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Funding for WRDS and the creation of this electronic document was provided by the Wyoming Water Development Commission (http://wwdc.state.wy.us)

BIGHORN AND NOWOOD BASINS
INSTREAM FLOW STUDY
LEVEL I
BIGHORN COUNTY, WYOMING

Prepared For

Wyoming Water Development Commission
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1.0 GENERAL FLOW ANALYSIS

1.1 INTRODUCTION

In 1986, the state of Wyoming passed the Instream Flow Law (W.S. 41-3-1001 to 1014), which enables unappropriated water flowing in any stream in Wyoming to be appropriated and declared a beneficial use as instream flows to maintain or improve fisheries. The Wyoming Game and Fish Commission (WGFC) is responsible for determining flows necessary to maintain fisheries in the state. The Wyoming Game and Fish Department (WGFD) acts under the direction of the WGFC to conduct multidisciplinary studies to inform the selection of stream segments and the identification of flow needs for filing requests. Requests are submitted to the Wyoming Water Development Commission (WWDC), which then completes hydrologic studies to assess the feasibility of each instream flow request. Studies are then provided to the Wyoming State Engineer's Office (SEO), which conducts public hearings and considers all available information prior to approving or denying each instream flow application. An approved instream flow water right has a priority date corresponding to the date the SEO received and recorded the application, and water rights with senior priority dates must be recognized in administration of each stream.

Biota Research and Consulting, Inc. (Biota) has been contracted by the WWDC to complete a hydrologic study to assess the feasibility of instream flow requests in 3 stream segments in the Lower Bighorn and Nowood Basins in Bighorn County, Wyoming. Stream study segments include reaches of North Beaver Creek, South Beaver Creek, and Dry Medicine Lodge Creek (Table 1). The WGFD completed instream flow studies in these three stream segments (Robertson 2012 and 2013), developed seasonal flow recommendations for each segment (Table 2), and established a filed priority date of July 30, 2013 for all segments.

Table 1. Instream flow study segment details, Lower Bighon and Nowood Basins, Bighorn County, Wyoming.

Segment Name	Temporary Filing Number	Filed Segment Length (mi)	Segment Extents (UTM NAD 83 zone 12, meters)					
			Legal Description	Easting	Northing		Easting	Northing
North Beaver Creek	35 1/335	3.03	T55N R91W Sec10	753,538E	4,960,875N	Downstream to	753,188E	4,960,631N
			T55N R91W Sec9	753,188E	4,960,631N	Downstream to	752,768E	4,960,299N
			T55N R91W Sec16	752,768E	4,960,299N	Downstream to	751,924E	4,958,689N
			T55N R91W Sec21	751,924E	4,958,689N	Downstream to	751,654E	4,958,082N
			T55N R91W Sec20	751,654E	4,958,082N	Downstream to	750,963E	4,957,061N
South Beaver Creek	35 2/335	0.85	T55N R91W Sec28	752,879E	4,955,906N	Downstream to	752,604E	4,955,464N
			T55N R91W Sec33	752,604E	4,955,464N	Downstream to	752,150E	4,955,050N
Dry Medicine Lodge Creek	35 3/335	4.0	T54N R87W	485,753E	4,928,012N	Downstream to	782,843E	4,926,806N
			T52N R88W Sec33	782,843E	4,926,806N	Downstream to	782,187E	4,925,550N
			T51N R88W Sec4	782,187E	4,925,550N	Downstream to	781,390E	4,924,540N

Table 2. Monthly flow rates (cubic feet per second) requested by WGFD, Lower Bighorn and Nowood Basins, Bighorn County, Wyoming (Robertson, 2013).

Segment Name	Temporary Filing Number	Winter Oct 1 to Apr 30 (requested cfs)	Spring May 1 to Jul 15 (requested cfs)	Summer Jul 16 to Sep 30 (requested cfs)
North Beaver Creek	35 1/335	3.1	20	4.8
South Beaver Creek	35 2/335	2.8	17	5.5
Dry Medicine Lodge Creek	35 3/335	3.1	20	5.7

1.2 PROJECT AREA

The North and South Beaver Creek Instream Flow Study segments are located approximately 13 miles north of Shell, 40 miles west of Sheridan, and 30 miles east of Lovell on the southwest edge of the Bighorn mountain range (Figure 1). The Dry Medicine Lodge Creek Instream Flow Study segment is located approximately 18 miles east/southeast of Shell, 30 miles east of Basin, and 15 miles northeast of Hyattville in the Nowood River Basin in Bighorn County, Wyoming (Figure 1). Stream study segments are located on lands owned and administered by the Bureau of Land Management, the National Forest Service, and the State of Wyoming.

North Beaver Creek is within the Upper Beaver Creek 12 Code Hydrologic Unit (HUC12, 100800100204), which encompasses approximately 51.3 mi^2. The North Beaver Creek study segment is 3.3 miles in length, according to the National Hydrography Dataset (NHD) Flowline data. The segment catchment has a drainage area of 7.4 mi^2, mean basin elevation of 8,567 ft, maximum basin elevation of 10,042 ft, and stream length from the headwaters to the downstream end of the study segment of 6.4 mi (Figures 2 and 3). There is one diversion, the Symons Ditch, located within the study catchment, but the water right status is cancelled (Table 3).

South Beaver Creek is also within the Upper Beaver Creek HUC12 (100800100204). The South Beaver Creek study segment is 0.8 miles in length, according to the National Hydrography Dataset (NHD) Flowline data. The segment catchment has a drainage area of 7.6 mi^2, mean basin elevation of 8,692 ft, maximum basin elevation of 10,161 ft, and stream length from the headwaters to the downstream end of the study segment of 6.7 mi (Figures 4 and 5). There is one irrigation diversion, the Davis Ditch, located upstream of the study segment within the study catchment (Table 3). The London Ditch diversion is located immediately downstream of the study segment and is outside of the study catchment.

Dry Medicine Lodge Creek is within the Lower Medicine Lodge Creek HUC12 (100800080606), which encompasses approximately 57.6 mi^2. The Dry Medicine Lodge Creek study segment is 4.0 miles in length, according to the National Hydrography Dataset (NHD) Flowline data. The segment catchment has a drainage area of 6.9 mi^2, mean basin elevation of 9,451 ft, maximum basin elevation of 10,880 ft, and stream length from the headwaters to the downstream end of the study segment of 5.7 mi (Figures 6 and 7). There are no diversions located within the study catchment (Table 3).

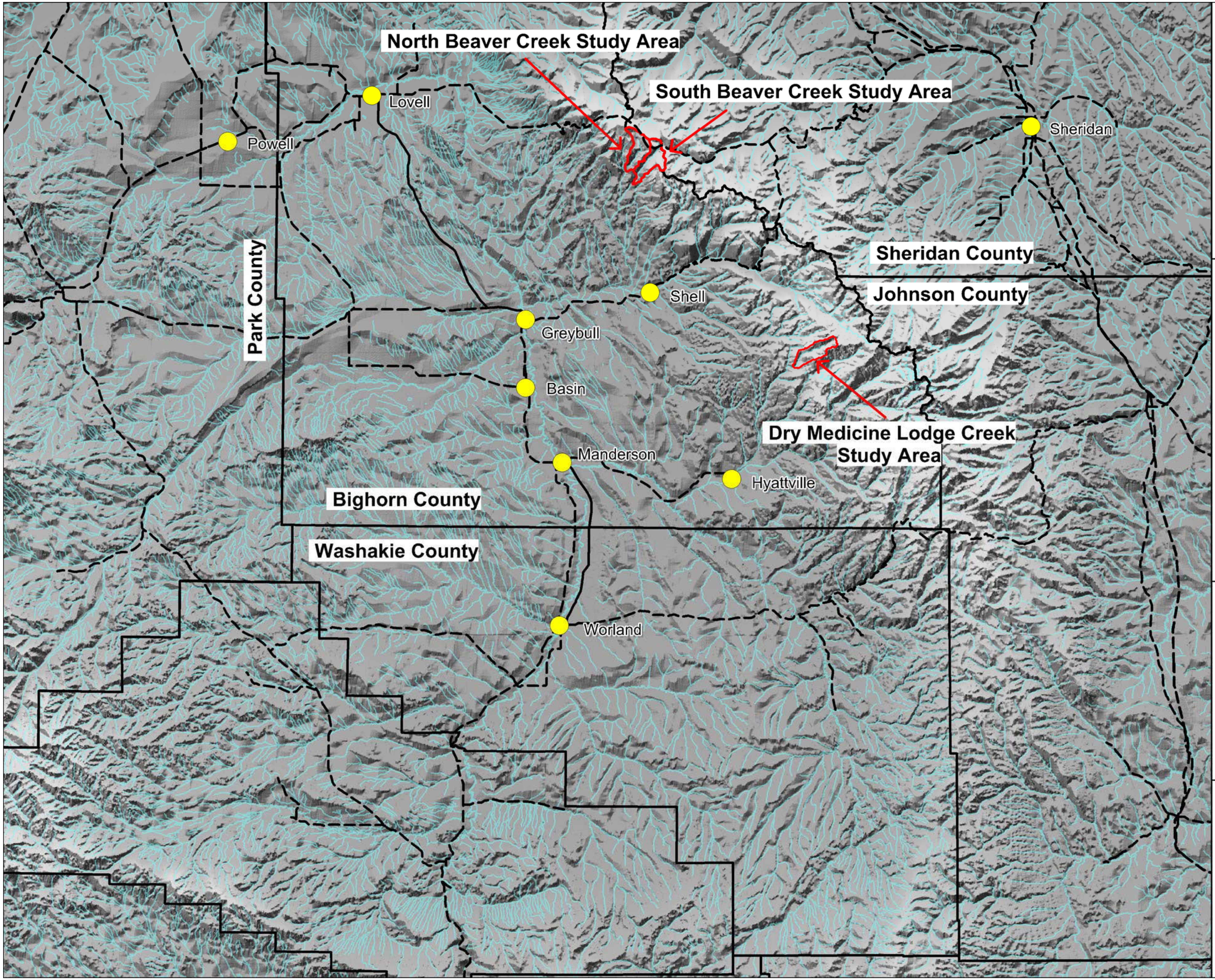

Figure 1
Location and characteristics of the
Bighorn/Nowood Basins
Instream Flow Study area
Bighorn County, Wyoming

November 1, 2015

Scale: 1 inch = 10 miles

Legend

- Study Basins
- Hydrography
- County Line
- Cities and Towns
- Major Roads

Bighorn County

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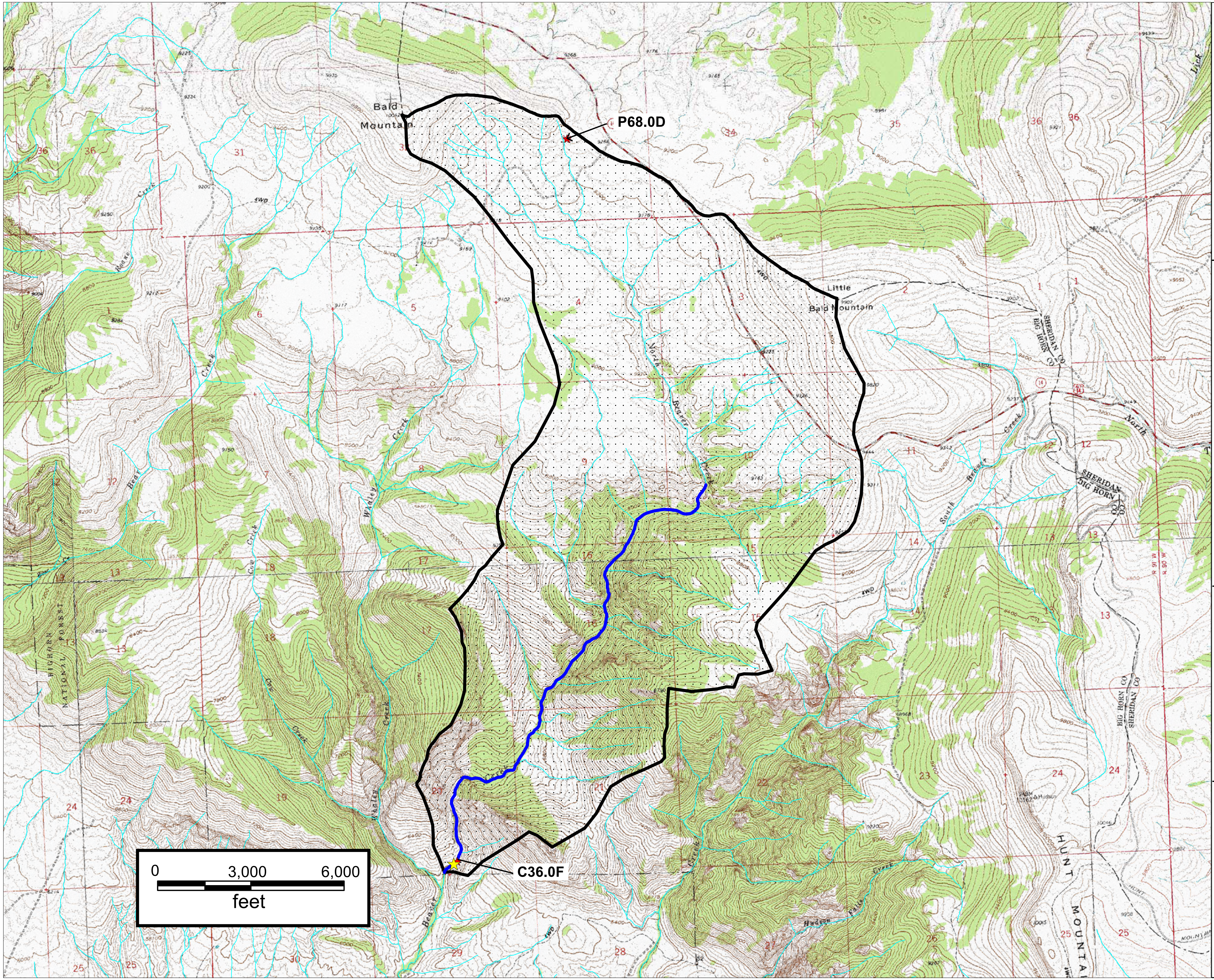


Figure 2
North Beaver Creek study catchment
Beaver Creek Basin study area
Bighorn County, Wyoming

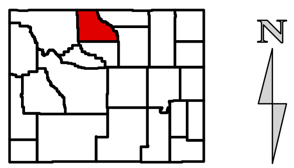
November 1, 2015

Scale: 1 inch = 3,000 feet

Legend

- Study Segment
- Hydrography
- Temporary Gaging Station
- Water Right POD (and Number)
- Study Catchment
- State and Public Lands

Bighorn County



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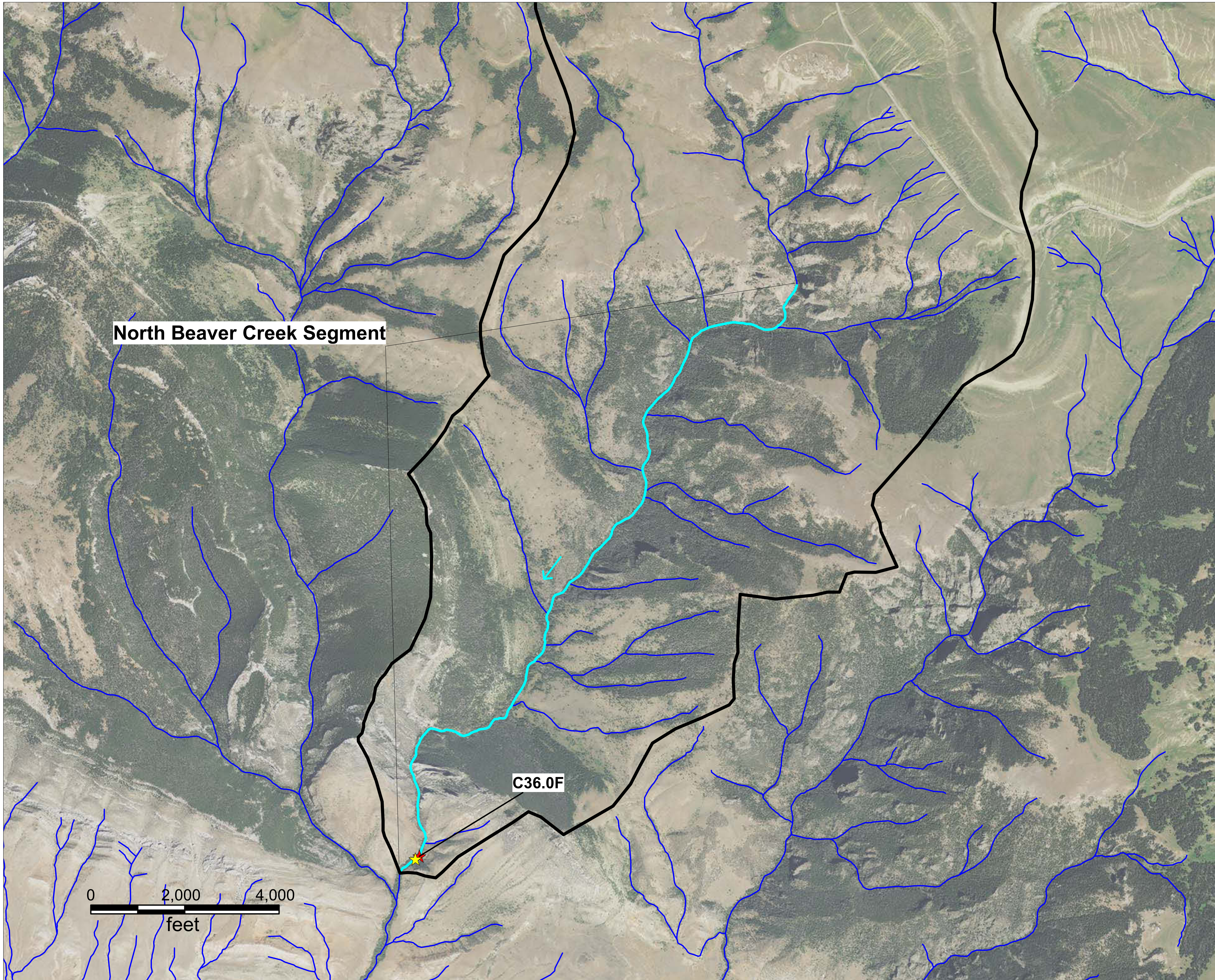


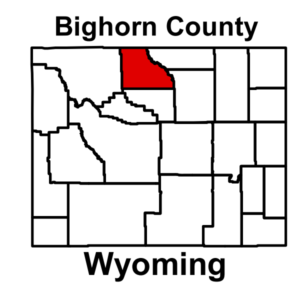
Figure 3
North Beaver Creek study segment
Beaver Creek Basin Instream Flow study area
Bighorn County, Wyoming

November 1, 2015

Scale: 1 inch = 2,000 feet
2012 Aerial Photography

Legend

- Study Segment
- Hydrography
- Temporary Gaging Station
- Water Right POD (and Number)
- Study Catchment



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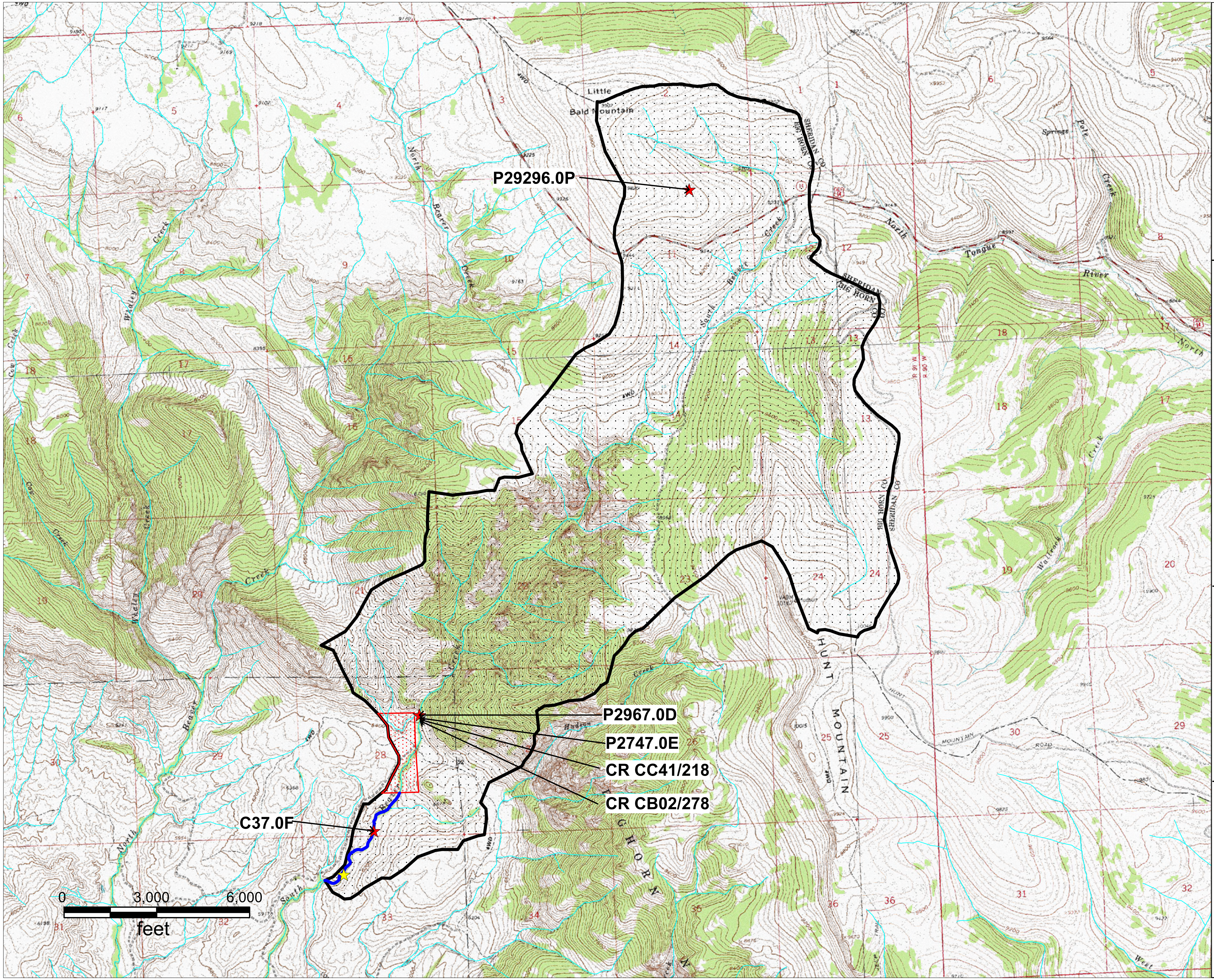


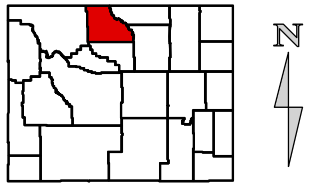
Figure 4
South Beaver Creek study catchment
Beaver Creek Basin Instream Flow study area
Bighorn County, Wyoming

November 1, 2015

Scale: 1 inch = 3,000feet

Legend

- Study Segment
- Hydrography
- Temporary Gaging Station
- Water Right POD (and Number)
- Study Catchment
- Private Lands
- State and Public Lands



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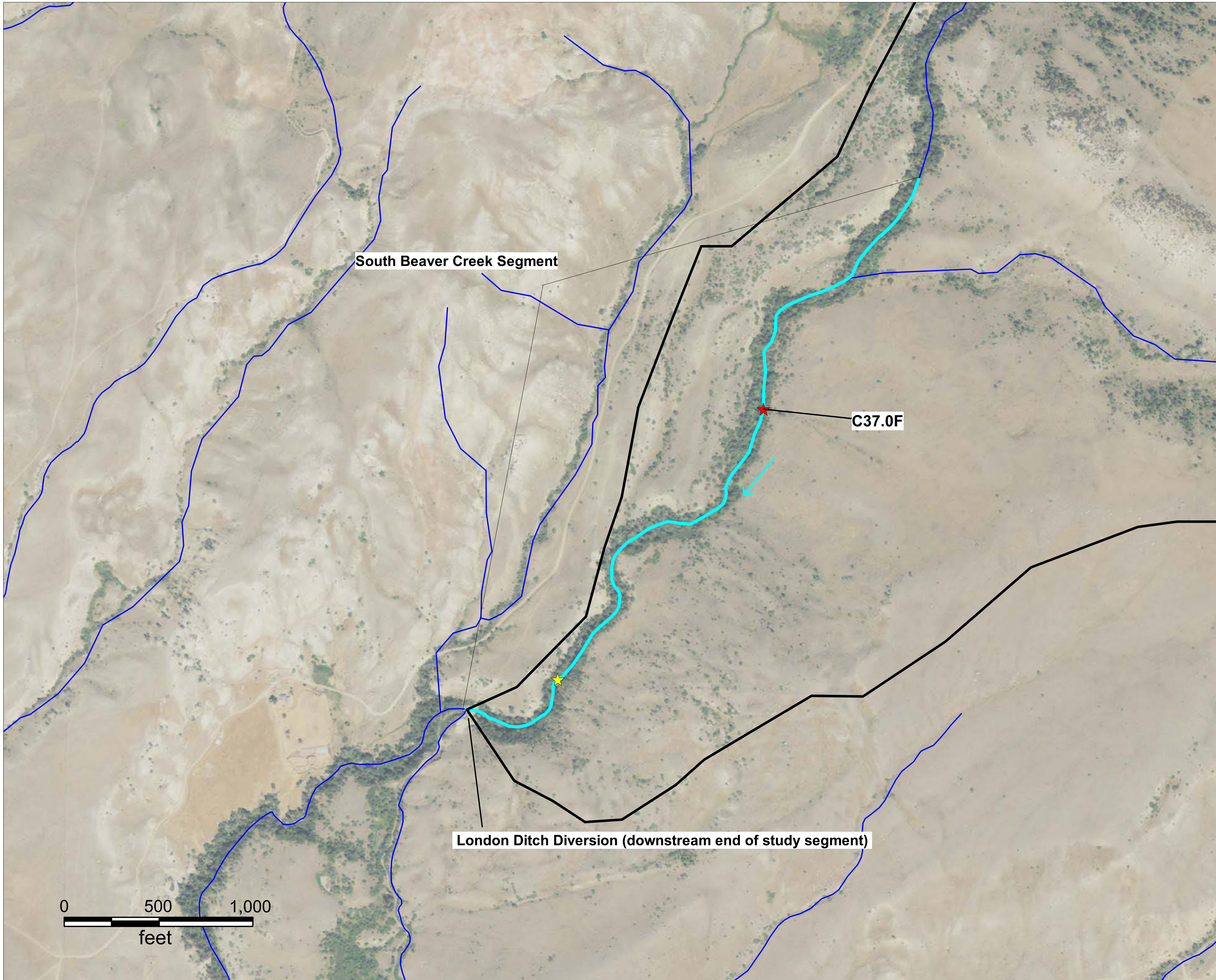

