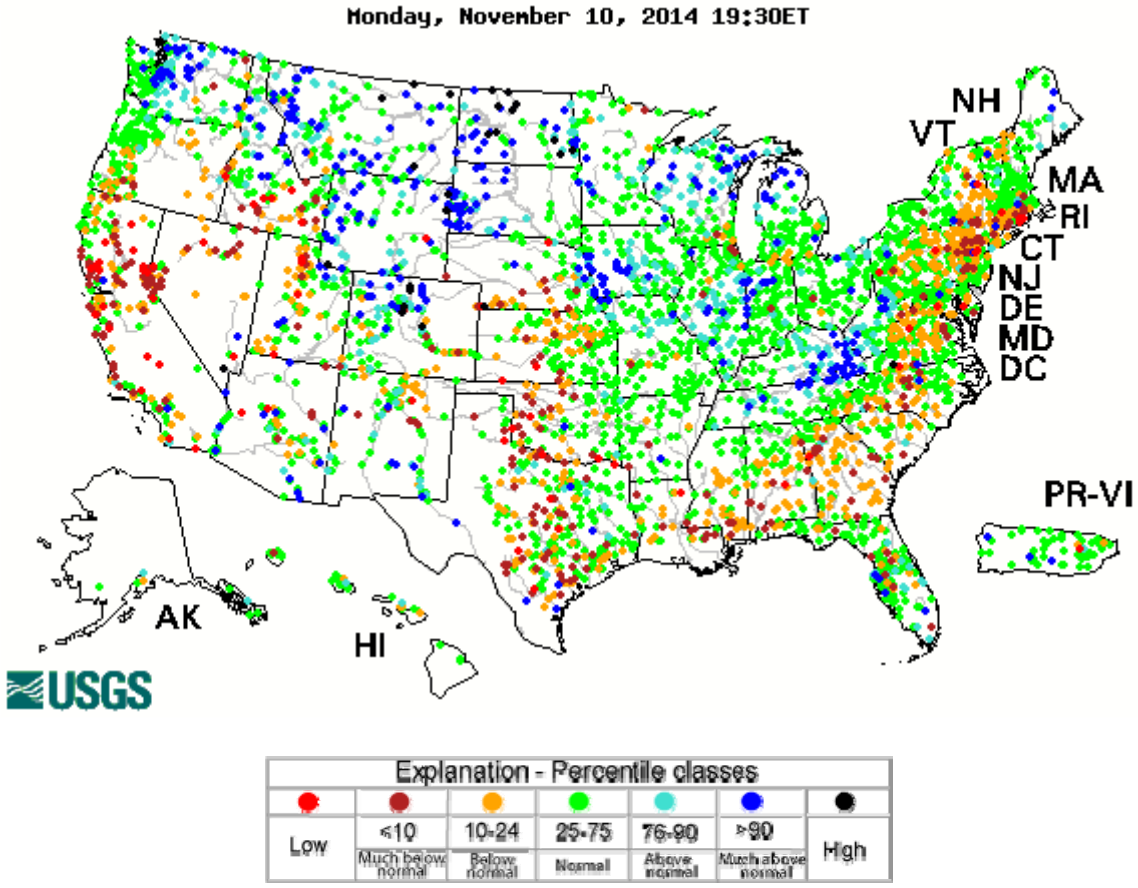


Figure 10. USGS Streamflow Conditions as a Percentile of Normal in the Missouri River Basin as of November 10, 2014.
Source: USGS. http://waterwatch.usgs.gov/index.php

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.

Based on the National Operational Hydrologic Remote Sensing Center (NOHRSC) assessment (**Figure 11**) as of February 1, 2015 most plains snow water equivalent (SWE) amounts ranged from trace to 1-inch amounts throughout the upper Basin. Amounts ranging from 1 to 2 inches covered portions of central Wyoming and the upper James River basin in central North Dakota. Some areas have no snow. Compared to February 1, 2014 (**Figure 12**) plains SWE, February 1, 2015 SWE is much less. On February 1, 2014, plains SWE generally ranged from 1 to 2 inches of SWE in the eastern Dakotas and there was a larger coverage of trace to 1 inch amounts.

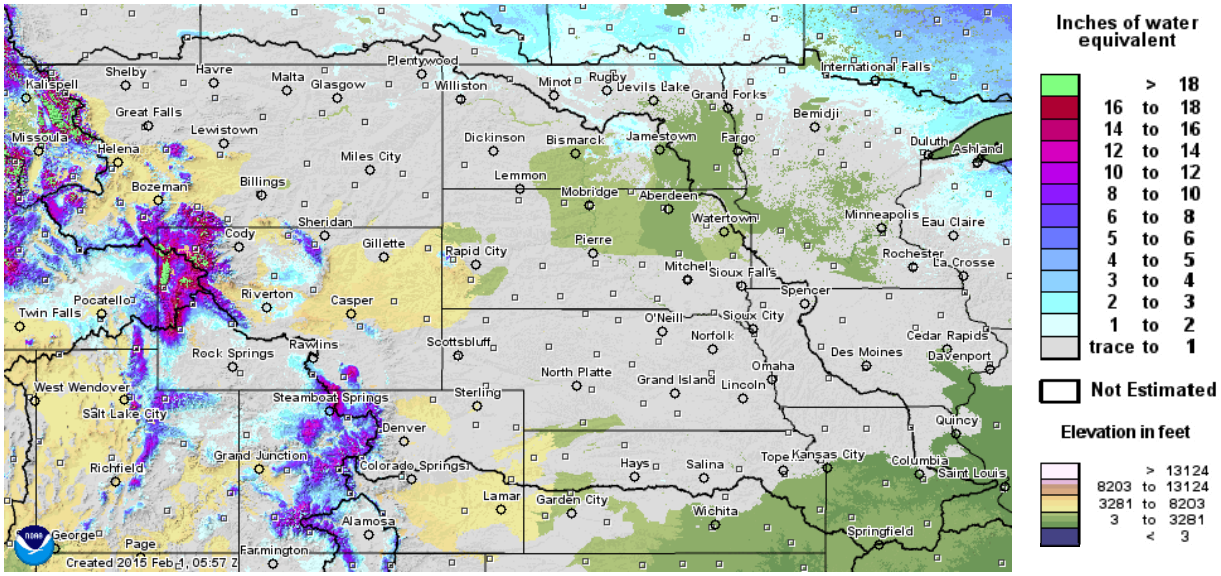


Figure 11. February 1, 2015 NOHRSC modeled plains snow water equivalent. Source: NOAA National Operational Hydrologic Remote Sensing Center. http://www.nohrsc.nws.gov/interactive/html/map.html

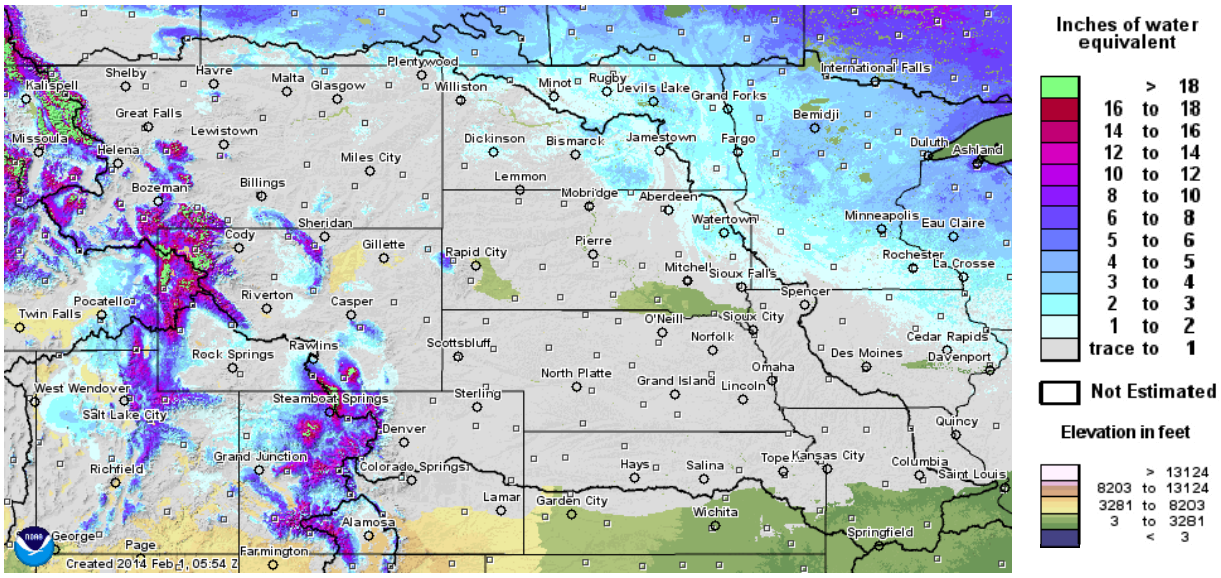


Figure 12. February 1, 2014 NOHRSC modeled plains snow water equivalent. Source: NOAA National Operational Hydrologic Remote Sensing Center. http://www.nohrsc.nws.gov/interactive/html/map.html

Using the MRBWM snowpack classification method, plains snowpack as of January 1, 2015 was classified as Light across the upper Basin in all reservoir reaches (**Table 3**). This classification includes plains snowpack accumulations that fall between the range of 0 to 1 inch of SWE in the Fort Peck, Oahe, Fort Randall and Gavins Point subbasins and 0 to 2 inches in the Fort Peck to Garrison and Gavins Point to Sioux City reaches.

Table 3. February 1, 2015 plains snowpack classification for runoff forecasting.

Reservoir Reach	Plains Snowpack Classification
Above Fort Peck	Light (0 – 1 inch SWE)
Fort Peck to Garrison	Light (0 – 2 inch SWE)
Garrison to Oahe	Light (0 – 1 inch SWE)
Oahe to Fort Randall	Light (0 – 1 inch SWE)
Fort Randall to Gavins Point	Light (0 – 1 inch SWE)
Gavins Point to Sioux City	Light (0 – 2 inch SWE)

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 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 greater than average runoff from an average mountain snowpack this year due to wetter than normal soil moisture conditions.

Figure 13 includes time series plots of the average mountain SWE beginning on October 1, 2014 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 **February 1, 2015**, the Corps of Engineers computed an average mountain SWE in the headwater basin above Fort Peck Dam of 9.7 inches, which is 93% of normal based on the 1981-2010 average SWE for the Fort Peck basin. In the subbasin between Fort Peck Dam and Garrison Dam, the Corps computed an average mountain SWE of 8.4 inches, which is 96% of normal based on the 1981-2010 average SWE for the Fort Peck to Garrison subbasin. Normally by February 1, 64% of the peak snow accumulation has occurred in the mountains. In comparison, February 1, 2014 mountain snowpack was 11.1 inches (107% of normal) in the Fort Peck subbasin and 9.9 inches (113% of normal) in the Fort Peck to Garrison subbasin.

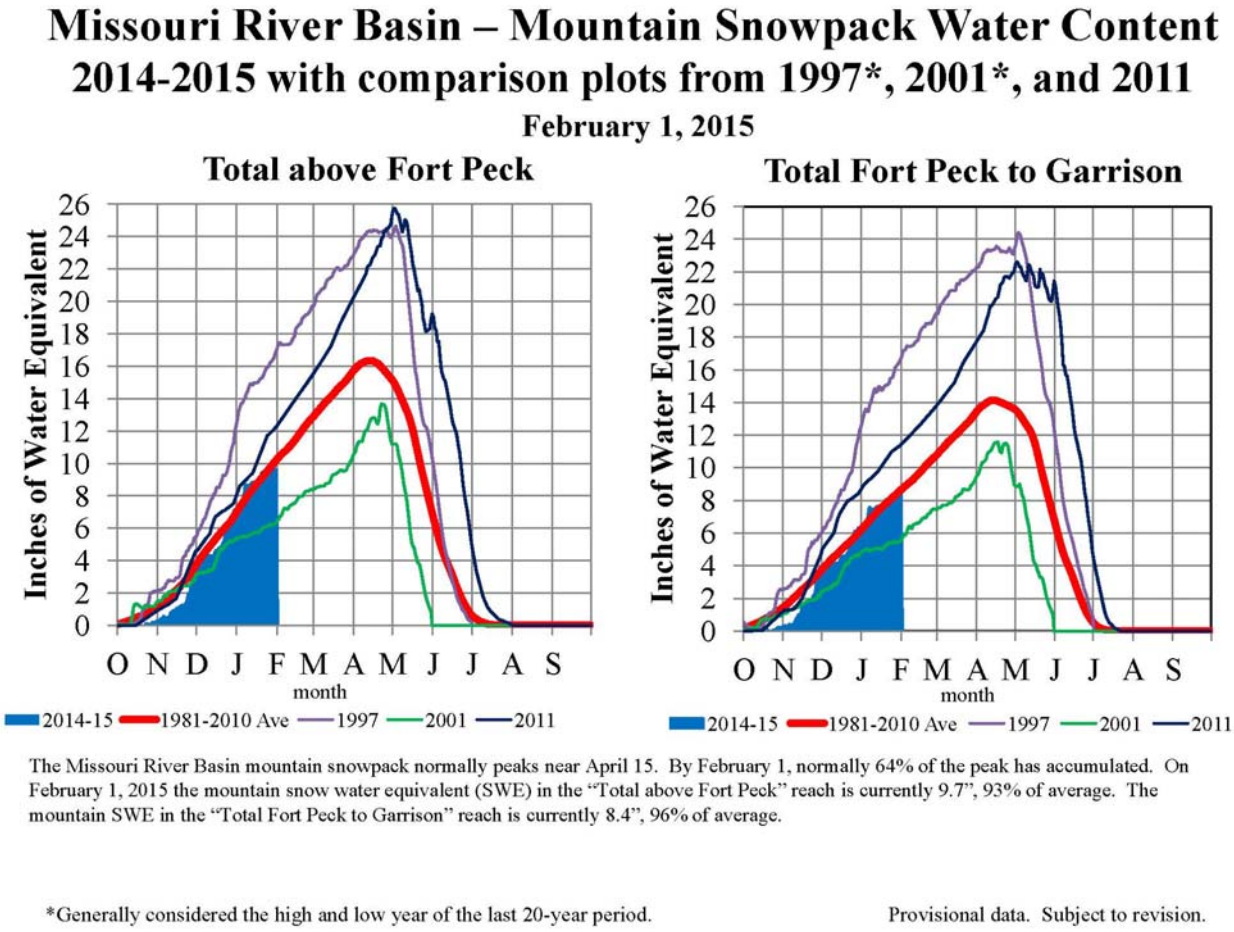


Figure 13. Mountain snowpack water content snow accumulation compared to normal and historic conditions. Corps of Engineers - Missouri River Basin Water Management.

Climate Outlook

ENSO (El Niño Southern Oscillation)

Based on the CPC analysis of equatorial sea surface temperatures (SST), positive anomalies continue across the Pacific Ocean, yet an ENSO-neutral phase continues. There is a 50-60% chance that El Niño conditions will be present during the next two months in the Northern Hemisphere winter. During the winter, El Niño conditions can increase chances for warmer and drier conditions in the Northern Plains. If El Niño has an impact on temperature and precipitation during the winter, the impact to upper Basin runoff is not realized until the spring and summer following an El Niño winter since most winter precipitation is snowfall. In some years El Niño has reduced the amount of mountain snowpack due to the warmer-than-normal temperatures, therefore reducing the volume of May-June-July runoff. The influence of a potential winter El Niño has been factored into the CPC's temperature and precipitation outlooks, and is discussed in the following section.

Temperature and Precipitation Outlooks

The NOAA Climate Prediction Center climate outlook for February 2015 (**Figure 14**) indicates an increased probability for above normal temperatures in the upper Missouri River Basin. Probabilities for above normal temperatures range from 33.3% to over 40%. With regard to precipitation, there are equal chances that precipitation will be above normal, normal and below normal in January throughout the entire upper Basin.

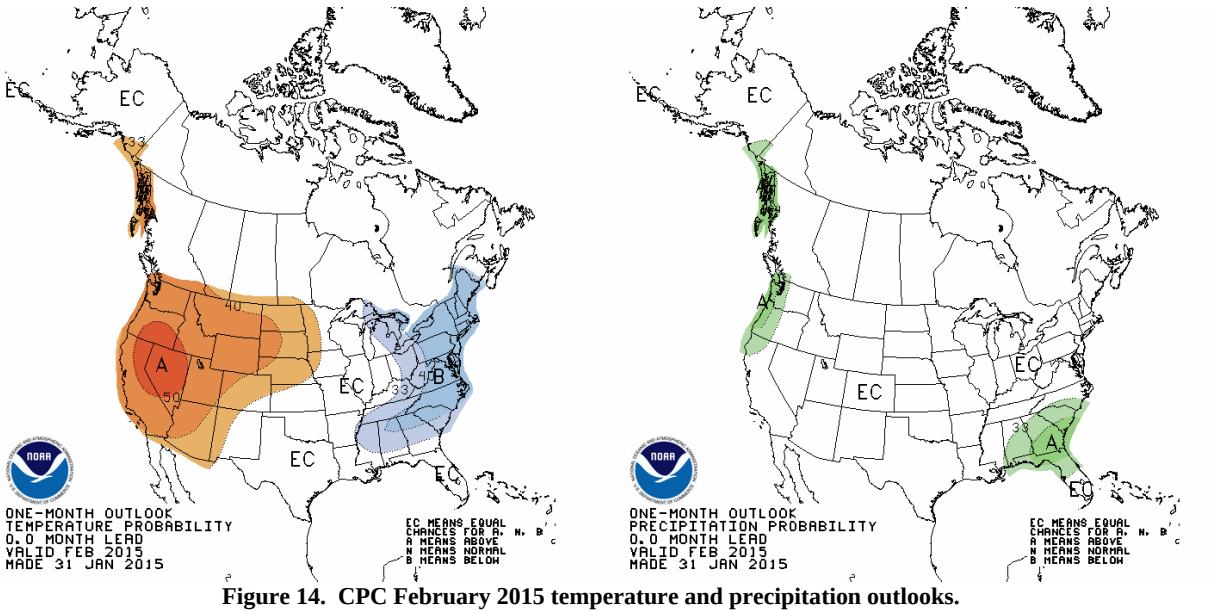


Figure 14. CPC February 2015 temperature and precipitation outlooks.

The February-March-April temperature outlook (**Figure 15**) indicates a slightly higher probability (33.3% to 40%) that temperatures will be above normal in Montana , western Wyoming, and western North Dakota, while there are equal chances for below normal, normal

and above normal temperatures in the remainder of the upper Basin. The February-March-April precipitation outlook indicates equal chances for below normal, normal and above normal precipitation in the upper Basin.

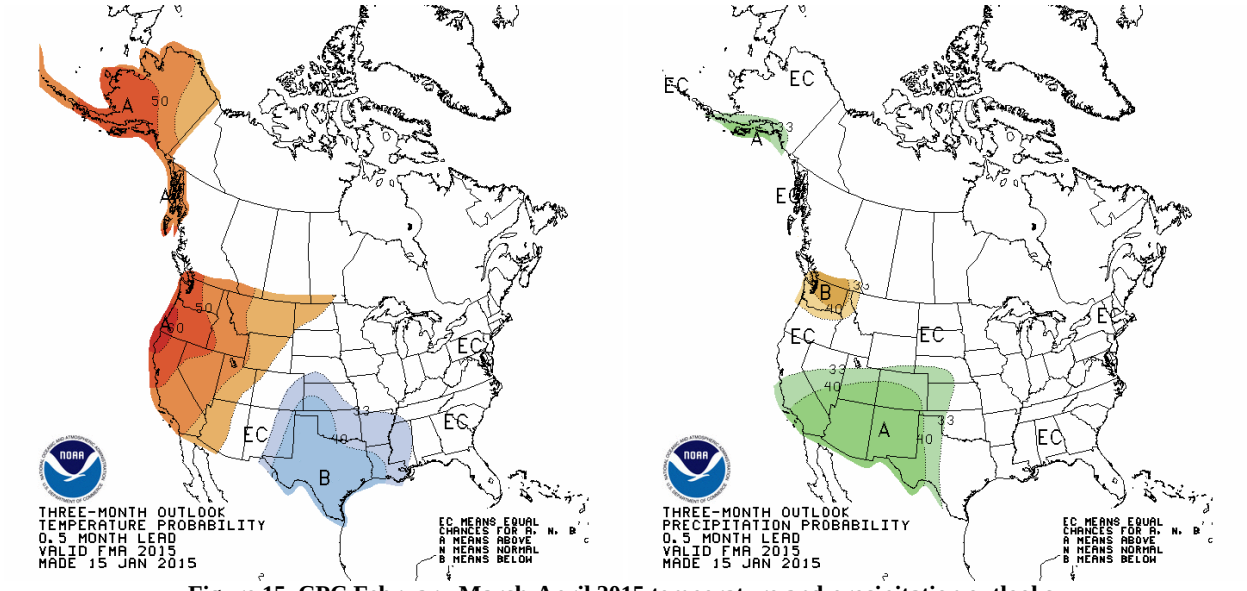


Figure 15. CPC February-March-April 2015 temperature and precipitation outlooks.

The May-June-July 2015 CPC temperature outlook (**Figure 16**) indicates there are equal chances for above normal, normal, and below normal temperatures throughout most of the upper Basin; however, in western Montana and Wyoming there is a slightly higher probability that temperatures will be above normal during the period. With regard to precipitation there are equal chances for above normal, normal, and below normal precipitation throughout the Basin.

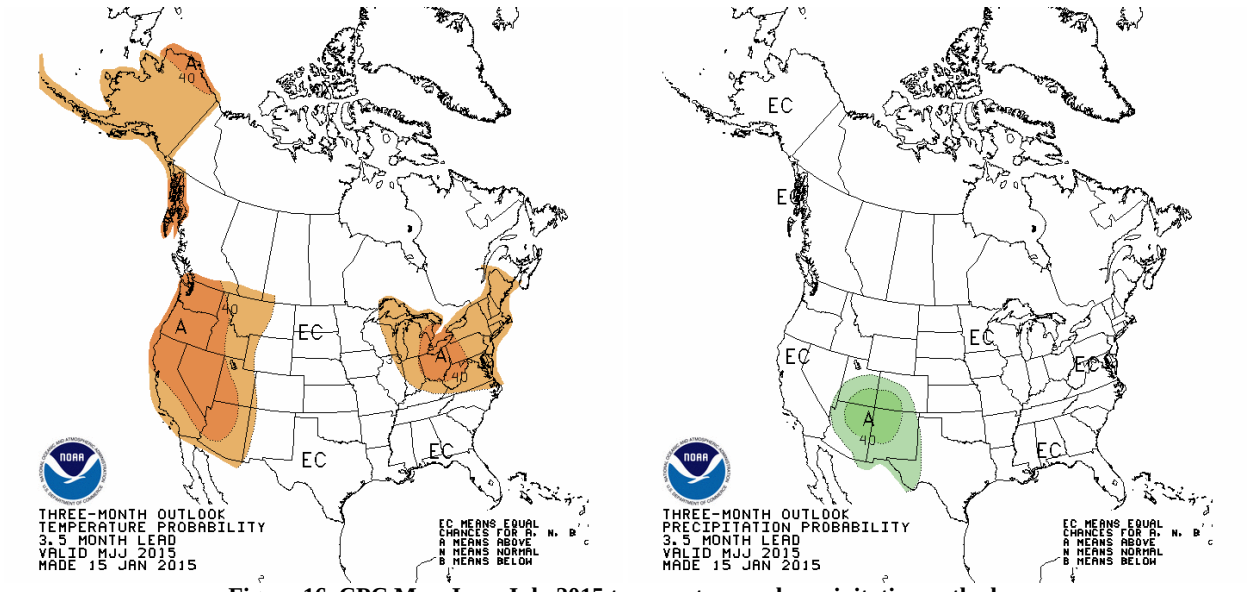


Figure 16. CPC May-June-July 2015 temperature and precipitation outlooks.

During the remainder of the calendar year, the CPC temperature outlooks for the August-September-October period (**Figure 17**) and the November-December 2015-January 2016 period (**Figure 18**) indicate slightly higher probabilities that temperatures will be above normal in the western Missouri River Basin, while there are equal chances temperatures will be above normal, normal or below normal in the remainder of the upper Basin. With regard to precipitation, there are equal chances precipitation will be above normal, normal or below normal during the August-September-October period (**Figure 17**) and the November-December 2015-January 2016 period (**Figure 18**).

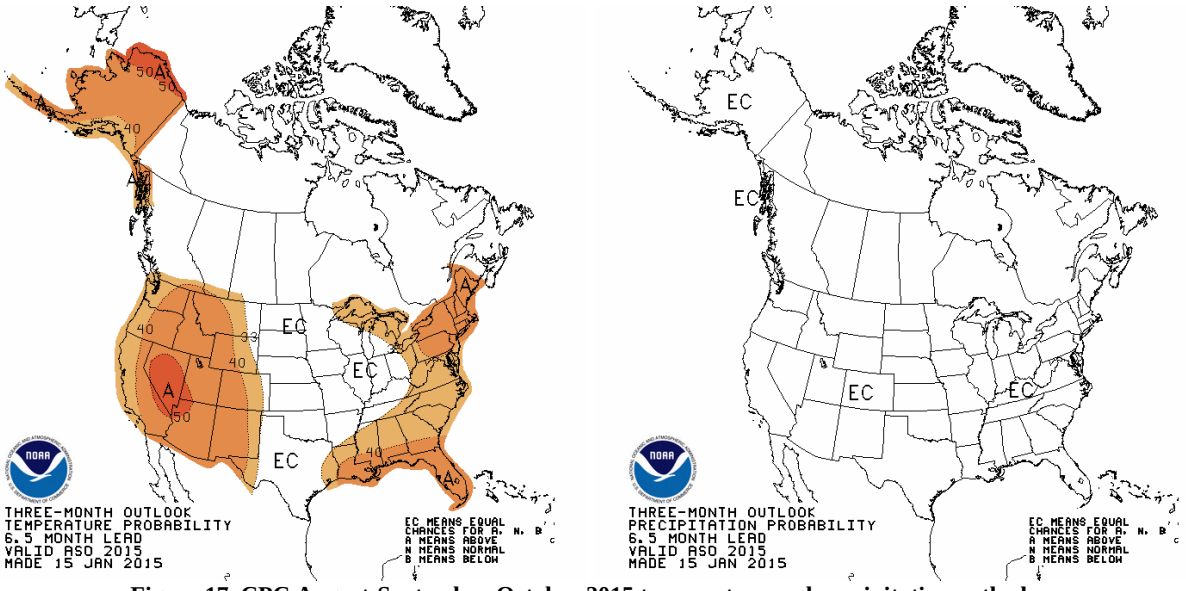


Figure 17. CPC August-September-October 2015 temperature and precipitation outlooks.

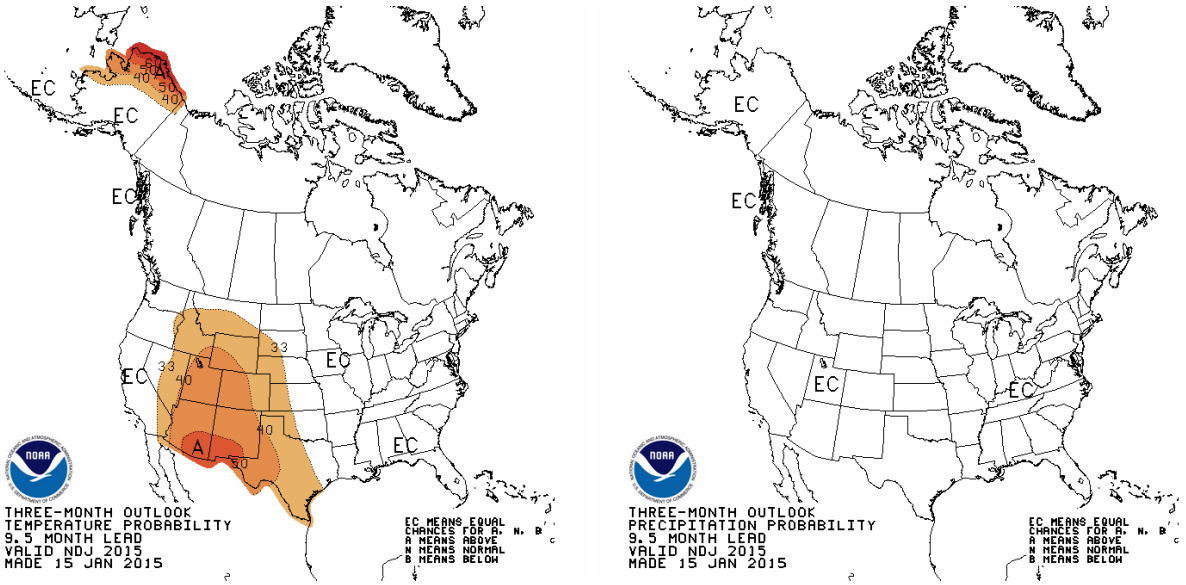


Figure 18. CPC November-December 2015-January 2016 temperature and precipitation outlooks.

February 2015 Calendar Year Runoff Forecast

The calendar year runoff forecast is **25.5 MAF (101% of average) above Sioux City** and **23.3 MAF (101% of average) above Gavins Point**. Due to the amount of variability in precipitation that can occur over the next 11 months, the range of expected inflow is quite large and ranges from the 35.0 MAF upper basic forecast to the 17.2 MAF lower basic forecast. The upper and lower basic forecasts provide a likely range of runoff scenarios that could occur given much wetter conditions or much drier conditions. The upper and lower basic forecasts are used in long-term regulation planning models to "bracket" the range of expected runoff. It should be noted, however, that it is possible, due to either much higher or much lower than forecasted precipitation occurring, that these ranges may be exceeded on either end.

Factors taken into consideration while preparing the 2015 forecast include: January runoff, continuing drought (in some portions of the upper basin) and soil moisture conditions, winter precipitation and streamflow, plains snowpack, mountain snowpack, and NOAA's Climate Prediction Center's monthly and seasonal temperature and precipitation outlooks.

February

Runoff in January was 1.36 MAF (178% of normal) due to warmer than normal temperatures during much of the month, which melted most of the plains snow and caused the loss of substantial quantities of Missouri River tributary and Missouri River ice. The February temperature outlook indicates there is an increased probability for above normal temperatures with equal chances for precipitation. Therefore, February runoff is forecast to follow a similar above normal trend as remaining river ice and plains snowpack melts. The February runoff forecast is 115% of normal.

March-April

Plains snowpack is a significant factor influencing the volume of runoff in March and April; however, snow and rainfall precipitation during this time period are also very important factors that need consideration. Furthermore, antecedent accumulated precipitation and antecedent soil moisture conditions have a significant influence on March-April runoff.

Plains snowpack in all reaches of the upper Basin ranges from 0 to 1 inch of SWE. The upper Basin experienced significantly above normal temperature in January, leading to much plains snowmelt; however, precipitation near the end of the month added a very light cover of snow. Since the above normal runoff occurring in January was due to some snowmelt and melting of river ice, which would typically occur in late February and March, the March-April runoff forecast was reduced slightly to 95% of normal.

May-June-July

During the May-June-July period, the mainstem system receives 50% of its annual runoff as a result of mountain snowmelt and spring and summer precipitation. This is the most active period for precipitation in the Missouri River Basin, so runoff can vary significantly as a result of the above or below normal rainfall.

For this 3-month period, the most reliable method for predicting runoff into Fort Peck and Garrison reservoirs is through regression equations that relate mountain snowpack to runoff. The February 1, 2015 mountain snowpack was 93% of average in the reach above Fort Peck and 96% of average in the reach between Fort Peck and Garrison. The CPC 3-month outlooks of May-June-July precipitation indicates an equal chances for above normal, normal and below normal precipitation in the Fort Peck and Garrison reaches. Taking into consideration these factors, 98% and 100% of normal runoff is forecast for the Fort Peck and Garrison reaches, respectively. Near normal runoff is forecast for the remaining reaches. The overall May-June-July runoff summation forecast is about 99% of normal.

The significance of accurately forecasting May-June-July runoff for the Fort Peck and Garrison reaches is based on the fact that, historically, an average of 9.2 MAF of runoff occurs during these 3 months into these 2 projects. That is 37% of the total annual runoff into the system.

August through December

For the latter half of 2015, NOAA's climate outlook indicates increased chances for above normal temperatures throughout the basin and equal chances for above, below and normal precipitation. Very little information is known at this time which can indicate how much runoff will occur during that time period because summer and fall runoff is determined by precipitation; therefore, normal runoff is forecast from August through December.

Expert Discussions

Prior to the December calendar year runoff forecast, MRBWM held a conference call on November 24 with Dr. Adnan Akyuz, North Dakota State Climatologist; Dr. Dennis Todey, South Dakota State Climatologist, and Mr. Scott Dummer, Missouri Basin River Forecast Center (MBRFC), to discuss the hydrologic state of the upper Missouri River Basin. These discussions were held in order to attain expert assessments of various hydrologic factors that the Corps considers in it runoff forecasts. A summary of the major points of this discussion follows.

Fall Precipitation and Streamflow

Fall precipitation is a very useful indicator of spring runoff in North Dakota, with the Red River Basin of the North being a prime example of the usefulness of fall precipitation as an indicator. Higher fall precipitation accumulations generally lead to higher fall streamflow, higher spring runoff and streamflow due to higher (wetter) soil moisture conditions, and higher levels of water in surface storage such as the prairie pothole lakes. At the onset of the winter freeze, much of this moisture is locked up in frozen soil moisture and will not be released until the spring thaw. Fall precipitation in 2014 has been well below normal over a large majority of the upper Missouri Basin (**Figure 5**), though there have been some regionally wet areas, especially west of the Missouri River near the Montana border. Compared to 2011, fall precipitation in 2014 has been much lower, and on the dry side of the fall precipitation spectrum.

At the start of river freeze-up streamflow conditions were near their 90^{th} percentile rankings at many stream gages in the upper Missouri Basin. According to Scott Dummer of the MBRFC, higher streamflow conditions increase the potential for freeze-up jams in the winter.

Soil Moisture, Soil Frost and Surface Storage

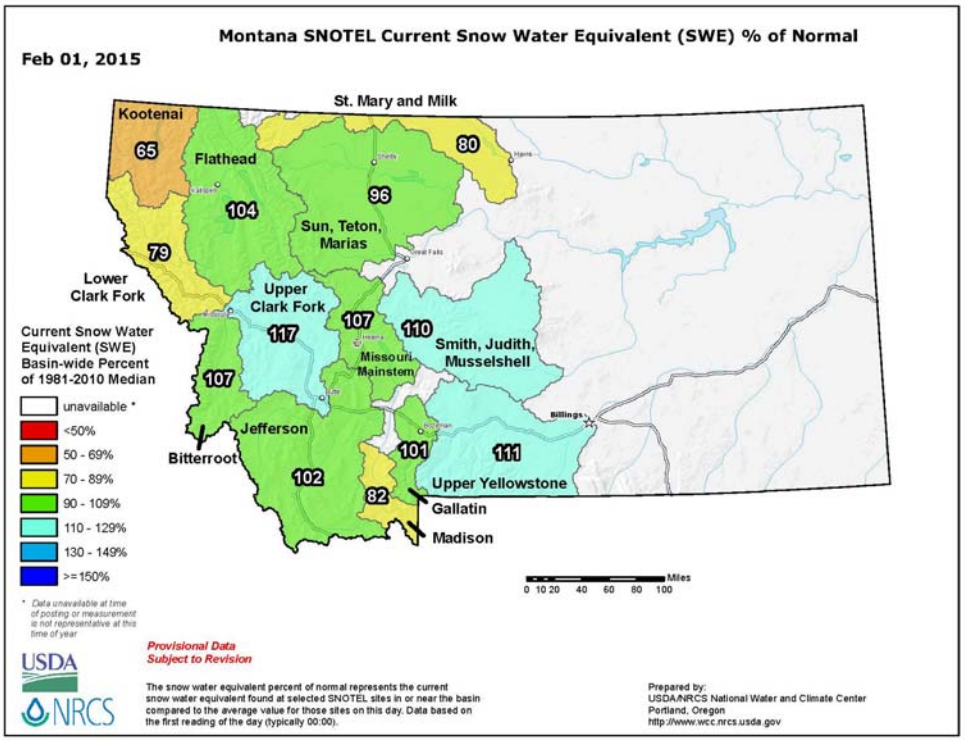
The NLDAS product is a modeled total column soil moisture product that is highly regionalized and the soil depth representation is very generalized. Therefore, anecdotal information from local observers is only accurate at the location and not regionally. Soil moisture over the upper Missouri Basin is quite varied as represented by the NLDAS ensemble mean soil moisture maps shown in **Figure 7** and **Figure 8**. The eastern Dakotas are dry, while the western Dakotas have above normal soil moisture averaged over the soil profile. According to Dr. Todey, the top 3 feet of soil in most areas of South Dakota are fairly dry; however, there is good soil moisture at 3 to 4 foot depths due to low summer evapotranspiration demands. According to Dr. Akyuz, the state of the soil prior to snow accumulation is important. Frozen soils, somewhat independent of soil moisture content, act as an impervious surface to water. Prior to the first snow accumulation in early November, soil frost developed due to the very cold temperatures in the upper Basin. Since the soils are currently frozen, the amount of runoff will depend on the amount of accumulated plains snow, the rate of snowmelt in the spring and spring rainfall.

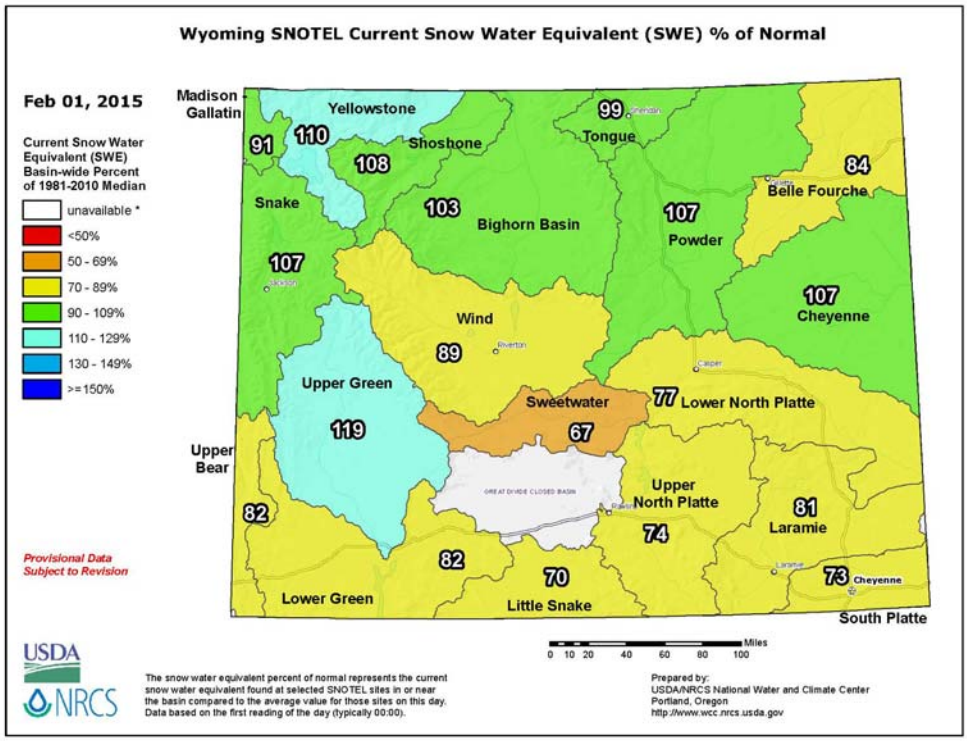
Furthermore, substantial surface or wetland storage in the prairie potholes region of North Dakota and South Dakota is available to store meltwater in the spring, rendering some of this region as non-contributing area to the Missouri River basin.

Winter Weather Forecast

The dominant factor influencing winter weather in the Missouri Basin is the Arctic oscillation, which describes the oscillation of cold air from the Canadian Arctic into the lower latitudes. The Arctic oscillation has typically brought cold air into the Missouri Basin during more severe winters. This factor is not typically predictable beyond a few weeks; therefore, no forecast can be made for the entire winter season based on this factor.

Additional Figures





USDA NRCS National Water & Climate Center

USDA NRCS National Water & Climate Center
 * - DATA CURRENT AS OF: February 04, 2015 02:26:05 PM
   - Based on February 01, 2015 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	81	84	96	87	75	66	97
	APR-SEP	95	85	110	101	88	79	112
St. Mary R at Int'l Boundary (2)	APR-JUL	340	78	440	380	300	240	435
	APR-SEP	400	79	500	440	360	295	505
Lima Reservoir Inflow (2)	APR-JUL	53	65	86	66	40	20	82
	APR-SEP	56	63	94	72	40	17.6	89
Clark Canyon Reservoir Inflow (2)	APR-JUL	57	56	144	92	22	-15.0	101
	APR-SEP	71	59	166	109	33	-4.0	120
Jefferson R nr Three Forks (2)	APR-JUL	675	91	1050	825	520	295	740
	APR-SEP	730	91	1150	900	560	310	800
Hebgen Reservoir Inflow (2)	APR-JUL	315	85	385	345	285	245	370
	APR-SEP	405	86	490	440	370	320	470
Ennis Reservoir Inflow (2)	APR-JUL	475	76	625	535	415	325	625
	APR-SEP	600	77	775	670	530	425	775
Missouri R at Toston (2)	APR-JUL	1540	86	2180	1800	1280	900	1790
	APR-SEP	1780	86	2540	2090	1470	1020	2070
Smith R bl Eagle Ck (2)	APR-JUL	127	120	180	148	106	74	106
	APR-SEP	144	124	205	169	119	83	116
Gibson Reservoir Inflow (2)	APR-JUL	390	99	480	425	350	295	395
	APR-SEP	430	98	530	470	390	330	440
Marias R nr Shelby (2)	APR-JUL	325	94	500	395	250	144	345
	APR-SEP	335	93	520	410	255	144	360
Milk R at Western Crossing	MAR-SEP	35	108	61	49	26	18	33*
Milk R at Eastern Crossing	MAR-SEP	77	95	149	95	59	43	81*

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	61	103	69	64	58	53	59
	APR-SEP	78	105	89	82	74	67	74
Wind R ab Bull Lake Ck (2)	APR-JUL	420	92	555	470	365	285	455
	APR-SEP	440	90	580	495	385	300	490
Bull Lake Ck nr Lenore	APR-JUL	124	89	157	137	111	92	139
	APR-SEP	153	91	193	169	136	112	169
Boysen Reservoir Inflow (2)	APR-JUL	485	80	890	645	320	79	610
	APR-SEP	540	81	975	715	360	101	665
Greybull R nr Meeteetse	APR-JUL	134	102	169	148	120	99	131
	APR-SEP	182	103	225	200	165	139	177
Shell Ck nr Shell	APR-JUL	52	95	67	58	46	37	55
	APR-SEP	64	97	80	70	57	47	66
Bighorn R at Kane (2)	APR-JUL	730	87	1250	935	520	210	840
	APR-SEP	790	87	1350	1020	565	235	905
NF Shoshone R at Wapiti	APR-JUL	480	104	565	515	445	395	460
	APR-SEP	535	104	625	570	500	445	515
SF Shoshone R nr Valley	APR-JUL	225	105	265	240	210	183	215
	APR-SEP	255	104	300	275	235	210	245
Buffalo Bill Reservoir Inflow (2)	APR-JUL	700	104	840	755	645	560	675
	APR-SEP	775	104	925	835	715	625	745
Bighorn R nr St. Xavier (2)	APR-JUL	1300	94	1910	1550	1050	685	1380
	APR-SEP	1380	95	2060	1650	1110	700	1460
Little Bighorn R nr Hardin	APR-JUL	93	95	141	112	74	45	98
	APR-SEP	109	98	162	130	88	56	111
Tongue R nr Dayton (2)	APR-JUL	83	97	114	96	70	52	86
	APR-SEP	95	97	128	108	82	62	98

Tongue River Reservoir Inflow (2)	APR-JUL	179	93	285	220	136	72	193
	APR-SEP	200	93	310	245	155	88	215
NF Powder R nr Hazelton	APR-JUL	9.7	107	12.2	10.7	8.7	7.2	9.1
	APR-SEP	10.4	105	13.0	11.5	9.4	7.8	9.9
Powder R at Moorhead	APR-JUL	169	95	270	210	129	69	177
	APR-SEP	189	96	290	230	147	86	196
Powder R nr Locate	APR-JUL	191	96	315	240	141	67	199
	APR-SEP	210	95	345	265	159	79	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	6.7	108	10.8	8.3	5.0	2.6	6.2
	APR-JUL	5.5	106	9.1	6.8	4.3	2.7	5.2
Pactola Reservoir Inflow (2)	MAR-JUL	25	100	43	32	17.0	5.8	25
	APR-JUL	21	95	41	28	14.9	7.8	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	APR-JUL	137	61	255	184	90	19.7	225
	APR-SEP	150	60	280	200	98	21	250
Encampment R nr Encampment	APR-JUL	80	62	126	99	62	34	129
	APR-SEP	85	62	133	104	66	37	138
Rock Ck nr Arlington	APR-JUL	39	80	56	46	32	22	49
	APR-SEP	42	81	60	49	35	24	52
Seminoe Reservoir Inflow (2)	APR-JUL	440	62	850	605	275	32	715
	APR-SEP	475	62	910	650	295	34	770
Sweetwater R nr Alcova	APR-JUL	28	47	64	42	12.9	6.0	59
	APR-SEP	30	47	69	46	14.7	7.0	64
La Prele Ck ab La Prele Reservoir	APR-JUL	7.8	39	27	15.6	3.1	0.50	19.9
	APR-SEP	7.8	39	27	15.6	3.1	0.50	19.9
North Platte R bl Glendo Res (2)	APR-JUL	445	54	710	550	340	181	820
	APR-SEP	445	52	720	555	330	166	850
North Platte R bl Guernsey Res (2)	APR-JUL	440	54	770	575	310	113	820
	APR-SEP	455	54	795	590	315	114	850
Laramie R nr Woods	APR-JUL	78	68	117	94	62	39	115
	APR-SEP	86	68	128	103	68	43	126
Little Laramie R nr Filmore	APR-JUL	37	73	55	44	29	18.0	51
	APR-SEP	39	71	60	48	31	18.5	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 2015 Calendar Year Runoff Forecast
March 6, 2015

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.

February 2015 Runoff

February 2015 runoff was 2.0 MAF (186% of normal) above Sioux City, and 1.9 MAF (193% of normal) above Gavins Point Dam The higher-than-normal runoff was due to warmer-than-normal temperatures in Montana and Wyoming that continued to melt any accumulated plains snowpack and keep tributaries flowing. This additional runoff in February is runoff that would normally occur in March and April during the normal time of the spring thaw.

2015 Calendar Year Forecast Synopsis

The March 1 forecast for the 2015 Missouri River runoff above Sioux City, IA is **24.6 MAF (97% of normal)**. Runoff above Gavins Point Dam is forecast to be **22.8 MAF (99% of normal)**. 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 32.9 MAF upper basic forecast to the 17.3 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 lower than normal (lower basic) is attributed to all 6 reaches for

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 National Drought Mitigation Center's drought monitor for February 24, 2015 (**Figure 1**), when compared to the drought monitor for January 27, 2015 (**Figure 2**), shows a slight expansion of Abnormally Dry (D0) conditions in the Northern Plains and a decrease in the southern portion of the Basin. Since January 27, D0 conditions expanded in western South Dakota. D0 conditions were removed in south-eastern Nebraska and north-eastern Kansas, southern Iowa, and northern Missouri. The U.S. Seasonal Drought Outlook in **Figure 3** indicates that very little change is expected to drought conditions through May 31, 2015 with the exception of a small area in the eastern Dakotas where drought conditions are expected to persist or intensify.

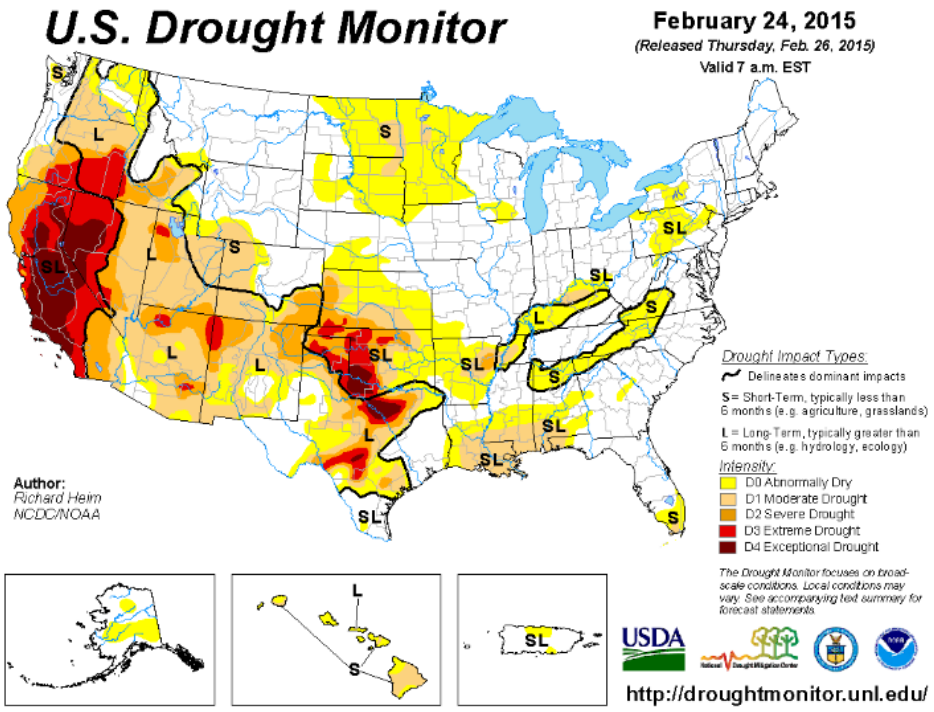


Figure 1. National Drought Mitigation Center U.S. Drought Monitor for February 24, 2015.

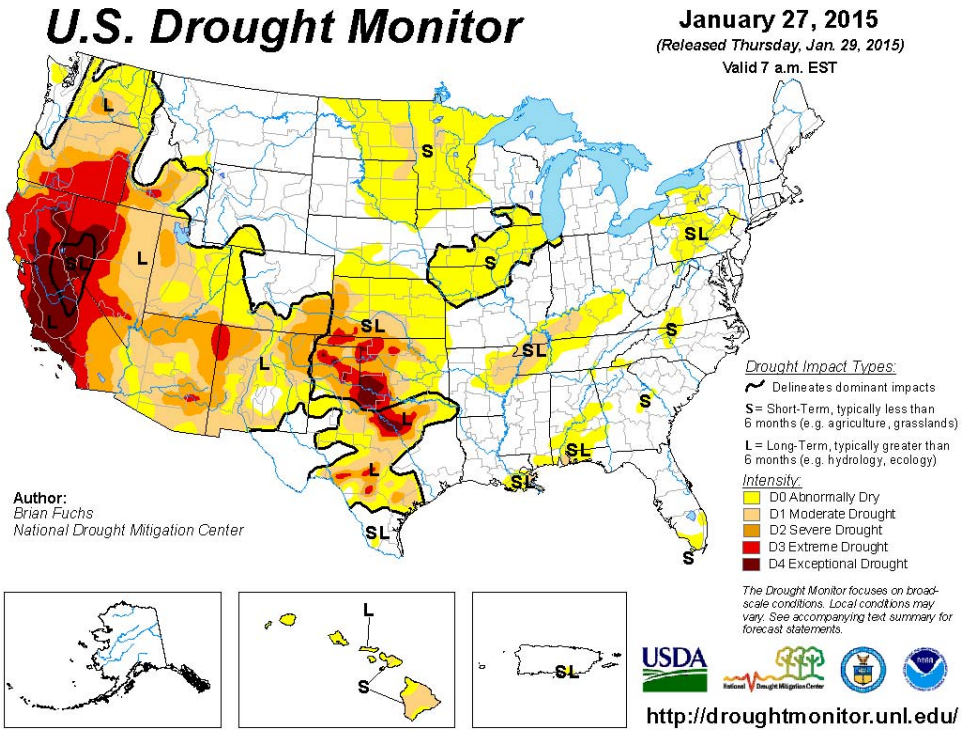


Figure 2. National Drought Mitigation Center U.S. Drought Monitor for January 27, 2015.

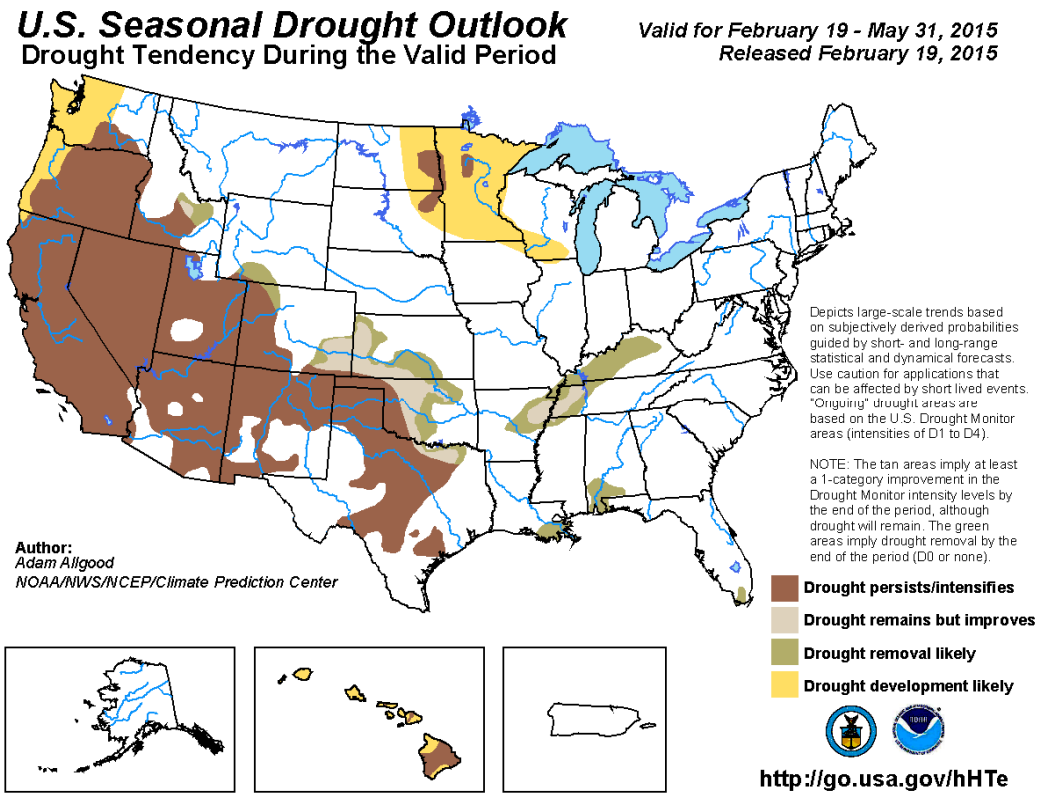


Figure 3. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

February precipitation accumulations are shown in **Figure 4** as both inches of precipitation and percent of normal monthly precipitation. From a climatological perspective, February is a dry month in the upper Basin. In February 2015, precipitation amounts ranged from less than 0.1 inch to 1 inch in most of Nebraska, South Dakota, and Wyoming. Parts of Wyoming received up to 2 inches. As a percent of normal, northern Montana and central-Wyoming were generally much wetter than normal with areas of over 400% of normal precipitation, while much of the Dakotas in the upper Basin were below normal. Precipitation in the upper Missouri and Yellowstone headwaters has been normal to more than one-inch below normal this winter.

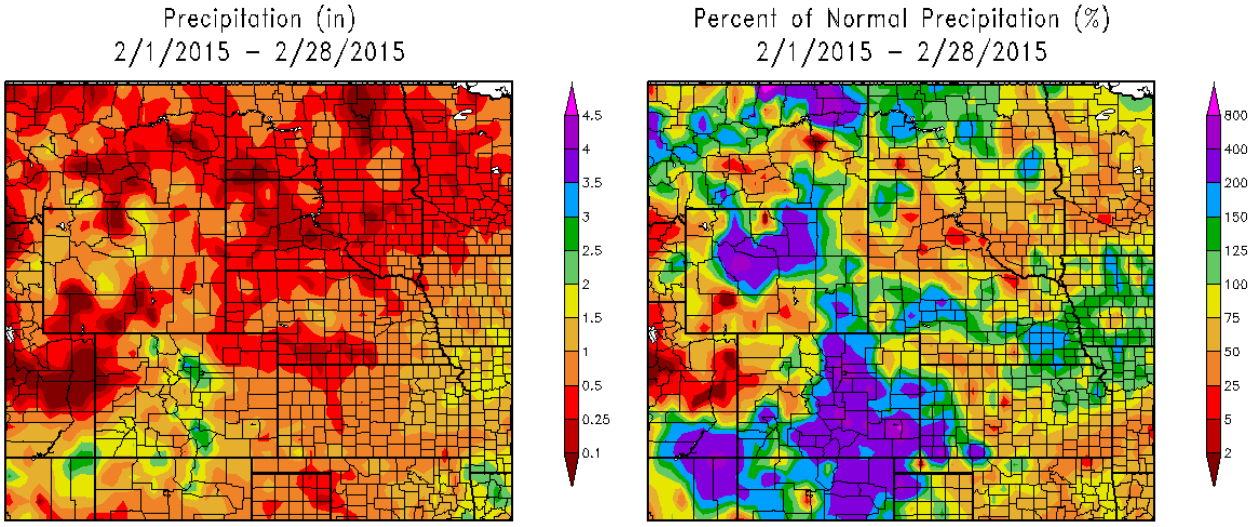


Figure 4. February 2015 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

December-January-February precipitation accumulations are shown in **Figure 5** as both inches and percent of normal precipitation. The three-month accumulation reveals that precipitation accumulations have been less than 70% of normal over much of the Dakotas with the exception of greater than normal precipitation in a portion of central North Dakota. Above normal precipitation accumulations occurred over parts of Montana, Wyoming, and Nebraska. Central Wyoming in particular has received 200% to 300% of normal precipitation.

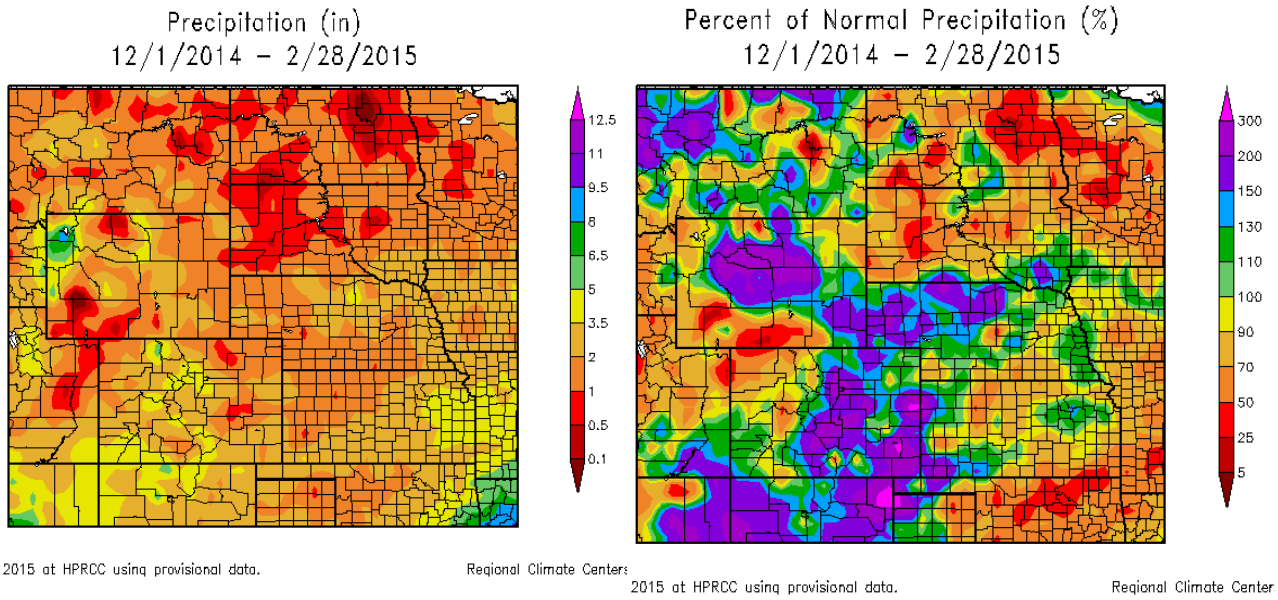


Figure 5. December 1, 2014 – February 28, 2015 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Temperature

February temperature departures from normal in degrees Fahrenheit (deg F) are shown in **Figure 6**. February temperatures in the Basin were warmer than normal in the west and below normal in the east. Western Montana and Wyoming were 3 to 6 deg F above normal, and the eastern Dakotas and eastern Nebraska 6 to 9 deg F below normal. Three-month (December-January-February) temperature departures are also shown in **Figure 6**. The Missouri River Basin is generally 2 to 4 deg F above normal in the west and near to slightly below normal in the eastern Dakotas and lower Basin.

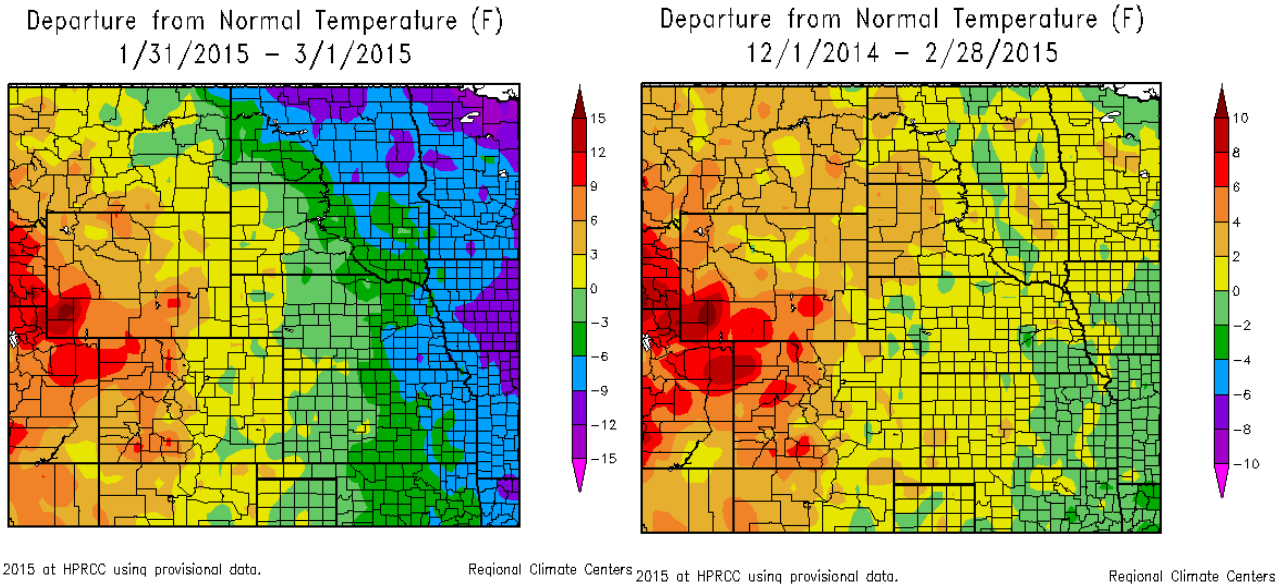


Figure 6. February 2015 and December 2014-February 2015 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

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 monthly runoff.

