

# RECLAMATION

*Managing Water in the West*

## Flaming Gorge Technical Working Group

### March 7, 2016 Hydrology Summary

Heather Patno

For the purposes of discussions related to implementing the ROD in 2016, an evaluation has been made of the current hydrologic conditions in the Upper Green River (*i.e.* above Flaming Gorge Dam) and Yampa River Basins. The evaluation centered on the historical unregulated inflow statistics for Flaming Gorge Dam during the period from 1963 through 2015. Based on these statistics and the March 1, 2016 final forecast of 660,000 acre-feet for Flaming Gorge, the hydrologic classification will be moderately dry (70% to 90% exceedance) for spring 2016.

The combined April through July forecast of the Yampa River at Maybell and Little Snake at Lily is 1,035,000 acre-feet. This forecast would fall into the average (below median) hydrologic classification of the ROD.

Snow water equivalent (SWE) as of March 7, 2016, for the Upper Green River and Yampa/White River Basins are 94 and 91 percent of median, respectively. Flaming Gorge SWE is similar to 1995 and 2007, while Deerlodge SWE is similar to 1995, 1998 and 2007. The Tower snotel site, used as a reference point for Yampa snowpack and runoff, currently has 28.1 inches of SWE (77 percent of median). On March 7, Tower SNOTEL measured SWE inches of:

- 1995 = 38.1 in; FG 1,419 kaf unreg inflow (145%); Yampa 1,869 kaf obs spring (147%)
- 1998 = 40 in; FG 1,444 unreg inflow (147%); Yampa 1,620 kaf obs spring (127%)
- 2007 = 27.9; FG 369 unreg inflow (38%); Yampa 735 kaf obs spring (58%)

The difference between the Tower SNOTEL figures and Yampa River observed spring volume differs significantly and needs to be considered when comparing any values this early in the snow accumulation season. Additionally, the unregulated inflow volumes for Flaming Gorge Reservoir were significantly lower than the current March final forecast of 660 kaf.

# Basin Hydrology

## Green River Basin Hydrology

The March 2, 2016, final forecast of April through July unregulated inflow (current forecast) for Flaming Gorge Reservoir is 660,000 acre-feet (AF) (67% of 30-year average). This forecast falls at approximately 77% exceedance based on the historic unregulated inflow record (1963-2015).

Figure 1 illustrates the Upper Green River SWE as of March 7, 2016 and compares it against water years 1995 and 2007. Figures 2 and 3 show the spatial extent of significant areas of modeled snow accumulation for the Upper Green River Basin and how this is incorporated into the water supply forecasts. Figure 3 indicates that the forecast for Flaming Gorge Reservoir has continued to decline and the March 7, 2016, estimated forecast has decreased from 660 kaf to 606 kaf from one week ago.

Figure 4 illustrates the current forecast in relation to the historic unregulated inflow volumes. Figure 5 illustrates Flaming Gorge Reservoir March final forecast probability (percent exceedance).

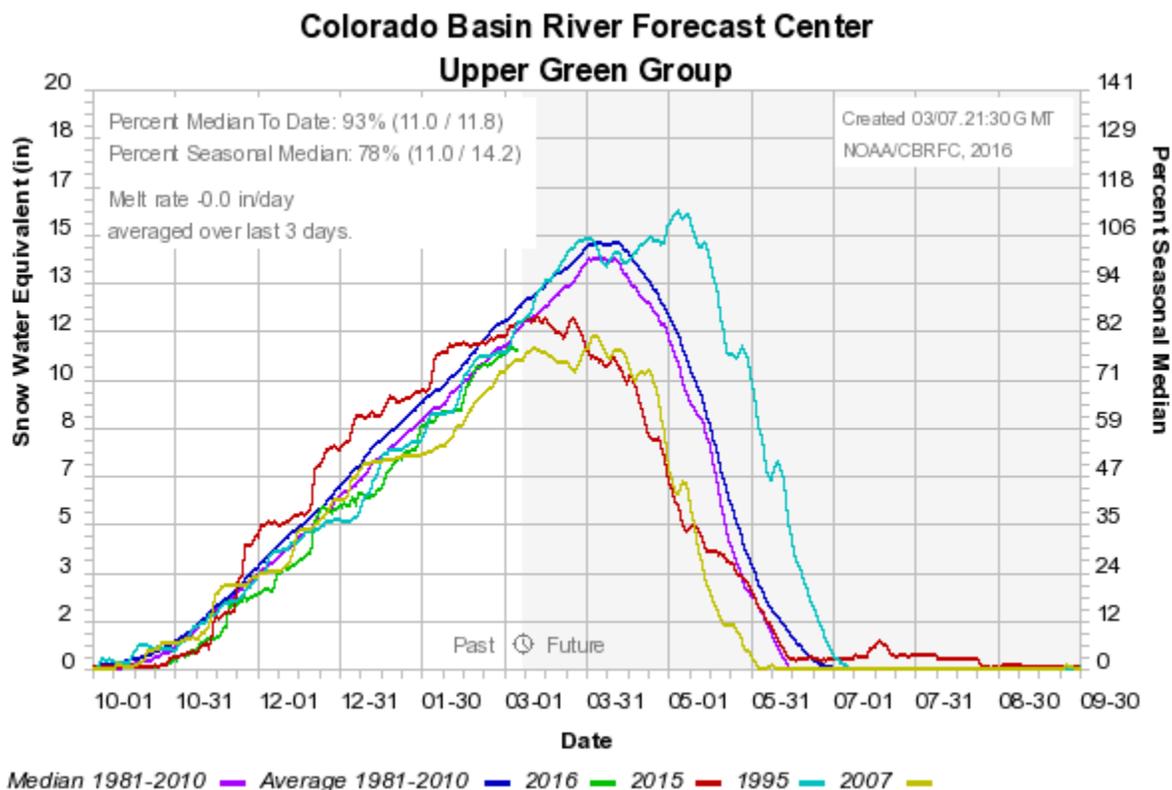


FIGURE 1. Upper Green River Basin Snotel Tracking. 1981-2010 percent of median compared against 2016 YTD Snow Water Equivalent (SWE) and 1995, 2007 and 2015 percent of average SWE