Figure 5
South Beaver Creek study segment
Beaver Creek Basin Instream Flow study area
Bighorn County, Wyoming

November 1, 2015

Scale: 1 inch = 500 feet
2012 Aerial Photography

Legend

- Study Segment
- Hydrography
- Temporary Gaging Station
- Water Right POD (and Number)
- Study Catchment

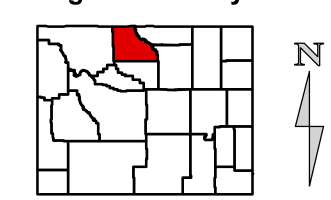

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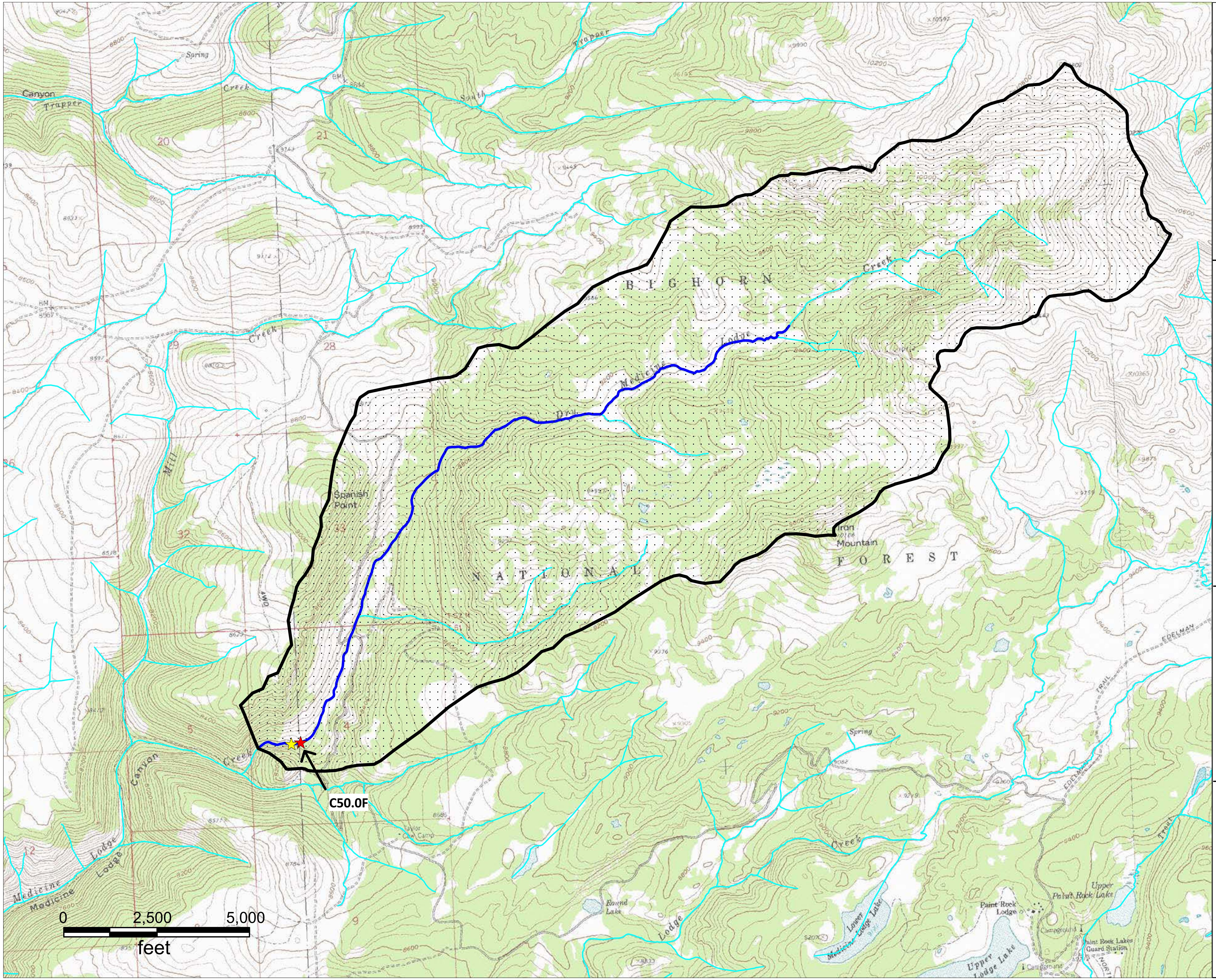
Figure 6
Dry Medicine Lodge Creek study catchment
Nowood River Basin
Instream Flow Study
Bighorn County, Wyoming

November 1, 2015

Scale: 1 inch = 2,500 feet



Legend

- Study Segment
- Hydrography
- Temporary Gaging Station
- Water Right POD (and Number)
- Study Catchment
- State and Public Lands

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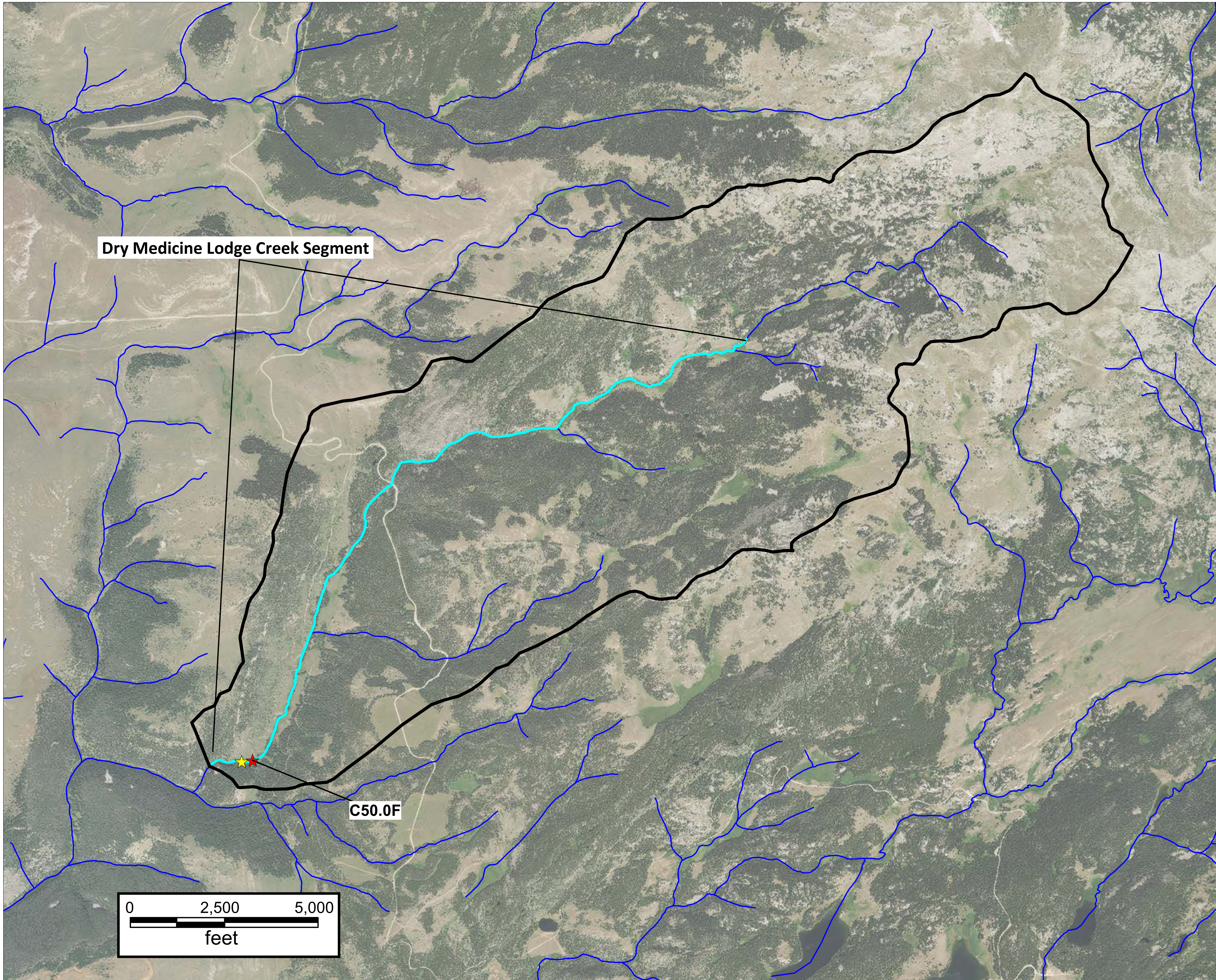


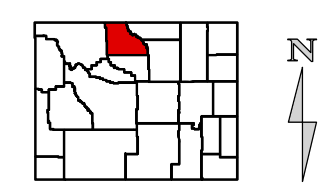
Figure 7
Dry Medicine Lodge Creek study segment
Nowood River Basin
Instream Flow Study
Bighorn County, Wyoming

November 1, 2015

Scale: 1 inch = 2,500 feet

Legend

- Study Segment
- Hydrography
- Temporary Gaging Station
- Water Right POD (and Number)
- Study Catchment



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1.3 WATER RIGHTS

Water rights within study segment catchments were initially identified with a search by location (legal description) using the Wyoming State Engineer's Office (SEO) on-line E-Permit database. An in-person search was subsequently completed at the SEO in Cheyenne. That effort included review of the linen plats depicting adjudicated water rights; review of the paper plats depicting unadjudicated permits and applications; and review of the township cards that list permitted wells. The linen plats are continuously updated by the SEO, the paper plats have not been updated since 2013, and the township cards have not been updated since 2004. The most recent surface water applications and groundwater permits and applications are contained within the E-Permit system. All water rights identified within or upstream of the study segment catchments are presented in Table 3 and depicted in Figure 8.

Table 3. Water rights in the Lower Bighorn and Nowood Basins study area, Bighorn County, Wyoming.

WR Number	Priority Date	Status Summary	Facility Name	Facility Type	Uses	Total Flow (CFS) Appropriation (GPM)	Stream Source
C36.0F*	02/09/1983	Fully Adjudicated	Beaver Creek Instream Flow	Not Applicable	ISF		Beaver Creek
C37.0F*	02/09/1983	Fully Adjudicated	South Fork Beaver Creek Instream Flow	Not Applicable	ISF		South Fork Beaver Creek
C50.0F*	02/09/1983	Fully Adjudicated	Dry Medicine Lodge Creek Instream Flow	Not Applicable	ISF		Dry Medicine Lodge Creek
CR CB02/278	12/22/1900	Fully Adjudicated	Davis Ditch	Stream	IRR_SW	1.63	South Fork Beaver Creek
P2967.0D	12/22/1900	Fully Adjudicated	Davis Ditch	Stream	IRR_SW	1.62	South Fork Beaver Creek
CR CC41/218	07/27/1912	Fully Adjudicated	Enlarged Davis Ditch	Stream	IRR_SW	1.72	South Fork Beaver Creek
P2747.0E	07/27/1912	Fully Adjudicated	Enlarged Davis Ditch	Not Applicable	IRR_SW	1.72	South Fork Beaver Creek
P68.0D	06/09/1891	*Cancelled*	Symons Ditch	Stream	MIL; MIN	2	Little Bighorn River
P29296.0P	02/28/1975	Fully Adjudicated	Chapman #1	Not Applicable	DOM_GW	10	

*Instream flow right for livestock drinking water supply.

There are adjudicated instream flow rights near the downstream end of each of the 3 study segments. These instream flow water rights are court awarded rights that enable the US Forest Service to pass certain amounts of water past specific locations on the watercourses in order to provide a drinking water source for livestock. This type of surface water right has been addressed in previous Wyoming Water Development Office Instream Flow Studies (Rio Verde Enbgineering, 2006). During the Lower Bighorn and Nowood Basin studies, these water rights were identified but appropriated flows were not subtracted from virgin flows during the unappropriated direct flow analysis.

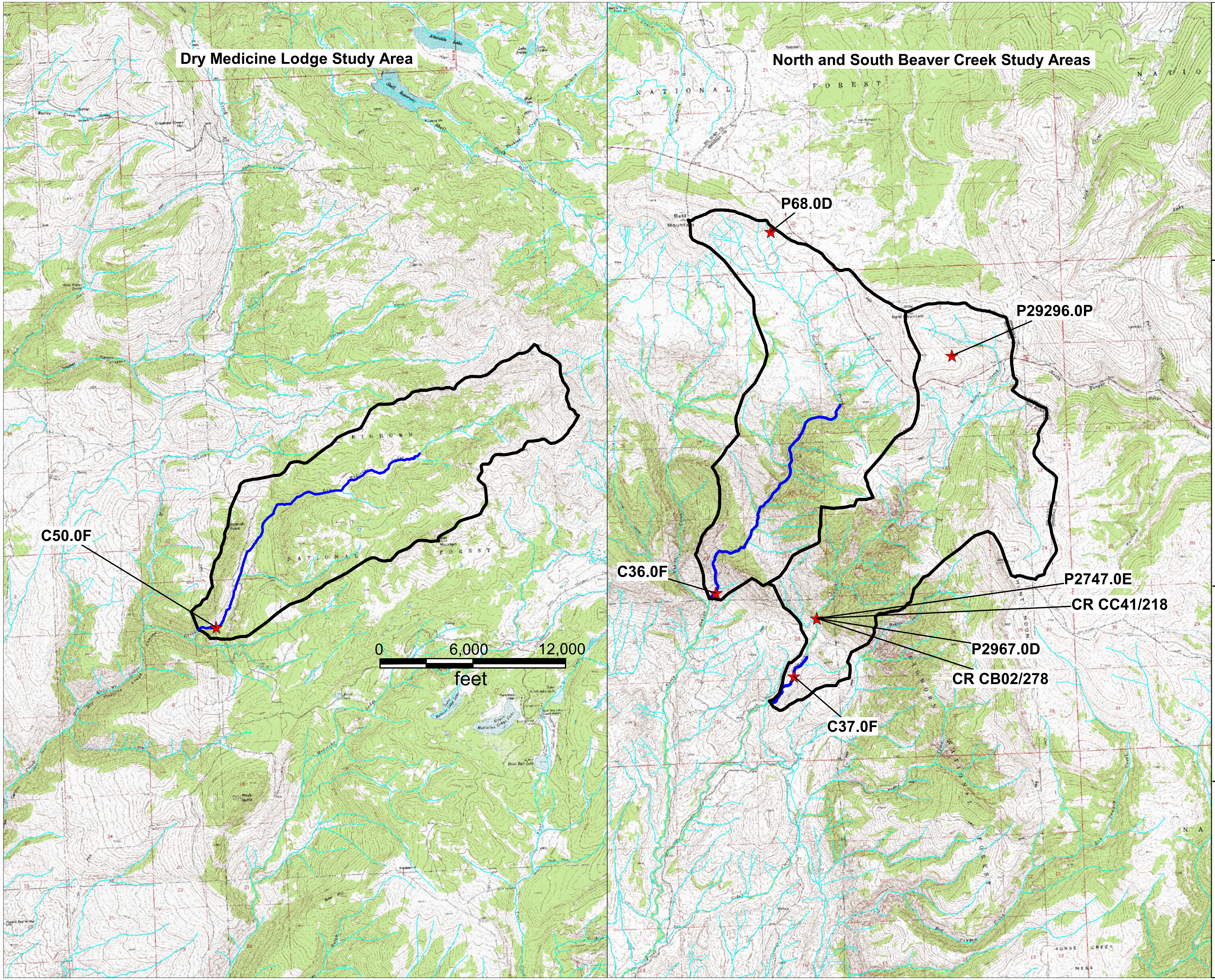


Figure 8
Water right location and number
Lower Bighorn and Nowood Basins
Instream Flow Study
Bighorn County, Wyoming

November 1, 2015

Scale: 1 inch = 6,000feet

Legend

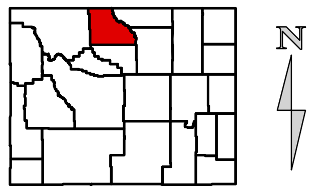
Study Segment

Hydrography

Water Right POD (and Number)

Study Catchment

Bighorn County



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1.4 FLOW RECORDS

Historic diversion rates and flow records were investigated using various available datasets and records, including the following:

1. Wyoming State Engineer's Office;
2. Wyoming Water Resources Data System;
3. Local water commissioners' records, as available;
4. Local irrigators' records, as available;
5. USGS records (online and through correspondence); and
6. Other pertinent records of flow and storage as available.

The SEO indicated that they do not have long-term period of record flow data from any of the stream segments or the diversion located within the study basin. The Wyoming Water Resources Data System (WRDS) does not contain long-term flow records measured within the stream segments or the diversion in the study basin. Local irrigators and water users served by the Davis Ditch diversion within the South Beaver Creek study catchment indicated that quantitative stream flow or diversion rate data were not available. The US Geological Survey maintains multiple stream flow gauging stations in proximity to the study stream segments, but does not have current or historic flow measurement records within the study basin.

The lack of quantitative stream flow or diversion records within the project area basin required that the hydrologic regime of study stream segments be quantified using empirical and analytical techniques.

1.5 STREAM GAUGING

Temporary stream gauging stations were established near the downstream end of each of the three study segments. Temporary gauge locations did not coincide exactly with those established by the Wyoming Game and Fish Department during previous studies of the stream segments, but were located as close to the downstream end of the study segment as practicable. Gauging stations were operational from late June to October 14, 2014 and from early April to October 20, 2015. Gauges were located in proximity to an existing stable hydraulic control, where section control could be expected to maintain the relationship between stage and discharge at low flows, and where channel control could be expected to define the relationship between stage and discharge at higher flows. Each gauging station was equipped with a staff plate with increments of 0.01 ft., a perforated stilling well enclosed in filter fabric, and a pressure transducer data logger programmed to record stage at 15-min intervals throughout the deployment period. Direct discharge measurements were conducted at each temporary gauging station across a wide range of flow rates during the study period. Direct discharge measurement data were plotted against local staff plate stage readings to generate site-specific rating curves that correlate stage to discharge. The stage of zero discharge was then identified and used to shift the rating curve to accurately depict low flow values. The developed rating curves were then used to derive flow data from recorded stage data.

1.5.1 North Beaver Creek

The temporary gauging station in the North Beaver Creek study segment was established on June 25th 2014 within a boulder and large woody debris dominated reach defined as a step-pool system with stable banks (Figure 9). A total of seven direct discharge measurements were performed at the site from June 2014 to October 2015 across a range of discharge rates ranging from 2.5 cfs to 18.1 cfs. A stage-discharge correlation was derived for the North Beaver Creek site using all seven of the direct discharge measurement data points (Figure 10). A hydrograph depicting discharge at 15-minute intervals, mean daily discharge, and direct discharge measurement data collected in 2015 is presented in Figure 11.

Figure 9. North Beaver Creek gauging station, Bighorn County, Wyoming.

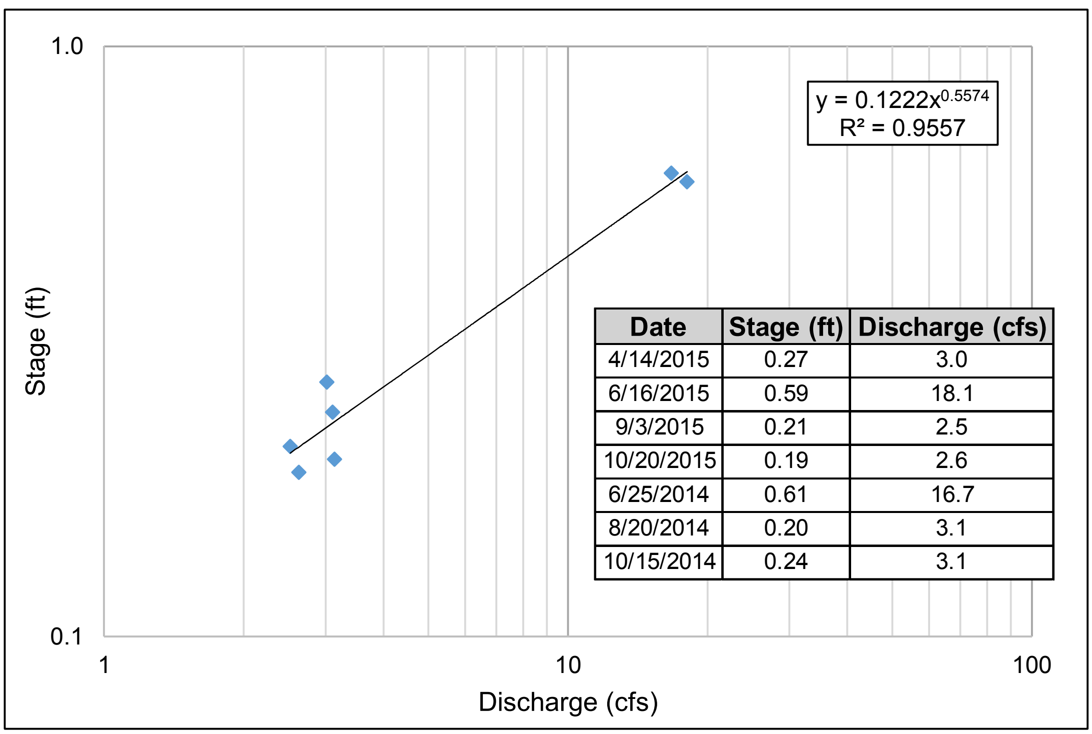


Figure 10. North Beaver Creek stage-discharge correlation, Bighorn County, Wyoming.

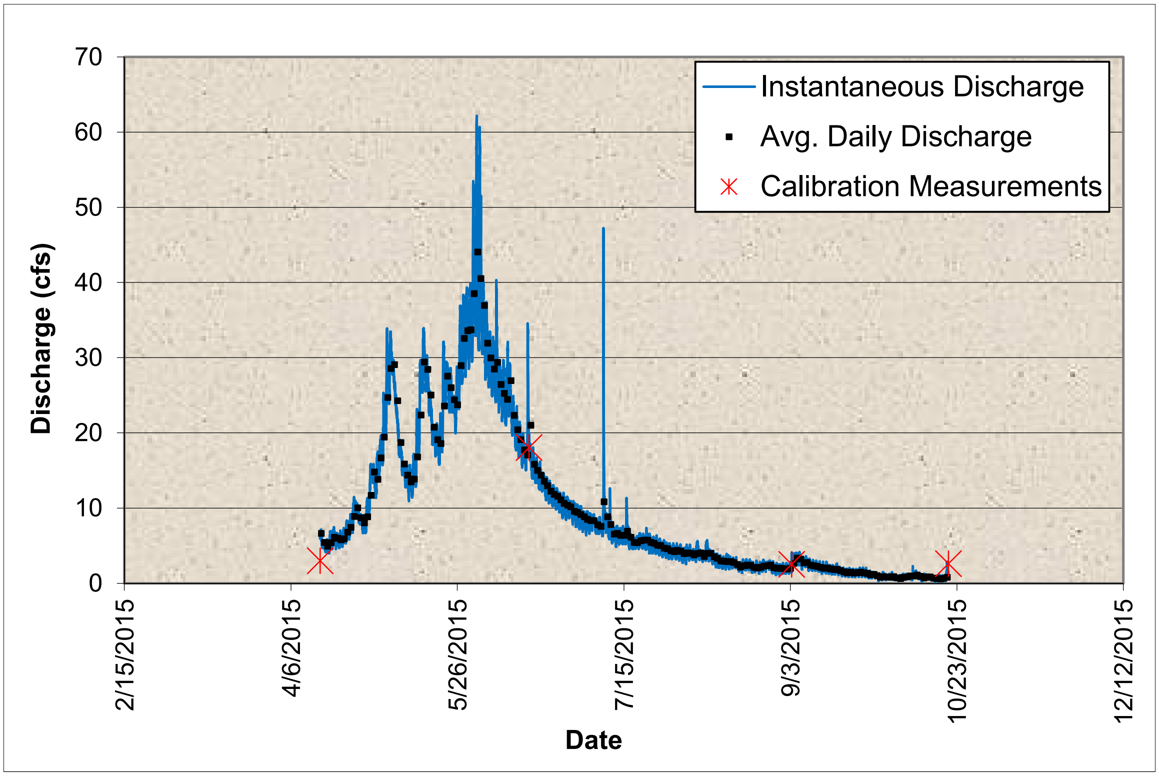


Figure 11. North Beaver Creek 2015 hydrograph, Bighorn County, Wyoming.

