Appendix D3
Threatened and Endangered Species Metrics

Appendix D3 — Threatened and Endangered Species Metrics

1.0 Introduction

This appendix describes the methods used to formulate the metrics for the threatened and endangered species attribute of interest. The following locations were selected based on existing flow recommendations and their compatibility with existing modeling capabilities: the Colorado River near Cameo, Colorado (Cameo); Gunnison River near Grand Junction, Colorado (Grand Junction); Colorado River near the Colorado-Utah state line (State Line); Yampa River near Maybell, Colorado (Maybell); Green River near Greendale, Utah (Greendale); Green River at Jensen, Utah (Jensen); Green River at Green River, Utah (Green River, Utah); Duchesne River near Randlett, Utah (Randlett); and San Juan River near Bluff, Utah (Bluff).

All selected locations have existing flow recommendations that specify suggested flows varying by month/season and hydrologic year type. The hydrologic year type varies based on the hydrologic conditions in the sub-basin as indicated by some reference value—for example, the forecasted inflow into a reservoir or the projected flow at a gage. In general, the recommendations include a base flow period and a spring peak flow period. In most cases, the recommendations are specified at the daily time step, though there are recommendations for average monthly flows at several locations. The distinction between the two is important. If the recommendations are stated in terms of average monthly flows, they can be directly incorporated into the Colorado River Simulation System (CRSS); only Cameo and Maybell have these direct monthly recommendations. Although CRSS operates at a monthly time step, recent modifications to the model allow for plausible daily flow sequences to be generated at certain gage locations. At Greendale, Jensen, and Bluff, the daily recommendations can be directly compared to the stochastically generated daily flow sequences. At the remaining locations (Grand Junction, State Line, Green River, Utah, and Randlett), the daily flow recommendations were approximated as monthly volumes so that CRSS output could be used to evaluate the metrics. The methodology section details how the quantified flow targets were estimated for use in the Colorado River Basin Study (Study). In the quantified flow targets section, the target monthly volumes that were developed are presented.

2.0 Methodology

2.1 Direct Use of Monthly Recommendations

The flow recommendations for Cameo (Osmundson, 2001) and Maybell (Modde and Smith, 1995) are stated in terms of average monthly flow rates; therefore, they can be directly incorporated into a monthly time step model without any additional modifications. The monthly recommendations are presented in a later section.

2.2 Monthly Approximations of Daily Recommendations

At locations where flow recommendations are expressed as daily values and where CRSS does not have the ability to produce daily flow sequences, historical gage data were used to create an estimated daily flow sequence. This daily flow sequence was then converted to a monthly volume, as described in detail below.

Although the details of the flow recommendations vary between locations, they have many common elements. The flow recommendations are expressed as target ranges for the rate and/or the duration of flow, for example, 7 to 10 days at 3,000 to 3,500 cubic feet per second (cfs). Low and high target volumes were developed, which use the lower and upper bounds of the ranges, respectively. Additionally, flow recommendations define different hydrologic year types. Typically, the hydrologic year types are defined by the exceedance probability of the current year's forecasted runoff conditions compared to the historical record[1]. The flow recommendations vary between year types to resemble the natural variability, so for each location there are low and high target volumes for every month and every hydrologic year type. Because the timing of the peak runoff varies between years, the monthly targets for April through July are combined for an overall spring target volume. The peak flow recommendations are typically for 1 to 4 weeks of the April through July period, so historical gage data are used as the pattern for the ascending and descending limbs of the hydrograph. The following steps outline the procedure to develop the monthly flow targets, which were repeated at each location.