Figure 7 shows the NOAA NLDAS ensemble mean soil moisture percentiles on February 25, 2015 for the total modeled soil column, which is about 2 meters. The NLDAS soil moisture depiction is an average value for the soil moisture column. The average soil moisture in **Figure 7** indicates above normal soil moisture conditions throughout Montana, Wyoming, western North Dakota and western South Dakota. Soil moisture is greater than the 70^{th} percentile in the aforementioned areas and greater than the 98^{th} percentile in north central Montana. These high soil moisture conditions developed as a result of the record August rainfall; however drying has occurred at the soil surface resulting in less soil moisture in surface layers compared to deeper soil layers. This difference in soil moisture by depth is discussed in a later paragraph. Total column soil moisture in the eastern Dakotas is drier than normal with some conditions ranging from the 10^{th} to 20^{th} percentile.

The Ensemble Mean current total column soil moisture anomaly for the contiguous U.S. on February 25, 2015 is shown in **Figure 8**. These anomalies represent soil moisture averaged over the entire 2-meter soil column, so they do not reflect differences in soil moisture content at various depths. According to the modeled estimate, soil moisture anomalies in the western Dakotas, Montana and western Wyoming range from at least 25 – 50 mm (0.98 – 1.96 inches) above normal with some of north central Montana achieving 100 – 150 mm anomalies (3.95 – 5.91 inches). In contrast, anomalies in the eastern Dakotas range from 25 – 100 mm (0.98 – 3.94 inches) below normal. As stated in the previous paragraph, soil moisture in the surface layer is less than the average soil moisture content in the plains.

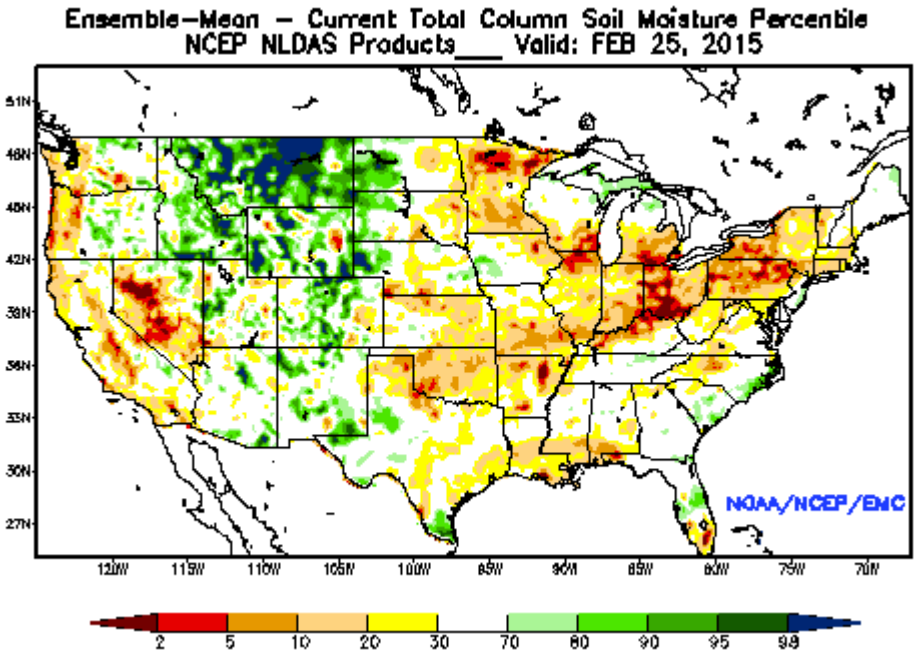


Figure 7. Total Column Soil Moisture Percentile on February 25, 2015. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

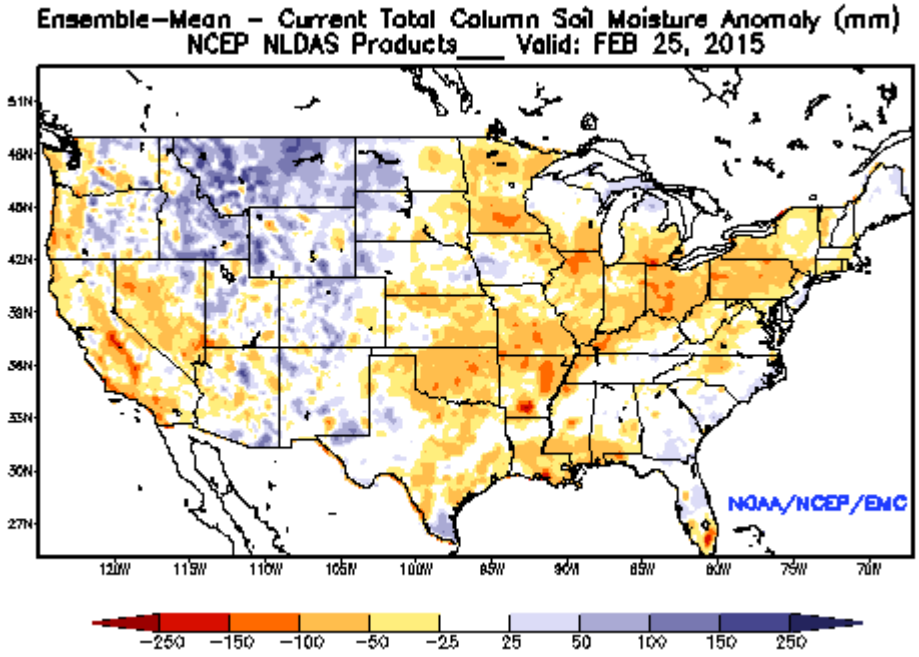


Figure 8. Calculated Soil Moisture Anomaly (mm) on February 25, 2015. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

The difference in soil moisture by depth is illustrated in **Table 1** and **Table 2**, percent soil moisture by depth at two USDA Soil Climate Analysis Network (SCAN) locations in the upper Basin. Over the last seven days in February, soil moisture has remained relatively unchanged

within each respective measurement depth at both Dell Rapids, SD and Sidney, MT. At Dell Rapids, SD, soil moisture is driest in the 8-inch depth showing some wetting near the surface during the past month. At Sidney, MT soil moisture is much less at 2- to 4-inch depths than at 16-inch, 20-inch and 40-inch depths. Soil moisture amounts are greatest in the 20- to 40-inch range at both locations. The high total column soil moisture percentiles and anomalies shown in **Figures 7** and **8** are primarily due to the higher contribution of subsoil moisture; however, the surface layer soil moisture is dry compared to subsoil moisture, providing additional capacity to absorb moisture from snowmelt and spring precipitation.

Table 1. Percent soil moisture by depth at the EROS Data Center USDA SCAN Site near Dell Rapids, SD.

USDA SCAN Site - EROS Data Center, Dell Rapids, SD					
Date	Percent Soil Moisture By Depth				
	2-inch	4-inch	8-inch	20-inch	40-inch
2/23/2015	12.8	13.6	10.1	18.9	27.4
2/24/2015	14.1	14.6	10.7	18.3	27.4
2/25/2015	14.8	15.1	11.3	18.4	27.4
2/26/2015	14.1	14.3	10.9	18.4	27.3
2/27/2015	13.5	14.1	10.5	18.3	27.3
2/28/2015	13.5	13.9	10.5	18.1	27.3
3/1/2015	14.0	14.4	10.7	17.9	27.4

Table 2. Percent soil moisture by depth at the USDA SCAN Site near Sidney, MT.

USDA SCAN Site – Sidney, MT					
Date	Percent Soil Moisture By Depth				
	2-inch	4-inch	8-inch	20-inch	40-inch
2/23/2015	8.6	10.2	15.4	15.1	21.2
2/24/2015	9.6	11.1	15.8	15.1	21.3
2/25/2015	9.4	11.0	16.0	15.1	21.2
2/26/2015	8.3	9.9	15.3	15.1	21.2
2/27/2015	8.0	9.7	15.0	14.7	21.2
2/28/2015	8.2	9.8	15.0	14.5	21.1
3/1/2015	8.5	10.0	15.0	14.4	21.1

Frost Conditions

In late December and early January, cold temperatures froze surface soils and allowed soil frost to develop at the greatest soil depths of the season. Soils experienced some thawing with warmer weather conditions in January. Soil frost was added and some re-freezing occurred in the eastern part of the basin throughout February. **Figure 9** shows depth of frost penetration at National Weather Service (NWS) Weather Forecast Office (WFO) locations in the Missouri Basin as of February 26, 2015. While several frost depth measurements are missing, measurements indicate soil frost exists across the basin, but is shallow in the western and southern portion of the basin. Substantial frost appears to exist in the eastern portion of the basin. Soil frost acts as a semi-impervious layer to snowmelt or precipitation infiltration into the soil.

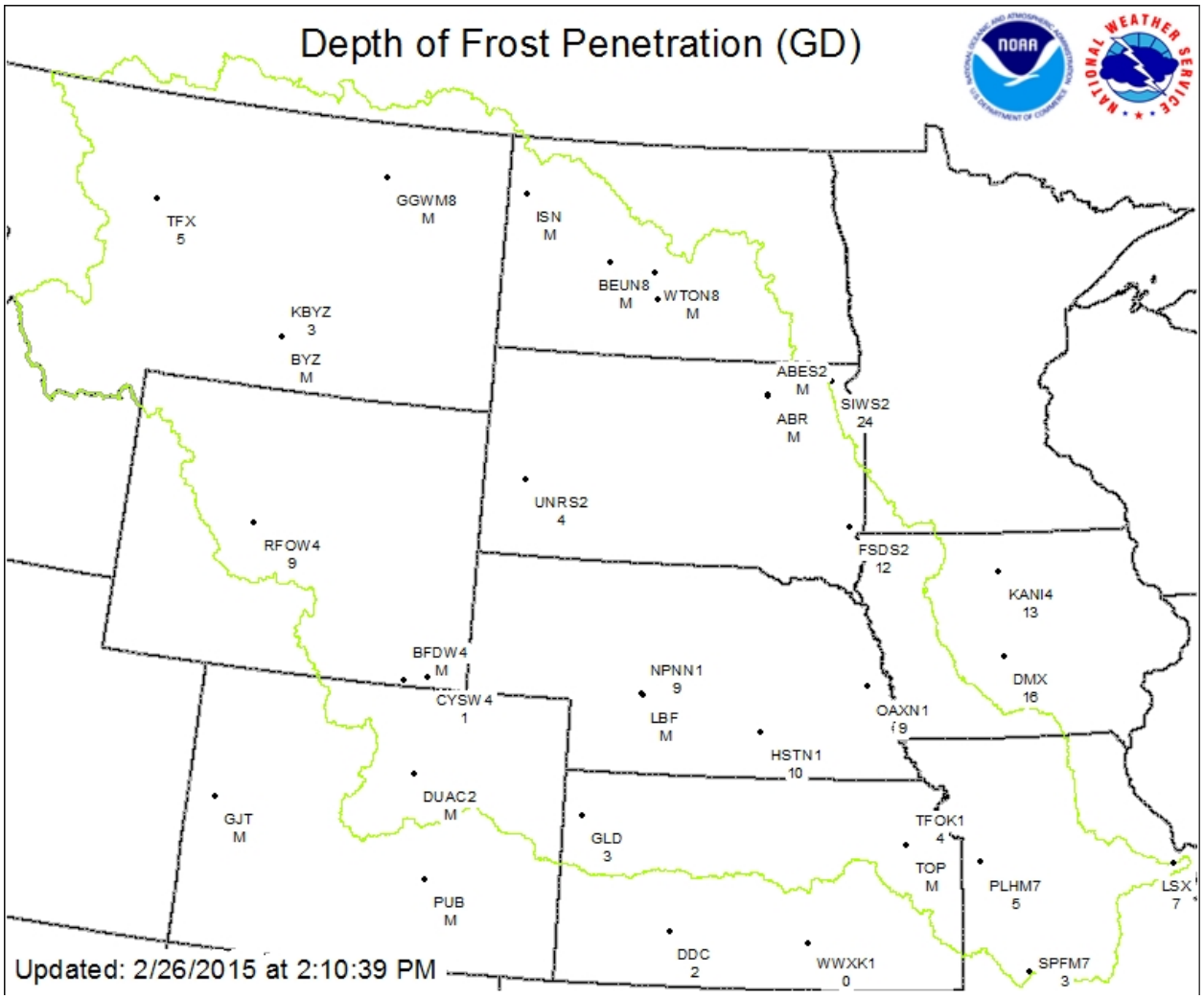


Figure 9. Measured frost depth (inches) at NWS WFO offices as of February 26, 2015. Source: NWS MBRFC. http://www.crh.noaa.gov/mbrfc

Streamflow Conditions

The current streamflow conditions depicted by their percentile rankings are shown in **Figure 10**. Current streamflow conditions in the upper Basin are ice-affected, therefore, streamflow ranking percentiles have not been calculated for most of the Missouri River and its tributaries since the streams froze in mid to late November. Missouri Basin streamflow conditions on November 10, 2014 are shown in **Figure 11**. These conditions are based on the ranking of the November 10, 2014 streamflow versus the historical record of streamflow for that date. Streamflow conditions on November 10, 2014 were normal (25^{th} – 75^{th} percentile) in the eastern Dakotas within the Missouri Basin, and in portions of north central Wyoming and western Montana. Much-above normal streamflow conditions (> 90^{th} percentile) stand out as the blue and black gage locations on the map in many areas of Montana, Wyoming and the western Dakotas in the upper Basin, and in eastern Nebraska and western Iowa in the lower Basin.

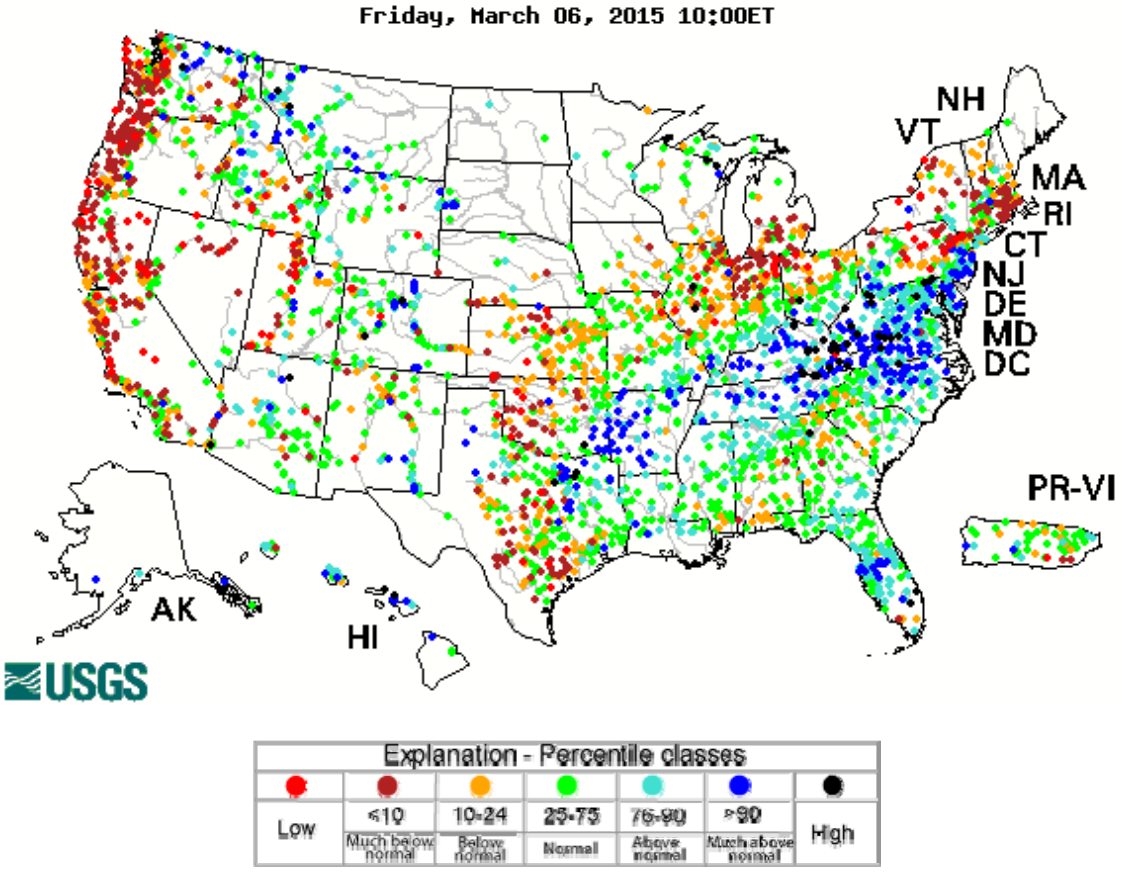


Figure 10. USGS Streamflow Conditions as a Percentile of Normal in the Missouri River Basin as of March 6, 2015. Source: USGS. http://waterwatch.usgs.gov/index.php

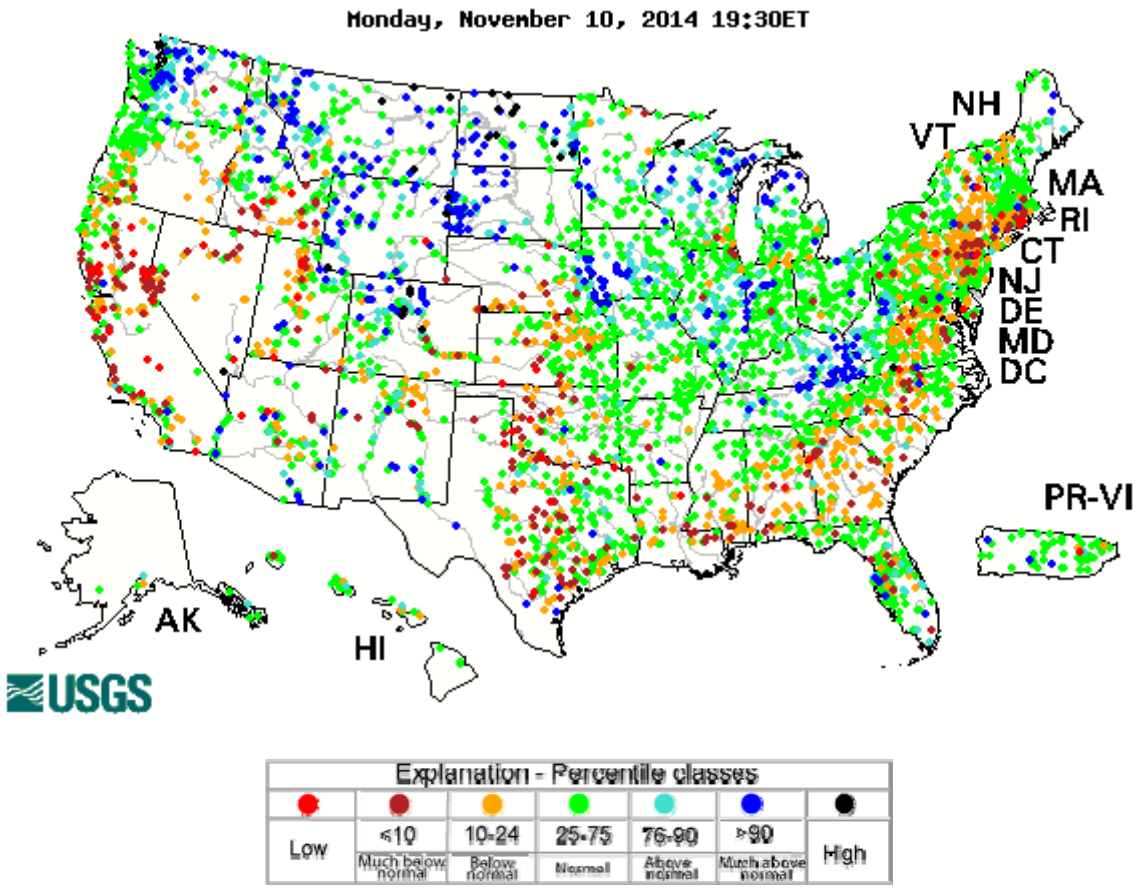


Figure 11. USGS Streamflow Conditions as a Percentile of Normal in the Missouri River Basin as of November 10, 2014. Source: USGS. http://waterwatch.usgs.gov/index.php

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.

Based on the National Operational Hydrologic Remote Sensing Center (NOHRSC) assessment (**Figure 12**) as of March 1, 2015 most plains snow water equivalent (SWE) amounts ranged from no snow to 1-inch amounts throughout the upper Basin. Amounts ranging from 1 to 2 inches covered the upper James River basin in central North Dakota. Some areas have no snow. Compared to March 1, 2014 (**Figure 13**) plains SWE, March 1, 2015 SWE is generally less. On

March 1, 2014, plains SWE generally ranged from 1 to 2 inches of SWE in the northern basin and there was a larger coverage of trace to 1 inch amounts.

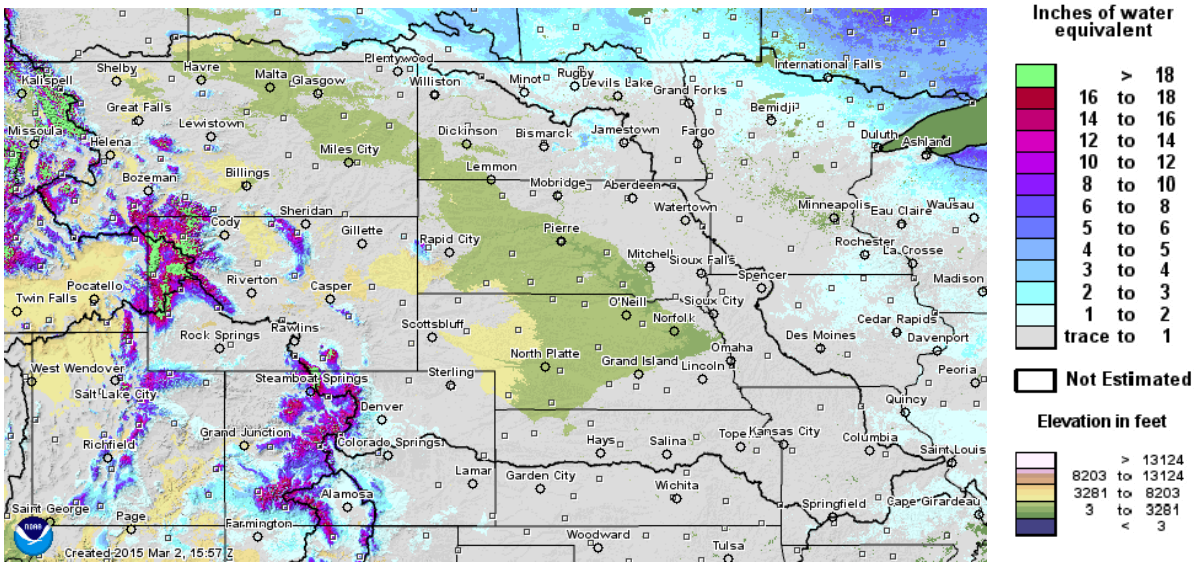


Figure 12. March 1, 2015 NOHRSC modeled plains snow water equivalent. Source: NOAA National Operational Hydrologic Remote Sensing Center. http://www.nohrsc.nws.gov/interactive/html/map.html

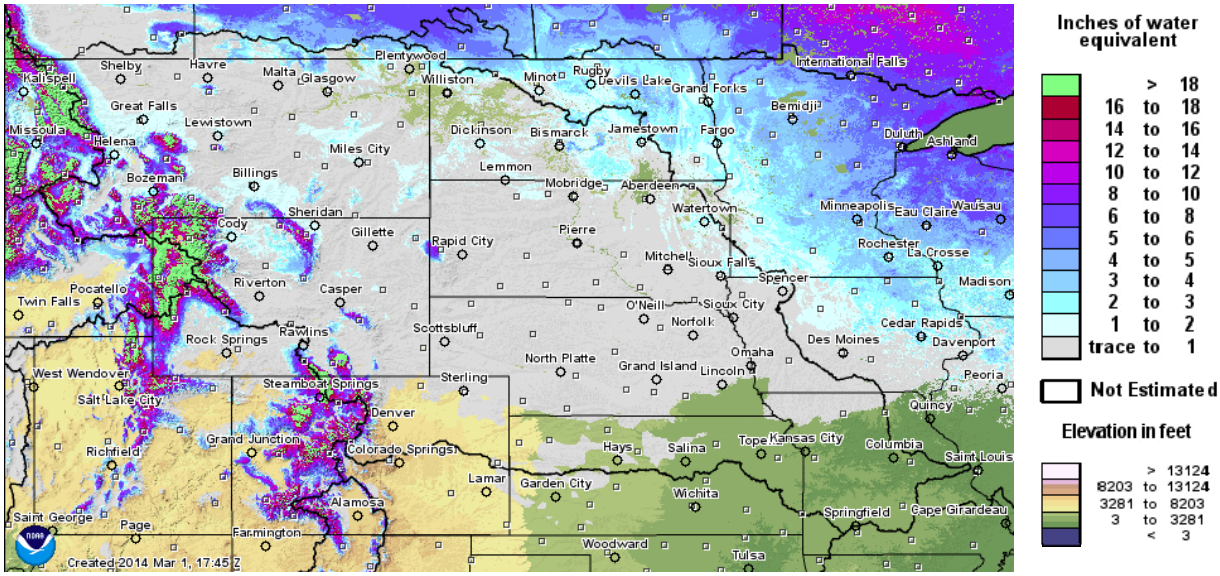


Figure 13. March 1, 2014 NOHRSC modeled plains snow water equivalent. Source: NOAA National Operational Hydrologic Remote Sensing Center. http://www.nohrsc.nws.gov/interactive/html/map.html

Using the MRBWM snowpack classification method, plains snowpack as of March 1, 2015 was classified as None or Light across the upper Basin in all reservoir reaches (**Table 3**). These classifications include plains snowpack accumulations that fall between the range of 0 to 1 inch of SWE in the Fort Peck, Garrison, Oahe, Gavins Point, and Sioux City subbasins and no SWE in the Oahe to Fort Randall subbasin.

Table 3. March 1, 2015 plains snowpack classification for runoff forecasting.

Reservoir Reach	Plains Snowpack Classification
Above Fort Peck	Light (0 – 1 inch SWE)
Fort Peck to Garrison	Light (0 – 1 inch SWE)
Garrison to Oahe	Light (0 – 1 inch SWE)
Oahe to Fort Randall	None (0 inch SWE)
Fort Randall to Gavins Point	Light (0 – 1 inch SWE)
Gavins Point to Sioux City	Light (0 – 1 inch SWE)

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 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 greater than average runoff from an average mountain snowpack this year due to wetter than normal soil moisture conditions.

Figure 14 includes time series plots of the average mountain SWE beginning on October 1, 2014 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 **March 1, 2015**, the Corps of Engineers computed an average mountain SWE in the headwater basin above Fort Peck Dam of 11.5 inches, which is 88% of normal based on the 1981-2010 average SWE for the Fort Peck basin. In the subbasin between Fort Peck Dam and Garrison Dam, the Corps computed an average mountain SWE of 10.6 inches, which is 97% of normal based on the 1981-2010 average SWE for the Fort Peck to Garrison subbasin. Normally by March 1, 79% of the peak snow accumulation has occurred in the mountains. In comparison, March 1, 2014 mountain snowpack was 16.2 inches (122% of normal) in the Fort Peck subbasin and 14.8 inches (133% of normal) in the Fort Peck to Garrison subbasin.

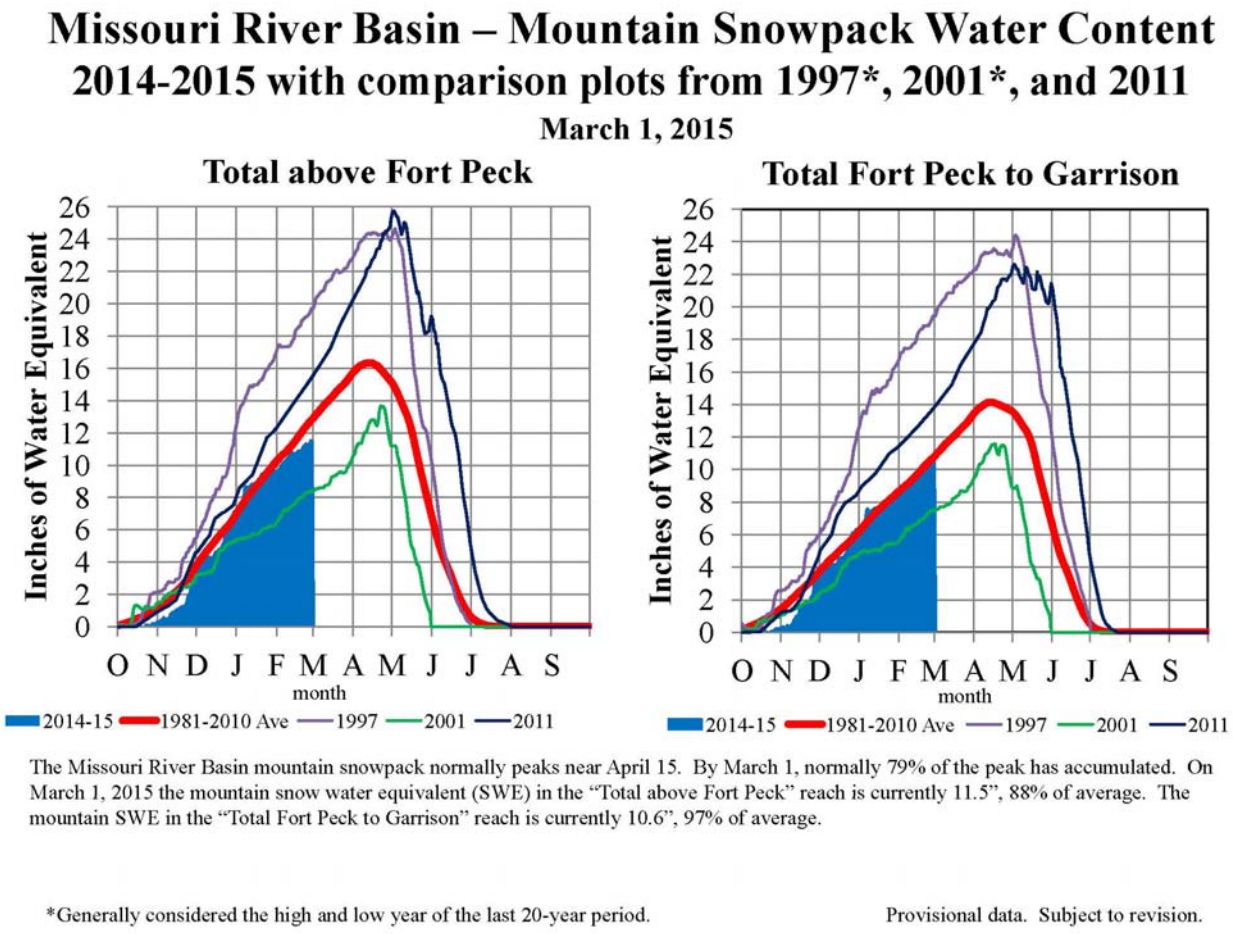


Figure 14. Mountain snowpack water content snow accumulation compared to normal and historic conditions. Corps of Engineers - Missouri River Basin Water Management.

Climate Outlook

ENSO (El Niño Southern Oscillation)

During February 2015, El Niño conditions were observed across the western and central equatorial Pacific. There is a 50-60% chance that El Niño conditions will continue through the Northern Hemisphere summer 2015. Due to the expected weak strength of El Niño, global impacts are not anticipated. Furthermore, El Niño typically has an impact on temperature and precipitation during the winter, with the impact to runoff observed when mountain snowpack melts during the spring and summer. Since El Niño conditions have not persisted through the winter, no impact is expected to May-June-July runoff as a result of El Niño. The influence of a potential El Niño has been factored into the CPC's temperature and precipitation outlooks looking forward.

Temperature and Precipitation Outlooks

The NOAA Climate Prediction Center climate outlook for March 2015 (**Figure 15**) indicates an increased probability for below normal temperatures in the upper Missouri River Basin. Probabilities for below normal temperatures range from 33.3% to 40%. There are equal chances for above normal, normal and below normal temperatures throughout central Montana and Wyoming. With regard to precipitation, there are equal chances that precipitation will be above normal, normal and below normal in March throughout the entire upper Basin.

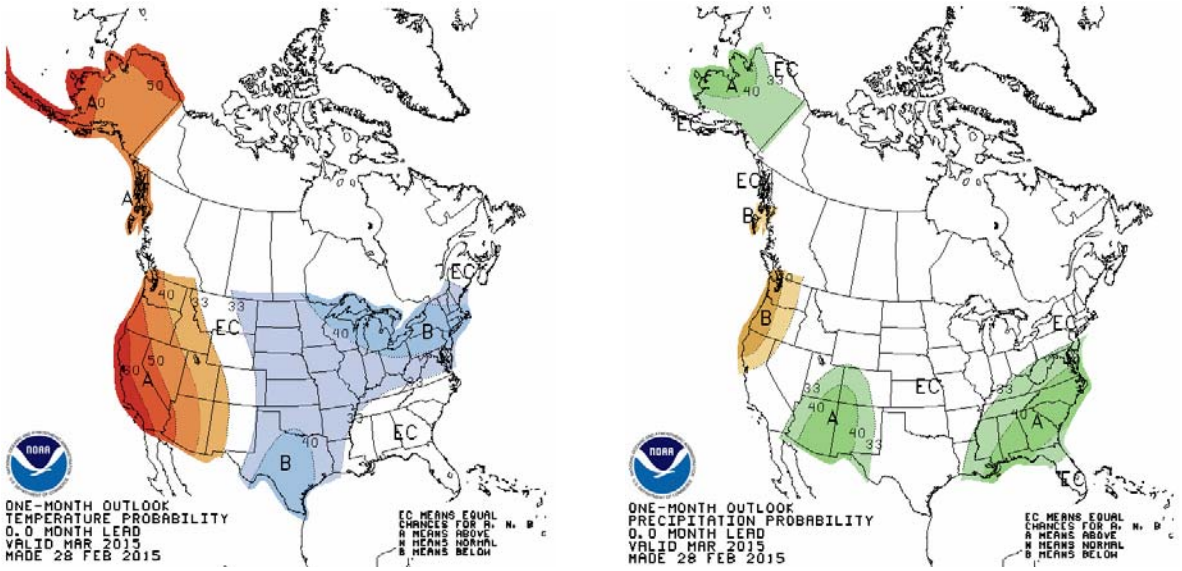


Figure 15. CPC March 2015 temperature and precipitation outlooks.

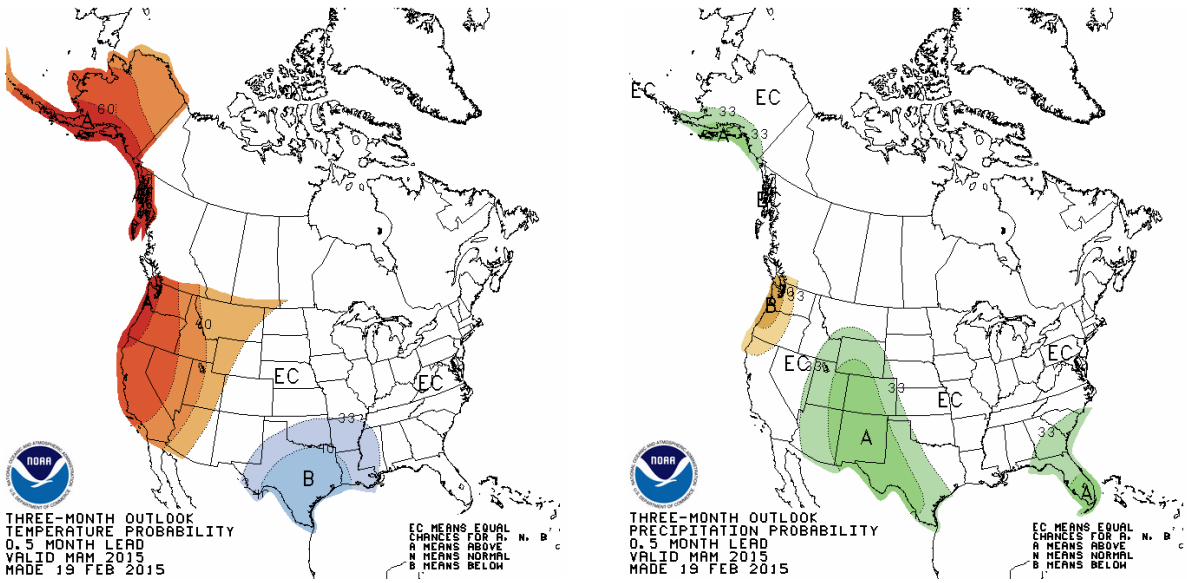


Figure 16. CPC March-April-May 2015 temperature and precipitation outlooks.

The March-April-May temperature outlook (**Figure 16**) indicates a slightly higher probability (33.3% to 40%) that temperatures will be above normal in Montana and western Wyoming. There are equal chances for above normal, normal and below normal temperatures in the

Dakotas and Nebraska. The March-April-May precipitation outlook indicates equal chances for below normal, normal and above normal precipitation in much of Montana, the Dakotas and Nebraska. There are increased chances for above normal precipitation in Wyoming.

The June-July-August 2015 CPC temperature outlook (**Figure 17**) indicates there are equal chances for above normal, normal, and below normal temperatures throughout most of the upper Basin; however, in western Montana and Wyoming there is a slightly higher probability that temperatures will be above normal during the period. With regard to precipitation there are equal chances for above normal, normal, and below normal precipitation throughout the Basin.

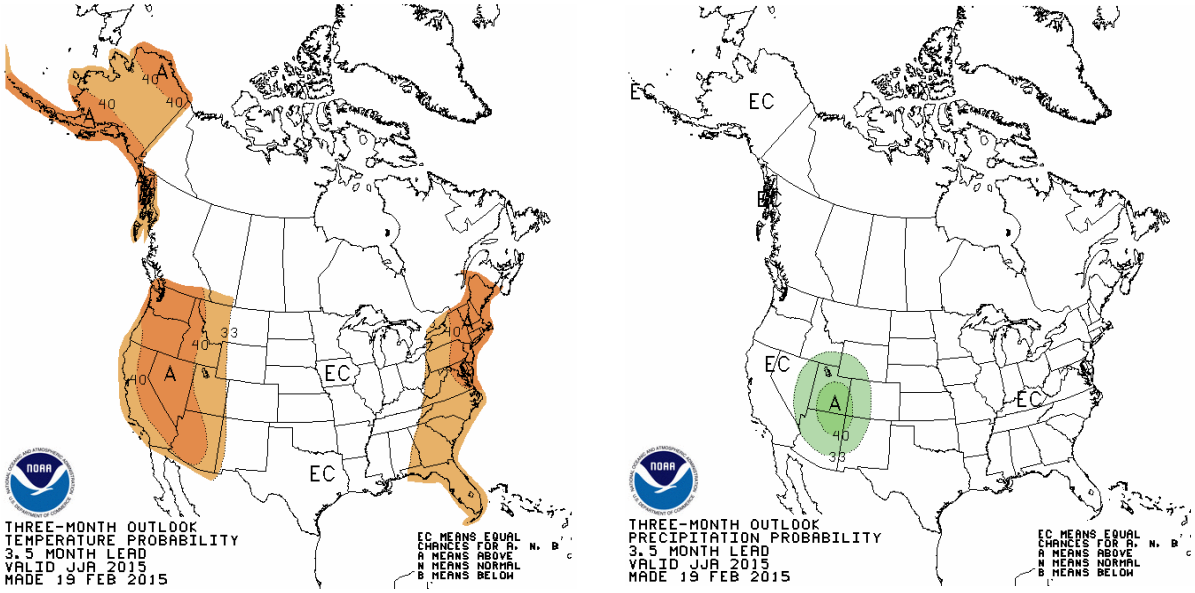


Figure 17. CPC June-July-August 2015 temperature and precipitation outlooks.

During the remainder of the calendar year, the CPC temperature outlooks for the September-October-November period (**Figure 18**) and the December 2015-February 2016 period (**Figure 19**) indicate there are mostly equal chances for above normal, normal and below normal temperatures throughout most of the upper Basin with the exception of increased chances for above normal chances in southern Montana and Wyoming from September through November. With regard to precipitation, there are equal chances precipitation will be above normal, normal or below normal during the September-October-November period (**Figure 18**) and the December 2015-February 2016 period (**Figure 19**).

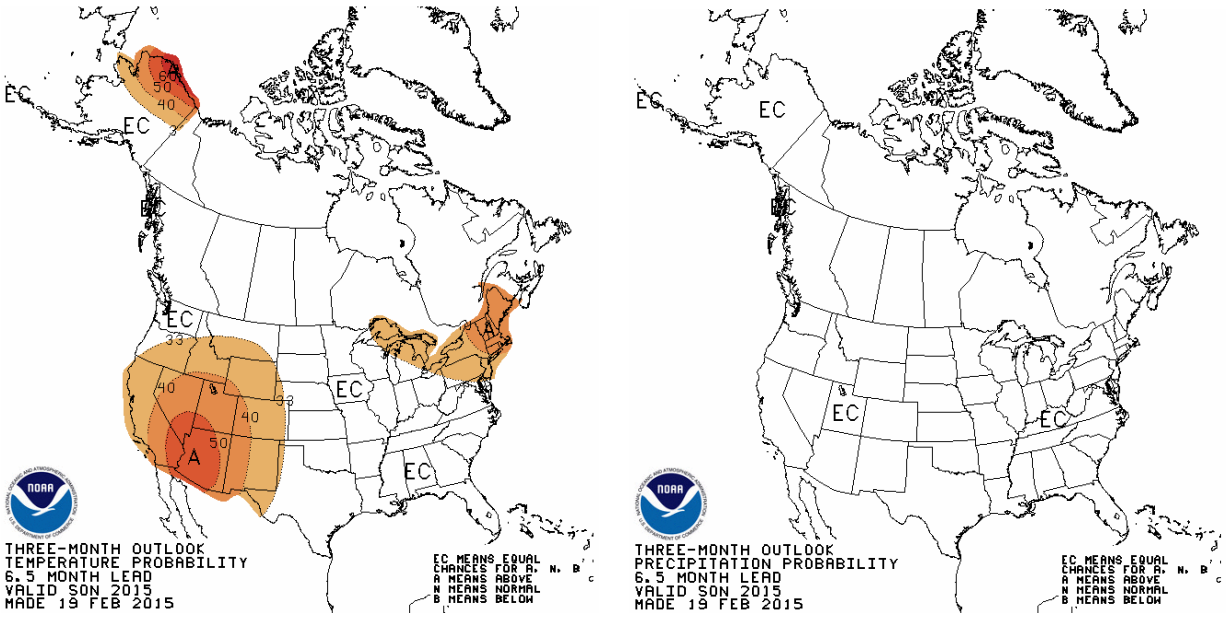


Figure 18. CPC September-October-November 2015 temperature and precipitation outlooks.

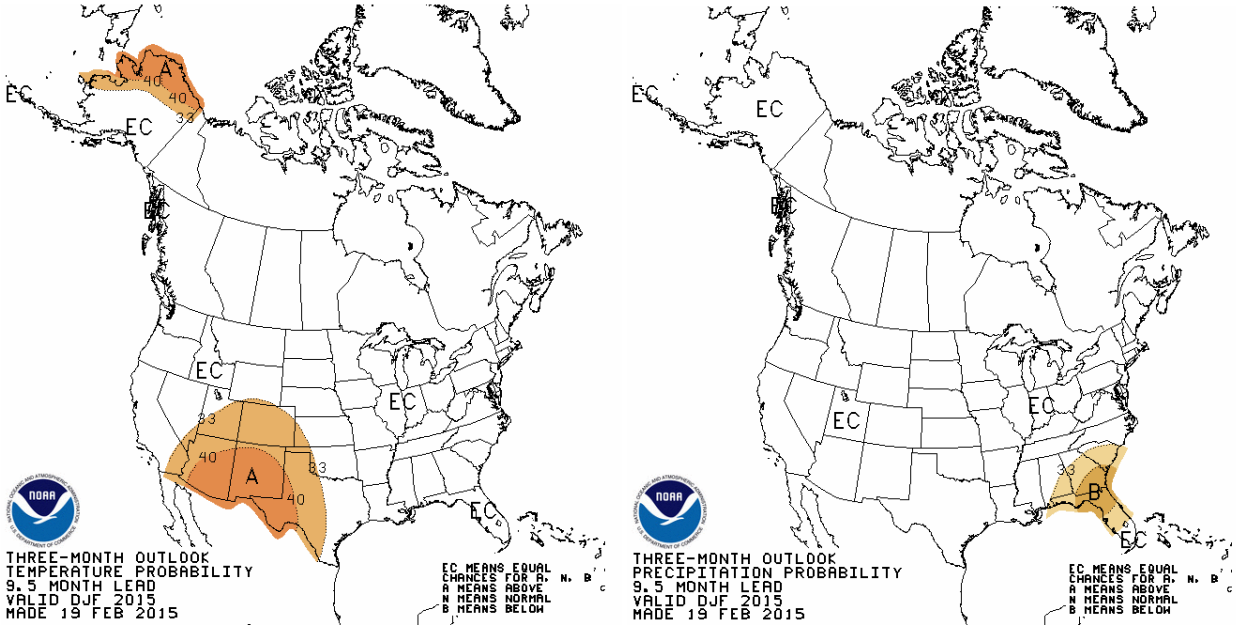


Figure 19. CPC December 2015-January-February 2016 temperature and precipitation outlooks.

March 2015 Calendar Year Runoff Forecast

The calendar year runoff forecast is **24.5 MAF (97% of average) above Sioux City** and **22.8 MAF (99% of average) above Gavins Point**. Due to the amount of variability in precipitation that can occur over the next 10 months, the range of expected inflow is quite large and ranges from the 32.9 MAF upper basic forecast to the 17.3 MAF lower basic forecast. The upper and lower basic forecasts provide a likely range of runoff scenarios that could occur given much

wetter conditions or much drier conditions. The upper and lower basic forecasts are used in long-term regulation planning models to "bracket" the range of expected runoff. It should be noted, however, that it is possible, due to either much higher or much lower than forecasted precipitation occurring, that these ranges may be exceeded on either end.

In determining our runoff forecast for the remainder of 2015 we consider several factors. Those factors are: observed January and February runoff, drought conditions, which currently exist in some portions of the upper basin, current soil moisture conditions, observed winter precipitation and plains snowpack, current mountain snowpack, and NOAA's Climate Prediction Center's monthly and seasonal temperature and precipitation outlooks.

March-April

February runoff above Sioux City, IA was 2.0 MAF, 186% of normal. The higher-than-normal runoff was due to warmer-than-normal temperatures in Montana and Wyoming that continued to melt any accumulated plains snowpack, some low elevation snowpack and inhibit ice formation on tributaries and the Missouri River. This additional runoff in February is runoff that would normally occur in March and April during the normal time of the spring thaw.

Plains snowpack is a significant factor influencing the volume of runoff in March and April; however, snow and rainfall precipitation during this time period are also very important factors that need consideration. Furthermore, antecedent accumulated precipitation and antecedent soil moisture conditions have a significant influence on March-April runoff.

Plains snow experienced frequent melting in the upper Basin in January and February. The March temperature outlook indicates there is an increased probability for below normal temperatures with equal chances for precipitation. Since small amounts of plains snow is available for a March melt, the overall March runoff forecast is 89% of normal. April runoff is forecast to be 80% of normal. Runoff is forecast to be above normal in the Fort Peck reach as a result of above normal soil moisture and above normal December through February precipitation. Runoff is forecast to be below normal in all other reaches.

May-June-July

During the May-June-July period, the mainstem system receives 50% of its annual runoff as a result of mountain snowmelt and spring and summer precipitation. This is the most active period for precipitation in the Missouri River Basin, so runoff can vary significantly as a result of the above or below normal rainfall.

For this 3-month period, the most reliable method for predicting runoff into Fort Peck and Garrison reservoirs is through regression equations that relate mountain snowpack to runoff. The March 1, 2015 mountain snowpack was 88% of average in the reach above Fort Peck and 97% of average in the reach between Fort Peck and Garrison. The CPC 3-month outlooks of May-June-

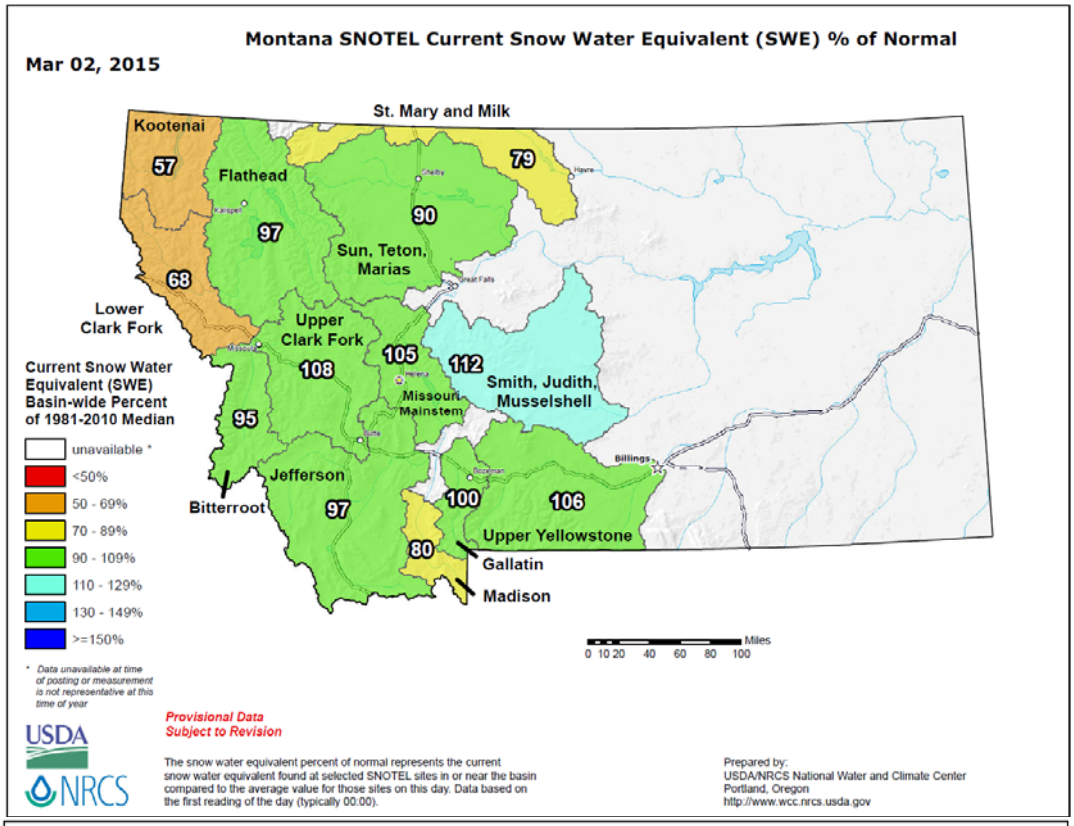
July precipitation indicates an equal chances for above normal, normal, and below normal precipitation in the Fort Peck and Garrison reaches. Taking into consideration these factors, 85% and 93% of normal runoff is forecast for the Fort Peck and Garrison reaches, respectively. Slightly below normal runoff is forecast for the remaining reaches. The overall May-June-July runoff summation forecast is about 90% of normal.

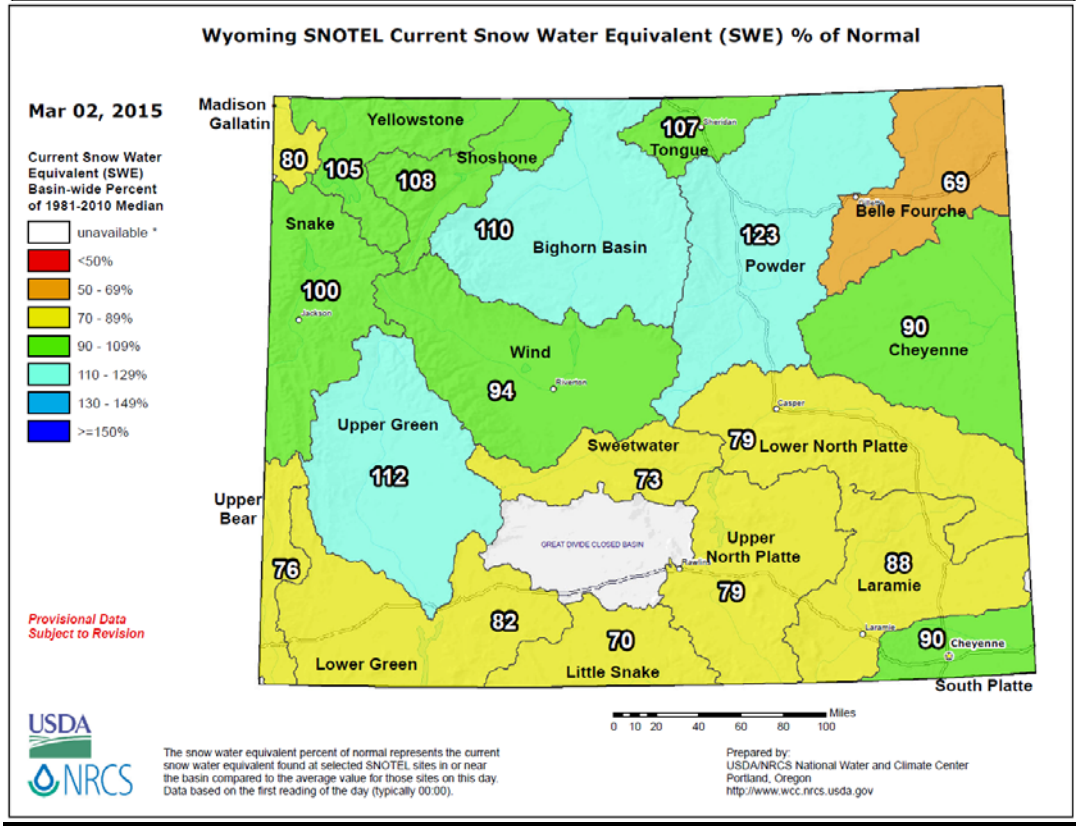
The significance of accurately forecasting May-June-July runoff for the Fort Peck and Garrison reaches is based on the fact that, historically, an average of 9.2 MAF of runoff occurs during these 3 months into these 2 projects. That is 37% of the total annual runoff into the system.

August through December

For the latter half of 2015, NOAA's climate outlook indicates increased chances for above normal temperatures in parts of the Basin and equal chances for above, below and normal precipitation. Very little information is known at this time which can indicate how much runoff will occur during that time period because summer and fall runoff is determined by precipitation; therefore, near normal runoff is forecast from August through December.

Additional Figures





USDA NRCS National Water & Climate Center

USDA NRCS National Water & Climate Center
 * - DATA CURRENT AS OF: March 05, 2015 02:51:20 PM
   - Based on March 01, 2015 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	78	80	94	85	72	63	97
	APR-SEP	93	83	109	99	86	76	112
St. Mary R at Int'l Boundary (2)	APR-JUL	325	75	425	370	285	225	435
	APR-SEP	390	77	495	435	350	285	505
Lima Reservoir Inflow (2)	APR-JUL	41	50	77	57	29	8.6	82
	APR-SEP	43	48	84	59	27	2.4	89
Clark Canyon Reservoir Inflow (2)	APR-JUL	54	53	139	88	19.7	-15.0	101
	APR-SEP	67	56	160	105	29	-4.0	120
Jefferson R nr Three Forks (2)	APR-JUL	615	83	1030	780	435	182	740
	APR-SEP	665	83	1120	845	465	183	800
Hebgen Reservoir Inflow (2)	APR-JUL	295	80	360	320	270	230	370
	APR-SEP	375	80	455	405	345	295	470
Ennis Reservoir Inflow (2)	APR-JUL	465	74	605	520	410	325	625
	APR-SEP	580	75	745	650	515	420	775
Missouri R at Toston (2)	APR-JUL	1480	83	2170	1760	1190	780	1790
	APR-SEP	1690	82	2510	2020	1360	880	2070
Smith R bl Eagle Ck (2)	APR-JUL	125	118	181	148	103	69	106
	APR-SEP	142	122	210	168	115	76	116
Gibson Reservoir Inflow (2)	APR-JUL	360	91	460	400	315	255	395
	APR-SEP	395	90	510	445	350	285	440
Marias R nr Shelby (2)	APR-JUL	310	90	490	380	235	131	345
	APR-SEP	315	88	505	395	235	123	360
Milk R at Western Crossing	MAR-SEP	34	104	62	47	25	16.2	33*
Milk R at Eastern Crossing	MAR-SEP	78	96	152	95	60	45	82*

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	60	102	69	64	56	51	59
	APR-SEP	77	104	89	82	72	65	74
Wind R ab Bull Lake Ck (2)	APR-JUL	425	93	535	470	380	315	455
	APR-SEP	450	92	580	505	400	320	490
Bull Lake Ck nr Lenore	APR-JUL	127	91	157	139	114	96	139
	APR-SEP	155	92	194	171	140	117	169
Boysen Reservoir Inflow (2)	APR-JUL	515	84	900	670	360	129	610
	APR-SEP	565	85	1000	740	395	137	665
Greybull R nr Meeteetse	APR-JUL	148	113	186	163	133	111	131
	APR-SEP	200	113	250	220	182	154	177
Shell Ck nr Shell	APR-JUL	55	100	71	61	49	40	55
	APR-SEP	67	102	84	74	60	50	66
Bighorn R at Kane (2)	APR-JUL	810	96	1330	1020	600	290	840
	APR-SEP	875	97	1440	1100	645	310	905
NF Shoshone R at Wapiti	APR-JUL	465	101	565	505	425	365	460
	APR-SEP	515	100	630	560	470	405	515
SF Shoshone R nr Valley	APR-JUL	230	107	275	250	210	184	215
	APR-SEP	265	108	315	285	245	215	245
Buffalo Bill Reservoir Inflow (2)	APR-JUL	705	104	860	770	640	545	675
	APR-SEP	780	105	955	850	710	605	745
Bighorn R nr St. Xavier (2)	APR-JUL	1380	100	2020	1640	1130	750	1380
	APR-SEP	1480	101	2190	1760	1190	765	1460
Little Bighorn R nr Hardin	APR-JUL	100	102	147	119	81	53	98
	APR-SEP	113	102	165	134	92	61	111
Tongue R nr Dayton (2)	APR-JUL	88	102	119	101	75	57	86
	APR-SEP	100	102	134	114	86	66	98
Tongue River Reservoir Inflow (2)	APR-JUL	195	101	305	240	150	85	193
	APR-SEP	220	102	335	265	171	102	215

NF Powder R nr Hazelton	APR-JUL	10.6	116	13.8	11.9	9.3	7.4	9.1
	APR-SEP	11.4	115	14.7	12.8	10.0	8.1	9.9
Powder R at Moorhead	APR-JUL	189	107	305	235	143	75	177
	APR-SEP	210	107	330	255	162	92	196
Powder R nr Locate	APR-JUL	215	108	350	270	159	79	199
	APR-SEP	235	107	380	295	179	93	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	5.6	90	9.4	7.1	4.1	1.78	6.2
	APR-JUL	4.5	87	7.5	5.6	3.5	2.3	5.2
Pactola Reservoir Inflow	MAR-JUL	21	84	39	28	13.7	3.0	25
	APR-JUL	17.8	81	33	24	12.9	7.1	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
* Milk River medians are for years 1980-2008 & marked "30%" is 25% exceedance and marked "70%" is 75% exceedance

Upper Missouri River Basin
April 2015 Calendar Year Runoff Forecast
April 1, 2015

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.

2015 Calendar Year Forecast Synopsis

The April 1, 2015 forecast for runoff above Sioux City is **20.3 MAF** (80% of normal). Above Gavins Point Dam, we are forecasting **18.8 MAF** (82% of normal). The large decrease in the calendar year runoff forecast is due to the significant change in mountain snowpack since March 1. Mountain snowpack peaked about one month earlier than normal, and the peak snowpack is much lower than normal. As a result the May, June and July runoff from the mountain snowpack is forecast to be significantly less than the previous forecast. 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 fairly large and ranges from the 25.8 MAF 101% of normal) upper basic forecast to the 15.5 MAF (61.4% of normal) 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 lower than normal (lower basic) is attributed to all 6 reaches for 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 number of forecast months decreases.

March 2015 Runoff

All plains snowpack that had accumulated during the winter had melted in January and February, leading to above normal runoff in January (178% of normal) and February (186% of normal). March 2015 runoff was 2.2 MAF (74% of normal) above Sioux City, and 2.0 MAF (77% of normal) above Gavins Point Dam. March runoff was below normal because no plains snowpack runoff occurred during March, due to the absence of plains snowpack. Furthermore, March precipitation was well below normal, therefore, very little rainfall runoff was observed.

Current Conditions

Drought Analysis

The National Drought Mitigation Center's drought monitor for March 24, 2015 (**Figure 1**), when compared to the drought monitor for February 24, 2015 (**Figure 2**), shows additional expansion of Abnormally Dry (D0) conditions into the western Dakotas, north central Nebraska and portions of southwest Montana and northwest Wyoming. Furthermore, Moderate Drought (D1) conditions have developed in a small area of western South Dakota. Since January 27, D0 conditions expanded in western South Dakota. The U.S. Monthly Drought Outlook in **Figure 3** indicates that drought development is likely in South Dakota, and existing D1 conditions will persist or intensify in April 2015.

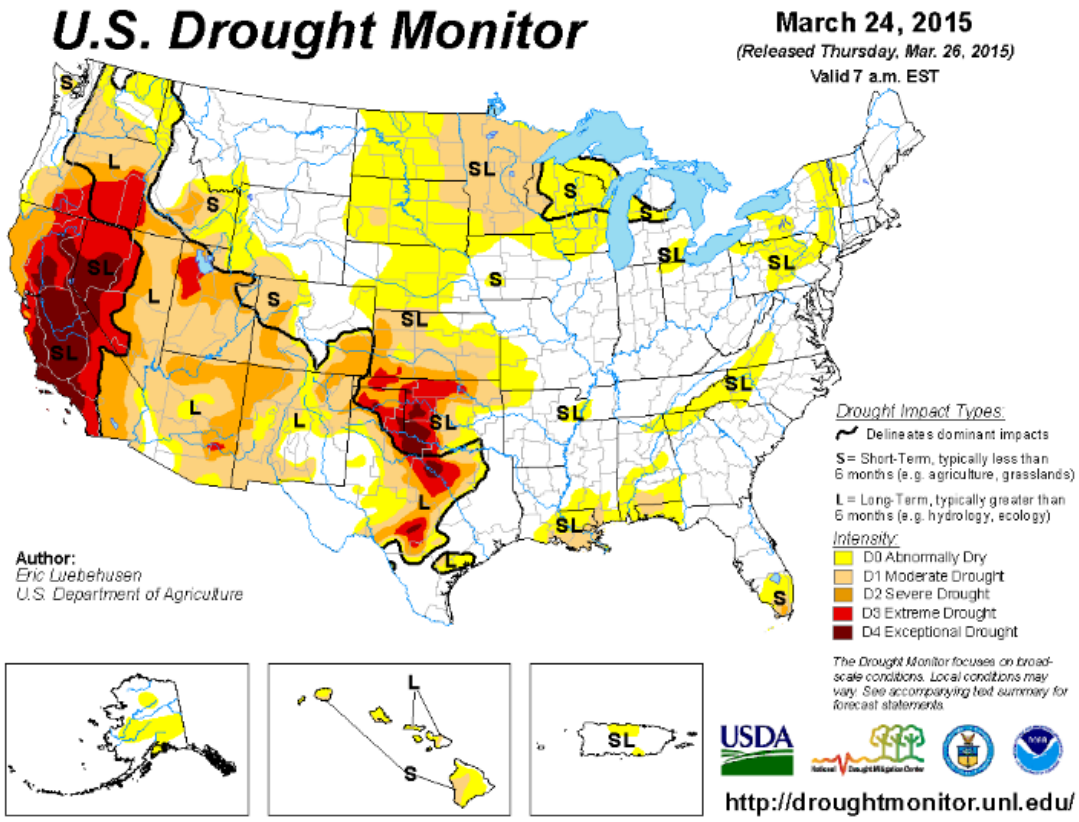


Figure 1. National Drought Mitigation Center U.S. Drought Monitor for February 24, 2015.