1.5.2 South Beaver Creek

The temporary gauging station in the South Beaver Creek study segment was established on June 24th 2014 in a boulder and bedrock dominated reach defined as a step-pool system with stable banks (Figure 12). A total of seven direct discharge measurements were performed at the site from June 2014 to October 2015 across a range of discharge rates ranging from 1.4 cfs to 22.7 cfs. A stage-discharge correlation was derived for the South Beaver Creek site using all seven of the direct discharge measurement data points (Figure 13). A hydrograph depicting discharge at 15-minute intervals, mean daily discharge, and direct discharge measurement data collected in 2015 is presented in Figure 14.

Figure 12. South Beaver Creek gauging station, Bighorn County, Wyoming.

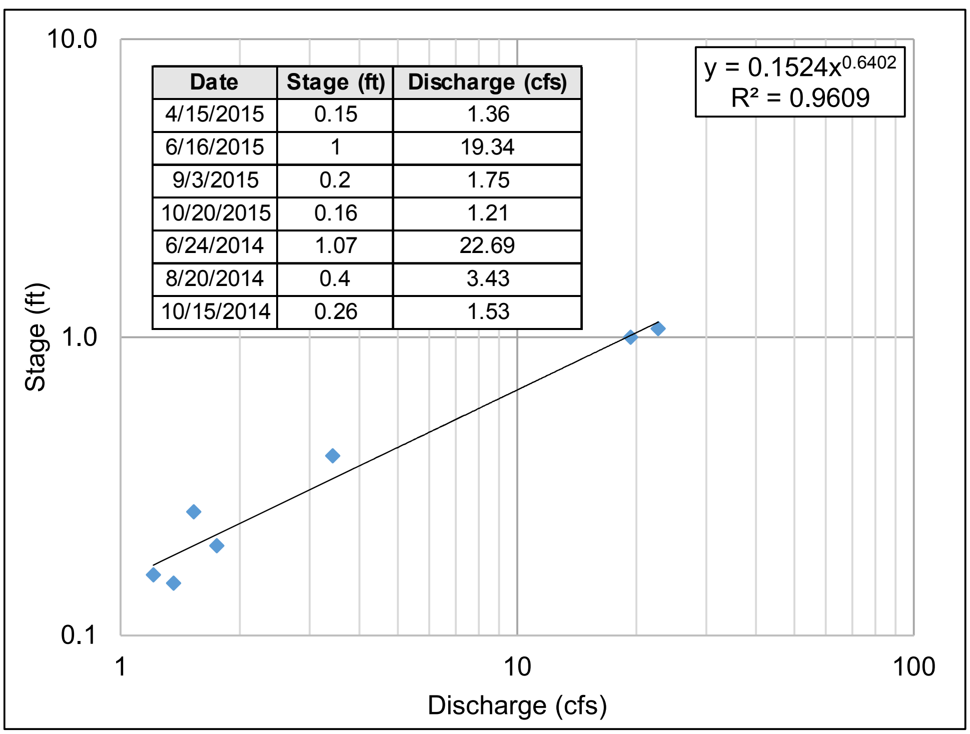


Figure 13. South Beaver Creek stage-discharge correlation, Bighorn County, Wyoming.

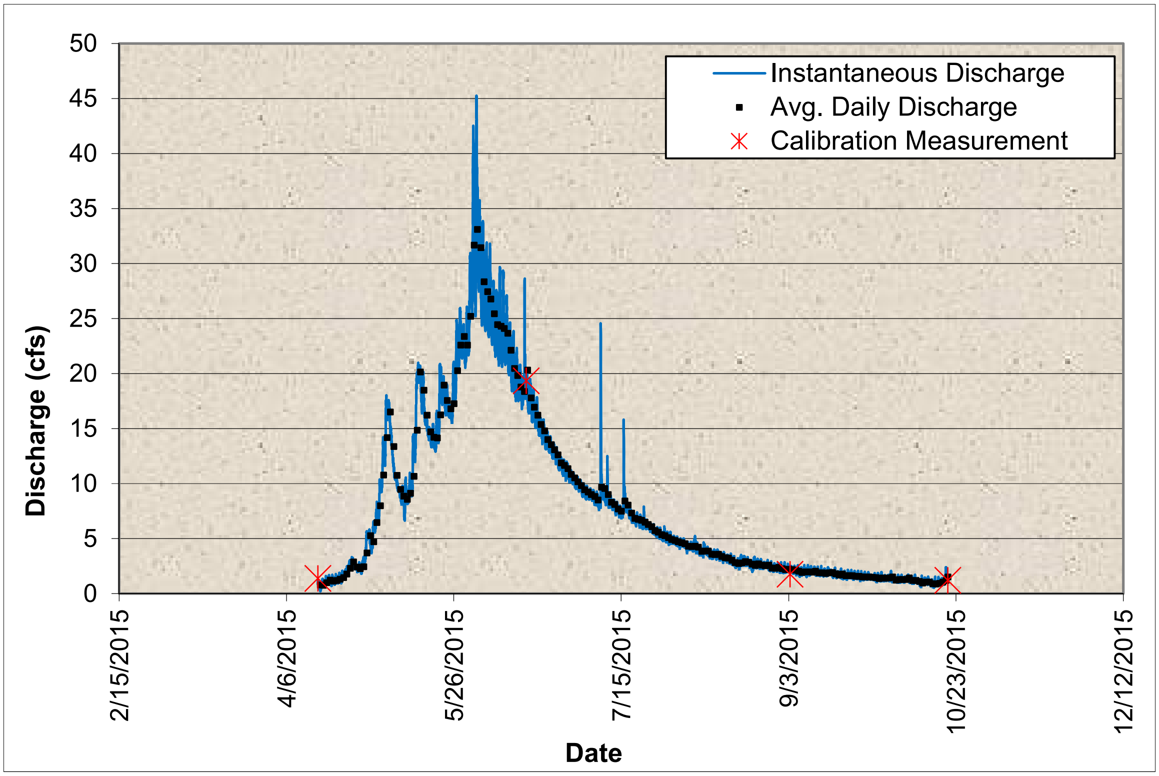
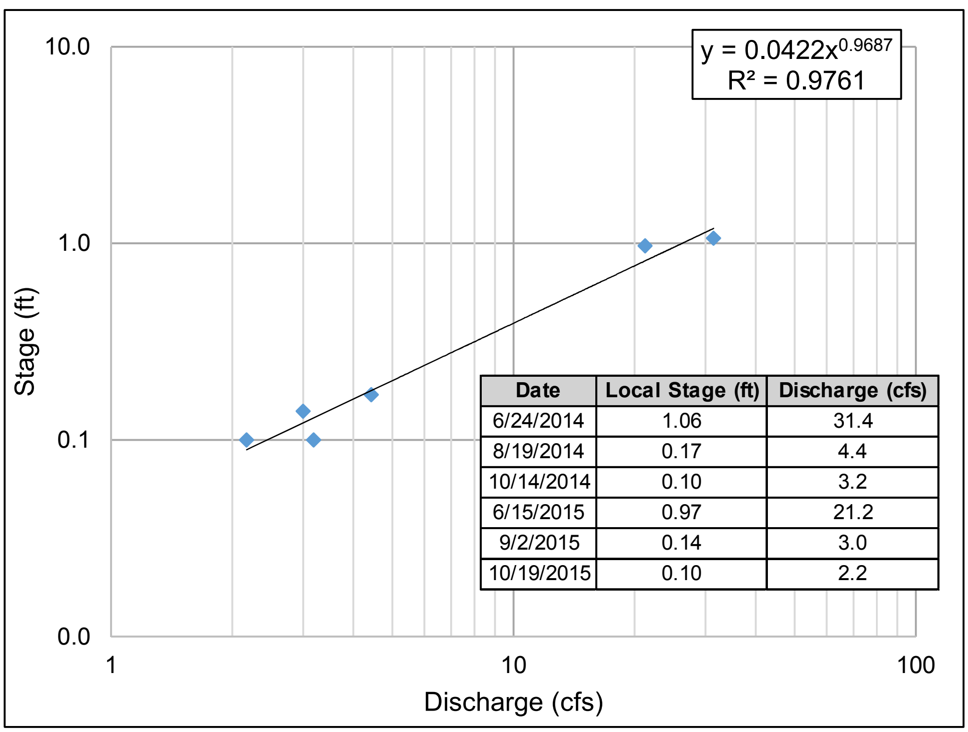


Figure 14. South Beaver Creek 2015 hydrograph, Bighorn County, Wyoming.

1.5.3 Dry Medicine Lodge Creek

The temporary gauging station in the Dry Medicine Lodge Creek study segment was established on June 24th, 2014 in a boulder and large woody debris dominated reach defined as a step-pool system with stable banks (Figure 15). A total of six direct discharge measurements were performed at the site from June 2014 to October 2015 across a range of discharge rates ranging from 2.2 cfs to 31.4 cfs. (Note that the gauging station could not be activated in 2015 until June due to road closures and seasonal access restrictions.) A stage-discharge correlation was derived for the Dry Medicine Lodge Creek site using all six direct discharge measurements data points (Figure 16). A hydrograph depicting discharge at 15-minute intervals, mean daily discharge, and direct discharge measurement data collected in 2015 is presented in Figure 17.

Figure 15. Dry Medicine Lodge Creek gauging site, Bighorn County, Wyoming



Date	Local Stage (ft)	Discharge (cfs)
6/24/2014	1.06	31.4
8/19/2014	0.17	4.4
10/14/2014	0.10	3.2
6/15/2015	0.97	21.2
9/2/2015	0.14	3.0
10/19/2015	0.10	2.2

Figure 16. Dry Medicine Lodge Creek stage-discharge correlation, Bighorn County, Wyoming.

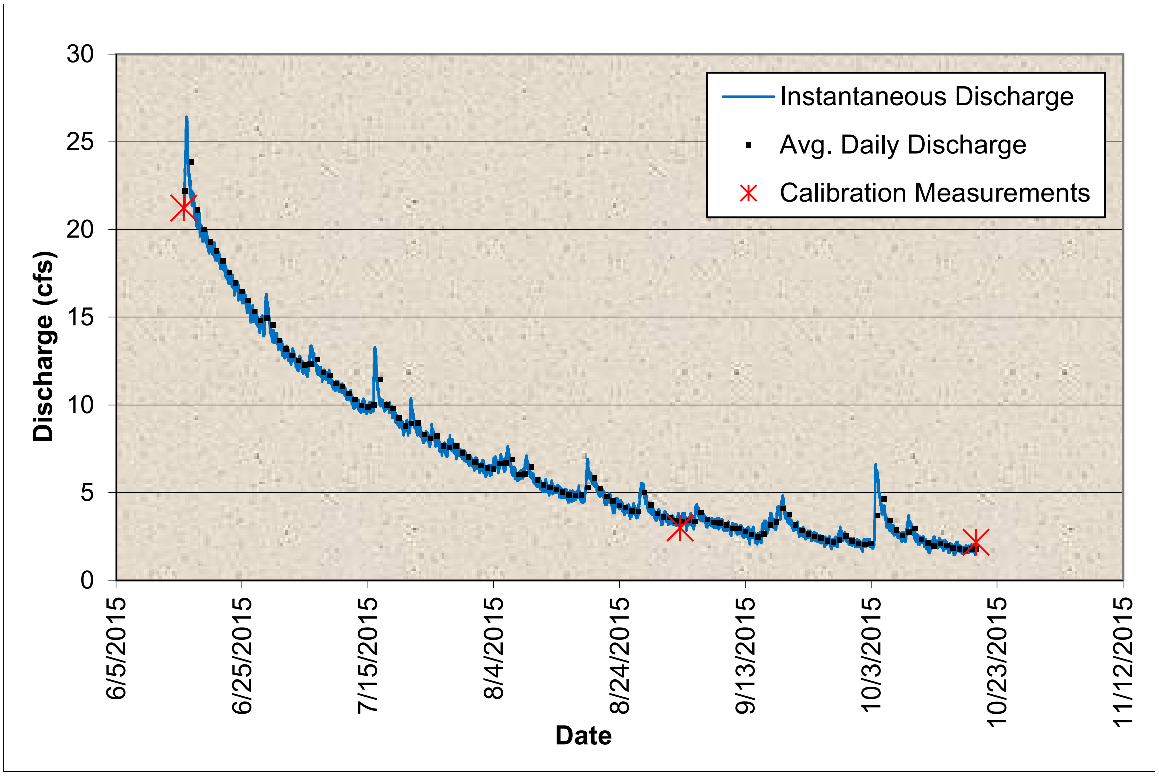


Figure 17. Dry Medicine Lodge Creek 2015 hydrograph, Bighorn County, Wyoming

1.6 HYDROLOGY

Hydrologic investigations focused on the quantification of virgin flows within study segments, or the surface water resource available within the sub-basins prior to any diversion withdrawals, consumptive uses, depletions, or return flows. Two methodologies were used to assess hydrologic conditions within study segments, including: (1) regional regression equations to calculate hydrologic conditions based upon catchment attributes (as presented in Lowham 1988 and Miselis et al 1999); and (2) concurrent discharge measurement techniques to establish a correlation between an established gauging station and the study segments (as presented in Lowham 2009).

1.6.1. Regional Regression Equation Approach

Regional regression equations were utilized to calculate hydrologic conditions based on basin characteristics. Equations presented in the following publication were determined to be applicable to the study segment sub-watersheds:

1. *Development of Improved Hydrologic Models for Estimating Streamflow Characteristics of the Mountainous Basins in Wyoming* (Miselis et. al., 1999);

The Miselis 1999 publication examines the mountainous regions of Wyoming and presents mountain range-specific regression equations for mean annual flow, mean monthly flows, and minimum monthly flows. Analyses of the two Beaver Creek and the Dry Medicine Lodge Creek study segments were completed using basin attribute correlation equations deemed statistically significant, with p-value less than 0.05. Regression equations utilized in this investigation included those developed for the Bighorn Mountains that correlate hydrologic conditions to mean basin elevation, drainage area, precipitation, and stream length.

The Miselis (1999) regression equations were used to calculate mean annual discharge at the USGS Shell Creek above Shell Creek Reservoir gauge site (Figure 18) based upon sub-basin attributes of drainage area (23.1 sq mi), mean basin elevation (10,030 ft), mean annual precipitation (18 in), and stream length from the gauge site to the headwaters (8.2 miles). The predicted mean annual flow rates based on regression equations were compared to mean annual flow calculated from measured flow data at the gauge site (Table 4). The difference between predicted and measured mean annual flow ranged from -59% to 0%.

The most accurate result of the Shell Creek reference gauge analysis was obtained using the Miselis (1999) regression equation for the Bighorn Mountains based upon mean basin elevation. Application of the Miselis (1999) hydrologic model that incorporates only the mean basin elevation parameter predicted flows in the study segments to be similar to those of the reference gauge because the mean basin elevation of the USGS Shell Creek reference gauge is similar to those of the study segment catchments. However, the stream flows in the study stream segments are much less than stream flows at the Shell Creek reference gauge because the study catchments are dramatically smaller than (about half the size of) the Shell Creek reference gauge catchment. Because the model does not account for the reduced catchment size and correspondingly diminished flow regime of the study segments, it over-predicts hydrologic attributes of the study segments.

The next most accurate result of the Shell Creek reference gauge analysis was obtained using the Miselis (1999) regression equations for the Bighorn Mountains based upon stream length (derived from NHD data). These hydrologic models accounted for the differences in catchment size between the study segments and the reference gauge, and yielded relatively accurate results for the measured flow regime of the reference gauge. The hydrologic models based upon stream length were, therefore, used to estimate mean annual flows for all of the study segments (Table 5). Calculated mean annual flow rates in the study segments were used to quantify mean monthly and mean daily flow rates in the study segments using dimensionless data from the reference gauge. The monthly flow rates at the reference gauge from the period of record were divided by the reference gauge mean annual flow, then multiplied by the study segment mean annual flow. Similarly, mean daily flow data from the reference gauge period of record were divided by the reference gauge mean annual flow, then multiplied by the study segment mean annual flow. These dimensionless analysis techniques enabled quantification of mean monthly and mean daily flow rates in the study segments to inform monthly flow availability and flow duration analyses.

Table 4. Mean annual flow from measured data and regional regression correlations, USGS Shell Creek gauge (#06278300).

Methodology	Equation	QAA (cfs)	Difference (predicted vs. measured, as percent)	Standard Error
USGS Gage Data, 58 years of record	n/a	33.32	0%	n/a
Miselis et al. (1999): Bighorn Mountains, Mean Elevation	254000 Elev^-0.97	33.39	0%	41.5%
Miselis et al. (1999): Bighorn Mountains, Drainage Area	0.65418 DA^0.97	13.75	-59%	29.4%
Miselis et al. (1999): Bighorn Mountains, Precipitation	0.09290 P^1.93	24.59	-26%	66.5%
Miselis et al.(1999): Bighorn Mountains, Stream Length	2.23254 SL^1.17	26.18	-21%	21.9%

Table 5. Study segment catchment attributes and mean annual flow calculated using Miselis (1999) equations based upon stream length.

Study Segment	Stream Length (miles)	Drainage Area (sq mi)	Mean Basin Elevation (ft)	Mean Annual Discharge (cfs)
North Beaver Creek	6.4	7.36	8,567	19.7
South Beaver Creek	6.7	7.6	8,692	20.7
Dry Medicine Lodge Creek	5.7	6.9	9,451	17

1.6.2 Concurrent Discharge Approach

The concurrent discharge approach enables estimation of stream flows at ungauged streams based upon an empirically-derived correlation between the ungauged stream and a proximate active gauging station. The technique requires identification of an active stream gauging station in the vicinity with a long period of record, referred to as the reference gauge. The reference gauge should be located near the study area and should have similar physical and climatic characteristics to those of the study area.

The selection of a suitable reference gauge for correlation with the Beaver Creek and Nowood River Basin study segments was completed based upon investigation of proximate gauge location, drainage area, basin orientation, elevation, and period of record. Several regional active and inactive US Geological Survey (USGS) gauges were investigated as potential reference gauges (Figure 18), and the Shell Creek gauge located above Shell Creek Reservoir (USGS #06278300) was selected for use as a reference gauge due to the proximity of the gauge to the study segments, the absence of diversion in the gauge catchment, and the similarity of the gauge catchment size and elevation to those of the study segments. The Shell Creek reference gauge has the following attributes:

Shell Creek, above Shell Creek Reservoir (USGS #06278300)

- Drainage area: 23.1 sq mi
- Elevation: 9,050 ft
- Location: Latitude 44°30’29”, Longitude 107°24’11”

Direct discharge measurements and flow data collected at temporary gauging sites within the study segments (presented in Section 1.5 Stream Gauging) were used to develop correlations between discharge at the ungauged study segments and the Shell Creek reference gauge. A power function correlation using mid-month (the 15th day) discharge data has been demonstrated to accurately represent mean monthly flows, but more accurate results can be obtained by incorporating additional data from the 5th and 25th of each month (Lowham 2009). Correlations between ungauged study segments and the reference gauge were therefore developed using temporary gauge data collected in 2014 and 2015 from the 5th, 15th, and 25th of each month during the temporary gauge station deployment period. In addition, direct discharge measurement data collected in the study segments by the Wyoming Game and Fish Department from July to September of 2011 were incorporated into the correlations because those data were collected several years prior and their inclusion increases the temporal duration of collected data incorporated into the correlations (Figure 19).

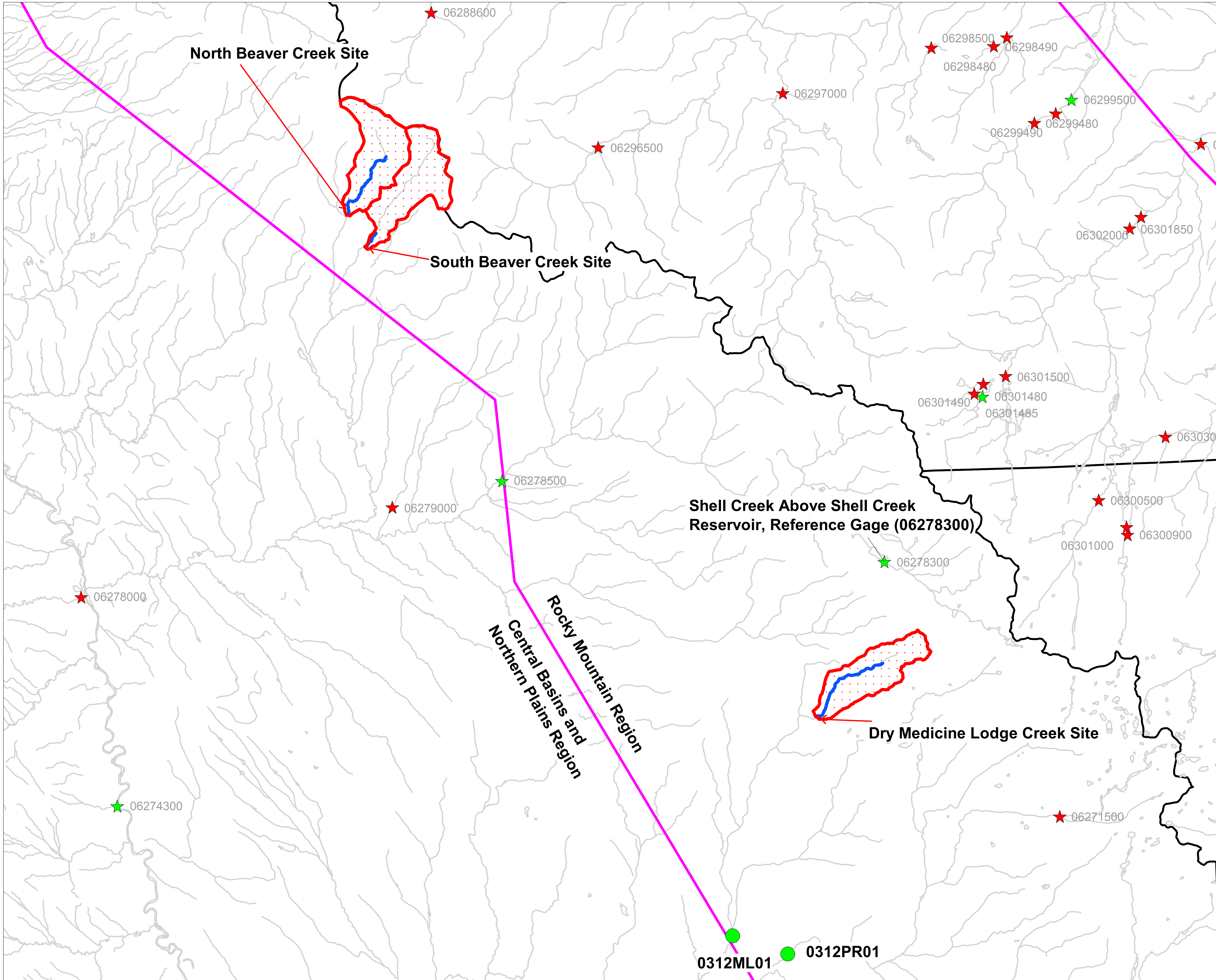


Figure 18
Established stream gauging stations
Bighorn County, Wyoming

November 1, 2015

Scale: 1 inch = 20,000 feet

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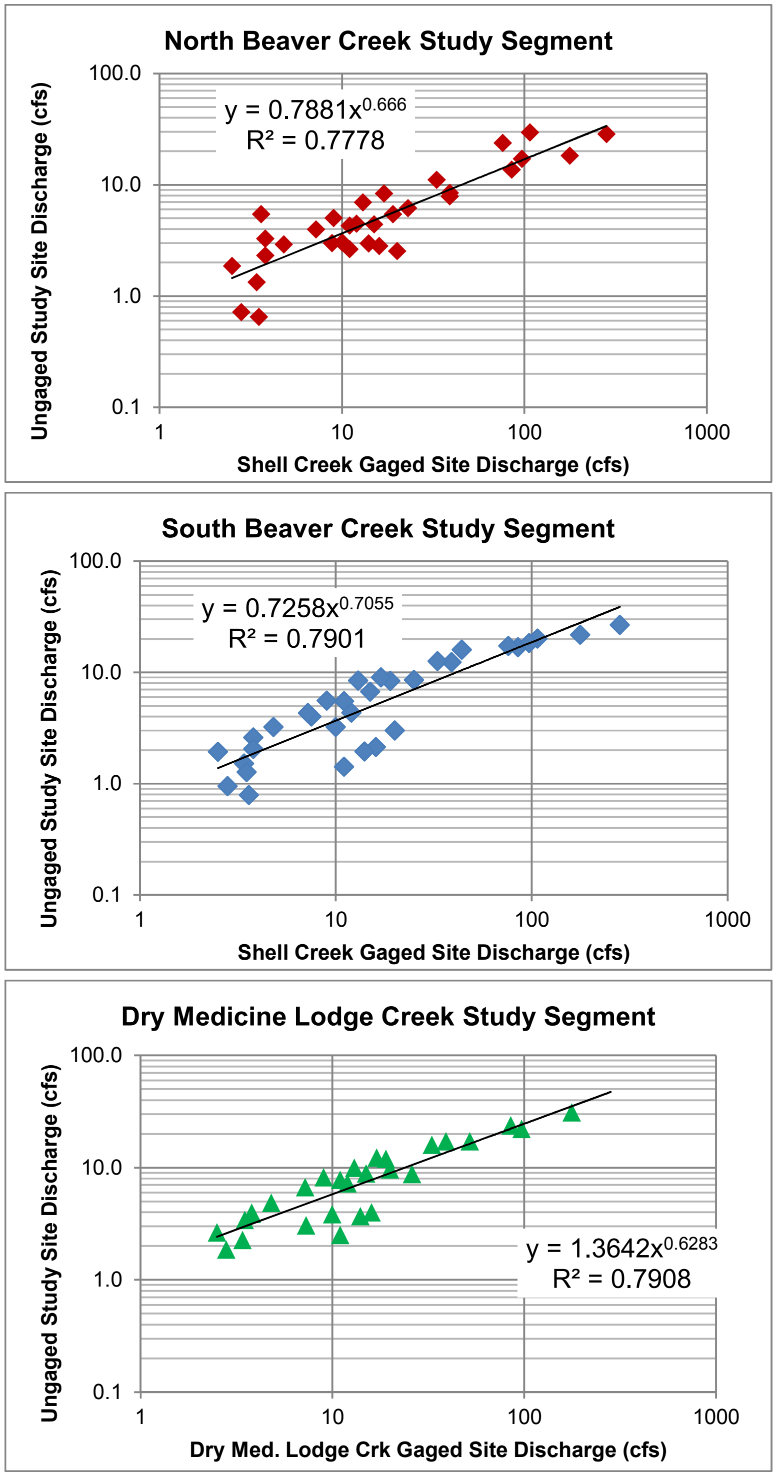


Figure 19. Concurrent discharge correlation equations between stream study segments and reference gauge (USGS Shell Creek #06278300).