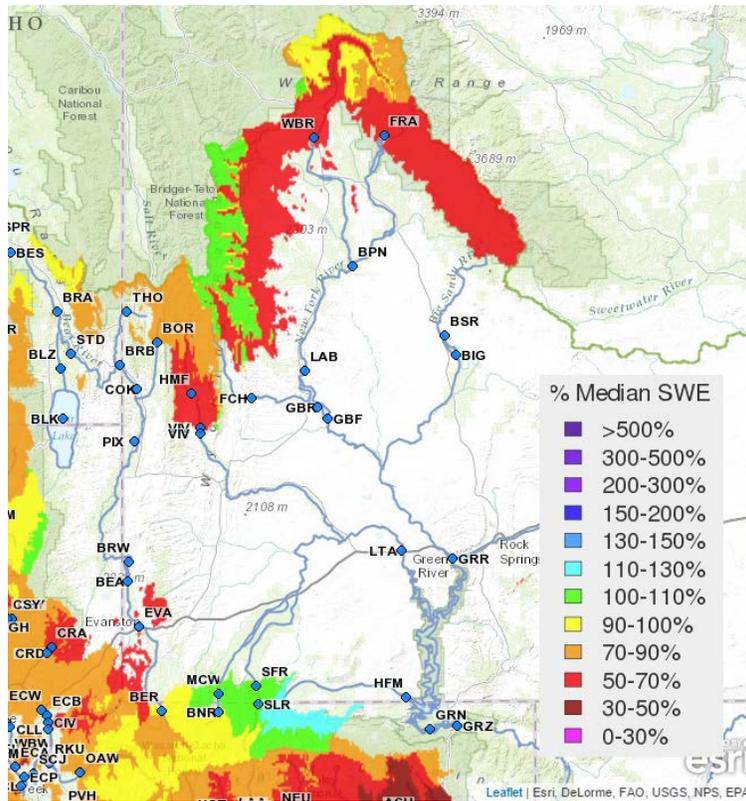


FIGURE 2. Upper Green River Basin modeled SWE significant areas as of March 7, 2016.

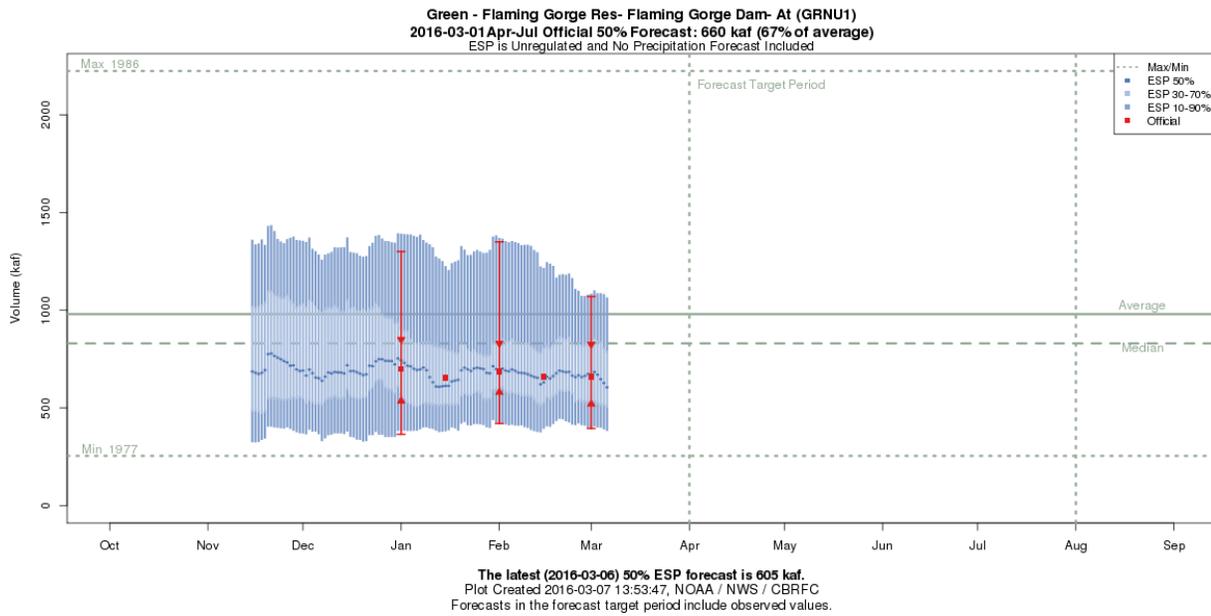


FIGURE 3. Upper Green River Basin Water Supply Forecast as of March 7, 2016.

