Streamflow Measurement and Monitoring Plan

For Purposes of Distributing Water to Hydropower and Minimum Streamflow Water Rights in the Milner Dam to Murphy Gaging Station Reach of the Snake River, Idaho

Prepared by the

Swan Falls Technical Working Group

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Executive Summary

This report outlines a protocol for measuring, monitoring, and reporting average daily flows at the Snake River streamflow gage near Murphy, Idaho[1] (referred to herein as the "Murphy Gaging Station"). The protocol is being developed for the purpose of distribution of water to hydropower water rights 02-100, 02-2001A, 02-2001B, 02-2032A, 02-2032B, 02-2036, 02-2056, 02-2057, 02-2059, 02-2060, 02-2064, 02-2065, 02-4000A, 02-4000B, 02-4001A, 02-4001B, 02-10135, 36-2013, 36-2018, 36-2026, 37-2128, 37-2471, 37-2472, 37-20709, and 37-20710 and to minimum streamflow water rights 02-201, 02-223 and 02-224.[2] Collectively, these hydropower and minimum streamflow water rights provide for an average daily flow of 3,900 cfs from April 1 to October 31 and 5,600 cfs from November 1 to March 31 as measured at the Murphy Gaging Station.

The partial decrees for the above-listed water rights require that the calculation of the average daily flow at the Murphy Gaging Station be based on actual flow conditions as adjusted to account for fluctuations resulting from the operation of Idaho Power facilities. The purpose of this document is to outline a measurement and reporting protocol for making this adjustment.

The Technical Working Group (TWG) has proposed and evaluated two methods for quantifying fluctuations on Snake River flows at the Murphy Gaging Station resulting from Idaho Power Company (Idaho Power) operations. Both methods focus on quantifying and removing the effects of Idaho Power reservoir storage accruals and releases on calculated average daily flow at the Murphy Gaging Station. The Reservoir-Stage Method is used to calculate the effects of reservoir accruals and releases on downstream flows based on measured changes in reservoir stage (i.e., reservoir water levels, also referred to as "headwater" levels). The Flow Method is used to calculate changes in reservoir storage based on differences between measured and estimated reservoir inflows and outflows.

The Reservoir-Stage Method is recommended as the primary approach for determining changes in reservoir storage as a result of Idaho Power operations. This method only requires accurate reservoir-stage measurements to quantify changes in reservoir storage. By comparison, the Flow Method requires accurate streamflow measurements above and

[1] USGS Station 13172500.

[2] Hydropower water rights nos. 02-100, 02-2032A, 02-4000A, and 02-4001A are held by Idaho Power Company. Hydropower water rights nos. 02-2001A, 02-2001B, 02-2032B, 02-2036, 02-2056, 02-2057, 02-2059, 02-2060, 02-2064, 02-2065, 02-4000B, 02-4001B, 02-10135, 36-2013, 36-2018, 36-2026, 37-2128, 37-2471, 37-2472, 37-20709, and 37-20710 are held by the State of Idaho as trustee. Minimum flow water rights nos. 02-201, 02-223 and 02-224 are held by the Idaho Water Resource Board (IWRB).

below each reservoir and accurate measurements of other inflows and outflows (such as tributary flows, irrigation diversions, irrigation return flows, precipitation, reach gains/losses, etc.). Each of these additional measurements introduces potential error and/or data uncertainty.

Both the Reservoir-Stage and Flow Measurement Methods require “routing” (or tracking) of changes in Snake River flow at the Murphy Gaging Station resulting from Idaho Power (1) storage releases from upstream of Milner Dam and/or (2) reservoir storage accruals or releases in Lower Salmon Falls, Bliss, CJ Strike, and Swan Falls reservoirs. Routing assumptions for calculating travel time and attenuation are currently based on approximate “rule of thumb” information. Travel times vary with flow rate; attenuation of reservoir releases depend, in part, on downstream reservoir operations and flow rate. Travel times and attenuation rates between the reservoirs and the Murphy Gaging Station have not yet been quantified at various flow rates. (The TWG recommends that current travel times and attenuation assumptions be tested and further quantified.)

