PEABODY TROUT CREEK RESERVOIR PROJECT
ROUTT COUNTY, COLORADO
(FERC PROJECT NO. P-14446)

PRELIMINARY DRAFT HYDROLOGY AND STREAMFLOW ASSESSMENT STUDY REPORT

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Table of Contents

1.0 INTRODUCTION ... 1

2.0 GOALS AND OBJECTIVES OF STUDY ... 4

3.0 PROJECT NEXUS ... 4

4.0 PROPOSED METHODOLOGY ... 4

4.1 Measured Flows ... 4

4.2 Estimated Flows ... 5

5.0 RESULTS OF STUDY ... 10

5.1 Comparison of Estimated and Measured Flows ... 10

6.0 REFERENCES ... 13

List of Tables

Table 1 Mean Monthly Measured Flow at the Trout Creek Gage

Table 2 Linear Regressions for the Elk River at Clark Gage and Elk River at Milner Gage

Table 3 Ditches Upstream of the Elk River at Clark Gage

Table 4 Diversions, Return Flows, and Reservoir Operations Upstream of the Elk River at Clark Gage (October 2013 – October 2014)

Table 5 Ditches Upstream of the Trout Creek Gage

Table 6 Diversions and Return Flows Upstream of the Trout Creek Gage (October 2013 – October 2014)