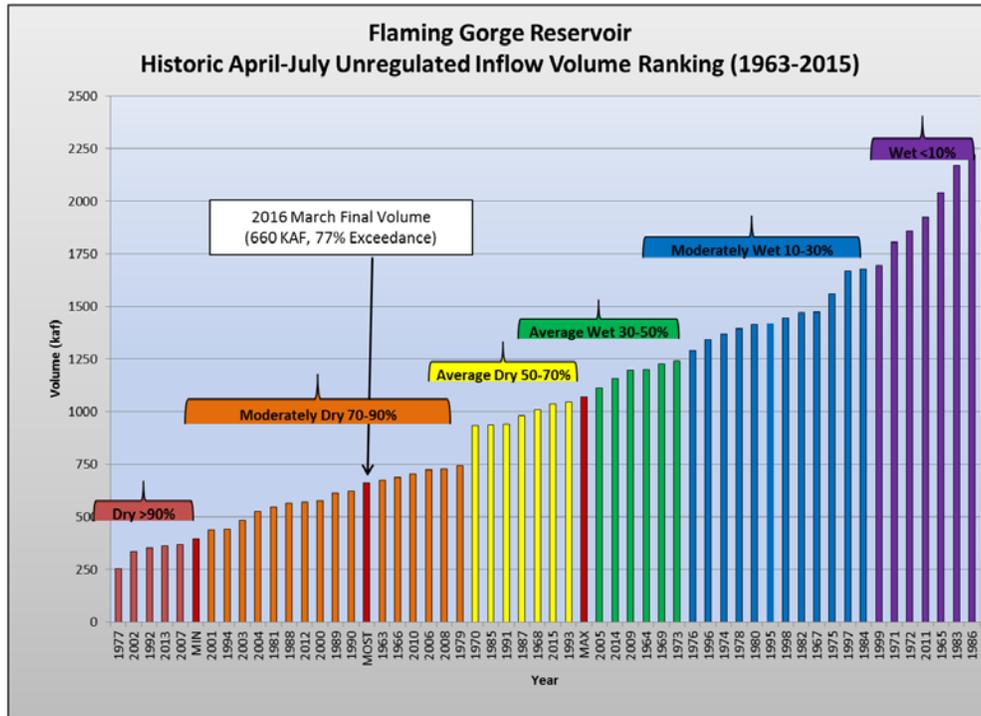


FIGURE 4. Flaming Gorge Reservoir March final forecast and ranked historic April-July unregulated inflow volume for years 1963-2015

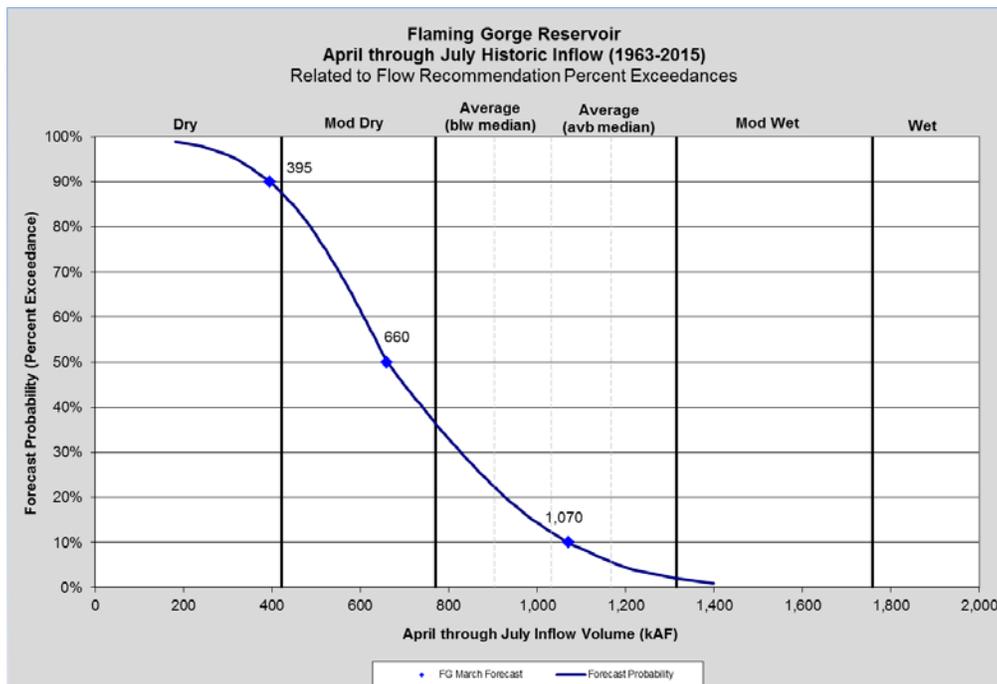


FIGURE 5. Flaming Gorge Reservoir March final forecast probability (percent exceedance) and historic April-July unregulated inflow volume for years 1963-2015

## Yampa River Basin Hydrology

The combined current forecast for the Little Snake at Lily plus Yampa River at Maybell is 1,035,000 AF (83% of 30-year average). This forecast falls at approximately 66% exceedance based on a ranking of the historic record (1922-2015).

Figure 6 illustrates the Yampa River at Deerlodge Park SWE as of March 7, 2016 and compares it against water years 1995, 1998 and 2007.

Figures 7 and 8 show the spatial extent of significant areas of modeled snow accumulation for the Yampa River Basin and how this is incorporated into the water supply forecasts. Figure 8 indicates that the forecast for the Yampa River at Deerlodge has continued to decline and the March 7, 2016, estimated forecast has decreased from 1,030 kaf to 922 kaf from one week ago.<sup>1</sup>

Figure 9 below shows the current forecast in relation to historic flow volumes. Figure 10 illustrates the Yampa River at Maybell plus Lily March final forecast probability (percent exceedance).