The Reservoir-Stage Method may be unsatisfactory during times of substantial wind-loading. Although the region generally experiences mild wind conditions during low-flow periods in July, intense and shifting winds may either (1) temporarily limit the use of this method or (2) or require additional analysis or averaging to better quantify reservoir stage during wind events. Thus, efforts should continue to develop the Flow Method as a backup to the Reservoir-Stage Method. Streamflow measurements made as part of the Flow Method can (and should) be used to verify conclusions drawn using the Reservoir-Stage Method.

Snake River flow measurements based on rating curves are vulnerable to error associated with changes in channel morphology and/or aquatic growth. Manual streamflow measurements (which are not vulnerable to changes in channel morphology or aquatic growth over time) should therefore be conducted on a frequent basis at the Murphy Gaging Station if and when Snake River flows approach the minimum flows established in the above-listed partial decrees.

The TWG recommends implementing and calculating adjusted average daily flow at the Murphy Gaging Station using the Reservoir-Stage Method for at least a year to evaluate method reliability and routing assumptions. In addition, because of uncertainty in travel-time estimates, inability to fully track and document compound attenuation in multiple reservoirs, and other factors, TWG suggests that the use of multi-day averaging of the adjusted average daily flow at the Murphy Gaging Station be considered for administrative actions. The effect of the multi-day averaging will be to “smooth” short-term fluctuations resulting from (1) Idaho Power operations that may not be fully quantified by this implementation of the Reservoir-Stage Method, (2) natural flow variations, (3) irrigation diversions and returns, and (4) measurement/estimation error.

The TWG views that Reservoir-Stage Method as the best currently-available approach for measuring and calculating the adjusted average daily flow at the Murphy Gaging Station.

However, the TWG anticipates that the measurement protocols described in this report will undergo future refinements based on measurement-technology improvements, establishment of new measurement locations, improved travel-time and attenuation data and/or simulations, etc.

Table of Contents

List of Figures

List of Tables

Appendices

1. INTRODUCTION

1.1. Purpose

The purpose of this report is to outline a measurement and monitoring protocol for use in the distribution of water to hydropower water rights 02-100, 02-2001A, 02-2001B, 02-2032A, 02-2032B, 02-2036, 02-2056, 02-2057, 02-2059, 02-2060, 02-2064, 02-2065, 02-4000A, 02-4000B, 02-4001A, 02-4001B, 02-10135, 36-2013, 36-2018, 36-2026, 37-2128, 37-2471, 37-2472, 37-20709, and 37-20710[3] and to minimum streamflow water rights 02-201, 02-223 and 02-224 (see also Table 1, page 86).

Collectively, these rights provide for an "average daily flow" of 3,900 cfs from April 1 to October 31, and 5,600 cfs from November 1 to March 31 as measured at the Murphy Gaging Station. The partial decrees for these water rights provide that calculation of the average daily flow at the Murphy Gaging Station be based on actual flow conditions adjusted to account for fluctuations resulting from the operation of Idaho Power facilities.[4]

1.2. Objectives

The objective of the measurement and monitoring protocol is to provide a reasonable, transparent, and scientifically defensible method for calculating and reporting average daily flow[5] at the Murphy Gaging Station for purposes of distributing water to the above-listed water rights, especially at times of low flow in the Snake River. In the past, 3-day averaging was used to "smooth" fluctuations in Snake River flow data from the Murphy Gaging Station. A more detailed method for calculating the average daily flow at the Murphy Gaging Station absent fluctuations caused by Idaho Power operations has not heretofore been developed.

Specific objectives in preparing this document included the following:

1. Provide a basis for understanding Snake River flows at Swan Falls Dam by describing Snake River hydrology, reviewing historical flows at Swan Falls

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[3] Each of these partial decrees contains the following provision regarding the Swan Falls Agreement: "This partial decree is consistent with the Swan Falls Agreement dated October 25, 1984, the Contract to Implement Chapter 259, Sess. Laws, 1983 dated October 25, 1984 and the Consent Judgments entered in Ada County Civil Cases Nos. 62237 (Mar. 9, 1990) and 81375 (Feb. 16, 1990). The Swan Falls Agreement dated October 25, 1984, shall not be merged into nor integrated with this partial decree, but shall remain in full force and effect independent of this partial decree.

[4] Examples of partial decrees containing these provisions are provided in Appendix A.

[5] Subsequently referred to as the "adjusted average daily flow" – see Section 1.3 below.