Table 7 Monthly Measured versus Estimated Flows at the Trout Creek Gage

List of Figures

Figure 1 Location Map

Figure 2 Measured Flows at the Trout Creek Gage

Figure 3 Estimated vs. Measured Daily Flows at the Trout Creek Gage

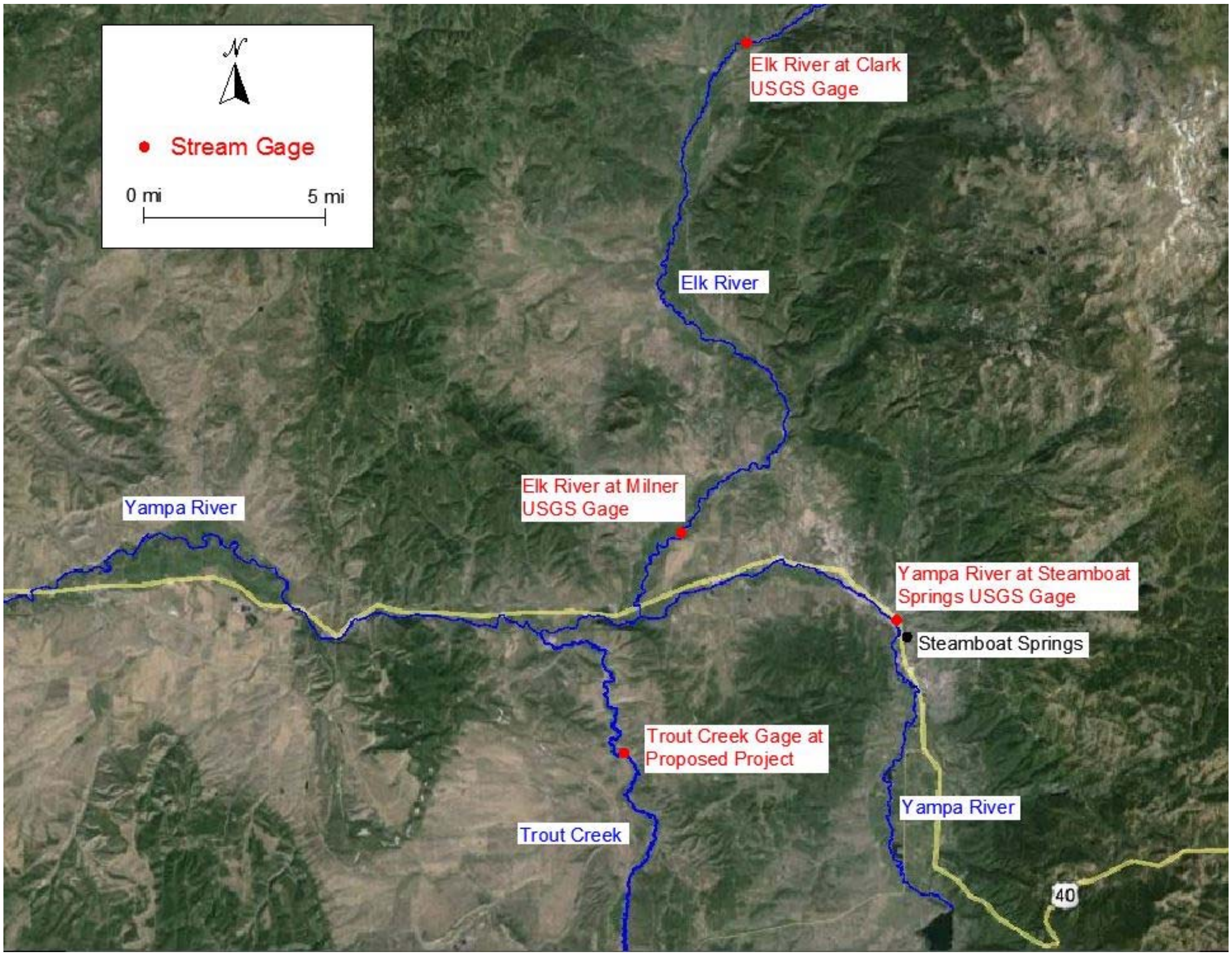
List of Acronyms

CDSS	Colorado Decision Support System
CDWR	Colorado Division of Water Resources
cfs	cubic feet per second
ESA	Endangered Species Act
FERC	Federal Energy Regulatory Commission
Project	Peabody Trout Creek Reservoir Project
PTCR	Peabody Trout Creek Reservoir, LLC
TZA	TZA Water Engineers
USGS	U.S. Geological Survey
Yampa Model	Yampa River Basin Water Resources Planning Model

1.0 INTRODUCTION

Peabody Trout Creek Reservoir, LLC (PTCR) is applying for a Federal Energy Regulatory Commission (FERC) hydropower license for a proposed multi-purpose water storage project in Routt County, Colorado. The Peabody Trout Creek Reservoir Project (Project) includes a proposed dam and reservoir on Trout Creek, which is a tributary to the Yampa River, approximately 15 miles southwest of Steamboat Springs (see Figure 1). The Project will alter streamflows in Trout Creek and the Yampa River since it will provide a water supply source to support PTCR's mining operations. A model is needed to evaluate changes in the timing and quantity of streamflows downstream of the Project in Trout Creek and the Yampa River. The model will be used to simulate streamflows with and without the Project on-line. Simulated streamflows will be used to evaluate effects on flow-dependent resources.

Figure 1. Location Map



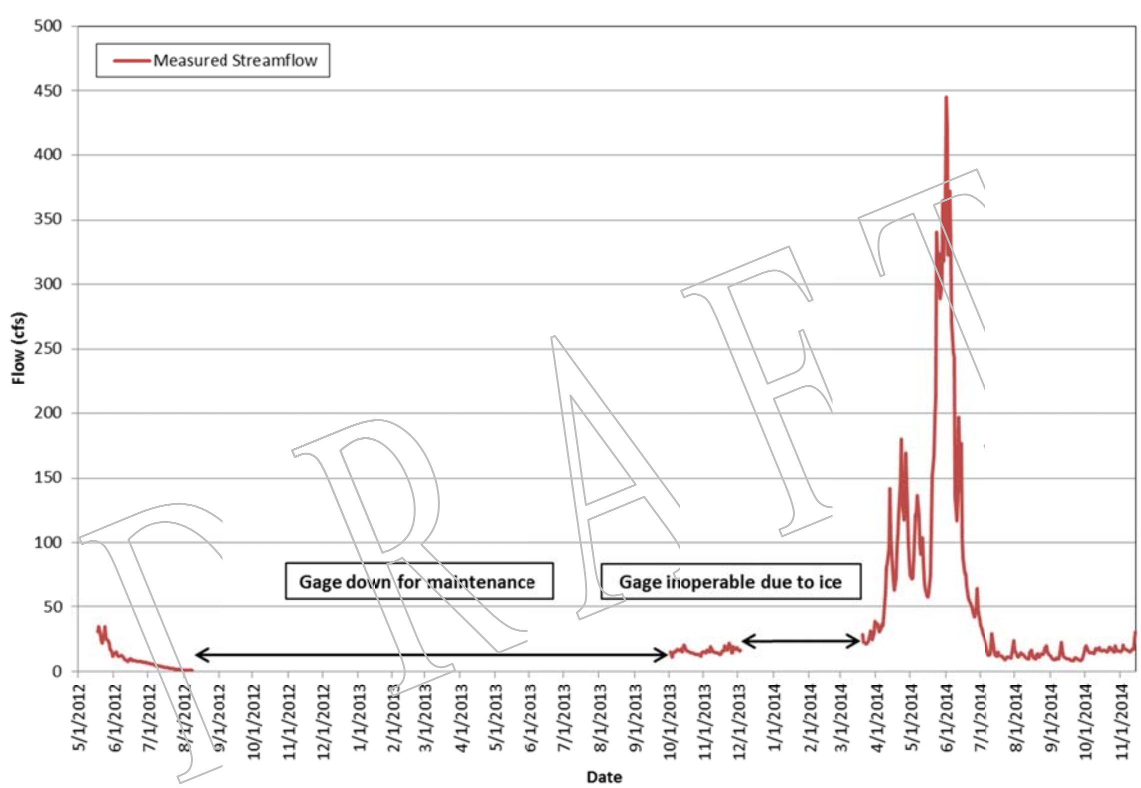
The Colorado Decision Support System (CDSS) Yampa River Basin Water Resources Planning Model (Yampa Model) was selected to analyze changes in streamflow on a monthly basis downstream of the Project for the Pre-Application Document (URS 2012). CDSS is a water management system developed by the Colorado Water Conservation Board and the Colorado Division of Water Resources (CDWR) for each of Colorado's major water basins. Due to the lack of published U.S. Geological Survey (USGS) stream gage records for Trout Creek, the CDSS Yampa Model relies on streamflow data for the Elk River at Clark gage (USGS No. 09241000) to predict natural flows in Trout Creek. The Elk River at Clark gage is located approximately 20 miles north of the proposed Project, as shown on Figure 1. Natural flows are defined as gaged flows plus adjustments for reservoir evaporation, releases and filling, diversions, gaged inflows, transbasin imports, and irrigation or other returns to the river. Therefore, the effects of most man-made alterations to the water supply are considered. The CDSS Yampa Model initially used the "neighboring gage" approach for estimating natural flows in Trout Creek. This approach multiplies the natural flow at the Elk River at Clark gage by a correlation factor, which is the ratio of the area multiplied by average annual precipitation of the watershed above the Trout Creek gage to the area multiplied by average annual precipitation of the watershed above the Elk River at Clark gage. TZA Water Engineers (TZA) refined the approach used in the CDSS Yampa Model as described in *Revised Estimate of Runoff on Trout Creek* (TZA 2012). TZA's revised approach takes into account that percent runoff varies with depth of precipitation.