1.6.3 Hydrologic Analysis Results

Flow data from the reference gauge (USGS Shell Creek Above Shell Creek Reservoir #06278300) period of record were analyzed to identify wet, dry, and average water years based on mean annual discharge; the years with mean annual discharge in the 20th percentile or less were classified as 'dry', years with mean annual discharge in the 80th percentile or greater were classified as' wet', and years between the 20th and 80th percentile were classified as 'average' water years. The mean daily flow data from all years classified as 'average' were used to calculate mean monthly flows at the reference gauge during the average water year (Table 6). The regional regression equation methodology was used to calculate mean monthly flow in the study segments by dividing the reference gauge mean monthly flows by the reference gauge mean annual flow, then multiplying the dimensionless flow by the study segment mean annual flow. The concurrent discharge correlation equation methodology was used to calculate mean monthly flows in the study segments by applying the correlation equations that relate study segment flow rates to reference gauge flow rate.

The mean monthly discharge estimates derived using the Miselis et al. (1999) regional regression equations are higher than those estimated using the concurrent discharge approach by an average factor of 2.1. Due to the discrepancy in results obtained from the regional regression and concurrent discharge techniques, methods to combine results using a weighted average approach were investigated. The regression and concurrent discharge estimates are assumed to be independent for the majority of the months (Parrett et al, 1990; U.S. Water Resource Council, 1981). Therefore, the regression equation and concurrent discharge method results were weighted proportionally to the inverse of their standard error to create a weighted average (Parrett et al, 1990; U.S. Water Resource Council, 1981). This approach incorporates two investigation methodologies, regional regression equations and concurrent discharge measurement techniques, and is described as an appropriate technique in Parrett et al (1990). The following equation (Equation 1) was used determine the weighted average of the two estimates:

$$Z = \frac{x\,SE_y + y\,SE_x}{SE_y + SE_x}$$

Where Z = weighted average
x = estimate using concurrent discharge approach
y = estimate using regional regression equations
SE_y = standard error for the regional regression equations (Miselis, 1999)
SE_x = standard error estimated using the average percent difference between actual and estimated flows from concurrent discharge approach (Lowham, 2009)

Results of mean monthly flows calculated using both the regional regression equations, the concurrent discharge methodology, and the weighted average analyses are presented in Table 7. The resultant weighted averages were utilized for subsequent analysis during the instream flow study.

Table 6. Mean monthly flow during average years at the reference gauge (USGS Shell Creek #06278300)

Time Period	Shell Creek Mean Monthly Flow (cfs)
January	3
February	2
March	2
April	6
May	90
June	212
July 1-15	68
July 16-31	25
August	13
September	9
October	8
November	6
December	4

Table 7. Study segment mean monthly discharge (cfs) rates estimated using regional regression equations, concurrent discharge measurement, and weighted average approaches.

Methodology	Jan	Feb	Mar	Apr	May	Jun	Ju 1-15	Jul 16-31	Aug	Sep	Oct	Nov	Dec
North Beaver Creek Study Segment													
Region Regression Equation, Bighorn Mountains Stream Length (Miselis 1999)	2.5	2.1	1.9	4.9	57.0	118.5	34.9	34.9	10.7	6.7	5.2	4.0	3.1
Concurrent Discharge	1.6	1.4	1.4	2.6	15.8	27.9	13.1	6.8	4.3	3.3	3.1	2.5	1.9
Weighted Average	**1.9**	**1.6**	**1.6**	**3.6**	**31.5**	**51.8**	**18.1**	**13.2**	**5.8**	**4.2**	**3.7**	**2.9**	**2.3**
South Beaver Creek Study Segment													
Region Regression Equation, Bighorn Mountains Stream Length (Miselis 1999)	2.7	2.3	2.0	5.3	59.8	122.5	36.2	36.2	11.3	7.2	5.6	4.3	3.3
Concurrent Discharge	1.5	1.4	1.3	2.5	17.3	31.7	14.2	7.1	4.3	3.3	3.1	2.4	1.8
Weighted Average	**1.8**	**1.7**	**1.5**	**3.7**	**33.4**	**55.7**	**19.2**	**13.7**	**5.9**	**4.3**	**3.8**	**3.0**	**2.2**
Dry Medicine Lodge Creek Study Segment													
Region Regression Equation, Bighorn Mountains Stream Length (Miselis 1999)	2.0	1.7	1.4	3.9	49.3	107.4	31.2	31.2	9.2	5.6	4.3	3.2	2.5
Concurrent Discharge	2.6	2.4	2.3	4.1	23.0	39.5	19.3	10.4	6.7	5.3	4.9	4.0	3.1
Weighted Average	**2.4**	**2.2**	**2.0**	**4.0**	**33.0**	**57.4**	**22.0**	**15.1**	**7.3**	**5.4**	**4.7**	**3.8**	**2.9**

2.0 UNAPPROPRIATED DIRECT FLOW ANALYSIS

Unappropriated direct flows calculated using the weighted average approach (which incorporated regional regression methods and concurrent discharge methods from average years) were determined by subtracting appropriated flows from virgin flows. Appropriated flows were determined based on the maximum allowable diversion rate when the diversion is in priority. Irrigation diversion rates were determined based upon water right priority, legal duty, and surplus water in accordance with the conditions presented in Table 8.

Table 8. Irrigation diversion rate assumptions applied to appropriated direct flow analysis in the Lower Bighorn and Nowood River Basin study segments.

Rate	Condition
1 cfs/70 acres	All pre-March 1945 permitted water rights, diversion based on priority
1 cfs/70 acres	All pre-March 1945 permitted water rights when surplus water is available
1 cfs/70 acres	All post-March 1945 to pre-March 1985 water rights when pre-March 1945 water rights have a 2 cfs/70 acre supply
1 cfs/70 acres	All post-March 1945 and pre-March 1985 water rights when surplus water is available
1 cfs/70 acres	All post-March 1985 water rights after all pre-March 1985 water rights have been given a 2 cfs/70 acre supply

2.1 DEPLETIONS AND CONSUMPTIVE USE

Depletions to stream flow include flow loss from consumptive use, deep groundwater loss, or out of basin diversions. Potential depletions within the study area include those due to irrigation or storage; there are no depletions due to municipal or industrial uses in the study segment catchments. There is one irrigation diversion within the study area; the Davis Ditch is located upstream of the South Beaver Creek study segment but in the study catchment (Figure 20). There is no long term record of flows diverted through the system. However, the Davis Ditch (and the Davis Ditch Enlargement) have combined rights to 3.35 cfs, and the pre-1945 permitted water rights are entitled to twice that amount (or 6.7 cfs) when surplus water is available. The Davis Ditch system irrigates approximately 92.3 acres (based upon review of aerial imagery; Figure 21) that are located entirely out of the South Beaver Creek study segment catchment.

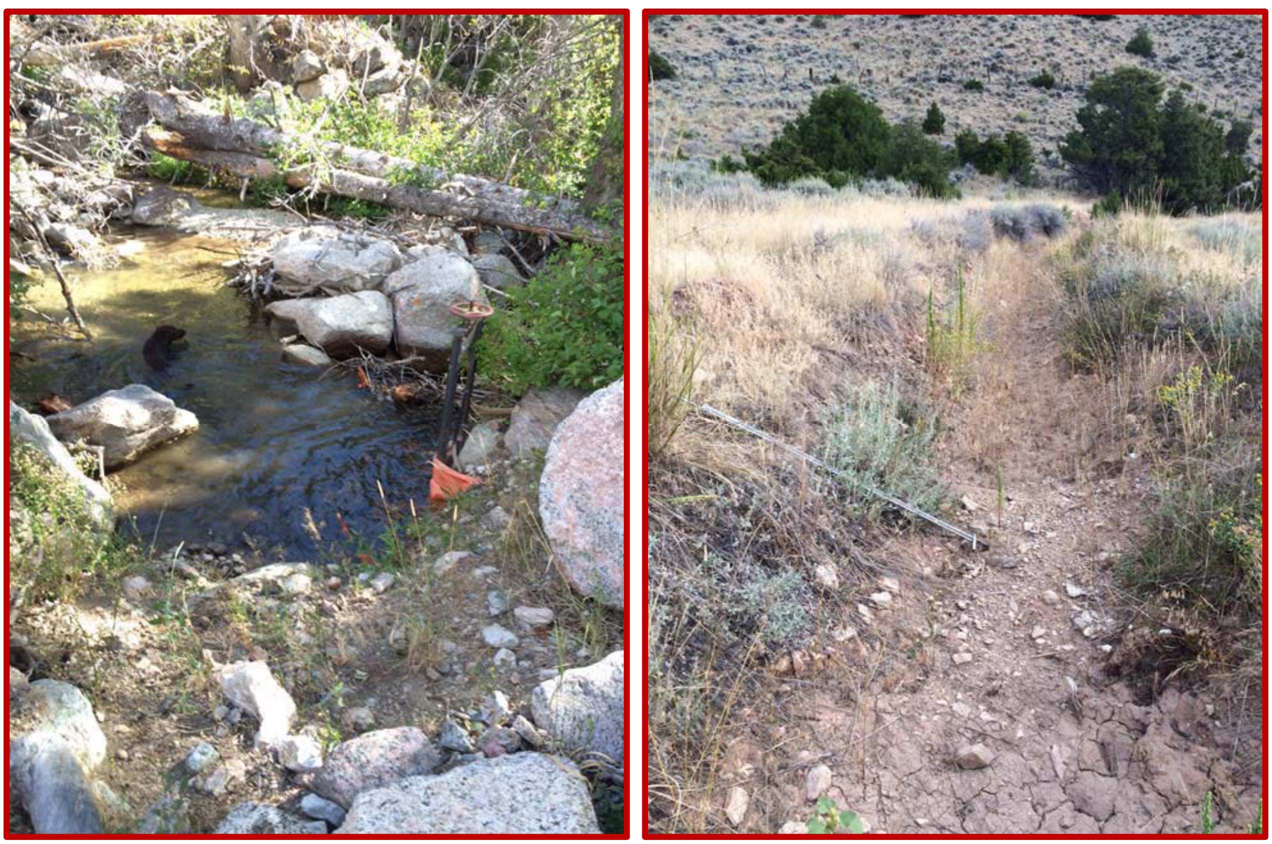
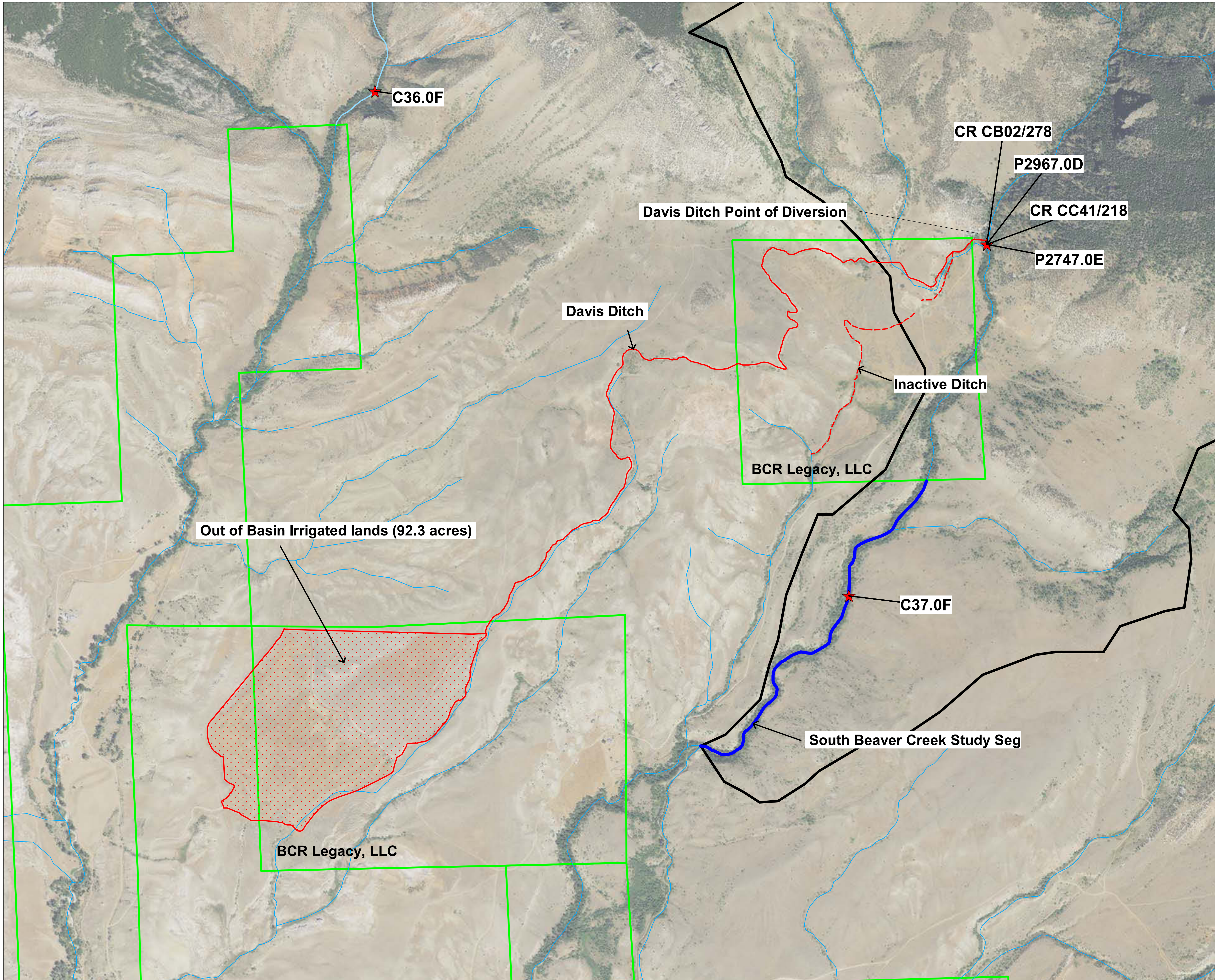


Figure 20. Davis Ditch head-gate and typical characteristics, South Beaver Creek study segment catchment.

Figure 21
Diversion Network and Water Right Numbers
Beaver Basin Instream Flow Study area
Bighorn County, Wyoming

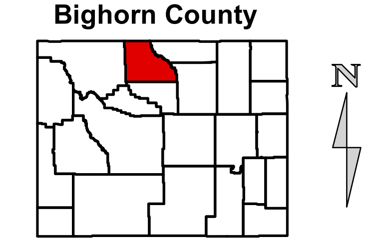
December 1, 2015

Scale: 1 inch = 1,000 feet
USGS Quadrangles: La Marsh Creek West,
Pine Grove Ranch, Pole Gulch, Ketchum Buttes



Legend

- Study Catchments
- Study Segment
- Hydrography
- Diversion Ditch
- Water Right POD (and Number)
- Parcel Boundaries
- Out-of-Basin Irrigated Lands



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Quantification of depletions was completed during the unappropriated direct flow analysis. Consumptive uses were not calculated because the Davis Ditch is an out-of-basin diversion. Depletions and return flows were determined in accordance with the assumptions presented in Table 9.

Table 9. Depletion and return flow determination assumptions, Lower Bighorn and Nowood River Basin Instream Flow Study.

Category	Determination Equation
Storage	Depletion = Diversion - Return Flow
Industrial Use	Depletion = Diversion
Municipal Use	Depletion = 0.45 x Diversion
Irrigation Use	Depletion = 0.5 x Diversion
Out of Basin Diversion	Depletion = 1.0 x Diversion

Historic diversion rates within the Davis Ditch system were not available, so appropriated flows were used to estimate monthly diversion rates. The Davis Ditch appropriated flow is 3.35 cfs, and the pre-1945 permitted water right can divert twice that amount when there is surplus water. All lands irrigated by the Davis Ditch delivery network are located beyond the South Beaver Creek study segment basin, so depletion is calculated as the entire appropriation of 6.7 cfs.

2.2 RETURN FLOWS

Return flow is defined as the portion of diverted surface water that returns to the stream. Out-of-basin diversions are considered a depletion with no return flows. All water diverted through the Davis Ditch irrigates lands located beyond the South Beaver Creek study segment catchment; there are no in-basin irrigated lands or return flows, so the net depletion resulting from the Davis Ditch is equal to the entire appropriation of 6.7 cfs (Table 10).

Table 10. Diversion model for Davis Ditch in the South Beaver Creek study segment catchment.

Parameter	Jan	Feb	Mar	Apr	May	June	Jul 1-15	Jul 16-31	Aug	Sep	Oct	Nov	Dec
Diversion Appropriation (cfs)	0.00	0.00	0.00	0.00	6.7	6.7	6.7	6.7	6.7	0.00	0.00	0.00	0.00
In-Basin Diversion (cfs)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Return Flows (cfs)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Net Depletion (cfs)	0.00	0.00	0.00	0.00	6.7	6.7	6.7	6.7	6.7	0.00	0.00	0.00	0.00

2.3 AVERAGE YEAR MEAN MONTHLY FLOW ANALYSIS

Mean monthly flows were calculated in each study stream segment for the average water year using the weighted average methodology (Equation 1). Appropriated flows were subtracted to determine unappropriated direct flow. Return flows were not incorporated because the only diversion in the study segment catchments is an out-of-basin diversion. Unappropriated direct flows were compared to the instream flow request to identify shortages or surpluses of available surface water resources.

2.3.1 North Beaver Creek

North Beaver Creek has sufficient unappropriated flows to accommodate the instream flow request from April through June, from mid-July through August, and in October in an average year. The system has insufficient unappropriated direct flows to accommodate the instream flow request from November through March, in late July, and in September. Results are depicted in tabular and graphical form in Table 11 and Figures 22 and 23.

Table 11. North Beaver Creek study segment mean monthly discharge analysis.

Parameter	Jan	Feb	Mar	Apr	May	Jun	July 1-15	July 16-31	Aug	Sep	Oct	Nov	Dec
Mean Monthly Flow (cfs)	1.9	1.6	1.6	3.6	31.5	51.8	18.1	13.2	5.8	4.2	3.7	2.9	2.2
Appropriated Flow (cfs)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Return Flow (cfs)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unappropriated Direct Flow (cfs)	1.9	1.6	1.6	3.6	31.5	51.8	18.1	13.2	5.8	4.2	3.7	2.9	2.2
Instream Flow Request (cfs)	3.1	3.1	3.1	3.1	20.0	20.0	20.0	4.8	4.8	4.8	3.1	3.1	3.1
Shortage/Surplus (cfs)	-1.2	-1.5	-1.6	0.5	11.5	31.8	-1.9	8.4	1.0	-0.6	0.6	-0.2	-0.9

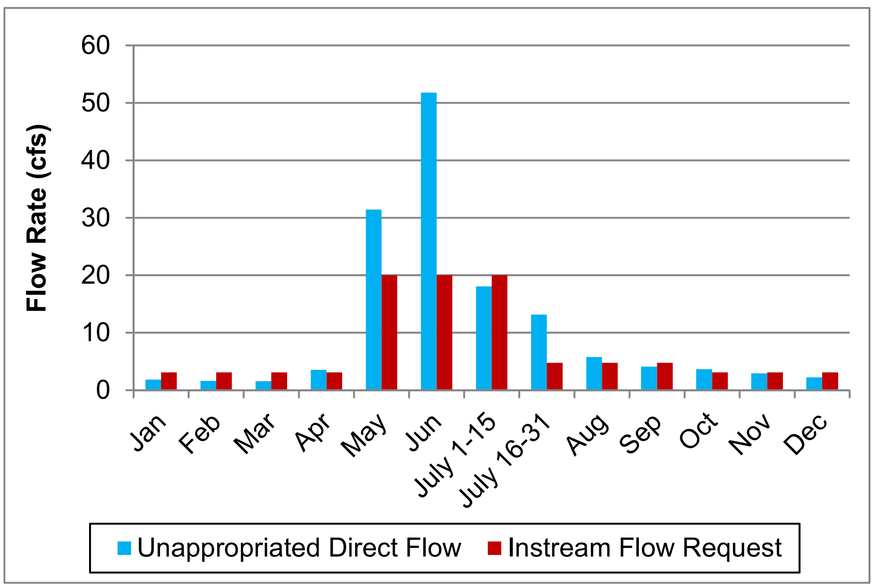

Figure 22. North Beaver Creek study segment unappropriated direct flow and instream flow request.

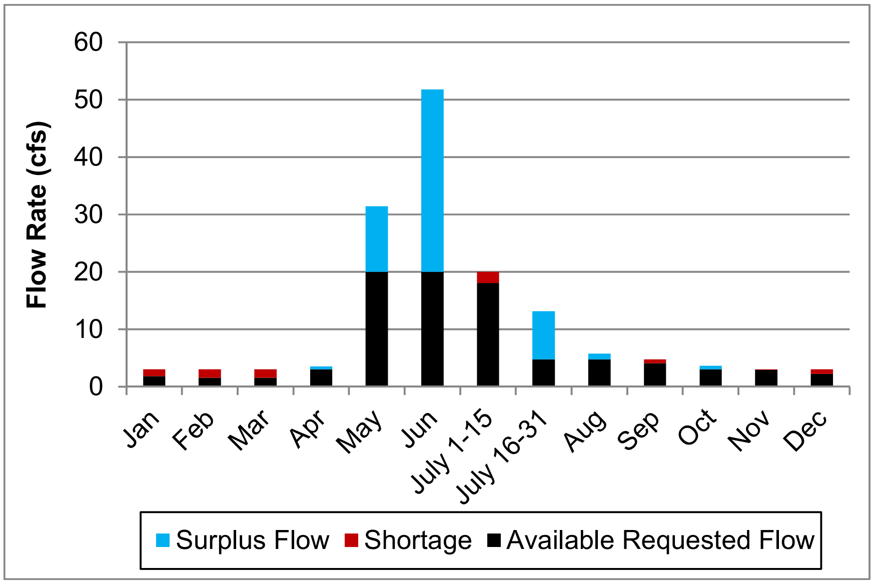

Figure 23. North Beaver Creek study segment instream flow request and availability.

2.3.2 South Beaver Creek

South Beaver Creek has sufficient unappropriated flows to satisfy the instream flow request from April through June, in late July, and from October through November in an average year. The system has insufficient unappropriated direct flows to accommodate the instream flow request from December to March, in late July, and from August to September in an average year. Results are depicted in tabular and graphical form in Table 12 and Figures 24 and 25.

Table 12. South Beaver Creek study segment mean monthly discharge analysis.