Dam, and summarizing inflows and outflows to the Snake River between Milner Dam and the Murphy Gaging Station;

2. Describe Idaho Power facilities and ways in which operations at these facilities can impact measured flows at the Murphy Gaging Station;
3. Describe alternative methods considered for quantifying fluctuations stemming from Idaho Power operations; and
4. Select a protocol for measuring and reporting average daily Snake River flows at the Murphy Gaging Station consistent with provisions of the partial decrees listed in Section 1.1. Test the protocol using data from a variety of hydrologic conditions; make recommendations for improving the protocol. Document the protocol methodology, results, and quantify uncertainty.

1.3. Terminology

The USGS National Water Information Service (NWIS) and the partial decrees listed in Section 1.1 use the term "average daily flow" in two different ways. For general flow measurement and reporting purposes, the USGS and Idaho Power reports average daily flow at various measurement stations along the Snake River as the average of actual measurements collected at regular intervals (e.g., every 15 minutes) over a 24-hour period. In contrast, for the purposes of distribution of water under the above-listed partial decrees, the term "average daily flow" means the above-described average daily flow at the Murphy Gaging Station adjusted to account for "any fluctuations resulting from the operation of Idaho Power facilities."[6] Thus, for clarity, flow terms are defined in this report as follows:

- "Average daily flow" is used to describe the average daily flow that has been historically calculated and reported by the USGS and/or Idaho Power (e.g., the average of measurements collected at 15-minute intervals over a 24-hour period) for all Snake River gaging stations *except* the Murphy Gaging Station.
- "Unadjusted average daily flow" is used to describe the average daily flow historically calculated and reported by the USGS and/or Idaho Power for the Murphy Gaging Station (e.g., the average of measurements collected at 15-minute intervals over a 24-hour period). The "unadjusted average daily flow" is essentially the same as the "average daily flow" listed in the previous bullet; the word "unadjusted" emphasizes that the average daily flow has *not* been adjusted to account for fluctuations resulting from Idaho Power operations.

[6] See, for example, Provision 1 in the partial decree for water right 02-00100.

- "Adjusted average daily flow" is the average daily flow at the Murphy Gaging Station that has been adjusted to account for Idaho Power operations as provided in the above-listed partial decrees.

1.4. Report Organization

This report is organized as follows:

- Section 2 describes provisions of the partial decrees listed in Section 1.1 pertaining to the adjusted average daily flow at the Murphy Gaging Station for purposes of distribution of water to these hydropower and minimum streamflow water rights;
- Section 3 provides an overview of Snake River hydrology between Milner Dam and the Murphy Gaging Station;
- Section 4 describes Idaho Power facilities in the reach between Milner Dam and the Murphy Gaging Station, and discusses Snake River flow fluctuations resulting from Idaho Power operations;
- Section 5 describes two methods for calculating the effects of fluctuations resulting from Idaho Power operations on streamflows at the Murphy Gaging Station;
- Section 6 demonstrates the calculation of adjusted average daily flow at the Murphy Gaging Station using the reservoir-stage method;
- Section 7 summarizes sources of measurement error and data uncertainty; and
- Section 8 lists conclusions and recommendations.

Figures referenced in the text begin on page 44; referenced tables begin on page 86. Additional supporting material and references are included in appendix form.

1.5. Swan Falls Technical Working Group

This Snake River measurement and monitoring protocol is being developed by the Swan Falls Technical Working Group (TWG). The TWG includes the following members:

- Jon Bowling, Idaho Power;
- Chuck Brendecke, AMEC Environment & Infrastructure, Inc. (on behalf of the Idaho Ground Water Appropriators);
- Liz Cresto, Idaho Department of Water Resources (IDWR);
- David Hoekema, IDWR
- Christian Petrich, SPF Water Engineering, LLC (on behalf of the State of Idaho);

- Greg Sullivan, Spronk Water Engineers, Inc. (on behalf of the City of Pocatello);
- Pete Vidmar, Idaho Power; and
- Sean Vincent, IDWR.

David Evetts and Molly Wood of the U.S. Geological Survey (USGS), while not members of the TWG, provided technical expertise and support to this effort.