The TZA methodology for predicting natural flows takes into account differences, including drainage area, precipitation, and runoff characteristics, between the Trout Creek and Elk Creek basins. The Elk River watershed is a larger watershed at a higher elevation with more rugged topography and fewer irrigation diversions than the Trout Creek watershed. The mean annual precipitation for the watershed above the Elk River at Clark gage is 38.3 inches, which is considerably more than the mean annual precipitation for the watershed above the Trout Creek gage, which is 25.1 inches (TZA 2012). TZA determined that as precipitation increases, the percentage of precipitation that runs off increases. Therefore, the basin yield from the Trout Creek watershed is expected to be less than the Elk River watershed. While it is expected that the yield in Trout Creek is less than the yield in the Elk River, the base flows in the Elk River might be more consistent than on Trout Creek due to the larger watershed and fewer irrigation diversions. Based on TZA's analysis, natural flows in Trout Creek at the Project site were estimated to be 10.5 percent (correlation factor of 0.105) of the natural flows at the Elk River at Clark gage (TZA 2012).

Typically, for new dams on previously un-gaged streams, streamflow data are collected to verify that the assumptions made to predict Project inflows are reasonable. Streamflow measurements have been collected on Trout Creek at the proposed Project site downstream of the confluence of Trout Creek and Middle Creek since 1979. These measurements have been collected due to monitoring requirements related to PTCR's mining operations in the Trout Creek Basin as well as for diligence on the water rights for the proposed Project. Those measurements differ from published USGS gage data in that they were spot measurements taken using field equipment, whereas USGS streamflow measurements are taken at established gage sites with recording equipment and are considered more accurate. In general, streamflow measurements were taken once per month from 1979 through 1998, with occasional flow measurements taken during winter months. From 1999 through 2011, the frequency of flow measurements increased due to increased monitoring requirements related to PTCR's mining operations in the Trout Creek

Basin and multiple flow measurements were often taken each month primarily from April through September with occasional flow measurements taken during winter months . In 2012, a gage and recording equipment were installed at the proposed Project dam site (see Figure 1) by Rivers Unlimited to record streamflow measurements on a continuous basis. Streamflow measurements were recorded on an hourly basis from May 18, 2012, through August 8, 2012 (see Figure 2). The gage was shut down in August 2012 for maintenance and then came back online on October 2, 2013. The gage was shut down again during the winter of 2013 (i.e., December 4, 2013, through March 19, 2014) and most recently on November 12, 2014, due to ice build-up at the gage.

Figure 2. Measured Flows at the Trout Creek Gage



The purpose of the first phase of this study is to use measured streamflow data collected at the proposed Project site over the last year to verify the reasonableness of the TZA methodology used to estimate natural flows in Trout Creek and to adjust the TZA methodology and the CDSS Yampa Model, if necessary.

Subsequent phases of this study will include using the CDSS Yampa Model, adjusted as appropriate, to simulate operations of the proposed Project to estimate streamflows downstream of the reservoir in Trout Creek and the Yampa River. Simulated streamflows with and without the Project on-line will be used to determine Project-related depletions including evaporative depletions, and produce flow and reservoir elevation-duration curves. Simulated pre- and post-

Project daily streamflows will also be used to inform other Project studies and analyses. This study report will later be revised to include the results of subsequent phases of this study after modeling of the proposed Project is complete.

2.0 GOALS AND OBJECTIVES OF STUDY

The goals and objectives of this phase of the study are to:

(1) Measure and record streamflows at the gage on Trout Creek over the course of one year.