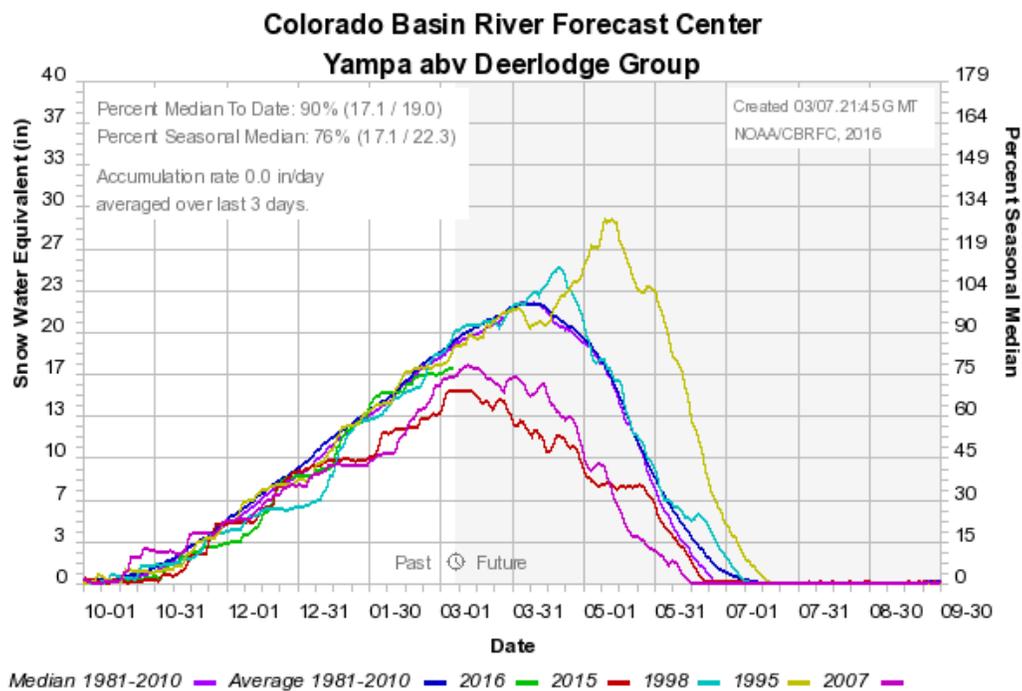


FIGURE 6. Yampa River above Deerlodge SNOTEL Group. 1981-2010 percent of average SWE compared against 2016 YTD, and analog years 1995, 1998, 2007 and 2015 percent of median SWE

<sup>1</sup> The Yampa River at Deerlodge forecast volume differs from the Yampa River – Maybell Plus Lily volume. The historic gage record to calculate the Maybell plus Lily forecast volume is significantly longer than the Deerlodge dataset. The forecast volumes will be close, but the actual volume may differ due to routing in the CBRFC forecast model.



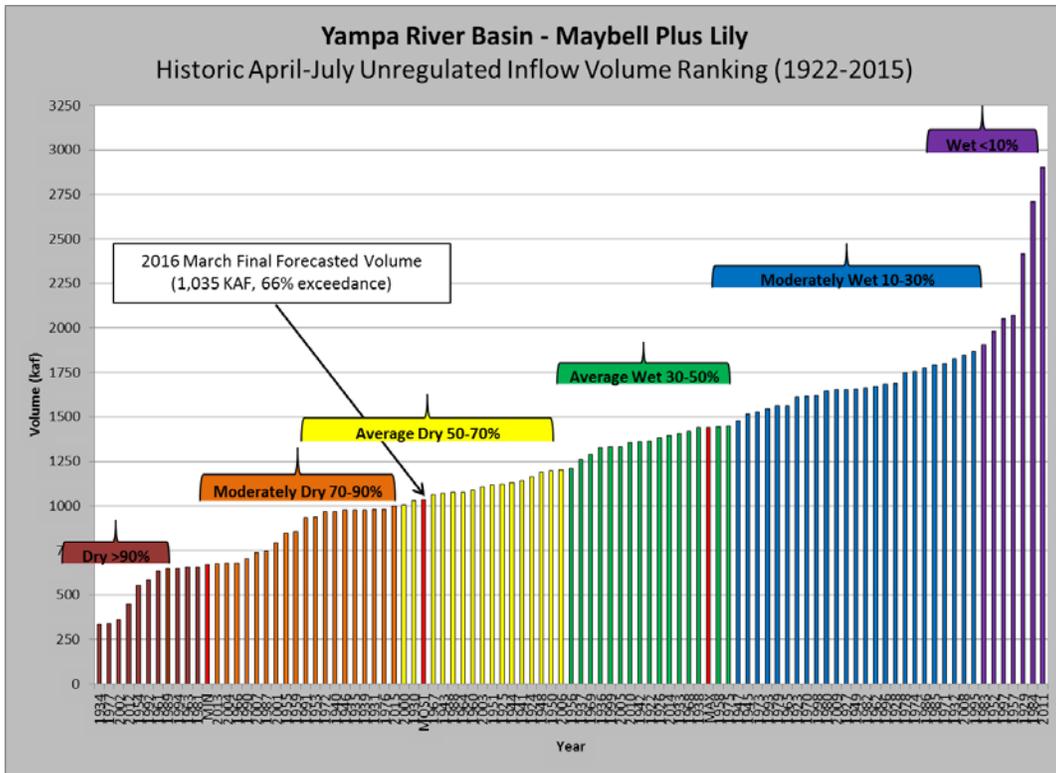


FIGURE 9. Yampa River Basin (Maybell plus Lily) March forecast and ranked April-July unregulated inflow volume for years 1922-2015