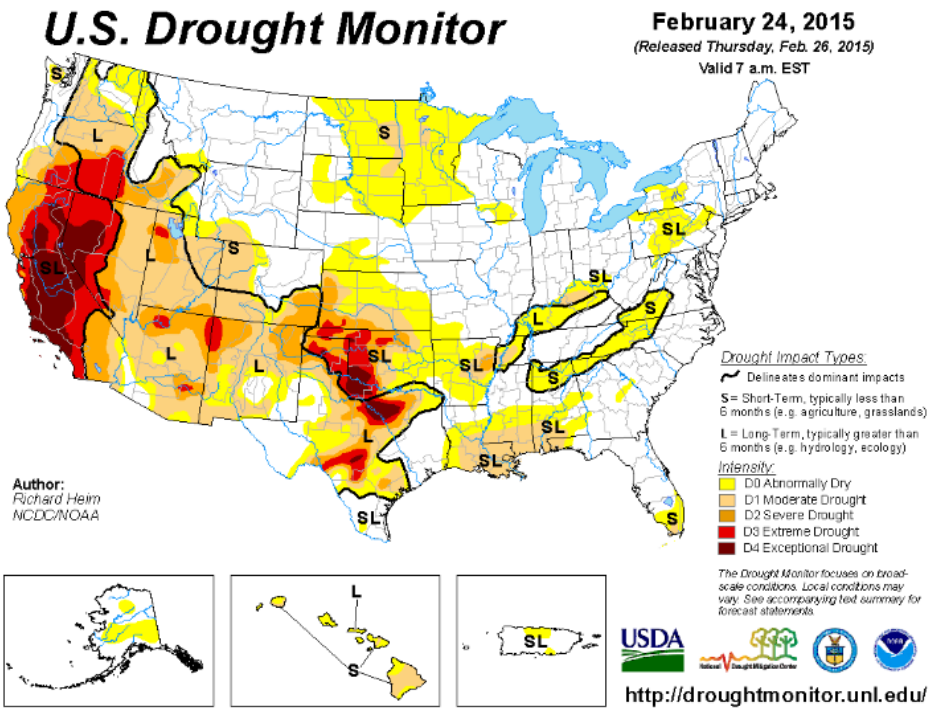


Figure 2. National Drought Mitigation Center U.S. Drought Monitor for January 27, 2015.

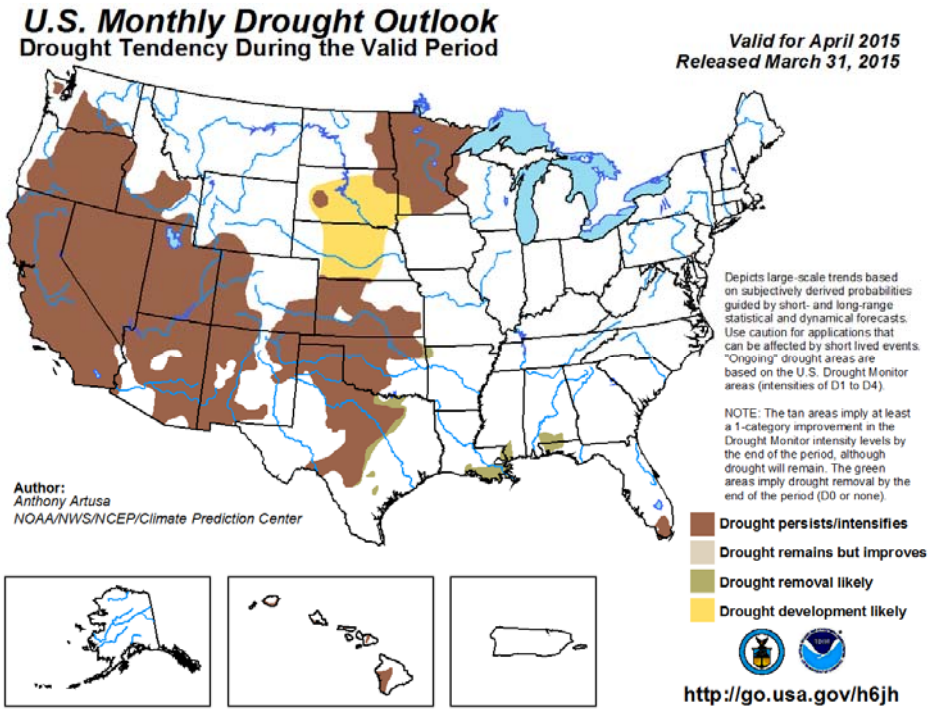


Figure 3. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

March precipitation accumulations are shown in **Figure 4** as both inches of precipitation and percent of normal monthly precipitation. The March precipitation accumulation was less than one inch of precipitation in most of the upper Basin. Many areas received less than 0.5 inch of precipitation. As a percent of normal, large portions of the upper Basin received less than 50 percent of normal precipitation and as little as 5% of normal precipitation in central Nebraska. Areas that received greater than 50% of normal precipitation include much of North Dakota, northern Montana and localized regions of Wyoming.

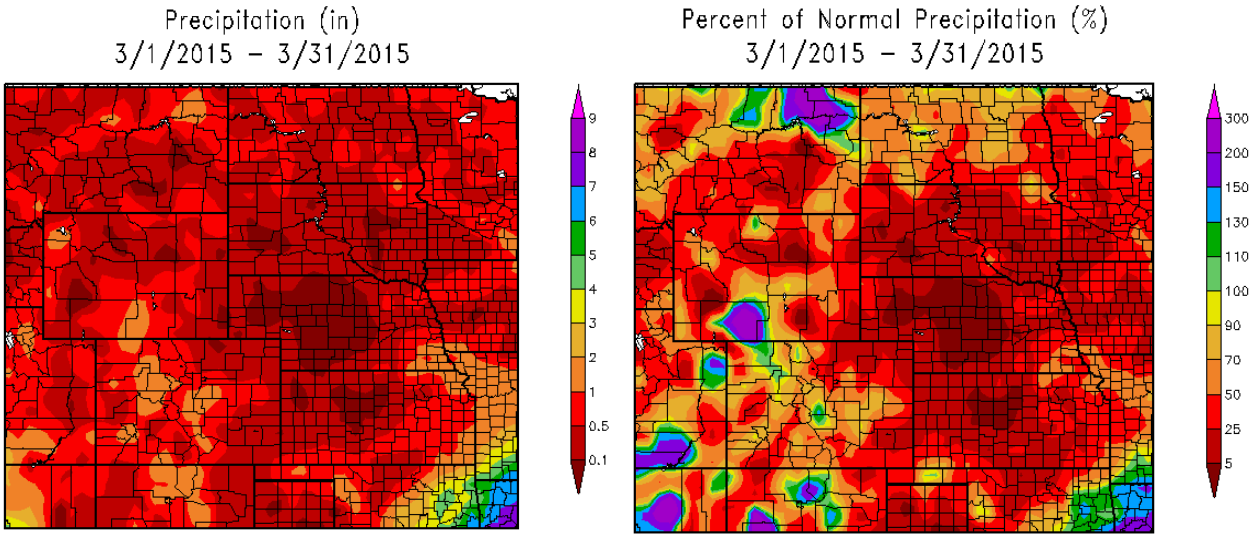


Figure 4. March 2015 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

January-February-March precipitation accumulations are shown in **Figure 5** as both inches and percent of normal precipitation. The three-month accumulation reveals that precipitation accumulations have been less than 70% of normal in a majority of the plains. Conditions have been driest over South Dakota, Nebraska and eastern North Dakota. Above normal precipitation accumulations occurred over parts of northern where accumulations have ranged from 110% to over 150% of normal precipitation.

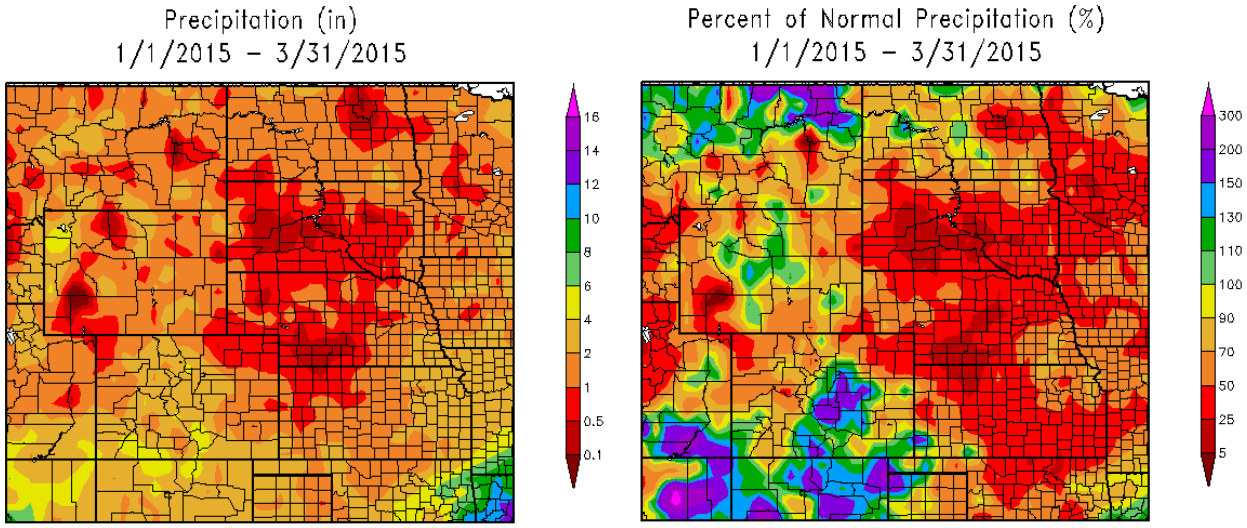


Figure 5. January 1, 2015 – March 31, 2015 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Temperature

March temperature departures from normal in degrees Fahrenheit (deg F) are shown in **Figure 6**. March temperatures in the upper Basin were greater than 6 deg F warmer than normal in a large portion of the upper Basin including Montana, western North Dakota and western South Dakota, and greater than 4 deg F warmer than normal in all other areas of the upper Basin. Three-month (January-February-March) temperature departures are also shown in **Figure 6**. Three-month upper Basin temperatures have ranged from near normal in the eastern Dakotas to 2 to 6 deg F warmer than normal in the regions west of the Missouri River.

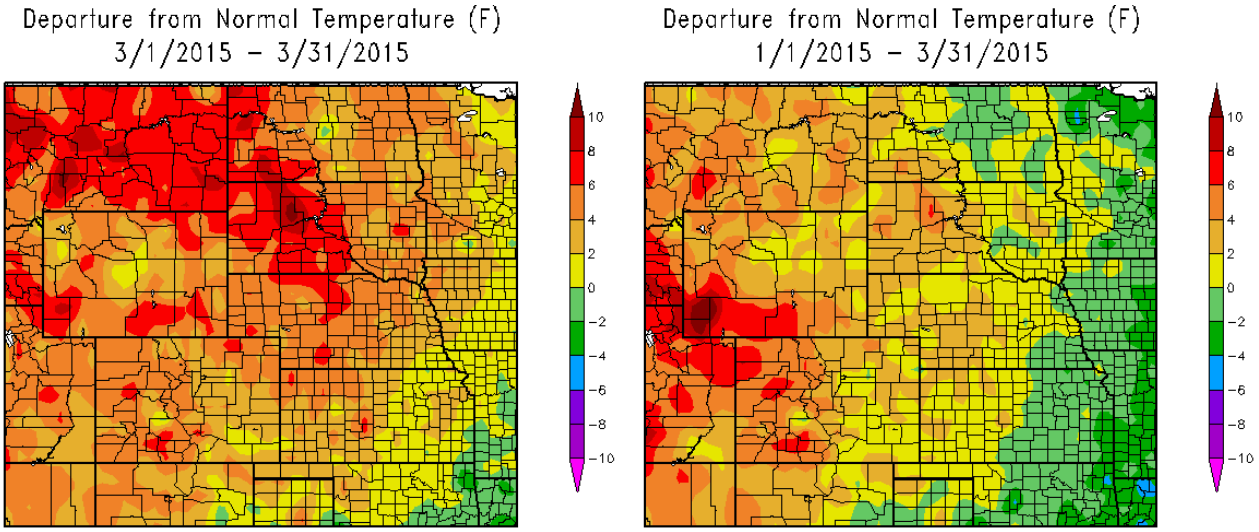


Figure 6. March 2015 and January – March 2015 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

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 monthly runoff.

Figure 7 shows the NOAA NLDAS ensemble mean soil moisture percentiles on March 29, 2015 for the total modeled soil column, which is about 2 meters. The NLDAS soil moisture depiction is an average value for the soil moisture column. The average soil moisture in **Figure 7** still indicates above normal soil moisture conditions throughout Montana, Wyoming, western North Dakota and western South Dakota. Soil moisture is greater than the 70th percentile in the aforementioned areas and greater than the 98th percentile in north central Montana. These high soil moisture conditions developed as a result of the record August rainfall; however drying has occurred throughout the soil moisture column. Total column soil moisture in the eastern Dakotas is drier than normal with some conditions ranging from the 5th to 20th percentile.

The Ensemble Mean current total column soil moisture anomaly for the contiguous U.S. on March 29, 2015 is shown in **Figure 8**. These anomalies represent soil moisture averaged over the entire 2-meter soil column, so they do not reflect differences in soil moisture content at various depths. According to the modeled estimate, soil moisture anomalies in the western Dakotas, Montana and western Wyoming range from at least 25 – 50 mm (0.98 – 1.96 inches) above normal with some of north central and western Montana achieving 100 – 150 mm anomalies (3.95 – 5.91 inches). In contrast, below normal anomalies in the eastern Dakotas range from 25 – 100 mm (0.98 – 3.94 inches) below normal.

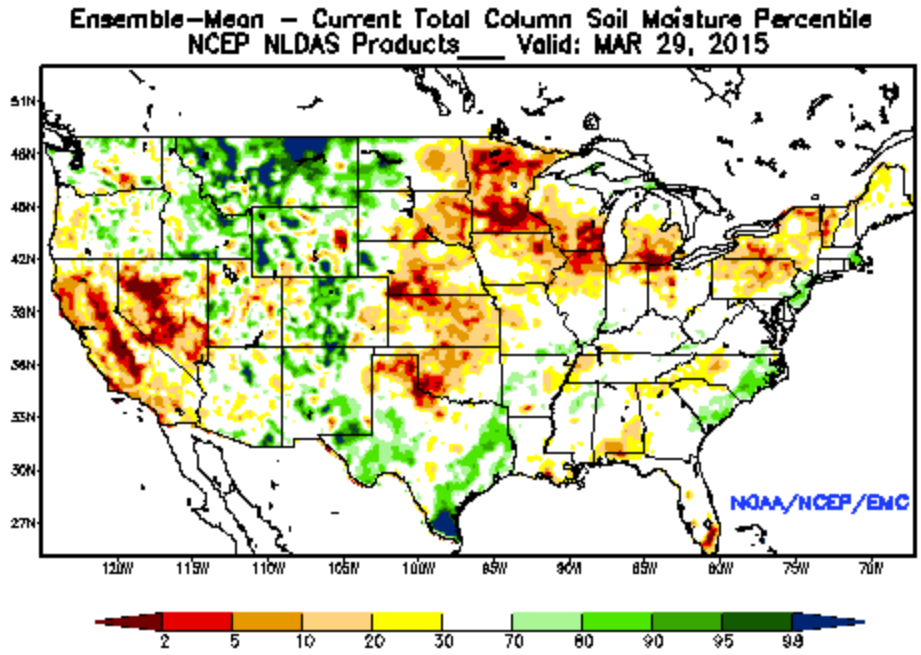


Figure 7. Total Column Soil Moisture Percentile on March 29, 2015. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

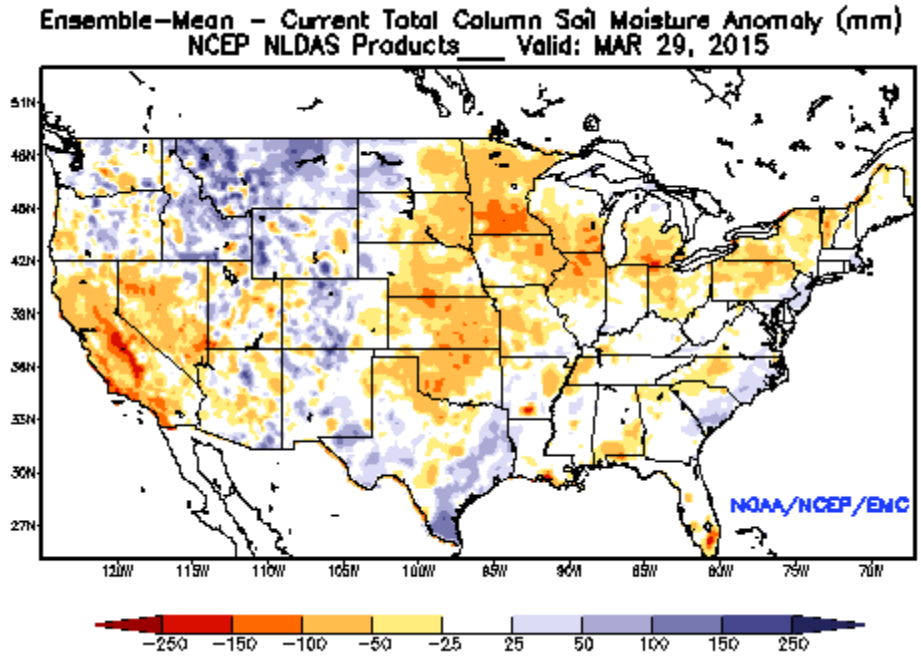


Figure 8. Calculated Soil Moisture Anomaly (mm) on March 29, 2015. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

Differences in soil moisture by depth are illustrated in **Table 1** and **Table 2**, percent soil moisture by depth at two USDA Soil Climate Analysis Network (SCAN) locations in the upper Basin. Over the last seven days in February, soil moisture has remained relatively unchanged

within each respective measurement depth at Dell Rapids, SD and Sidney, MT. At Dell Rapids, SD, soil moisture is driest at the 20-inch with wetter soil near the surface as a result of some precipitation near the end of March. At Sidney, MT soil moisture is also driest at the 20-inch depth, but wetter at the 2-, 4- and 8-inch depths. Although soil moisture as a volumetric percent at Dell Rapids, SD is greater than soil moisture at Sidney, MT, soil moisture conditions at Dell Rapids are actually drier than normal as indicated in **Figures 7** and **8.** In contrast, soil moisture conditions at Sidney, MT are wetter than normal even though the soil contains less moisture than Dell Rapids.

Table 1. Percent soil moisture by depth at the EROS Data Center USDA SCAN Site near Dell Rapids, SD.

USDA SCAN Site - EROS Data Center, Dell Rapids, SD					
Date	Percent Soil Moisture By Depth				
	2-inch	4-inch	8-inch	20-inch	40-inch
3/25/2015	37.4	38.8	32.9	20.0	
3/26/2015	36.6	38.2	32.1	20.2	
3/27/2015	35.5	37.5	31.3	20.3	
3/28/2015	35.8	37.3	31.2	20.4	No Data
3/29/2015	36.4	37.9	31.7	20.7	
3/30/2015	36.1	37.6	31.3	20.8	
3/31/2015	35.8	37.3	30.6	21.0	

Table 2. Percent soil moisture by depth at the USDA SCAN Site near Sidney, MT.

USDA SCAN Site – Sidney, MT					
Date	Percent Soil Moisture By Depth				
	2-inch	4-inch	8-inch	20-inch	40-inch
3/25/2015	24.9	26.3	25.2	19.7	20.9
3/26/2015	25.6	26.5	25.3	19.7	20.9
3/27/2015	27.3	28.0	26.0	19.7	21.0
3/28/2015	27.0	28.0	27.6	19.7	21.0
3/29/2015	28.3	29.2	29.5	19.8	21.0
3/30/2015	27.7	29.0	30.5	19.8	21.1
3/31/2015	26.8	28.6	30.4	20.0	21.0

Frost Conditions

In late December and early January, cold temperatures froze surface soils and allowed soil frost to develop at the greatest soil depths of the season. Soils experienced some thawing with warmer weather conditions in January. Soil frost was added and some re-freezing occurred in the eastern part of the basin throughout February. **Figure 9** shows depth of frost penetration at National Weather Service (NWS) Weather Forecast Office (WFO) locations in the Missouri Basin as of March 31, 2015. Several locations still indicate a frost layer within the soil, while most others indicate frost data is missing or soil frost is no longer present. With the warmer temperatures expected to persist in the basin in April, soil frost will soon be a nonfactor in runoff.

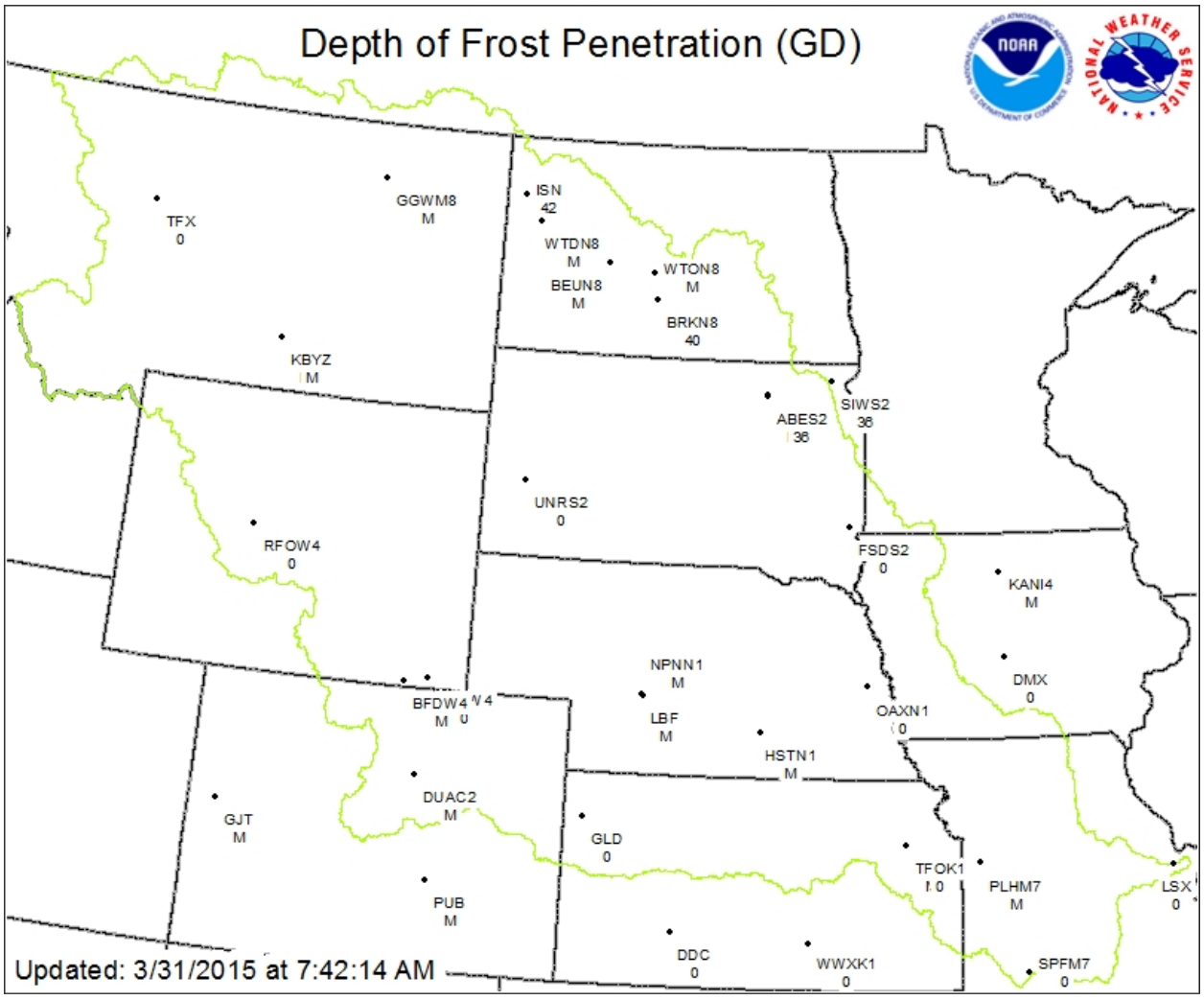


Figure 9. Measured frost depth (inches) at NWS WFO offices as of March 31, 2015. Source: NWS MBRFC.
http://www.crh.noaa.gov/mbrfc

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.

Plains snow cover during January and February 2015 was intermittent and with very limited snow accumulation. Due to much warmer than normal temperatures, remaining plains snow melted during March, and none was present as of April 1, 2015. Please refer to previous runoff summaries for information on the 2015 plains snowpack .

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 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 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, 2014 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 **April 1, 2015**, the Corps of Engineers computed an average mountain SWE in the headwater basin above Fort Peck Dam of 10.7 inches, which is 68% of normal based on the 1981-2010 average SWE for the Fort Peck basin. In the subbasin between Fort Peck Dam and Garrison Dam, the Corps computed an average mountain SWE of 10.1 inches, which is 74% of normal based on the 1981-2010 average SWE for the Fort Peck to Garrison subbasin. Compared to past April 1 mountain snow water equivalents, mountain SWE is the lowest above Fort Peck and the second lowest from Fort Peck to Garrison in the past 30 years.

Normally by April 1, 97% of the peak snow accumulation has occurred in the mountains. Also, mountain snowpack normally peaks around April 15. However, it appears that the mountain snowpack peaked on March 9 at 11.8 inches (74% of the normal peak) above Fort Peck and on March 9 at 11.1 inches (78% of the normal peak) in the Fort Peck to Garrison Reach.

The early and well below normal mountain snowpack peak is a significant change in the mountain snowpack trend since March 1. Prior to March 1, mountain snowpack was tracking near the average mountain snowpack in both basins. On March 1 mountain snowpack was 88% of the March 1 normal above Fort Peck, and 97% of the March 1 normal from Fort Peck to Garrison. Since March 1, the snowpack peaked on March 9 and has begun a slow decline in the absence of significant mountain precipitation and the presence of warmer-than-average temperatures.

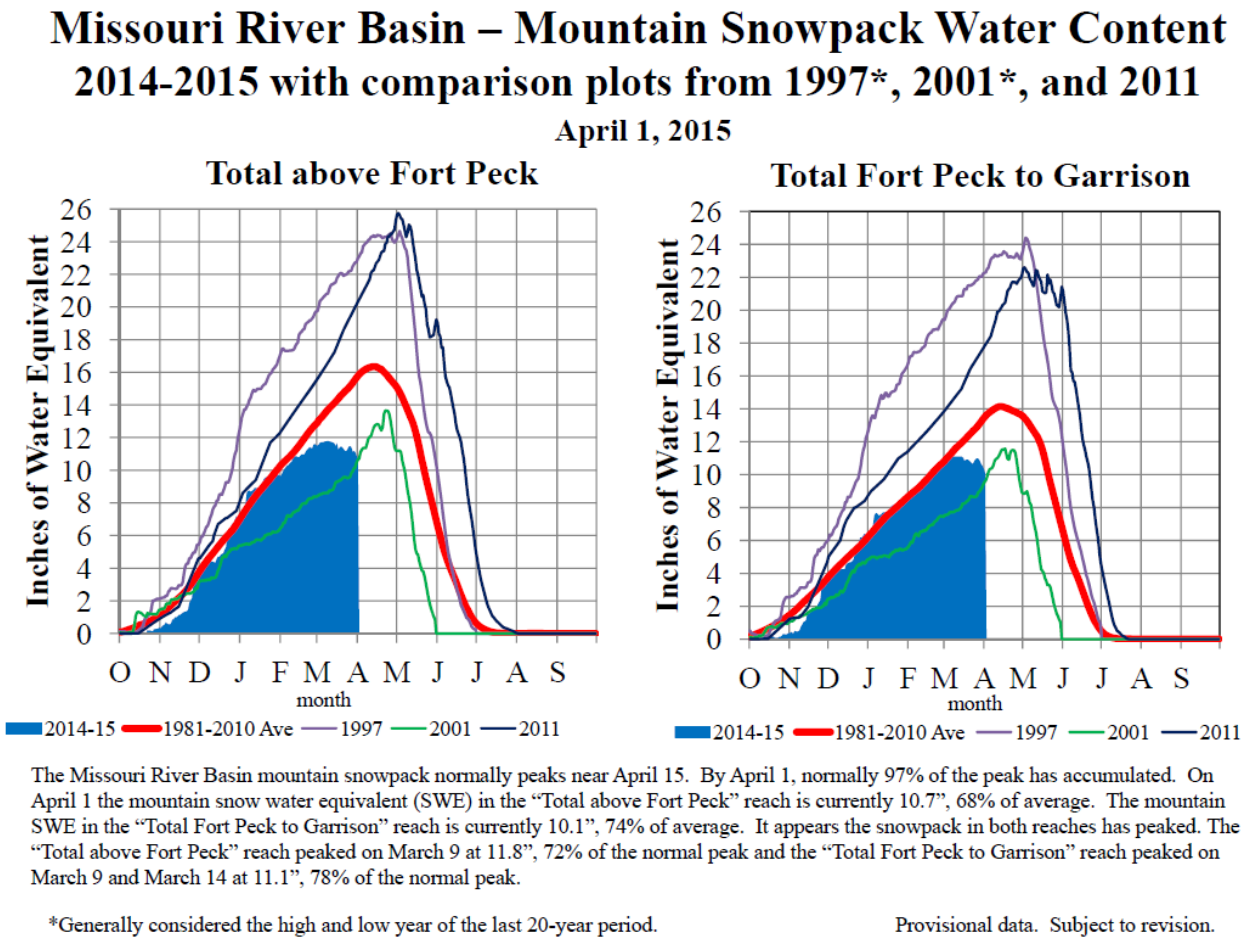


Figure 10. Mountain snowpack water content snow accumulation compared to normal and historic conditions. Corps of Engineers - Missouri River Basin Water Management.

Climate Outlook

ENSO (El Niño Southern Oscillation)

El Niño conditions were declared by the NOAA Climate Prediction Center (CPC) in March 2015. There is a 50-60% chance that El Niño conditions will continue through the Northern Hemisphere summer 2015. The influence of a potential El Niño has been factored into the CPC's temperature and precipitation outlooks looking forward.

Temperature and Precipitation Outlooks

The CPC climate outlook for March 2015 (**Figure 11**) indicates an increased probability for above normal temperatures in the lower Missouri River Basin. In the upper Basin the outlook calls for equal chances for above normal, normal or below normal temperatures. With regard to April precipitation, the CPC indicates that there are increased chances for below normal precipitation over a large portion of the Missouri Basin centered over Nebraska and extending into eastern Wyoming, southeast Montana, southern North Dakota, South Dakota and western Iowa.

The CPC's April-May-June outlook (**Figure 12**) calls for increased chances for above normal temperatures in the mountains and northern plains, but normal temperatures in the lower Basin. In terms of precipitation, there are equal chances for above normal, normal and below normal precipitation in Montana, the Dakotas and Nebraska with a chance for below normal precipitation in eastern North Dakota and South Dakota. There is a slight increase in the chances for above normal precipitation in southern Wyoming.

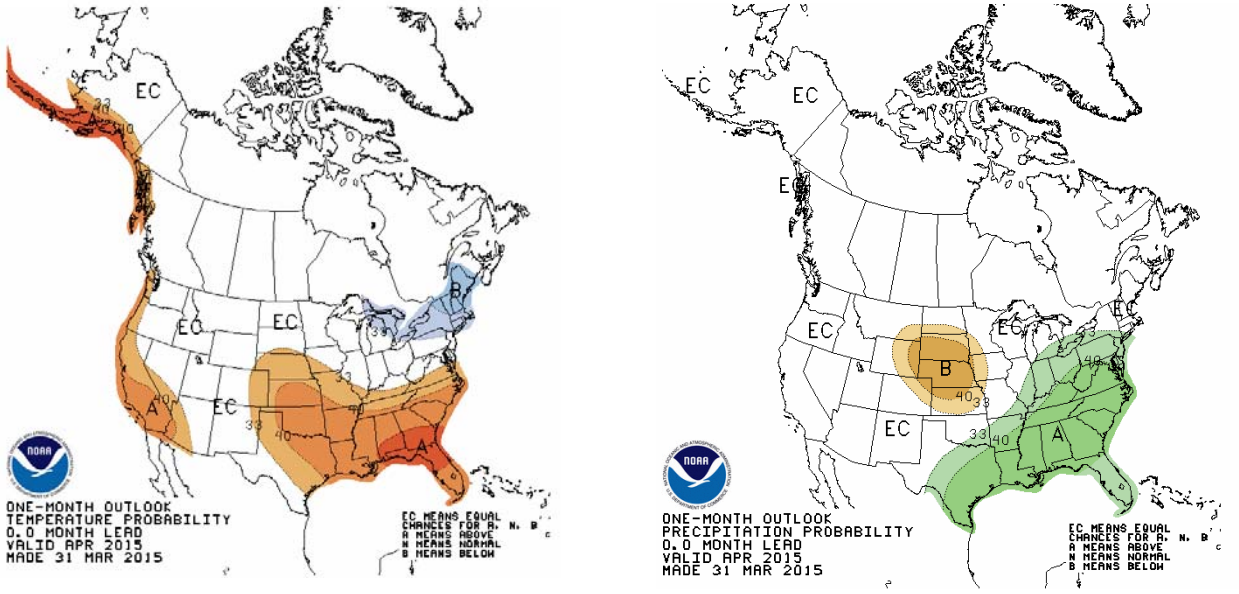


Figure 11. CPC April 2015 temperature and precipitation outlooks.

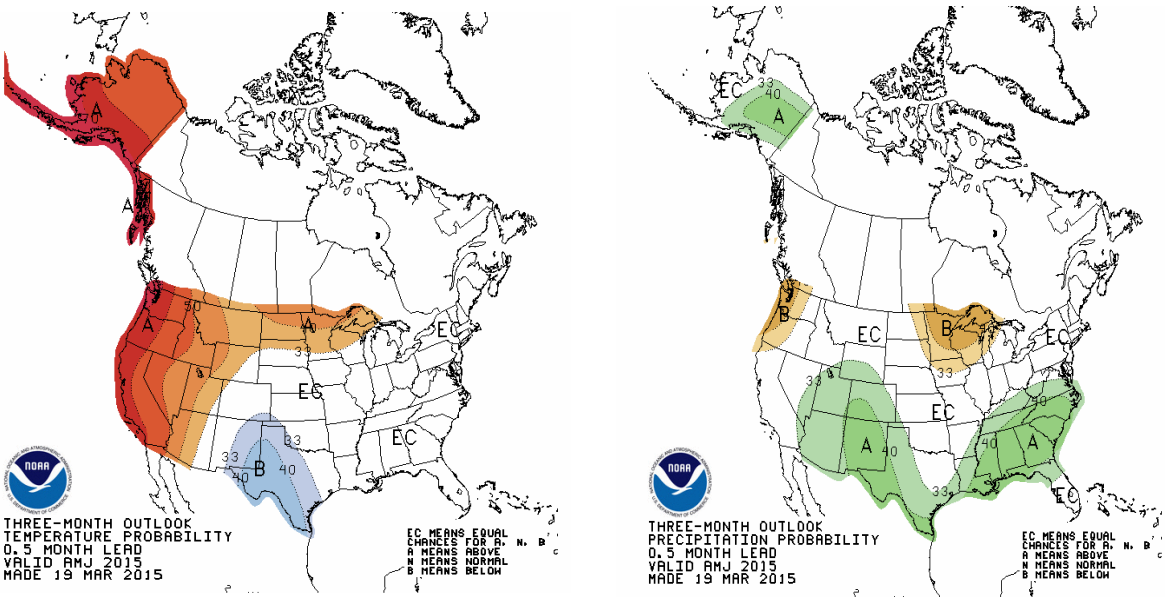


Figure 12. CPC April-May-June 2015 temperature and precipitation outlooks.

The July-August-September 2015 CPC temperature outlook (**Figure 13**) indicates there are increased chances for above normal temperatures in the mountains and northern plains, but normal temperatures in South Dakota and the lower Basin. With regard to precipitation there are equal chances for above normal, normal, and below normal precipitation in all areas of the upper Basin with the exception of an increased probability for above normal precipitation in Wyoming.

During the October-November-December period, the CPC temperature outlook (**Figure 14**) indicates an increased chance for above normal temperatures Montana, Wyoming, North Dakota and northwest South Dakota, while there are equal chances for above normal, normal and below normal temperatures in the remainder of the basin. With regard to precipitation, there are equal chances for above normal, normal and below normal precipitation in the entire Missouri Basin.

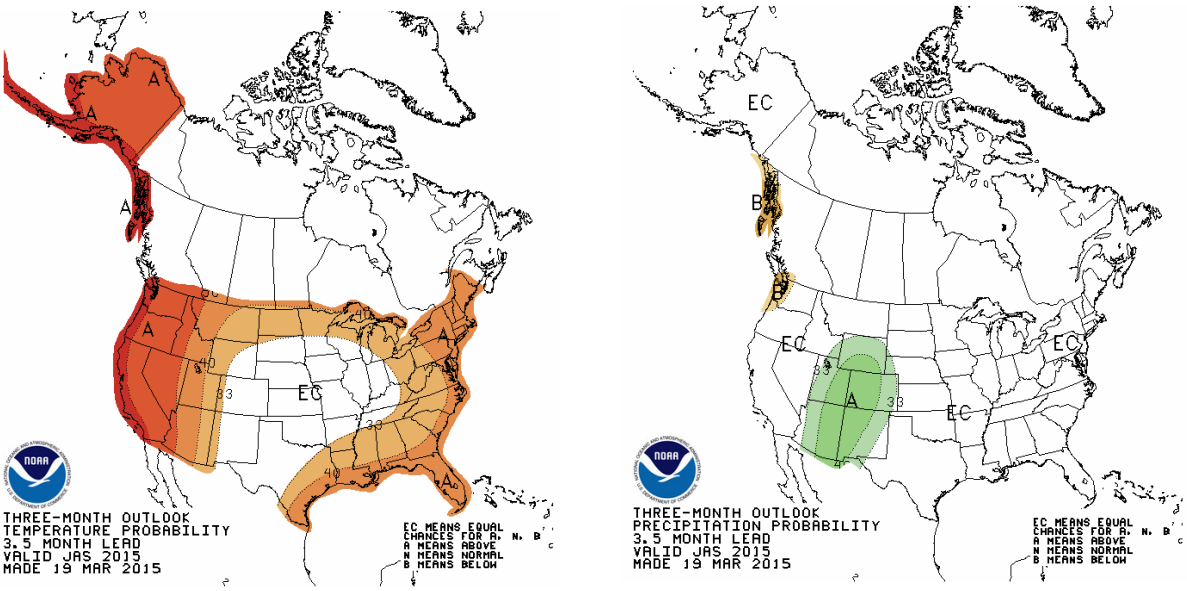


Figure 13. CPC July-August-September 2015 temperature and precipitation outlooks.

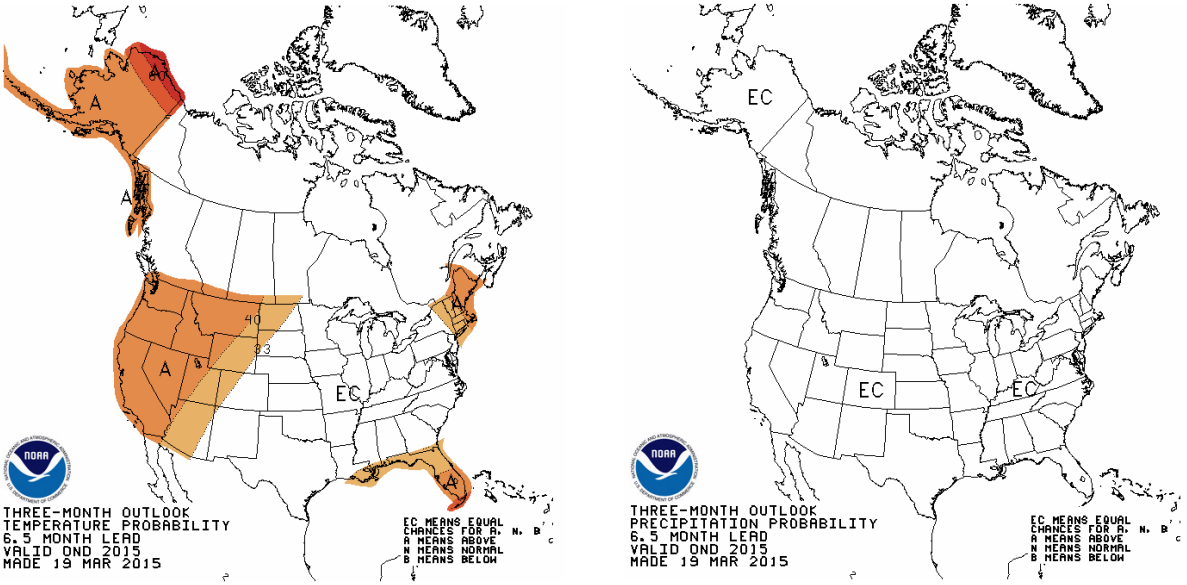


Figure 14. CPC October-November-December 2015 temperature and precipitation outlooks.

April 2015 Calendar Year Runoff Forecast

The April 1, 2015 forecast for runoff above Sioux City is **20.3 MAF** (80% of normal). Above Gavins Point Dam, the forecast is **18.8 MAF** (82% of normal). The large decrease in the calendar year runoff forecast is due to the significant change in mountain snowpack since March 1. Mountain snowpack peaked about one month earlier than normal, and the peak snowpack is much lower than normal. As a result the May, June and July runoff from the mountain snowpack is forecast to be significantly less than the previous forecast. 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 fairly large and ranges from the 25.8 MAF (101% of normal) upper basic forecast to the 15.5 MAF (61.4% of normal) lower basic forecast.

For comparison, the April 1, 2015 USDA NRCS Missouri River Basin water supply forecasts are provided on pages 18 and 19. The water supply forecasts represented by the 50%-exceedance category indicate runoff volumes are forecast to be much lower than the 30-year average runoff as a percent of normal. For example, the 50%-exceedance April-September runoff volume on the Missouri River at Toston, MT is 1150 kAF, which is 56% of the 30-year average runoff volume o f 2070 kAF. Similarly, the 50%-exceedance April-September runoff volume on the Bighorn River near St. Xavier, MT is 920 kAF, which is 63% of the 30-year average runoff volume. The low water supply forecasts reflect the impacts of early and low peaking mountain snowpack, below normal precipitation accumulations, and warmer than normal temperatures that have occurred throughout the Rocky Mountains since October 1, 2014.

The most important factors influencing the calendar year runoff forecast at this time are the absence of plains snowpack, the rainfall deficit since January 1, the low mountain snowpack, and the CPC's monthly and seasonal temperature and precipitation outlooks.

April

January and February runoff above Sioux City, IA were 1.4 MAF (178% of normal) and 2.0 MAF (186% of normal), respectively. The higher-than-normal runoff was due to warmer-than-normal temperatures in Montana and Wyoming that continued to melt any accumulated plains snowpack, some low elevation snowpack and inhibit ice formation on tributaries and the Missouri River. This additional runoff in February is runoff that would normally occur in March and April during the normal time of the spring thaw. March runoff above Sioux City, IA was 2.2 MAF (74% of normal). Due to the absence of plains snowpack and the increased probability for below normal precipitation, April runoff is also expected to be 72% of normal and similar to observed March runoff by reservoir reach. Since many low elevation mountain SNOTEL locations have begun to melt, mountain streamflow is expected to increase sometime during April.

May-June-July

During the May-June-July period, the mainstem system receives 50% of its annual runoff as a result of mountain snowmelt and spring and summer precipitation. This is the most active period for precipitation in the Missouri River Basin, so runoff can vary significantly as a result of the above or below normal rainfall.

For this 3-month period, the most reliable method for predicting runoff into Fort Peck and Garrison reservoirs is through regression equations that relate mountain snowpack to runoff. The April 1, 2015 mountain snowpack was 68% of average in the reach above Fort Peck and 74% of average in the reach between Fort Peck and Garrison. Using the April 1 snowpack regression equations, Fort Peck reach runoff is forecast to be 1.9 MAF, which is about 54% of normal May-June-July runoff. Using the April 1 snowpack regression equations, the Fort Peck to Garrison reach runoff is forecast to be 3.8 MAF, which is about 66% of normal May-June-July runoff.

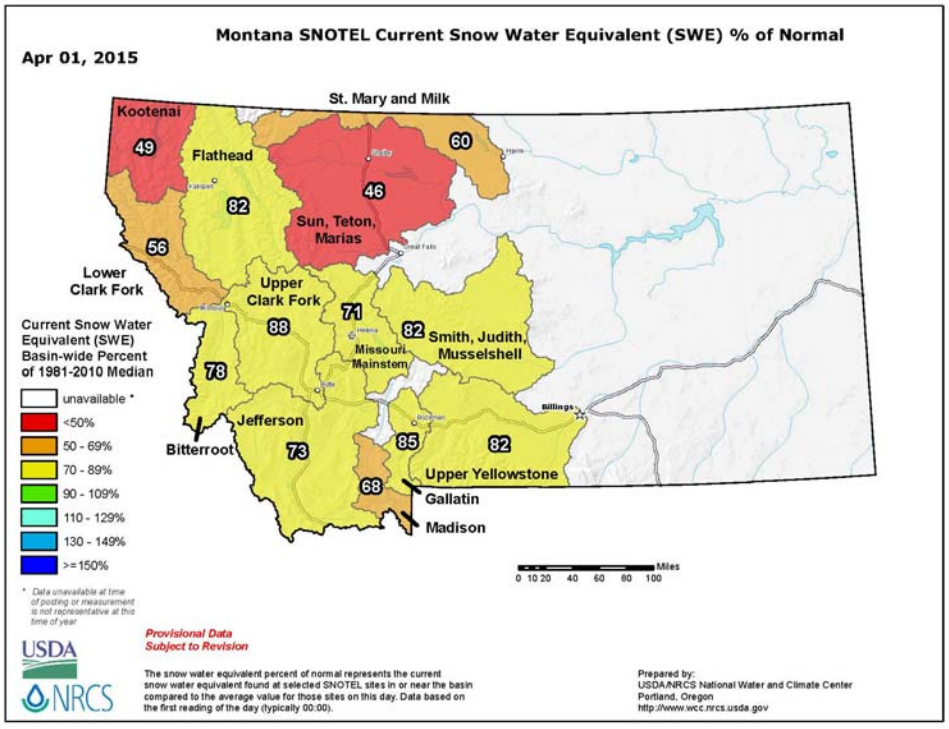
The CPC climate outlooks indicate there are increased chances for above normal temperatures during the May-June-July period, while there are indications precipitation will range from normal to below normal. Taking into consideration these climate forecasts, well below normal runoff is forecast to occur in the Oahe, Fort Randall, Gavins Point and Sioux City reaches through July. The overall May, June and July runoff forecasts as a percent of normal above Sioux City are 67%, 58% and 60% of normal, respectively.

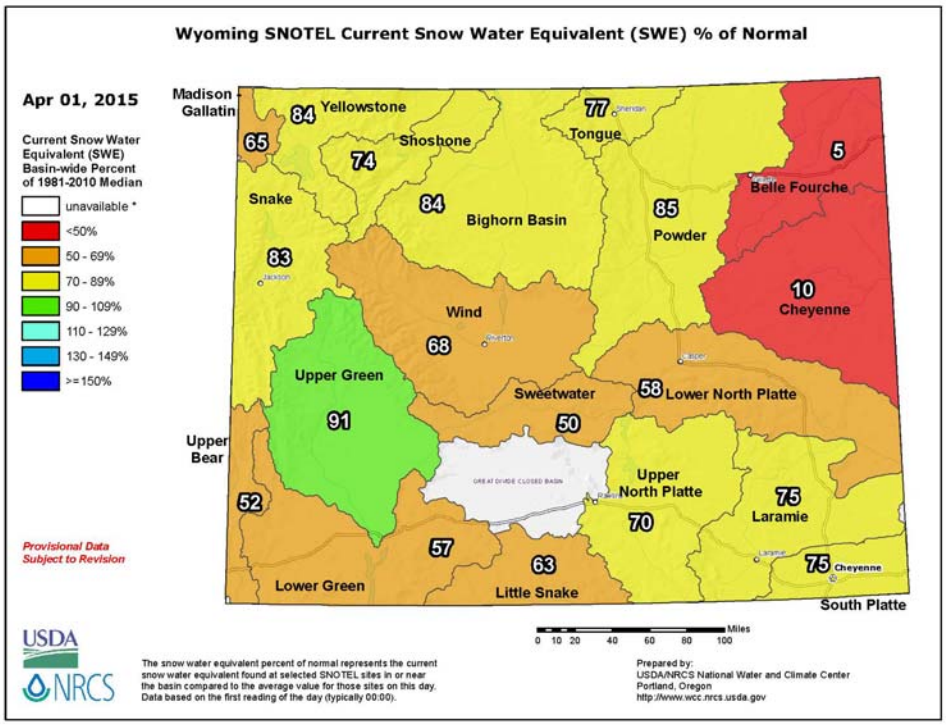
August through December

August runoff in the Fort Peck and Garrison reaches is highly correlated with July runoff, therefore, the August runoff forecasts in the Fort Peck and Garrison reaches are 84% and 90% of normal, respectively.

NOAA's climate outlook indicates increased chances for above normal temperatures in parts of the Basin and equal chances for above, below and normal precipitation. Very little information is known at this time which can indicate how much runoff will occur during that time period because summer and fall runoff is determined by precipitation; therefore, near normal runoff is forecast from August through December.

Additional Figures





USDA NRCS National Water & Climate Center Water Supply Forecasts

* - DATA CURRENT AS OF: April 05, 2015 04:06:52 PM
  - Based on April 01, 2015 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	77	79	91	83	71	63	97
	APR-SEP	91	81	107	98	84	75	112
St. Mary R at Int'l Boundary (2)	APR-JUL	320	74	415	360	280	225	435
	APR-SEP	385	76	485	425	345	285	505
Lima Reservoir Inflow (2)	APR-JUL	16.4	20	34	23	9.4	1.00	82
	APR-SEP	15.0	17	35	23	7.0	1.00	89
Clark Canyon Reservoir Inflow (2)	APR-JUL	17.5	17	84	44	7.0	-16.0	101
	APR-SEP	25	21	95	53	10.0	-5.0	120
Jefferson R nr Three Forks (2)	APR-JUL	300	41	640	440	161	110	740
	APR-SEP	300	38	680	455	146	96	800
Hebgen Reservoir Inflow (2)	APR-JUL	235	64	285	255	215	184	370
	APR-SEP	305	65	365	330	285	250	470
Ennis Reservoir Inflow (2)	APR-JUL	375	60	490	420	325	255	625
	APR-SEP	475	61	615	530	420	340	775
Missouri R at Toston (2)	APR-JUL	1010	56	1580	1240	780	440	1790
	APR-SEP	1150	56	1840	1430	870	465	2070
Smith R bl Eagle Ck (2)	APR-JUL	90	85	141	111	69	38	106
	APR-SEP	103	89	166	128	77	40	116
Gibson Reservoir Inflow (2)	APR-JUL	285	72	370	320	255	205	395
	APR-SEP	320	73	410	355	285	230	440
Marias R nr Shelby (2)	APR-JUL	157	46	320	225	91	40	345
	APR-SEP	160	44	340	235	88	64	360

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	51	86	58	54	48	44	59
	APR-SEP	66	89	77	70	62	55	74
Wind R ab Bull Lake Ck (2)	APR-JUL	290	64	385	330	250	195	455
	APR-SEP	305	62	415	350	255	189	490
Bull Lake Ck nr Lenore	APR-JUL	94	68	130	108	79	57	139
	APR-SEP	116	69	161	134	97	70	169
Boysen Reservoir Inflow (2)	APR-JUL	290	48	625	425	153	50	610
	APR-SEP	325	49	695	475	173	50	665
Greybull R nr Meeteetse	APR-JUL	101	77	145	119	83	57	131
	APR-SEP	137	77	191	159	115	83	177
Shell Ck nr Shell	APR-JUL	47	85	61	53	41	33	55
	APR-SEP	59	89	75	65	52	42	66
Bighorn R at Kane (2)	APR-JUL	430	51	945	635	220	60	840
	APR-SEP	455	50	1030	685	225	45	905
NF Shoshone R at Wapiti	APR-JUL	370	80	445	400	340	295	460
	APR-SEP	410	80	500	445	375	320	515
SF Shoshone R nr Valley	APR-JUL	195	91	230	210	180	158	215
	APR-SEP	225	92	270	245	205	181	245
Buffalo Bill Reservoir Inflow (2)	APR-JUL	600	89	730	650	545	465	675
	APR-SEP	660	89	820	725	595	500	745
Bighorn R nr St. Xavier (2)	APR-JUL	890	64	1500	1140	645	280	1380
	APR-SEP	920	63	1620	1200	635	220	1460
Little Bighorn R nr Hardin	APR-JUL	81	83	122	98	64	39	98
	APR-SEP	95	86	141	114	77	49	111
Tongue R nr Dayton (2)	APR-JUL	66	77	93	77	55	39	86
	APR-SEP	75	77	105	87	63	45	98
Tongue River Reservoir Inflow (2)	APR-JUL	129	67	230	169	90	31	193
	APR-SEP	146	68	250	189	104	41	215
NF Powder R nr Hazelton	APR-JUL	8.0	88	10.4	9.0	7.0	5.6	9.1
	APR-SEP	8.6	87	11.2	9.7	7.5	6.0	9.9
Powder R at Moorhead	APR-JUL	123	69	240	170	77	7.9	177

	APR-SEP	140	71	260	188	92	21	196
Powder R nr Locate	APR-JUL	138	69	275	194	82	6.0	199
	APR-SEP	155	70	305	215	95	6.3	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
May 2015 Calendar Year Runoff Forecast
May 7, 2015

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.

2015 Calendar Year Forecast Synopsis

The May 1, 2015 forecast for runoff above Sioux City is **19.3 MAF** (76% of normal). Above Gavins Point Dam, we are forecasting **17.8 MAF** (77% of normal). May's runoff forecast is about 1 MAF less than the April forecast. April runoff in the upper Missouri Basin was 52% of normal due to well below average precipitation in the upper Basin and continuing drought conditions. The forecast for May-July runoff into Fort Peck and Garrison is expected to be only 60% of average. This is due to less than average accumulations of mountain snowpack, which peaked in early March, about a month earlier than normal. The runoff into the lower 4 reaches is also expected to be much less than average during May-July.

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 fairly large and ranges from the 23.6 MAF (94% of normal) upper basic forecast to the 15.5 MAF (62% of normal) 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 lower than normal (lower basic) is attributed to all 6 reaches for 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 number of forecast months decreases.

April 2015 Runoff

All plains snowpack that had accumulated during the winter had melted in January and February, leading to above normal runoff in January (178% of normal) and February (186% of normal). March 2015 runoff was 2.2 MAF (74% of normal) above Sioux City. April 2015 runoff was 1.5 MAF (52% of normal) above Sioux City. March and April runoff was below normal because no plains snowpack runoff occurred, due to the absence of plains snowpack. April precipitation was well below normal above Sioux City, therefore, very little rainfall runoff was observed.

Current Conditions

Drought Analysis

The National Drought Mitigation Center's drought monitor for April 28, 2015 (**Figure 1**), when compared to the drought monitor for March 24, 2015 (**Figure 2**), shows additional expansion of Abnormally Dry (D0) conditions in southwest Montana. Furthermore, Moderate Drought (D1) conditions have developed across South Dakota, eastern North Dakota, and central Nebraska. Some Severe Drought (D2) has developed in central and eastern South Dakota. The U.S. Monthly Drought Outlook in **Figure 3** indicates that drought in the Dakotas and Nebraska is expected to persist or intensify in May 2015.

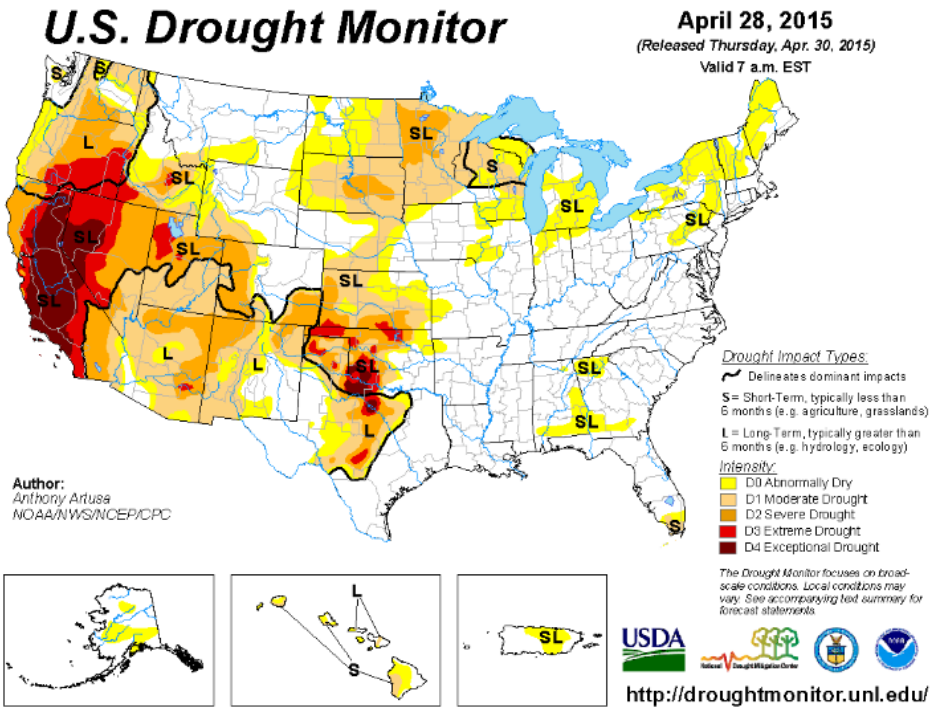


Figure 1. National Drought Mitigation Center U.S. Drought Monitor for April 28, 2015.

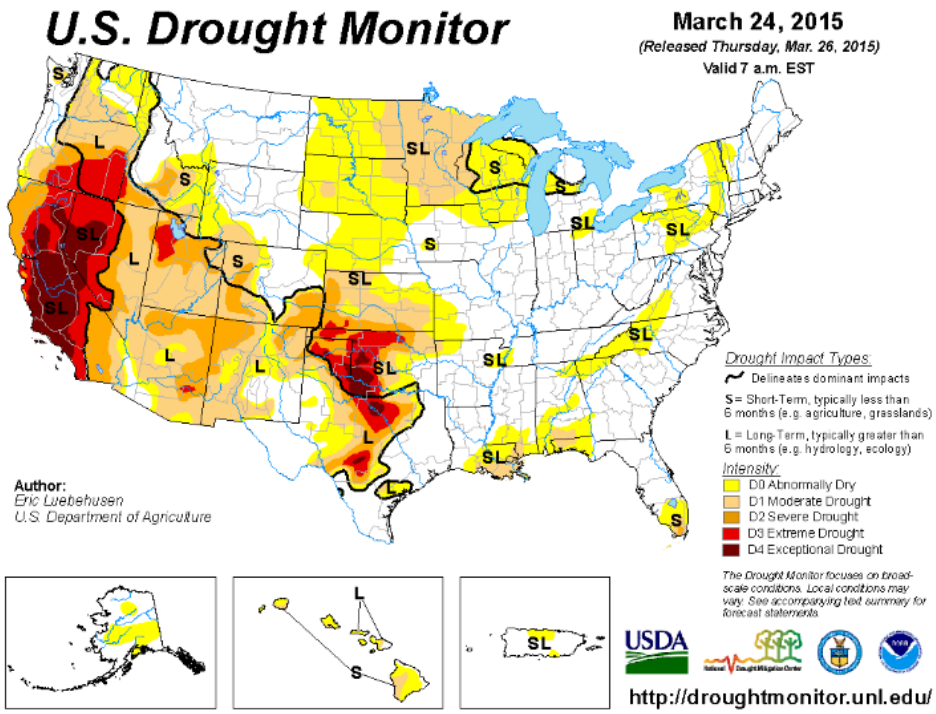


Figure 2. National Drought Mitigation Center U.S. Drought Monitor for March 24, 2015.

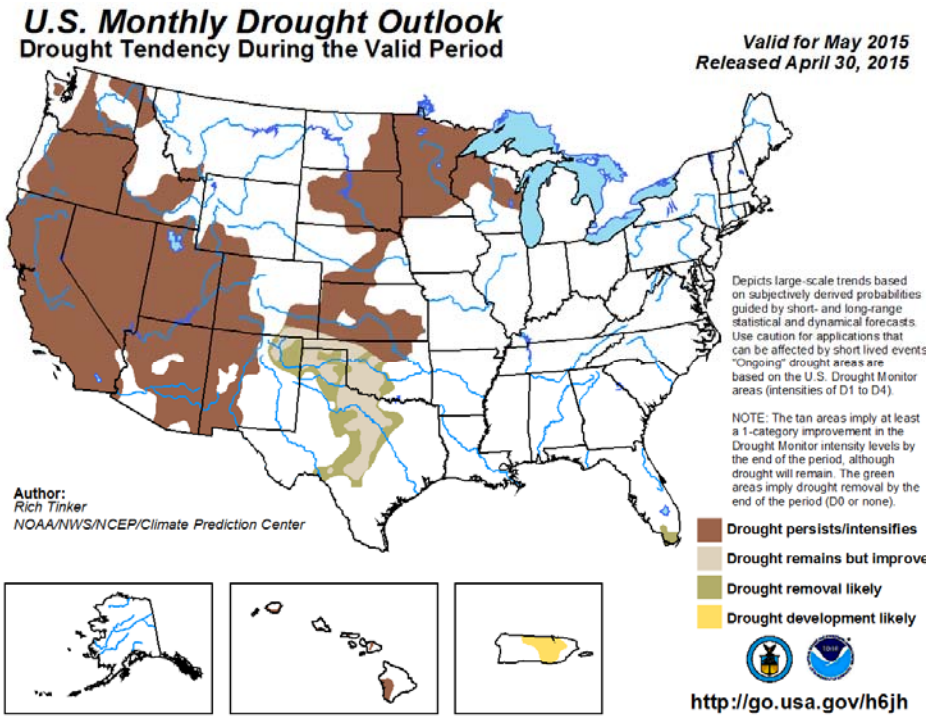


Figure 3. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

April precipitation accumulations are shown in **Figure 4** as both inches of precipitation and percent of normal monthly precipitation. The April precipitation accumulation was less than 2.0 inches of precipitation in most of the upper Basin. Many areas received less than 0.5 inch of precipitation. As a percent of normal, large portions of the upper Basin received less than 50 percent of normal precipitation. Much of the Platte River basin received greater-than-normal precipitation.