(2) Compare measured streamflows in Trout Creek with streamflows that are estimated using the methodology and correlation factor that was developed by TZA.

(3) Evaluate whether the TZA methodology is reasonable and adjust the methodology, if necessary, to more accurately predict natural flows in Trout Creek.

(4) Revise the CDSS Yampa Model, if necessary, to incorporate changes to Trout Creek natural flow estimates.

Subsequent phases of the study will include simulation of pre- and post-Project conditions using the CDSS Yampa Model to estimate streamflows downstream of the Project in Trout Creek and the Yampa River on a daily basis. Pre- and post-Project streamflows will be analyzed to determine Project-related depletions, including evaporative depletions, and produce flow and reservoir elevation duration curves. Pre- and post-Project streamflows simulated using the CDSS Yampa Model will be provided to inform other Project studies and analyses and predict potential impacts on flow-dependent resources, including potential effects on the aquatic habitat and the four federally listed Endangered Species Act (ESA) fish species included in the Colorado River Endangered Fish Recovery Program.

3.0 PROJECT NEXUS

The proposed Project operations will alter the existing streamflow regime in Trout Creek and the Yampa River. Several resources will be influenced by changes in the timing and quantity of streamflows. For example, reservoir operations and evaporative water losses may impact aquatic habitat for the four federally listed ESA fish species: Colorado pikeminnow (*Ptychocheilus lucius*), bonytail (*Gila elegans*), humpback chub (*Gila cypha*), and razorback sucker (*Xyrauchen texanus*). To evaluate Project impacts on flow-dependent resources, information is needed that accurately portrays existing streamflow conditions and future conditions with the proposed Project online.

4.0 PROPOSED METHODOLOGY

4.1 MEASURED FLOWS

In 2012, Rivers Unlimited installed a gage and recording equipment to record streamflow measurements on a continuous basis. Streamflow measurements were recorded from May 18, 2012 through August 8, 2012. The gage was shut down in August 2012 for maintenance and then came back online on October 2, 2013. The gage was also shut down during the winter of 2013 (i.e., December 4, 2013, through March 19, 2014) and most recently on November 12, 2014, due to ice build-up at the gage. Rivers Unlimited provided hourly gage data for the Trout Creek gage, which was used to determine average daily flows (Rivers Unlimited 2015). Measured mean daily streamflows from May 18, 2012, through November 12, 2014, are presented on Figure 1. Table 1 provides mean monthly streamflows for months that data were collected for the entire month.

Table 1. Mean Monthly Measured Flow at the Trout Creek Gage

Month[1] Year	Mean Monthly Streamflow (cfs)
June 2012	9.9
July 2012	3.7
November 2013	16.6
April 2014	88.4
May 2014	161.7
June 2014	150.2
July 2014	17.3
August 2014	13.4
September 2014	11.1
October 2014	6.9

Notes:
[1]Only months with streamflow data collected for the entire month are included.
cfs = cubic feet per second

4.2 ESTIMATED FLOWS

The CDSS Yampa Model relies on the methodology developed by TZA to estimate natural flows in Trout Creek based on the Elk River at Clark gage (USGS No. 09241000). The Elk River at Clark gage was in operation for the majority of the period from October 1910 through September 2003; however, the gage often did not operate during the winter months. Since the Elk River at Clark gage was not in operation in 2013 and 2014 when streamflow data were collected on a continuous basis at the Trout Creek gage, it was necessary to estimate the flows at the Elk River at Clark gage for that period.

The Elk River near Milner gage (USGS No. 09242500) is located downstream of the Elk River at Clark gage, as shown on Figure 1. The gage near Milner was generally in operation from 1910 through 1927 and from 1990 through the present; therefore, there are periods of overlapping data between that gage and the Elk River at Clark gage. Linear relationships were developed by regressing the daily Elk River near Milner gage data against the Elk River at Clark gage data for each month from April through November. Relationships were not developed for December through March because the gages were frequently not operated during the winter. The results of the linear regressions for each month are presented in Table 2. The regressions show there is a very strong relationship between the two gages with the possible exception of November. The values listed in Table 2 were used in conjunction with the available data from the Elk River near Milner gage to estimate daily streamflows at the Elk River at Clark gage from October 2013 through October 2014. A sample calculation using the values in Table 2 is provided below.

*Apr 1, 2014 Elk River at Clark Flow = 0.583 * Apr 1, 2014 Elk River at Milner Flow -62.7*

Natural flows at the Elk River at Clark gage were estimated by adding upstream diversions for irrigation, diversions to storage and reservoir evaporation, and subtracting releases from storage and estimated return flows. The equation for calculating natural flows is shown below.