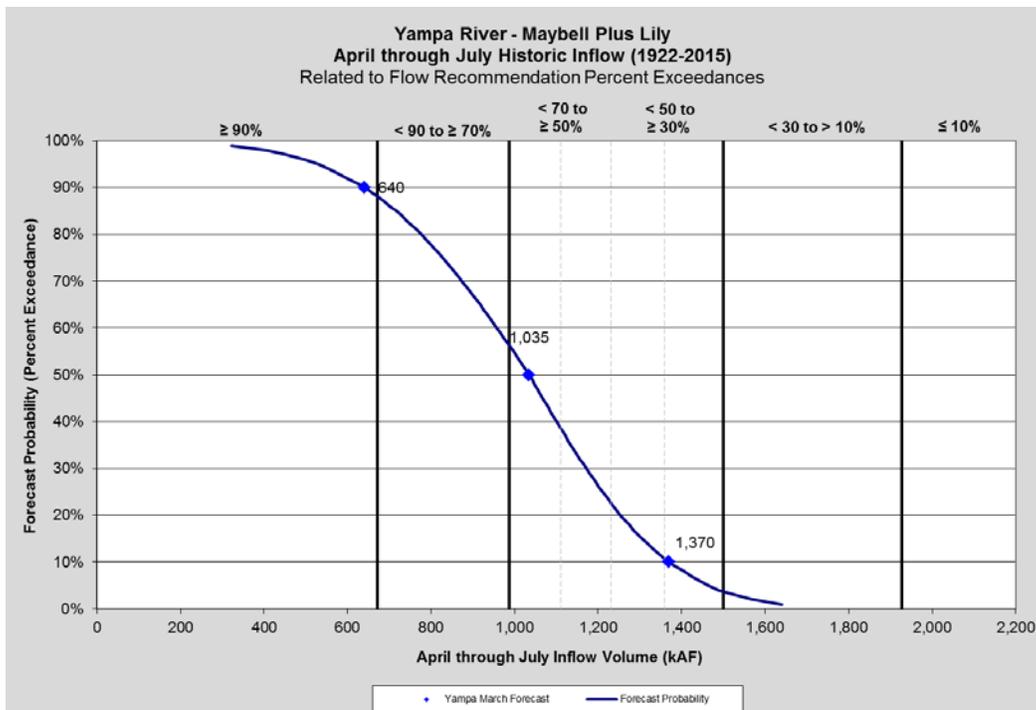


FIGURE 10. Yampa River – Maybell Plus Lily March final forecast probability (percent exceedance) and historic April-July unregulated inflow volume for years 1963-2015

## ***Probabilities of Flow Events for Spring 2016***

The Flaming Gorge unregulated inflow and Yampa River forecasts are moderately dry and average (below median), respectively, and trending drier. Conditions this year are similar to last year and 2007. An analysis was completed to assist in the determination of appropriate flow objectives for spring and summer 2016. The ten most similar historic years for the Yampa River Basin (Maybell plus Lily) compared to the current forecast (Table 1) were analyzed assuming a normal distribution.

Table 2 presents the percent exceedance of cumulative days greater than or equal to various flow levels at Yampa River (Maybell plus Lily). The current analysis indicates that it is likely Yampa River flows above 10,000 cfs will not be achieved this year.

**Table 1**  
**Yampa River (Maybell plus Lily) – April through July Unregulated Volume**  
**Ten Similar Years to the March 2, 2016 Final Forecast**  
**Thousand Acre-Feet (KAF)**

<b>Year</b>	<b>April-July Unreg Inflow Volume (KAF)</b>
MIN	670
1931	979
1976	981
2015	1,000
2000	1,005
1930	1,031
MOST	1,035
1967	1,062
1943	1,071
1988	1,074
1964	1,075
1960	1,089
MAX	1,440

**Table 2**  
**Spring 2016 – Days above Specific Flow Thresholds in the Yampa River**  
**(Maybell plus Lily)**  
**Based on the March 2, 2016, Final Forecast**  
**Percent Exceedance (%)**

March Final Forecast	% Exceed	Days above 3500 cfs	Days above 4500 cfs	Days above 5500 cfs	Days above 6500 cfs	Days above 7500 cfs	Days above 8500 cfs	Days above 10000 cfs
<b>YAMPA</b>	25%	75	59	44	35	24	17	6
	50%	61	50	40	31	18	8	2
	75%	57	49	37	27	17	6	1
	90%	50	44	32	14	5	3	0

## Colorado Basin River Forecast Center Yampa River Analysis

The Colorado Basin River Forecast Center (RFC) calculates percent exceedance based on thirty years of historic temperature and precipitation data (1981-2010) using a modified Monte Carlo method to provide projections of flow. The RFC provides projections based upon (1) strict observance to the historic dataset and (2) incorporation of the ten-day quantitative precipitation forecast (QPF). QPF is the expected amount of melted precipitation over the ten-day climate forecast period.

The RFC provides a synopsis of the current seasonal outlook for the Yampa River at Deerlodge. This synopsis is provided below:

*This outlook is based on flows from ESP with model states as of March 1. Seasonal precipitation is near average in the Yampa River Basin at 90 percent of normal. Precipitation was above average for the month of January followed by an extremely dry February. February precipitation was only 55 percent of normal. In addition to the dry conditions, temperatures were also much above normal for the month of February.*

*The current snow water equivalent as of March 1 is 93 percent of median in the Yampa River Basin. However, there is much variation between individual SNOTEL sites within the basin. Many of the high elevation SNOTEL locations are lower as a percent of median than the basin wide median. This is the result of the lack of high elevation snowfall accumulation during the fall.*

*The ridge of high pressure that has dominated the weather for the month of February and first week in March will begin to weaken over the next few days as models advertise a shift in the weather pattern. The first storm system will arrive Sunday afternoon followed by unsettled weather and a return to normal seasonal temperatures next week. Details of possible storms after Monday are unknown at this time.*

The RFC provides updated Yampa River April through July seasonal exceedance probabilities for both the river flows and daily maximum peak flow. Table 3 presents the RFC projections based on current information. Figures 11 and 12 illustrate the probabilities of the Yampa River

at Deerlodge river flows exceeding certain thresholds and exceedance probabilities over the April through July spring period.