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul 1-15	Jul 16-31	Aug	Sep	Oct	Nov	Dec
Mean Monthly Flow (cfs)	1.8	1.7	1.5	3.7	33.4	55.7	19.2	13.7	5.9	4.3	3.8	3.0	2.2
Appropriated Flow (cfs)	0.0	0.0	0.0	0.0	6.7	6.7	6.7	6.7	6.7	0.0	0.0	0.0	0.0
Return Flow (cfs)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unappropriated Direct Flow (cfs)	1.8	1.7	1.5	3.7	26.7	49.0	12.5	7.0	0.0	4.3	3.8	3.0	2.2
Instream Flow Request (cfs)	2.8	2.8	2.8	2.8	17.0	17.0	17.0	5.5	5.9	5.5	2.8	2.8	2.8
Shortage/Surplus (cfs)	-1.0	-1.1	-1.3	0.9	9.7	32.0	-4.5	1.5	-5.9	-1.2	1.0	0.2	-0.6

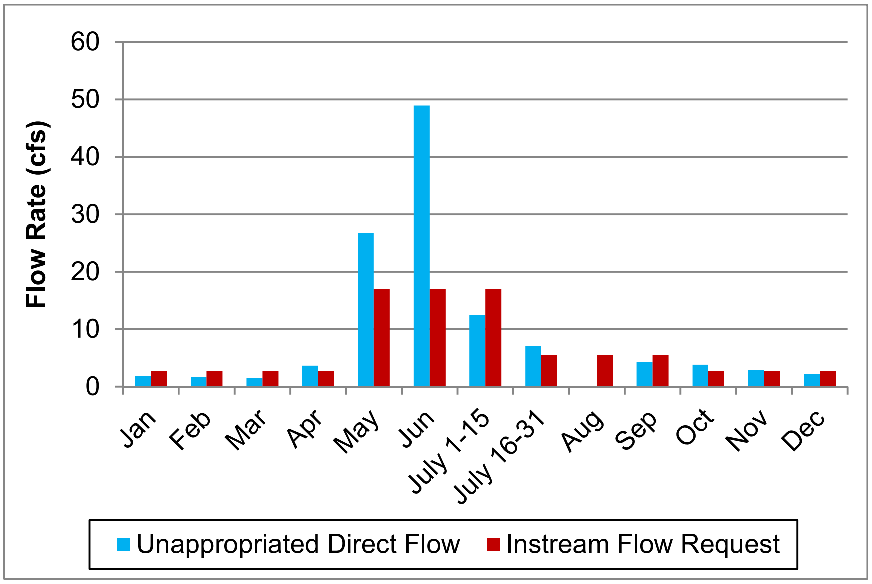

Figure 24. South Beaver Creek study segment unappropriated direct flow and instream flow request.

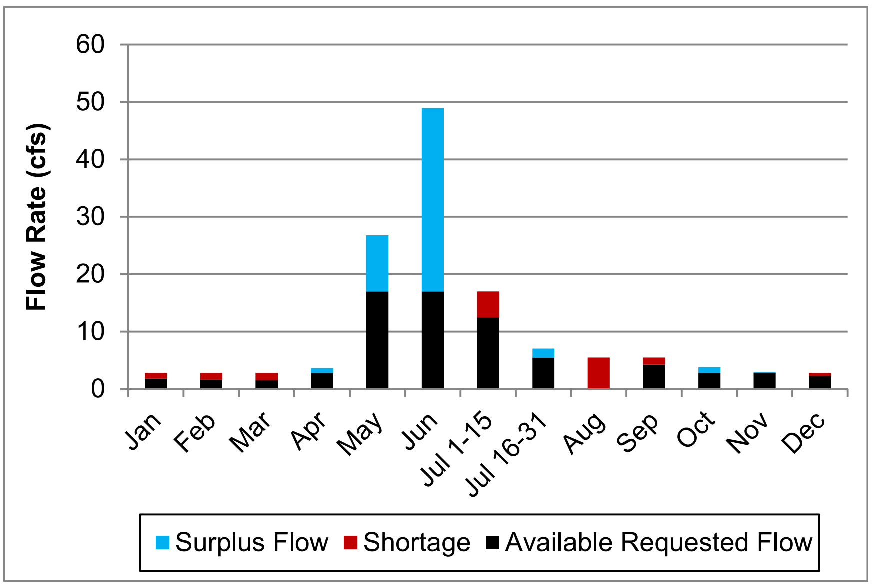

Figure 25. South Beaver Creek study segment instream flow request and availability.

2.3.3 Dry Medicine Lodge Creek

Dry Medicine Lodge Creek has sufficient unappropriated flows to accommodate the instream flow request from April through August, and from October through November in an average year. The system has insufficient unappropriated direct flows to accommodate the instream flow request from December through March, and in September in an average year. The results are depicted in tabular and graphical form in Table 13 and Figures 26 and 27.

Table 13. Dry Medicine Lodge Creek study segment mean monthly discharge analysis.

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul 1-15	Jul 16-31	Aug	Sep	Oct	Nov	Dec
Mean Monthly Flow (cfs)	2.4	2.2	2.0	4.0	33.0	57.4	22.0	15.1	7.3	5.4	4.7	3.8	2.9
Appropriated Flow (cfs)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Return Flow (cfs)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unappropriated Direct Flow (cfs)	2.4	2.2	2.0	4.0	33.0	57.4	22.0	15.1	7.3	5.4	4.7	3.8	2.9
Instream Flow Request (cfs)	3.1	3.1	3.1	3.1	20.0	20.0	20.0	5.7	5.7	5.7	3.1	3.1	3.1
Shortage/Surplus (cfs)	-0.7	-0.9	-1.1	0.9	13.0	37.4	2.0	9.4	1.6	-0.3	1.6	0.7	-0.2

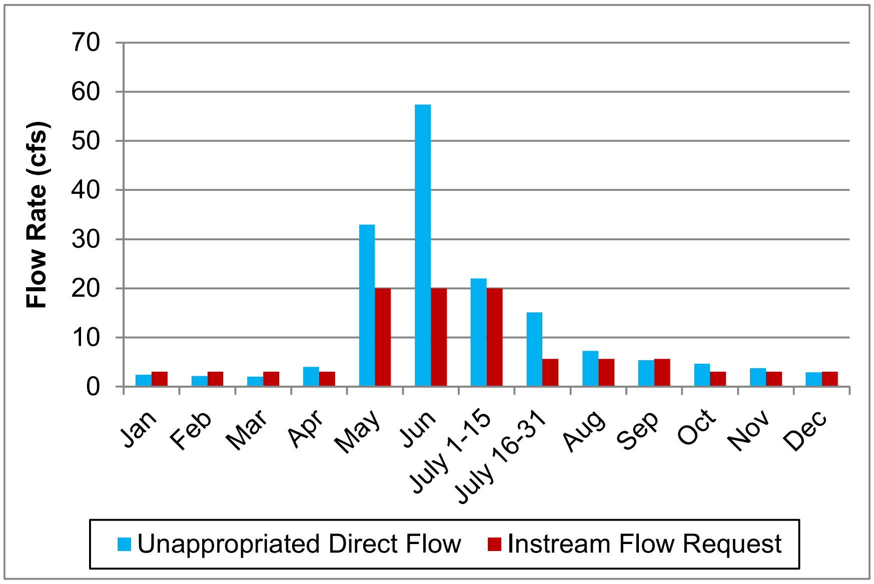

Figure 26. Dry Medicine Lodge Creek study segment unappropriated direct flow and instream flow request.

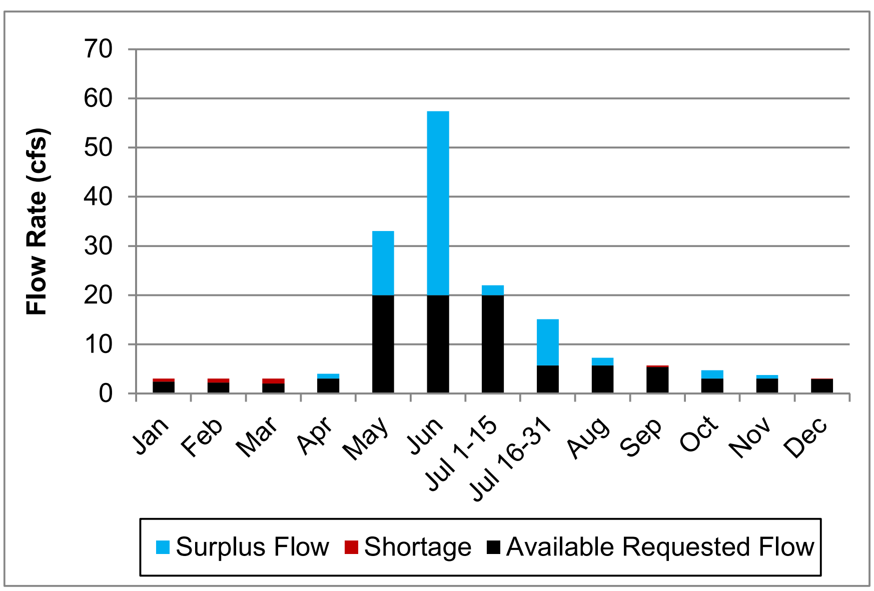

Figure 27. Dry Medicine Lodge Creek study segment instream flow request and availability.

2.4 FLOW SHORTAGE, STORAGE ANALYSIS, AND DESIGN

The North Beaver Creek, South Beaver Creek, and Dry Medicine Lodge Creeks have substantial surpluses of unappropriated direct flow during the months of May and June in an average year. Study segment catchments were assessed to investigate potential to establish off-channel water storage facilities that could retain surplus water during spring months and release stored water during fall and winter months to provide unappropriated flows to satisfy the instream flow request. Assessment found that all three study watercourses are confined by steep colluvial hill slopes throughout the upstream portions of the catchments. Bounding topographic conditions in the upper basins are consistently steep (30-40% grades), which precludes economically viable opportunities for off-channel storage of surface water that could be operated to store surplus flows during spring months and release flows to provide additional surface water resources during fall and winter months. Preliminary designs and cost analyses of storage facilities are therefore not provided.

2.5 DAILY UNAPPROPRIATED FLOW EXCEEDANCE ANALYSIS

Unappropriated direct flow exceedance was quantified within each stream study segment to identify the mean daily flow rate as percentage of time during each month. The regional regression equation methodology was used to calculate mean daily flows in the study segments by dividing the reference gauge mean daily flow record from ‘average years’ by the reference gauge mean annual flow, then multiplying the dimensionless flow by the study segment mean annual flow. The concurrent discharge correlation equation methodology was used to calculate mean daily flows in the study segments by applying the correlation equations (that relate study segment and reference gauge flow rates) to the reference gauge mean daily flow record from ‘average years’. A weighted average approach (Equation 1) was then used to combine results obtained from the regression equation and concurrent discharge methods and determine mean daily flow rates in the study segments. The results were used to identify the percent exceedance of the instream flow request. Analyses also identified the 20% and 50% exceedance unappropriated direct flows, or the flows in each stream study segment that occur one fifth or half of the time during each month, respectively.

Table 14 presents a summary of flow duration analysis results by month in each segment. Periods during which the instream flow request surpasses the 20% exceedance unappropriated direct flow are highlighted in green, while months during which the instream flow request is less than the 20% exceedance unappropriated direct flow are highlighted in red. Appendix A includes flow duration curves generated for each study segment during each month of the year.

Table 14. Monthly mean daily unappropriated flow exceedance summary, Lower Beaver and Nowood Basin Instream Flow Study.

Parameter	Jan	Feb	March	April	May	June	July 1-15	July 16-31	Aug	Sept	Oct	Nov	Dec
North Beaver Creek													
Requested Instream Flow (cfs)	3.1	3.1	3.1	3.1	20	20	20	4.8	4.8	4.8	3.1	3.1	3.1
Percent Exceedance of Requested Flow (%)	0%	0%	1%	17%	45%	83%	33%	80%	35%	19%	51%	25%	2%
Est. 50% Exceedance (cfs)	1.5	1.2	1.3	1.5	16.7	41.5	14.8	7.4	3.9	3.0	3.1	2.4	1.7
Est. 20% Exceedance (cfs)	1.9	1.5	1.6	2.6	48.0	82.8	27.3	11.5	5.9	4.6	4.6	3.3	2.2
South Beaver Creek													
Requested Instream Flow (cfs)	2.8	2.8	2.8	2.8	17	17	17	5.5	5.5	5.5	2.8	2.8	2.8
Percent Exceedance of Requested Flow (%)	0%	0%	0%	18%	45%	78%	29%	39%	7%	11%	51%	26%	3%
Est. 50% Exceedance (cfs)	1.5	1.0	1.0	1.3	11.2	35.3	9.8	4.4	2.0	2.7	2.8	2.2	1.5
Est. 20% Exceedance (cfs)	1.9	1.3	1.2	2.4	41.6	76.0	21.4	7.3	3.3	4.2	4.2	3.0	2.0
Dry Medicine Lodge Creek													
Requested Instream Flow (cfs)	3.1	3.1	3.1	3.1	20	20	20	5.7	5.7	5.7	3.1	3.1	3.1
Percent Exceedance of Requested Flow (%)	5.7%	0%	1%	19.1%	50%	92%	49%	79%	34%	19%	70%	41%	9%
Est. 50% Exceedance (cfs)	2.2	1.3	1.3	1.7	20.2	49.7	17.9	8.9	4.6	3.6	3.7	2.8	2.0
Est. 20% Exceedance (cfs)	2.6	1.7	1.6	3.1	57.3	97.8	32.9	13.9	7.1	5.5	5.5	3.9	2.5

3.0 CONCLUSIONS

Analysis of the hydrologic regimes in the Lower Bighorn and Nowood River Basin Instream Flow Study segments was completed using regional regression equations and concurrent discharge measurement techniques. Results obtained from the two applied methods varied, and the regional regression equations generally resulted in higher flow estimations than the concurrent discharge method. In order to resolve discrepancy in methodological findings, a weighted average approach (Equation 1) was applied to combine obtained results. Results of the weighted average analyses indicate that mean monthly unappropriated direct flows are not sufficient to satisfy the instream flow request during all months of an average year. Quantification of mean daily flow duration by month indicates that the requested instream flows are generally greater than the 20% exceedance flows from May to August and from October to November. However, the requested instream flows are generally less than the 20% exceedance flows in September and in the winter months from December to April.

Direct discharge measurements and continuous stream gauging data collected in the study segments during 2014 and 2015 provide empirical data that precisely quantify hydrologic regime during the study period. Regional regression equations that derive hydrologic attributes based upon catchment parameters are a standard hydrologic investigation tool that have been applied consistently across countless basins in Wyoming. The application of a weighted average approach to combine these methodologies provides results based upon robust regional empirical data and site specific stream gauging and direct discharge measurement data.

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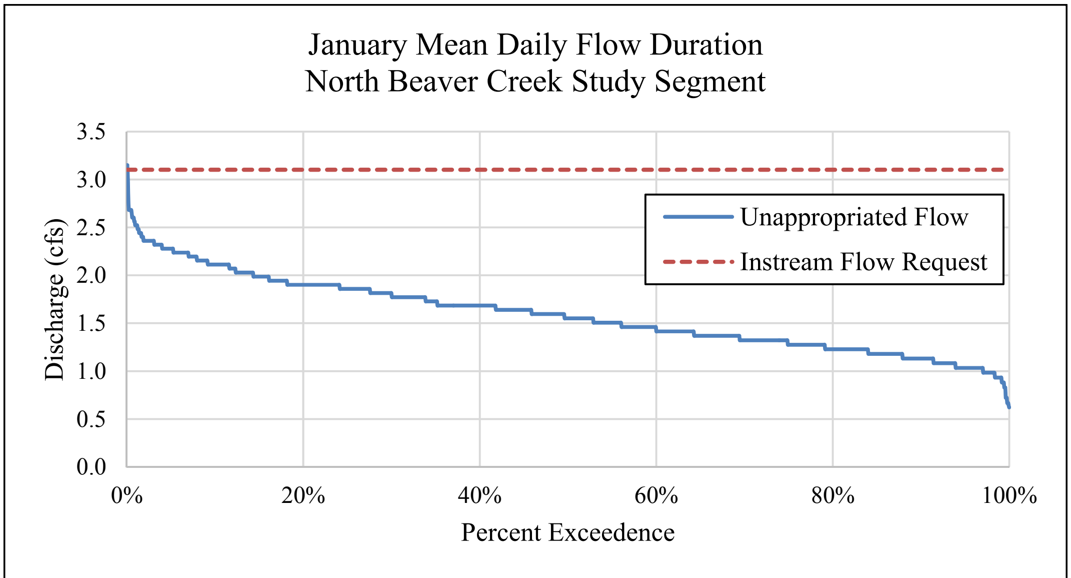
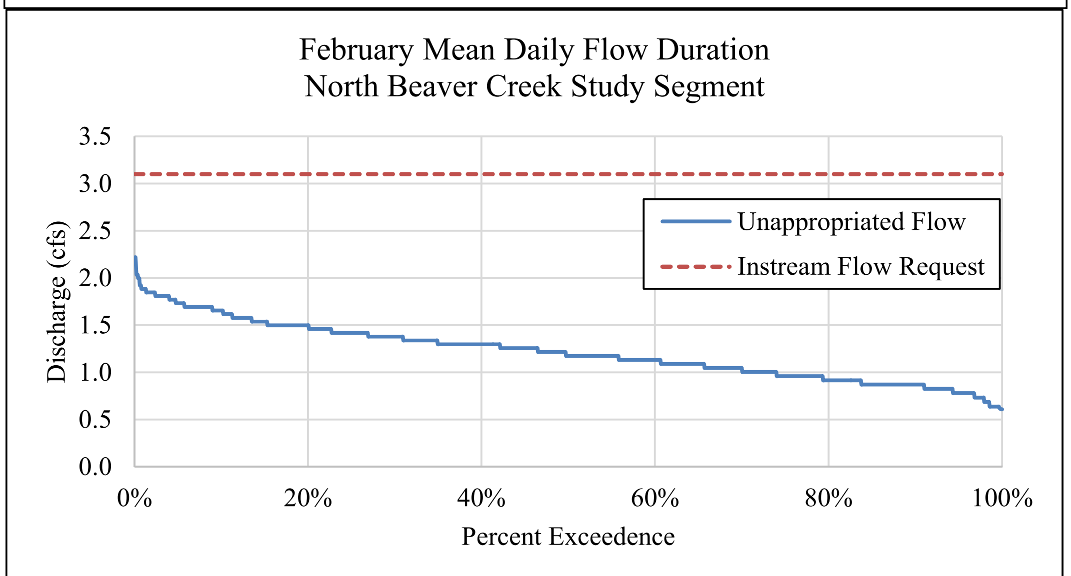
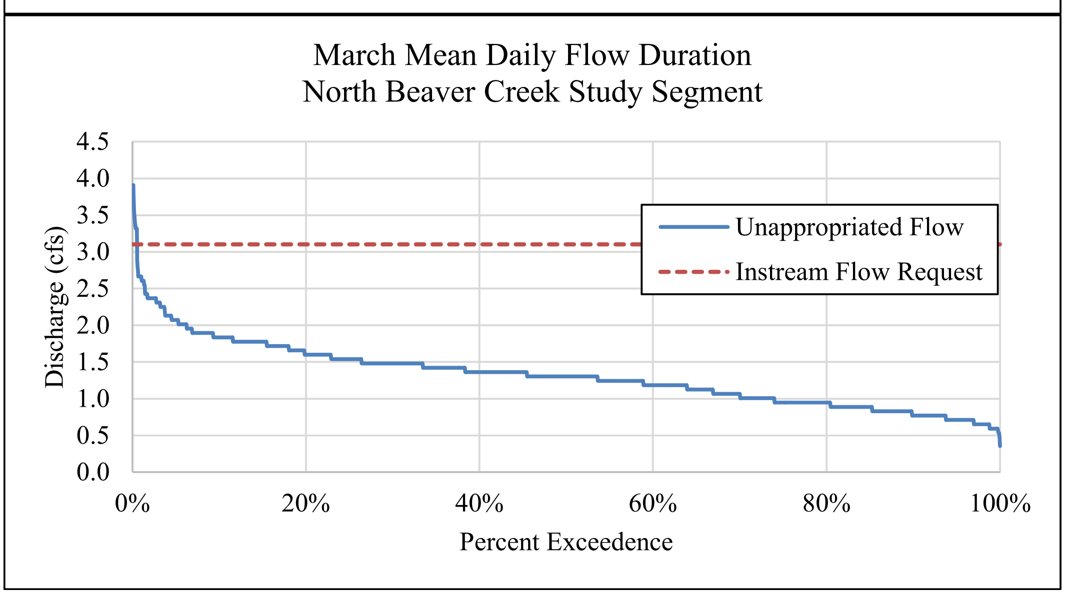
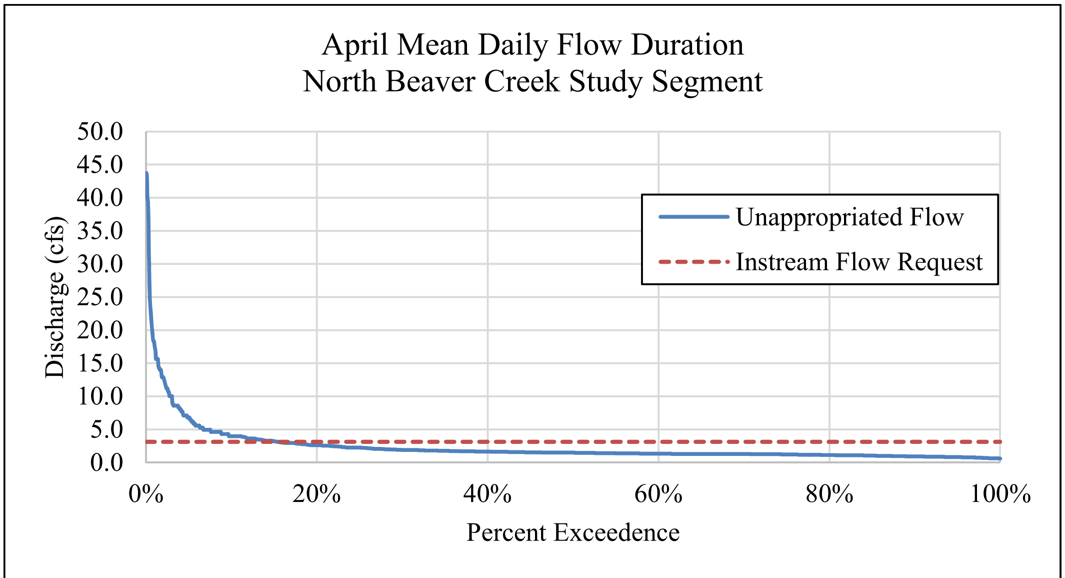
APPENDIX A

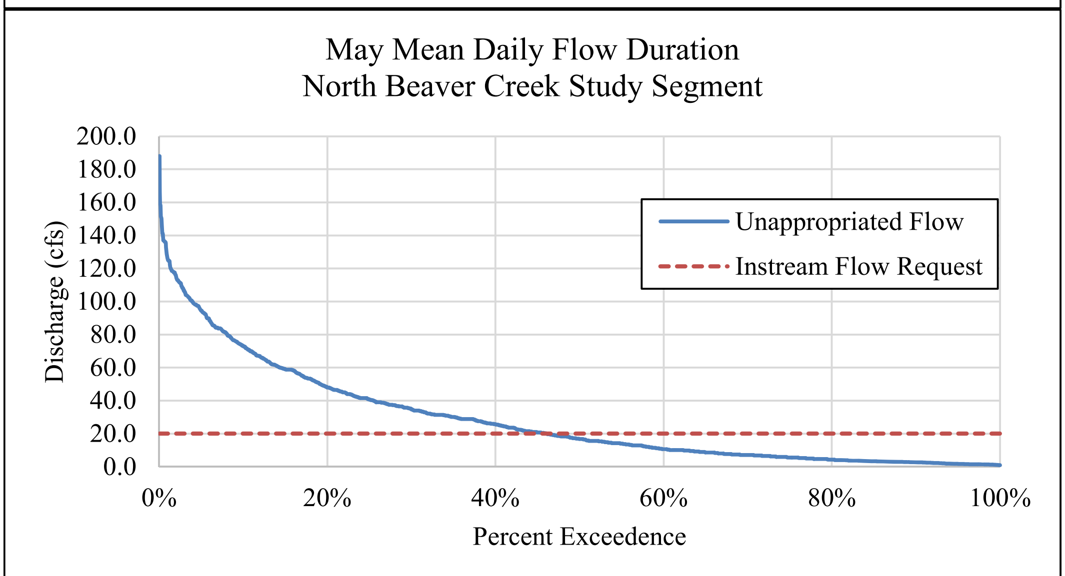
MEAN DAILY FLOW DURATION CURVES

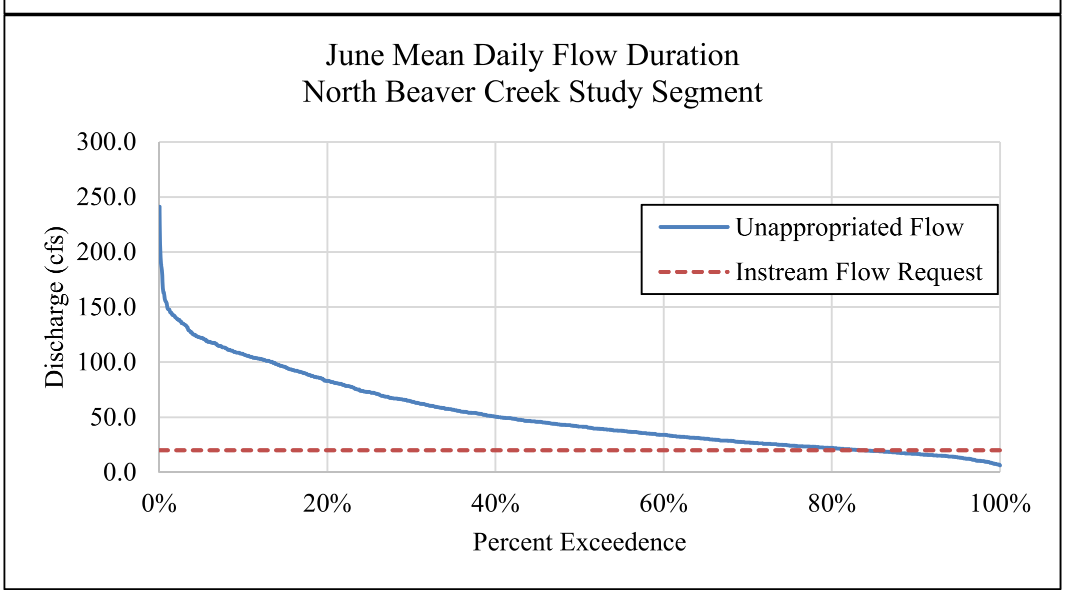

January Mean Daily Flow Duration
North Beaver Creek Study Segment
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Discharge (cfs)
0%
20%
40%
60%
80%
100%
Percent Exceedence
Unappropriated Flow
Instream Flow Request