Natural Flow at Elk River at Clark = Estimated Flow at Elk River at Clark + Irrigation Diversions + Diversions to Storage + Reservoir Evaporation – Reservoir Releases – Irrigation Return Flows

Table 2. Linear Regressions for the Elk River at Clark Gage and Elk River at Milner Gage

Month[1]	X Coefficient	Intercept	R^2
April	0.583	-62.7	0.88
May	0.626	-19.7	0.94
June	0.680	-25.7	0.78
July	0.654	38.8	0.87
August	0.627	23.7	0.94
September	0.590	22.9	0.83
October	0.387	36.3	0.81
November	0.349	36.6	0.57

Note:
[1]Linear regressions were not completed for December through March due to the limited amount of overlapping data at the two gages.

Diversions upstream of the Elk River at Clark gage were obtained from the District 57 and 58 Water Commissioner since those data are not yet available from the State's CDSS database. The diversions at the ditches listed in Table 3 were considered. Total monthly diversions at those ditches are shown in Table 4. In addition to the ditches shown in Table 3, Steamboat Lake Reservoir and Lester Creek Reservoir (also known as Pearl Lake) are also located upstream of the Elk River at Clark gage. End-of-month contents for those reservoirs were obtained from the CDWR and used to estimate monthly evaporation, reservoir releases, and diversions to storage. The combined effect on flows in Elk River due to operations at those reservoirs is shown in Table 4. Diversions to storage and evaporation are shown as positive values since they must be added to the flow at the Elk River at Clark gage to determine natural flows, whereas reservoir releases are shown as negative values since releases must be subtracted from the flow at the Elk River at Clark gage to determine the natural flow.

Table 3. Ditches Upstream of the Elk River at Clark Gage

Structure Number	Structure Name
5800580	Centennial Placer Ditch 1
5800587	Fetcher Ditch

Table 3. Ditches Upstream of the Elk River at Clark Gage

Structure Number	Structure Name
5800595	Coulton Creek Ditch
5800651	Frye System Ditch 2
5800653	Frye System Ditch 1
5800754	Lula Park Ditch
5800784	Morris Taylor Ditch
5800833	Reddert Ditch
5800835	Reynolds Humphery Ditch
5800842	Rose Wheeler Ditch
5800909	Trullinger Ditch
5801690	Button Ditch No. 1
5801703	Centennial Placer Ditch 2
5801746	Karls Ditch No. 1
5801878	Boat House Pump & Pipeline
5800613	Diamond Park Ditch
5800928	Wheeler Bros Ditch
5800694	Hoover Jacques Ditch
5800717	Kinney Ditch
5800895	Sunnyside Ditch
5800811	Oligarchy Ditch

Table 4. Diversions, Return Flows, and Reservoir Operations Upstream of the Elk River at Clark Gage (October 2013 – October 2014)

Description	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Total[3]
Diversions[1]	497	0	0	0	0	0	0	318	1,423	2,303	1,568	628	379	**7,116**
Return Flows	114	41	26	18	13	8	3	50	401	641	389	173	109	**1,987**
Reservoir Operations[2]	-172	-341	-232	-159	-80	50	2,086	991	212	246	-695	-392	246	**1,762**

Notes:
[1]Diversion data provided by the District 57 and 58 Water Commissioner.
[2]Reservoir operations include the combined effect on Elk River flows due to diversions to storage, releases, and evaporation. Releases are treated as negative numbers since they must be subtracted to determine natural flows; diversions to storage and evaporation are treated as positive numbers since they must be added to determine natural flows.
[3]Due to rounding, figures may not total exact amount shown.

Irrigation return flows upstream of the Elk River at Clark gage were estimated for the diversions shown in Table 4 using data from the CDSS Yampa Model, including the location of return flows based on irrigated lands under each ditch, a unit response function developed to lag groundwater return flows, and the average monthly irrigation efficiency. The unit response function used in the CDSS Yampa Model for ditches along the Elk River shows the majority (approximately 75 percent) of surface and groundwater return flows accrue to the river within the first month, which is consistent with lands irrigated relatively close to the river. This unit response function was developed using the Glover solution and the State's Analytical Stream Depletion Model, which are commonly used to determine return flow patterns (Leonard Rice Engineers, Inc. 2003). Estimated monthly lagged irrigation return flows upstream of the Elk River at Clark gage are summarized in Table 4.

The natural flow in Trout Creek upstream of the Project was estimated by multiplying the monthly natural flow at the Elk River at Clark gage by the TZA correlation factor, 0.105. Since natural flows do not include the effects of man-made alterations to the water supply, they cannot be compared directly with measured streamflows at the Trout Creek gage. In order to estimate streamflows at the Trout Creek gage, diversions and return flows upstream of the gage must be subtracted and added, respectively, to the natural flows. Table 5 lists the ditches upstream of the Trout Creek gage that were considered. Total monthly diversions and estimated return flows upstream of the Trout Creek gage are shown in Table 6. Note that estimated return flows above the Trout Creek gage are almost 60 percent of the upstream diversions, whereas the estimated return flows above the Elk River at Clark gage are less than 30 percent of the upstream diversions. Several of the ditches that divert from the Elk River are located relatively close to the Elk River at Clark gage and a portion of the irrigated lands are located downstream of the gage. As a result, the proportion of return flows from upstream diversions that accrue to Elk River above the Elk River at Clark gage is less compared to the Trout Creek gage.