**Table 3**  
**Maximum Peak Daily Flow on the Yampa River at Deerlodge**  
**Based on the March 4, 2016, RFC Analysis**  
**Percent Exceedance (%)**

CBRFC March 3, 2016 Projections	% Exceed	Maximum Daily Peak (cfs)	Number of Days to Peak from 04/01/15	Number of Days Above 10,000 cfs	Number of Days above 14,000 cfs
<b>YAMPA</b>	10%	15,990	74	26	6
	25%	11,759	68	11	0
	50%	10,250	60	1	0
	75%	8,704	49	0	0
	90%	6,990	39	0	0

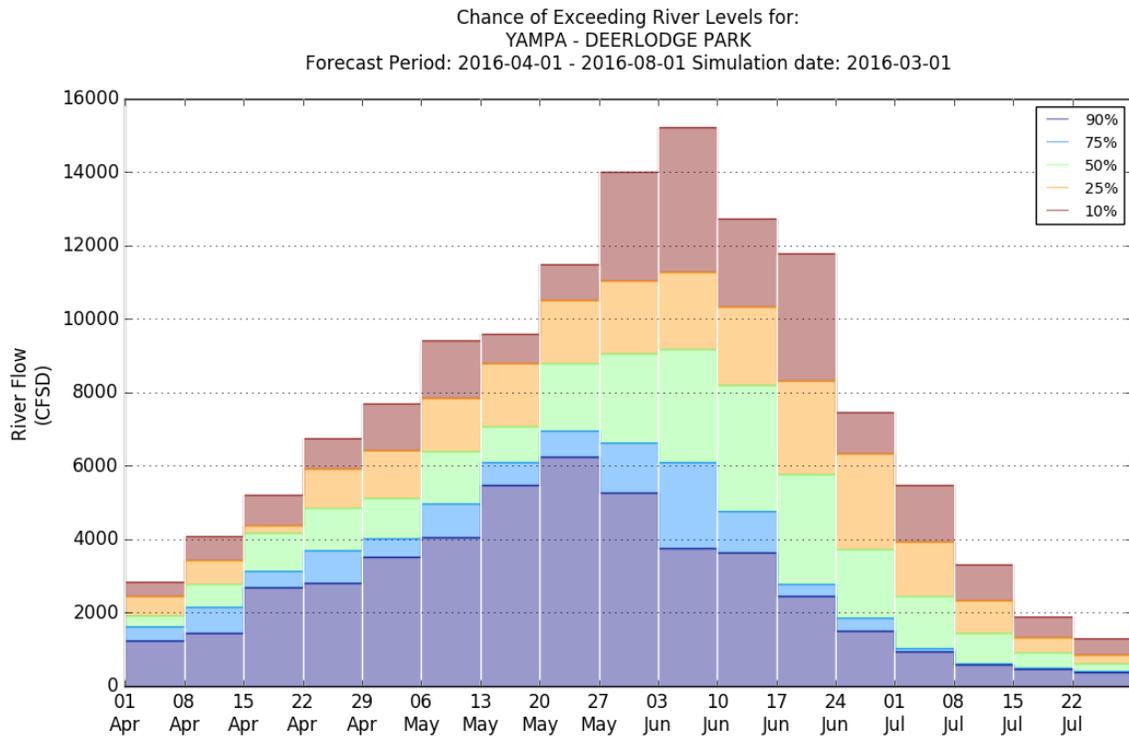


FIGURE 11. RFC March 1, 2016 projection of Yampa River at Deerlodge flows exceeding thresholds for various percent exceedance for the 2016 April through July spring period.

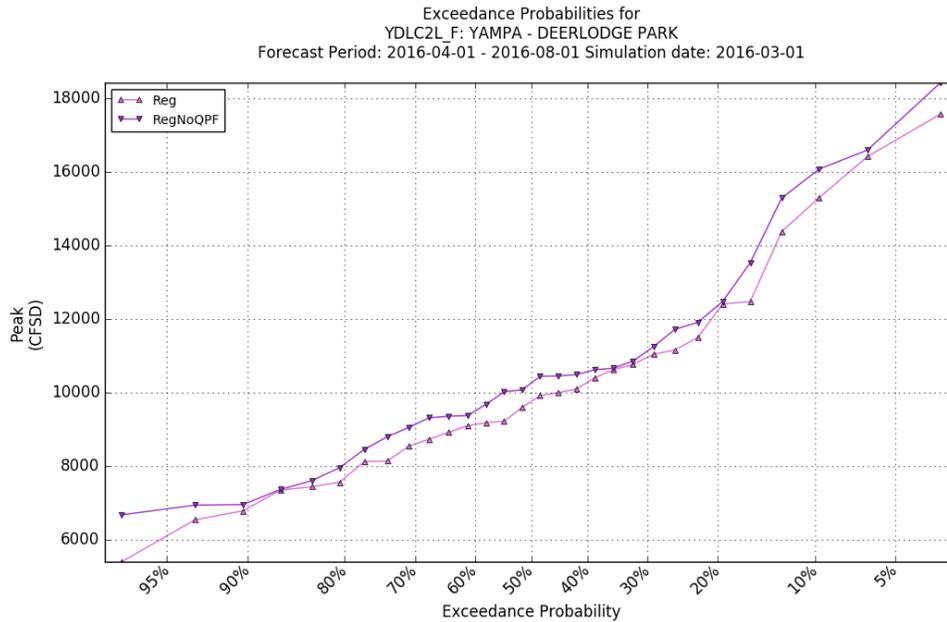


FIGURE 12. RFC March 1, 2016 projection of Yampa River at Deerlodge flow exceeding thresholds for based on the historic observed, simulation of historic climate with current initial conditions and simulation of historic climate including the ten-day QPF with initial conditions.