2. Partial Decree Provisions

2.1. Adjusted Average Daily Flow at the Murphy Gaging Station

As defined in Section 1.3 above, the term "adjusted average daily flow" refers to the calculation of the average daily flow at the Murphy Gaging Station for purposes of distribution of water in accordance with the partial decrees for hydropower and minimum streamflow water rights between Milner Dam and the Murphy Gaging Station (see Section 1.1). These decrees provide for an "average daily flow" of 3,900 cfs from April 1 to October 31, and 5,600 cfs from November 1 to March 31 at the Murphy Gaging Station.[7] Calculation of the "average daily flow" is to be based on actual flow conditions adjusted to account for "fluctuations resulting from the operation of Idaho Power Company facilities:"

> Average daily flow, as used herein, shall be based upon actual flow conditions; thus, any fluctuations resulting from the operation of Idaho Power Company facilities shall not be considered in the calculation of such flows.

The partial decrees listed in Section 1.1, with the exception of water right 02-201,[8] state that "actual flow conditions" means "all flows actually present at the Murphy Gaging Station," except "fluctuations resulting from Idaho Power operations." The hydropower partial decrees listed in Section 1.1 further state that:

> Fluctuations resulting from the operation of Idaho Power's operations are the sole exclusion to the rule that all flows actually present at the Murphy Gaging Station constitute actual flow conditions.[9]

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[7] The Snake River near Murphy (Station 13172500) is located approximately 7.5 miles northeast of Murphy at Snake river mile 453.5, approximately 4.2 miles downstream from Idaho Power's Swan Falls power plant. The gaging station was operated by the USGS beginning in August 1912 until Idaho Power began operating the gaging station in July of 2001.

[8] The "actual flow" condition present in the other rights listed in Section 1.1 was not included in partial decree 02-201 because this right pre-dated the Swan Falls settlement and because partial decrees 02-223 and 02-224 are the rights upon which a delivery call would be based in the event that the adjusted average daily flow in the Snake River at the Murphy Gaging Station fall below 3,900 cfs.

[9] While this passage was not included in the partial decrees for the Idaho Water Resource Board's minimum flow water rights at the Murphy Gaging Station (which were entered prior to the entry of the partial decrees for the hydropower water rights) the SRBA District Court found that concerns over consistency between the minimum flow water rights and the hydropower water rights were "fully

The partial decrees listed in Section 1.1 also provide that "flows of water purchased, leased, owned or otherwise acquired by [Idaho Power] from sources upstream of its power plants, including above Milner Dam, and conveyed to and past its plants below Milner Dam shall be considered fluctuations resulting from the operation of Idaho Power Company facilities." The effects of such flows, therefore, are considered in the calculation of the adjusted average daily flow at the Murphy Gaging Station for purposes of distributing water under the partial decrees.

2.2. Milner Dam and the "Trust Area"

The partial decrees listed in Section 1.1 also include provisions that exclude the Snake River upstream from Milner Dam, and surface and ground water tributary thereto, from consideration in the distribution of water to the partial decrees listed in Section 1.1:

> For the purposes of the determination and administration of this water right, no portion of the waters of the Snake River or surface or ground water tributary to the Snake River upstream from Milner Dam shall be considered. This water right may not be administered or enforced against any diversions or uses of the waters identified in this paragraph.[10]

Thus, only the area in which groundwater and surface water is deemed tributary to the Snake River between Milner Dam and the Murphy Gaging Station is to be considered for purposes of distribution of water to the partial decrees listed in Section 1.1. This area is defined by IDWR administrative rules (and is referred to in this report) as the "Trust Area"[11] (see also Section 3.2 below).

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resolved" in the proceedings on Basin-Wide Issue No. 13. *Order Withdrawing Issue No. 4, Subcase No. 00-91013 (Basin-Wide Issue 13)* (Nov. 1, 2011).

[10] This provision recites, in part, a portion of Idaho Code § 42-203B(2). The SRBA District Court has also decreed a similar "General Provision" for Basin 02. *Order Of Partial Decree For General Provisions In Basin 02, Subcase No. 00-92002GP* (Nov. 20, 2012). These provisions, and the related Milner zero minimum flow provisions of the State Water Plan, *Idaho State Water Plan* (2012), at 43, 46, recognize the historic "two rivers" policy.

[11] See IDAPA 37.03.08.030.