1. Obtain all historical, daily gage data.
2. Rank each year based on annual (water year) volume.

   Compute the exceedance for each year as:

   $$Exceedance = \frac{m}{n+1}$$

   where m = rank and n = the number of years in the record

3. Categorize each year based on the exceedance percentages of each hydrologic year type.
4. Depending on location, between 4 and 6 year types can exist[2].
5. Compute the average daily flow for each hydrologic year type from April 1 through July 31.
6. Assign a daily flow rate for each day as follows:
   a. During the base flow period, assign the minimum target base flow from the respective flow recommendation (Figure D3-1).
   b. Using the peak flow date as the center of the hydrograph, assign each day's flow as the minimum target flow for the minimum number of days in the respective flow recommendation:

[1] The year types are dependent on the length of the historical record. As such, the flows presented here may differ from the flow recommendations that exist for regulatory purposes. The inclusion of these approximated flows should not in any way change or affect the flow recommendations that are used for regulatory purposes.

[2] The number of year types varies among locations because the respective flow recommendation documents do not use the same number of year types at all locations. The method here uses the same year types as the respective documentation.

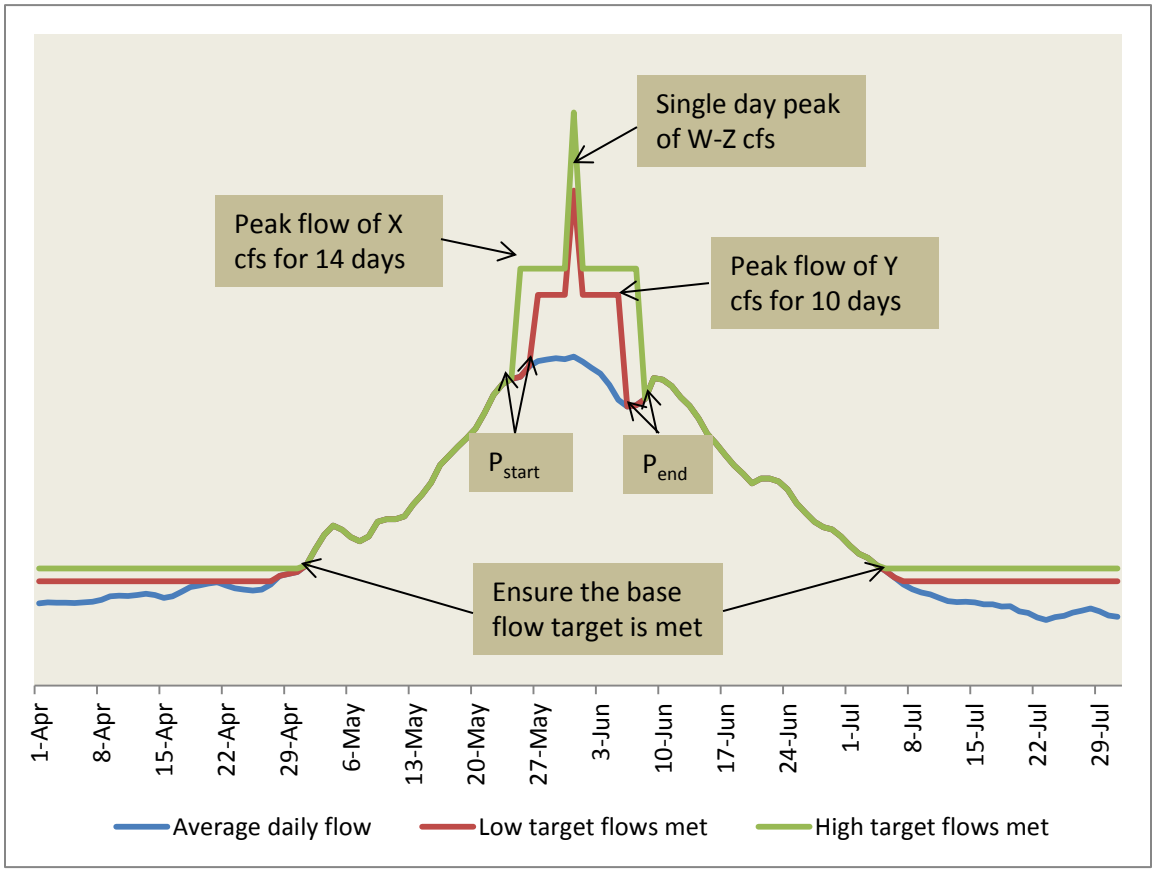
i. Denote the start day of this peak target as P_{start} and the ending day as P_{end} (Figure D3-1).

c. Starting on April 1 and going through P_{start}, assign each daily flow as the maximum of the base flow target and the average daily flow (from step 5) for the current day:

i. Repeat for P_{end} through July 31.