### ***Larval Trigger Study Plan Projected Operations***

Previous to the implementation of the ROD, the U.S. Fish and Wildlife Service issued a Biological Opinion in 1992 that timed releases from Flaming Gorge to occur during the spring peak of the Yampa River. Under the ROD, Flaming Gorge releases are timed during the Yampa River spring peak and immediate post peak.

The Larval Trigger Study Plan (LTSP) experimental protocol alters Flaming Gorge releases to occur after razorback sucker larvae have been observed in the Green River below Flaming Gorge Dam. This modification in timing of spring peak releases alters projected operations from Flaming Gorge as compared against historic releases.

Table 4 outlines the LTSP matrix used to determine the peak flow measured at Jensen, targeted study wetlands, number of days exceeded for each hydrologic classification. Figure 13 below illustrates one potential Flaming Gorge release utilizing a similar hydrologic year that synchronizes both the Upper Green and Yampa River Basins to the current one.

**Table 4  
Larval Trigger Study Plan Table 2 Matrix**

**TABLE 2. Matrix to Be Used in Studying the Effectiveness of a Larval Trigger**

Peak Flow (x) as Measured at Jensen, Utah	Proposed Study Wetlands <sup>(a, b)</sup>	Number of Days (x) Flow to Be Exceeded and Corresponding Hydrologic Conditions <sup>(c)</sup>		
		1 ≤ x < 7	7 ≤ x < 14	x ≥ 14
8,300 ≤ x < 14,000 cfs	Stewart Lake (f), Above Brennan (f), Old Charley Wash (s)	Dry	Moderately dry	Moderately dry and average (below median)
14,000 ≤ x < 18,600 cfs	Same as previous plus Thunder Ranch (f), Bonanza Bridge (f), Johnson Bottom (s), Stirrup (s), Leota 7 (s)	Average (below median)	Average (below median)	Average (below median)
18,600 ≤ x < 20,300 cfs	Same as previous	Average (above median)	Average (above median)	Average (above median)
20,300 ≤ x < 26,400 cfs	Same as previous plus Baeser Bend (s), Wyasket (s), additional Leota units (7a and 4), Sheppard Bottom (s)	Moderately wet	Moderately wet	Moderately wet
x ≥ 26,400 cfs	Same as previous	Wet	Wet	Wet

(a) f = flow-through wetland, s = single-breach wetland

(b) Up to eight wetlands would be sampled in a given year with the three in the lowest flow category being sampled in all years.

(c) Refer to Table 1 for exceedance percentages and peak flow recommendations for each hydrologic condition. Note that the hydrologic conditions presented are the driest that could support a particular combination of peak flow magnitude and duration. For any combination, wetter hydrology could also support an experiment.

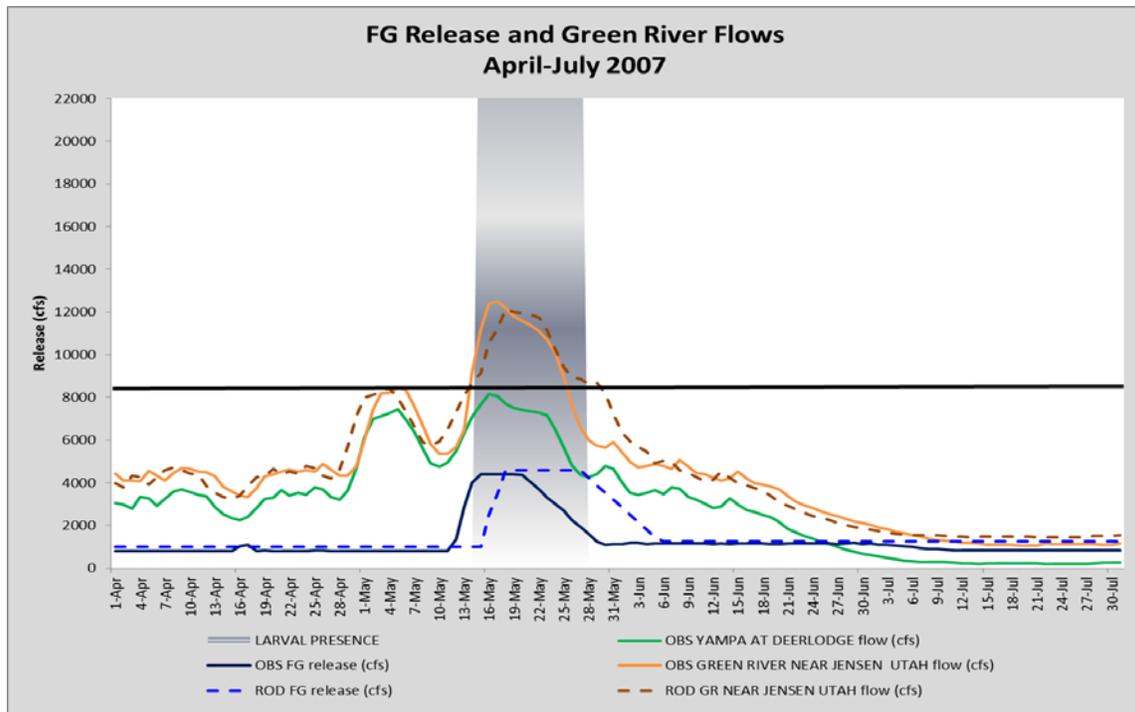


FIGURE 13. Flaming Gorge release, Yampa and Jensen flows for WY2007 and projected operations under LTSP using 2007 flows. Shaded grey area indicates larval presence.