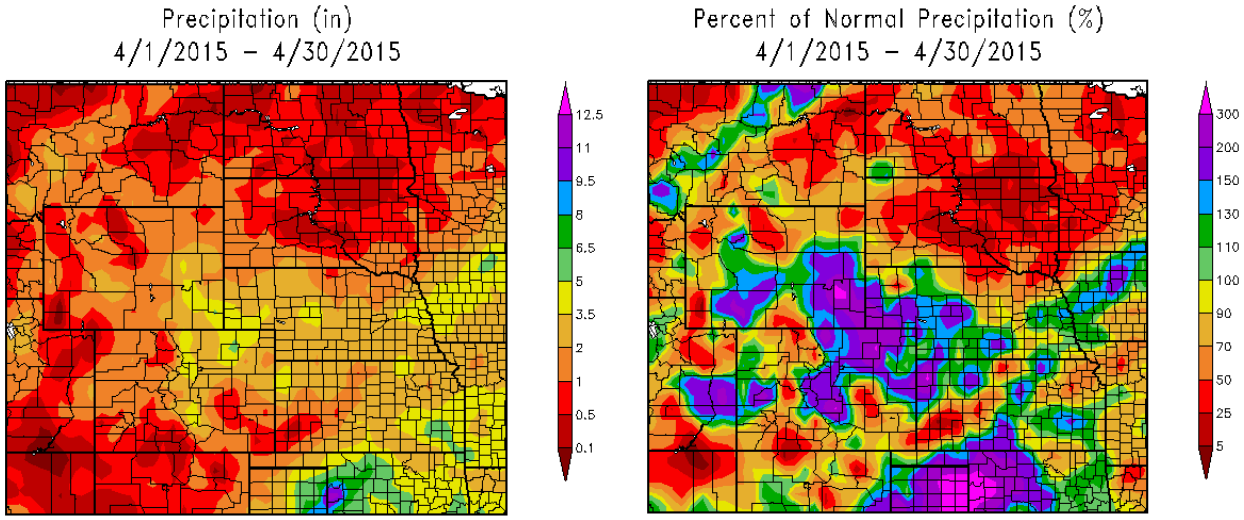


Figure 4. April 2015 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

February-March-April precipitation accumulations are shown in **Figure 5** as both inches and percent of normal precipitation. The three-month accumulation reveals that precipitation accumulations have been less than 70% of normal in a majority of the plains. Conditions have been driest with less than 50% of normal precipitation over southern Montana, South Dakota, North Dakota and northern Nebraska. Above normal precipitation accumulations occurred over parts of northern Montana and the upper Platte River basin where accumulations have been as high as 200% of normal.

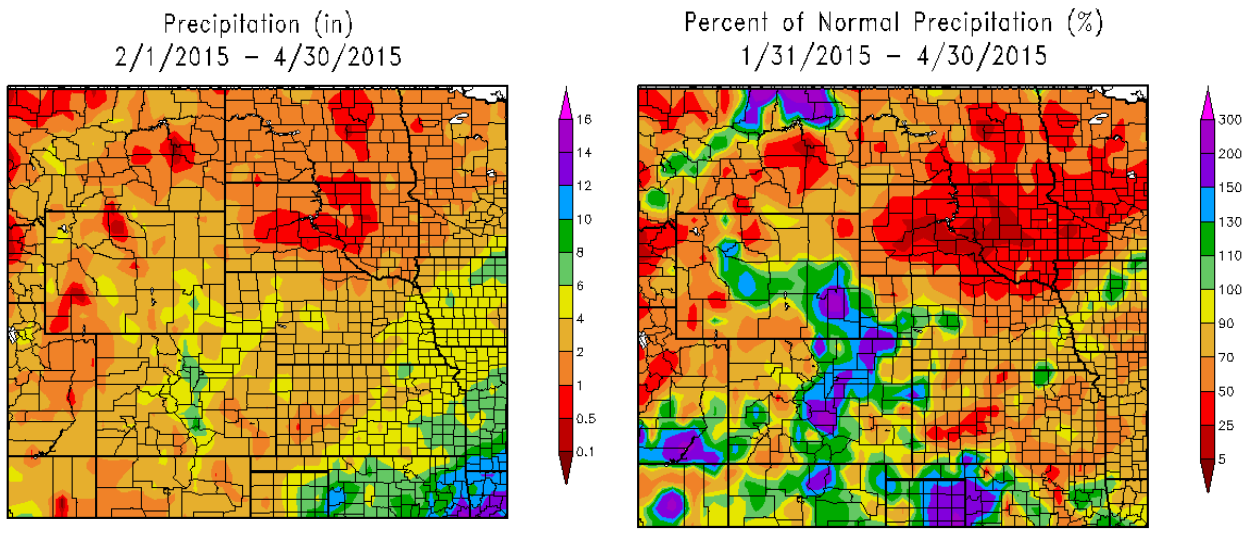


Figure 5. February 1, 2015 – April 30, 2015 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Temperature

April temperature departures from normal in degrees Fahrenheit (deg F) are shown in **Figure 6**. April temperatures in the upper Basin were near normal in Montana, Wyoming, and North Dakota and greater than 2 deg F warmer than across South Dakota and Nebraska. Three-month (February-March-April) temperature departures are also shown in **Figure 6**. Three-month upper Basin temperatures have ranged from slightly below normal in the eastern Dakotas to 2 to 6 deg F warmer than normal in the regions west of the Missouri River.

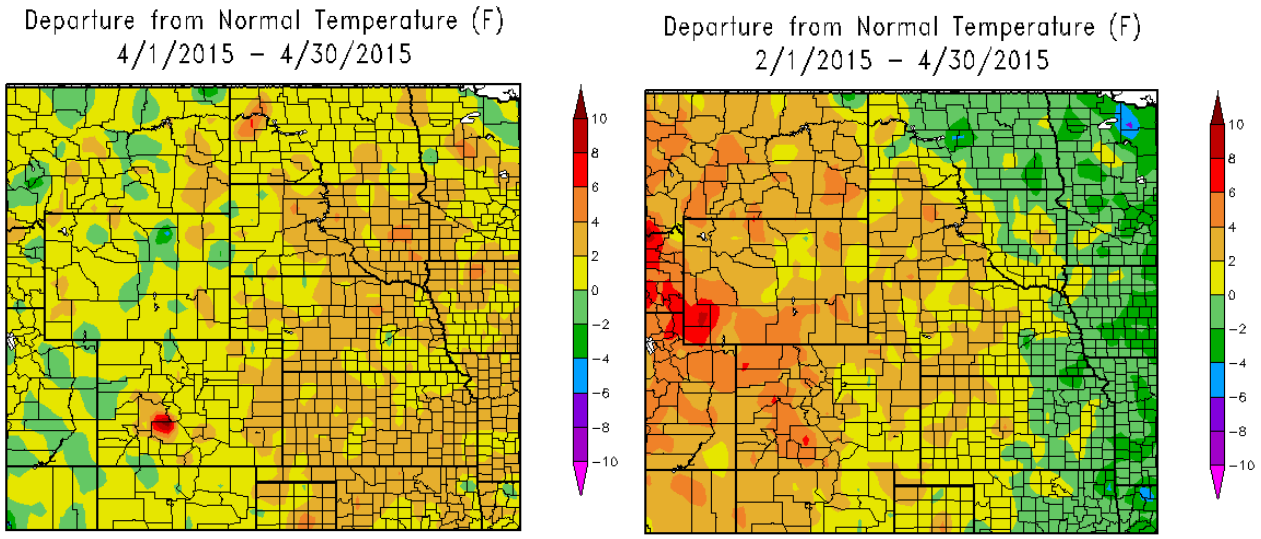


Figure 6. April 2015 and February – April 2015 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

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 monthly runoff.

Figure 7 shows the NOAA NLDAS ensemble mean soil moisture percentiles on April 26, 2015 for the total modeled soil column, which is about 2 meters. The NLDAS soil moisture depiction is an average value for the soil moisture column. The average soil moisture in **Figure 7** still indicates above normal soil moisture conditions throughout Montana, Wyoming, western North Dakota and western South Dakota. Soil moisture is greater than the 70th percentile in the aforementioned areas and greater than the 98th percentile in north central Montana. These high soil moisture conditions developed as a result of the record August rainfall; however drying has occurred throughout the soil moisture column. Total column soil moisture in the eastern Dakotas is drier than normal with some conditions ranging from the 2nd to 20th percentile.

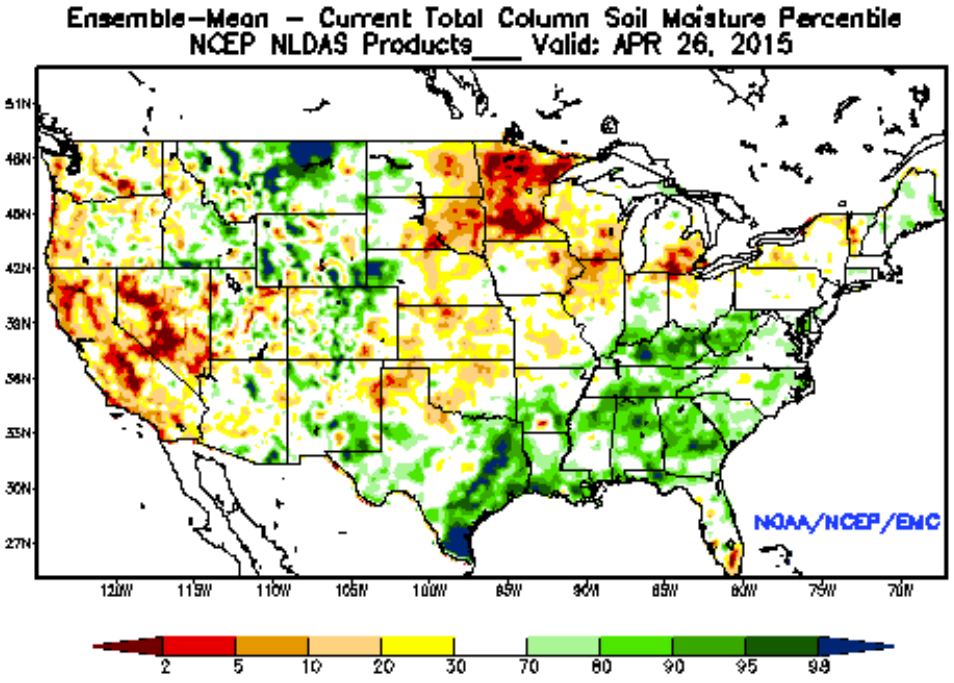


Figure 7. Total Column Soil Moisture Percentile on April 26, 2015. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

The Ensemble Mean current total column soil moisture anomaly for the contiguous U.S. on April 26, 2015 is shown in **Figure 8**. These anomalies represent soil moisture averaged over the entire 2-meter soil column, so they do not reflect differences in soil moisture content at various depths. According to the modeled estimate, soil moisture anomalies in the western Dakotas, Montana

and western Wyoming range from at least 25 – 50 mm (0.98 – 1.96 inches) above normal with some of north central and western Montana achieving 100 – 150 mm anomalies (3.94 – 5.91 inches). In contrast, below normal anomalies in the eastern Dakotas range from 50 – 100 mm (1.97 – 3.94 inches) below normal.

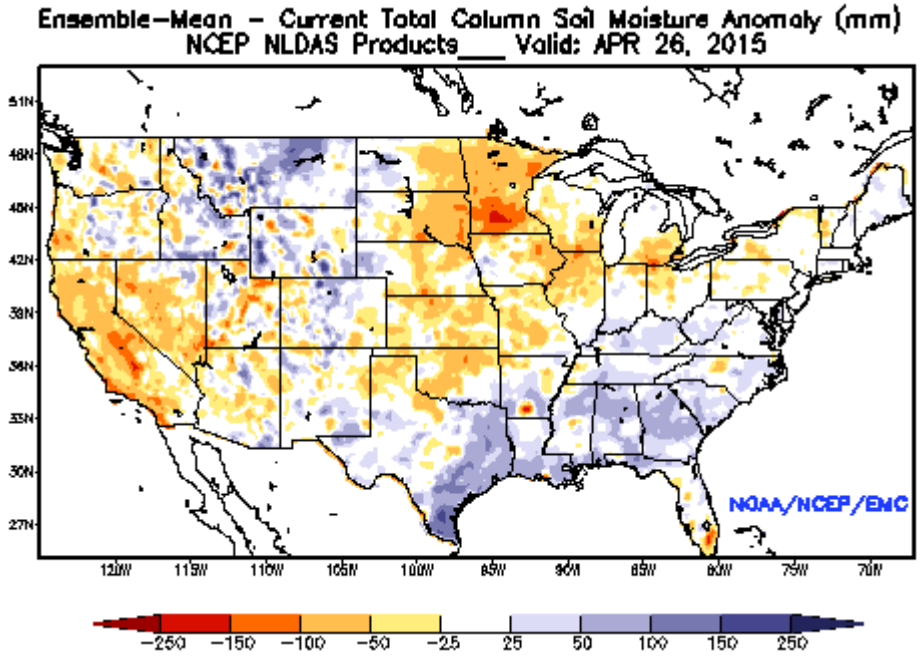


Figure 8. Calculated Soil Moisture Anomaly (mm) on April 26, 2015. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

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 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 greater than average runoff from an average mountain snowpack this year due to wetter than normal soil moisture conditions.

Figure 9 includes time series plots of the average mountain SWE beginning on October 1, 2014 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 **April 30, 2015**, the Corps of Engineers computed an average mountain SWE in the headwater basin above Fort Peck Dam of 9.1 inches, which is 56% of the normal April 15 peak

or 61% of the April 30 average based on the 1981-2010 average SWE for the Fort Peck basin. In the subbasin between Fort Peck Dam and Garrison Dam, the Corps computed an average mountain SWE of 8.9 inches, which is 63% of the normal April 15 peak or 66% of the April 30 average based on the 1981-2010 average SWE for the Fort Peck to Garrison subbasin. Normally, mountain snowpack peaks around April 15. However, the mountain snowpack peaked on March 9 at 11.8 inches (72% of the normal peak) above Fort Peck and on March 9 at 11.1 inches (78% of the normal peak) in the Fort Peck to Garrison reach. The early and well below normal mountain snowpack peak has a significant impact on the low May through July runoff volume forecast.

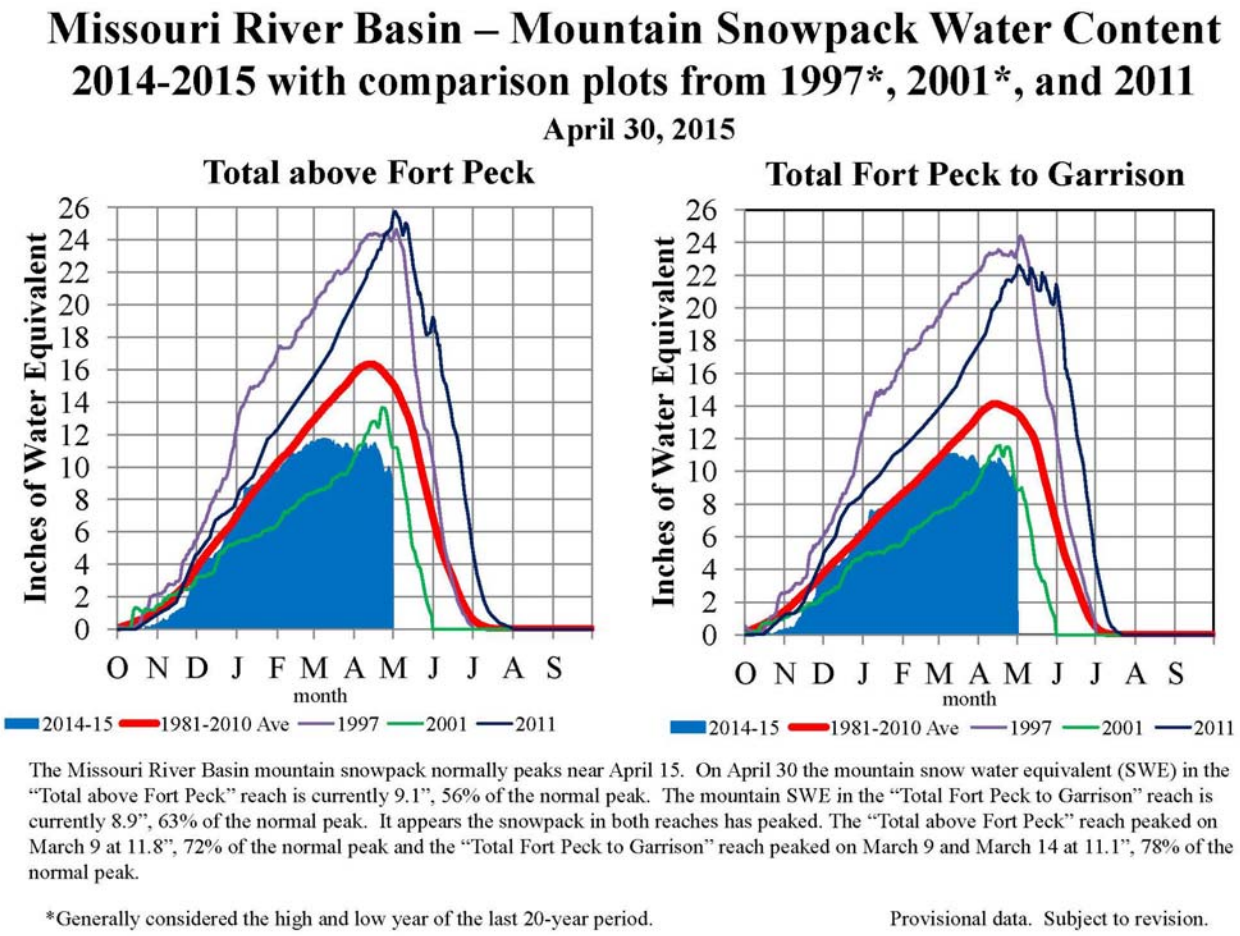


Figure 9. Mountain snowpack water content snow accumulation compared to normal and historic conditions. Corps of Engineers - Missouri River Basin Water Management.

Climate Outlook

ENSO (El Niño Southern Oscillation)

El Niño conditions were declared by the NOAA Climate Prediction Center (CPC) in March 2015. There is approximately 70% chance that El Niño conditions will continue through the Northern Hemisphere summer 2015, and a greater than 60% chance it will last through autumn.

The influence of a potential El Niño has been factored into the CPC's temperature and precipitation outlooks looking forward.

Temperature and Precipitation Outlooks

The CPC climate outlook for May 2015 (**Figure 10**) indicates equal chances for above normal, normal and below normal temperatures in the Missouri River Basin except for western Montana which has increased chances of above normal temperatures. With regard to May precipitation, the CPC indicates that there are increased chances for above normal precipitation in the southern portion of the Missouri River Basin especially in the basin below Gavins Point Dam. The Missouri River Basin above Gavins Point Dam has equal chances of above normal, normal and below normal precipitation.

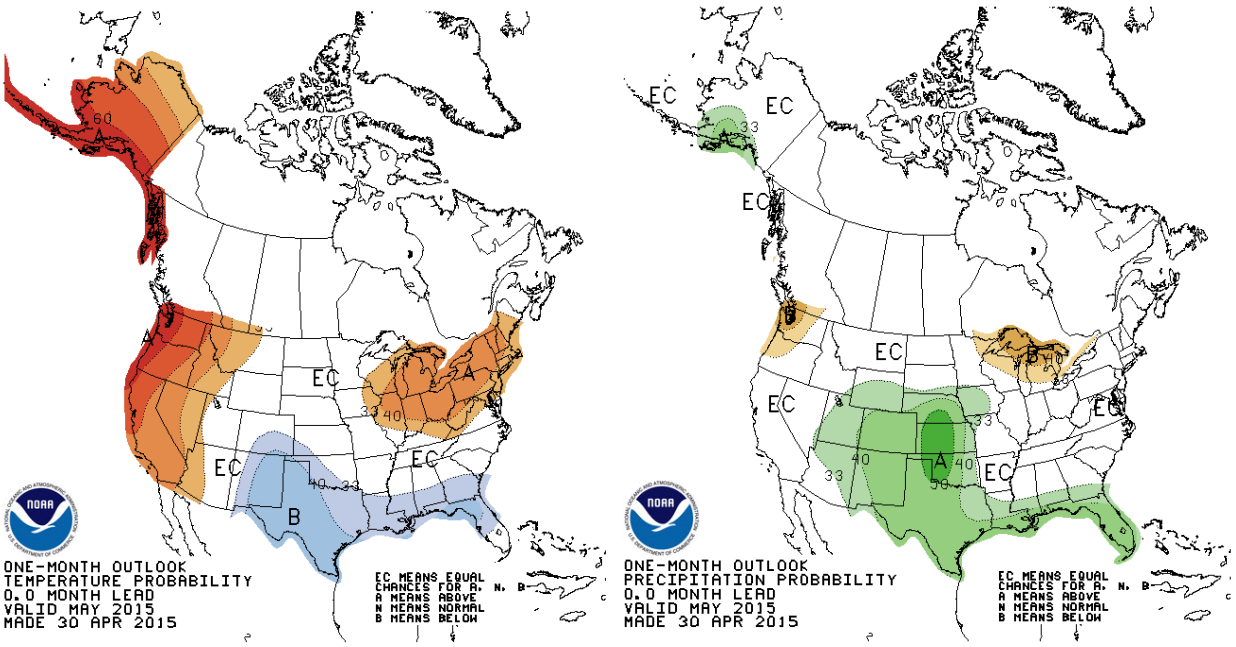


Figure 10. CPC May 2015 temperature and precipitation outlooks.

The CPC's May-June-July outlook (**Figure 11**) calls for increased chances for above normal temperatures in the mountains, but normal temperatures in the plains and lower Basin. In terms of precipitation, there are increased chances for above normal precipitation in Colorado, Wyoming, and southern Montana. Equal chances of above normal, normal and below normal precipitation are forecasted for northern Montana, the Dakotas, Nebraska, and Iowa.

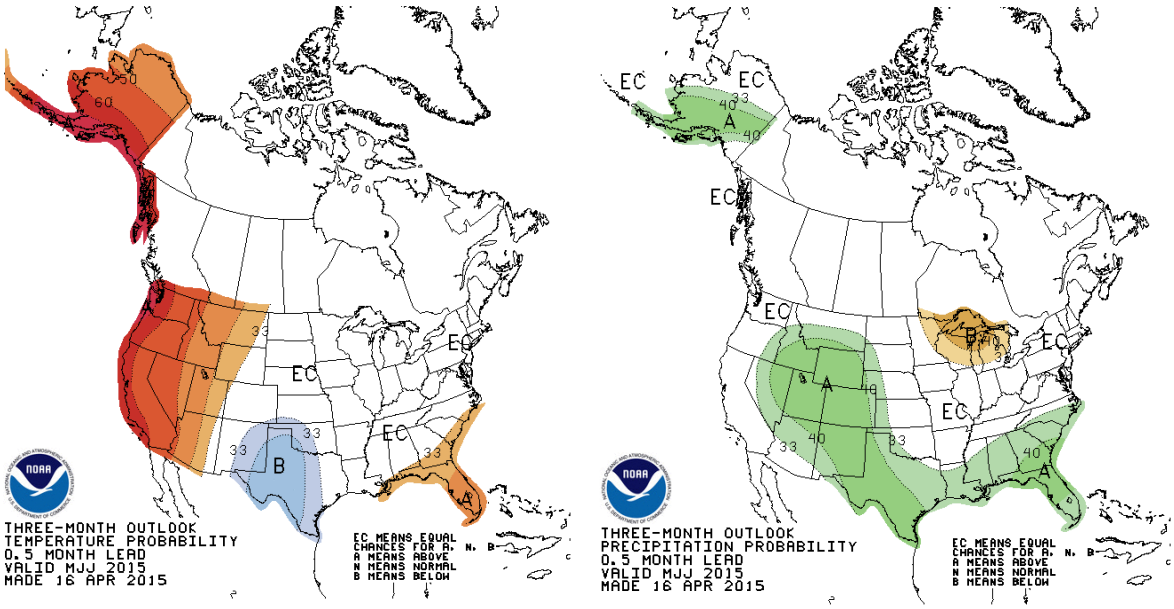


Figure 11. CPC May-June-July 2015 temperature and precipitation outlooks.

The August-September-October 2015 CPC temperature outlook (**Figure 12**) indicates there are increased chances for above normal temperatures in Montana and much of Wyoming, equal chances in the Central Plains, and increased chances for below normal temperatures in southeast South Dakota, eastern Nebraska, Iowa, northeast Kansas and Missouri. With regard to precipitation there are equal chances for above normal, normal, and below normal precipitation in all areas of the upper Basin with the exception of an increased probability for above normal precipitation in Wyoming and western Nebraska.

During the November-December-January period, the CPC temperature outlook (**Figure 13**) indicates an increased chance for above normal temperatures in Montana, Wyoming, and the Dakotas, while there are equal chances for above normal, normal and below normal temperatures in the southern portion of the Missouri Basin. With regard to precipitation, there are increased changes for below normal precipitation in Montana, Wyoming, and the western Dakotas. The remainder of the basin has equal chances for above normal, normal and below normal precipitation.

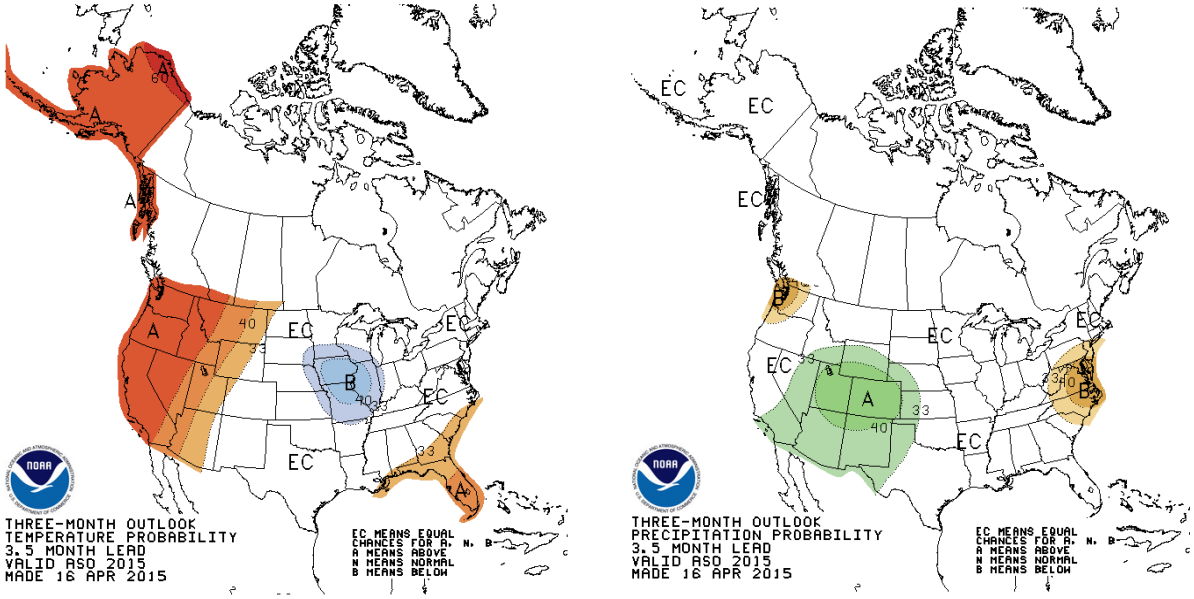


Figure 12. CPC August-September-October 2015 temperature and precipitation outlooks.

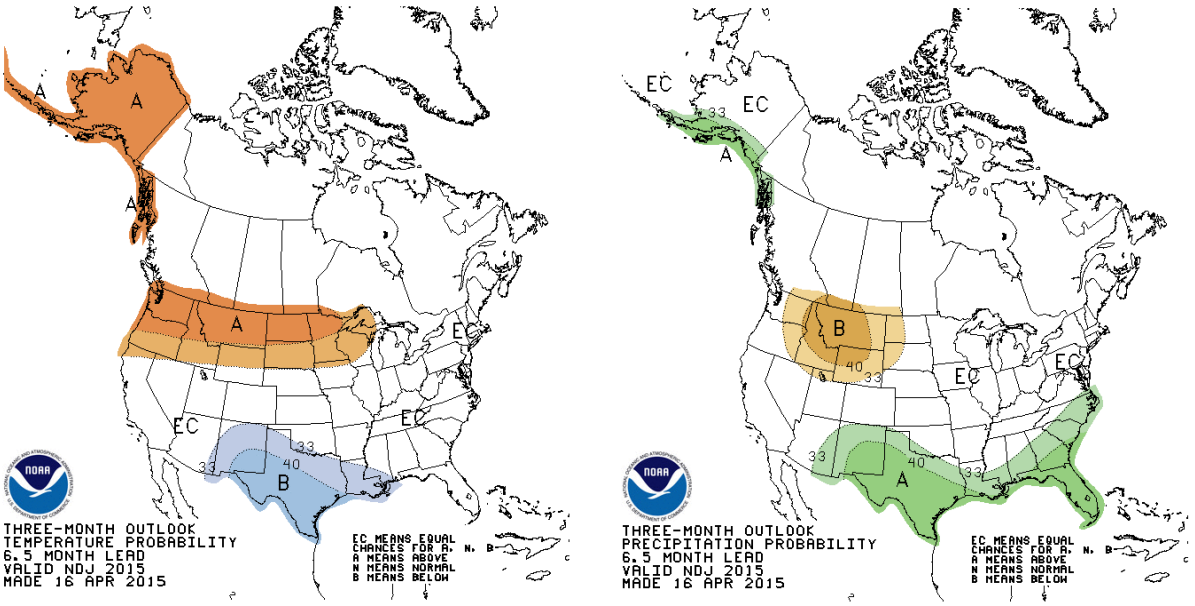


Figure 13. CPC November-December 2015-January 2016 temperature and precipitation outlooks.

May 2015 Calendar Year Runoff Forecast

The May 1, 2015 forecast for runoff above Sioux City is **19.3 MAF** (76% of normal). Above Gavins Point Dam, the forecast is **17.8 MAF** (77% of normal). May's runoff forecast is about 1 MAF less than the April forecast. April runoff in the upper Missouri Basin was 52% of normal due to well below average precipitation in the upper Basin and continuing drought conditions. The forecast for May-July runoff into Fort Peck and Garrison is expected to be only 60% of average. This is due to less than average accumulations of mountain snowpack, which peaked in early March, about a month earlier than normal. The runoff into the lower 4 reaches is also expected to be much less than average during May-July. 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 fairly large and ranges from the 23.6 MAF (94% of normal) upper basic forecast to the 15.5 MAF (62% of normal) lower basic forecast.

For comparison, the May 1, 2015 USDA NRCS Missouri River Basin water supply forecasts are provided on pages 18 and 19. The water supply forecasts represented by the 50%-exceedance category indicate runoff volumes are forecast to be much lower than the 30-year average runoff as a percent of normal. For example, the 50%-exceedance May-September runoff volume on the Missouri River at Toston, MT is 740 kAF, which is 42% of the 30-year average runoff volume of 1760 kAF. Similarly, the 50%-exceedance May-September runoff volume on the Bighorn River near St. Xavier, MT is 650 kAF, which is 49% of the 30-year average runoff volume of 1340 kAF. The low water supply forecasts reflect the impacts of early and low peaking mountain snowpack, below normal precipitation accumulations, and warmer than normal temperatures that have occurred throughout the Rocky Mountains since October 1, 2014.

The most important factors influencing the calendar year runoff forecast at this time are the absence of plains snowpack, the rainfall deficit since January 1, the low mountain snowpack, and the CPC's monthly and seasonal temperature and precipitation outlooks.

May-June-July

During the May-June-July period, the mainstem system receives 50% of its annual runoff as a result of mountain snowmelt and spring and summer precipitation. This is the most active period for precipitation in the Missouri River Basin, so runoff can vary significantly as a result of the above or below normal rainfall.

For this 3-month period, the most reliable method for predicting runoff into Fort Peck and Garrison reservoirs is through regression equations that relate mountain snowpack to runoff. The May 1, 2015 mountain snowpack was 68% of average in the reach above Fort Peck and 74% of average in the reach between Fort Peck and Garrison. May-June-July runoff is most accurately forecast using the peak snowpack accumulation. The mountain snowpack peaked on March 9 at 72% of the normal peak above Fort Peck and on March 9 at 78% of the normal peak in the Fort Peck to Garrison reach. Based on the peak snowpack, Fort Peck reach runoff is

forecast to be 1.9 MAF, which is about 54% of normal May-June-July runoff. Fort Peck to Garrison reach runoff is forecast to be 3.65 MAF, which is about 63% of the normal May-June-July runoff.

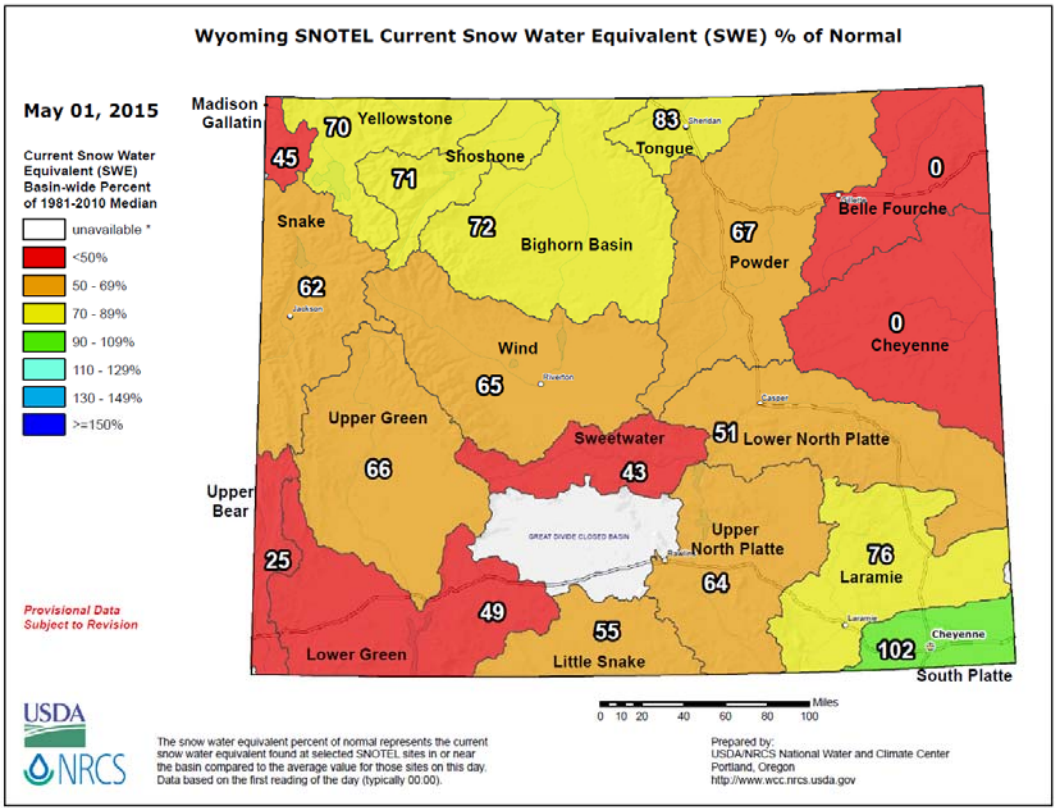
The CPC climate outlooks indicate there are increased chances for above normal temperatures during the May-June-July period, while there are indications precipitation will range from normal to below normal. Taking into consideration these climate forecasts, well below normal runoff is forecast to occur in the Oahe, Fort Randall, Gavins Point and Sioux City reaches through July. The forecast runoff summations above Sioux for May, June and July as a percent of normal are 64%, 55% and 54% of normal, respectively.

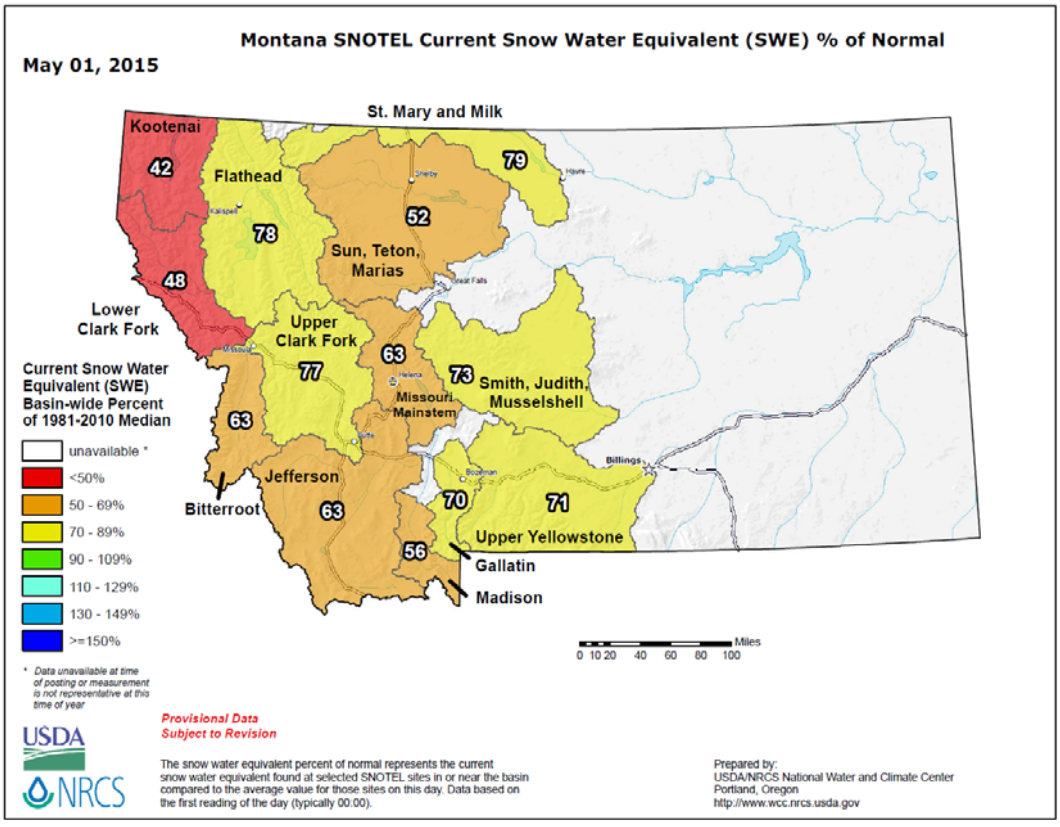
August through December

August runoff in the Fort Peck and Garrison reaches is highly correlated with July runoff, therefore, the August runoff forecasts in the Fort Peck and Garrison reaches are 84% and 90% of normal, respectively.

NOAA's climate outlook indicates increased chances for above normal temperatures in parts of the upper Basin, while there are increased chances for below normal temperatures in the lower Basin through late summer and early fall. With regard to precipitation, chances for above normal precipitation are increased in the Rocky Mountains through October, but the November and December outlook indicates increased chances for below normal precipitation in the upper Basin. With this limited amount of information at this time, late summer and fall runoff is difficult to predict at this time; therefore, near normal runoff is forecast from August through December.

Additional Figures





USDA NRCS National Water & Climate Center Water Supply Forecasts

* - DATA CURRENT AS OF: May 06, 2015 11:55:34 AM
  - Based on May 01, 2015 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	MAY-JUL	67	78	81	73	61	53	86
	MAY-SEP	81	80	97	88	74	65	101
St. Mary R at Int'l Boundary (2)	MAY-JUL	290	73	375	325	255	205	400
	MAY-SEP	345	73	440	385	310	250	470
Lima Reservoir Inflow (2)	MAY-JUL	8.0	14	22	12.9	4.4	1.00	57
	MAY-SEP	8.0	13	22	12.7	4.2	1.00	64
Clark Canyon Reservoir Inflow (2)	MAY-JUL	-20	-31	39	3.7	-35	-51	64
	MAY-SEP	-13.0	-16	50	12.7	-36	-50	83
Jefferson R nr Three Forks (2)	MAY-JUL	137	24	430	255	61	19.0	575
	MAY-SEP	143	23	475	275	70	9.0	635
Hebgen Reservoir Inflow (2)	MAY-JUL	154	50	205	175	133	102	305
	MAY-SEP	220	54	280	245	196	159	405
Ennis Reservoir Inflow (2)	MAY-JUL	265	50	375	310	220	154	530
	MAY-SEP	370	54	500	420	315	235	680
Missouri R At Toston	MAY-JUL	615	42	1080	800	430	149	1480
	MAY-SEP	740	42	1320	972	508	160	1760
Smith R bl Eagle Ck (2)	MAY-JUL	69	78	115	88	50	23	89
	MAY-SEP	81	82	137	104	58	25	99
Gibson Reservoir Inflow (2)	MAY-JUL	240	68	305	265	210	174	355
	MAY-SEP	275	70	345	300	245	200	395
Marias R nr Shelby (2)	MAY-JUL	124	44	270	182	66	10.0	285
	MAY-SEP	121	40	280	186	56	10.0	300
Milk R At Western Crossing	MAY-JUL	10.6	65	23	15.5	5.7	1.00	16.3
	MAY-SEP	12.0	68	26	17.6	6.4	1.00	17.7

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	48	84	55	51	45	40	57
	MAY-SEP	62	86	73	66	57	51	72
Wind R Ab Bull Lake Ck	MAY-JUL	270	63	373	312	228	167	430
	MAY-SEP	290	62	391	331	249	189	465
Bull Lake Ck Nr Lenore	MAY-JUL	102	76	130	113	91	74	135
	MAY-SEP	125	75	159	139	111	91	166
Boysen Reservoir Inflow (2)	MAY-JUL	255	46	500	355	155	7.6	560
	MAY-SEP	295	48	580	410	179	9.1	615
Greybull R nr Meeteetse	MAY-JUL	79	64	101	88	70	57	124
	MAY-SEP	113	66	160	132	94	66	170
Shell Ck nr Shell	MAY-JUL	42	81	56	48	36	28	52
	MAY-SEP	53	84	68	59	47	38	63
Bighorn R at Kane (2)	MAY-JUL	310	40	625	440	184	5.0	770
	MAY-SEP	340	41	690	480	197	5.0	830
NF Shoshone R at Wapiti	MAY-JUL	305	71	385	335	275	225	430
	MAY-SEP	345	71	435	385	310	255	485
SF Shoshone R nr Valley	MAY-JUL	165	83	197	178	152	133	200
	MAY-SEP	191	81	230	205	176	154	235
Buffalo Bill Reservoir Inflow (2)	MAY-JUL	455	72	580	505	405	330	630
	MAY-SEP	515	74	655	570	460	375	700
Bighorn R nr St. Xavier (2)	MAY-JUL	620	49	1010	780	460	225	1260
	MAY-SEP	650	49	1090	830	475	210	1340
Little Bighorn R Nr Hardin	MAY-JUL	67	79	110	84	50	24	85
	MAY-SEP	74	76	123	94	54	25	97
Tongue R Nr Dayton (adj)	MAY-JUL	61	76	85	71	51	37	80
	MAY-SEP	72	78	98	83	61	46	92
Tongue River Reservoir Inflow (2)	MAY-JUL	116	66	205	152	80	26	175
	MAY-SEP	135	68	230	174	96	39	198
NF Powder R nr Hazelton	MAY-JUL	5.5	66	8.1	6.5	4.4	2.8	8.3

	MAY-SEP	6.1	68	8.9	7.2	4.9	3.2	9.0
Powder R at Moorhead	MAY-JUL	63	42	148	97	28	2.0	151
	MAY-SEP	81	48	171	117	45	2.0	170
Powder R nr Locate	MAY-JUL	65	40	174	109	21	1.00	164
	MAY-SEP	82	44	200	131	34	1.00	185

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 2015 Calendar Year Runoff Forecast
June 4, 2015

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.

2015 Calendar Year Forecast Synopsis

The June 1, 2015 forecast for runoff above Sioux City is **22.5 MAF** (89% of normal). Above Gavins Point Dam, we are forecasting **20.9 MAF** (91% of normal). The June runoff forecast is 3.2 MAF greater than the May 1 forecast. The increase in the calendar year runoff forecast is a product of four factors:

1. About 2 times normal precipitation during May over parts of the Garrison, Oahe, and Fort Randall reaches;
2. High tributary flows in these reaches, which are expected to continue for several more weeks;
3. Soil moisture conditions that are now moderately wet in Wyoming and western South Dakota, and near-normal in most other regions; and
4. The one- to three-month precipitation outlooks now indicate increased chances for above normal precipitation in the central to northern Rocky Mountains and the plains, especially South Dakota.

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 fairly large and ranges from the 26.8 MAF

(106% of normal) upper basic forecast to the 18.7 MAF (74% of normal) 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 normal (upper basic) and lower than normal (lower basic) is attributed to all 6 reaches for 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 number of forecast months decreases.

May 2015 Runoff

May's runoff was 3.7 MAF (110% of average), significantly higher than the 2.1 MAF we forecast in our May 1 runoff forecast. Oahe's May runoff was 3 times normal and Fort Randall's May runoff was more than 2 times normal.

Current Conditions

Drought Analysis

The drought-like conditions that dominated the upper basin in March and April ended in May. The National Drought Mitigation Center's drought monitor for May 26, 2015 (**Figure 1**), when compared to the drought monitor for April 28, 2015 (**Figure 2**), shows significant contraction of Moderate (D1) and Severe (D2) drought conditions in North Dakota, South Dakota and Nebraska. On the contrary, Abnormally Dry (D0) conditions have developed in northwest and eastern Montana. The U.S. Monthly Drought Outlook in **Figure 3** indicates that there will be very limited change to drought conditions in the Missouri River Basin and possibly some drought removal in eastern South Dakota and northeast Nebraska from May 21 to August 31, 2015.

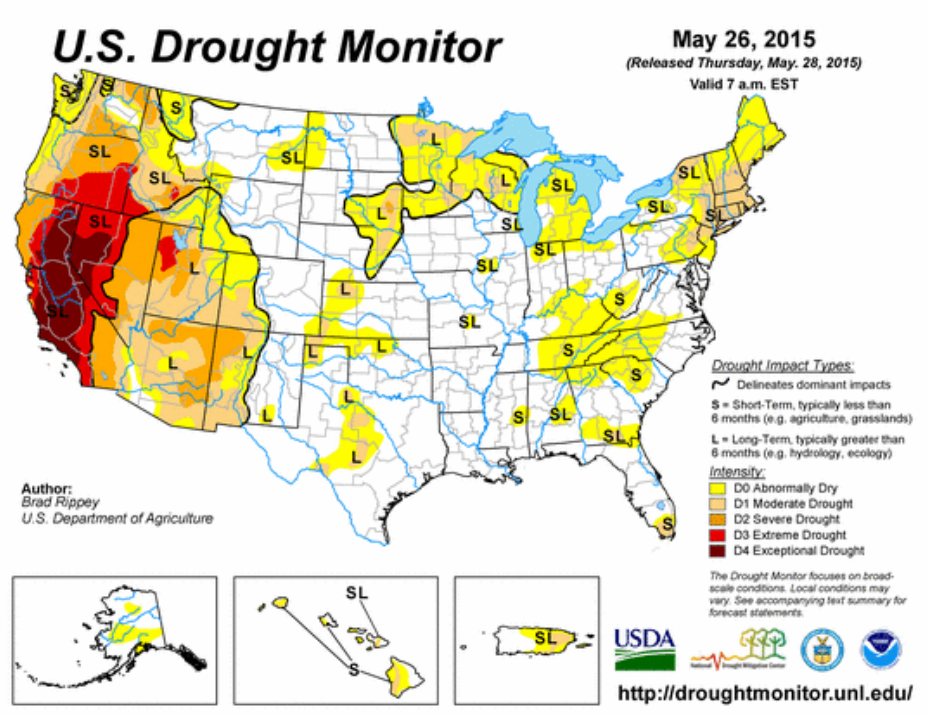


Figure 1. National Drought Mitigation Center U.S. Drought Monitor for May 26, 2015.

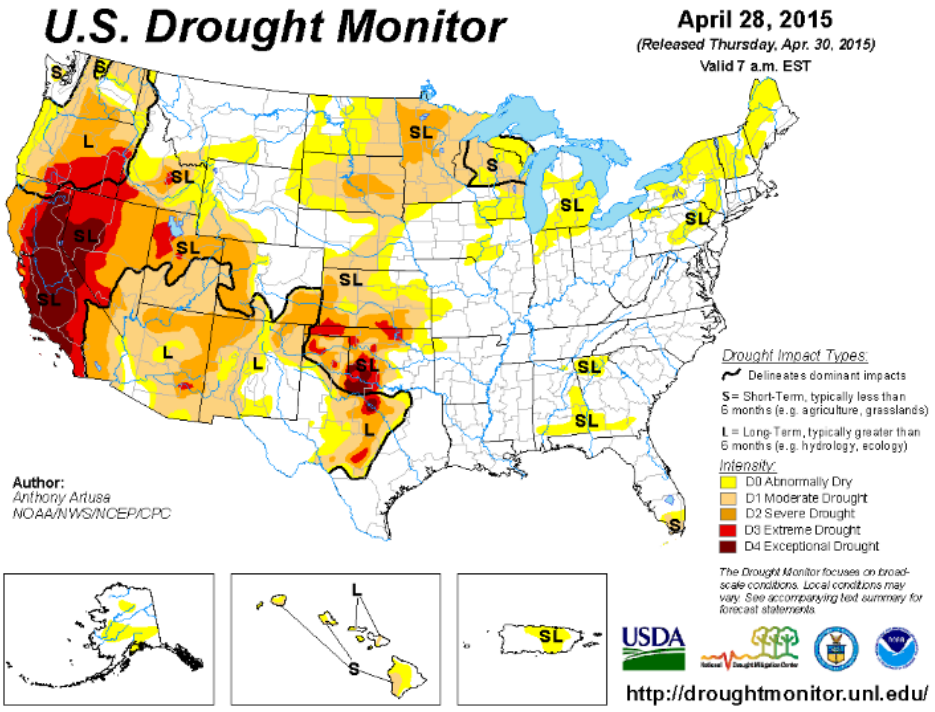


Figure 2. National Drought Mitigation Center U.S. Drought Monitor for April 28, 2015.

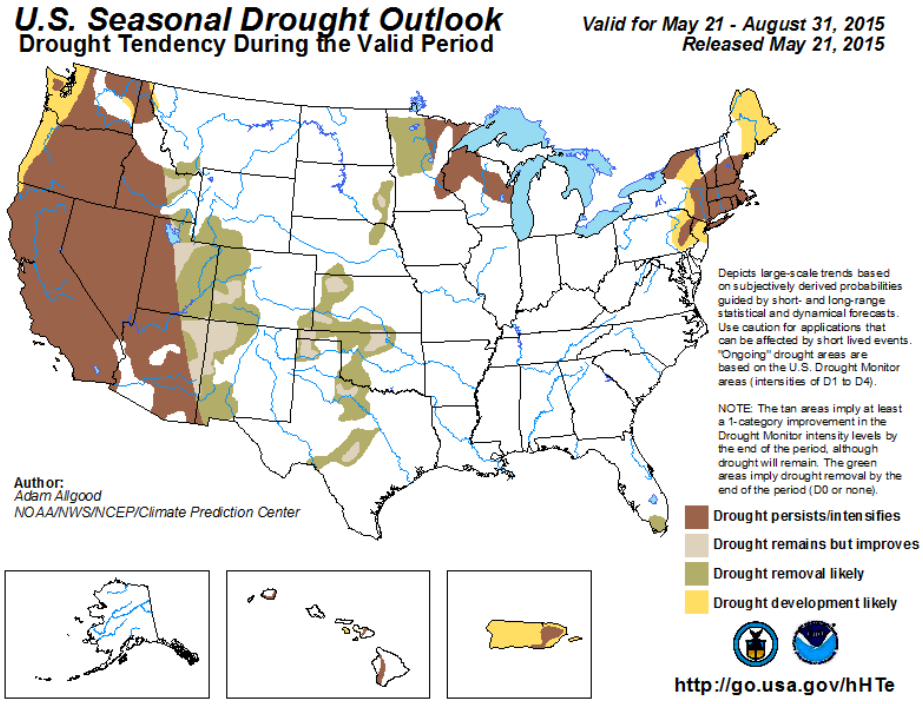


Figure 3. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

May precipitation accumulations are shown in **Figure 4** as both inches of precipitation and percent of normal monthly precipitation. May precipitation was well above normal in locations in southwest Montana, Wyoming, Colorado, western Nebraska, much of South Dakota, and significant portions of southern and eastern North Dakota. Many of these areas received greater than 200 percent of normal precipitation. Furthermore, precipitation in the lower basin was above normal in eastern Nebraska, western Iowa and western Missouri.

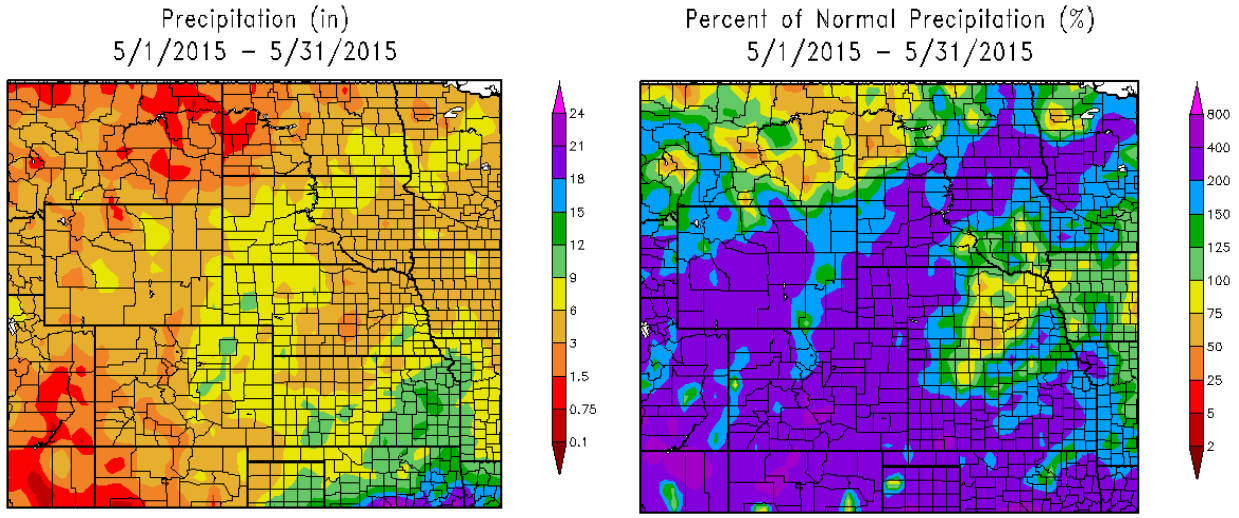


Figure 4. May 2015 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

March-April-May precipitation accumulations are shown in **Figure 5** as both inches and percent of normal precipitation. The three-month accumulation reveals that precipitation accumulations are still below normal in portions of Montana, western North Dakota, eastern South Dakota, northwest Iowa and eastern Nebraska. Three-month accumulations are well above normal in Wyoming, western Nebraska, western South Dakota and southeast North Dakota.

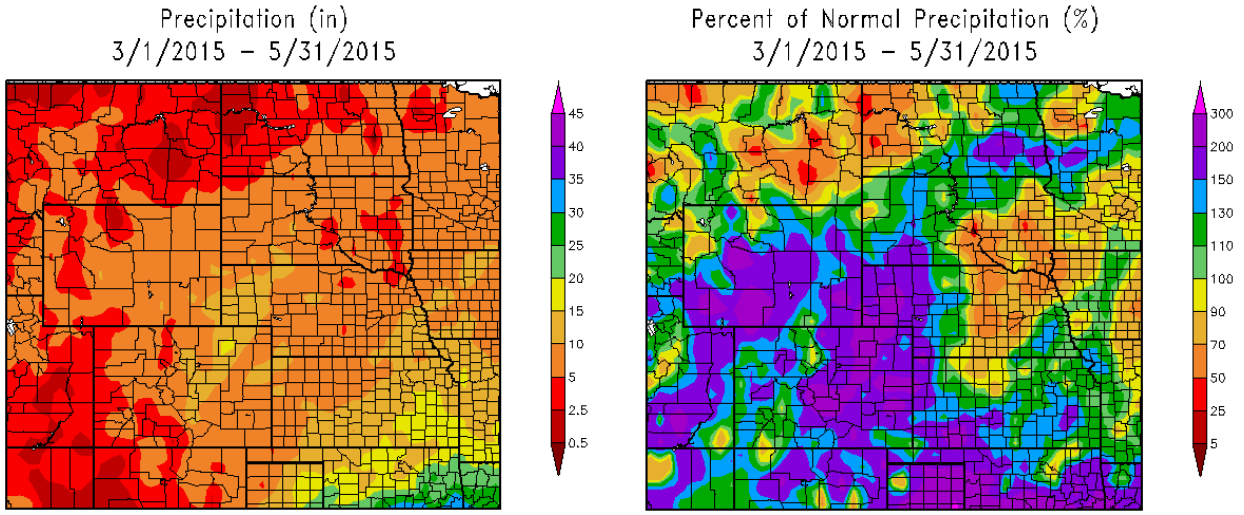


Figure 5. March 1, 2015 – May 31, 2015 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Temperature

May temperature departures from normal in degrees Fahrenheit (deg F) are shown in **Figure 6**. May temperatures in the upper Basin were well below normal ranging from 1 to 5 degrees below normal in most areas. Three-month (March-April-May) temperature departures are also shown in **Figure 6**. Although May temperatures have been below normal, March-April-May temperatures have ranged from 1 to 4 degrees above normal.

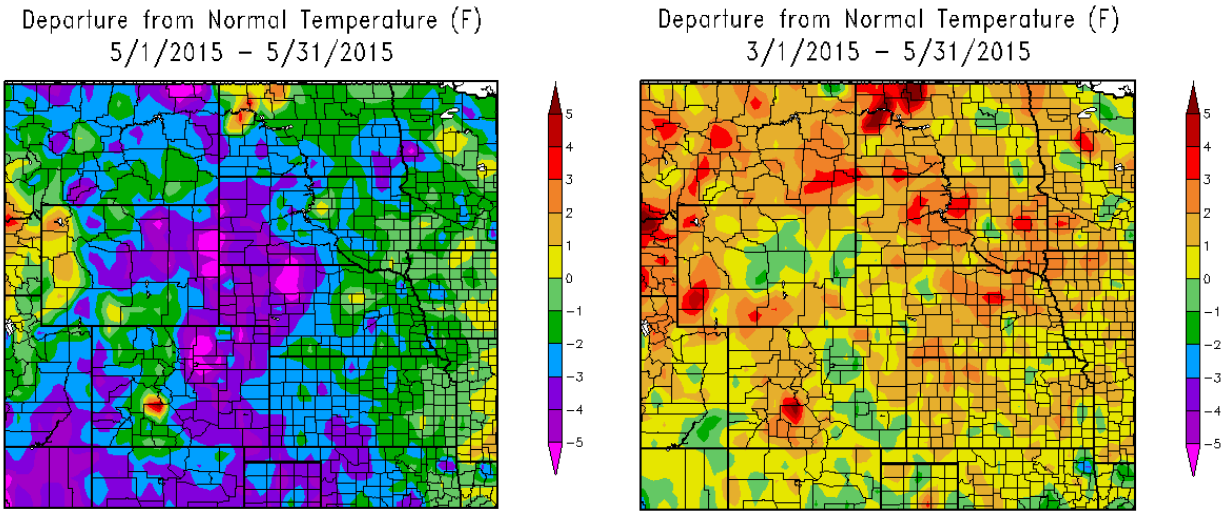


Figure 6. May 2015 and March – May 2015 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

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 monthly runoff.

Figure 7 shows the NOAA NLDAS ensemble mean soil moisture percentiles on May 31, 2015 for the total modeled soil column, which is about 2 meters. The NLDAS soil moisture depiction is an average value for the soil moisture column. The average soil moisture in **Figure 7** indicates above normal soil moisture conditions throughout much of the upper Basin. Soil moisture is ranges from the 70th to 98th percentile. The wettest areas where soil moisture is greater than the 98th percentile include western Nebraska, Wyoming and portions of central Montana. Soil moisture conditions are also much wetter than normal (80th to 98th percentile) in western South Dakota. Soil moisture conditions in the eastern Dakotas and portions of eastern Nebraska were still drier than normal as of May 31.

The Ensemble Mean current total column soil moisture anomaly for the contiguous U.S. on May 31, 2015 is shown in **Figure 8**. These anomalies represent soil moisture averaged over the entire 2-meter soil column, so they do not reflect differences in soil moisture content at various depths. According to the modeled estimate, soil moisture anomalies in the western Dakotas, Montana and western Wyoming ranged from at least 25 – 150 mm (0.98 – 5.91 inches) above normal.

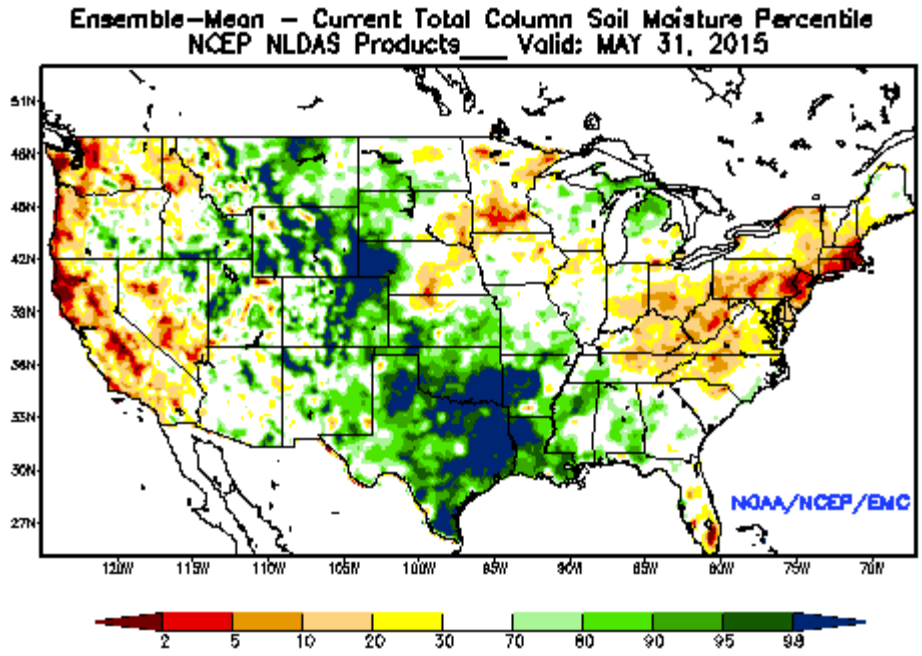


Figure 7. Total Column Soil Moisture Percentile on May 31, 2015. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

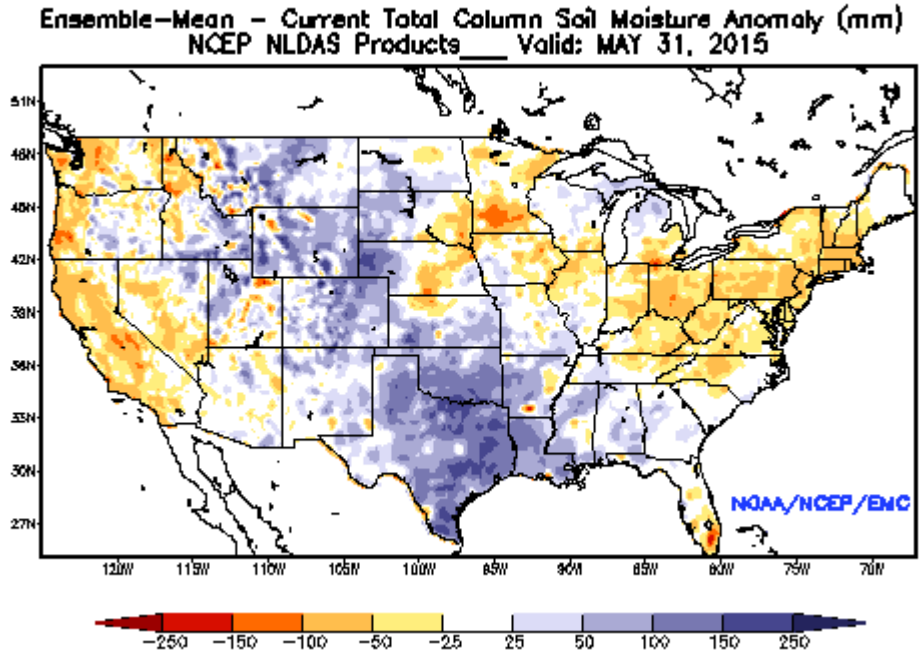


Figure 8. Calculated Soil Moisture Anomaly (mm) on May 31, 2015. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

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 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 greater than average runoff from an average mountain snowpack this year due to wetter than normal soil moisture conditions.