7. Sum the daily flows for each month.
8. Sum the monthly volumes for April through July.
9. This results in the "low" target monthly and seasonal volumes.
10. Repeat steps 6 to 8 selecting the maximum target flows and the maximum number of days at the target flows to compute the "high" monthly targets.
11. Repeat steps 6 to 10 for each hydrologic year type.

FIGURE D3-1
April through July Flow Schematic
Historical average daily flow is modified to meet the low and high base flow and peak flow recommendations. The peak flow recommendations are centered on the single day peak of the average daily flow.



2.3 Direct Use of Daily Recommendations

Model upgrades allow for daily flow recommendations to be directly used as metrics at several locations within the Colorado River Basin. The operating rules within CRSS for Flaming Gorge and Navajo were updated to reflect the recent Records of Decision (Bureau of Reclamation [Reclamation], 2006a, 2006b) which modify the reservoir operations to help meet the respective flow recommendations below both reservoirs. The peak flow targets below both reservoirs are daily in nature, for example, 7 days at 18,600 cfs. Therefore, to adequately reflect the true operations of the reservoirs, CRSS aggregates daily operations to a total monthly volume released from the reservoirs. In doing so, the daily releases are stored in the CRSS results and can be compared with the daily flow recommendations during the peak flow period. Additionally, the flow requirements below both reservoirs are for locations that aggregate reservoir releases with other tributary inflows. Daily tributary flows are stochastically generated from monthly volumes in the model to produce a plausible daily tributary flow sequence for the peak flow period (April through July). When the tributary flows are combined with the reservoir releases, this total flow can be directly compared to the daily flow recommendations (Butler, 2011). The daily flow sequences are not intended to be predictive; rather, in the framework of the probabilistic nature of CRSS, they produce a plausible daily flow sequence and provide variability in the daily flows for each model run. Average monthly releases are used during the base flow periods (August through March) because the reservoir releases are relatively constant during these periods.

3.0 Quantified Flow Targets

The direct monthly and daily flow recommendations are presented in the following sections. The computed monthly volumes for the monthly approximations of daily recommendations are also provided.

3.1 Direct Use of Monthly Recommendations

The flow recommendations from Osmundson (2001) are used directly for the threatened and endangered species metric at Cameo. Table D3-1 presents these recommendations.

TABLE D3-1
Average Monthly Flow Recommendations, in cfs, for the Colorado River near Cameo, Colorado

Category	Dry	Below Average	Above Average	Wet
Rate	**20%**	**30%**	**25%**	**25%**
Exceedance	**81–100%**	**51–80%**	**26–50%**	**0–25%**
January	1,555	1,600	1,600	1,600
February	1,555	1,600	1,600	1,600
March	1,555	1,600	1,600	1,600
April	3,010	3,410	3,590	4,360
May	8,710	9,160	10,530	12,170
June	8,350	12,850	15,750	17,160
July	2,980	4,650	6,870	8,560
August	2,460	2,890	3,280	3,280
September	2,460	2,890	3,280	3,280
October	2,460	2,890	3,280	3,280
November	1,555	1,600	1,600	1,600
December	1,555	1,600	1,600	1,600

Source: Osmundson, 2001

For the Yampa River near Maybell, Colorado, Modde and Smith (1995) and the subsequent Yampa River Programmatic Biological Opinion (U.S. Fish and Wildlife Service [USFWS], 2005 and 2008) recommend baseflows ranging from 120 cfs to 134 cfs throughout the year. Given the spatial and temporal scale of CRSS, the model will not be able to meaningfully distinguish between this range. For this reason, the Study assumed a baseflow target of 120 cfs for this metric.