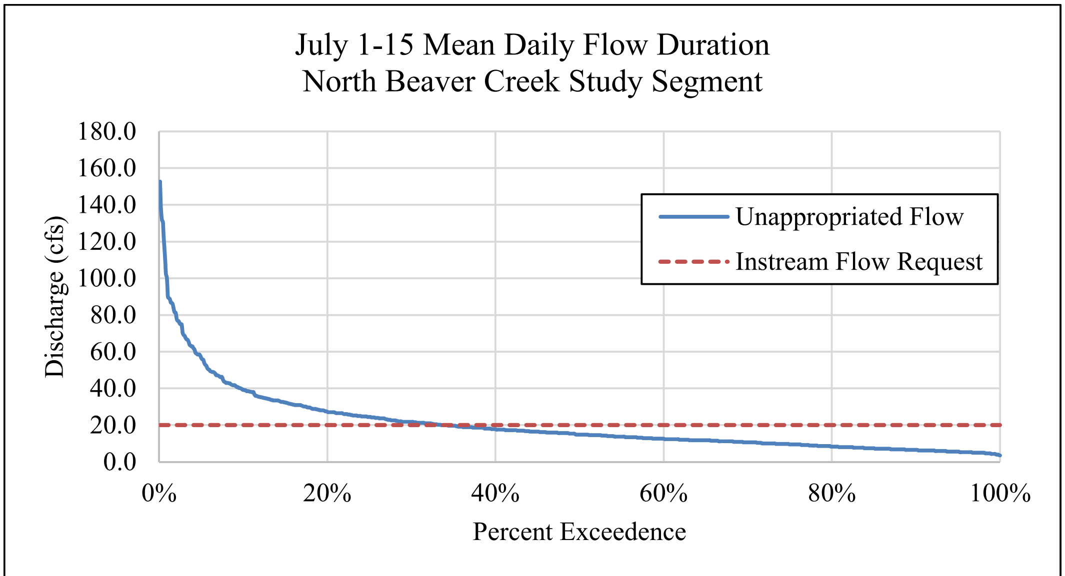

February Mean Daily Flow Duration
North Beaver Creek Study Segment
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Discharge (cfs)
0%
20%
40%
60%
80%
100%
Percent Exceedence
Unappropriated Flow
Instream Flow Request

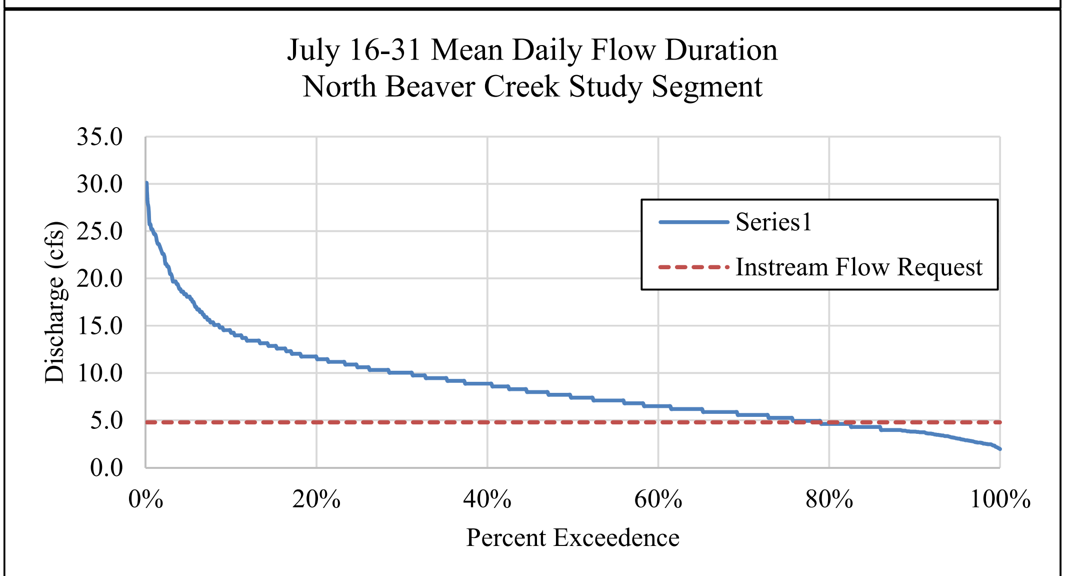

March Mean Daily Flow Duration
North Beaver Creek Study Segment
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Discharge (cfs)
0%
20%
40%
60%
80%
100%
Percent Exceedence
Unappropriated Flow
Instream Flow Request

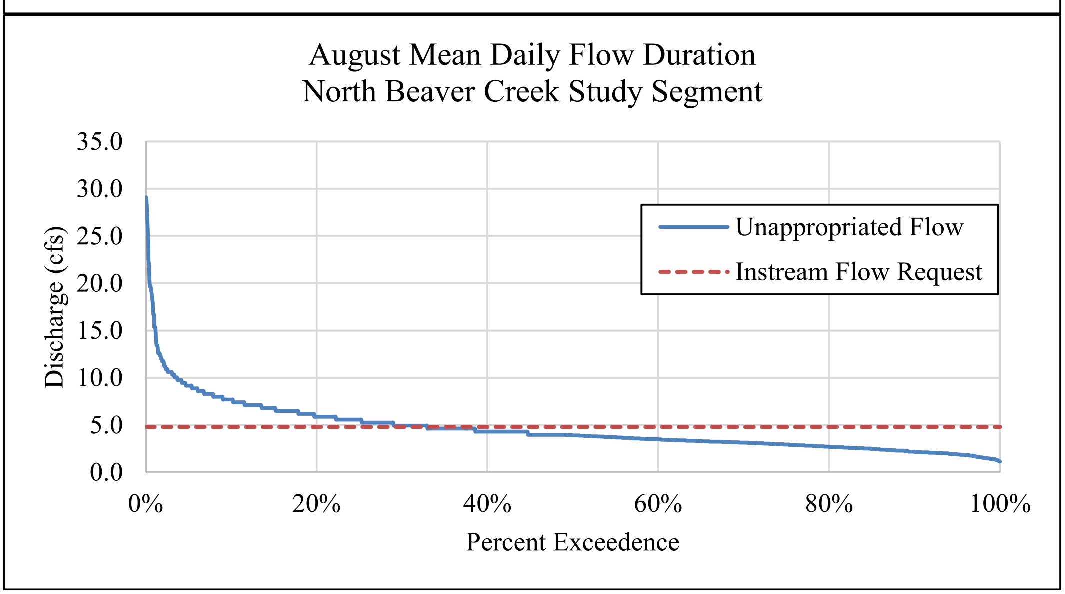

April Mean Daily Flow Duration
North Beaver Creek Study Segment
Discharge (cfs)
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0%
20%
40%
60%
80%
100%
Percent Exceedence
Unappropriated Flow
Instream Flow Request

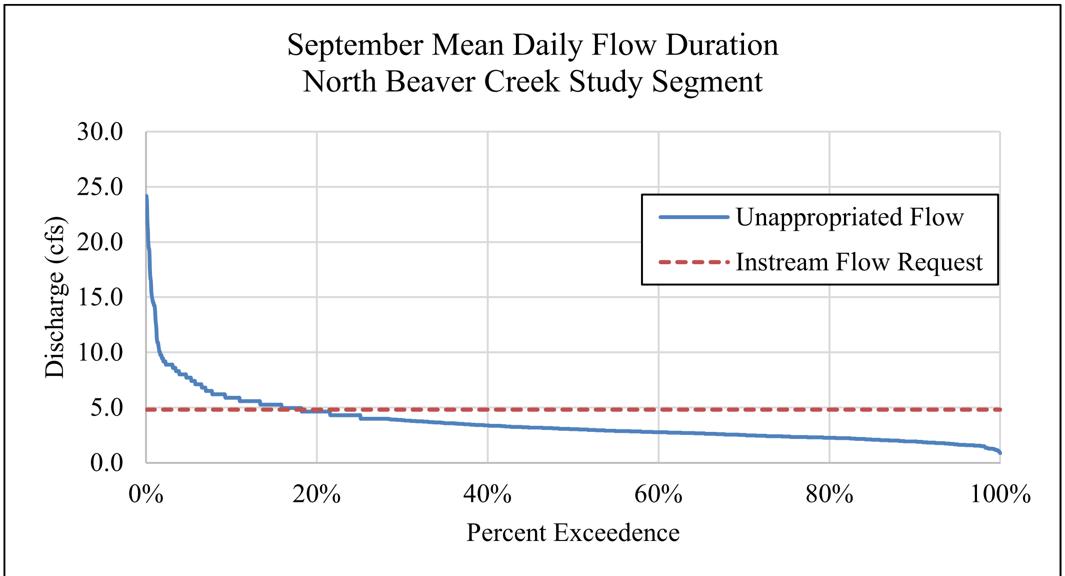

May Mean Daily Flow Duration
North Beaver Creek Study Segment
Discharge (cfs)
200.0
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
0%
20%
40%
60%
80%
100%
Percent Exceedence
Unappropriated Flow
Instream Flow Request

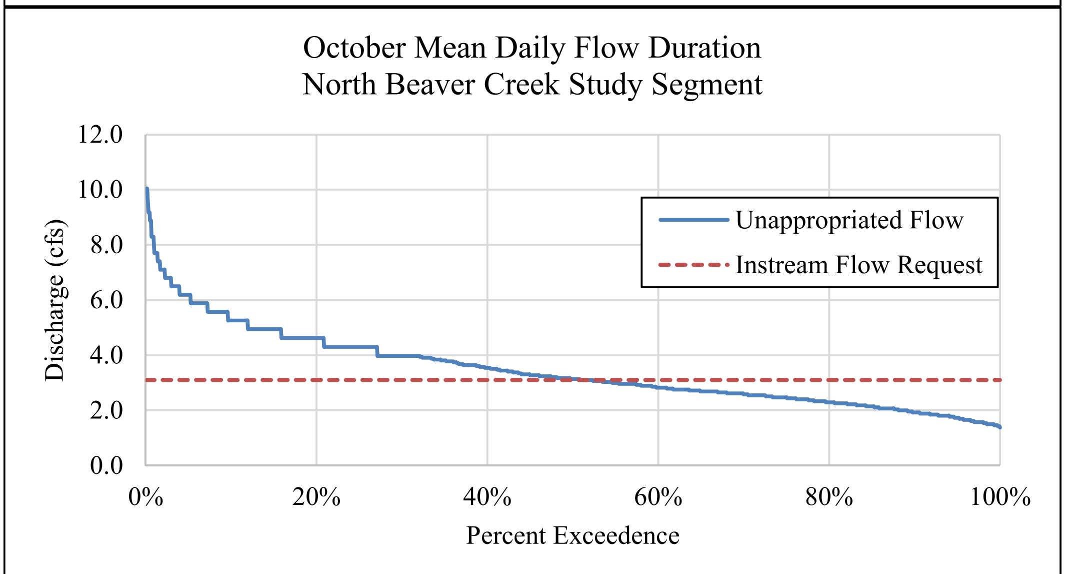

June Mean Daily Flow Duration
North Beaver Creek Study Segment
Discharge (cfs)
300.0
250.0
200.0
150.0
100.0
50.0
0.0
0%
20%
40%
60%
80%
100%
Percent Exceedence
Unappropriated Flow
Instream Flow Request

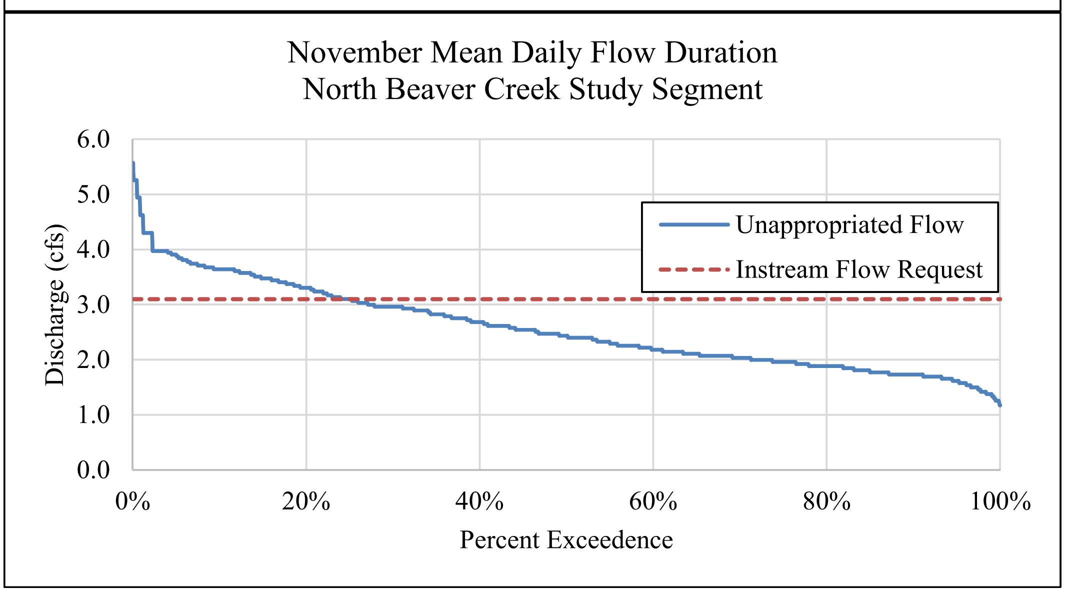

July 1-15 Mean Daily Flow Duration
North Beaver Creek Study Segment
Discharge (cfs)
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
0%
20%
40%
60%
80%
100%
Percent Exceedence
Unappropriated Flow
Instream Flow Request

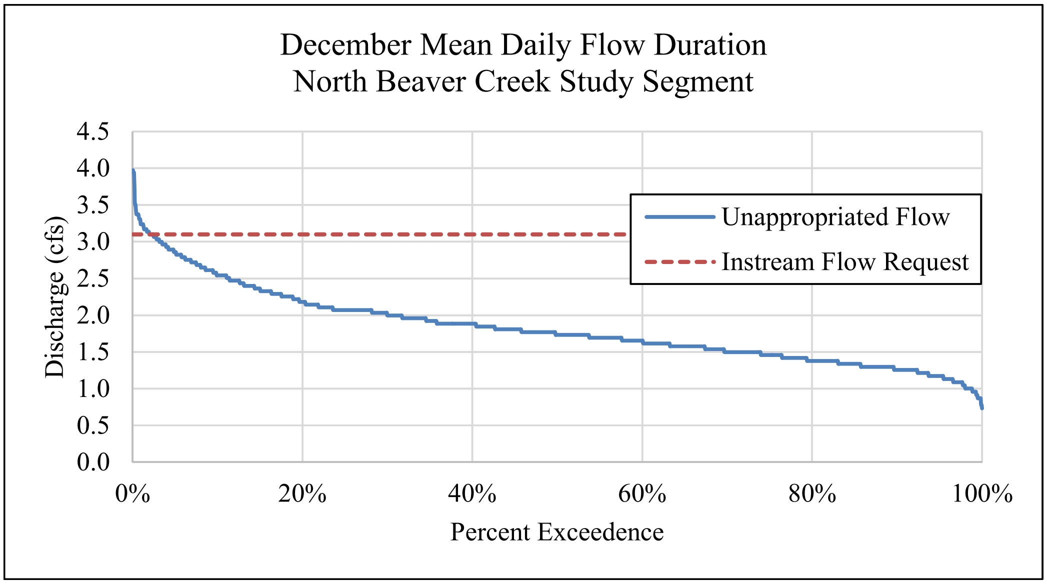

July 16-31 Mean Daily Flow Duration
North Beaver Creek Study Segment
Discharge (cfs)
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0%
20%
40%
60%
80%
100%
Percent Exceedence
Series1
Instream Flow Request

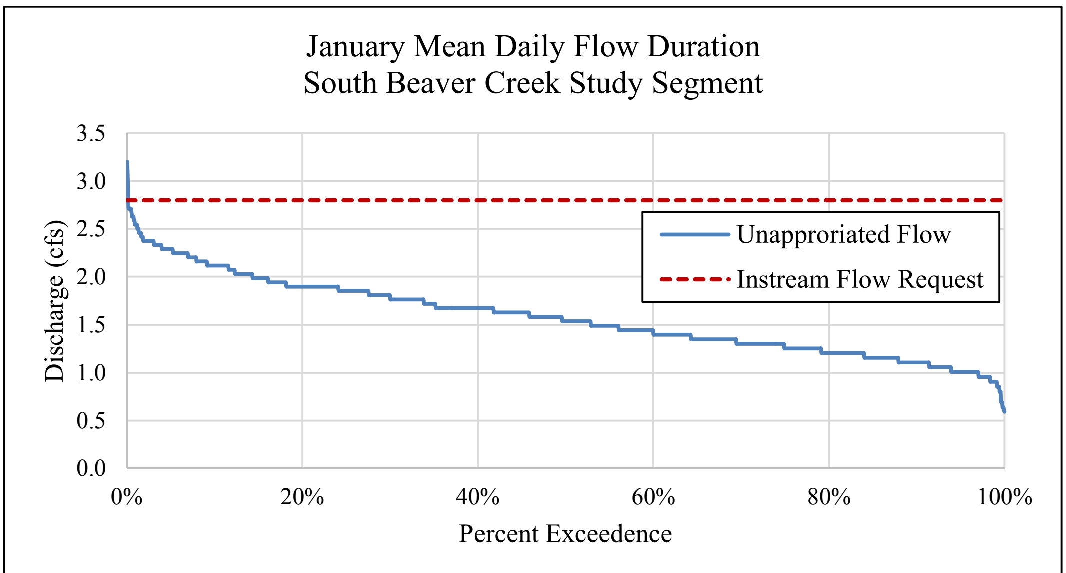

August Mean Daily Flow Duration
North Beaver Creek Study Segment
Discharge (cfs)
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0%
20%
40%
60%
80%
100%
Percent Exceedence
Unappropriated Flow
Instream Flow Request

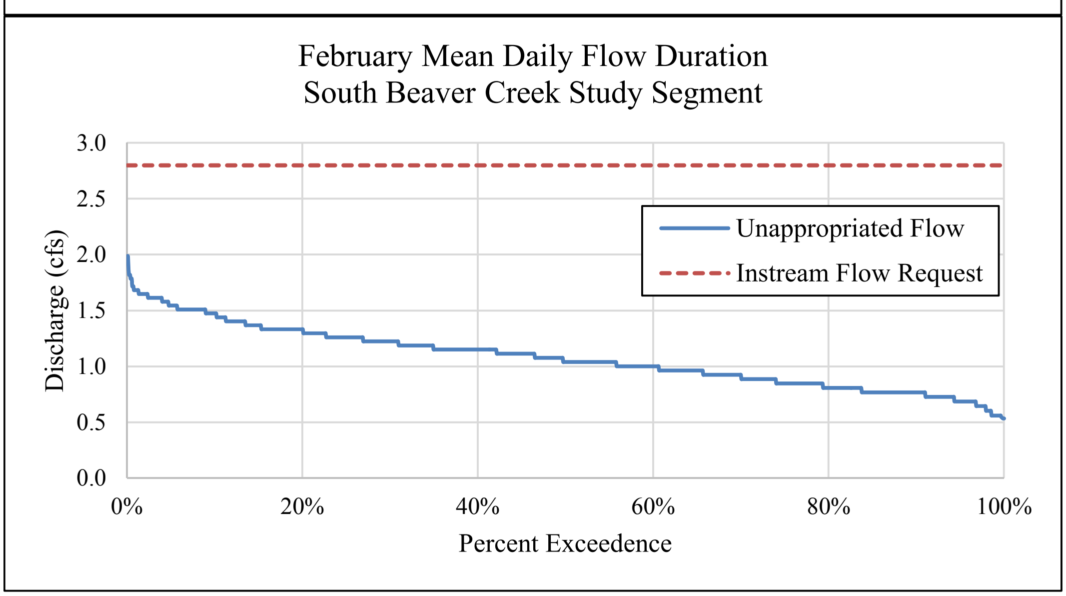

September Mean Daily Flow Duration
North Beaver Creek Study Segment
Discharge (cfs)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0%
20%
40%
60%
80%
100%
Percent Exceedence
Unappropriated Flow
Instream Flow Request

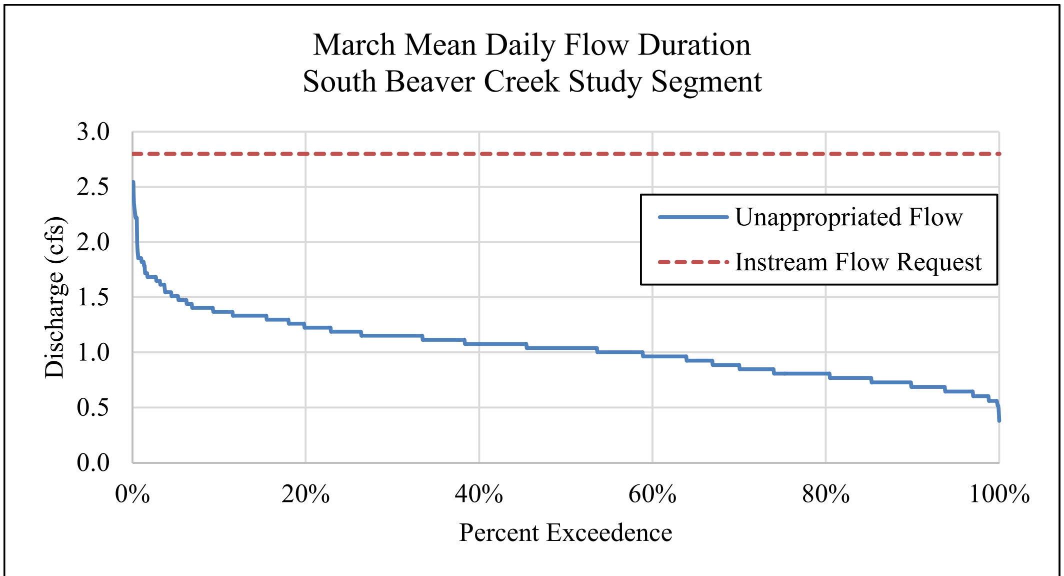

October Mean Daily Flow Duration
North Beaver Creek Study Segment
Discharge (cfs)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0%
20%
40%
60%
80%
100%
Percent Exceedence
Unappropriated Flow
Instream Flow Request


November Mean Daily Flow Duration
North Beaver Creek Study Segment
Discharge (cfs)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0%
20%
40%
60%
80%
100%
Percent Exceedence
Unappropriated Flow
Instream Flow Request

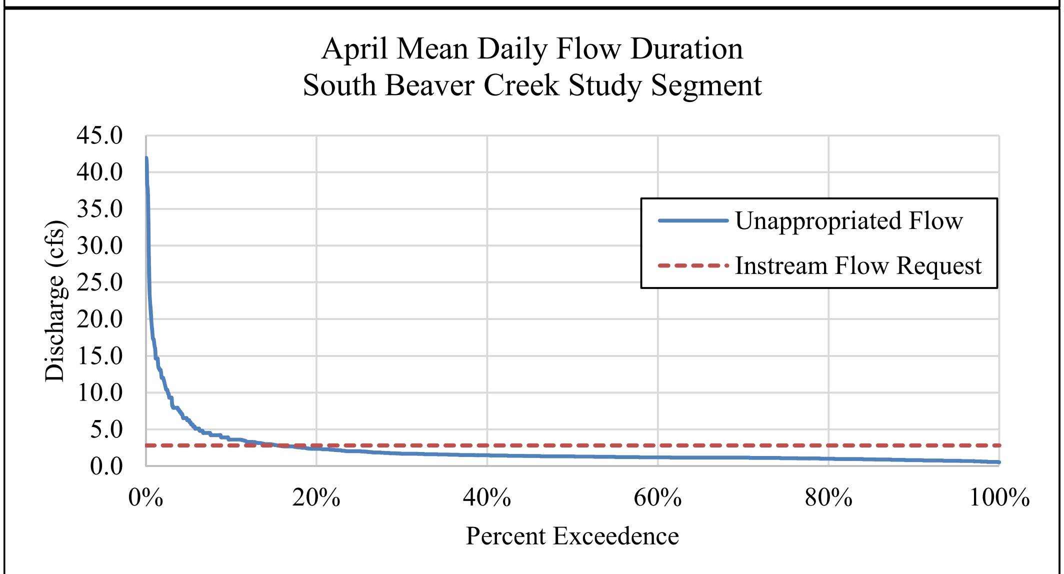

December Mean Daily Flow Duration
North Beaver Creek Study Segment
Discharge (cfs)
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0%
20%
40%
60%
80%
100%
Percent Exceedence
Unappropriated Flow
Instream Flow Request