3. Hydrology

3.1. Introduction

The following sections describe Snake River hydrology between Milner Dam and the Murphy Gaging Station to better understand approaches for calculating adjusted average daily flows at the Murphy Gaging Station. Section 3.2 provides an overview of basin characteristics, major tributaries, contributions from springs, and channel-seepage characteristics. Section 3.3 summarizes historical streamflows in the reach from Milner Dam to Swan Falls Dam, followed by a description of Idaho Power storage releases and U.S. Bureau of Reclamation (USBR) flow augmentation releases in Section 3.4. Irrigation diversions, which reduce flow in the Snake River, are summarized in Section 3.5.

3.2. Overview

The Snake River flows over 1,000 miles from the western slope of the continental divide in Wyoming to its mouth at the Columbia River in Washington. Water flowing past Swan Falls Dam represents direct or indirect discharge from all Snake River basin areas upstream of Swan Falls Dam (Figure 1). From its headwaters at elevations greater than 10,000 feet to Swan Falls Dam (at an elevation of approximately 2,300 feet), the Snake River upstream of the Murphy Gaging Station drains an area in excess of 41,900 square miles.

The 181-mile Snake River reach from Milner Dam to the Murphy Gaging Station (Figure 2) flows through an incised canyon that in places extends to a depth of more than 700 feet below the relatively flat basalt plain. The water-level elevation along this reach falls approximately 1,824 feet from the reservoir behind Milner Dam (elevation 4,133.5 feet)[12] to Swan Falls Dam (reservoir elevation 2,314 feet), representing an average gradient of approximately 10 feet per mile (Figure 3). The area in which surface water and groundwater is tributary to this reach (i.e., the Trust Area) covers approximately 25,600 square miles (Figure 4).

[12] Travel-time schematic presented by Idaho Power to Technical Working Group on February 28, 2012.

3.3. Historical Flows

3.3.1. Introduction

This section begins with a review of streamflow gaging locations, and then presents a summary of historical Snake River flows, tributary inflows, and reach-gains from Eastern Snake Plain Aquifer discharge. This section also presents a discussion of irrigation diversions and seepage gains and losses.

3.3.2. Streamflow Gaging Locations

Locations of Snake River and major tributary stream gages in the reach between Milner Dam and the Murphy Gaging Station are shown in Figure 5. Most of these gages were originally established by the USGS (Table 2). Six of the 11 gages listed in Table 2 are now owned, maintained, and operated by Idaho Power.[13]

The Murphy Gaging Station is owned and operated by Idaho Power. The USGS reviews Idaho Power's gaging methodologies and data from this gage. Flow data are tabulated and reported by both of these entities.

3.3.3. Snake River Flows from Milner Dam to the Murphy Gaging Station

The following subsections describe hydrographs based on Snake River streamflow data collected from gaging sites between Milner Dam and below the Murphy Gaging Station. All of the hydrographs are based on 1981 through 2012 water-year data. This period-of-record includes the standard 30-year, 1981-2010 time period recommended for defining "normal conditions" (WMO, 1989).[14]

The hydrographs include the following:

1. The average of average daily flows recorded for each calendar day during the 1981-2012 time period);
2. Minimum flows (the lowest average daily flow recorded for a given day over a multi-year period).
3. 10th percentile exceedance flows (the average daily flow exceeded by 10% of the average daily flows on a given day over a multi-year period); and

[13] All six of the gages owned, operated, and maintained by Idaho Power are done so under the supervision of, and in cooperation with, the USGS. This cooperative effort between Idaho Power and the USGS helps ensure that streamflow measurements and reporting meet USGS standards.

[14] The Natural Resource Conservation Service (and RCS) also uses a 30-year time period to define normal conditions (ftp://ftp-fc.sc.egov.usda.gov/ID/snow/watersupply/NRCS_Idaho_1981-2010_normal-info.pdf.).

4. 90th percentile exceedance flows (the average daily flow exceeded by 90% of the average daily flows on a given day over a multi-year period).