Table 5. Ditches Upstream of the Trout Creek Gage

Structure Number	Structure Name
5700513	Connell Ditch
5700518	David M Chapman Ditch 2
5700543	Helfenbein Seepage Ditch
5700550	Jefferson Ditch
5700552	Jones Kleckner Ditch
5700578	Pine Grove Ditch
5700593	Slough Ditch
5700598	Spruce Hill Ditch
5700600	Thompson Ditch 1
5700601	Thompson Ditch 2
5700617	Whetstone Outlet Ditch
5700620	William H Jones Ditch
5700749	Rocky Ditch
5701013	Alex Ditch
5701048	Fuller Ditch
5700609	Trout Creek Ditch 2
5700608	Trout Creek Ditch 3
5700545	Homestead Ditch

Table 5. Ditches Upstream of the Trout Creek Gage

Structure Number	Structure Name
5700635	Koll Ditch
5700576	Orno Ditch
5700517	David M Chapman Ditch
5700561	Male Moore Co Ditch
5700555	Last Chance Ditch
5704629	Rich Ditch

Table 6. Diversions and Return Flows Upstream of the Trout Creek Gage (October 2013 – October 2014)

Description	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Total[2]
Diversions[1]	125	0	10	0	0	0	0	219	2,478	3,240	894	24	39	**7,028**
Return Flows	204	95	67	46	33	17	6	83	1,056	1,620	706	170	102	**4,204**

Notes:
[1]Diversion data provided by the District 57 and 58 Water Commissioner.
[2]Due to rounding, figures may not total exact amount shown.

Monthly estimated flows at the Trout Creek gage were disaggregated to daily flows using daily disaggregation factors developed for a nearby gage that most closely reflects flow conditions in the Trout Creek basin. The disaggregation factor for a given day equals the daily flow that day divided by the total flow for the corresponding month at the same gage, as shown in the following equation.

April 1, 2014 Disaggregation Factor = (April 1, 2014 Measured Flow/Total Measured April 2014 Flow)

*April 1, 2014 Estimated Flow at Trout Creek Gage = Total Estimated April Flow at Trout Creek Gage * April 1, 2014 Disaggregation Factor*

Several gages were considered for disaggregation, including the Elk River near Milner (USGS No. 09242500), Yampa River at Steamboat Springs (USGS No. 09239500), Yampa River below Stagecoach Reservoir (USGS No. 09237500), and Fish Creek at Upper Station near Steamboat Springs (USGS No. 09238900) gages. These gages were selected due to their proximity to the Trout Creek basin and the longevity of their period of record. Daily disaggregation factors were developed for each of these gages using the equation shown above. Note that the daily flows at the Yampa River at Steamboat Springs gage were adjusted to account for reservoir releases and diversions to storage at Catamount and Stagecoach reservoirs prior to developing the daily disaggregation factors to remove the effects of reservoir operations. The daily disaggregation factors for each gage were multiplied by the estimated monthly flows at the Trout Creek gage to determine daily flows, which were compared with measured flows at the Trout Creek gage.

Based on a comparison of daily measured flows and flows estimated using disaggregation factors developed for each of the gages listed above, the Yampa River at Steamboat Springs gage was determined to most closely match daily flow variations on Trout Creek. The Yampa River at Steamboat Springs gage provided the best match with measured flows at Trout Creek with respect to the timing of runoff (rise and fall of the hydrograph) and increases in flow that were most likely due to precipitation events. The Yampa River at Steamboat Springs gage was also selected because it has the longest period of record of the gages listed, which overlaps well with the 1950 through 2005 study period selected for evaluating the proposed Project.

5.0 RESULTS OF STUDY

5.1 COMPARISON OF ESTIMATED AND MEASURED FLOWS

Table 7 provides a comparison of estimated and measured monthly flows at the Trout Creek gage for the period from October 2013 through October 2014 (see Figure 3). This period was selected because it represents the longest period that data were collected on a continuous basis and because there is less information available on the location, methodology, and equipment used to measure streamflows prior to the installation of that gage by Rivers Unlimited. Estimated flows were determined using the methodology described in Section 4.2. The total estimated flow for the period from October 2013 through October 2014 (excluding December through March) was 27,256 acre-feet versus a total measured flow of 29,677 acre-feet, which is a difference of approximately eight percent. Data are not presented for December 2013 through March 2014 because the Trout Creek gage was not operated due to icing conditions. On a monthly basis, flows compare well during the period from May through August with differences ranging from two to eight percent. Differences in flows from September through April are greater and range up to 36 percent in April. With the exception of April, flows in these months are considerably less; therefore, while the magnitude of the difference is relatively small, the percentage difference is much greater. September through November is less of a concern since diversions to storage at the proposed Project site would occur primarily during the runoff season from April through July.