January Mean Daily Flow Duration
South Beaver Creek Study Segment
Discharge (cfs)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0%
20%
40%
60%
80%
100%
Percent Exceedence
Unappropriated Flow
Instream Flow Request

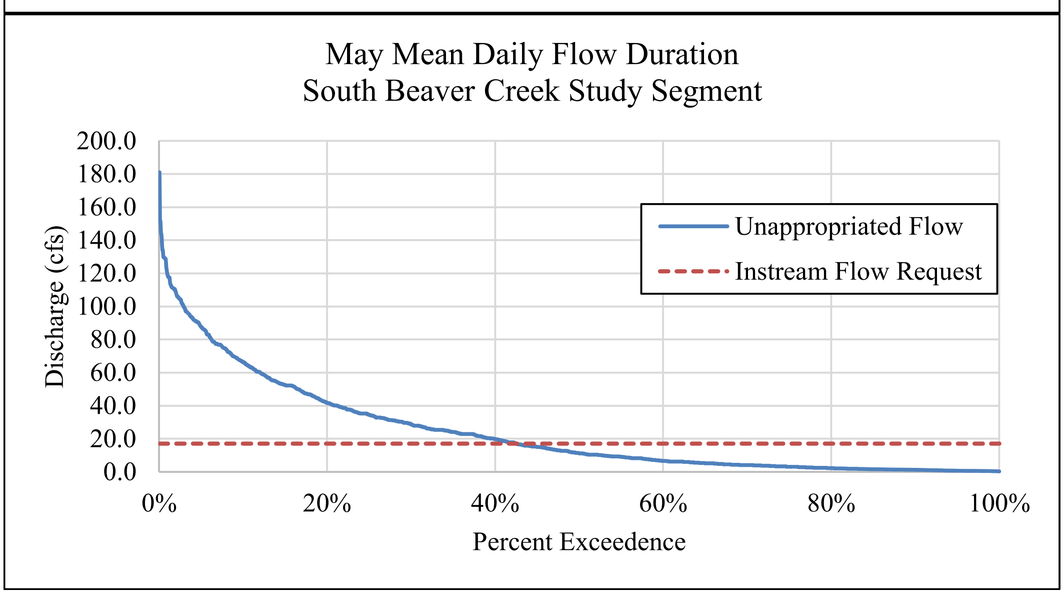

February Mean Daily Flow Duration
South Beaver Creek Study Segment
Discharge (cfs)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0%
20%
40%
60%
80%
100%
Percent Exceedence
Unappropriated Flow
Instream Flow Request



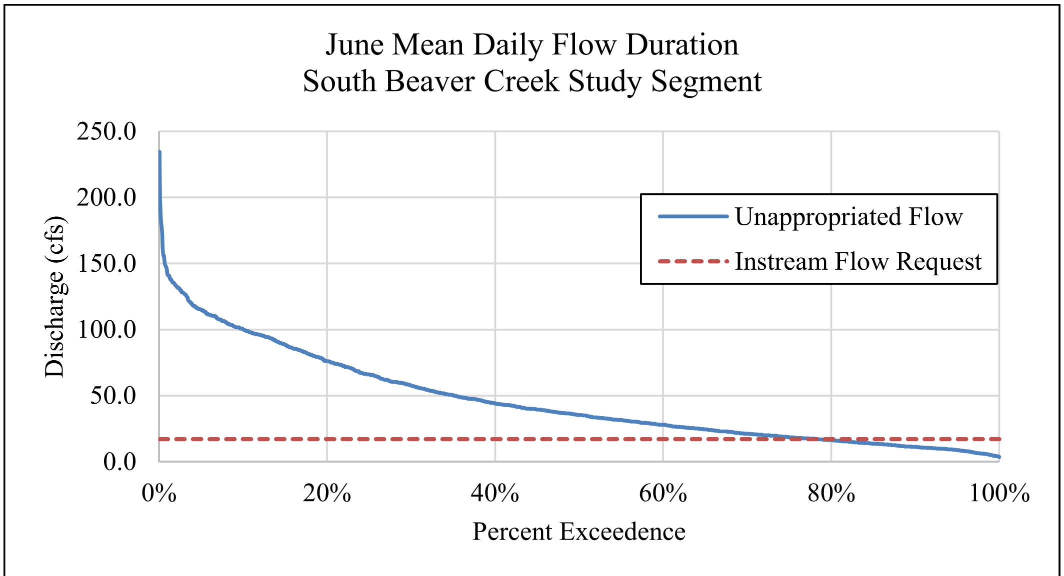
March Mean Daily Flow Duration
South Beaver Creek Study Segment
Discharge (cfs)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0%
20%
40%
60%
80%
100%
Percent Exceedence
Unappropriated Flow
Instream Flow Request

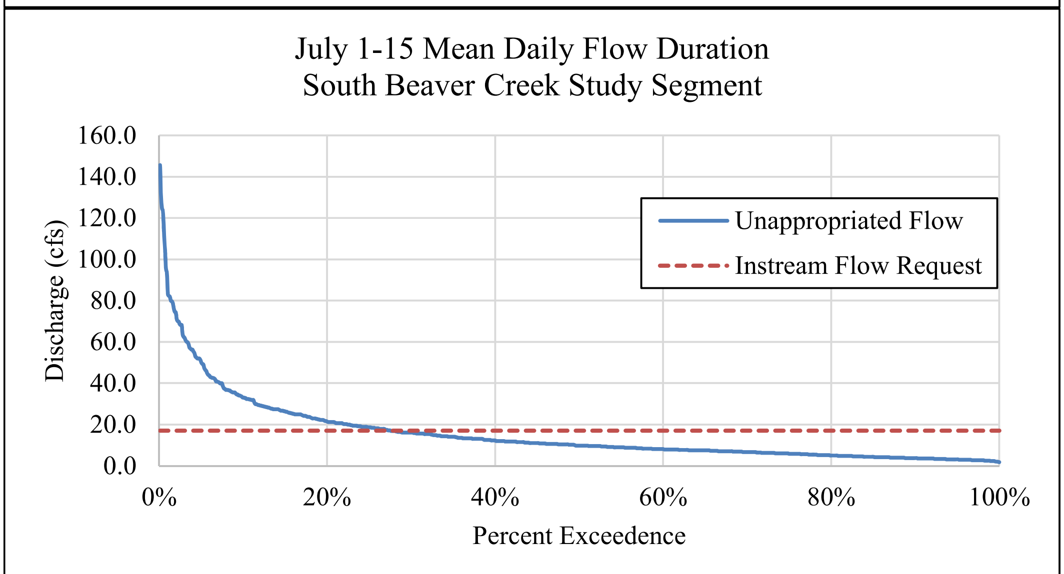


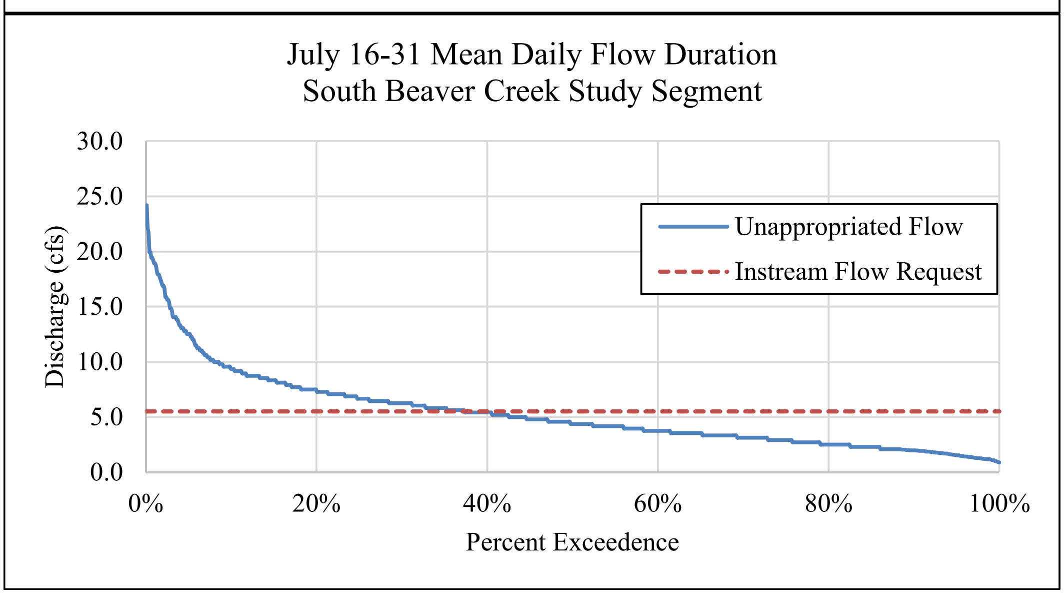
April Mean Daily Flow Duration
South Beaver Creek Study Segment
Discharge (cfs)
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0%
20%
40%
60%
80%
100%
Percent Exceedence
Unappropriated Flow
Instream Flow Request

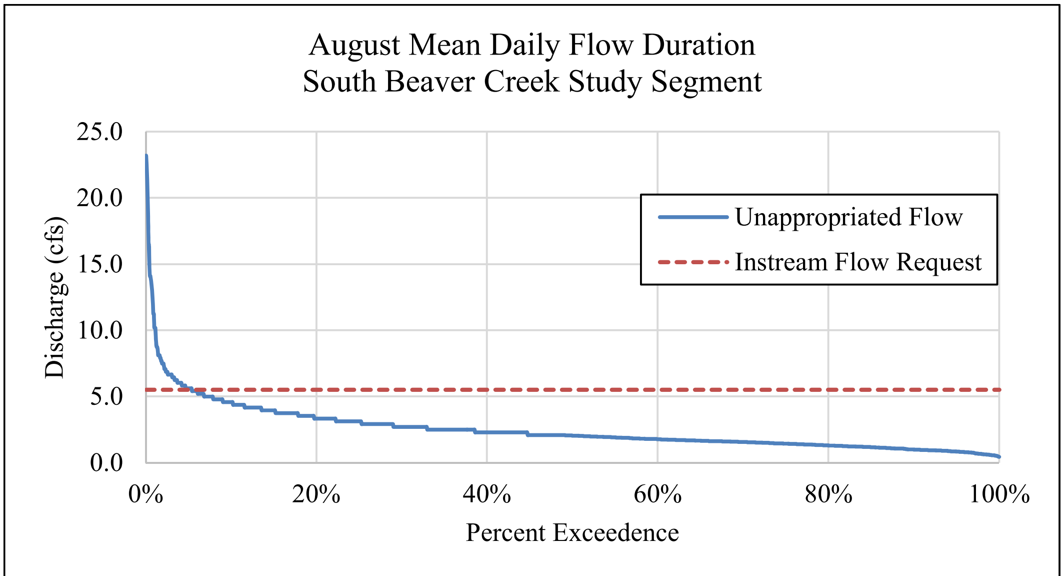


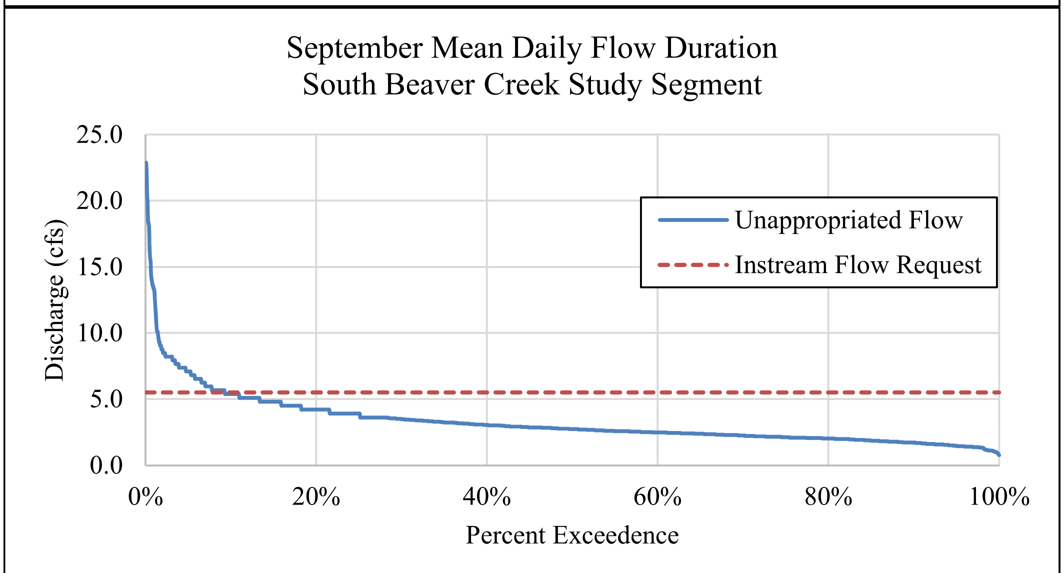
May Mean Daily Flow Duration
South Beaver Creek Study Segment
Discharge (cfs)
200.0
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
0%
20%
40%
60%
80%
100%
Percent Exceedence
Unappropriated Flow
Instream Flow Request

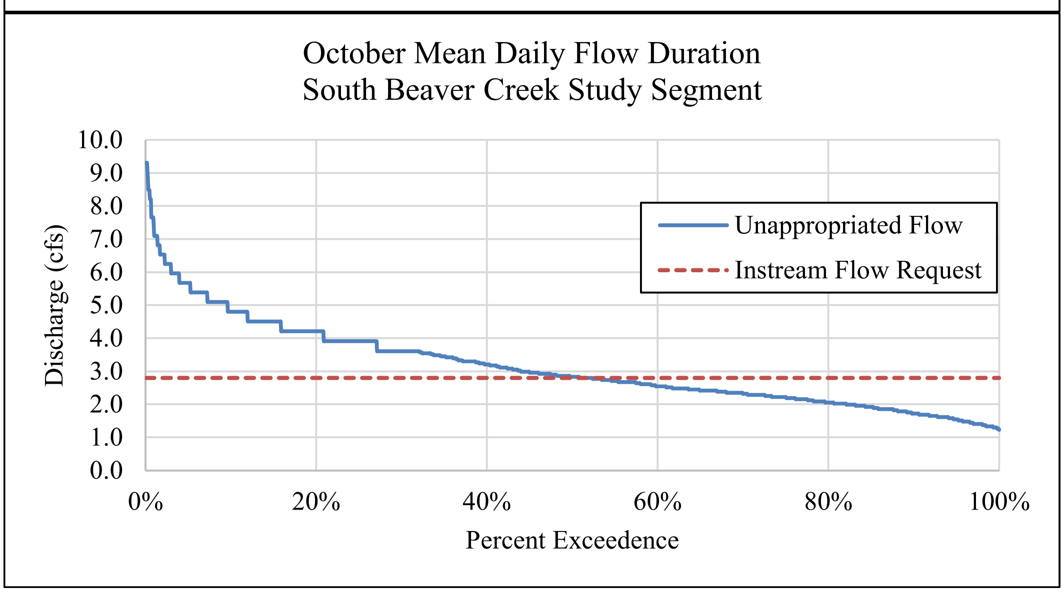

June Mean Daily Flow Duration
South Beaver Creek Study Segment
Discharge (cfs)
250.0
200.0
150.0
100.0
50.0
0.0
0%
20%
40%
60%
80%
100%
Percent Exceedence
Unappropriated Flow
Instream Flow Request

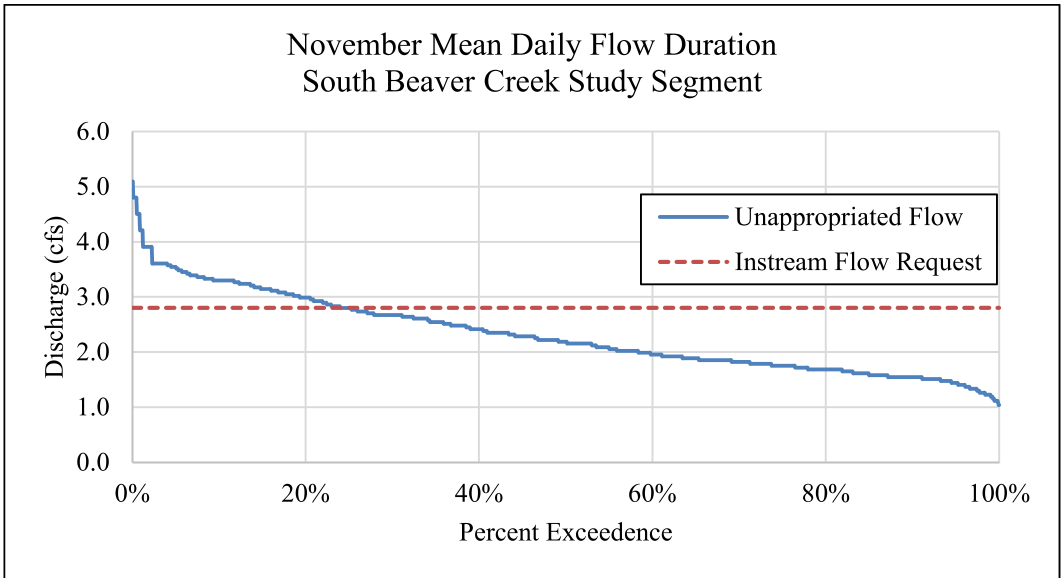

July 1-15 Mean Daily Flow Duration
South Beaver Creek Study Segment
Discharge (cfs)
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
0%
20%
40%
60%
80%
100%
Percent Exceedence
Unappropriated Flow
Instream Flow Request


July 16-31 Mean Daily Flow Duration
South Beaver Creek Study Segment
Discharge (cfs)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0%
20%
40%
60%
80%
100%
Percent Exceedence
Unappropriated Flow
Instream Flow Request

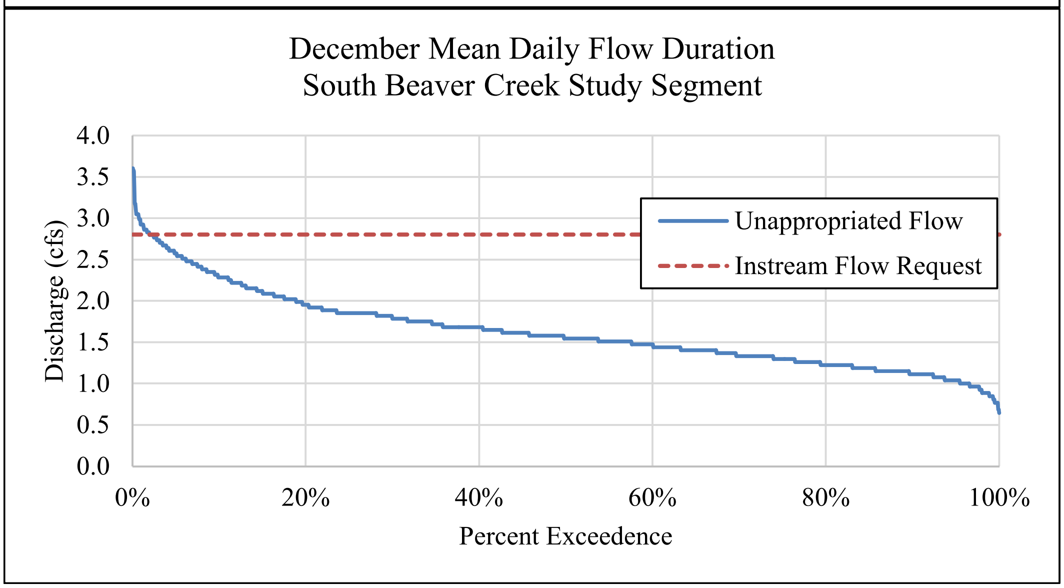

August Mean Daily Flow Duration
South Beaver Creek Study Segment
Discharge (cfs)
25.0
20.0
15.0
10.0
5.0
0.0
0%
20%
40%
60%
80%
100%
Percent Exceedence
Unappropriated Flow
Instream Flow Request


September Mean Daily Flow Duration
South Beaver Creek Study Segment
Discharge (cfs)
25.0
20.0
15.0
10.0
5.0
0.0
0%
20%
40%
60%
80%
100%
Percent Exceedence
Unappropriated Flow
Instream Flow Request

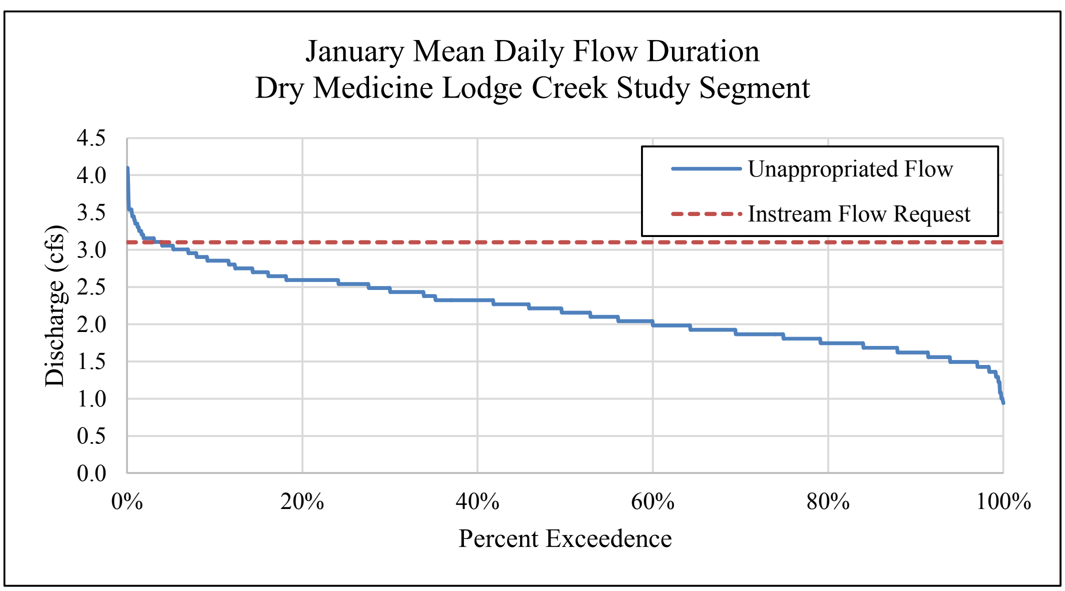

October Mean Daily Flow Duration
South Beaver Creek Study Segment
Discharge (cfs)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0%
20%
40%
60%
80%
100%
Percent Exceedence
Unappropriated Flow
Instream Flow Request



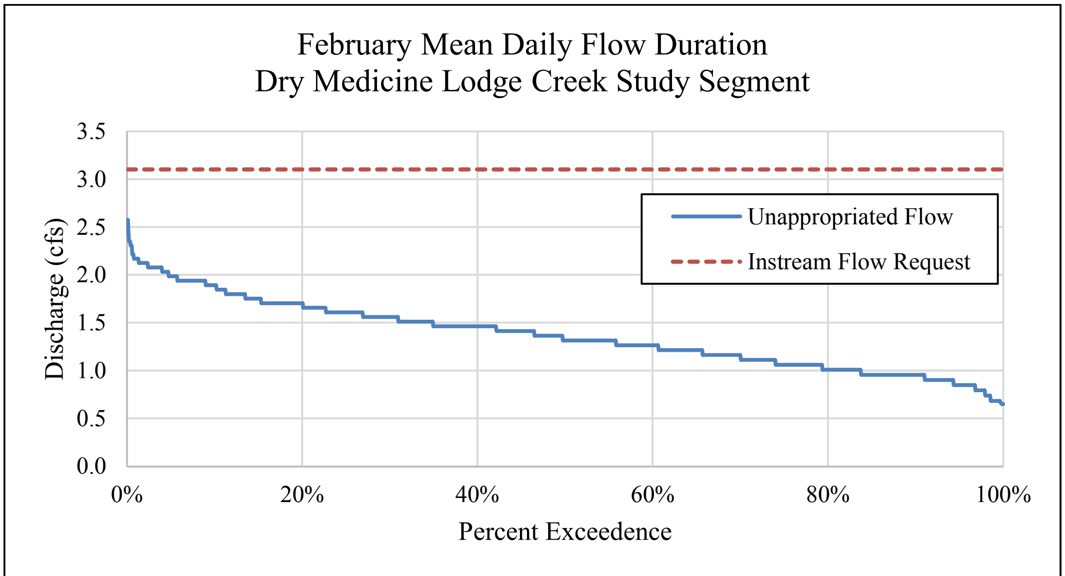
November Mean Daily Flow Duration
South Beaver Creek Study Segment
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Discharge (cfs)
0%
20%
40%
60%
80%
100%
Percent Exceedence
Unappropriated Flow
Instream Flow Request