3.2 Monthly Approximations of Daily Recommendations

After following the procedure described earlier for Grand Junction, State Line, Green River, Utah, and Randlett, the following volumetric targets were developed. The low targets for Grand Junction were developed from USFWS data (2009), and the high targets were developed from the upper bounds found in McAda (2003); the Grand Junction targets are presented in table D3-2. Table D3-3 presents the high and low targets for the State Line, both of which were developed from McAda (2003). Table D3-4 shows the high and low targets for Green River, Utah, which were developed based on the ranges in Reclamation (2005). Table D3-5 presents the monthly approximations for the Randlett flow recommendations from Modde and Keleher (2003).

The goal of aggregating the April through July flow targets was to capture the runoff volume in one target. The historical data show that the runoff tends to occur earlier in drier years than in the wetter years for the Duchesne River near Randlett. To reflect this, the runoff volume was aggregated from March through June in dry and average years and the wet and extremely wet years were aggregated from April through July.

TABLE D3-2
Low and High Monthly Approximations (acre-feet [af]) of Flow Recommendations for the Gunnison River near Grand Junction, Colorado

Year Type Exceedance	Dry 90–100%		Moderately Dry 70–90%		Average Dry 50–70%	
	Low	High	Low	High	Low	High
January	46,116	64,562	46,116	64,562	64,562	122,975
February	41,653	58,314	41,653	58,314	58,314	111,074
March	48,575	64,562	48,575	64,562	64,562	122,975
April–July	346,518	349,836	652,198	718,906	920,874	971,017
August	54,724	64,562	64,562	64,562	64,562	122,975
September	52,959	62,479	52,959	62,479	62,479	119,008
October	48,575	64,562	48,575	64,562	64,562	122,975
November	47,008	62,479	47,008	62,479	62,479	119,008
December	46,116	64,562	46,116	64,562	64,562	122,975
Year Type Exceedance	**Average Wet 30–50%**		**Moderately Wet 10–30%**		**Wet 0–10%**	
	Low	**High**	**Low**	**High**	**Low**	**High**
January	64,562	122,975	64,562	153,719	64,562	153,719
February	58,314	111,074	58,314	138,843	58,314	138,843
March	64,562	122,975	64,562	153,719	64,562	153,719
April–July	1,320,185	1,339,779	1,621,987	1,734,757	1,800,077	2,091,909
August	64,562	122,975	92,231	153,719	92,231	153,719
September	62,479	119,008	62,479	148,760	62,479	148,760
October	64,562	122,975	64,562	153,719	64,562	153,719
November	62,479	119,008	62,479	148,760	62,479	148,760
December	64,562	122,975	64,562	153,719	64,562	153,719

TABLE D3-3
Low and High Monthly Approximations (af) of Flow Recommendations for the Colorado River near the Colorado-Utah State Line

Year Type Exceedance	Dry 90–100%		Moderately Dry 70–90%		Average Dry 50–70%	
	Low	High	Low	High	Low	High
January	110,678	110,678	153,719	245,950	153,719	245,950
February	99,967	99,967	138,843	222,149	138,843	222,149
March	110,678	110,678	153,719	245,950	153,719	245,950
April–July	870,512	882,380	1,511,575	1,727,954	2,102,851	2,240,154
August	110,678	110,678	153,719	245,950	153,719	245,950
September	107,107	107,107	148,760	238,017	148,760	238,017
October	110,678	110,678	153,719	245,950	153,719	245,950
November	107,107	107,107	148,760	238,017	148,760	238,017
December	110,678	110,678	153,719	245,950	153,719	245,950
Year Type Exceedance	**Average Wet 30–50%**		**Moderately Wet 10–30%**		**Wet 0–10%**	
	Low	**High**	**Low**	**High**	**Low**	**High**
January	184,463	295,140	184,463	295,140	184,463	368,926
February	166,612	266,579	166,612	266,579	166,612	333,223
March	184,463	295,140	184,463	295,140	184,463	368,926
April–July	3,008,537	3,228,714	4,095,964	4,220,322	4,843,930	5,270,515
August	184,463	295,140	184,463	295,140	184,463	368,926
September	178,512	285,620	178,512	285,620	178,512	357,025
October	184,463	295,140	184,463	295,140	184,463	368,926
November	178,512	285,620	178,512	285,620	178,512	357,025
December	184,463	295,140	184,463	295,140	184,463	368,926

TABLE D3-4
Low and High Monthly Approximations (af) of Flow Recommendations for the Green River at Green River, Utah.