Table 7. Monthly Measured versus Estimated Flows at the Trout Creek Gage

Month[1] Year	Estimated Flow at Elk River at Clark Gage[2]	Diversions Upstream of Elk River at Clark Gage	Estimated Return Flows Upstream of Elk River at Clark Gage	Reservoir Operations Upstream of Elk River at Clark Gage[3]	Estimated Natural Flow at Elk River at Clark Gage[4]	Estimated Natural Flow at Trout Creek Gage[5]	Diversions Upstream of Trout Creek Gage	Estimated Return Flows Upstream of the Trout Creek Gage	Estimated Flow at Trout Creek Gage[6]	Measured Flow at Trout Creek Gage	Percent Difference Measured versus Estimated Flow
October 2013	6,847	497	114	-172	7,058	741	125	204	820	958	**14%**
November 2013	5,635	0	41	-341	5,253	552	0	95	646	989	**35%**
April 2014	29,846	0	3	2,086	31,929	3,353	0	6	3,359	5,260	**36%**
May 2014	100,186	318	50	991	101,445	10,652	219	83	10,516	9,940	**-6%**
June 2014	90,969	1,423	401	212	92,203	9,681	2,478	1,056	8,259	8,937	**8%**
July 2014	23,885	2,303	641	246	25,793	2,708	3,240	1,620	1,088	1,066	**-2%**
August 2014	9,724	1,568	389	-695	10,208	1,072	894	706	884	827	**-7%**
September 2014	6,920	628	173	-392	6,983	733	24	170	879	663	**-33%**
October 2014	6,539	379	109	246	7,055	741	39	102	804	1,037	**22%**
Total[7]	**280,550**	**7,116**	**1,921**	**2,182**	**287,926**	**30,232**	**7,019**	**4,042**	**27,256**	**29,677**	**8%**

Notes:

[1]Data are not presented for December 2013 through March 2014 because the Trout Creek gage was not operated during that period due to icing conditions.

[2]Flows estimated at the Elk River at Clark gage were based on the Elk River at Milner gage.

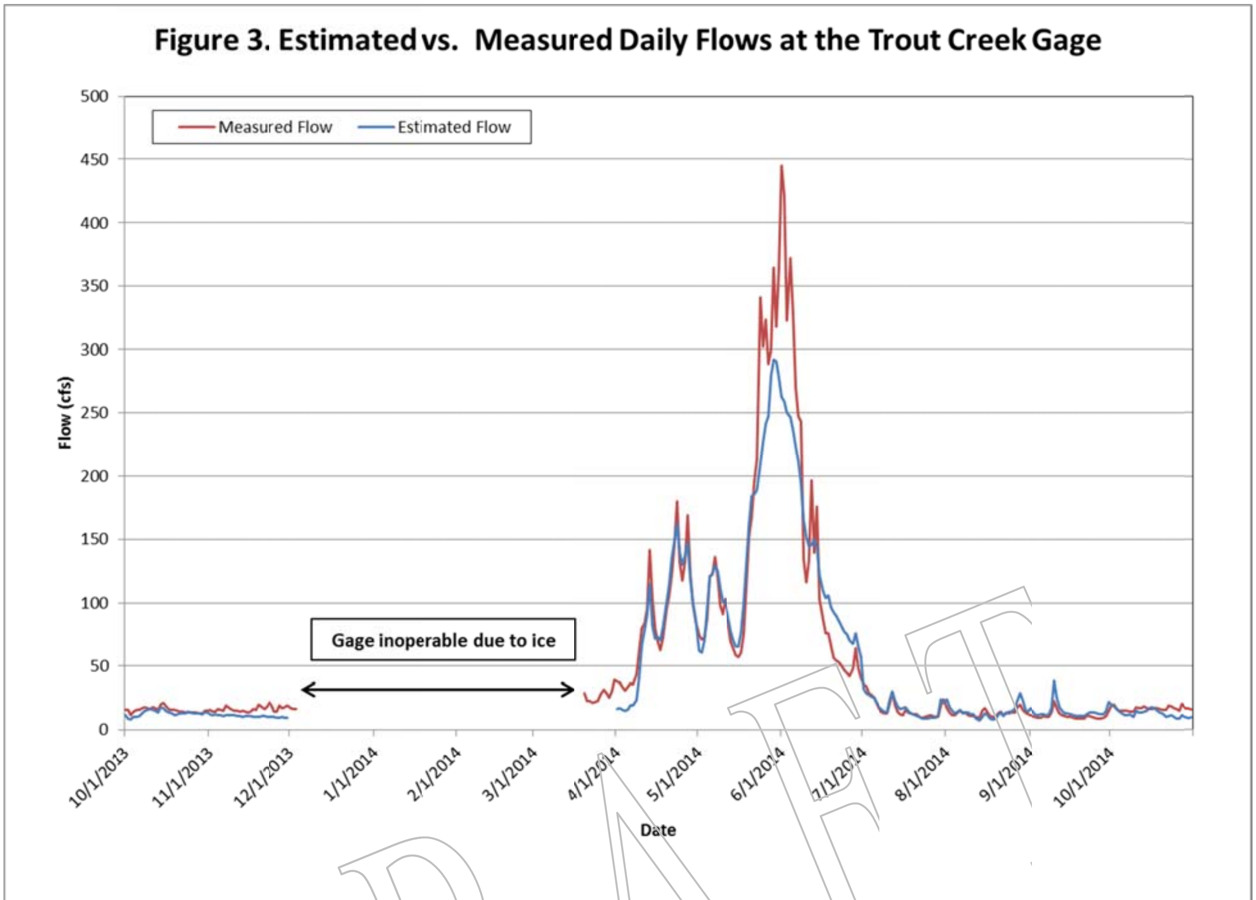
[3]Reservoir operations include the combined effect on Elk River flows due to diversions to storage, releases, and evaporation. Releases are treated as negative numbers since they must be subtracted to determine natural flows; diversions to storage and evaporation are treated as positive numbers since they must be added to determine natural flows.