Figure 9 includes time series plots of the average mountain SWE beginning on October 1, 2014 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 **June 1, 2015**, the Corps of Engineers computed an average mountain SWE in the headwater basin above Fort Peck Dam of 2.3 inches, which is 37% of the June 1 average based on the 1981-2010 average SWE for the Fort Peck basin. In the subbasin between Fort Peck Dam and Garrison Dam, the Corps computed an average mountain SWE of 3.7 inches, which is 60% of the June 1 average based on the 1981-2010 average SWE for the Fort Peck to Garrison subbasin. Normally, mountain snowpack peaks around April 15. However, the mountain snowpack peaked on March 9 at 11.8 inches (72% of the normal peak) above Fort Peck and on March 9 at 11.1 inches (78% of the normal peak) in the Fort Peck to Garrison reach. The early and well below normal mountain snowpack peak has a significant impact on the low May through July runoff volume forecast.

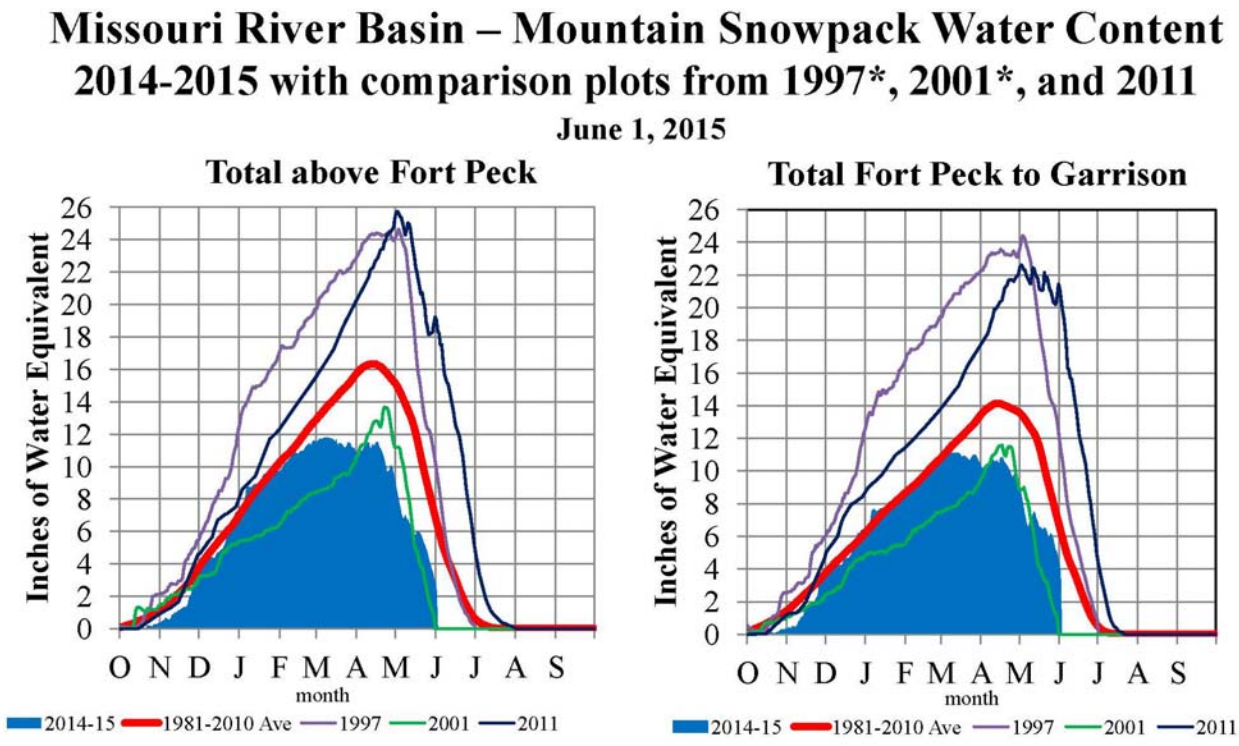


Figure 9. Mountain snowpack water content snow accumulation compared to normal and historic conditions. Corps of Engineers - Missouri River Basin Water Management.

Climate Outlook

ENSO (El Niño Southern Oscillation)

El Niño conditions were declared by the NOAA Climate Prediction Center (CPC) in March 2015. There is approximately 90% chance that El Niño conditions will continue through the Northern Hemisphere summer 2015, and a greater than 80% chance it will last through autumn. The influence of a potential El Niño has been factored into the CPC's temperature and precipitation outlooks looking forward.

Temperature and Precipitation Outlooks

The CPC climate outlook for June 2015 (**Figure 10**) indicates increased chances for above normal temperatures in Montana and North Dakota, increased chances for below normal temperatures in portions of the lower Basin, and equal chances for above normal, normal and below normal temperatures in the region between. With regard to June precipitation, the CPC indicates that there are increased chances for above normal precipitation in most of the upper Basin with the exception of northeast Montana and North Dakota.

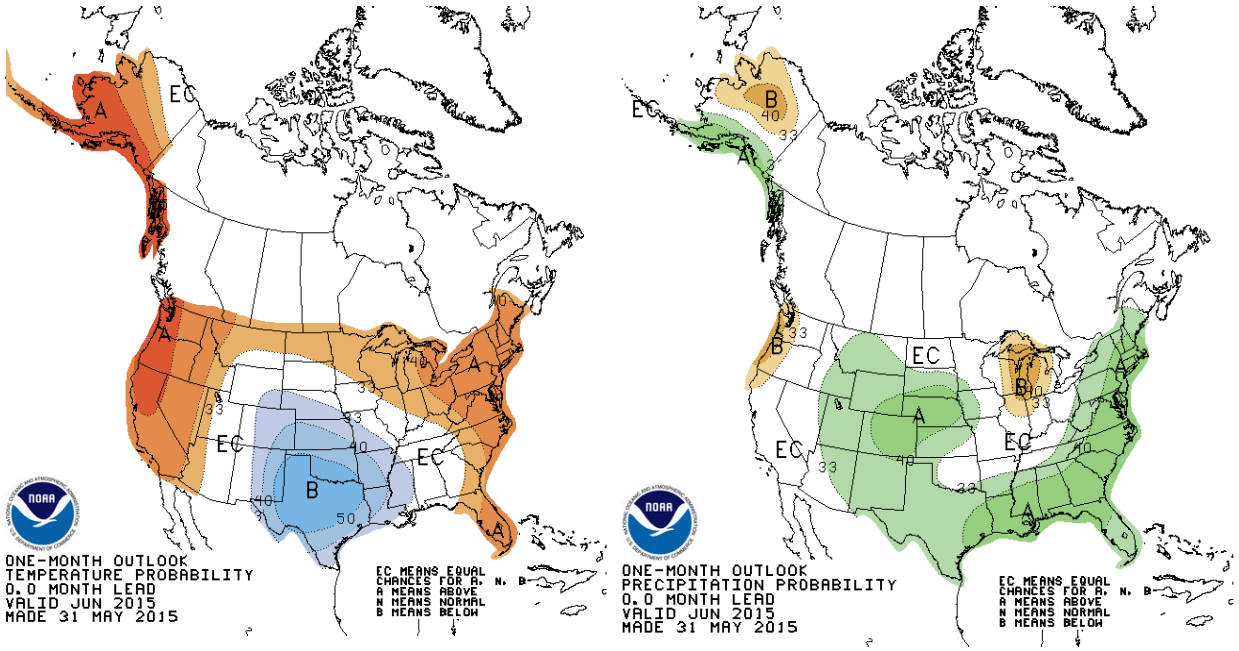


Figure 10. CPC June 2015 temperature and precipitation outlooks.

The CPC's June-July-August outlook (**Figure 11**) calls for increased chances for above normal temperatures in the mountains, but normal temperatures in the plains and lower Basin. In terms of precipitation, there are increased chances for above normal precipitation in Colorado, Wyoming, and southern Montana. Equal chances of above normal, normal and below normal precipitation are forecasted for northern Montana, the Dakotas, Nebraska, and Iowa.

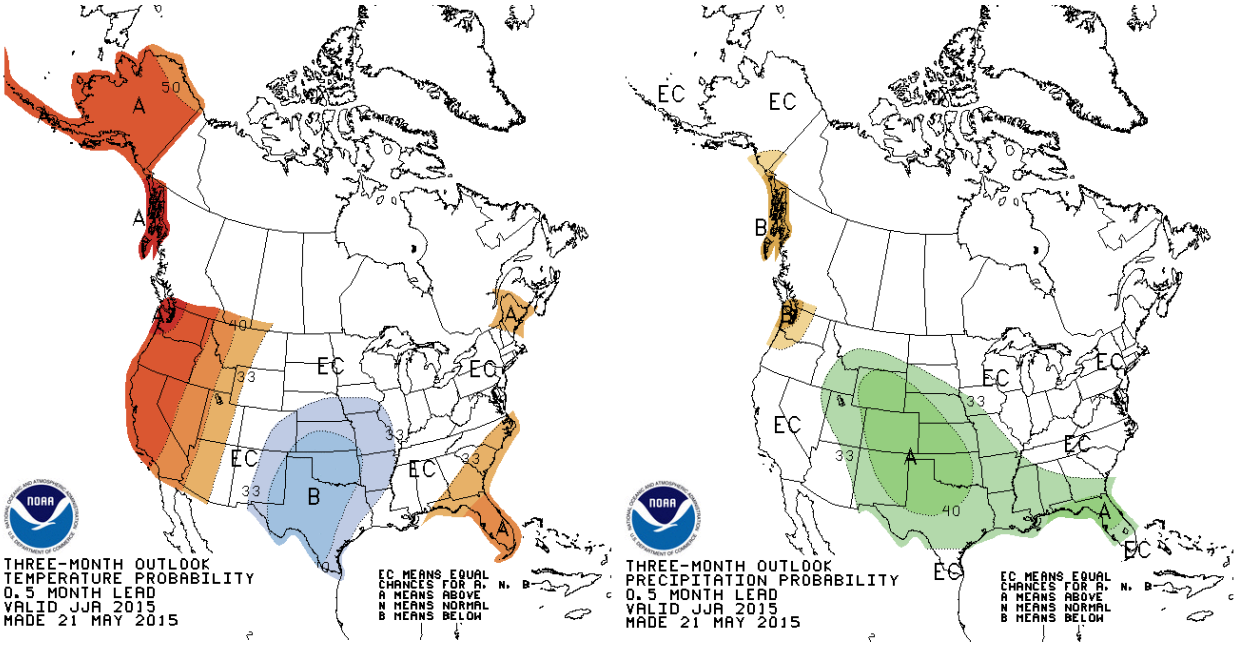


Figure 11. CPC June-July-Aug 2015 temperature and precipitation outlooks.

The September-October-November 2015 CPC temperature outlook (**Figure 12**) indicates increased chances for cooler conditions in the lower Basin, but increased chances for above normal temperatures in the northern Rockies, Montana and North Dakota. With regard to precipitation there are increased chances for above normal precipitation in the central Rockies, increased chances for below normal precipitation in northwest Montana, and equal chances in the remainder of the upper Basin.

During the December-January-Feburary period, the CPC temperature outlook (**Figure 13**) indicates increased chances for above normal temperatures in Montana, Wyoming, and the Dakotas, while there are equal chances for above normal, normal and below normal temperatures in the southern portion of the Missouri Basin. With regard to precipitation, there are increased changes for below normal precipitation in Montana, northern Wyoming, and western South Dakota. The remainder of the basin has equal chances for above normal, normal and below normal precipitation.

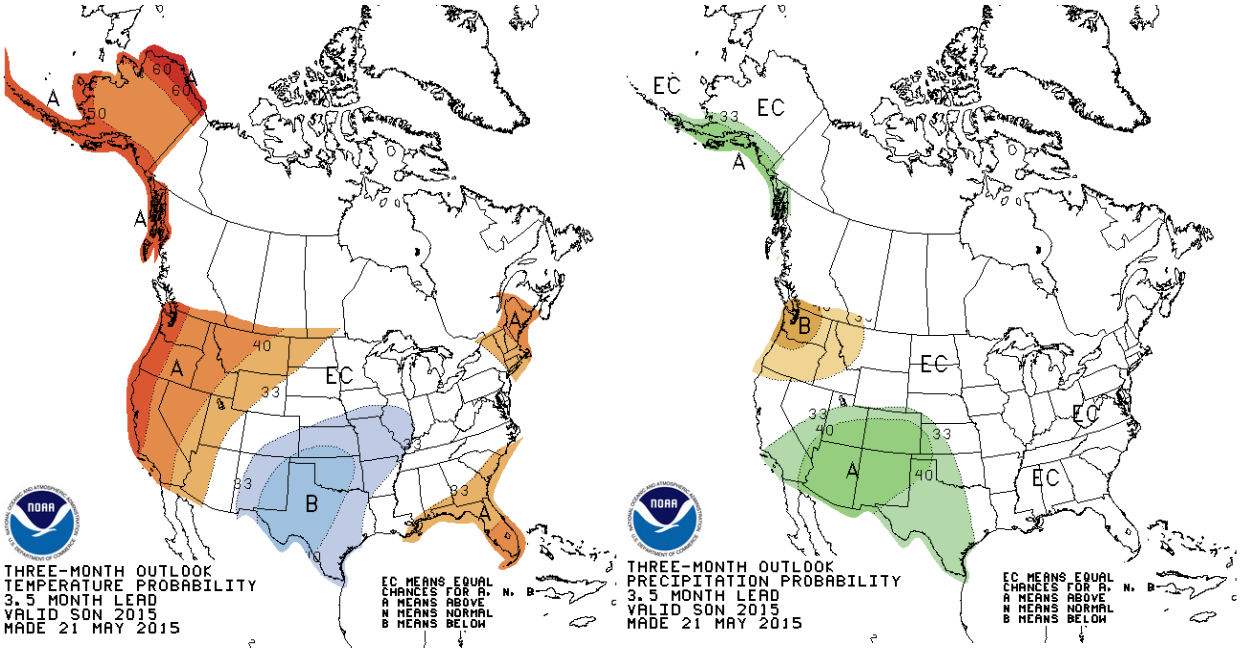


Figure 12. CPC Sep-Oct-Nov 2015 temperature and precipitation outlooks.

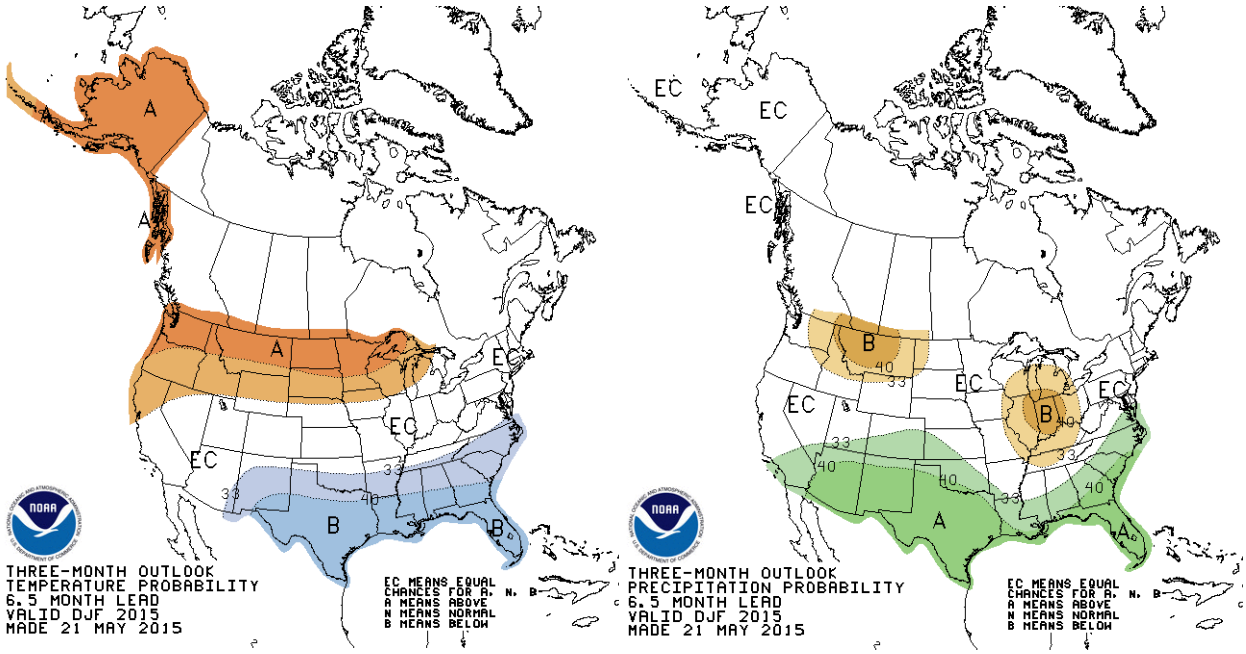


Figure 13. CPC Dec 2015-Jan-Feb 2016 temperature and precipitation outlooks.

June 2015 Calendar Year Runoff Forecast

The June 1, 2015 forecast for runoff above Sioux City is **22.5 MAF** (89% of normal). Above Gavins Point Dam, we are forecasting **20.9 MAF** (91% of normal). The June runoff forecast is 3.2 MAF greater than the May 1 forecast. The increase in the calendar year runoff forecast is a product of four factors:

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 fairly large and ranges from the 26.8 MAF (106% of normal) upper basic forecast to the 18.7 MAF (74% of normal) lower basic forecast.

May 2015 Runoff

May's runoff was 3.7 MAF (110% of average), significantly higher than the 2.1 MAF we forecast in our May 1 runoff forecast. Oahe's May runoff was 3 times normal and Fort Randall's May runoff was more than 2 times normal.

June-July

During the May-June-July period, the mainstem system receives 50% of its annual runoff as a result of mountain snowmelt and spring and summer precipitation. This is the most active period for precipitation in the Missouri River Basin, so runoff can vary significantly as a result of the above or below normal rainfall.

For this 3-month period, the most reliable method for predicting runoff into Fort Peck and Garrison reservoirs is through regression equations that relate mountain snowpack to runoff. The June 1, 2015 mountain snowpack was 37% of average in the reach above Fort Peck and 60% of average in the reach between Fort Peck and Garrison. May-June-July runoff is most accurately forecast using the peak snowpack accumulation. The regression equations may also be modified using observed and forecast temperature and precipitation in the Fort Peck and Garrison reaches. Based on the peak snowpack with adjustments for temperature and precipitation, Fort Peck reach runoff is forecast to be about 59% of normal during June and July. Fort Peck to Garrison reach runoff is forecast to be about 70% of normal in June and 63% of normal in July.

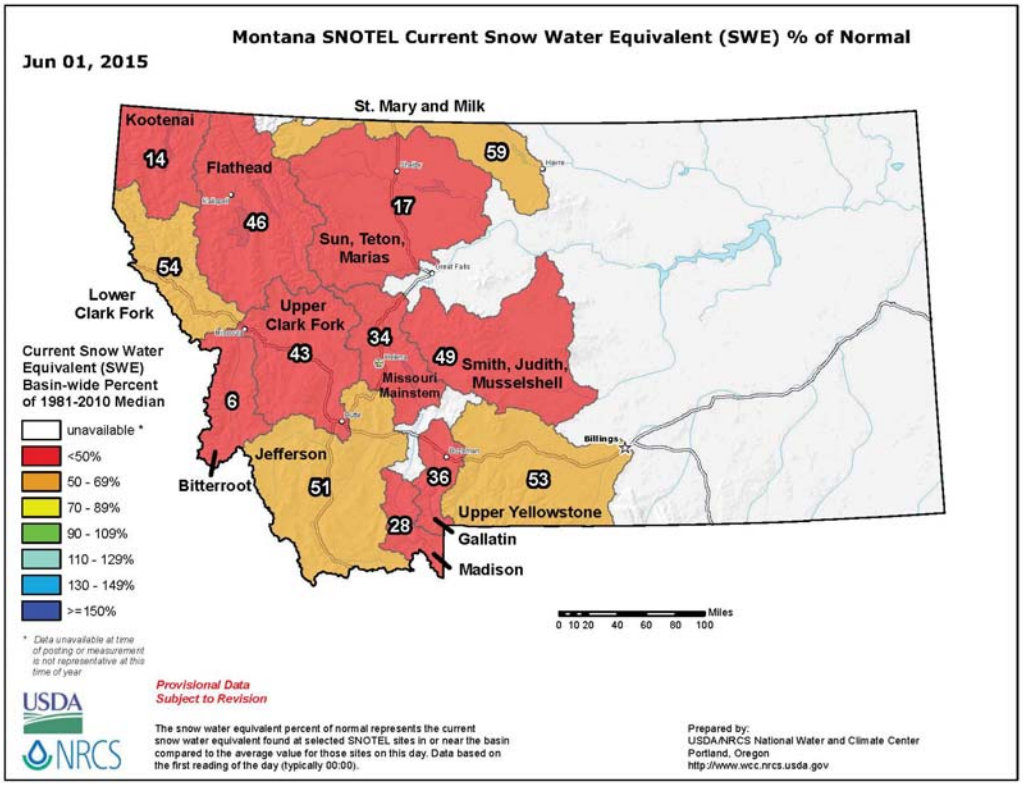
Since May runoff in the Oahe reach was about 3 times normal and runoff in the Fort Randall reach was about 2 times normal, above normal runoff is expected to continue in these reaches during June, given the wet soil moisture conditions and the CPC precipitation outlook for above normal precipitation in June. Runoff is also expected to be above normal in July. Runoff in the Gavins Point and Sioux City reaches are expected to be below normal in June and July.

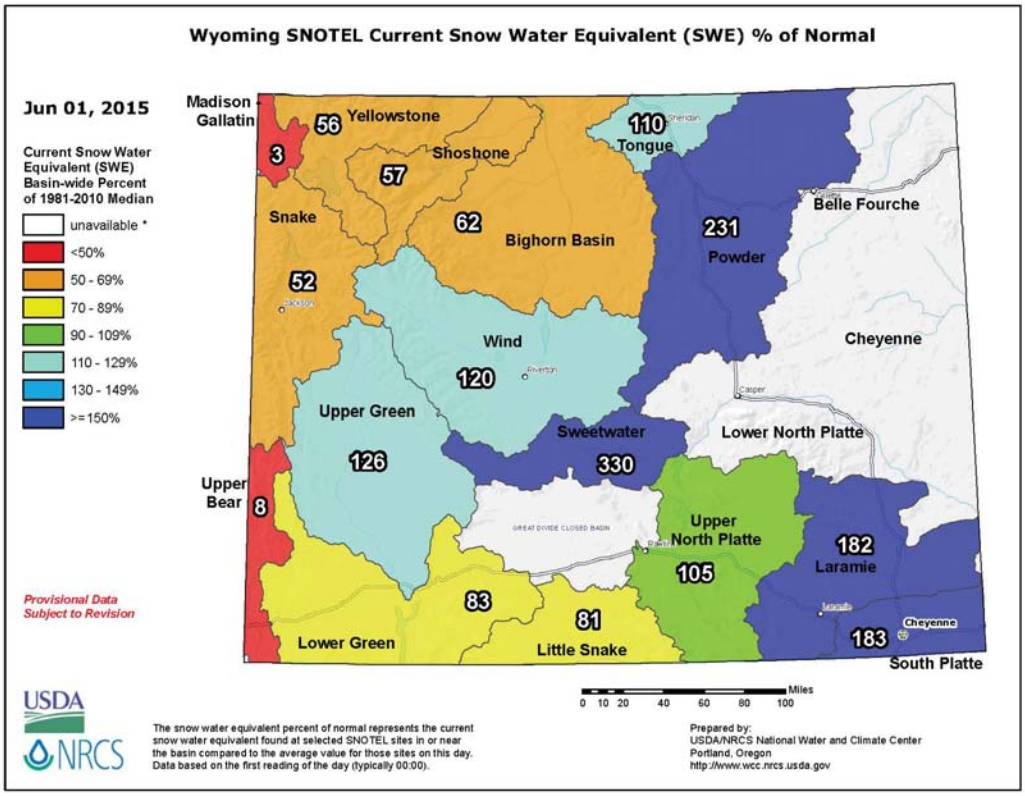
August through December

August runoff in the Fort Peck and Garrison reaches is highly correlated with July runoff, therefore, the August runoff forecasts in the Fort Peck and Garrison reaches are 84% and 90% of normal, respectively.

NOAA's climate outlook indicates increased chances for above normal temperatures in parts of the upper Basin, while there are increased chances for below normal temperatures in the lower Basin through late summer and early fall. With regard to precipitation, chances for above normal precipitation are increased in the Rocky Mountains and high plains August, but from September through November, equal chances for much of the upper Basin. Above normal runoff is forecast for the Oahe and Fort Randall reaches in August, though returning to normal in September. With the amount of accurate forecast information available for late summer and fall at this time, normal runoff is forecast from September through December.

Additional Figures





USDA NRCS National Water & Climate Center Water Supply Forecasts

* - DATA CURRENT AS OF: June 03, 2015 06:37:07 PM
  - Based on June 01, 2015 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	JUN-JUL	30	54	43	35	25	17.1	56
	JUN-SEP	44	62	59	50	37	29	71
St. Mary R at Int'l Boundary (2)	JUN-JUL	148	54	220	176	120	78	275
	JUN-SEP	192	56	270	225	161	114	345
Lima Reservoir Inflow (2)	JUN-JUL	6.1	20	19.8	11.6	3.2	0.58	31
	JUN-SEP	6.8	17	24	13.9	3.3	1.00	39
Clark Canyon Reservoir Inflow (2)	JUN-JUL	8.2	23	52	26	-9.7	-36	35
	JUN-SEP	24	44	74	44	3.6	-26	55
Jefferson R nr Three Forks (2)	JUN-JUL	166	47	360	245	88	-17.0	355
	JUN-SEP	194	47	430	290	99	-35	415
Hebgen Reservoir Inflow (2)	JUN-JUL	79	44	122	96	62	36	178
	JUN-SEP	147	53	199	168	126	95	280
Ennis Reservoir Inflow (2)	JUN-JUL	149	45	215	176	122	82	330
	JUN-SEP	255	53	335	285	220	169	485
Missouri R at Toston (2)	JUN-JUL	390	41	760	540	240	23	940
	JUN-SEP	570	47	1080	775	365	65	1220
Smith R bl Eagle Ck (2)	JUN-JUL	32	59	65	45	18.0	10.0	54
	JUN-SEP	42	65	88	61	24	12.0	65
Gibson Reservoir Inflow (2)	JUN-JUL	122	58	176	144	100	68	210
	JUN-SEP	163	65	220	186	140	105	250
Marias R nr Shelby (2)	JUN-JUL	24	17	134	68	-5.0	-30	143
	JUN-SEP	25	16	150	76	-5.0	-30	158
Milk R at Western Crossing	JUN-JUL	4.5	71	24	12.5	1.80	0.100	6.3
	JUN-SEP	5.7	80	28	14.8	2.2	0.20	7.1

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	40	85	48	43	37	33	47
	JUN-SEP	55	87	66	59	50	44	63
Wind R ab Bull Lake Ck (2)	JUN-JUL	265	80	360	305	225	169	330
	JUN-SEP	275	75	380	315	230	164	365
Bull Lake Ck nr Lenore (2)	JUN-JUL	107	99	131	117	97	83	108
	JUN-SEP	137	99	169	150	124	105	139
Boysen Reservoir Inflow (2)	JUN-JUL	320	75	505	395	245	135	425
	JUN-SEP	375	77	600	465	280	145	485
Greybull R nr Meeteetse	JUN-JUL	95	99	120	105	85	70	96
	JUN-SEP	141	99	174	154	128	108	142
Shell Ck nr Shell	JUN-JUL	34	97	43	38	30	24	35
	JUN-SEP	45	98	57	50	41	34	46
Bighorn R at Kane (2)	JUN-JUL	460	81	700	555	360	220	570
	JUN-SEP	515	82	815	635	390	210	630
NF Shoshone R at Wapiti	JUN-JUL	225	74	285	250	205	168	305
	JUN-SEP	270	75	345	300	240	199	360
SF Shoshone R nr Valley	JUN-JUL	138	88	164	148	127	112	157
	JUN-SEP	167	88	200	181	154	134	189
Buffalo Bill Reservoir Inflow (2)	JUN-JUL	380	82	485	420	340	275	465
	JUN-SEP	455	85	585	505	400	325	535
Bighorn R nr St. Xavier (2)	JUN-JUL	730	79	1040	855	605	420	920
	JUN-SEP	810	80	1210	975	645	405	1010
Little Bighorn R nr Hardin	JUN-JUL	49	92	77	60	37	19.9	53
	JUN-SEP	60	91	94	74	47	26	66
Tongue R nr Dayton (2)	JUN-JUL	43	88	59	49	37	27	49
	JUN-SEP	55	89	74	63	47	36	62
Tongue River Reservoir Inflow (2)	JUN-JUL	97	88	142	115	79	53	110
	JUN-SEP	118	88	174	141	96	63	134
NF Powder R nr Hazelton	JUN-JUL	4.9	109	7.1	5.8	4.0	2.7	4.5

	JUN-SEP	5.7	110	8.1	6.7	4.7	3.3	5.2
Powder R at Moorhead	JUN-JUL	91	99	145	113	69	37	92
	JUN-SEP	114	104	180	141	87	48	110
Powder R nr Locate	JUN-JUL	101	100	173	130	72	30	101
	JUN-SEP	127	104	215	163	90	36	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 2015 Calendar Year Runoff Forecast
July 8, 2015

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.

2015 Calendar Year Forecast Synopsis

The July calendar year runoff forecast for the Missouri Basin above Sioux City is **26.6 MAF** (**105%** of normal). June runoff was **6.8 MAF** (125% of normal). Observed June runoff was much greater than what was forecast on June 1st due to much greater than normal precipitation that has occurred over the past three months in the Garrison, Oahe and Fort Randall reaches. The total May and June Oahe reach runoff was over **2.1 MAF** (273% of normal), which was near the record high May and June total Oahe reach runoff, which occurred in 1995.

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 29.6 MAF (117% of normal) upper basic forecast to the 23.9 MAF (94% of normal) 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 forecasted for this July 1 forecast (6 months observed/6 months forecast), the range of wetter than normal (upper basic) and lower than normal (lower basic) is attributed to all 6 reaches for 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 number of forecast months decreases.

Current Conditions

Drought Analysis

The drought-like conditions that dominated the upper Basin in March and April ended in May; however, drought conditions have re-appeared in northern and western Montana due to low amounts of precipitation in those areas in June and the low levels of mountain snowpack that occurred this year. The developing drought is shown in the National Drought Mitigation Center's drought monitor for June 30, 2015 (**Figure 1**) and May 26, 2015 (**Figure 2**). While Abnormally Dry (D0) and Moderate Drought (D1) conditions have been alleviated due to June precipitation in eastern South Dakota and central and northern Nebraska, D1 and Severe Drought (D2) conditions have expanded across western and northern Montana. The U.S. Monthly Drought Outlook in **Figure 3** indicates drought development is very likely in western Montana within the Fort Peck reach during July 2015.

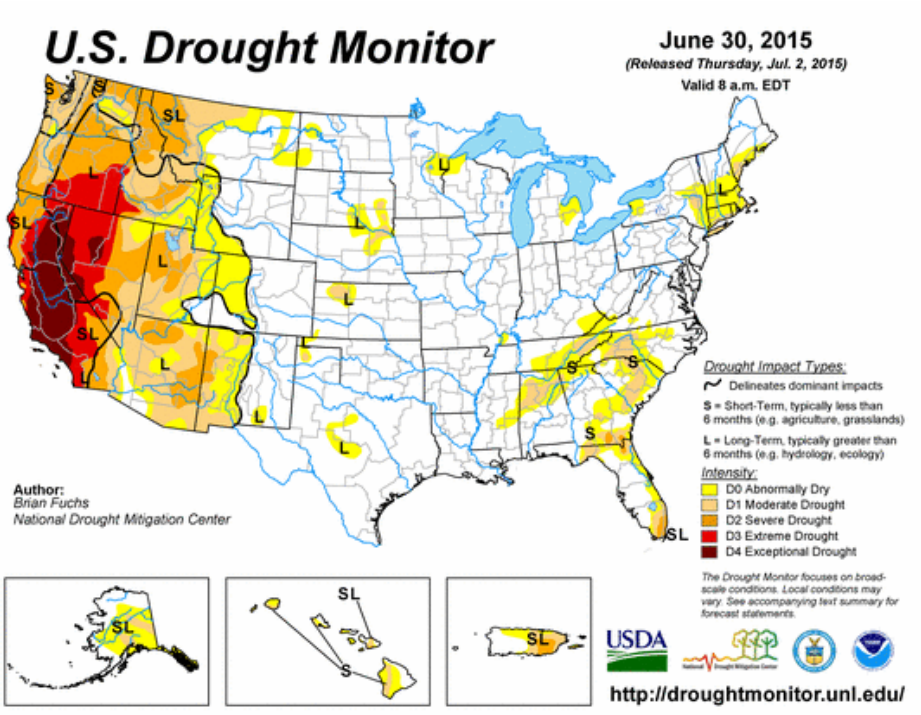


Figure 1. National Drought Mitigation Center U.S. Drought Monitor for June 30, 2015.

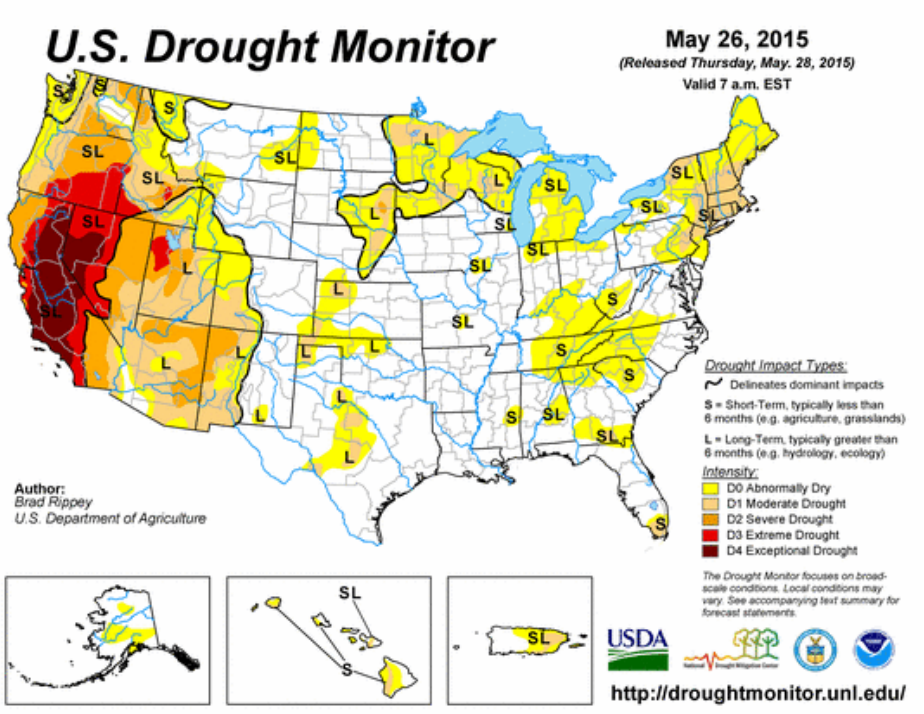


Figure 2. National Drought Mitigation Center U.S. Drought Monitor for May 26, 2015.

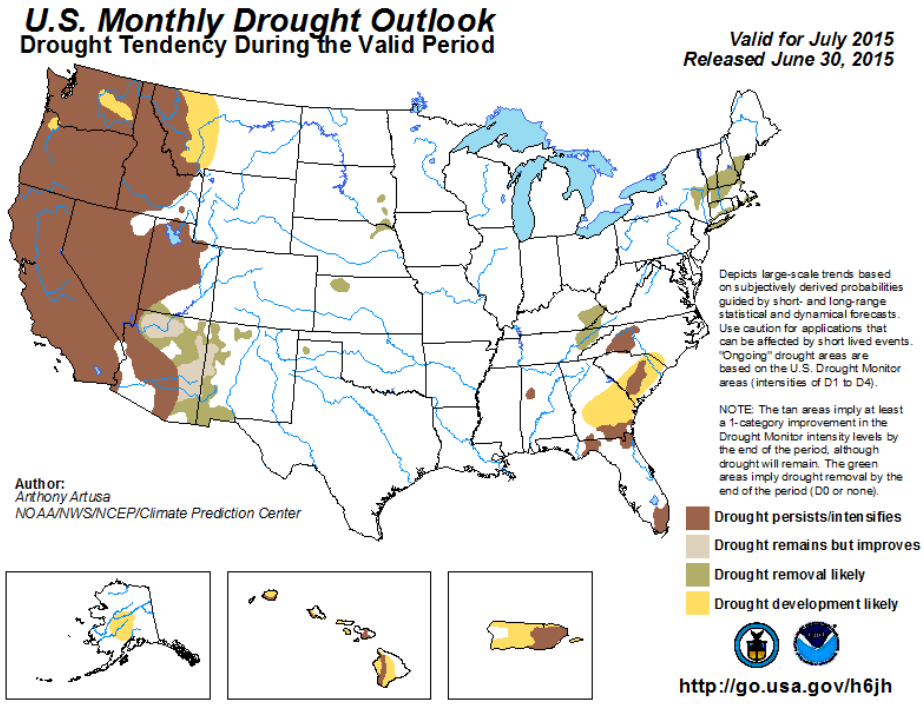


Figure 3. National Drought Mitigation Center U.S. Monthly Drought Outlook.

Precipitation

June precipitation accumulations are shown in **Figure 4** as both inches of precipitation and percent of normal monthly precipitation. Accumulated precipitation in June was well above normal in portions of eastern Montana, northeast Wyoming western North Dakota and western South Dakota. Western South Dakota and the Black Hills received more than 200% of normal precipitation in June. Precipitation accumulations have been well below normal in western and northern Montana.

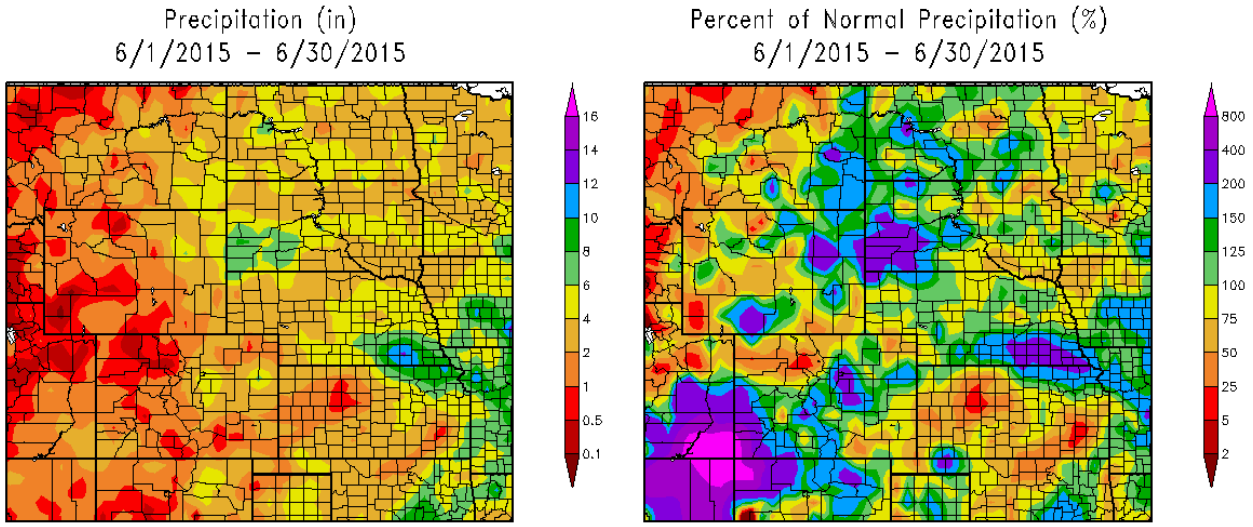


Figure 4. June 2015 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

April-May-June precipitation accumulations are shown in **Figure 5** as both inches and percent of normal precipitation. The three-month accumulation figures reveal that precipitation accumulations have been more than 150 % of normal in Wyoming, western and central South Dakota, southern North Dakota, western Nebraska, and much of the lower Basin. Three-month accumulations are below normal in much of Montana, northern North Dakota, southeast South Dakota, northeast Nebraska and northwest Iowa.

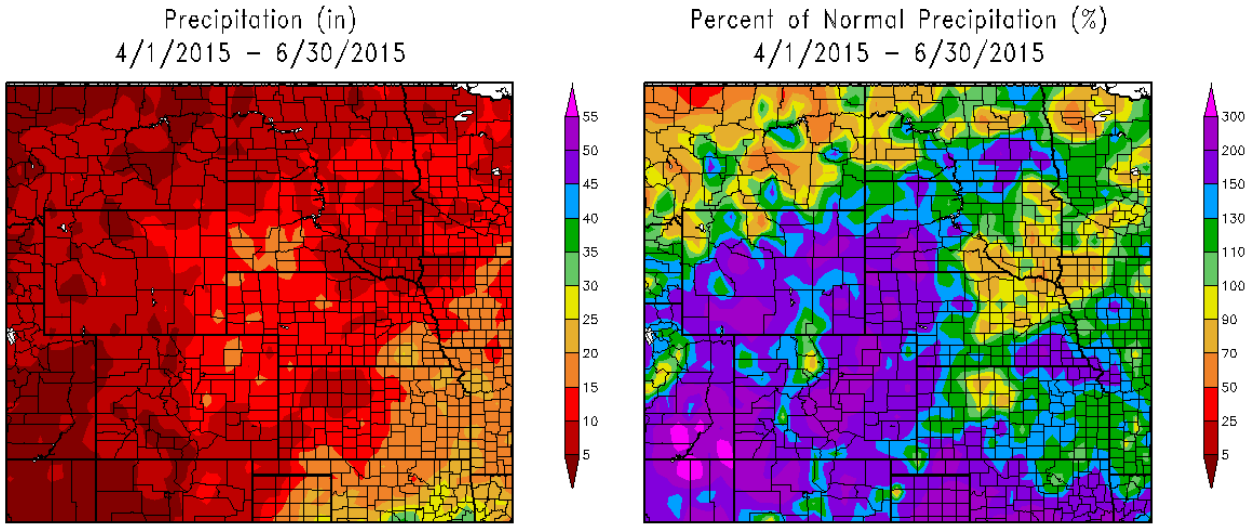


Figure 5. April – June 2015 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Temperature

June temperature departures from normal in degrees Fahrenheit (deg F) are shown in **Figure 6**. June temperatures in the upper Basin were 2 to 8 deg F above normal, especially in Montana and Wyoming. Temperatures in the lower Basin have been about normal in June. Three-month (April-May-June) temperature departures, shown in **Figure 6**, indicate above normal temperatures in the Fort Peck and Garrison reaches, below normal temperatures in the Oahe and Fort Randall reaches, and near normal temperatures in the remainder of the upper Basin.

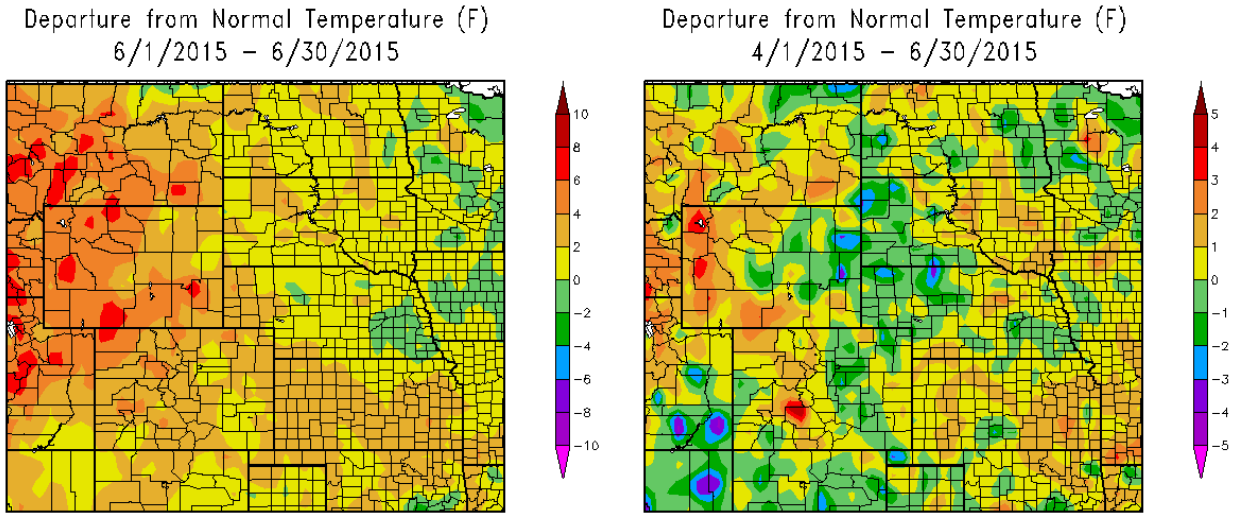


Figure 6. June 2015 and April– June 2015 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

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 monthly runoff.

Figure 7 shows the NOAA NLDAS ensemble mean soil moisture percentiles on July 3, 2015 for the total modeled soil column, which is about 2 meters. The NLDAS soil moisture depiction is an average value for the soil moisture column. **Figure 7** indicates above normal soil moisture conditions throughout much of the upper Basin. Soil moisture is above the 70th in most regions except in western Montana, eastern North Dakota and eastern South Dakota where it is generally below the 30th percentile. The wettest areas where soil moisture is greater than the 98th percentile include small portions of Wyoming and a region extending from the Black Hills of South Dakota into western Nebraska and eastern Wyoming. Although soil moisture conditions are still very wet in the upper Basin, soil moisture has declined since May 31 (**Figure 8**) due to lower precipitation accumulations in June.

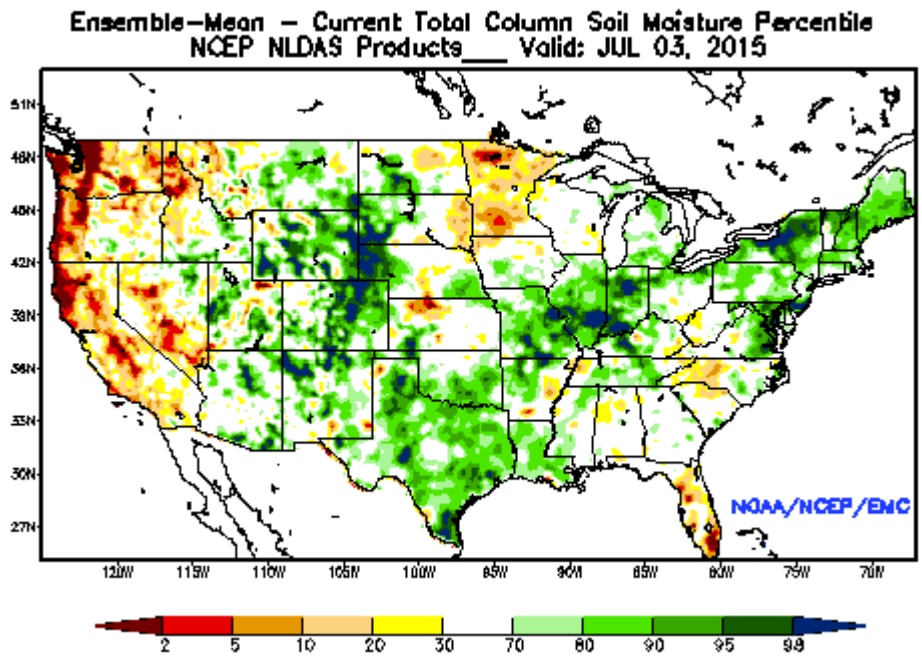


Figure 7. Total Column Soil Moisture Percentile on July 3, 2015. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

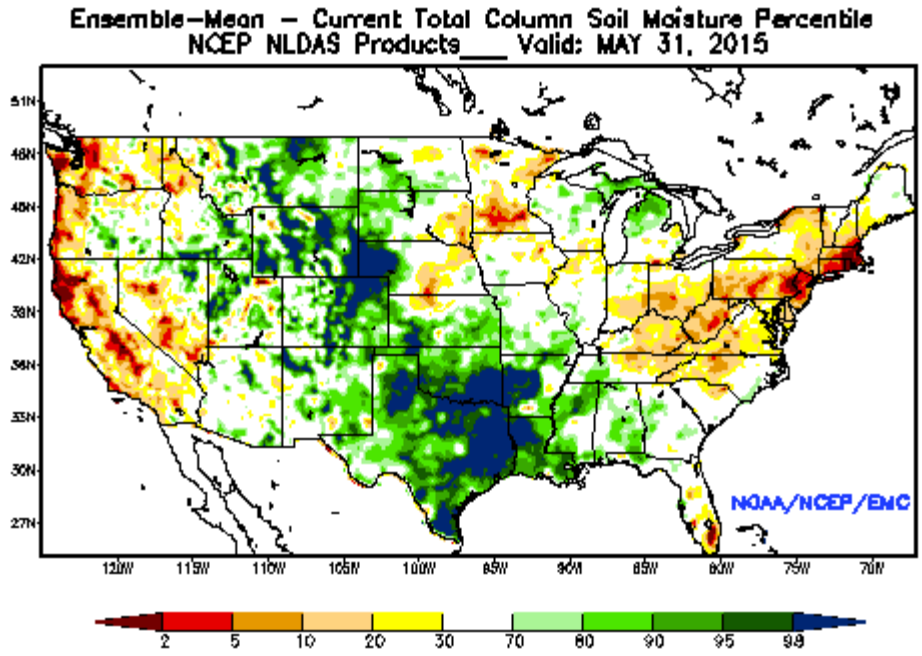


Figure 8. Total Column Soil Moisture Percentile on May 31, 2015. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

Streamflow Conditions

Missouri Basin streamflow conditions represented as percentile classes on July 7, 2015 are shown in **Figure 9**. These conditions are based on the ranking of the July 7, 2015 daily streamflow versus the historical record of streamflow for that date. Streamflow conditions have been above normal in the 75th to 90th percentile category throughout much of eastern Wyoming, southeast Montana and the Dakotas. Streamflow is still very high, exceeding the 90th percentile, in southwest South Dakota and portions of the lower Basin. In contrast, streamflow is normal (25th to 75th percentile) to below normal (10th to 24th percentile) in western and central Montana and western Wyoming due to the lack of plains snowpack this year. Some streamgages in these areas have fallen below the 10th percentile ranking.

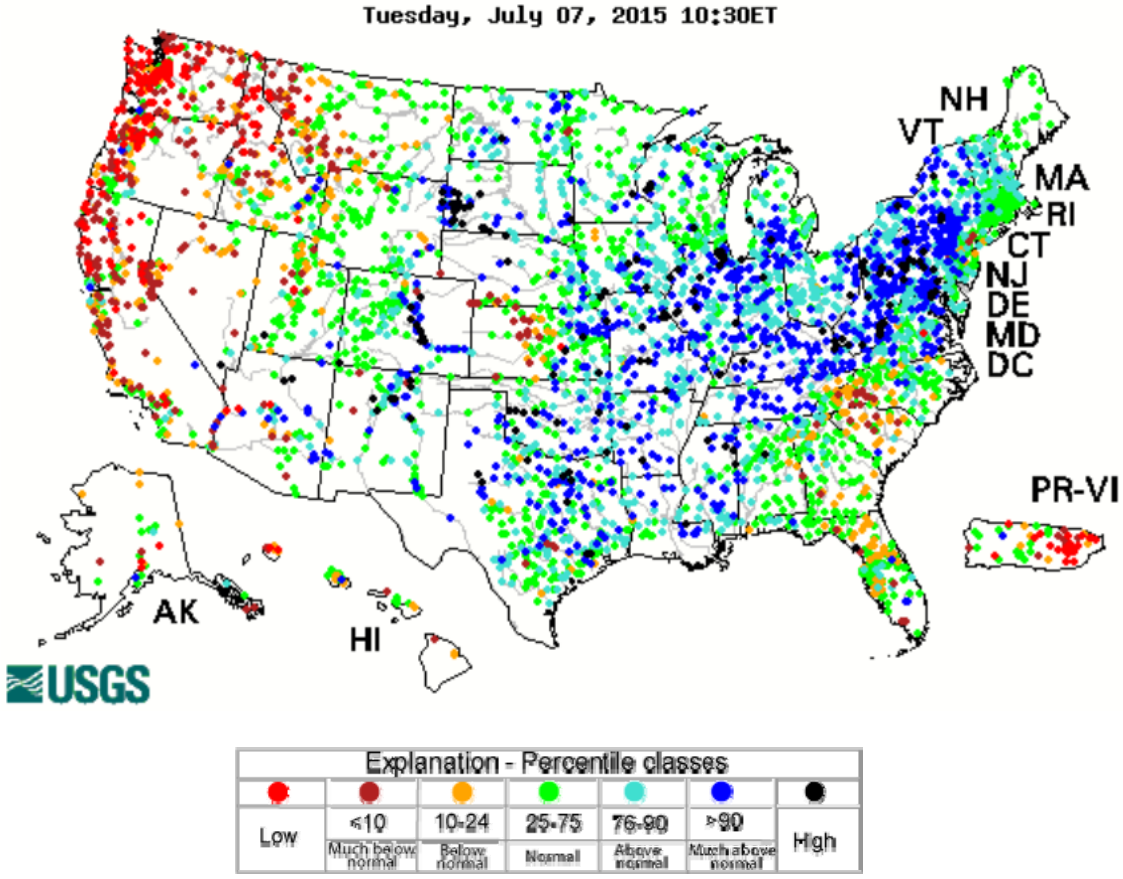


Figure 9. USGS Streamflow Conditions as a Percentile of Normal in the Missouri River Basin as of July 7, 2015. Source: USGS. http://waterwatch.usgs.gov/index.php

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 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 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, 2014 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 **July 1, 2015**, the Corps of Engineers computed an average mountain SWE of less than 0.1 inch in the headwater basin above Fort Peck Dam. In the subbasin between Fort Peck Dam and Garrison Dam, the Corps computed an average mountain SWE of less than 0.1 inch. The mountain snowpack peaked on March 9 at 11.8 inches (72% of the normal peak) above Fort Peck and on March 9 at 11.1 inches (78% of the normal peak) in the Fort Peck to Garrison reach. Normally, mountain snowpack peaks around April 15. Compared to the 2001 snowpack, the 2015 peaks are lower and earlier. The early and well below normal mountain snowpack peak was a major factor in forecasting July runoff into Fort Peck and Garrison.

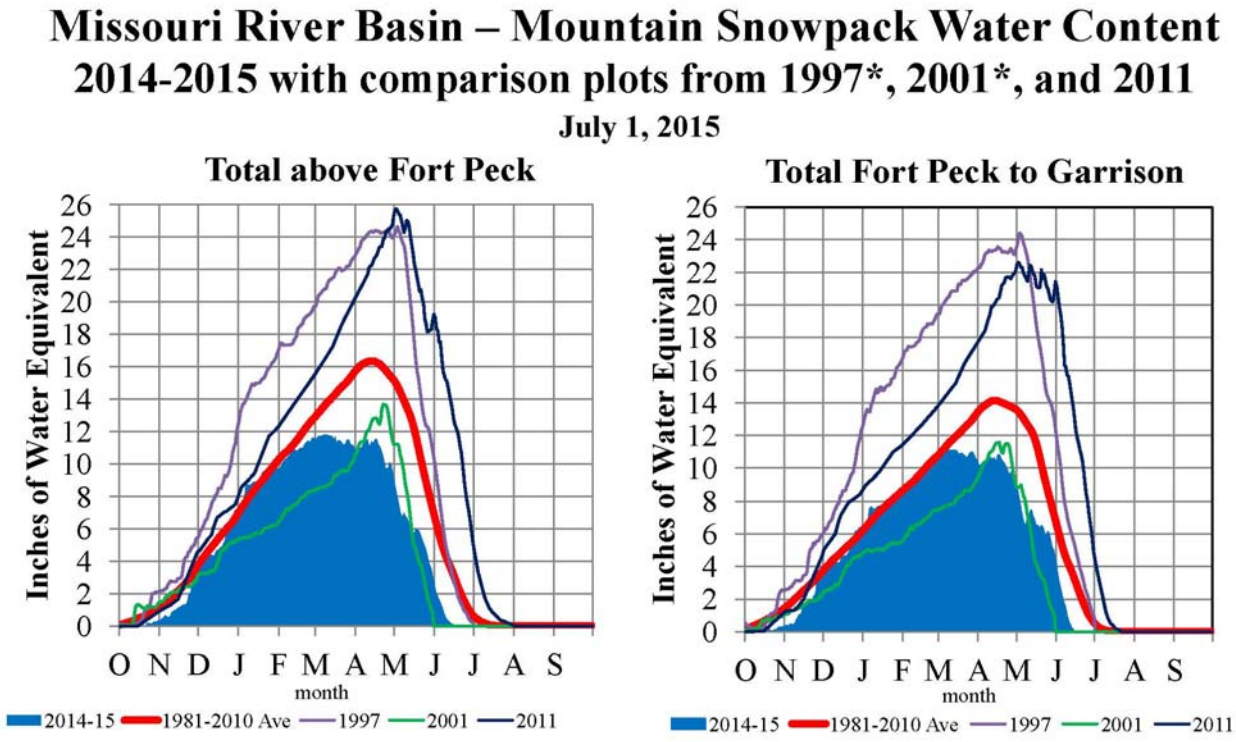


Figure 10. Mountain snowpack water content snow accumulation compared to normal and historic conditions. Corps of Engineers - Missouri River Basin Water Management.

Climate Outlook

ENSO (El Niño Southern Oscillation)

El Niño conditions were declared by the NOAA Climate Prediction Center (CPC) in March 2015. According to the CPC, there is a greater than 90% chance El Niño conditions will continue in the fall and an 85% chance it will continue into the 2015-2016 winter.

Discussions with Dr. Dennis Todey, South Dakota State Climatologist, and Mr. Doug Kluck, Central Region Climate Services Director for NOAA, were conducted to gain a better understanding of the possible impacts that El Niño may have on the late summer, fall and early winter temperature and precipitation patterns in the Missouri River Basin. The possible impact of El Niño has been factored into the climate outlooks described below.

Temperature and Precipitation Outlooks

The CPC climate outlook for July 2015 (**Figure 11**) indicates increased chances for above normal temperatures in western Montana, while there are increased chances for below normal temperatures in eastern Wyoming, the Dakotas, and the entire lower Basin. With regard to July precipitation, the CPC indicates that there are increased chances for above normal precipitation in the lower Basin, most of Wyoming and a majority of South Dakota. There is an increased chance for below normal precipitation in northwest Montana, but equal chances for above normal, normal and below normal precipitation in the remainder of Montana and North Dakota.

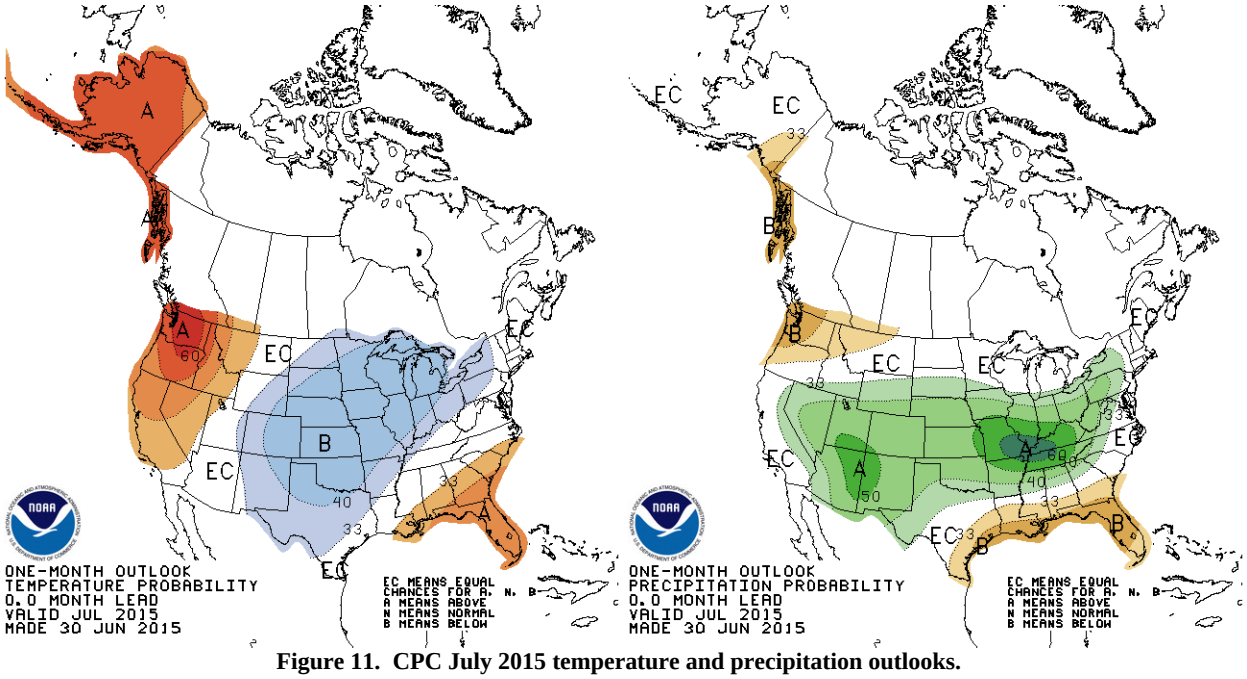


Figure 11. CPC July 2015 temperature and precipitation outlooks.

The CPC's July-August-September outlook (**Figure 12**) calls for increased chances for above normal temperatures in most of Montana and western Wyoming, equal chances in the remainder of the upper Basin, and increased chances for below normal temperatures in the lower Basin. In terms of precipitation, there are increased chances for above normal precipitation in the Missouri Basin with the exception of central and northern Montana, and North Dakota where there are equal chances for above normal, normal and below normal precipitation.