Year Type Exceedance	**Dry 90–100%**		**Moderately Dry 70–90%**		**Average 30–70%**	
	Low	**High**	**Low**	**High**	**Low**	**High**
January	79,934	159,868	92,231	209,058	110,678	258,248
February	72,198	144,397	83,306	188,826	99,967	233,256
March	79,934	159,868	92,231	209,058	110,678	258,248
April–July	1,092,416	1,144,000	1,728,100	1,755,882	2,827,360	2,893,744
August	79,934	159,868	92,231	209,058	110,678	258,248
September	77,355	154,711	89,256	202,314	107,107	249,917
October	79,934	159,868	92,231	209,058	110,678	258,248
November	77,355	154,711	89,256	202,314	107,107	249,917
December	79,934	159,868	92,231	209,058	110,678	258,248
Year Type Exceedance			**Moderately Wet 10–30%**		**Wet 0–10%**	
			Low	**High**	**Low**	**High**
January			166,017	288,992	196,760	288,992
February			149,950	261,025	177,719	261,025
March			166,017	288,992	196,760	288,992
April–July			3,813,639	3,813,639	4,699,530	4,699,530
August			166,017	288,992	196,760	288,992
September			160,661	279,669	190,413	279,669
October			166,017	288,992	196,760	288,992
November			160,661	279,669	190,413	279,669
December			166,017	288,992	196,760	288,992

TABLE D3-5
Monthly Approximations (af) of Flow Recommendations for the Duchesne River near Randlett, Utah

Year Type Exceedance	Dry 70–100%	Average 40–70%	Wet 10–40%	Extremely Wet 0–10%
January	3,074	3,074	7,071	7,071
February	2,777	2,777	6,387	6,387
March	47,619	173,642	7,071	7,071
April			368,554	534,897
May				
June				
July	3,074	3,074		
August	3,074	3,074	7,071	7,071
September	2,975	2,975	6,843	6,843
October	3,074	3,074	7,071	7,071
November	2,975	2,975	6,843	6,843
December	3,074	3,074	7,071	7,071

3.3 Direct Use of Daily Recommendations

The flow targets for Greendale, Jensen, and Bluff are presented in this section. Because CRSS can produce daily flow values at these sites, the tables presented are identical to those in the documents that establish the recommended flows. Table D3-6 presents both the base flow and peak flow recommendations for Greendale, and Table D3-7 presents the recommendations for Jensen. Table D3-8 presents the peak flow recommendations for Bluff. The base flow recommendations below Navajo are stated to be 500 to 1,000 cfs using a three-gage average (Reclamation, 2006c). Due to modeling constraints, Bluff is the only gage available below Navajo. It is assumed that if the base flow is met at Bluff, then the base flow recommendation is met (Butler, 2011).

TABLE D3-6
Flow Recommendations for Green River near Greendale, Utah

Year Type Exceedance	Dry 90–100%	Moderately Dry 70–90%	Average 30–70%	Moderately Wet 10–30%	Wet 0–10%
Maximum Spring Peak Flow (cfs)	4,600	4,600	4,600	4,600	8,600
Peak Flow Duration	Depends on inflows into the Green River and the flows needed to achieve recommended flows at Jensen and Green River, Utah				
Summer-to-Winter Base Flow (cfs)	800–1,000	800–1,300	800–2,200	1,500–2,600	1,800–2,700