Hydrographs portraying 1981-2012 Snake River flows below Milner Dam, near Kimberly, near Buhl, below Lower Salmon Falls, at King Hill, below CJ Strike Dam, and at the Murphy Gaging Station are shown in Figure 6 through Figure 13. These hydrographs show adjusted average daily flows ranging from less than 900 cfs below Milner Dam to approximately 13,000 cfs at the Murphy Gaging Station. High flows (illustrated by the 10th percentile exceedance flows) during the 1981-2012 water years are greater than 28,000 cfs. Low Snake River flows (represented by the 90th percentile hydrographs) ranged from zero flow at Milner Dam[15] and approximately 230 cfs at Kimberly to approximately 4,460 cfs at the Murphy Gaging Station.

High flows in the reach from Milner Dam to the Murphy Gaging Station generally occur in April, May, and June. Flows between Milner Dam and Lower Salmon Falls are typically lowest in August and September. Flows between Lower Salmon Falls and the Murphy Gaging Station are typically lowest in mid-June through mid-August.

3.3.4. Historical Snake River Flows near Murphy

Since 1981, unadjusted average daily flows at the Murphy Gaging Station (Station 13172500) have ranged from 4,160 cfs (July 12, 2003) to 40,000 cfs (June 16, 1997). Unadjusted average daily flows at the Murphy Gaging Station have ranged from approximately 6,600 cfs to over 13,000 cfs (Figure 12).

Typical unadjusted average daily flows at the Murphy Gaging Station exceed 3,900 cfs from April 1 to October 31 and 5,600 cfs from November 1 to March 31 by a substantial amount (Figure 12). Minimum unadjusted average daily flows and 90th percentile exceedance flows at the Murphy Gaging Station are closest to the 5,600 cfs in mid- to late-March (Figure 13). The start of irrigation diversions appear to have contributed to lower Snake River flows in late March, especially in low-flow years. The absolute lowest unadjusted average daily flows have occurred in early to mid-July.

The unadjusted minimum average daily flow at the Murphy Gaging Station dipped to 5,440 cfs on December 14, 1987 (Figure 13), which is below the partial-decree level of 5,600 cfs for winter months. However, the unadjusted average daily flow at the Murphy Gaging Station on the preceding day (December 13, 1987) was 7,220 cfs, and the unadjusted average daily flow on the following day (December 15, 1987) was 7,420 cfs. Therefore, the low flow recorded on December 14, 1987 likely was a result of fluctuations caused by Idaho Power operations.

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[15] The Idaho Code, the Idaho State Water Plan, and General Provision 4 for Basin 02 as decreed in the SRBA authorize the flow at Milner Dam to be reduced to zero cfs (see Section 2.2).

The average, 10^{th} percentile, 90^{th} percentile, and minimum unadjusted average daily flow values are developed from the 32-year (1981-2012 water years) data record. However, it is also illustrative to consider low-flow conditions in one continuous water year. The lowest unadjusted average daily flows for an entire water year occurred in 2003. Unadjusted average daily flows and a moving 3-day average of unadjusted average daily 2003 flows are shown in Figure 14 (along with 1981-2012 minimum and 90th percentile exceedance flows).

The minimum unadjusted average daily flow at the Murphy Gaging Station since 1981 was 4,160 cfs, recorded on July 12, 2003. This flow was 260 cfs above the 3,900-cfs adjusted average daily flow established in the partial decrees for the summer months.

3.3.5. Spring Discharge from the Eastern Snake Plain Aquifer

Inflows to the Snake River between Milner Dam and the Murphy Gaging Station include flows from the upper Snake River (i.e., from above Milner Dam), spring discharge, tributary inflows, irrigation return flows, and groundwater seepage. Flow from above Milner Dam and tributary inflows represent a substantial portion of the Snake River flow below Milner Dam during times of high water.

However, at times of low Snake River flows little or no flow passes by Milner Dam. Discharge from springs between Milner Dam and King Hill (Figure 15) contributes the majority of flow to the Snake River at the Murphy Gaging Station at times when there is little or no flow past Milner Dam.

Annual contributions from spring discharge during low-flow periods are illustrated in Figure 16.[16] Snake River 90^{th} percentile exceedance flows are typically less than 700 cfs below Milner Dam (essentially zero during the summer) and below 900 cfs near Kimberly. The 90^{th} percentile exceedance flows increase by approximately 300 cfs between Milner Dam and Kimberly, 1,400 cfs between Kimberly and Buhl; 3,200 cfs between Buhl and Lower Salmon Falls; and 1,600 cfs between Lower Salmon Falls and King Hill. The 90^{th} percentile exceedance flows reflect an average aggregate increase during low-water conditions of approximately 6,400 cfs between Milner Dam and King Hill.