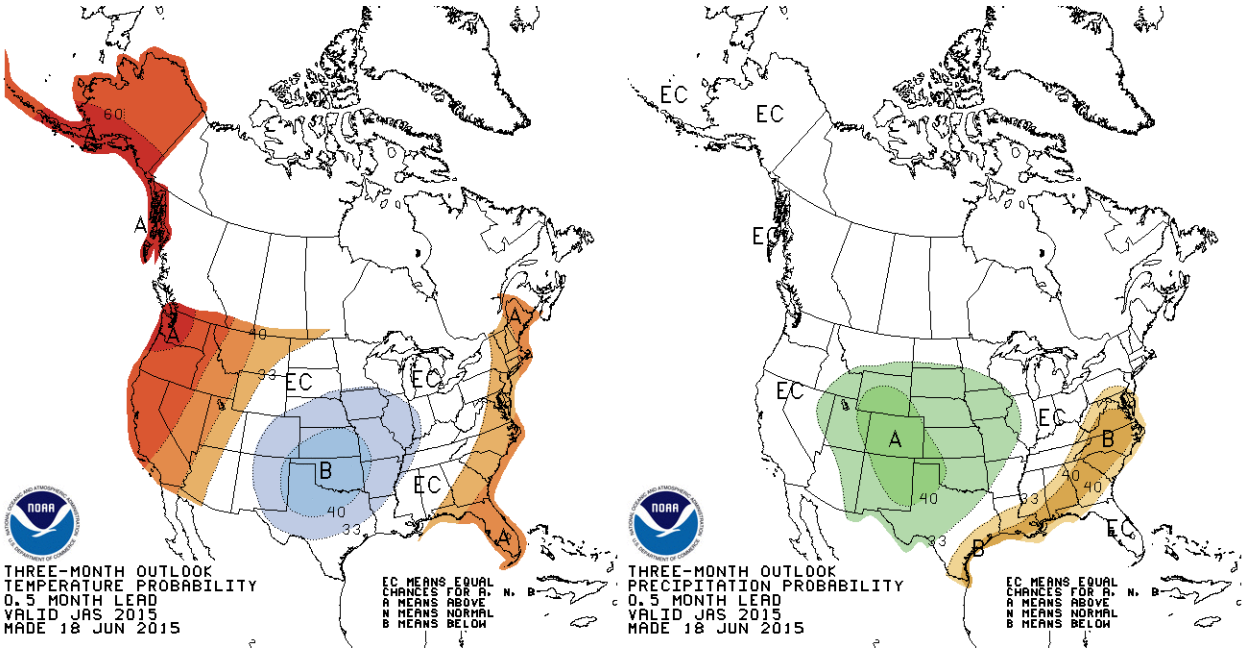


Figure 12. CPC July-August-September 2015 temperature and precipitation outlooks.

The October-November-December 2015 CPC temperature outlook (**Figure 13**) indicates a similar temperature pattern as the July-August-September outlook. The area of increased chances for above normal temperatures is slightly larger, covering all of Montana, the northwest tip of Wyoming, and most of North Dakota. There are equal chances for above normal, normal and below normal temperatures in the remainder of the upper Basin. With regard to precipitation there are increased chances for above normal precipitation in only the central Rockies; increased chances for below normal precipitation in Montana, northwest Wyoming and western North Dakota; and equal chances for above normal, normal and below normal precipitation in the remainder of the Missouri River Basin.

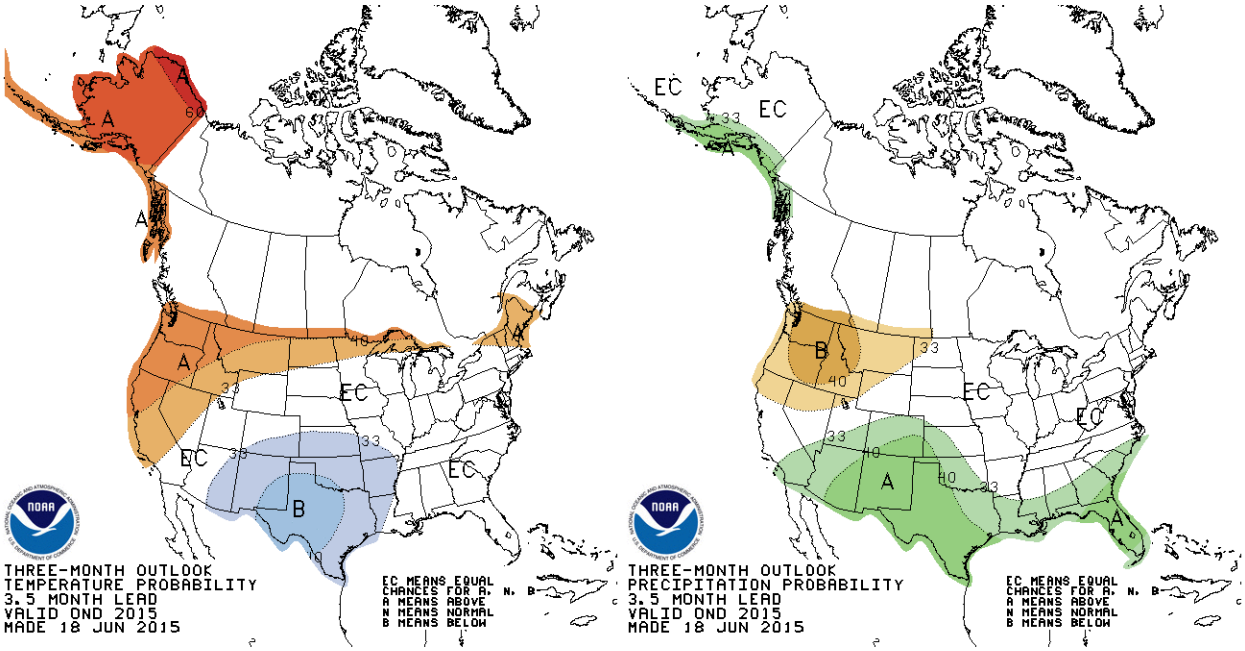


Figure 13. CPC October-November-December 2015 temperature and precipitation outlooks.

July 2015 Calendar Year Runoff Forecast

The July calendar year runoff forecast for the Missouri Basin above Sioux City is **26.6 MAF** (105% of normal). June runoff was 6.8 MAF (125% of normal). Observed June runoff was much greater than what was forecast on June 1st due to much greater than normal precipitation in the Garrison, Oahe and Fort Randall reaches.

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 29.6 MAF (117% of normal) upper basic forecast to the 23.9 MAF (94% of normal) lower basic forecast.

The calendar year runoff forecast takes into account current streamflow conditions, soil moisture conditions, mountain snowpack, and observed and forecast precipitation and temperatures.

Streamflow in eastern Montana, western North Dakota and western South Dakota continues to be higher than normal for this time of year. Streamflow is lower than normal in much of western and central Montana and the upper Yellowstone basin. Soil moisture conditions in the upper Basin are very wet, especially in Wyoming, southern North Dakota and western South Dakota, but not as wet as soil moisture conditions at the end of May.

Accumulated precipitation in June was well above normal in portions of eastern Montana, northeast Wyoming western North Dakota and western South Dakota. Western South Dakota and the Black Hills received more than 200% of normal precipitation in June. Precipitation accumulations have been well below normal in western and northern Montana.

Mountain snowpack melted in early June and Fort Peck and Garrison reservoirs are receiving the last remnants of the mountain snowpack runoff. Normally, some mountain snowpack remains in early July, which is NOT the case this year.

As a result of all of the forecast factors, runoff is predicted to be well above average in the Oahe and Fort Randall reaches in July, but diminishing in subsequent months. About average runoff is forecast for the Garrison, Gavins Point and Sioux City reaches. Finally, below average runoff is forecast to continue in the Fort Peck reach.

USDA NRCS National Water & Climate Center Water Supply Forecasts

* - DATA CURRENT AS OF: June 03, 2015 06:37:07 PM
  - Based on June 01, 2015 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	JUN-JUL	30	54	43	35	25	17.1	56
	JUN-SEP	44	62	59	50	37	29	71
St. Mary R at Int'l Boundary (2)	JUN-JUL	148	54	220	176	120	78	275
	JUN-SEP	192	56	270	225	161	114	345
Lima Reservoir Inflow (2)	JUN-JUL	6.1	20	19.8	11.6	3.2	0.58	31
	JUN-SEP	6.8	17	24	13.9	3.3	1.00	39
Clark Canyon Reservoir Inflow (2)	JUN-JUL	8.2	23	52	26	-9.7	-36	35
	JUN-SEP	24	44	74	44	3.6	-26	55
Jefferson R nr Three Forks (2)	JUN-JUL	166	47	360	245	88	-17.0	355
	JUN-SEP	194	47	430	290	99	-35	415
Hebgen Reservoir Inflow (2)	JUN-JUL	79	44	122	96	62	36	178
	JUN-SEP	147	53	199	168	126	95	280
Ennis Reservoir Inflow (2)	JUN-JUL	149	45	215	176	122	82	330
	JUN-SEP	255	53	335	285	220	169	485
Missouri R at Toston (2)	JUN-JUL	390	41	760	540	240	23	940
	JUN-SEP	570	47	1080	775	365	65	1220
Smith R bl Eagle Ck (2)	JUN-JUL	32	59	65	45	18.0	10.0	54
	JUN-SEP	42	65	88	61	24	12.0	65
Gibson Reservoir Inflow (2)	JUN-JUL	122	58	176	144	100	68	210
	JUN-SEP	163	65	220	186	140	105	250
Marias R nr Shelby (2)	JUN-JUL	24	17	134	68	-5.0	-30	143
	JUN-SEP	25	16	150	76	-5.0	-30	158
Milk R at Western Crossing	JUN-JUL	4.5	71	24	12.5	1.80	0.100	6.3
	JUN-SEP	5.7	80	28	14.8	2.2	0.20	7.1

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	40	85	48	43	37	33	47
	JUN-SEP	55	87	66	59	50	44	63
Wind R ab Bull Lake Ck (2)	JUN-JUL	265	80	360	305	225	169	330
	JUN-SEP	275	75	380	315	230	164	365
Bull Lake Ck nr Lenore (2)	JUN-JUL	107	99	131	117	97	83	108
	JUN-SEP	137	99	169	150	124	105	139
Boysen Reservoir Inflow (2)	JUN-JUL	320	75	505	395	245	135	425
	JUN-SEP	375	77	600	465	280	145	485
Greybull R nr Meeteetse	JUN-JUL	95	99	120	105	85	70	96
	JUN-SEP	141	99	174	154	128	108	142
Shell Ck nr Shell	JUN-JUL	34	97	43	38	30	24	35
	JUN-SEP	45	98	57	50	41	34	46
Bighorn R at Kane (2)	JUN-JUL	460	81	700	555	360	220	570
	JUN-SEP	515	82	815	635	390	210	630
NF Shoshone R at Wapiti	JUN-JUL	225	74	285	250	205	168	305
	JUN-SEP	270	75	345	300	240	199	360
SF Shoshone R nr Valley	JUN-JUL	138	88	164	148	127	112	157
	JUN-SEP	167	88	200	181	154	134	189
Buffalo Bill Reservoir Inflow (2)	JUN-JUL	380	82	485	420	340	275	465
	JUN-SEP	455	85	585	505	400	325	535
Bighorn R nr St. Xavier (2)	JUN-JUL	730	79	1040	855	605	420	920
	JUN-SEP	810	80	1210	975	645	405	1010
Little Bighorn R nr Hardin	JUN-JUL	49	92	77	60	37	19.9	53
	JUN-SEP	60	91	94	74	47	26	66
Tongue R nr Dayton (2)	JUN-JUL	43	88	59	49	37	27	49
	JUN-SEP	55	89	74	63	47	36	62
Tongue River Reservoir Inflow (2)	JUN-JUL	97	88	142	115	79	53	110
	JUN-SEP	118	88	174	141	96	63	134
NF Powder R nr Hazelton	JUN-JUL	4.9	109	7.1	5.8	4.0	2.7	4.5

	JUN-SEP	5.7	110	8.1	6.7	4.7	3.3	5.2
Powder R at Moorhead	JUN-JUL	91	99	145	113	69	37	92
	JUN-SEP	114	104	180	141	87	48	110
Powder R nr Locate	JUN-JUL	101	100	173	130	72	30	101
	JUN-SEP	127	104	215	163	90	36	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
August 2015 Calendar Year Runoff Forecast
August 4, 2015

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.

2015 Calendar Year Forecast Synopsis

The August calendar year runoff forecast for the Missouri Basin above Sioux City is **25.0 MAF** (**99%** of average). July runoff was **2.7 MAF** (81% of average). Observed July runoff was less than what was forecast on July 1st due to early melt-out of mountain snowpack in the Fort Peck and Garrison reaches. Observed July Oahe, Fort Randall and Gavins Point reach runoff was very close to the July 1 forecast volumes.

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 26.3 MAF (104% of average) upper basic forecast to the 23.8 MAF (94% of average) 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 average (upper basic) and lower than average (lower basic) 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 lessen as the number of observed months increases and number of forecast months decreases.

Current Conditions

Drought Analysis

Drought conditions have re-appeared in northern and western Montana in recent months due to low amounts of precipitation in those areas in June and July, and below average mountain snowpack this year. The drought conditions are shown in the National Drought Mitigation Center's drought monitor for July 28, 2015 (**Figure 1**) and June 30, 2015 (**Figure 2**). Extreme Drought (D3) conditions have developed in the mountainous portion of western Montana and Abnormally Dry (D0) conditions have expanded in eastern Montana and western North Dakota. The U.S. Seasonal Drought Outlook in **Figure 3** indicates drought will persist and likely intensify in western and north central Montana, while drought conditions are expected to development in central Montana during August, September and October.

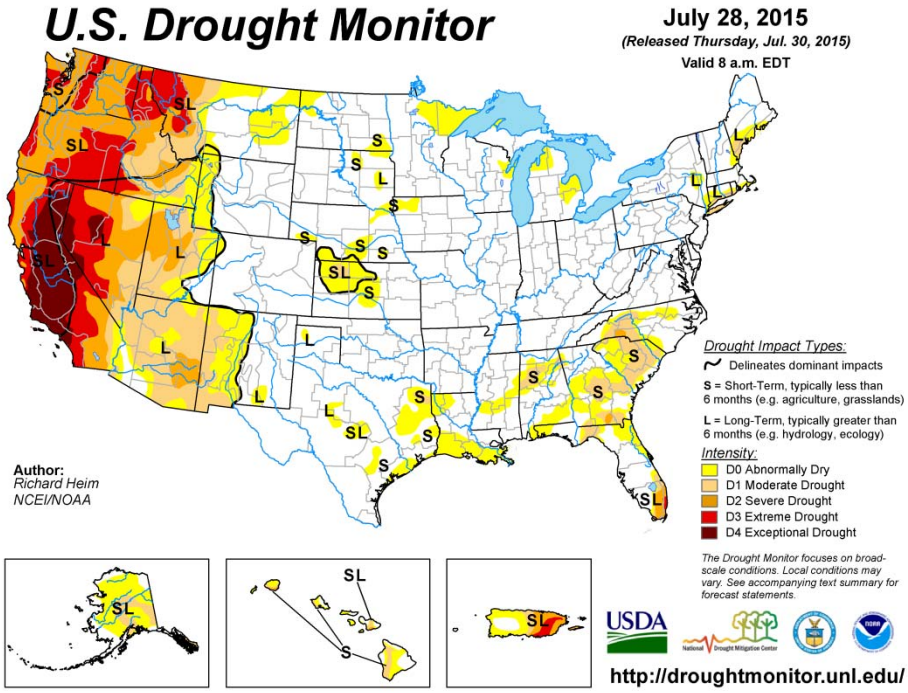


Figure 1. National Drought Mitigation Center U.S. Drought Monitor for July 28, 2015.

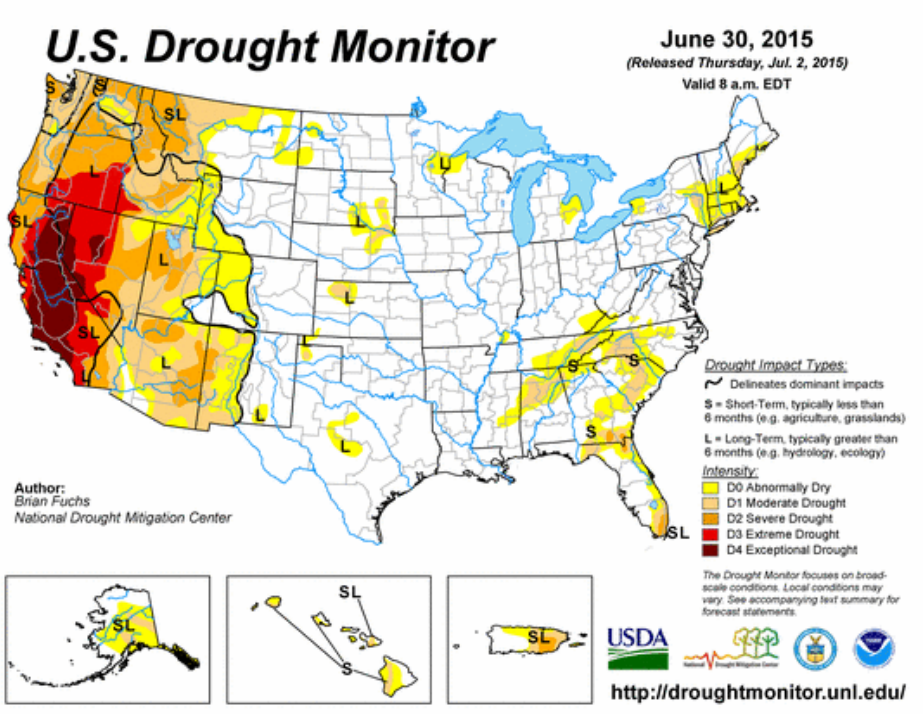


Figure 2. National Drought Mitigation Center U.S. Drought Monitor for June 30, 2015.

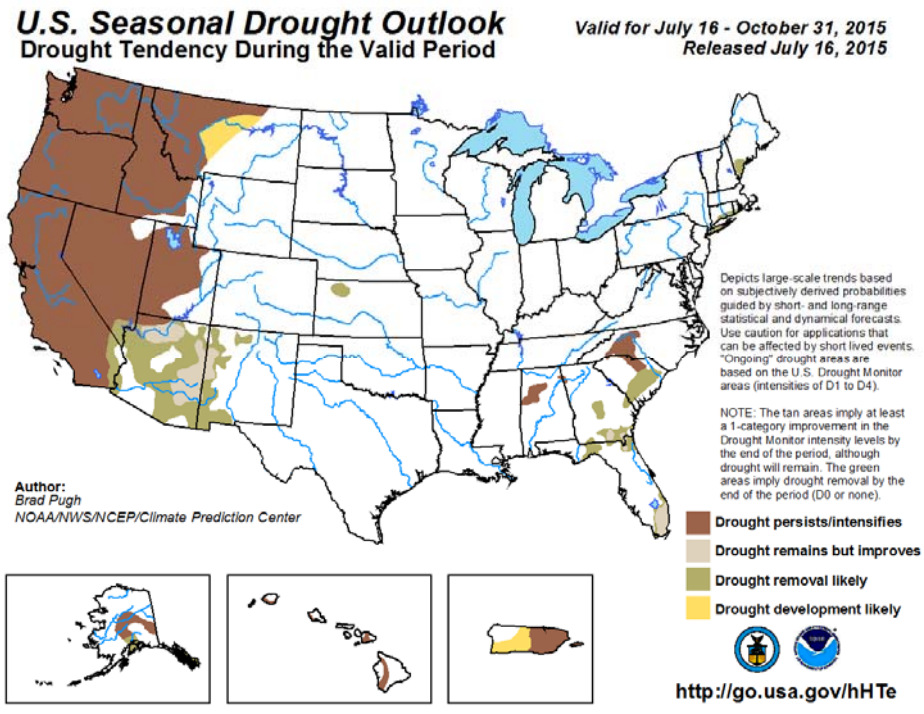


Figure 3. National Drought Mitigation Center U.S. Seasonal Drought Outlook.

Precipitation

July precipitation accumulations are shown in **Figure 4** as both inches of precipitation and percent of normal monthly precipitation. Above normal precipitation occurred regionally, but not basinwide. Precipitation was more than 150% of normal in northern Montana, southeast South Dakota, the southern Black Hills of South Dakota, northeast Kansas and much of Missouri. Below normal precipitation occurred locally in areas such as southeast Montana western South Dakota, and southern North Dakota.

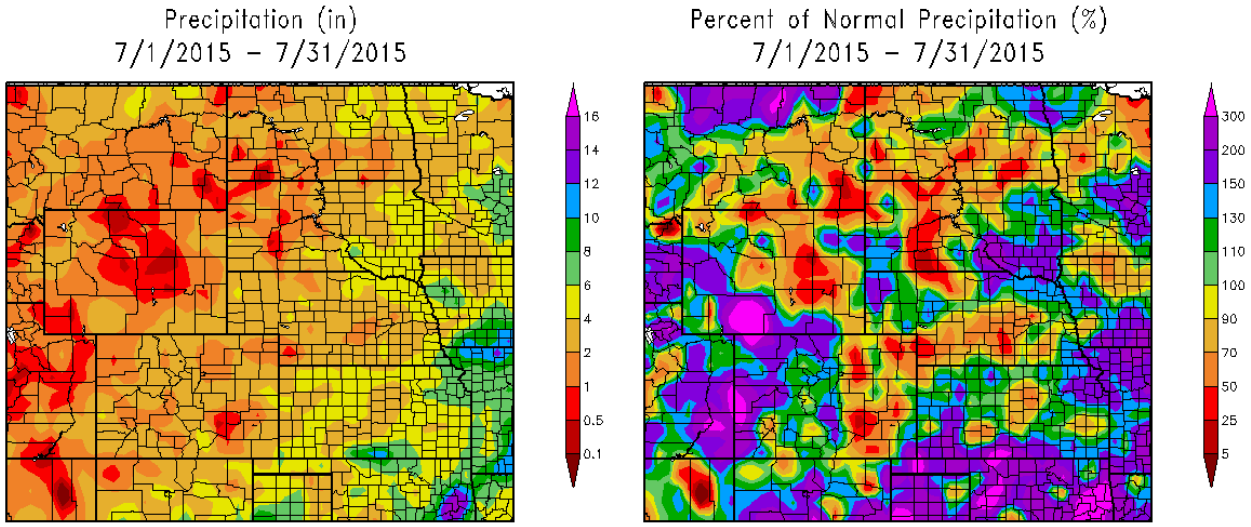


Figure 4. July 2015 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

May-June-July precipitation accumulations are shown in **Figure 5** as both inches and percent of normal precipitation. The three-month accumulation figures reflect above normal rainfall across Wyoming, western Nebraska, South Dakota and North Dakota. Above normal precipitation has also occurred over southern Iowa, southeast Nebraska, eastern Kansas and much of Missouri. Three-month precipitation has been below normal in Montana, northwest Iowa, and a fraction of central Nebraska.

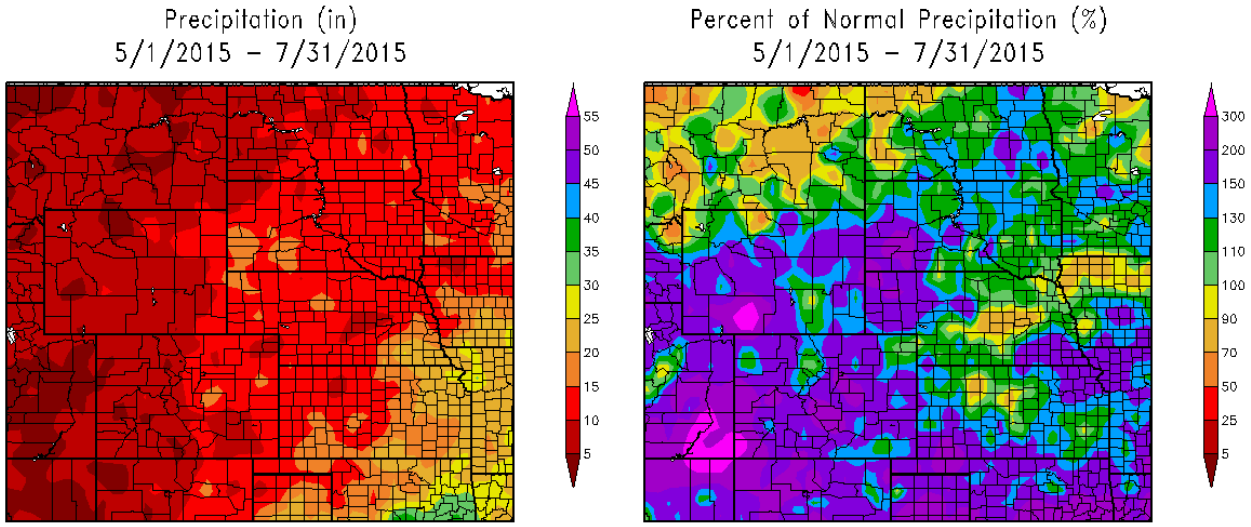


Figure 5. May – July 2015 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Temperature

July temperature departures from normal in degrees Fahrenheit (deg F) are shown in **Figure 6**. July temperatures in the upper Basin were about normal in Montana and South Dakota, below normal in Wyoming, and above normal in North Dakota. Lower basin temperatures have been slightly below normal in Nebraska, Iowa and Missouri. Three-month (May-June-July) temperature departures, shown in **Figure 6**, indicate below normal temperatures in central and eastern Wyoming, western South Dakota, Nebraska and Iowa. Above normal temperatures have occurred in western and central Montana, and western Wyoming.

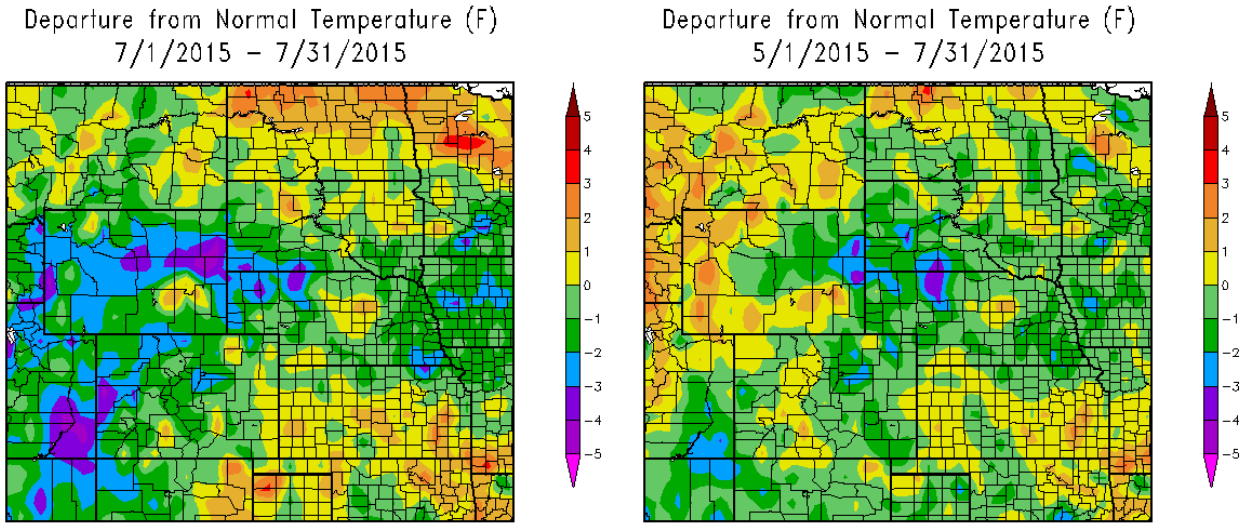


Figure 6. July 2015 and May – July 2015 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

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 monthly runoff.

Figure 7 shows the NOAA NLDAS ensemble mean soil moisture percentiles on July 29, 2015 for the total modeled soil column, which is about 2 meters. Soil moisture percentiles on July 3, 2015 are also shown in **Figure 8**. The NLDAS soil moisture depiction is an average value for the soil moisture column. **Figure 7** indicates above normal soil moisture conditions throughout much of the upper Basin. Soil moisture is above the 70th in many regions including central and northern Montana, Wyoming, western South Dakota and western Nebraska. Within the upper Basin, the wettest soil moisture conditions are in north central Montana, western South Dakota, and western Nebraska. Soil moisture is also considered wet in southeast Nebraska, southern Iowa, and Missouri. Normal to dry soil moisture conditions are present in eastern North Dakota, eastern South Dakota, and north central Nebraska.

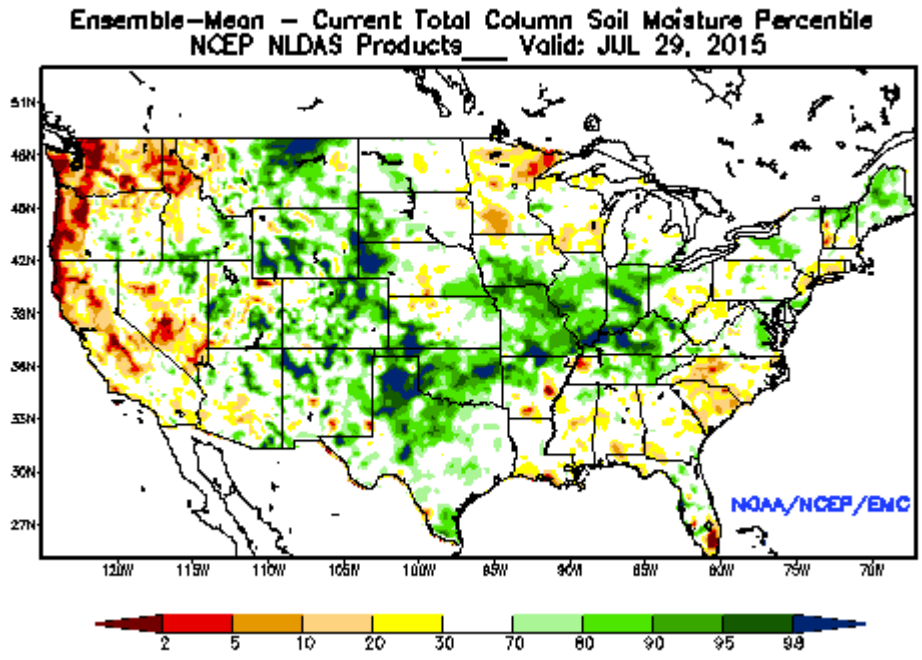


Figure 7. Total Column Soil Moisture Percentile on July 29, 2015. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

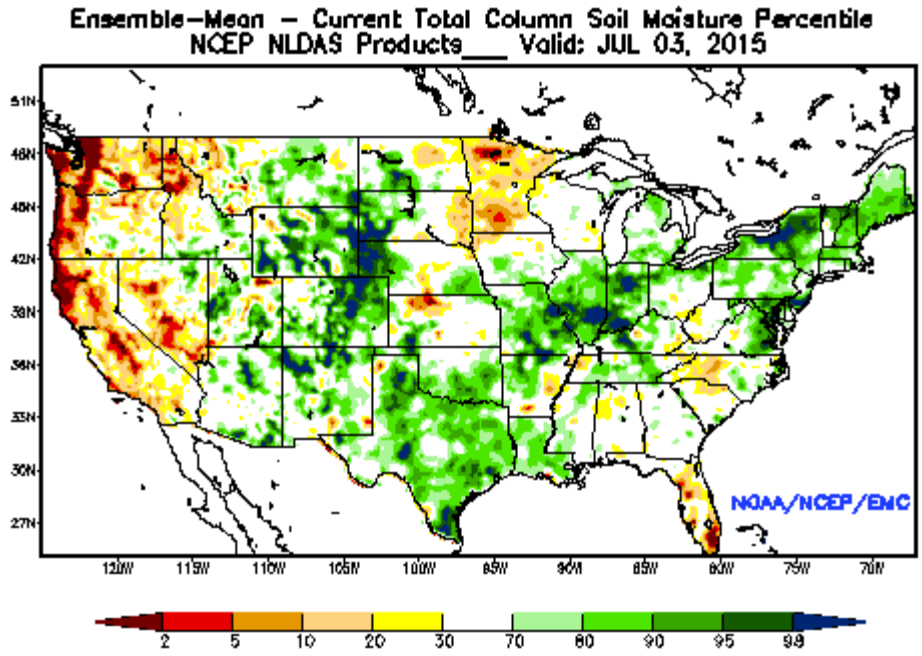


Figure 8. Total Column Soil Moisture Percentile on July 3, 2015. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

Streamflow Conditions

Missouri Basin streamflow conditions represented as percentile classes on August 1, 2015 are shown in **Figure 9**. These conditions are based on the ranking of the August 1, 2015 daily streamflow versus the historical record of streamflow for that date. Streamflow conditions have been above normal throughout portions of eastern Wyoming, north central Montana, the western Dakotas, eastern Nebraska, western Iowa and Missouri. Streamflow is still very high, exceeding the 90th percentile, in western South Dakota and portions of the lower Basin. In contrast, streamflow is normal (25th to 75th percentile) to below normal (less than the 24th percentile) in western and central Montana and central and western Wyoming due to the lack of plains snowpack this year. Some streamgages in these areas have fallen below the 10th percentile class.

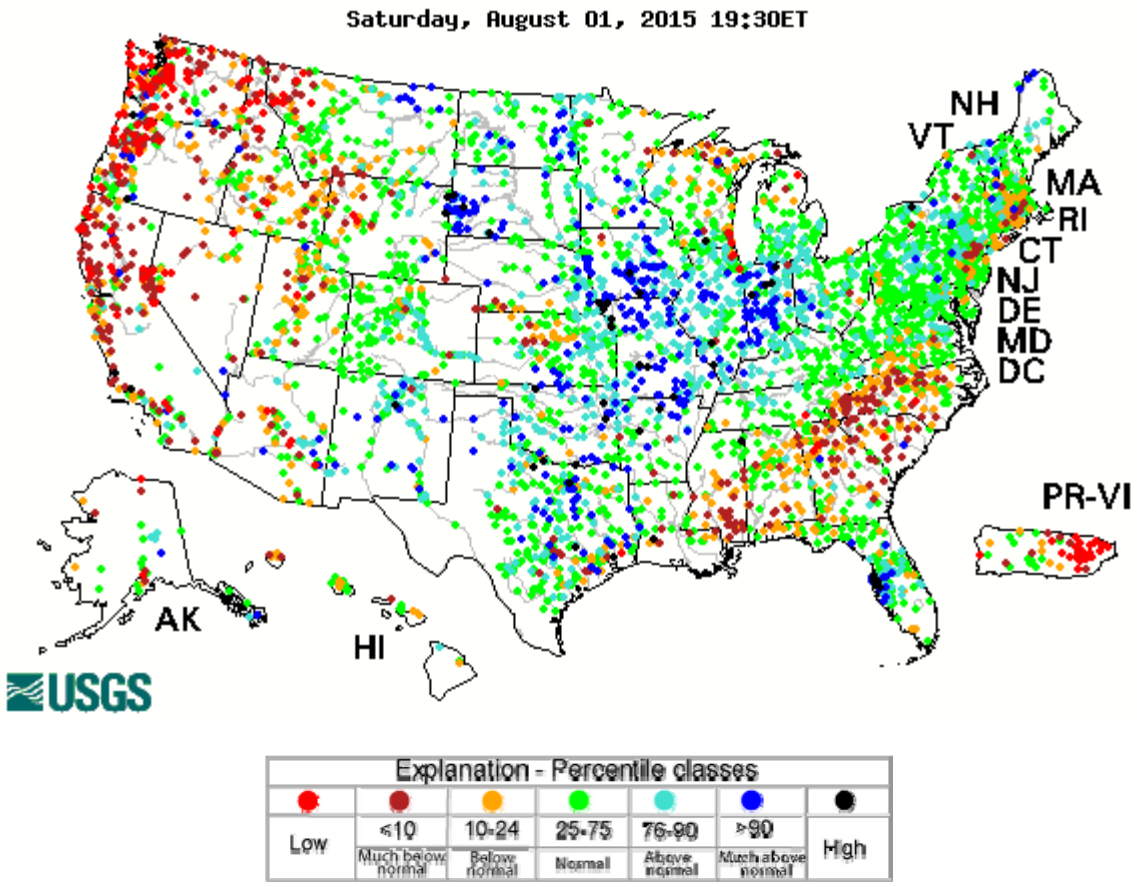


Figure 9. USGS Streamflow Conditions as a Percentile of Normal in the Missouri River Basin as of August 1, 2015. Source: USGS. http://waterwatch.usgs.gov/index.php

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 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 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, 2014 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 **July 1, 2015**, the Corps of Engineers computed an average mountain SWE of less than 0.1 inch in the headwater basin above Fort Peck Dam. In the subbasin between Fort Peck Dam and Garrison Dam, the Corps computed an average mountain SWE of less than 0.1 inch. The mountain snowpack peaked on March 9 at 11.8 inches (72% of the average peak) above Fort Peck and on March 9 at 11.1 inches (78% of the average peak) in the Fort Peck to Garrison reach. Normally, mountain snowpack peaks around April 15. Compared to the 2001 snowpack, the 2015 peaks are lower and earlier. The early and well below average mountain snowpack peak was a major factor in forecasting July runoff into Fort Peck and Garrison.

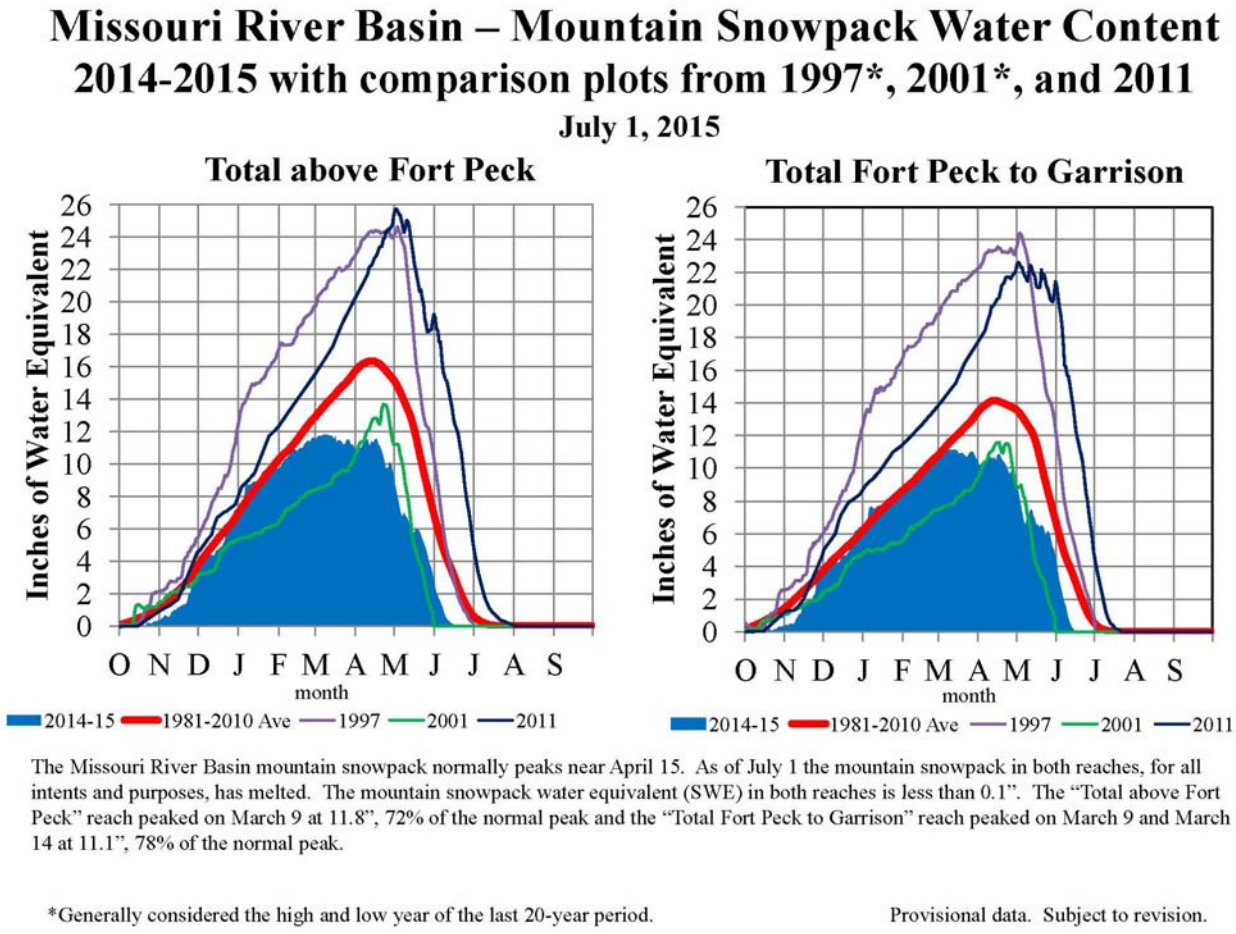


Figure 10. Mountain snowpack water content snow accumulation compared to average and historic conditions. Corps of Engineers - Missouri River Basin Water Management.

Climate Outlook

ENSO (El Niño Southern Oscillation)

El Niño conditions were declared by the NOAA Climate Prediction Center (CPC) in March 2015. According to the CPC, there is a greater than 90% chance that El Niño will continue through the Northern Hemisphere winter 2015-16, and an 80% chance it will continue through early spring 2016. CPC studies are predicting a strong El Niño event at its peak.

Discussions with Dr. Dennis Todey, the South Dakota State Climatologist, and Mr. Doug Kluck, the Central Region Climate Services Director for NOAA, were conducted to gain a better understanding of the possible impacts that El Niño may have on the late summer, fall and early winter temperature and precipitation patterns in the Missouri River Basin. Furthermore a north central U.S. early drought webinar was conducted, and MRBWM participated, on July 30 to present forecast weather and drought information and potential impacts due to the strong El Niño. The possible impact of El Niño has been factored into the climate outlooks described below.

Temperature and Precipitation Outlooks

The CPC climate outlook for August 2015 (**Figure 11**) indicates increased chances for above normal temperatures in western Montana, while there are increased chances for below normal temperatures in much of Wyoming, South Dakota, and the entire lower Basin. With regard to August precipitation, the CPC indicates that there are increased chances for above normal precipitation in the lower Basin, Wyoming and a majority of South Dakota. There are equal chances for normal precipitation in Montana and North Dakota.

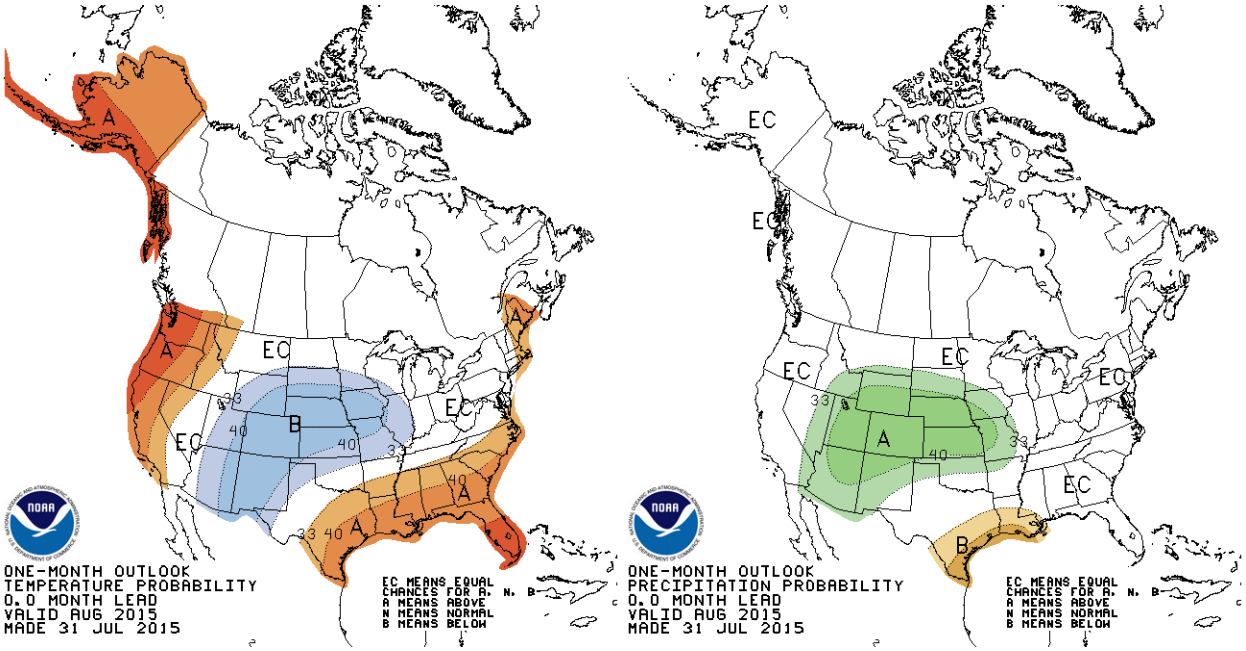


Figure 11. CPC August 2015 temperature and precipitation outlooks.

The CPC's August-September-October outlook (**Figure 12**) calls for increased chances for above normal temperatures in most of Montana and western Wyoming, equal chances in the remainder of the upper Basin, and increased chances for below normal temperatures in the lower Basin. In terms of precipitation, there are increased chances for above normal precipitation in the entire Missouri Basin with the exception of Montana, much of South Dakota and North Dakota where there are equal chances for above normal, normal and below normal precipitation.

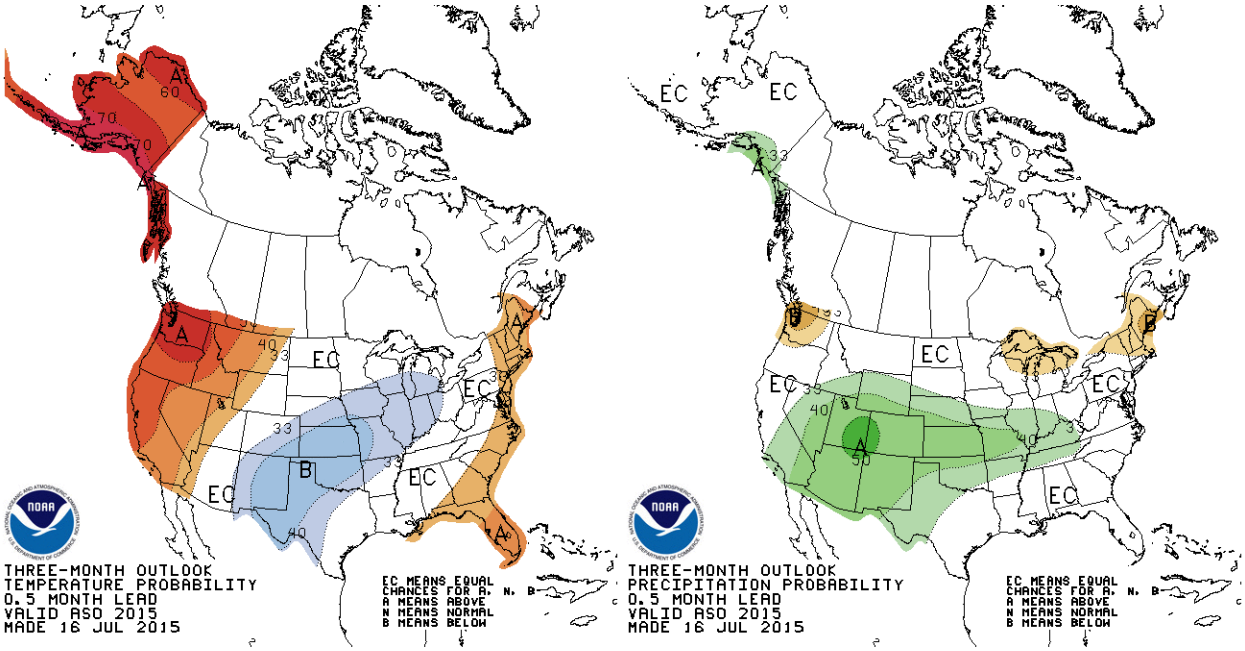


Figure 12. CPC August-September-October 2015 temperature and precipitation outlooks.

The November-December 2015 – January 2016 CPC temperature outlook (**Figure 13**) indicates a much larger area of increased chances for above normal temperatures throughout the upper Basin and equal chances for below normal, normal and above normal temperatures in the lower Basin. With regard to precipitation there are increased chances for below normal precipitation in the northern Rocky Mountains in Wyoming and Montana, as well as the remainder of Montana and much of North Dakota. There are equal chances for above normal, normal and below normal precipitation in the remainder of the Missouri River Basin.

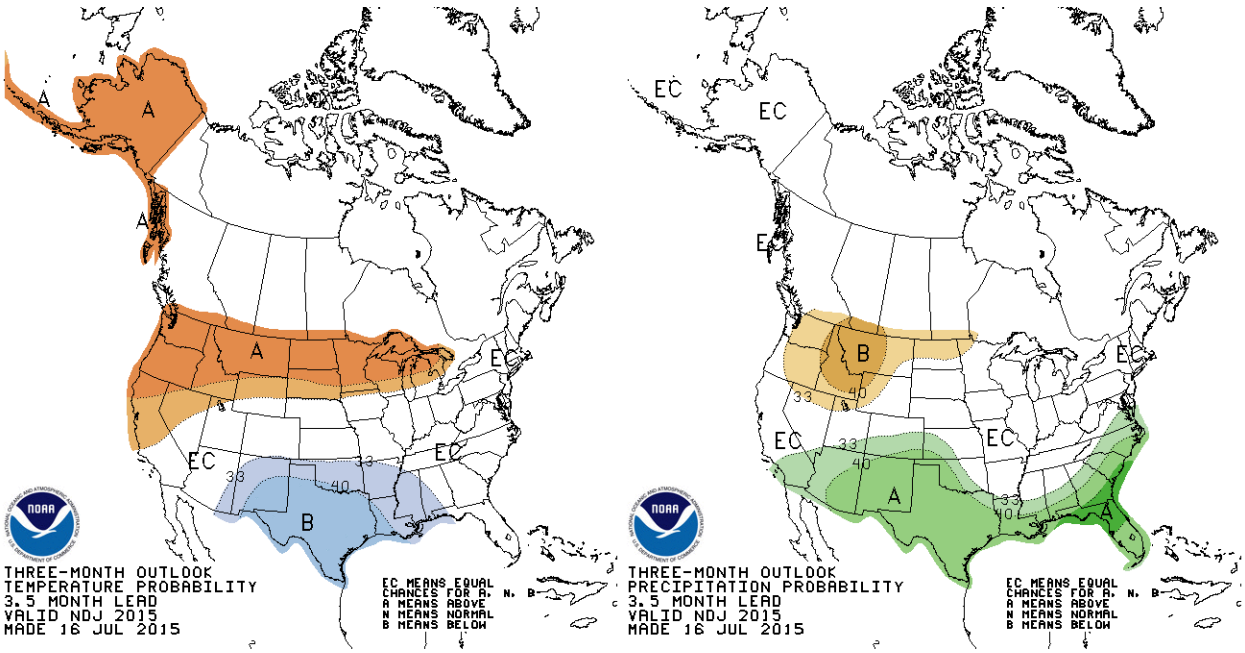


Figure 13. CPC November-December 2015 - January 2016 temperature and precipitation outlooks.

August 2015 Calendar Year Runoff Forecast

The August calendar year runoff forecast for the Missouri Basin above Sioux City is **25.0 MAF** (99% of average).

Observed July runoff was 2.7 MAF, 81% of average, due to below normal precipitation throughout much of the upper Basin, and low mountain snowpack, which contributes to runoff in the Fort Peck and Garrison reaches. In 2015, the mountain snowpack peaked at 72% of average above Fort Peck and 78% of average in the Fort Peck to Garrison reach. It also peaked more than one month earlier than normal. As a result, Fort Peck runoff in July was 51% of average and Garrison runoff in July was 65% of average. In contrast, Oahe runoff in July was 218% of average, and Fort Randall runoff in July was 247% 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 26.3 MAF (104% of average) upper basic forecast to the 23.8 MAF (94% of average) lower basic forecast.

The calendar year runoff forecast takes into account current streamflow conditions, soil moisture conditions, and observed and forecast precipitation and temperatures. Streamflow in western South Dakota continues to be higher than normal for this time of year. Streamflow is lower than normal in much of western and central Montana and the upper Yellowstone basin. Soil moisture conditions in the upper Basin are very wet, especially in Wyoming, southern North Dakota and western South Dakota, but not as wet as soil moisture conditions at the end of May. Accumulated precipitation in July was variable. Some areas received locally heavy rainfall, but a majority of the upper Basin received below normal rainfall.

The CPC climate outlooks from August through October indicate increased chances for above normal precipitation extending across Wyoming, South Dakota, Nebraska, Iowa, Kansas and Missouri, and increased chances for cooler than normal temperatures through October. The outlook also indicates normal chances of precipitation in Montana and North Dakota through October, but warmer than normal temperatures in western Montana. During the November-December-January period, temperature conditions are expected to become warmer than normal and drier than normal in the Fort Peck and Garrison reaches, but about normal in the other System reaches.

Due to below normal streamflow and runoff in the Fort Peck and Garrison reaches, below average runoff is forecast in the Fort Peck reach (72%) and Garrison reach (75%) in August. Above average runoff is forecast to continue in the Oahe through Sioux City reaches in August. From September through December, below average runoff is forecast for the Fort Peck and Garrison reaches, above average runoff is forecast in the Oahe and Fort Randall reaches, and average runoff is forecast in the Gavins Point and Sioux City reaches.

Upper Missouri River Basin
September 2015 Calendar Year Runoff Forecast
September 3, 2015

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.

2015 Calendar Year Forecast Synopsis

The September calendar year runoff forecast for the Missouri Basin above Sioux City is **25.0 MAF** (**99%** of average). August runoff was **1.5 MAF** (**108%** of average). Observed August runoff was slightly greater than normal in the Oahe, Fort Randall and Sioux City reaches due to above normal precipitation. Above normal precipitation also occurred over portions of eastern Nebraska and much of western Iowa.

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 25.9 MAF (102% of average) upper basic forecast to the 24.3 MAF (96% of average) 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 average (upper basic) and lower than average (lower basic) 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 lessen as the number of observed months increases and number of forecast months decreases.

Current Conditions

Drought Analysis

Drought conditions have re-appeared in northern and western Montana in recent months due to low amounts of precipitation in those areas in June, July, and August and below average mountain snowpack this year. The drought conditions are shown in the National Drought Mitigation Center's drought monitor for August 25, 2015 (**Figure 1**) and July 28, 2015 (**Figure 2**). Extreme Drought (D3) and Severe Drought (D2) conditions expanded slightly in western Montana. Abnormally Dry (D0) conditions have expanded in eastern Montana and western North Dakota; however, D0 conditions were mitigated by rainfall in the eastern Dakotas and northwest Iowa. The U.S. Seasonal Drought Outlook in **Figure 3** indicates drought will persist and likely intensify in western Montana through November. Conditions are not expected to change anywhere else in the Missouri Basin.

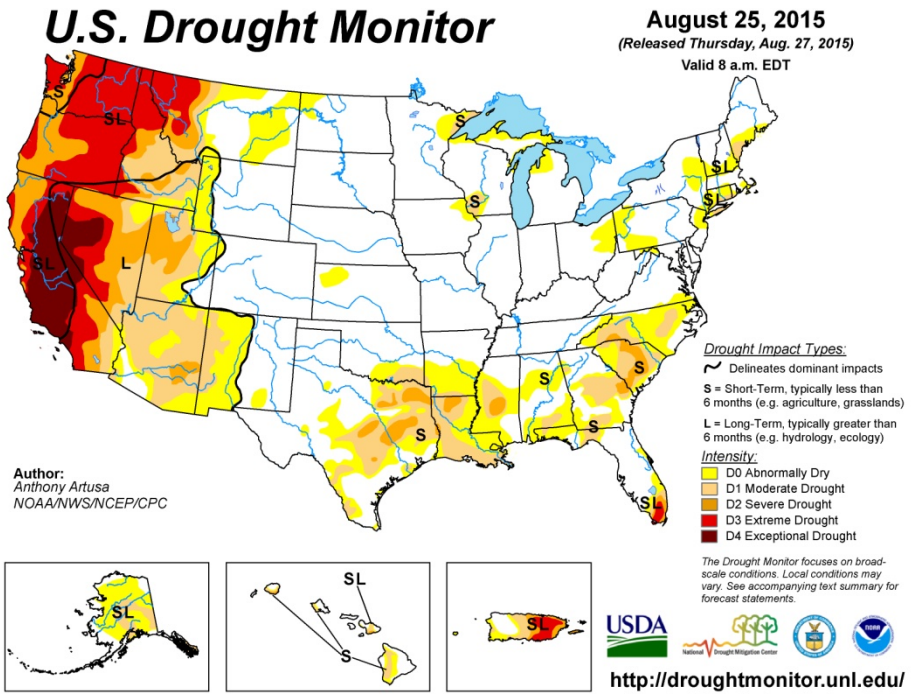


Figure 1. National Drought Mitigation Center U.S. Drought Monitor for August 25, 2015.

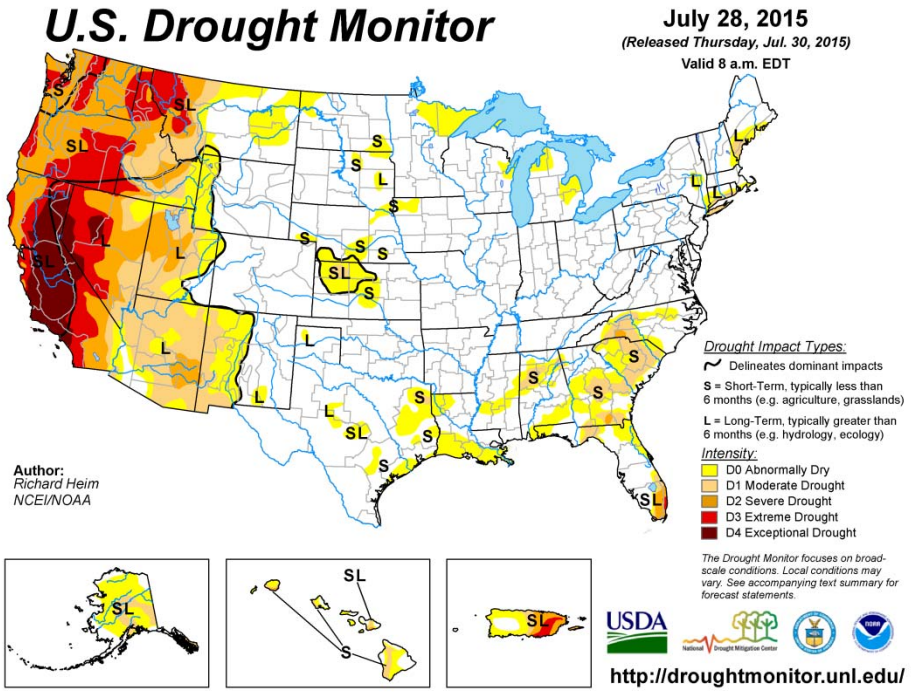


Figure 2. National Drought Mitigation Center U.S. Drought Monitor for July 28, 2015.

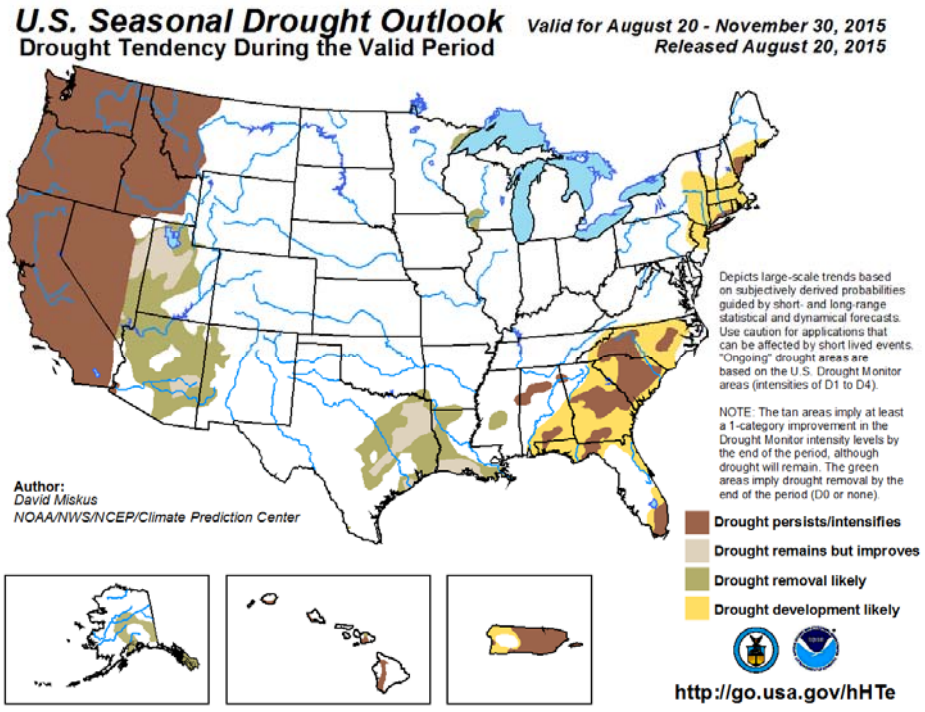


Figure 3. National Drought Mitigation Center U.S. Seasonal Drought Outlook.

Precipitation

August precipitation accumulations are shown in **Figure 4** as both inches of precipitation and percent of normal monthly precipitation. Above normal precipitation occurred in the Black Hills and surrounding area, much of South Dakota, eastern Nebraska and western Iowa. Precipitation was below normal across much of western Montana, central Wyoming, North Dakota, southeast Nebraska, northeast Kansas and northern Missouri. June-July-August precipitation accumulations are shown in **Figure 5**. The three-month accumulations reflect below normal precipitation across western and central Montana, central Wyoming and eastern North Dakota. An above normal precipitation pattern has dominated the Black Hills region, eastern South Dakota, eastern Nebraska, Iowa, and Missouri.