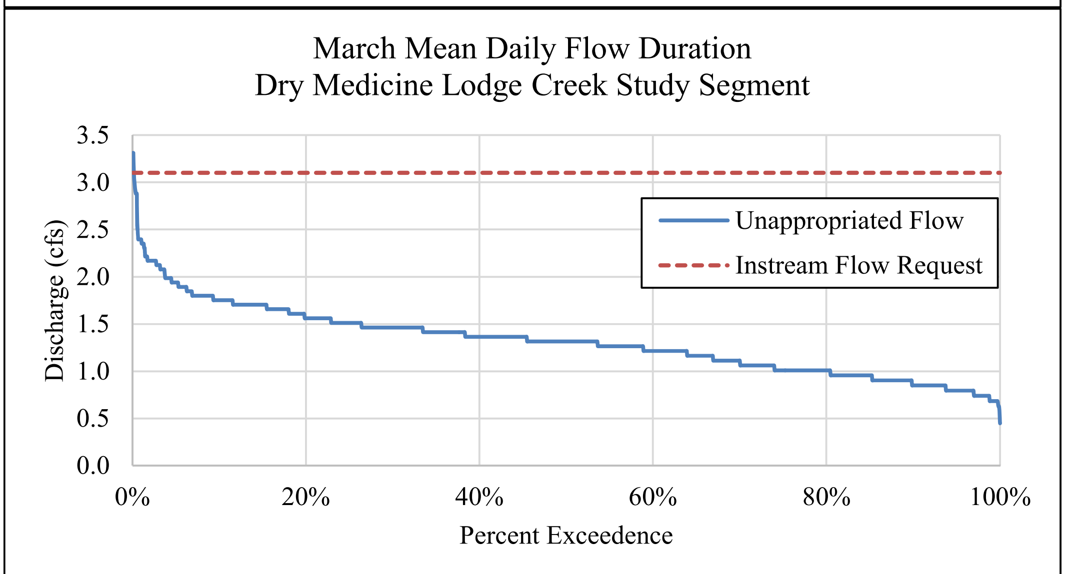


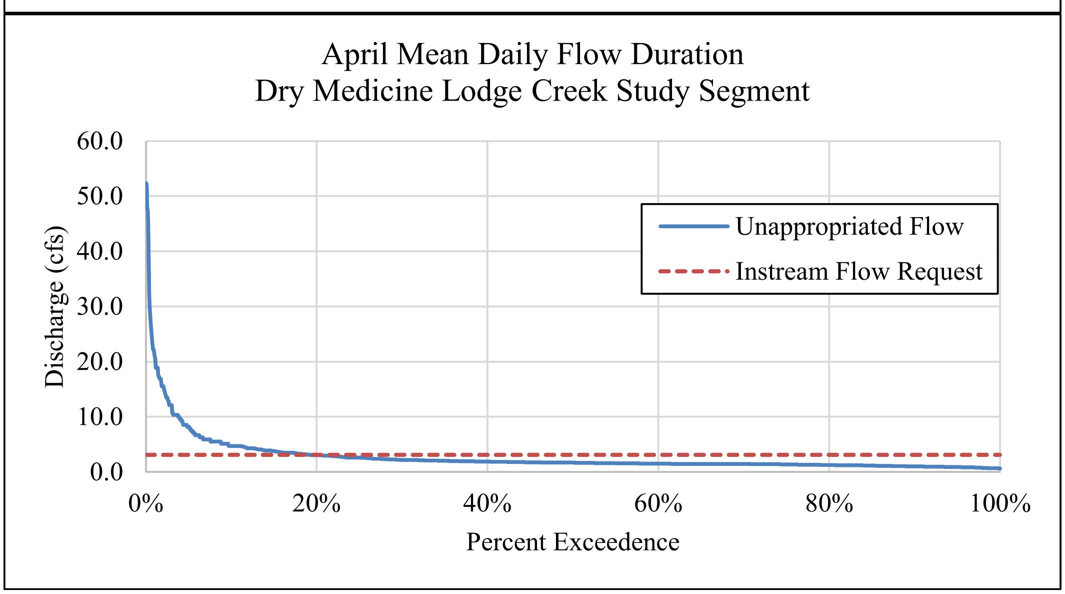
December Mean Daily Flow Duration
South Beaver Creek Study Segment
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Discharge (cfs)
0%
20%
40%
60%
80%
100%
Percent Exceedence
Unappropriated Flow
Instream Flow Request

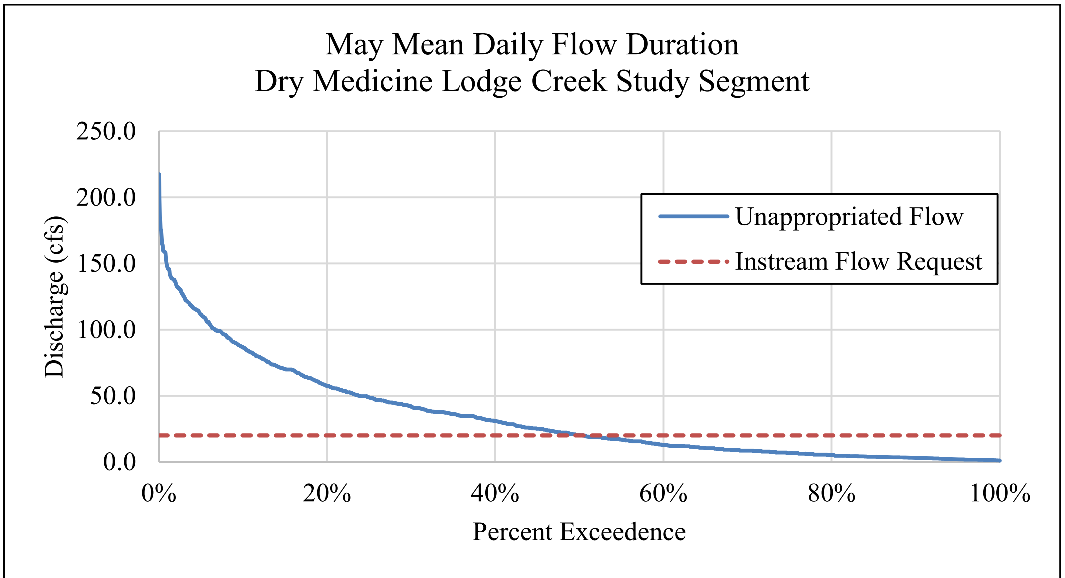


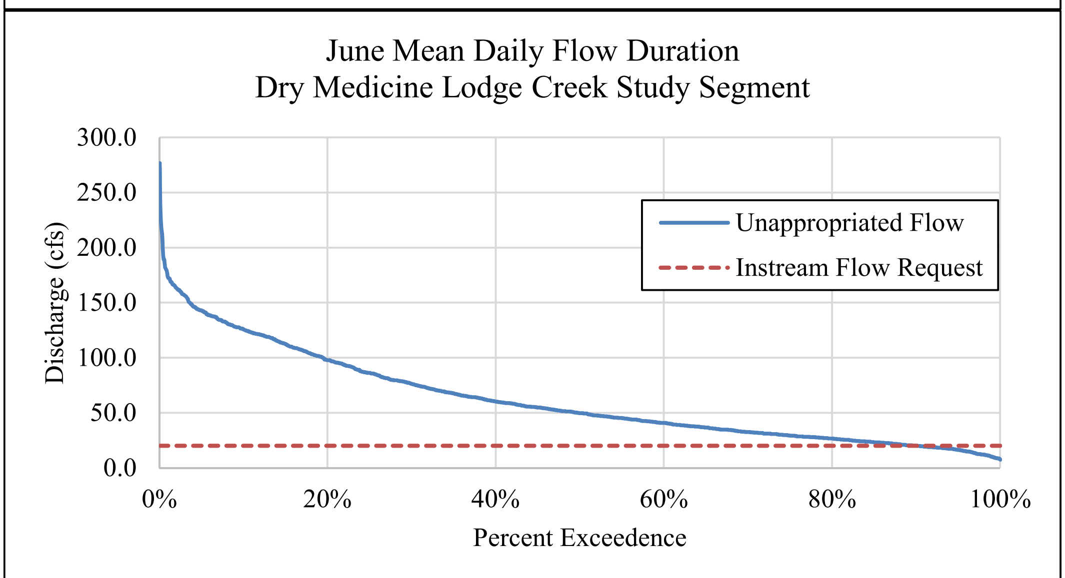
January Mean Daily Flow Duration
Dry Medicine Lodge Creek Study Segment
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Discharge (cfs)
0%
20%
40%
60%
80%
100%
Percent Exceedence
Unappropriated Flow
Instream Flow Request

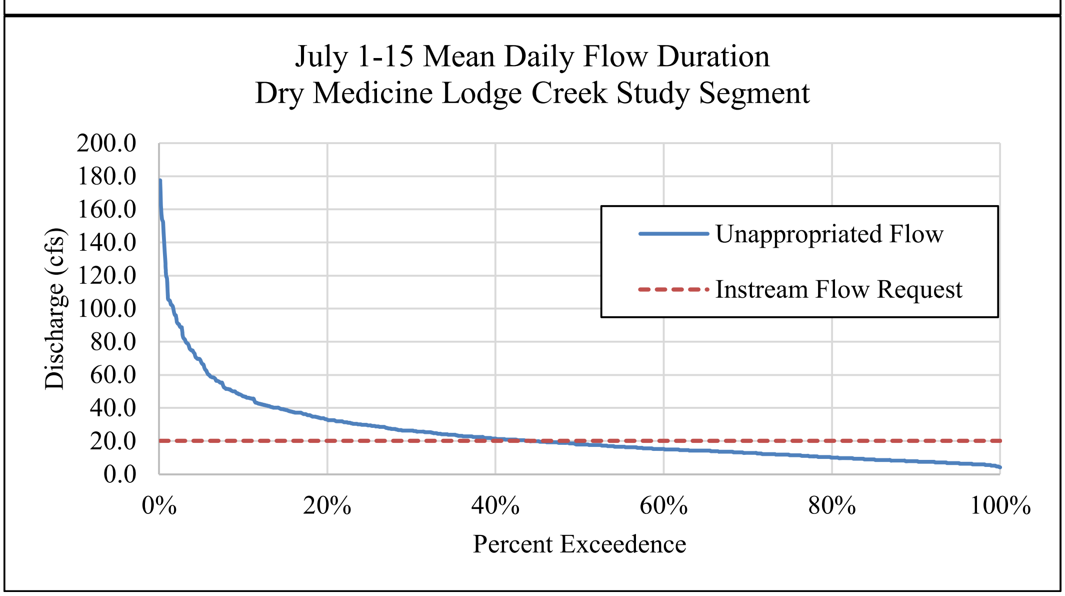

February Mean Daily Flow Duration
Dry Medicine Lodge Creek Study Segment
Discharge (cfs)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0%
20%
40%
60%
80%
100%
Percent Exceedence
Unappropriated Flow
Instream Flow Request

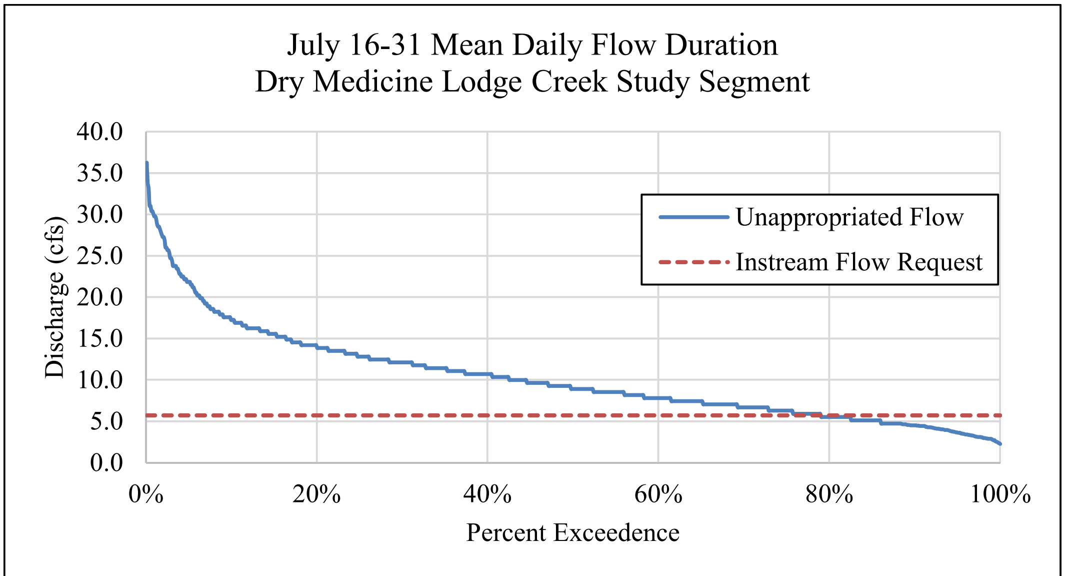

March Mean Daily Flow Duration
Dry Medicine Lodge Creek Study Segment
Discharge (cfs)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0%
20%
40%
60%
80%
100%
Percent Exceedence
Unappropriated Flow
Instream Flow Request

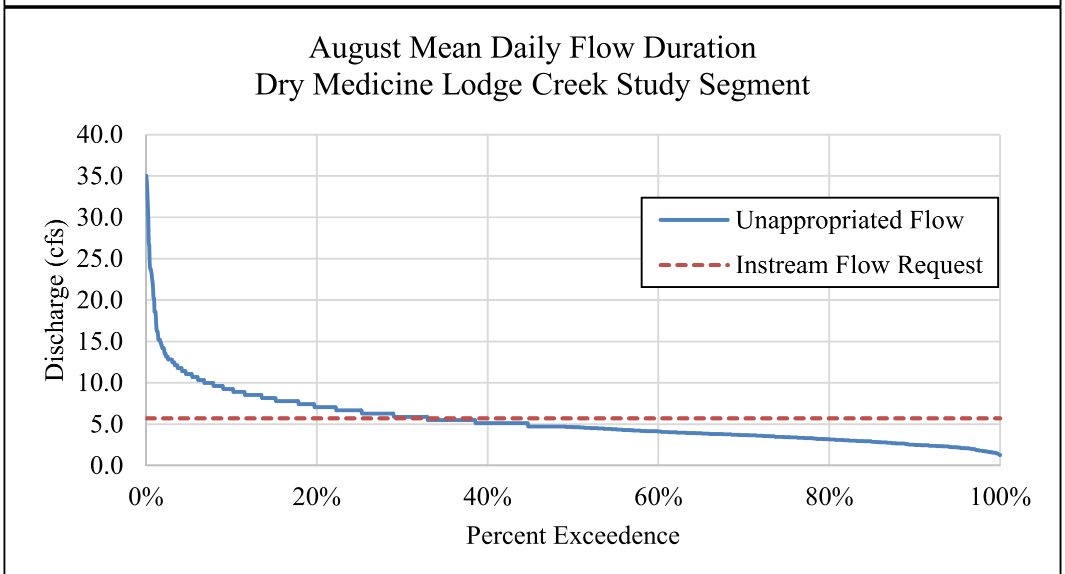

April Mean Daily Flow Duration
Dry Medicine Lodge Creek Study Segment
Discharge (cfs)
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0%
20%
40%
60%
80%
100%
Percent Exceedence
Unappropriated Flow
Instream Flow Request

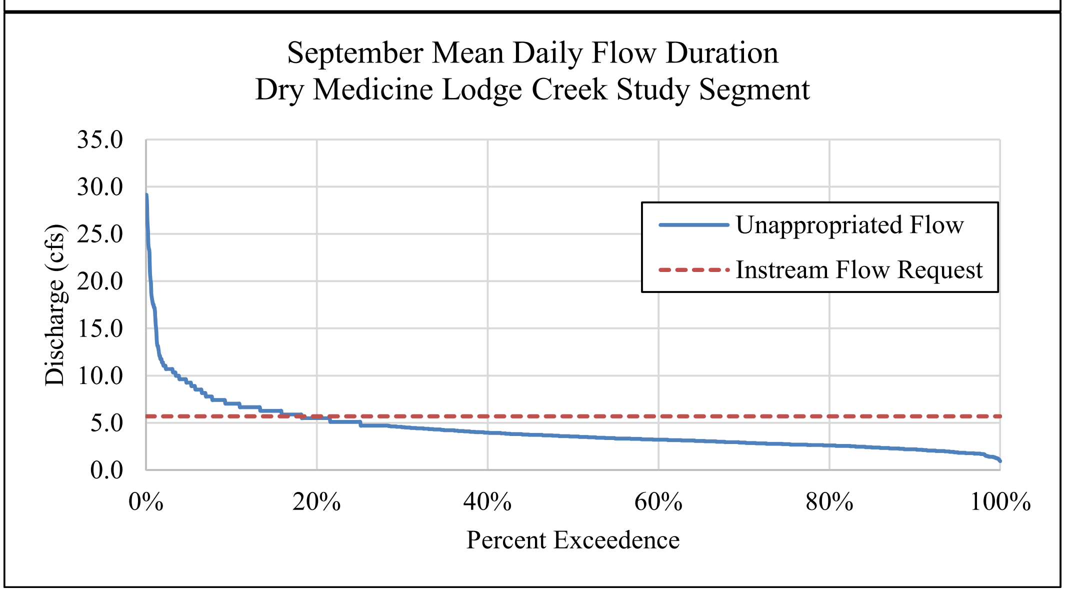

May Mean Daily Flow Duration
Dry Medicine Lodge Creek Study Segment
Discharge (cfs)
250.0
200.0
150.0
100.0
50.0
0.0
0%
20%
40%
60%
80%
100%
Percent Exceedence
Unappropriated Flow
Instream Flow Request


June Mean Daily Flow Duration
Dry Medicine Lodge Creek Study Segment
Discharge (cfs)
300.0
250.0
200.0
150.0
100.0
50.0
0.0
0%
20%
40%
60%
80%
100%
Percent Exceedence
Unappropriated Flow
Instream Flow Request


July 1-15 Mean Daily Flow Duration
Dry Medicine Lodge Creek Study Segment
Discharge (cfs)
200.0
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
0%
20%
40%
60%
80%
100%
Percent Exceedence
Unappropriated Flow
Instream Flow Request


July 16-31 Mean Daily Flow Duration
Dry Medicine Lodge Creek Study Segment
Discharge (cfs)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0%
20%
40%
60%
80%
100%
Percent Exceedence
Unappropriated Flow
Instream Flow Request


August Mean Daily Flow Duration
Dry Medicine Lodge Creek Study Segment
Discharge (cfs)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0%
20%
40%
60%
80%
100%
Percent Exceedence
Unappropriated Flow
Instream Flow Request


September Mean Daily Flow Duration
Dry Medicine Lodge Creek Study Segment
Discharge (cfs)
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0%
20%
40%
60%
80%
100%
Percent Exceedence
Unappropriated Flow
Instream Flow Request

Mailing Address:
Water Resources Data System
University of Wyoming, Dept 3943
1000 E University Avenue
Laramie, WY 82071

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Phone: (307) 766-6651
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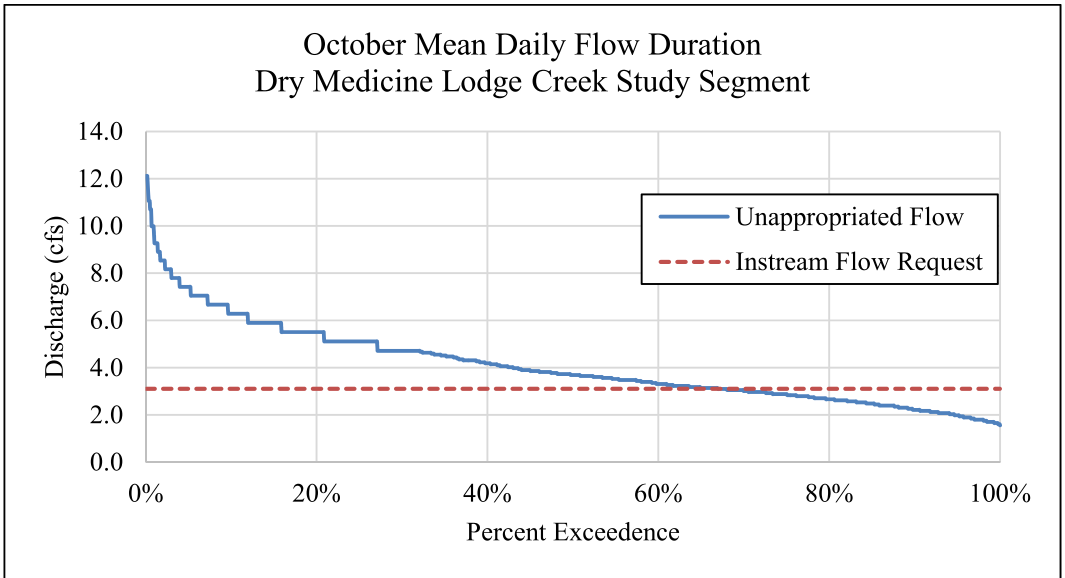
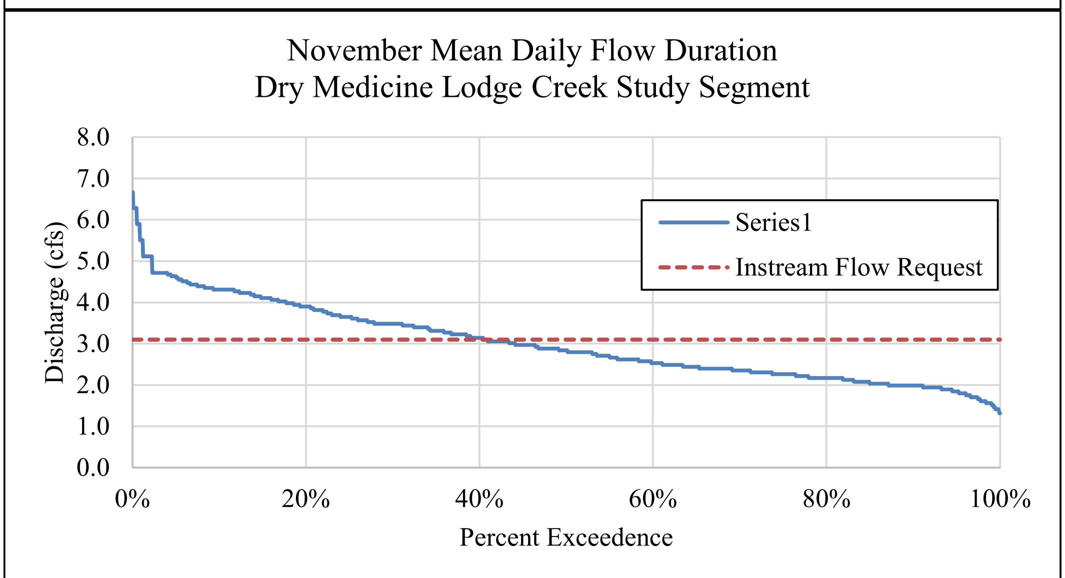
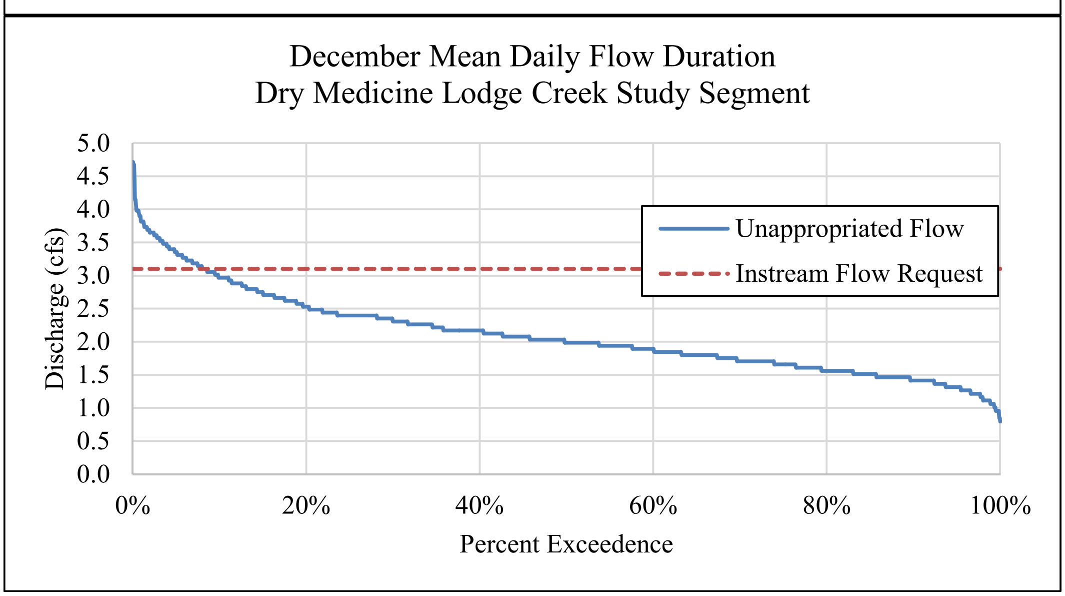
Funding for WRDS and the creation of this electronic document was provided by the Wyoming Water Development Commission (http://wwdc.state.wy.us)


October Mean Daily Flow Duration
Dry Medicine Lodge Creek Study Segment
Discharge (cfs)
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0%
20%
40%
60%
80%
100%
Percent Exceedence
Unappropriated Flow
Instream Flow Request


November Mean Daily Flow Duration
Dry Medicine Lodge Creek Study Segment
Discharge (cfs)
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0%
20%
40%
60%
80%
100%
Percent Exceedence
Series1
Instream Flow Request


December Mean Daily Flow Duration
Dry Medicine Lodge Creek Study Segment
Discharge (cfs)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0%
20%
40%
60%
80%
100%
Percent Exceedence
Unappropriated Flow
Instream Flow Request