Springs discharging from the Eastern Snake Plain Aquifer (ESPA) and other gains between Milner Dam and King Hill contribute a larger percentage of Snake River flow during July low-flow periods (Figure 17) then during other times of the year when other tributary inflows are greater. Historical 90^{th} percentile exceedance flows increase from

[16] Figure 16 contains plots of the 90th percentile exceedance flows at individual gages between Milner Dam and the Murphy Gaging Station. The difference between these 90th percentile hydrographs represents a gain to or loss from the Snake River channel. For example, the Snake River gains an average of approximately 3,000 cfs between the Snake River near Buhl and the Snake River below Lower Salmon Falls during October 90th percentile-flow conditions.

essentially zero flow at Milner Dam to 5,500 cfs at King Hill during low-water conditions in July (Figure 17 and Figure 18).

Estimated historical annual discharge from the ESPA into the Snake River between Milner Dam and King Hill increased from approximately 4,200 cfs in the early 1900s to approximately 6,700 cfs in the 1950s (Figure 19). Since the 1950s, average annual spring discharge has decreased to approximately 5,000 cfs.[17]

Reductions in Snake River flow below King Hill – largely as a result of agricultural irrigation diversions (see Section 3.5 below) – are also apparent in Figure 17. Snake River flows during early-July low-water conditions (i.e., 90th percentile exceedance flows) decrease by approximately 1,000 cfs between King Hill and the Murphy Gaging Station.

3.3.6. Tributary Inflows

Primary tributaries to the Snake River between Milner Dam and the Murphy Gaging Station include Salmon Falls Creek, the Malad River, and the Bruneau River (Figure 2). The peak runoff from these streams occurs between late April and early June (see Figure 20 through Figure 22). High flows (e.g., 10th percentile exceedance flows) in the Malad River and Bruneau River can exceed 2,000 and 3,000 cfs to the Snake River, respectively.

These tributaries contribute very little flow to the Snake River during low flow years, especially during July (when the Snake River experiences its lowest flows). Between 1981 and 2012, 90th percentile exceedance flows from these three tributaries added an average of 200 cfs or less to the Snake River in July. Although there are other streams contributing flow to the main-stem Snake River, aggregate contributions from tributaries are typically low in July.

3.3.7. Seepage

Groundwater-level contours indicate that the Snake River between Milner Dam and the Murphy Gaging Station is a gaining reach[18] (Figure 25). The ESPA discharges via springs and subsurface discharge into the Snake River between Milner Dam and King Hill (see Section 3.3.5 and Figure 15). Similarly, western Snake Plain aquifers, consisting primarily of sedimentary materials, discharge into the Snake River downstream of King Hill (Figure 25). Groundwater seepage into the Snake River below King Hill is much less than groundwater seepage and spring discharge into the Snake River above King Hill.

The USGS, Idaho Power, and IDWR measured streamflow at 18 sites along the 92-mile reach from King Hill to the Murphy Gaging Station on November 26-28, 2012

[17] IDWR data (provided by Liz Cresto, 5/3/2013).
[18] Meaning that the Snake River gains water from surrounding hydraulically-connected aquifers.

(Wood et al., *in preparation*). The measurement sites were located above, below, and within Swan Falls and CJ Strike reservoirs. Measurements were made with acoustic Doppler current profilers or acoustic Doppler velocimeters. Ten quality-assurance measurements were made with different instruments immediately after primary measurements to evaluate instrument bias.

Flow differences between measurement sites, after accounting for measurable surface inflows and outflows, were considered exchanges between surface-water (i.e., Snake River) and adjacent or underlying aquifers. The differences were compared to the total combined uncertainty of the measurements used in each calculation.

Preliminary indications are that most calculated flow differences between seepage-measurement sites were not significant (i.e., the river gains from seepage were less than the measurement uncertainty).[19] However, flow measurements at several sites indicated flow gains greater than the measurement uncertainty, indicating seepage from hydraulically-connected aquifers. Overall, the reach between King Hill and CJ Strike Dam had a net positive gain, which is consistent with inferred groundwater flow (Figure 25) toward the Snake River.