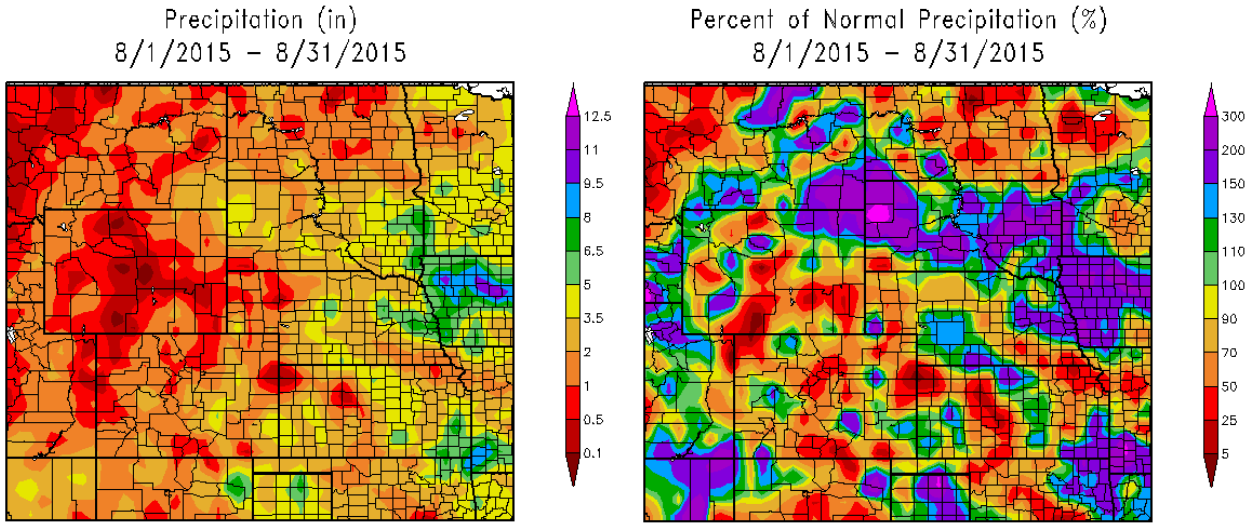


Figure 4. August 2015 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

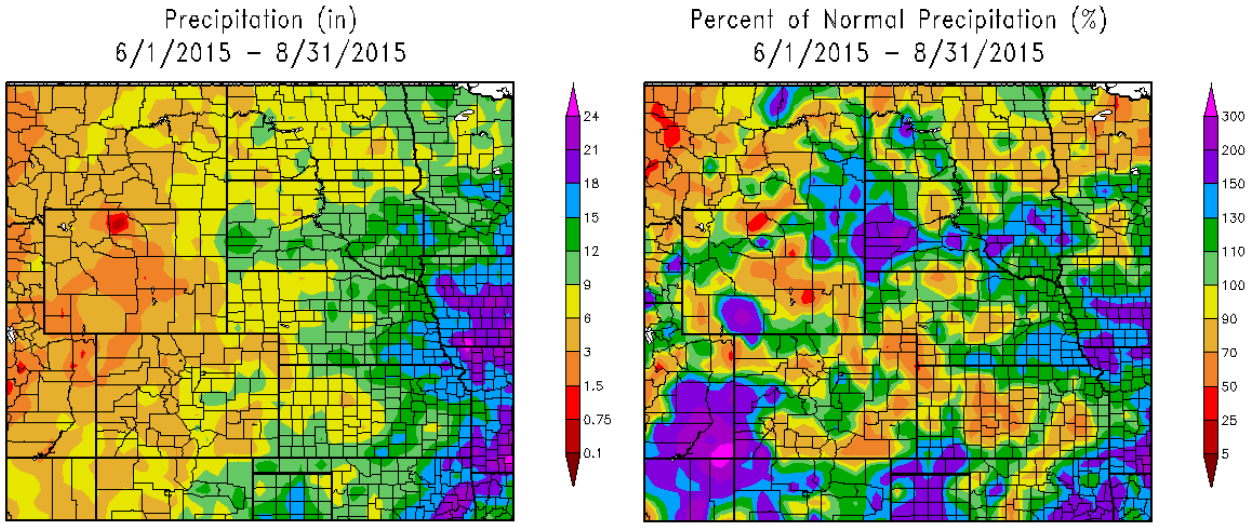


Figure 5. June - August 2015 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Temperature

August temperatures were within plus or minus 2 degrees Fahrenheit (deg F) from normal in the upper Basin above Sioux City, IA (**Figure 6)**. In the lower Basin, temperature departures ranged from 2 to 4 deg F below normal. Three-month (June-July-August) temperature departures in **Figure 6** show below normal temperatures in the lower Basin, but normal to 3 deg F above normal in the upper Basin, especially in the Rocky Mountains of Montana and Wyoming, the plains of Montana, and northern North Dakota.

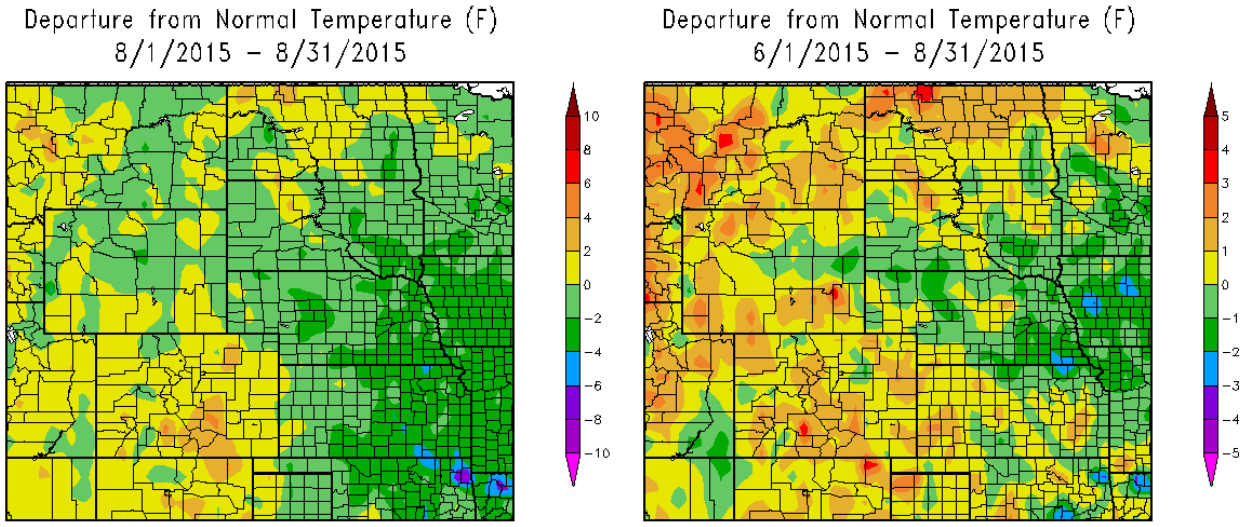


Figure 6. August 2015 and June - August 2015 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

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 monthly runoff.

Figure 7 shows the NOAA NLDAS ensemble mean soil moisture percentiles on August 27, 2015 for the total modeled soil column, which is about 2 meters. Soil moisture percentiles on July 29, 2015 are shown in **Figure 8**. The NLDAS soil moisture depiction is an average value for the soil moisture column. **Figure 7** indicates above normal soil moisture conditions throughout much of the upper Basin. Soil moisture is above the 70th percentile in many regions including central and northern Montana, Wyoming, South Dakota and western Nebraska. Within the upper Basin, the wettest soil moisture conditions are in western South Dakota and southeast Montana. Normal to dry soil moisture conditions are present in eastern North Dakota and western Montana. One notable change since July 29 is the increased soil wetness in eastern South Dakota.

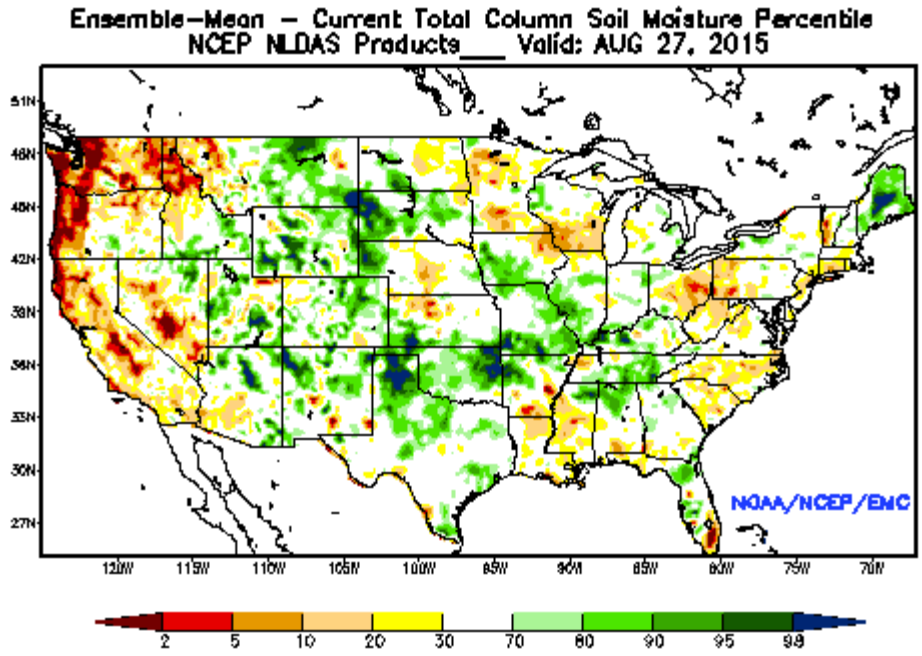


Figure 7. Total Column Soil Moisture Percentile on August 27, 2015. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

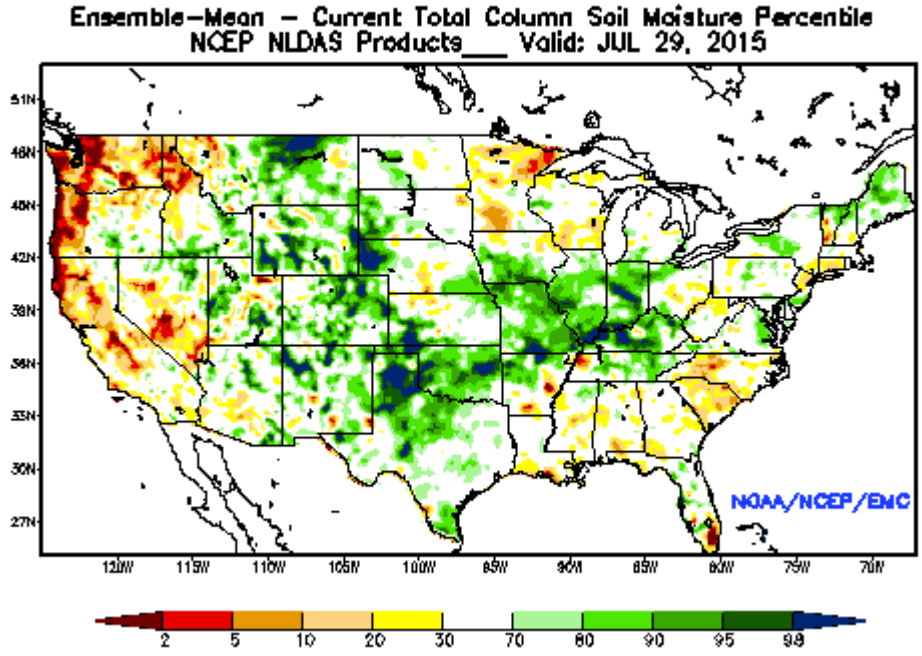


Figure 8. Total Column Soil Moisture Percentile on July 29, 2015. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

Streamflow Conditions

Missouri Basin streamflow conditions represented as percentile classes on September 1, 2015 are shown in **Figure 9**. These conditions are based on the ranking of the September 1, 2015 daily streamflow versus the historical record of streamflow for that date. Streamflow conditions have been above normal throughout portions of eastern Wyoming, northeast Montana, the western Dakotas, eastern Nebraska, western Iowa and Missouri. Streamflow is still very high, exceeding the 90th percentile, in western South Dakota. In contrast, streamflow is normal (25th to 75th percentile) to below normal (less than the 24th percentile) in western and central Montana and central and western Wyoming due to the lack of plains snowpack this year. Some streamgages in these areas have fallen below the 10th percentile.

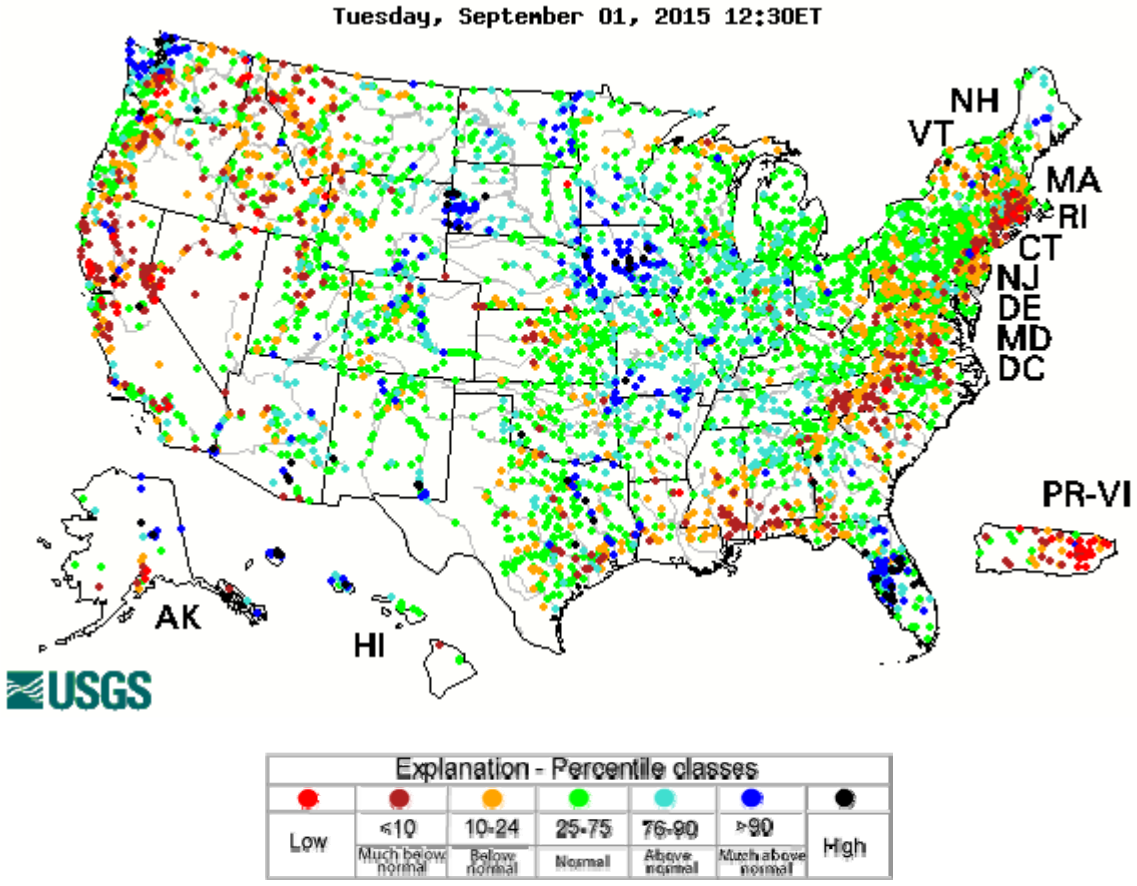


Figure 9. USGS Streamflow Conditions as a Percentile of Normal in the Missouri River Basin as of September 1, 2015. Source: USGS. http://waterwatch.usgs.gov/index.php

Climate Outlook

ENSO (El Niño Southern Oscillation)

According to the CPC, there is a greater than 90% chance that El Niño will continue through the Northern Hemisphere winter 2015-16, and an 85% chance it will last into early spring 2016. CPC studies are predicting a strong El Niño event at its peak. El Niño winters have a tendency to be warmer and drier than normal, and the influence of El Niño has been factored into the CPC's climate outlooks.

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. These webinars provide updates on near-term climate outlooks and impacts including the El Niño climate pattern and its implications on late summer, fall and early winter temperature and precipitation patterns in the Missouri River Basin. The possible impacts of El Niño have been factored into the CPC climate outlooks described below.

Temperature and Precipitation Outlooks

The CPC climate outlook for September 2015 (**Figure 10**) indicates increased chances for below normal temperatures in the Wyoming, southern Montana, western South Dakota and western Nebraska, but equal chances for above normal, normal and below normal temperatures in the remainder of the upper Basin. There are increased chances for above normal temperatures in Iowa and Missouri. With regard to precipitation, the CPC indicates that there are increased chances for above normal precipitation in all of the Missouri Basin.

The CPC's September-October-November outlook (**Figure 11**) calls for increased chances for above normal temperatures in Montana and much of Wyoming, equal chances in the remainder of the upper Basin, and increased chances for below normal temperatures in Kansas and western Missouri. In terms of precipitation, the outlook indicates there are increased chances for above normal precipitation in most of the lower Basin below Sioux City, and in Wyoming and South Dakota. There are equal chances for above normal, normal and below normal precipitation in Montana and North Dakota within the Missouri Basin.

The December 2015 – January –February 2016 CPC temperature outlook (**Figure 12**) indicates increased chances for above normal temperatures throughout the upper Basin and most of the lower Basin. With regard to precipitation there are increased chances for below normal precipitation in the northern Rocky Mountains in Wyoming and Montana, as well as the remainder of Montana and much of North Dakota. There are equal chances for above normal, normal and below normal precipitation in the remainder of the Missouri River Basin.

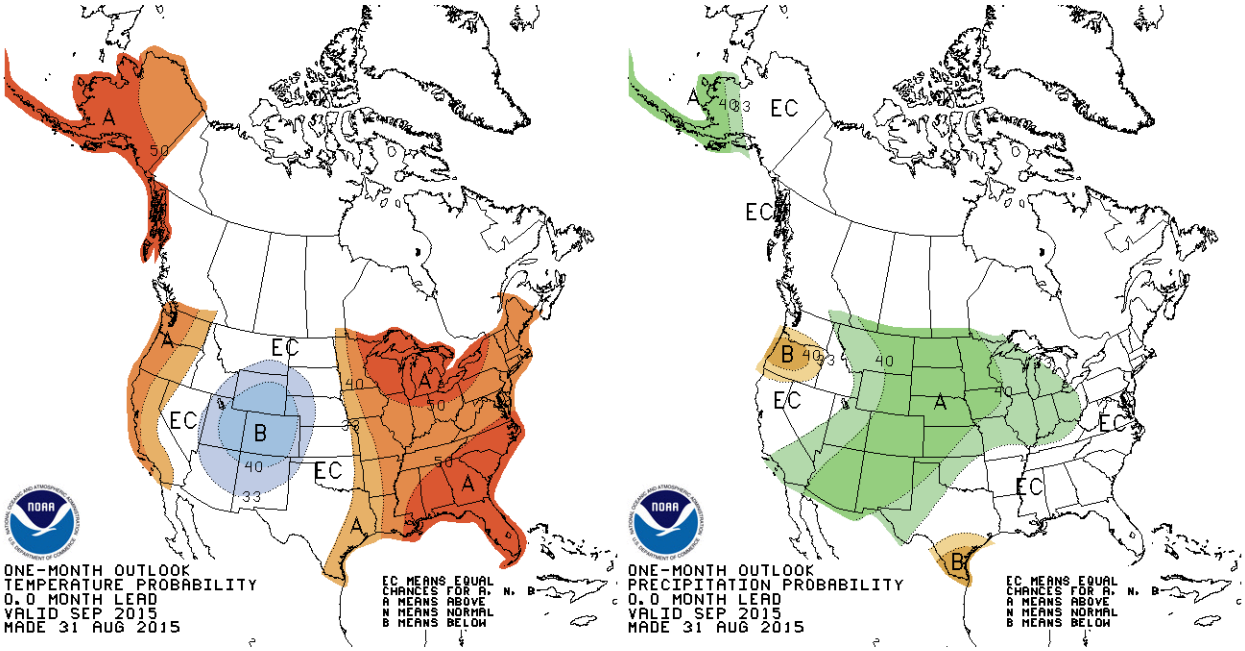


Figure 10. CPC September 2015 temperature and precipitation outlooks.

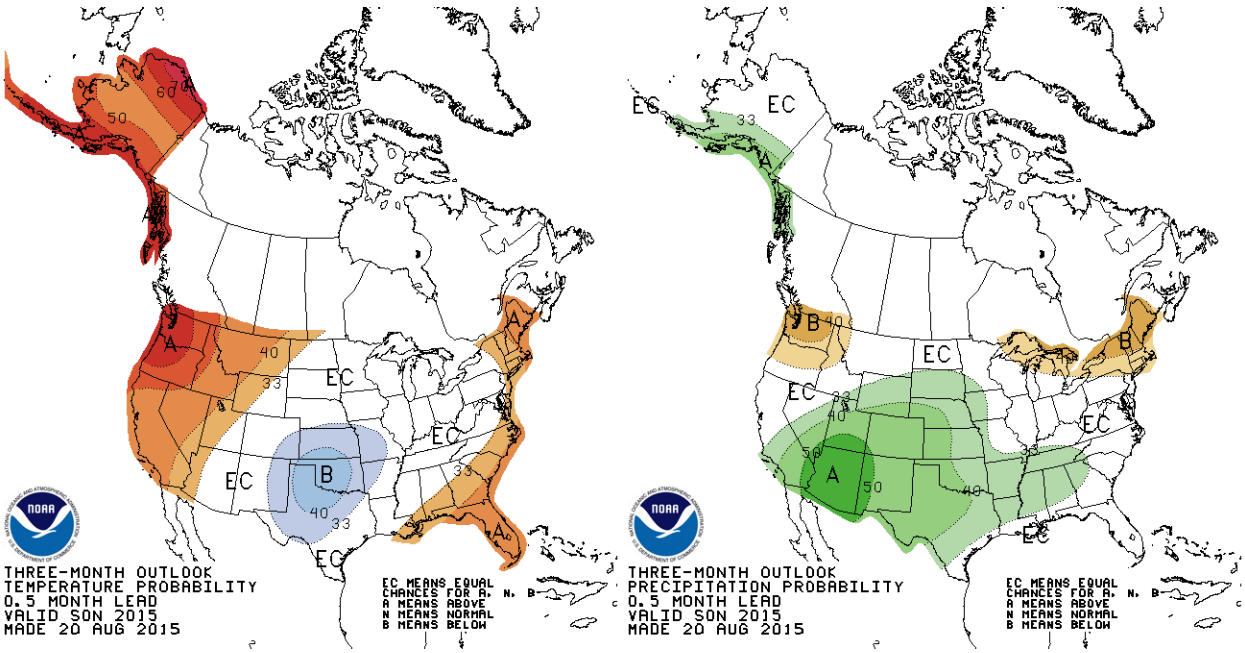


Figure 11. CPC September-October-November 2015 temperature and precipitation outlooks.

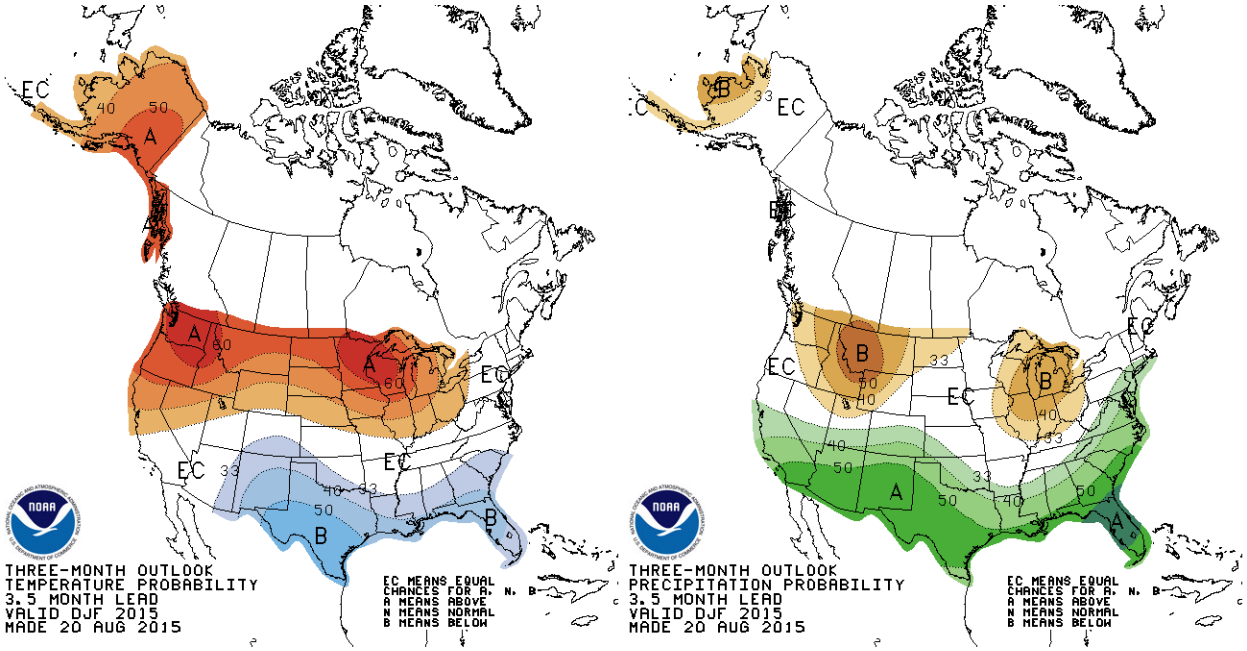


Figure 12. CPC December 2015 – January – February 2016 temperature and precipitation outlooks.

September 2015 Calendar Year Runoff Forecast

The September calendar year runoff forecast for the Missouri Basin above Sioux City is **25.0 MAF** (99% of average).

Observed August runoff was 1.5 MAF, 108% of average, due to above normal precipitation in the Black Hills region and most of South Dakota. As a result, Oahe, Fort Randall and the Sioux City reach runoff were well above average; however, they contributed 0.66 MAF of the total August runoff. Runoff in the Fort Peck, Garrison and Gavins Point reaches was well below 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 25.9 MAF (102% of average) upper basic forecast to the 24.3 MAF (96% of average) lower basic forecast.

The calendar year runoff forecast takes into account current streamflow conditions, soil moisture conditions, and observed and forecast precipitation and temperatures. Late summer and fall is typically the dry season in the upper Basin. Month-to-month streamflow correlations tend to be a good indicator of future runoff in September and October. As a result current streamflow trends are expected to continue. Also, above normal chances for October through November precipitation in the mid-Missouri Basin and below normal chances in the Rocky Mountains will have some influence on monthly runoff through December. Runoff during the remaining months of the year is forecast to be above normal in the Oahe, Fort Randall and Sioux City reaches, while runoff is forecast to be below normal in the Fort Peck, Garrison and Gavins Point reaches.

Upper Missouri River Basin
October 2015 Calendar Year Runoff Forecast
October 2, 2015

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.

2015 Calendar Year Forecast Synopsis

The September calendar year runoff forecast for the Missouri Basin above Sioux City is **24.9 MAF** (98% of average). September runoff was **1.0 MAF** (84**%** of average). Observed September runoff was higher than normal in the lower four reaches - Oahe, Fort Randall, Gavins Point, and Sioux City - due to above normal precipitation. Runoff in the upper two reaches – Fort Peck and Garrison – was well below normal due to below normal precipitation.

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 25.5 MAF (102% of average) upper basic forecast to the 24.4 MAF (96% of average) 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 average (upper basic) and lower than average (lower basic) is attributed to all 6 reaches for 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 number of forecast months decreases.

Current Conditions

Drought Analysis

Drought conditions have continued to expand in the basin over the last few months. The drought conditions are shown in the National Drought Mitigation Center's drought monitor for September 29, 2015 (**Figure 1**) and August 25, 2015 (**Figure 2**). Extreme Drought (D3) and Severe Drought (D2) conditions expanded slightly in western Montana. Abnormally Dry (D0) conditions have persisted in eastern Montana and have now developed in eastern North Dakota, eastern Wyoming, western Nebraska and north-central Kansas. The U.S. Seasonal Drought Outlook in **Figure 3** indicates drought will persist and likely intensify in western Montana and develop in central Montana through the end of the calendar year. Conditions are not expected to change anywhere else in the Missouri Basin.

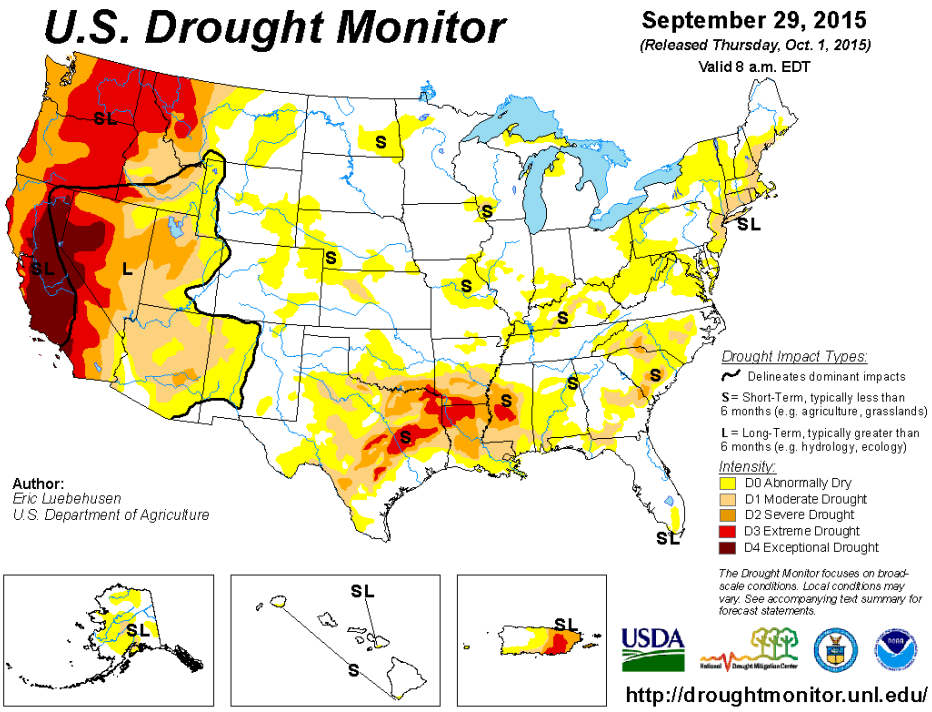


Figure 1. National Drought Mitigation Center U.S. Drought Monitor for September 29, 2015.

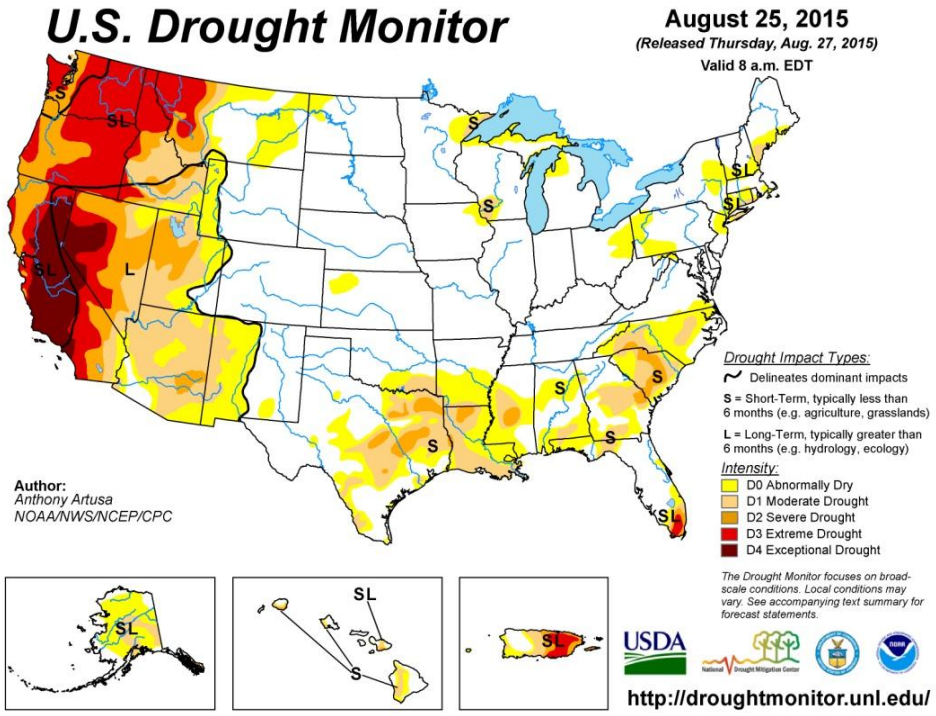


Figure 2. National Drought Mitigation Center U.S. Drought Monitor for August 25, 2015.

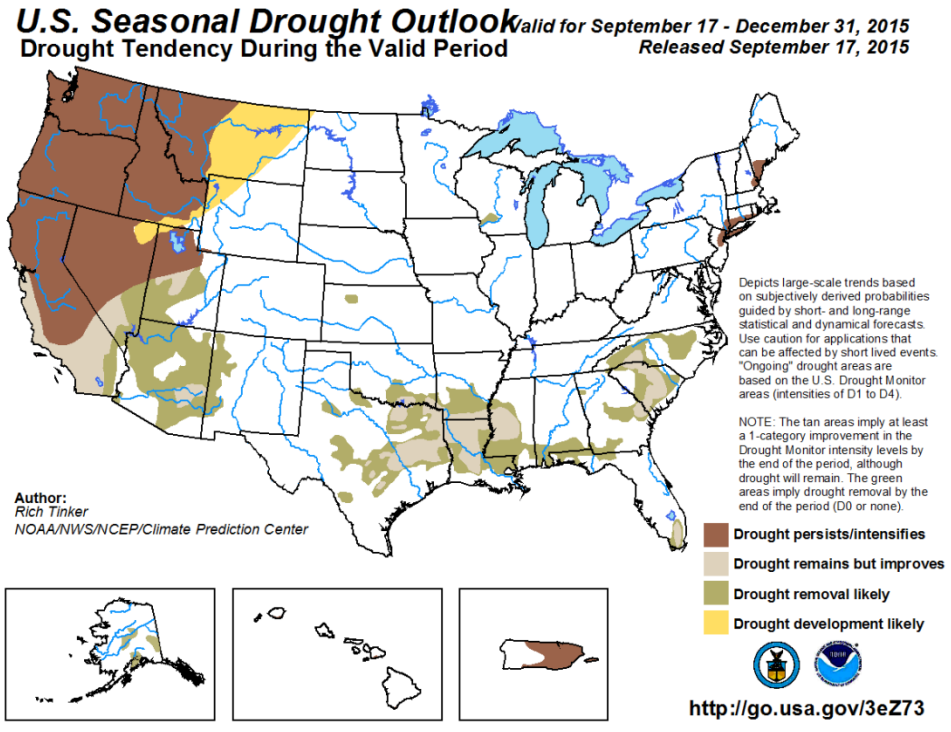


Figure 3. National Drought Mitigation Center U.S. Seasonal Drought Outlook, released September 17, 2015.

Precipitation

September precipitation accumulations are shown in **Figure 4** as both inches of precipitation and percent of normal monthly precipitation. Precipitation was either much above or much below normal in the basin. Because normal September precipitation in the upper basin historically is quite low, one storm could result in above normal totals. While the percent of normal graphic (**Figure 4, right**) shows that above normal precipitation fell in western Montana, western North Dakota, southeastern South Dakota, eastern Nebraska and western Iowa, the precipitation total graphic (**Figure 4, left**) indicates that, other than in the eastern Nebraska/western Iowa area where some monthly totals exceeded 7 inches, monthly totals in the rest of the basin were generally less than 3 inches. July-August-September precipitation accumulations are shown in **Figure 5**. The three-month accumulations reflect a wide array of above normal, normal and below normal precipitation across the basin, highlighted by the eastern Nebraska/western Iowa area recording much above normal precipitation.

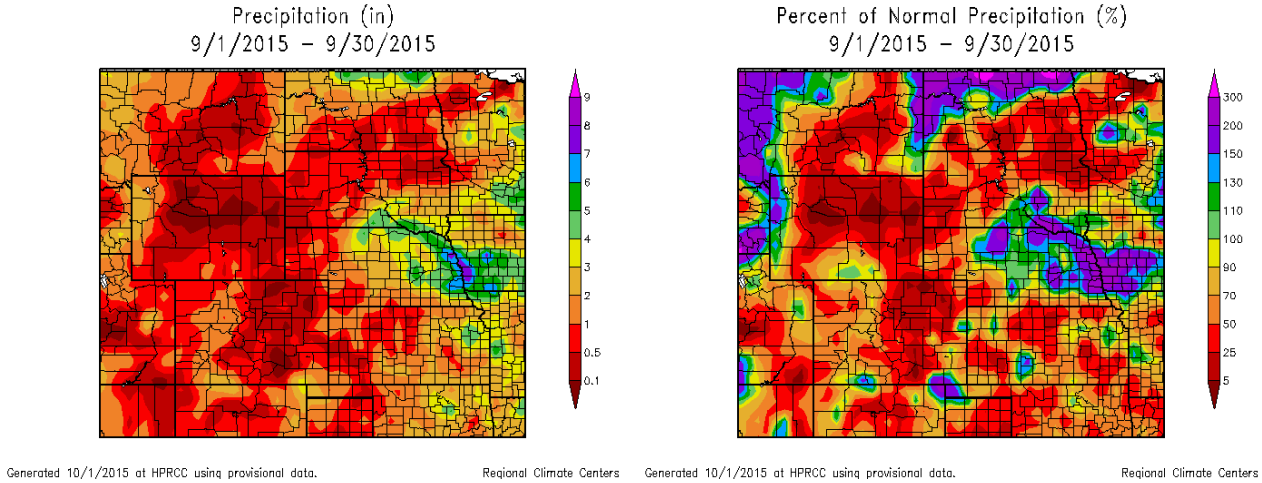


Figure 4. September 2015 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

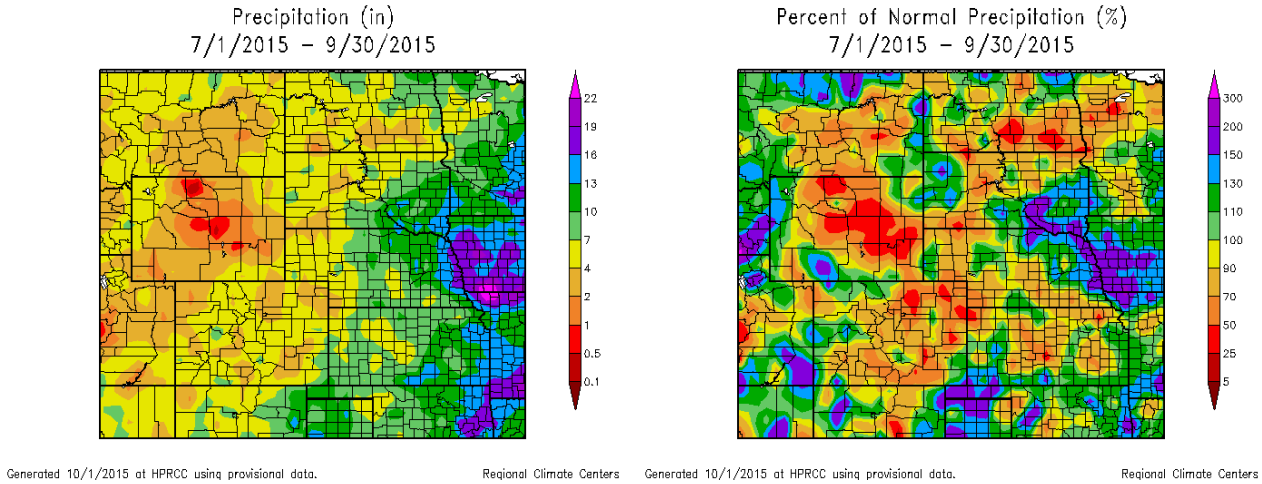


Figure 5. July-September 2015 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Temperature

September temperatures were 2 to 6 degrees Fahrenheit (deg F) warmer than normal over much of the basin (**Figure 6, left)** and some of areas of basin experienced monthly temperatures 6 to 10 deg F warmer than normal. Three-month (July-August-September) temperature departures (**Figure 6, right**) show that most of the basin recorded temperatures within +/-2 deg F of normal temperatures. The western portion of the basin, as well as western Iowa and western Missouri, was slightly cooler than normal over the 3-month period and the rest of the basin was slightly warmer than normal.

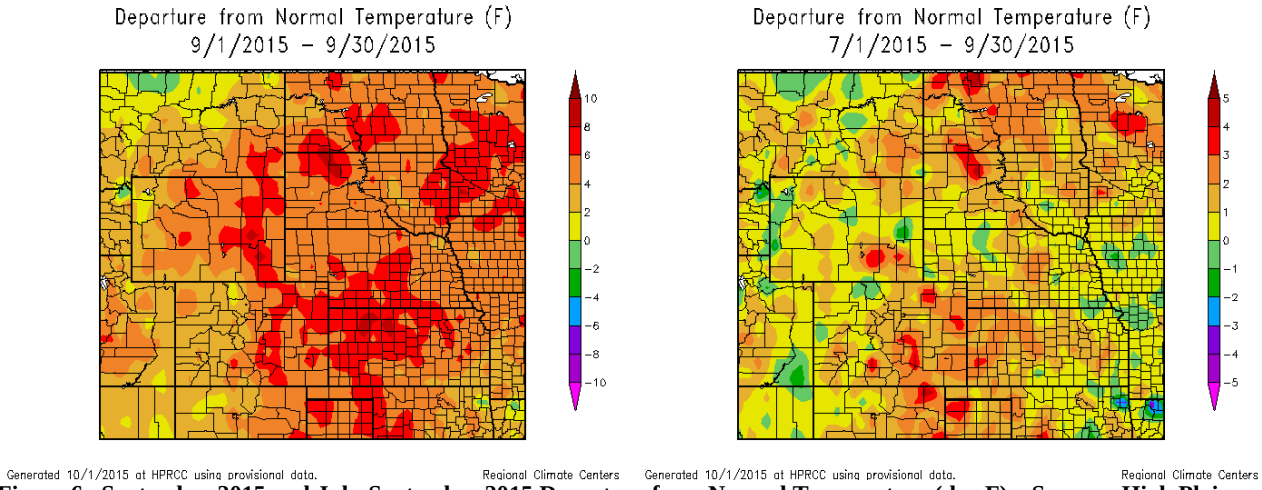


Figure 6. September 2015 and July-September 2015 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

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 monthly runoff.

Figure 7 shows the NOAA NLDAS ensemble mean soil moisture percentiles on September 27, 2015 for the total modeled soil column, which is about 2 meters. Soil moisture percentiles on August 27, 2015 are shown in **Figure 8**. The NLDAS soil moisture depiction is an average value for the soil moisture column. **Figure 7** indicates above normal soil moisture conditions throughout much of the upper Basin, albeit drier than what was shown one month earlier (**Figure 8**) Soil moisture is normal and above normal throughout most the basin. Areas with below normal soil moisture are evident in western Montana (outside of the Missouri Basin) as well as eastern North Dakota and central Kansas.

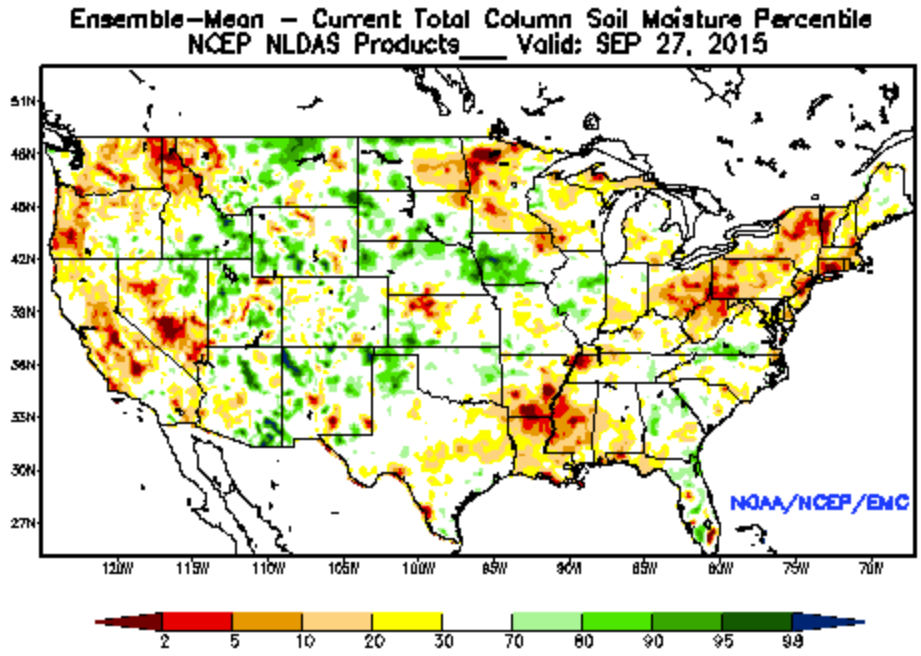


Figure 7. Total Column Soil Moisture Percentile on September 27, 2015. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

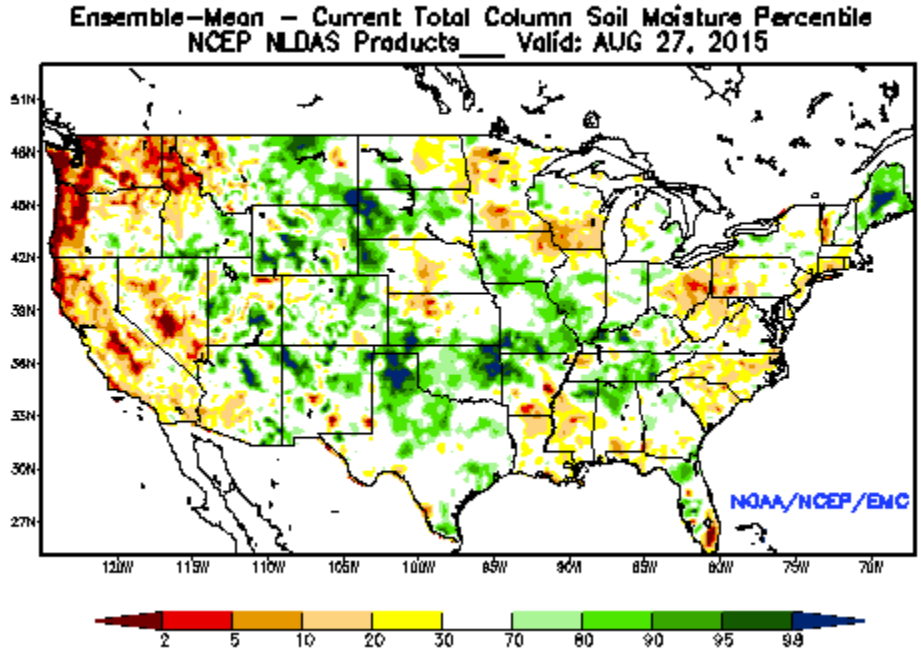
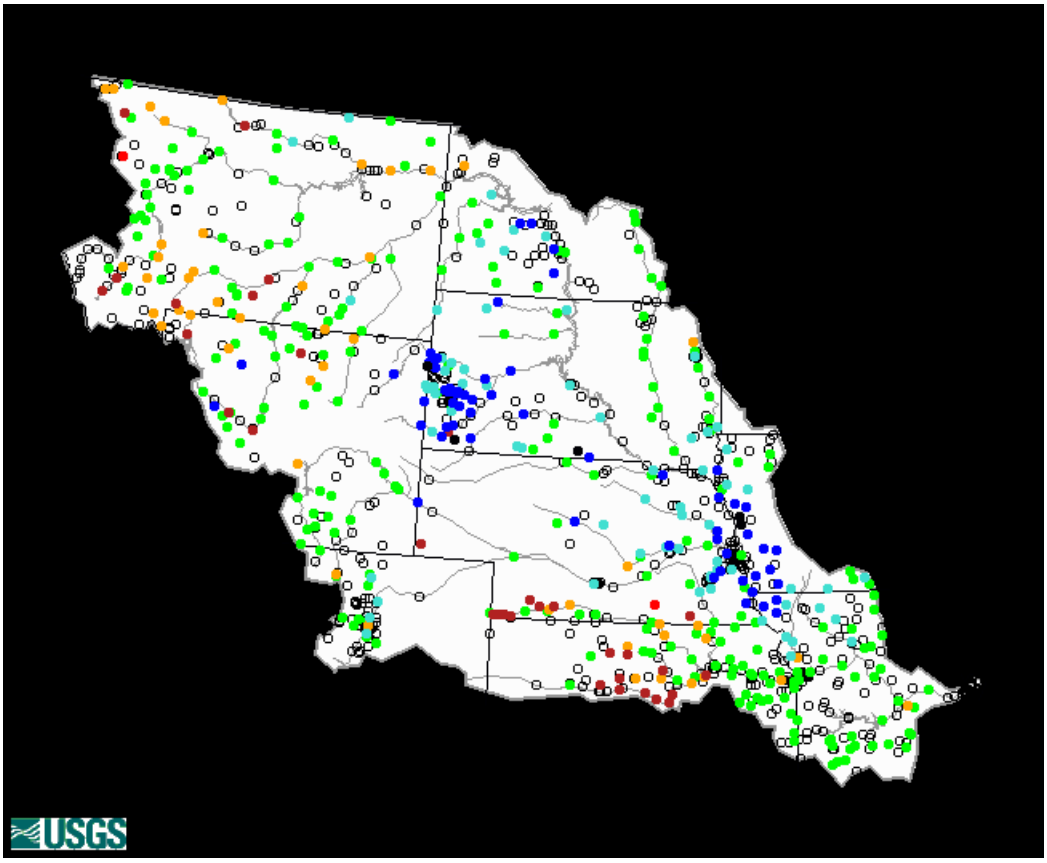


Figure 8. Total Column Soil Moisture Percentile on August 27, 2015. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

Streamflow Conditions

Missouri Basin streamflow conditions represented as percentile classes on October 1, 2015 are shown in **Figure 9**. These conditions are based on the ranking of the October 1, 2015 daily streamflow versus the historical record of streamflow for that date. Streamflow conditions have been much above normal (exceeding the 90th percentile) in western South Dakota, central North Dakota, eastern Nebraska, western Iowa and north-west Missouri. In contrast, streamflow is much below normal in central Kansas (below the 10th percentile). Aside from those areas just mentioned, the rest of the basin streamflows are within the below-normal and above-normal range (25th to 75th percentile).



Explanation - Percentile classes						
Low	<10	10-24	25-75	76-90	>90	High
	Much below normal	Below normal	Normal	Above normal	Much above normal	

Figure 9. USGS Streamflow Conditions as a Percentile of Normal in the Missouri River Basin as of October 1, 2015. Source: USGS. http://waterwatch.usgs.gov/index.php

Climate Outlook

ENSO (El Niño Southern Oscillation)

According to the CPC's latest monthly update on September 10, 2015 (http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso_advisory/ensodisc.pdf), "***there is an approximately 95% chance that El Niño will continue through Northern Hemisphere winter 2015-16, gradually weakening through spring 2016***". CPC studies are predicting a strong El Niño event at its peak. El Niño winters have a tendency to be warmer and drier than normal in the upper Missouri Basin, and the influence of El Niño has been factored into the CPC's climate outlooks.

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. These webinars provide updates on near-term climate outlooks and impacts including the El Niño climate pattern and its implications on late summer, fall and early winter temperature and precipitation patterns in the Missouri River Basin. The possible impacts of El Niño have been factored into the CPC climate outlooks described below.

Temperature and Precipitation Outlooks

For October (**Figure 10**), the CPC climate temperature outlook indicates increased chances for below normal temperatures in the upper basin and equal chances in the lower basin. With regard to precipitation, the CPC indicates that there are equal chances for above normal, below normal and normal precipitation in all of the Missouri Basin.

For October-November-December (**Figure 11**), the CPC is forecasting increased chances for above normal temperatures in the upper Basin and equal chances for the lower basin. For precipitation, the CPC is showing below normal precipitation in Montana, equal chances in the rest of the upper basin and above normal chances in the lower basin.

For January-February-March 2016 (**Figure 12**), the CPC temperature outlook indicates increased chances for above normal temperatures throughout the entire United States, including the upper Basin and a good portion of the lower basin. A "ribbon" of equal chances is indicated that includes most of Missouri-basin portions of Colorado and Kansas. Regarding precipitation, the CPC is indicating increased chances for below normal precipitation in the upper basin (except for South Dakota, which is equal chances) and equal chances or slightly above normal chances for the lower basin.

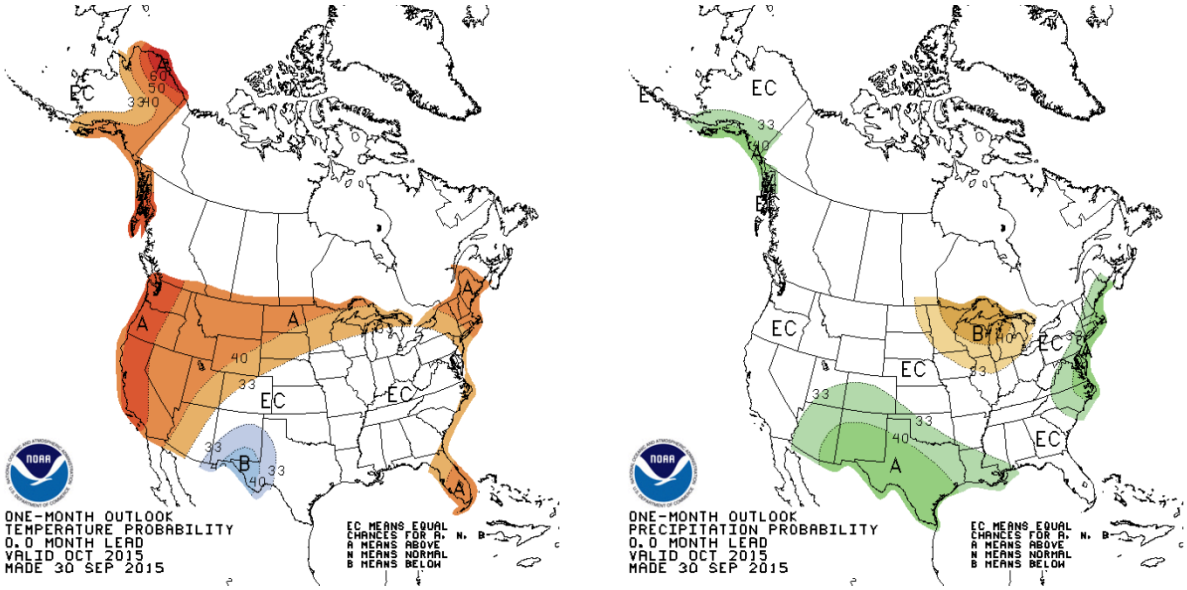


Figure 10. CPC October 2015 temperature and precipitation outlooks.

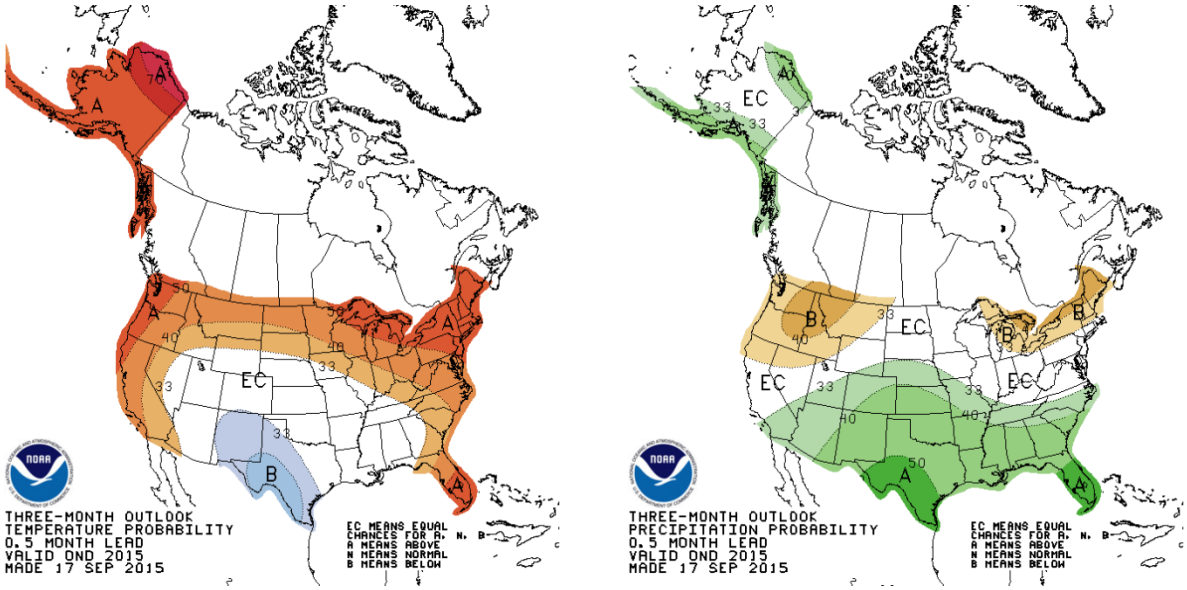


Figure 11. CPC October-November-December 2015 temperature and precipitation outlooks.

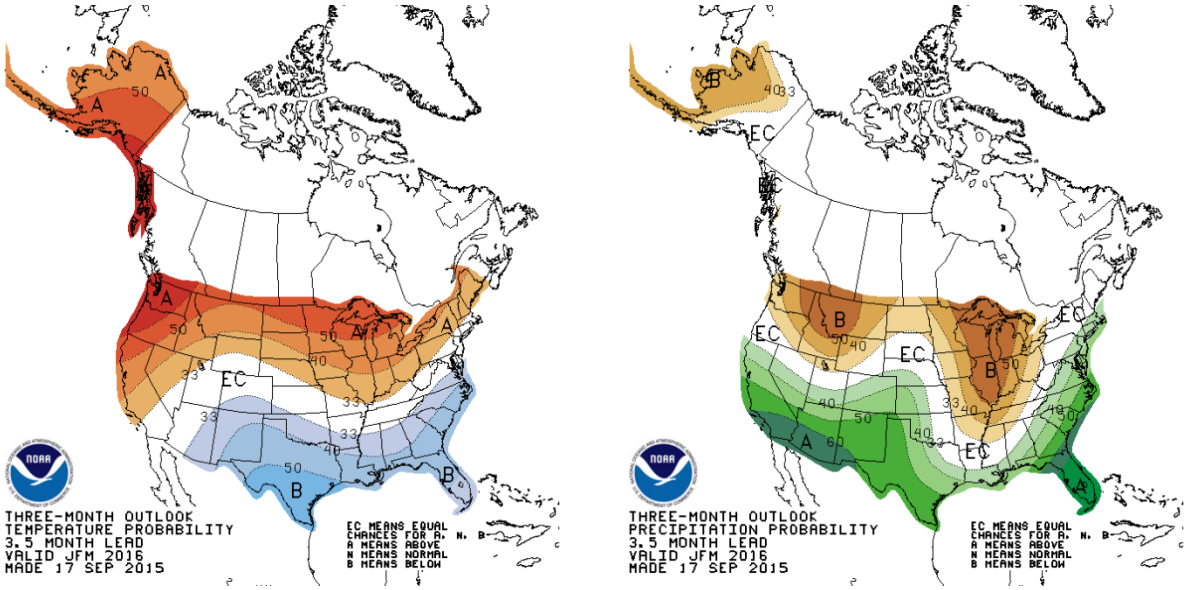


Figure 12. CPC January-February-March 2016 temperature and precipitation outlooks.

October 2015 Calendar Year Runoff Forecast

The October calendar year runoff forecast for the Missouri Basin above Sioux City is **24.9 MAF** (98% of average).

Observed September runoff was 1.0 MAF, 84% of average. Observed September runoff was higher than normal in the lower four reaches - Oahe, Fort Randall, Gavins Point, and Sioux City - due to above normal precipitation. Runoff in the upper two reaches – Fort Peck and Garrison – was well below normal due to below normal precipitation.

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 25.5 MAF (102% of average) upper basic forecast to the 24.4 MAF (96% of average) lower basic forecast.

Upper Missouri River Basin
October 2015 Calendar Year Runoff Forecast
November 2, 2015

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.

2015 Calendar Year Forecast Synopsis

The November calendar year runoff forecast for the Missouri Basin above Sioux City is **25.0 MAF** (99% of average). October runoff was **0.9 MAF** (78**%** of average). Observed October runoff was below average in all reservoir reaches except for the Gavins Point to Sioux City reach.

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 25.4 MAF (100% of average) upper basic forecast to the 24.7 MAF (98% of average) 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 lower than expected (lower basic) is attributed to all 6 reaches for 2 months. The result is a range or "bracket" for each reach, and thus, for the total runoff forecast.

Current Conditions

Drought Analysis

Drought conditions have persisted in the Missouri Basin during the fall. The drought conditions are shown in the National Drought Mitigation Center's drought monitor for October 27, 2015 (**Figure 1**) and September 29, 2015 (**Figure 2**). Extreme Drought (D3) and Severe Drought (D2) conditions have not changed in western Montana. Abnormally Dry (D0) conditions have persisted in eastern Montana, while D1 conditions have developed in eastern North Dakota, northeast Kansas and central Missouri. The U.S. Seasonal Drought Outlook in **Figure 3** indicates drought will persist and likely intensify in western Montana and continue to develop in Montana, northern Wyoming and western North Dakota through January 31, 2016.

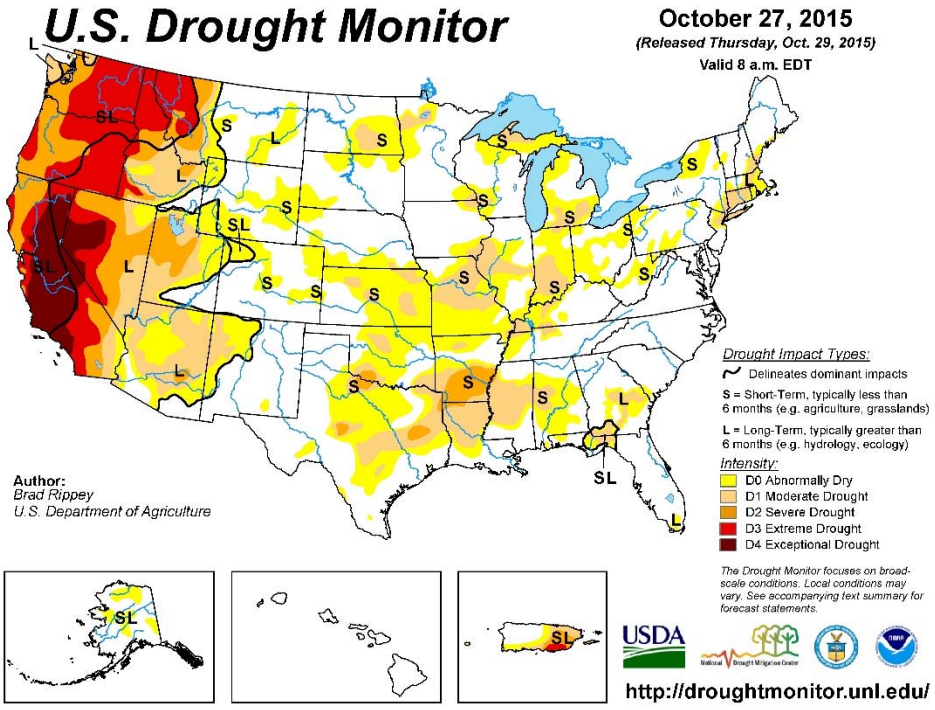


Figure 1. National Drought Mitigation Center U.S. Drought Monitor for October 27, 2015.

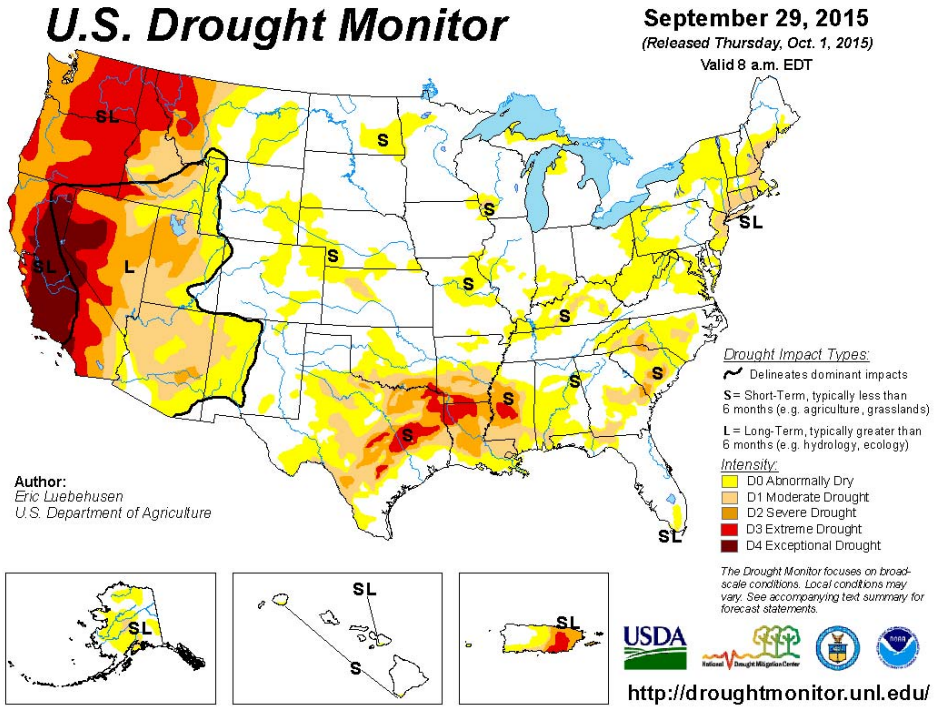


Figure 2. National Drought Mitigation Center U.S. Drought Monitor for September 29, 2015.