[4]The estimated natural flow at the Elk River at Clark gage equals the estimated flow at the Elk River at Clark gage plus diversions, minus return flows, plus reservoir operations.

[5]The estimated natural flow at the Trout Creek gage equals the estimated natural flow at the Elk River at Clark gage times a correlation factor of 0.105.

[6]The estimated flow at the Trout Creek gage equals the estimated natural flow at the Trout Creek gage minus diversions plus return flows.

[7]Due to rounding, figures may not total exact amount shown.



The measured flow at the Trout Creek gage is approximately 1,900 acre-feet higher than the estimated flow in April. The difference between measured and estimated flows in April may be due in part to the fact the mean elevation of the watershed above the Elk River at Clark gage is higher that the watershed above the Trout Creek gage. The mean elevation of the watershed above the Elk River at Clark gage is 9,104 feet, whereas the mean elevation of the Trout Creek watershed above the Trout Creek gage is approximately 7,790 feet, which is 1,314 feet lower (TZA 2012). As a result, runoff could be expected to start sooner in the Trout Creek basin due to warmer temperatures.

The TZA methodology, which used a single correlation factor of 0.105 each month to estimate the natural flows in Trout Creek, is limited in its ability to capture differences that may occur due to the timing of runoff between the Elk River and Trout Creek basins. To address this issue, the TZA methodology was revised slightly to shift 14 percent of the estimated flow in May to April. A shift of 14 percent was selected based on review of the flow estimates to minimize the differences between measured and estimated flows in April and May. This refinement reduced the monthly differences in estimated versus measured flows in April and May to eight and nine percent, respectively. The CDSS Yampa Model was revised and the natural file was updated to incorporate this adjustment to the TZA methodology.

Daily measured and estimated flows at the Trout Creek gage are shown on Figure 1. Note that Figure 1 includes the adjustment described above, which shifts a portion of the flow in May to April. Figure 1 demonstrates that the estimated flows track measured flows very well with the largest differences occurring from mid-May through mid-June when runoff peaked in 2014. The higher flow measurements at the Trout Creek gage during this period are less reliable for several reasons. The rating curve that was developed for the Trout Creek gage was based on numerous flow measurements that were less than 140 cubic feet per second (cfs) but only two measurements in excess of 140 cfs. The maximum measured flow used to develop the rating curve was 230 cfs. Based on the range of flow measurements used to develop the rating curve, the rating curve is considered most accurate in the range of 0 to about 140 cfs. The measured flow data indicate that flows exceeded 140 cfs from approximately mid-May to mid-June, which coincides with the period that estimated flows do not correspond well with measured flows. The difference in monthly and daily flows from mid-May to mid-June is less of a concern because the measured flows are less reliable during that period due to the rating curve. Additional flow measurements will be taken taking during the runoff period in 2015 to improve the accuracy of the rating curve at higher flow rates.

The comparison of monthly measured and estimated flows at the Trout Creek gage indicates that TZA's correlation factor of 0.105, with the minor adjustment recommended above, results in a good estimate of streamflows in Trout Creek and is recommended for use in the CDSS Yampa Model. The differences in monthly measured versus estimated streamflows are all less than 10 percent during the runoff period, which is considered most critical since that will coincide with periods that water would be diverted to storage with the proposed Project online. Given that the accuracy of most streamflow gages is on the order of 5 to 10 percent, a variation of less than 10 percent between estimated and measured flows is considered excellent. Differences in estimated versus measured flows could be due to the methodology and equations used to estimate flows at the Elk River at Clark gage and the amount, timing, and location of irrigation return flows since those are not measured values. In addition, higher flow measurements during runoff are considered less accurate due to limitations of the rating curve at higher flow rates as discussed above. Because the differences between measured and estimated flows may be due to these reasons, modifications to the correlation factor are not recommended other that the adjustment discussed above, which includes shifting a portion of the estimated flow in May to April to address earlier runoff in the Trout Creek basin.

6.0 REFERENCES

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