## Record of Decision Spring Flow Objectives

This hydrologic update provides information regarding current conditions and how it relates to the Operating Plan detailed in the 2005 Flaming Gorge Final Environmental Impact Statement (FEIS) in Section 2.5.3.1. The operating plan is to describe the current hydrologic classification of the Green River and Yampa River Basins, including the most probable runoff patterns for the two basins. The operating plan is also to identify the most likely Reach 2 flow magnitudes and durations that are to be targeted for the upcoming spring release. It further specifies that “[b]ecause hydrologic conditions often change during the April through July runoff period; the operations plan would contain a range of operating strategies that could be implemented under varying hydrologic conditions. Flow and duration targets for these alternate operating strategies would be limited to those described for one classification lower or two classifications higher than the classification for the current year.”

The potential classifications for 2016 are as follows:

### ***Moderately Dry Classification***

If the April through July unregulated inflow into Flaming Gorge Reservoir remains in the range from 422,000 AF to 770,000 AF the hydrological classification would be moderately dry. It is recommended to operate Flaming Gorge within the moderately dry hydrologic classification.

The peak flow as measured at Jensen, Utah this year would correspond with the moderately dry hydrologic condition. The LTSP outlines moderately dry flows between 8,300 cfs and 14,000 cfs at Jensen for a period between 7 to 14 days, and minimum seven-day duration above 8,300 cfs during larval drift. These flows provide connection at Stewart Lake, Above Brennan and Old Charley Wash.

The ROD spring flow objectives for moderately dry years are:

**Table 5 – Moderately Dry Spring Flow Objectives**

Reach	Spring Peak Magnitude (cfs)	Spring Peak Duration
Reach 1	≥ 4,600 cfs	That necessary to achieve duration target in Reach 2
Reach 2	≥ 8,300 cfs	1 week (i.e. 7 days)

Flow Recommendations and FEIS

### ***Dry Classification***

It is likely that hydrologic conditions into Flaming Gorge Reservoir will change before implementation of the proposed 2016 flow objectives. In the event conditions become drier and the Flaming Gorge Reservoir unregulated inflow forecast for April through July falls below 422,000 AF, the hydrological classification would be dry.

The peak flow as measured at Jensen, Utah this year would correspond with the dry hydrologic condition. The LTSP outlines moderately dry flows between 8,300 cfs and 14,000 cfs at Jensen for a period between 1 to 7 days, and minimum seven-day duration above 8,300 cfs during larval drift. These flows provide connection at Stewart Lake, Above Brennan and Old Charley Wash.

The ROD spring flow objectives for dry years are:

**Table 6 –Dry Spring Flow Objectives**

Reach	Spring Peak Magnitude (cfs)	Spring Peak Duration
Reach 1	≥ 4,600 cfs	That necessary to achieve duration target in Reach 2
Reach 2	≥ 8,300 cfs	2 days or more (except in extremely dry years (≥ 98% exceedance))

Flow Recommendations and FEIS

***Average (Below Median) Classification***

It is likely that hydrologic conditions into Flaming Gorge Reservoir will change before implementation of the proposed 2016 flow objectives. In the event conditions become wetter and the Flaming Gorge Reservoir unregulated inflow forecast for April through July falls between 770,000 AF to 1,033,000 AF, the hydrological classification would be average (below median).

The peak flow as measured at Jensen, Utah, would correspond with the average (below median) hydrologic condition with targeted flows between 14,000 and 18,600 cfs for a period between 1 to 14 days in Reach 2. These flows provide connection at the Stewart Lake, Above Brennan, Old Charley Wash, Thunder Ranch, Bonanza Bridge, Johnson Bottom, Stirrup and Leota 7 floodplains.

ROD spring flow objectives for average (below median) years are:

**Table 7 – Average (Below Median) Spring Flow Objectives**

Reach	Spring Peak Magnitude (cfs)	Spring Peak Duration
Reach 1	≥ 4,600 cfs	That necessary to achieve duration target in Reach 2
Reach 2	≥ 8,300 cfs in 50% of average years	One week (i.e. 7 days) in 50% of average years

Flow Recommendations and FEIS

***Average (Above Median) Classification***

If conditions become wetter than the current forecast at Flaming Gorge Reservoir and the April through July forecast increases between 1,033,000 AF and 1,315,000 AF, the hydrological classification would be average (above median).

The peak flow as measured at Jensen, Utah, would correspond with the average (above median) hydrologic condition with targeted flows between 18,600 and 20,300 cfs for a period between 1 to ≥14 days in Reach 2. These flows provide connection at the Stewart Lake, Above Brennan, Old Charley Wash, Thunder Ranch, Bonanza Bridge, Johnson Bottom, Stirrup and Leota 7 floodplains.

ROD spring flow objectives for average (above median) wet years are:

**Table 8 – Average (Above Median) Spring Flow Objectives**

Reach	Spring Peak Magnitude (cfs)	Spring Peak Duration
Reach 1	≥ 4,600 cfs	That necessary to achieve duration target in Reach 2
Reach 2	≥ 18,600 cfs in 50% of average years	Two weeks (i.e. 14 days) in 25% of all average years

Flow Recommendations and FEIS