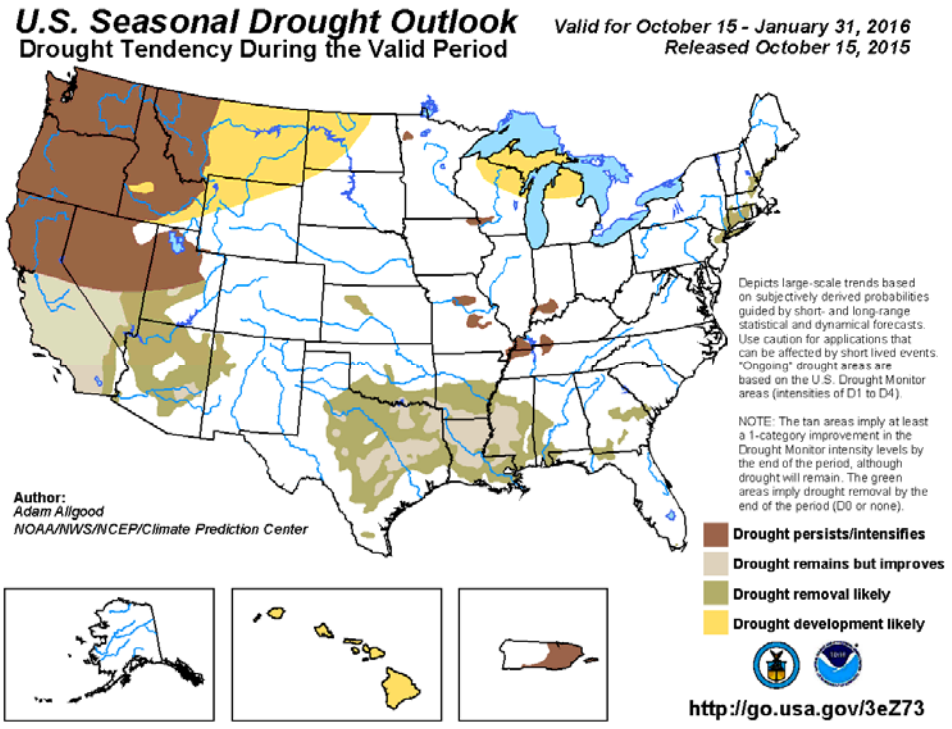


Figure 3. National Drought Mitigation Center U.S. Seasonal Drought Outlook, released October 15, 2015.

Precipitation

October precipitation accumulations are shown in **Figure 4** as both inches of precipitation and percent of normal monthly precipitation. Precipitation was either much above or much below normal in the basin. Because normal October precipitation in the upper basin historically is quite low, one storm could result in above normal totals. While the percent of normal graphic (**Figure 4, right**) shows that above normal precipitation fell in central and northern Montana, western North Dakota, western South Dakota, western Nebraska, the precipitation total graphic (**Figure 4, left**) indicates that monthly totals in those areas ranged from 1 to 3 inches of precipitation. October precipitation was well below normal (70 percent or much less) across much of eastern North Dakota, eastern South Dakota, eastern Nebraska, western Iowa, eastern Kansas, and Missouri (**Figure 4, right**).

August-September-October precipitation accumulations are shown in **Figure 5**. The three-month accumulations reflect a dry pattern across much of the Missouri Basin with the exception of some areas that received 130 to 200 percent of normal precipitation. These areas include north central Montana, western North Dakota, northwest South Dakota, eastern Nebraska, and western Iowa. Dry areas in the Missouri Basin include Wyoming, eastern North Dakota, northern South Dakota, Kansas, and Missouri.

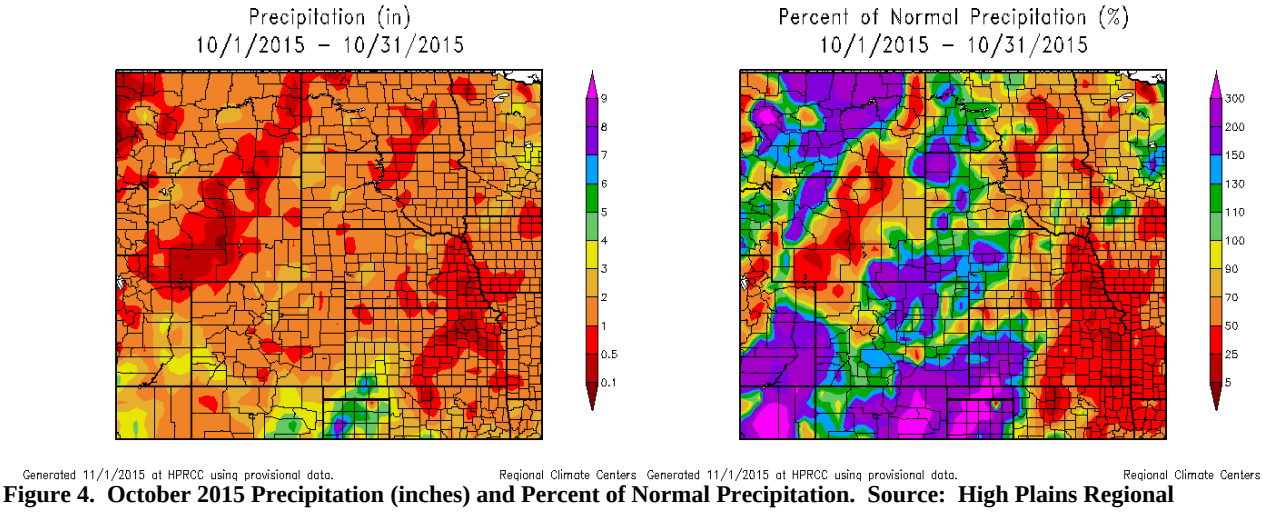


Figure 4. October 2015 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

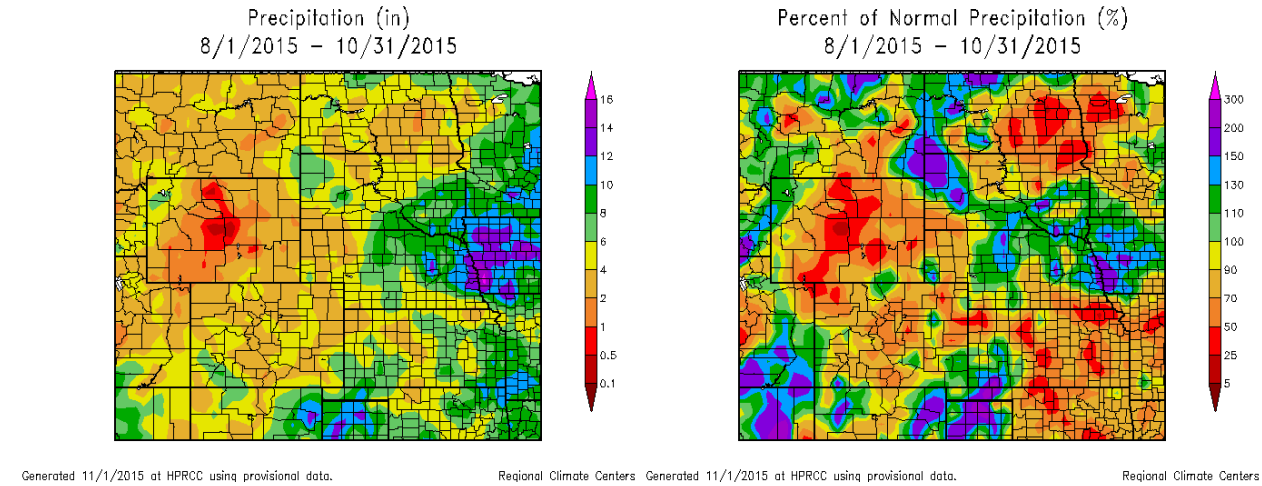


Figure 5. August-October 2015 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Temperature

October temperatures were generally 2 to 6 degrees Fahrenheit (deg F) warmer than normal over much of the Missouri Basin (**Figure 6, left)** and some of areas of the basin such as Wyoming experienced monthly temperatures 4 to 8 deg F warmer than normal. Temperatures were generally normal to 4 deg F above normal in the lower Missouri Basin. Three-month (August-September-October) temperature departures (**Figure 6, right**) show that most of the basin recorded temperatures 2 to 4 deg F above normal. Average temperatures in central Montana, Iowa, eastern Kansas, and Missouri ranged from normal to 2 deg F above normal (**Figure 6, right**).

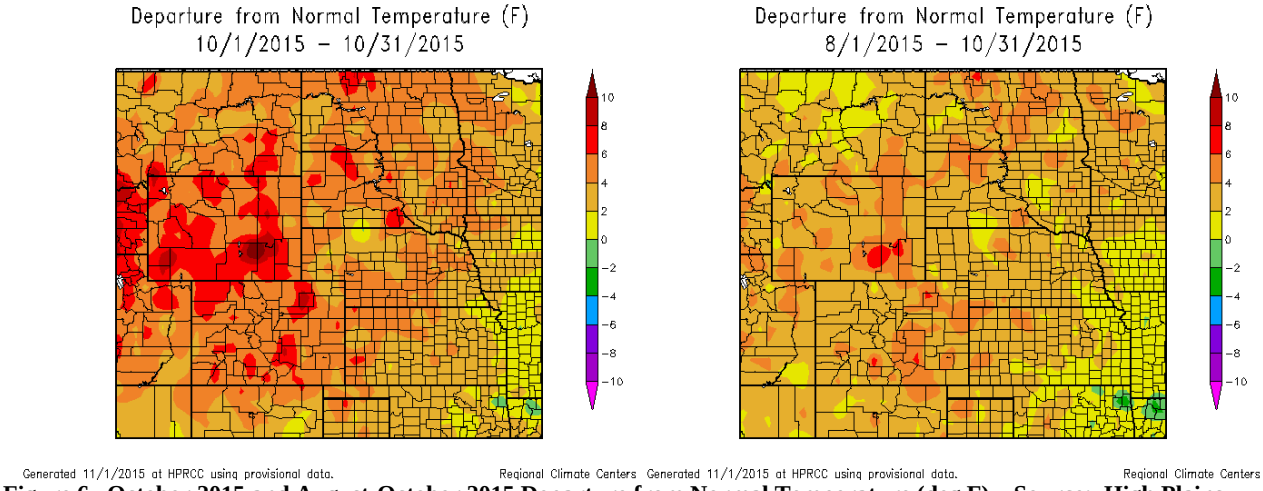


Figure 6. October 2015 and August-October 2015 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

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 monthly runoff.

Figure 7 shows the NOAA NLDAS ensemble mean soil moisture percentiles on October 28, 2015 for the total modeled soil column, which is about 2 meters. The NLDAS soil moisture depiction is an average value for the soil moisture column. **Figure 7** indicates above normal soil moisture conditions throughout portions of the upper Basin including northern and central Montana, western North Dakota, western South Dakota, western Nebraska, and western Iowa. Drier-than-normal soil moisture conditions are indicated in western Montana, much of Wyoming, eastern North Dakota, eastern South Dakota, much of Kansas and Missouri.

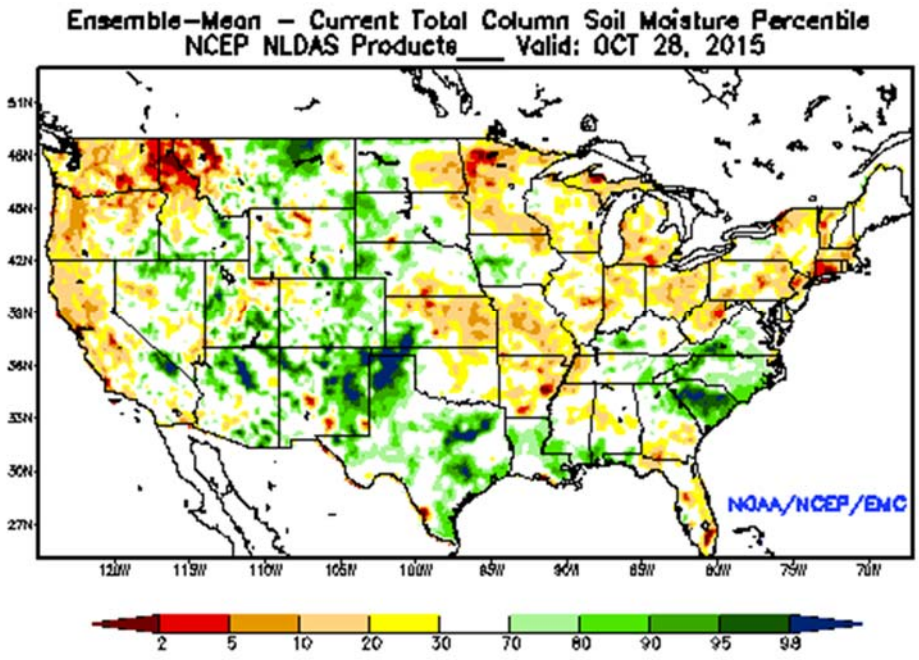


Figure 7. Total Column Soil Moisture Percentile on October 28, 2015. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

Streamflow Conditions

Missouri Basin streamflow conditions represented as percentile classes on November 1, 2015 are shown in **Figure 8**. These conditions are based on the ranking of the November 1, 2015 daily streamflow versus the historical record of streamflow for that date. Streamflow conditions have been much above normal (exceeding the 90th percentile) in the Black Hills of South Dakota, locations in western North Dakota, eastern Nebraska, and western Iowa. In contrast, streamflow is much below normal in western Montana and central Kansas (below the 10th percentile). Aside from those areas just mentioned, the rest of the basin streamflows are within the below-normal and above-normal range (25th to 75th percentile).

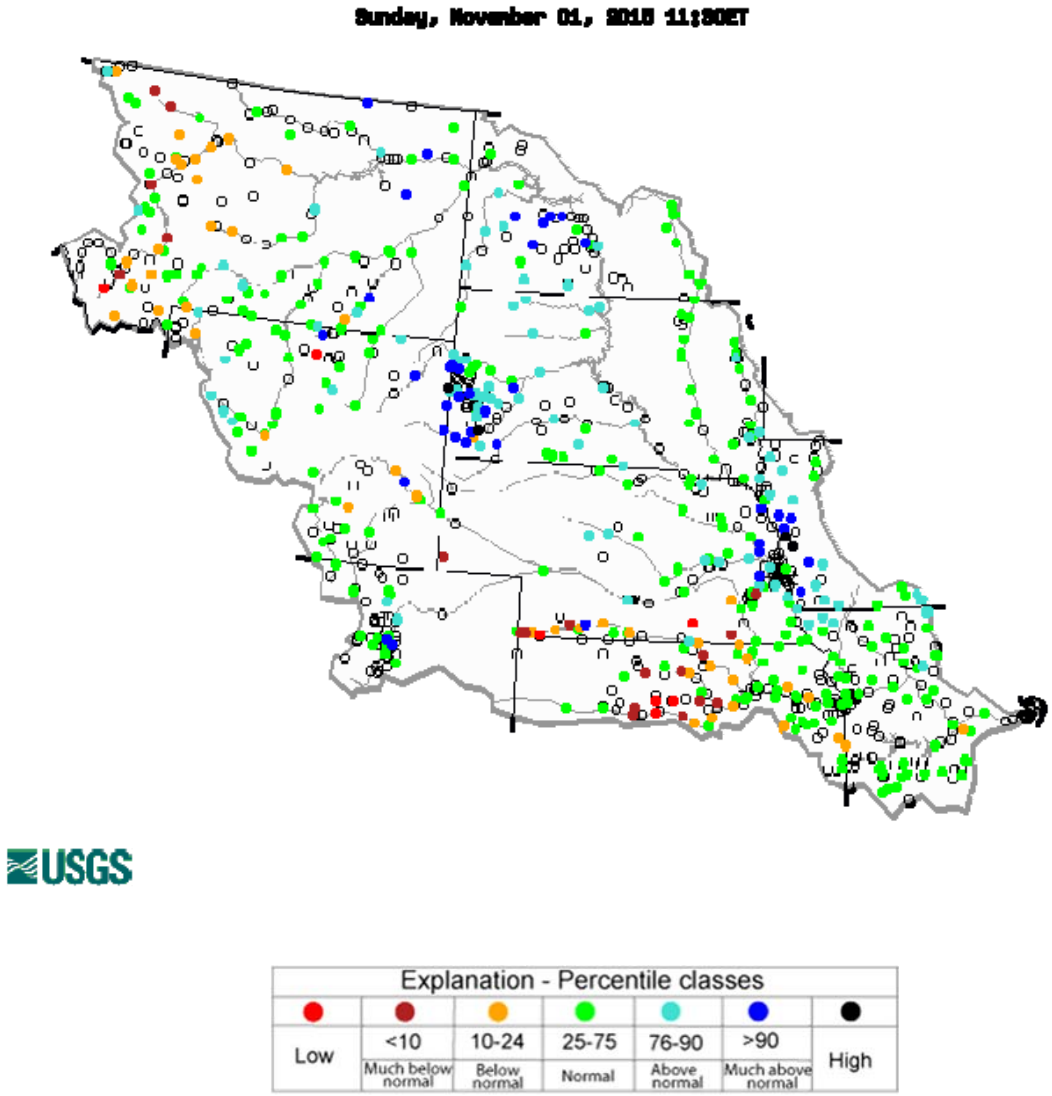


Figure 8. USGS Streamflow Conditions as a Percentile of Normal in the Missouri River Basin as of October 1, 2015. Source: USGS. http://waterwatch.usgs.gov/index.php

Climate Outlook

ENSO (El Niño Southern Oscillation)

According to the CPC's latest monthly update on October 26, 2015 (http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso_advisory/ensodisc.pdf), "***there is an approximately 95% chance that El Niño will continue through Northern Hemisphere winter 2015-16, gradually weakening through spring 2016***". CPC studies are predicting a strong El Niño event at its peak. El Niño winters have a tendency to be warmer and drier than normal in the upper Missouri Basin, and the influence of El Niño has been factored into the CPC's climate outlooks.

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. These webinars provide updates on near-term climate outlooks and impacts including the El Niño climate pattern and its implications on late summer, fall and early winter temperature and precipitation patterns in the Missouri River Basin. The possible impacts of El Niño have been factored into the CPC climate outlooks described below.

Temperature and Precipitation Outlooks

For October (**Figure 9**), the CPC climate temperature outlook indicates increased chances for above normal temperatures in most of the Missouri Basin. Equal chances for above normal, normal and below normal temperatures are indicated in central and western Wyoming and Colorado. With regard to precipitation, the CPC indicates that there are increased chances for above normal precipitation in southern Montana, Wyoming, western South Dakota, much of Nebraska, Kansas and Missouri in October. In the remainder of the Missouri Basin, there are equal chances for above normal, below normal and normal precipitation.

During November-December-January (**Figure 10**), the CPC is forecasting increased chances for above normal temperatures in the upper Basin and equal chances in Colorado, southern Nebraska, Kansas and Missouri. For precipitation, the CPC is showing increased chances for below normal precipitation in Montana, western North Dakota, and northwest Wyoming. There are increased chances for above normal precipitation over much of Colorado, southern Nebraska, and Kansas.

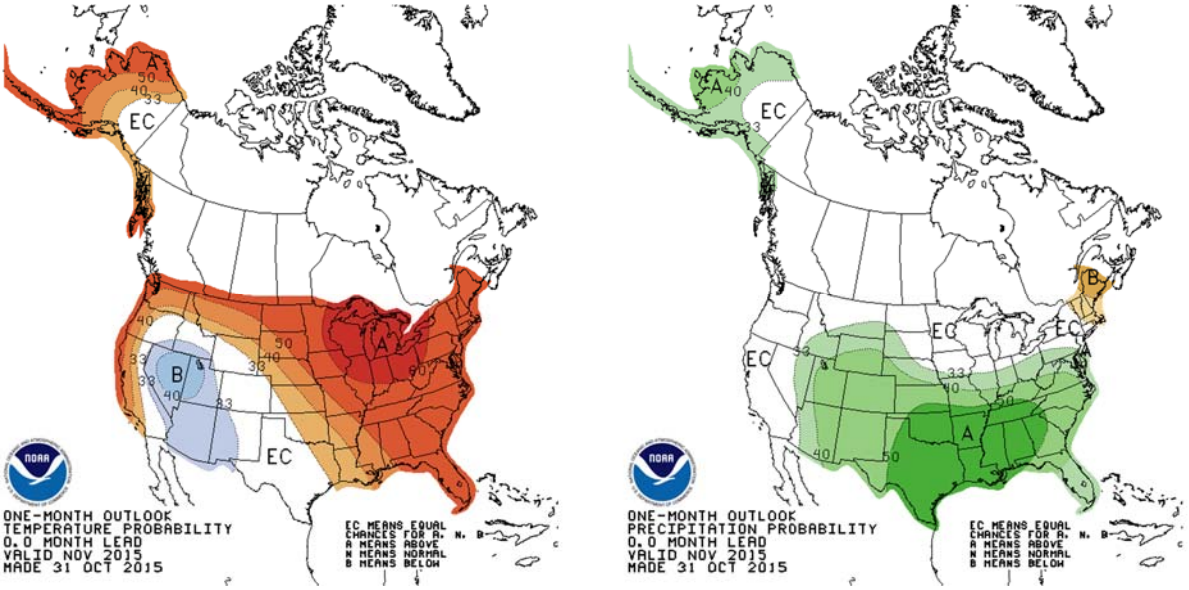


Figure 9. CPC November 2015 temperature and precipitation outlooks.

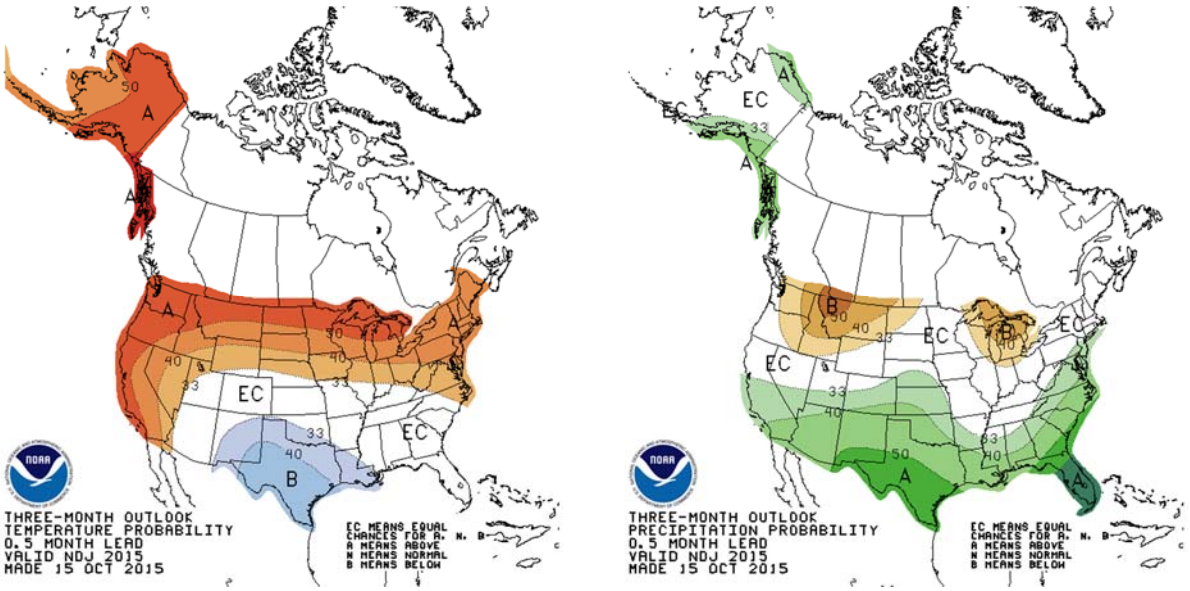


Figure 10. CPC November-December 2015-January 2016 temperature and precipitation outlooks.

November 2015 Calendar Year Runoff Forecast

The October calendar year runoff forecast for the Missouri Basin above Sioux City is **25.0 MAF** (99% of average).

Observed October runoff was 0.9 MAF, 78% of average. Observed October runoff was lower than normal in all reaches except the Sioux City reach.

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 25.4 MAF (100% of average) upper basic forecast to the 24.7 MAF (98% of average) lower basic forecast.

Upper Missouri River Basin
December 2015 Calendar Year Runoff Forecast
December 2, 2015

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.

2015 Calendar Year Forecast Synopsis

The December calendar year runoff forecast for the Missouri Basin above Sioux City is **25.3 MAF** (100% of average). November runoff was **1.0 MAF** (100% of average) above Sioux City, and November runoff above Gavins Point was 0.8 MAF (85% of average). Observed November runoff was above average in all reservoir reaches except for the Fort Peck (73% of average) and Garrison (57% of average) reaches.

Due to the amount of variability in precipitation and other hydrologic factors that can occur over the next month, the range of expected inflow ranges from the 25.5 MAF (101% of average) upper basic forecast to the 25.2 MAF (99% of average) 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/one month forecast), the range of greater than expected (upper basic) and lower than expected (lower basic) runoff is attributed to all 6 reaches for one month. The result is a range or “bracket” for each reach, and thus, for the total runoff forecast.

Current Conditions

Drought Analysis

Drought conditions have persisted in the upper Missouri Basin during the fall, but have improved in the lower Basin. The drought conditions are shown in the National Drought Mitigation Center's U.S. Drought Monitor for November 24, 2015 (**Figure 1**) and October 27, 2015 (**Figure 2**). Abnormally Dry (D0) conditions (**Figure 1**) have expanded slightly in western and south central Montana, Wyoming, and western South Dakota. Moderate Drought (D1) conditions have also expanded slightly in western Montana. In the lower Basin, recent precipitation has eliminated all signs of drought in Missouri and a small portion of eastern Kansas. The U.S. Seasonal Drought Outlook through February 29, 2016 (**Figure 3)** indicates drought will persist in western Montana and the James River Basin in central North Dakota. Drought is forecast to develop in most of Montana and northwest Wyoming.

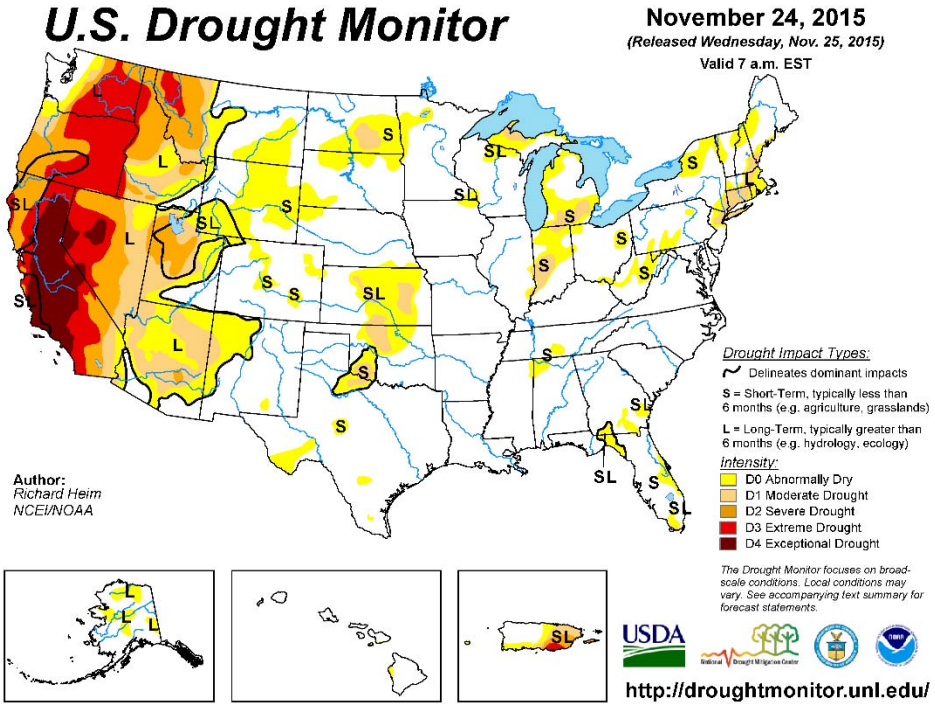


Figure 1. National Drought Mitigation Center U.S. Drought Monitor for November 24, 2015.

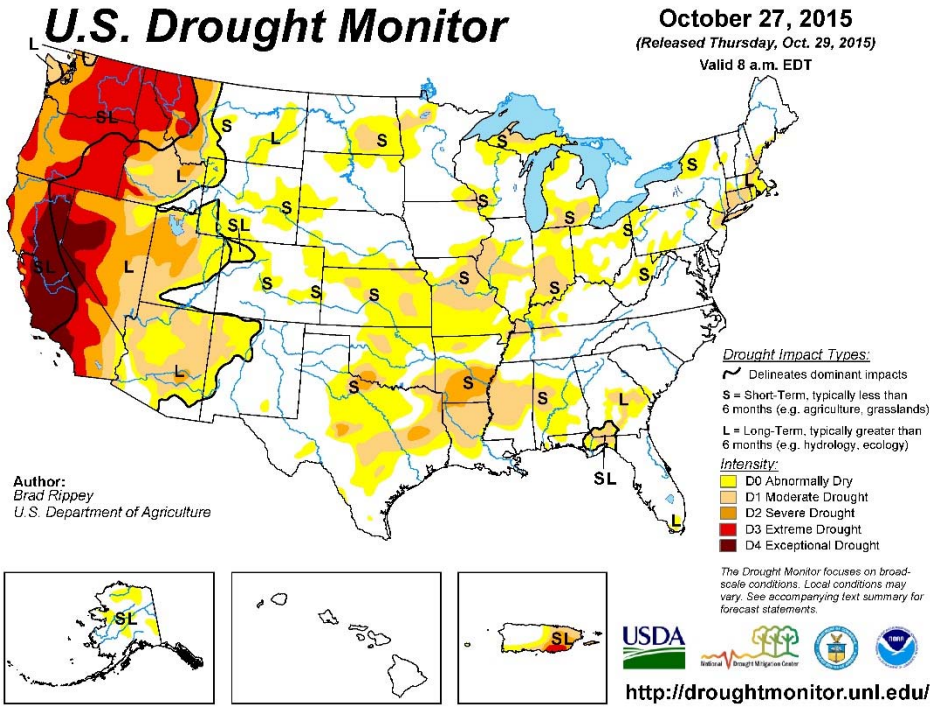


Figure 2. National Drought Mitigation Center U.S. Drought Monitor for October 27, 2015.

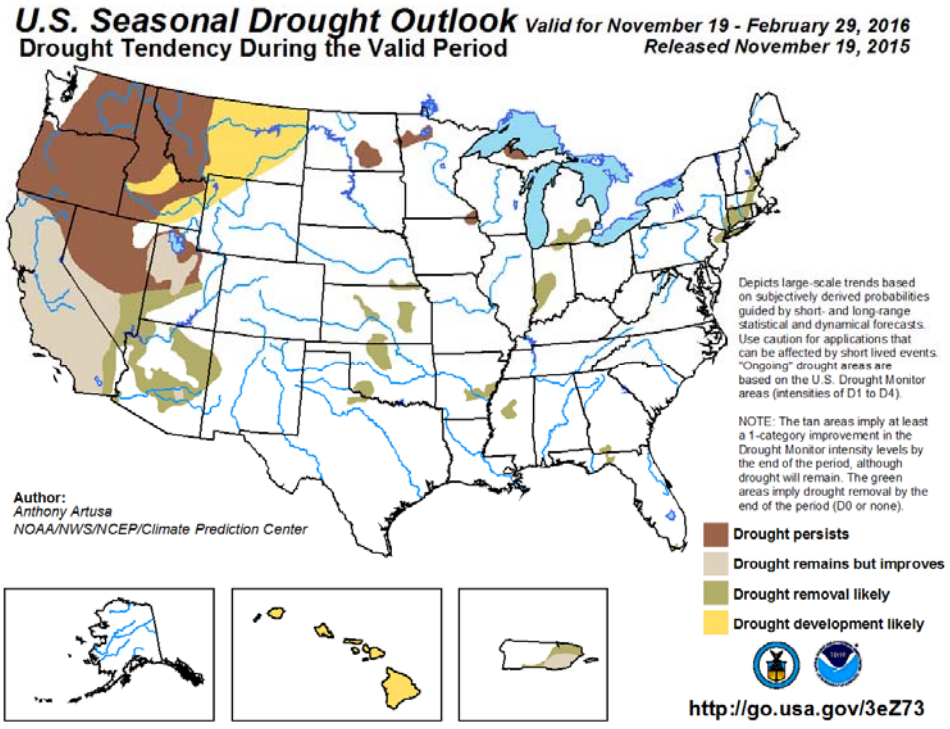


Figure 3. National Drought Mitigation Center U.S. Seasonal Drought Outlook, released November 19, 2015.

Precipitation

November precipitation accumulations are shown in **Figure 4** as both inches of precipitation and percent of normal monthly precipitation. Precipitation was above normal in western Montana and the lower Basin including Nebraska, Iowa, Kansas and Missouri. Precipitation as a percent of normal was more than 200 percent in many areas (**Figure 4, right**). Lower Basin precipitation was caused by several moderate storms resulting in total November rainfall ranging from 2 to 5 inches (**Figure 4, left**), and even greater amounts of November precipitation were observed in Missouri. In contrast upper Basin precipitation ranged from 1 to 2 inches in western Montana, but it was less than 0.5 inches over large portions of eastern Montana, northeast Wyoming and the western Dakotas (**Figure 4, left**) or less than 50% of normal (**Figure 4, right**). Precipitation was particularly low (less than 5% of normal) in an area of southwest North Dakota and northwest South Dakota.

September-October-November precipitation accumulations are shown in **Figure 5**. The three-month accumulations reflect a dry pattern across much of the upper Missouri Basin including much of Wyoming, southeastern Montana, much of southern North Dakota and northern South Dakota. These areas received less than 1 inch of precipitation during the three-month period (**Figure 5, left**) or less than 50 percent of normal precipitation (**Figure 5, right**). Areas that have received above normal precipitation include northern and western Montana, northern and western North Dakota, southeastern South Dakota, Nebraska and western Iowa. Precipitation as a percent of normal in these areas has been 130 percent of normal with as much as 150 percent of normal in the wettest areas. Precipitation in the lower Basin was particularly beneficial because it resulted in high than normal Missouri River tributary flows, which benefited navigation.

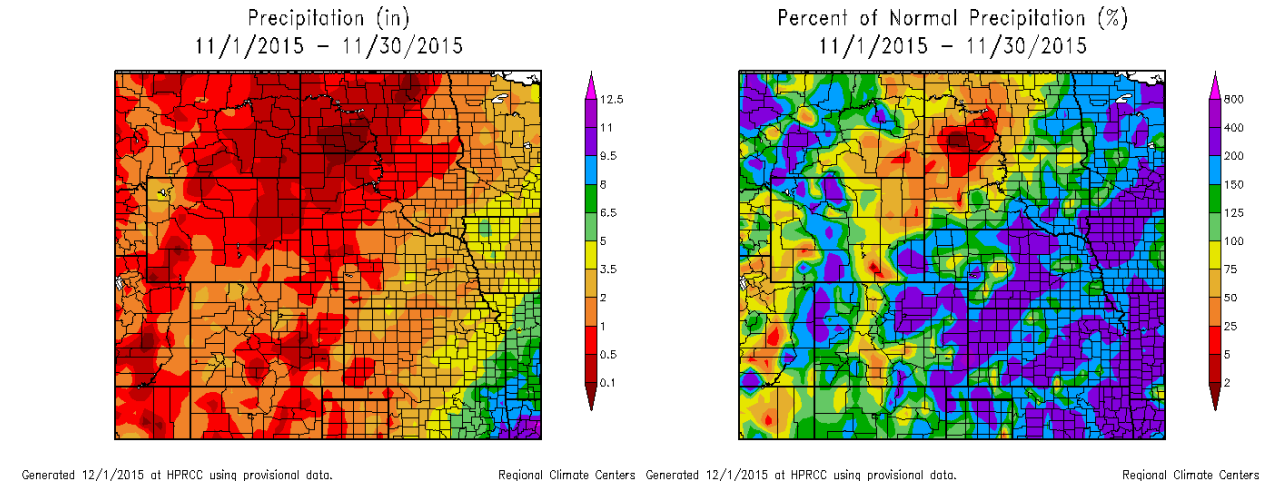


Figure 4. November 2015 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

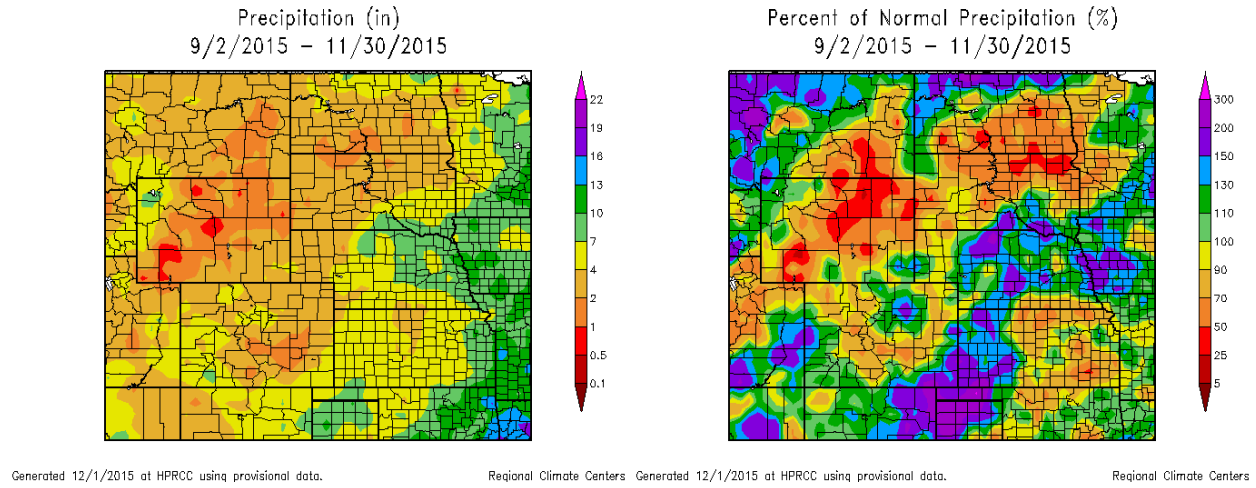


Figure 5. September-October-November 2015 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Temperature

November temperatures shown in the left pane of **Figure 6** show a pattern of normal to about 2 deg F below normal temperatures in the western third of the upper Basin to 4 to 6 deg F above normal temperatures in the eastern third of the upper Basin. Two-month (October-November) temperature departures (**Figure 6, right**) show that most of the basin recorded 2 to 6 deg F above normal temperatures, though temperature departures ranging from 6 to 8 deg F above normal have occurred over central and eastern South Dakota and North Dakota.

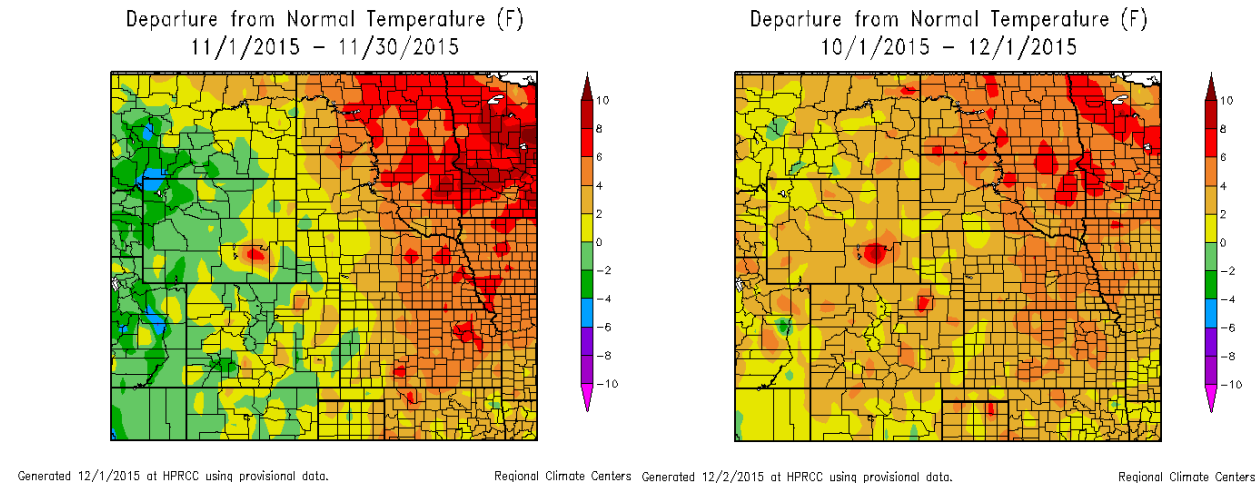


Figure 6. November 2015 and October-November 2015 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

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 monthly runoff.

Figure 7 shows the NOAA NLDAS ensemble mean soil moisture percentiles on November 26, 2015 for the total modeled soil column, which is about 2 meters. The NLDAS soil moisture depiction is an average value for the soil moisture column. **Figure 7** indicates above normal soil moisture conditions are persistent throughout much of the upper Basin. The wettest soils (greater than 95th percentile moisture) indicated on this map are located in north central Montana and western Iowa. Dry soils (less than 30th percentile moisture) are located in portions of western Montana, eastern North Dakota, northeast South Dakota and eastern Kansas.

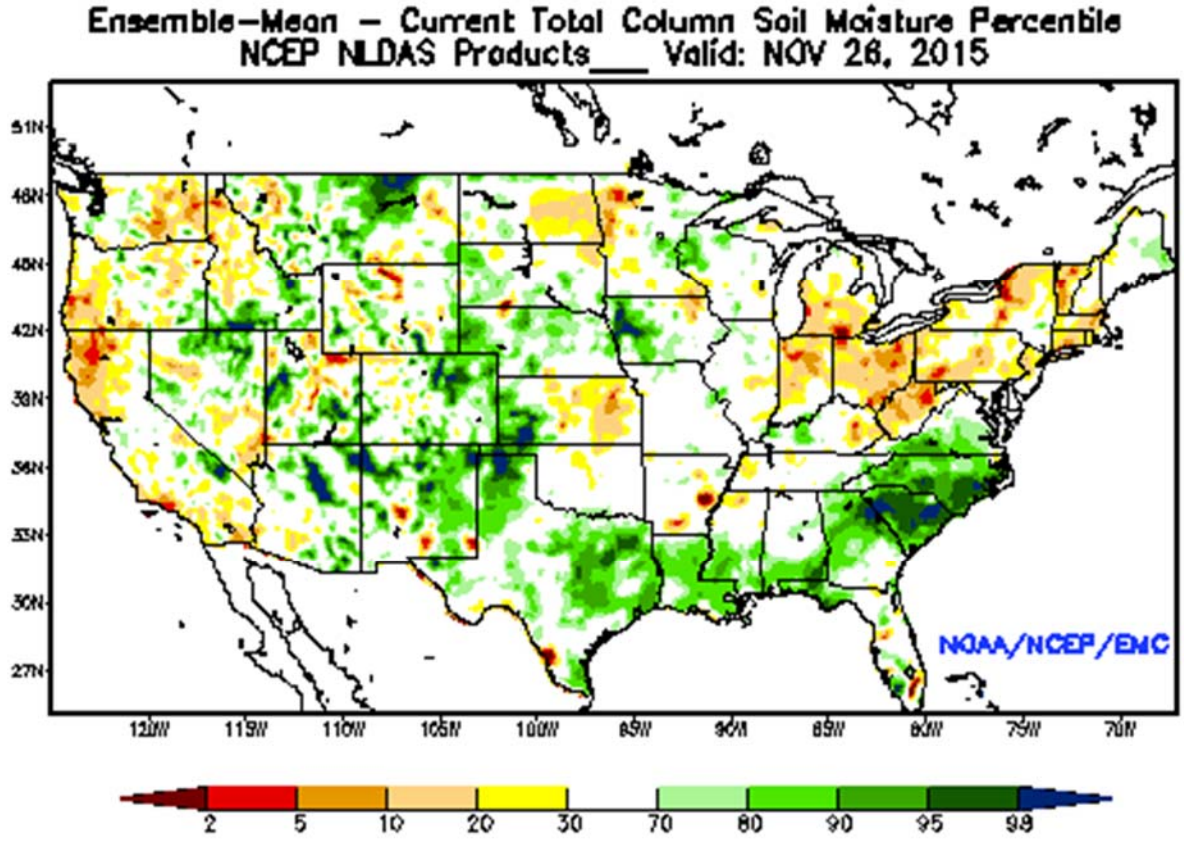


Figure 7. Total Column Soil Moisture Percentile on November 26, 2015. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

Streamflow Conditions

Missouri Basin streamflow conditions are shown in **Figure 8**. These conditions are based on the ranking of the November 30, 2015 daily streamflow versus the historical record of streamflow for that date. Streamflow conditions continue to be "Much above normal" (greater than the 90th percentile) in the Black Hills of South Dakota. Most notably, streamflow conditions in the lower Basin including Missouri River tributaries in Nebraska, Iowa, eastern Kansas and Missouri are classified as "Much above normal" (greater than the 90th percentile) to "High" as a result of above normal November precipitation. In the upper Basin, a majority of stations have no classification because the current stream gages are either ice-affected or the historical record is ice-affected. The few stations that are reporting indicate streamflow conditions, particularly in Montana and Wyoming, are "Normal" (25th-75th percentile) to "Below normal" (10th-24th percentile).

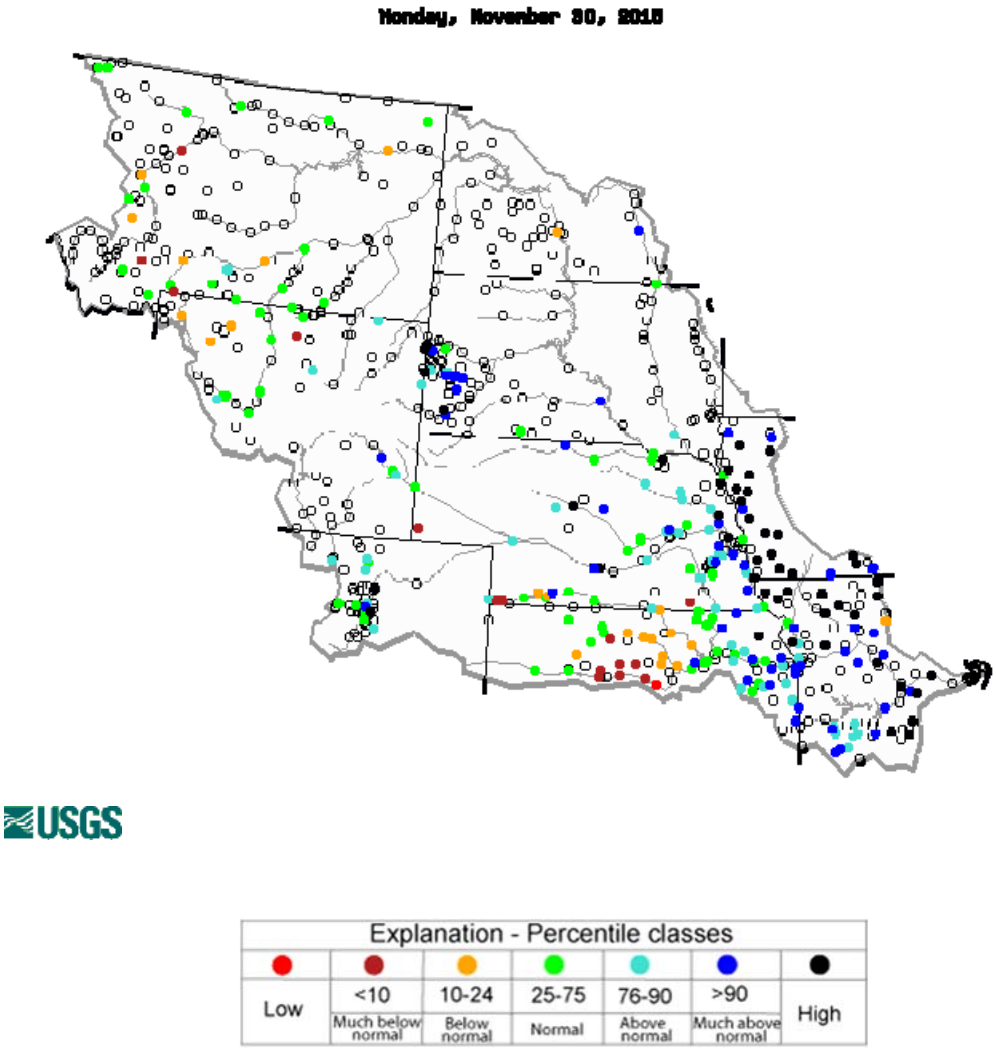


Figure 8 USGS Streamflow Conditions as a Percentile of Normal in the Missouri River Basin as of November 30, 2015. Source: USGS. http://waterwatch.usgs.gov/index.php

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. A March-April 2016 runoff forecast will not be made until January 1, 2016.

Based on the National Operational Hydrologic Remote Sensing Center (NOHRSC) assessment (**Figure 9**) as of December 1, 2015 there were trace to 1-inch amounts of snow water equivalent (SWE) over most of the upper Missouri Basin above Sioux City, IA. Recent snowfall on November 30, 2015 over southeast South Dakota and northwest Iowa has increased accumulations to the 1 to 2 inch SWE category. Snow accumulations over southwest Iowa, northwest Missouri, southeast Nebraska and northeast Kansas are likely a combination of snow and ice accumulation. Plains snowpack in the lower Basin is expected to melt within the next week because of warmer temperatures.

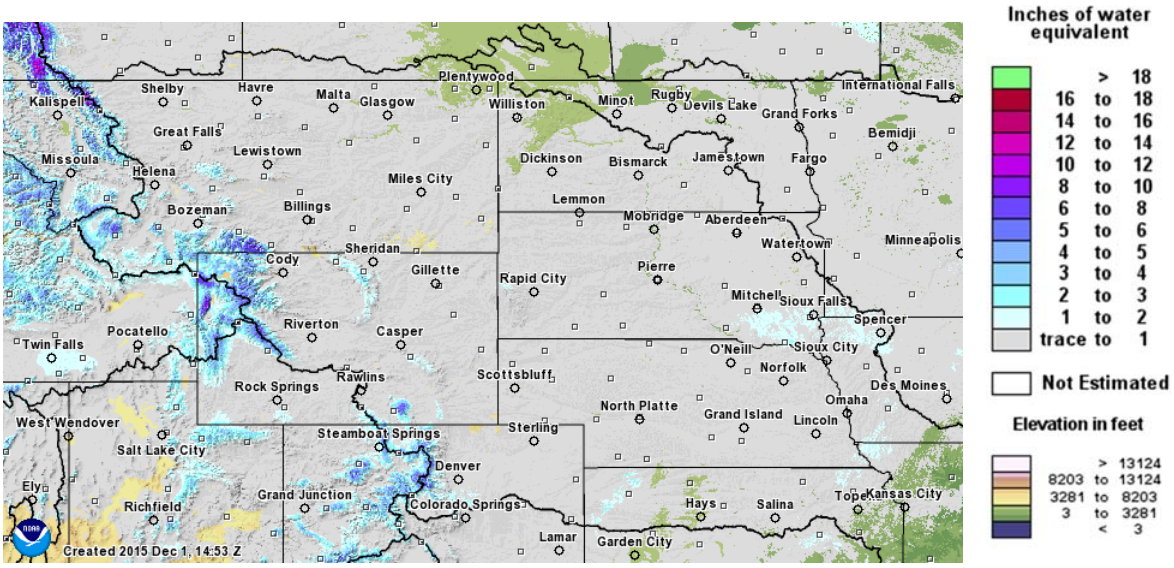


Figure 9. December 1, 2015 NOHRSC modeled plains snow water equivalent. Source: NOAA National Operational Hydrologic Remote Sensing Center. http://www.nohrsc.nws.gov/interactive/html/map.html

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 mainstem 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 greater than average runoff from an average mountain snowpack this year due to wetter than normal soil moisture conditions. A May-June-July 2016 runoff forecast will not be made until January 1, 2016.

Figure 10 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 **November 30, 2015**, the Corps of Engineers computed an average mountain SWE in the **Fort Peck reservoir reach of 2.9 inches, which is 76% of normal** 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 **2.3 inches, which is 61% of normal** based on the 1981-2010 average SWE for the Garrison reach. Normally by December 1, 26% of the peak snow accumulation has occurred in the mountains.

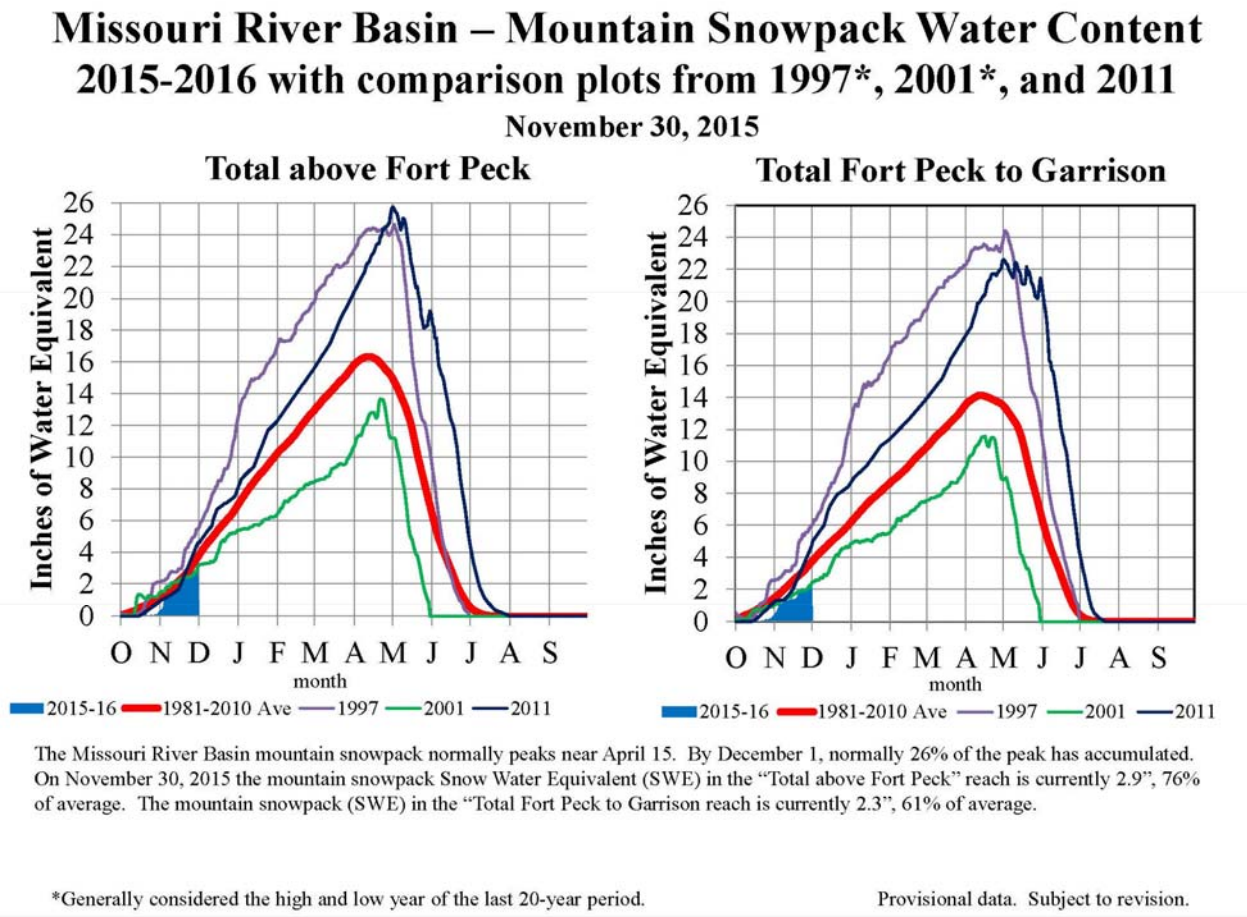


Figure 10. Mountain snowpack water content snow accumulation compared to normal and historic conditions. Corps of Engineers - Missouri River Basin Water Management.

Climate Outlook

ENSO (El Niño Southern Oscillation)

According to the CPC's latest monthly update[1] on November 30, 2015, "***El Niño conditions are present. El Niño will likely peak during the Northern Hemisphere winter 2015-2016, with a transition to ENSO-neutral anticipate during the late spring or early summer 2016***". CPC studies are predicting a strong El Niño event at its peak. El Niño winters have a tendency to be warmer and drier than normal in the upper Missouri Basin, and the influence of El Niño has been factored into the CPC's climate outlooks.

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. These webinars provide updates on near-term climate outlooks and impacts including the El Niño climate pattern and its implications on late summer, fall and early winter

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

temperature and precipitation patterns in the Missouri River Basin. The possible impacts of El Niño have been factored into the CPC climate outlooks described below.

Temperature and Precipitation Outlooks

For December (**Figure 11**), the CPC temperature outlook indicates increased chances for above normal temperatures in nearly all of the Missouri Basin. The greatest probabilities for **above normal temperatures** are forecast for the portion of the Missouri Basin east of the Missouri River including much of North Dakota, eastern South Dakota and Iowa. With regard to precipitation, the CPC indicates that there are increased chances for **below normal precipitation** in the upper Basin including Montana, North Dakota, northern and central Wyoming and northwest South Dakota. There are increased chances for **above normal precipitation** in Colorado, southwest Nebraska and western Kansas. There are equal chances in the remainder of the Basin including eastern Nebraska, Iowa and Missouri.

During December-January-February (**Figure 12**), the CPC outlook portrays a similar forecast: increased chances for **above normal temperatures** in the upper Basin, but equal chances in Colorado, Kansas and southern Missouri. For precipitation, the CPC outlook indicates increased chances for **below normal precipitation** in Montana, Wyoming, North Dakota and northern South Dakota. In southern portions of the Basin, there is a higher probability for **above normal precipitation** over portions of Colorado, Kansas and much of Nebraska.

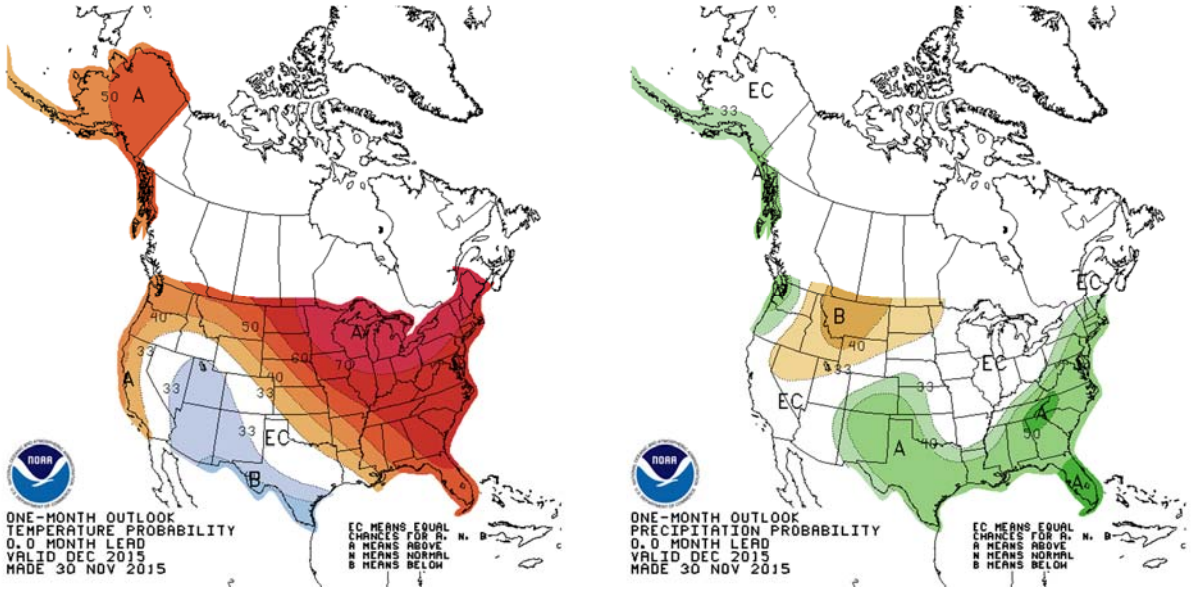


Figure 11. CPC December 2015 temperature and precipitation outlooks.

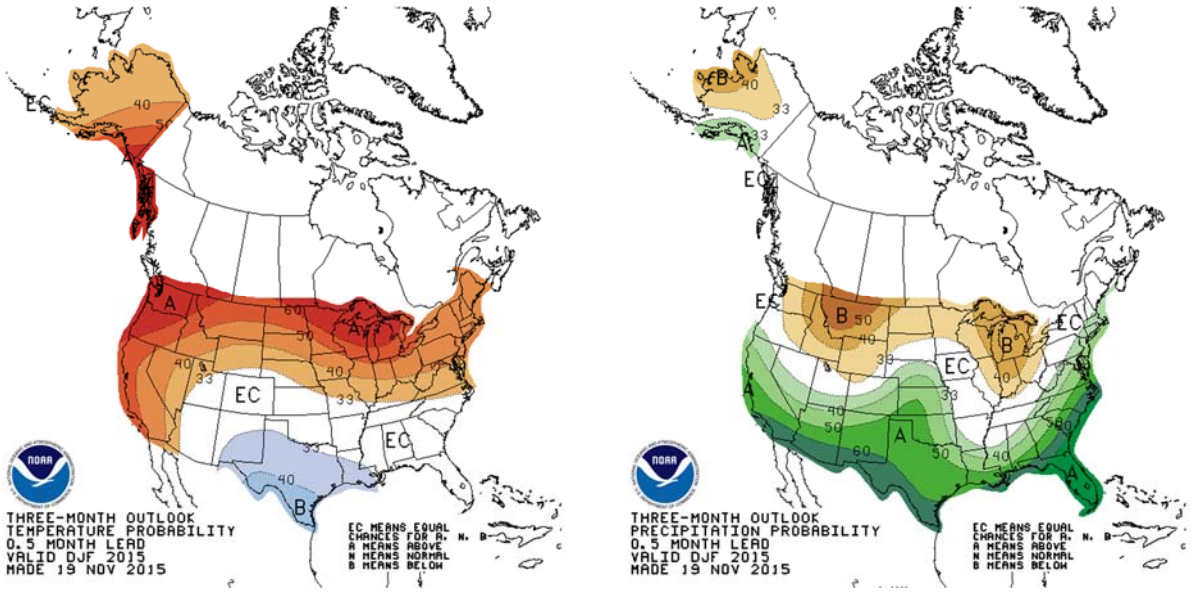


Figure 12. CPC December 2015-January-February 2016 temperature and precipitation outlooks.

December 2015 Calendar Year Runoff Forecast

The December calendar year runoff forecast for the Missouri Basin above Sioux City is **25.3 MAF** (100% of average). For the Basin above Gavins Point Dam, the 2015 calendar year runoff forecast is 22.9 MAF (99% of average).

Observed November runoff was 1.0 MAF (100% of average) above Sioux City. Observed November runoff was 0.8 MAF (85% of average) above Gavins Point Dam. November runoff was above average in all reservoir reaches except for the Fort Peck reach (73% of average) and the Garrison reach (57% of average).

Runoff in December is expected to continue along a similar trend as the past few months. December runoff above Sioux City is forecast to be 690 kAF (92% of average) while runoff above Gavins Point Dam is forecast to be 570 kAF (82% of average).