Source: Reclamation, 2005

TABLE D3-7
Flow Recommendations for Green River near Jensen, Utah

Year Type	Dry 90–100%	Moderately Dry 70–90%	Average 30–70%	Moderately Wet 10–30%	Wet 0–10%
Max Spring Peak Flow (cfs)	8,300	8,300	18,600[1]; 8,300[2]	20,300	26,400
Peak Flow Duration	Flows greater than 8,300 cfs should be maintained for 2 days or more except in extremely dry years (98% exceedance).	Flows greater than 8,300 cfs should be maintained for at least 1 week	Flows greater than 18,600 cfs should be maintained for 2 weeks in at least 1 of 4 average years.	Flows greater than 18,600 cfs should be maintained for 2 weeks or more.	Flows greater than 22,700 cfs should be maintained for 2 weeks or more and flows greater than 18,600 cfs for 4 weeks or more.
Summer-to-Winter Base Flow (cfs)	900–1,100	1,100–1,500	1,500–2,400	2,400–2,800	2,800–3,000

Source: (Reclamation, 2005)

[1] Recommended flows: 18,600 cfs in 1 of 2 average years.
[2] Recommended flows: 8,300 cfs in other average years.

TABLE D3-8
Peak Flow Recommendations for the San Juan River near Bluff, Utah

Target Peak Flow (cfs)	Minimum Duration (days)	Frequency	Maximum interval between occurrences (years)
> 10,000	5	20%	11
> 8,000	10	33%	7
> 5,000	21	50%	5
> 2,500	10	80%	3

Source: Reclamation, 2006b

4.0 Summary

The flow targets presented here were included in CRSS to track the threatened and endangered species attribute of interest at the discussed locations. The monthly approximations of the daily flow targets are neither prescriptive in nature nor an interpretation of a flow need. Rather, they are coarse approximations of the cited flow recommendations developed to fit into the available modeling resources. All target flows are well suited to compare how flow metrics perform across scenarios, although they are not meant to identify specific years in the future that flow targets are or are not met.

5.0 References

Bureau of Reclamation (Reclamation). 2005. *Operation of Flaming Gorge Dam Final Environmental Impact Statement*.

Bureau of Reclamation (Reclamation). 2006a. *Record of Decision Operation of Flaming Gorge Dam Final Environmental Impact Statement*.

Bureau of Reclamation (Reclamation). 2006b. *Record of Decision for the Navajo Reservoir Operations, Navajo Unit - San Juan River New Mexico, Colorado, Utah Final Environmental Impact Statement.*

Bureau of Reclamation (Reclamation). 2006c. *Final Environmental Impact Statement Navajo Reservoir Operations.*

Butler, R. A. 2011. *Modeling Techniques to Assess Long-term Reliability of Environmental Flows in Basin Scale Planning* (Master's Thesis). University of Colorado.

McAda, C. 2003. *Flow Recommendations to Benefit Endangered Fishes in the Colorado and Gunnison Rivers.*

Modde, T., & Keleher, C. 2003. *Flow Recommendations for the Duchesne River with a Synopsis of Information Regarding Endangered Fishes.*

Modde, T., & Smith, G. 1995. *Flow Recommendations for Endangered Fishes in the Yampa River*.

Osmundson, D. B. 2001. *Flow Regimes for Restoration and Maintenance of Sufficient Habitat to Recover Endangered Razorback Sucker and Colorado Pikeminnow in the Upper Colorado River: Interim Recommendations for the Palisade-to-Rifle Reach.*

U.S. Fish and Wildlife Service (USFWS). 2005. *Final Programmatic Biological Opinion on the Management Plan for Endangered Fishes in the Yampa River Basin*.

U.S. Fish and Wildlife Service (USFWS). 2008. *Rationale for Management of Water Releases from the Elkhead Reservoir Endangered Fish Pool to Augment August-October Base Flows in the Yampa River.*

U.S. Fish and Wildlife Service (USFWS). 2009. *Final Gunnison River Basin Programmatic Biological Opinion*.