3.4. Flow Augmentation and Idaho Power Storage Releases Above Milner Dam

Hydrographs shown in Figure 6 through Figure 14, and described in Sections 3.3.3 and 3.3.4, show periodic flows passing Milner Dam.[20] Water may pass Milner Dam as a result of flood control releases, reach gains below Minidoka Dam in excess of irrigation diversion demands, storage releases of water purchased, leased, owned, or otherwise acquired by Idaho Power from reservoirs above Milner Dam for hydroelectric generation in Idaho Power facilities, and salmon flow-augmentation releases from the upper Snake River Basin reservoirs intended to increase flows in the lower Snake River (from the Hells Canyon Complex to the mouth at the Columbia River).

3.4.1. Idaho Power Storage Releases

In addition to factoring out fluctuations resulting from Idaho Power operations at Lower Salmon Falls, Bliss, CJ Strike, and Swan Falls reservoirs, the partial decrees listed in Section 1.1 provide that releases of water rented, purchased, owned or otherwise acquired by Idaho Power from sources upstream of its facilities and conveyed through the Milner Dam to Murphy Gaging Station reach of the Snake River "shall be considered fluctuations resulting from the operation of Idaho Power

[19] Seepage results and descriptions of uncertainty will be provided upon completion of the USGS seepage report, expected in 2014.

[20] The "two rivers" provisions of the partial decrees, General Provision 4, the State Water Plan and the Idaho Code allow, but do not require, the flow at Milner Dam to be reduced to zero c.f.s.

Company facilities." Idaho Power owns approximately 44,275 acre-feet (AF) in American Falls Reservoir. Between 1981 and 2008, annual releases of Idaho Power storage water and Idaho Power rentals (Figure 23 and Table 6) ranged from 34,827 AF (2004) to 394,044 AF (1983).

Releases of Idaho Power's American Falls Reservoir storage water and water that Idaho Power rents from the Snake River Rental Pool passes through Milner Dam and are conveyed to and past the Idaho Power facilities between Milner Dam and the Murphy Gaging Station. The annual volume of these flows depends in part on available reservoir carry-over storage, winter snowpack, irrigation demand, etc. The increased flows at the Murphy Gaging Station resulting from releases of Idaho Power storage in American Falls Reservoir and water rented by Idaho Power must be tracked to the Murphy Gaging Station and then subtracted from the unadjusted average daily flow at the Murphy Gaging Station to determine the adjusted average daily flow for purposes of distribution of water under the Section 1.1 partial decrees.

3.4.2. Flow Augmentation

Salmon flow augmentation releases are controlled by the U.S. Bureau of Reclamation (USBR). The flow augmentation season begins on April 3 and ends on August 31. Flow augmentation releases have historically occurred between mid-May and the end of August. However, as part of the Columbia River system biological opinion (NOAA Fisheries, 2008), the USBR releases water earlier in the season to benefit downriver salmonid migration.

Annual flow augmentation volumes (Figure 24 and Table 7) from the upper Snake River basin (i.e., from upstream of Milner Dam) have ranged from zero AF (in 2002, 2003, and 2004) to 330,000 AF (1994). Approximate flow rates resulting from flow augmentation releases have ranged from zero to approximately 3,900 cfs.

Flow augmentation releases are included in the adjusted average daily flow at the Murphy Gaging Station for purposes of distribution of water to the partial decrees listed in Section 1.1. However, awareness of flow augmentation releases is important because these releases may increase, decrease, or cease entirely during low-flow periods when fluctuations from Idaho Power operations are being monitored, routed, or tracked for purposes of distribution of water under the partial decrees.[21]

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[21] Similarly, flows in the Snake River attributable to the Bell Rapids water right rental agreement between the Idaho Water Resource Board and the Bureau of Reclamation are considered part of "actual flow conditionsflows" for purpose of distribution of water to the partial decrees listed in Section 1.1.

3.5. Irrigation Diversions

There are approximately 758 water rights and 10 permits (Figure 26) authorizing diversions from the Snake River between Milner Dam and the Murphy Gaging Station. Non-hydropower rights represent an aggregate authorized maximum diversion rate of approximately 3,270 cfs (the actual maximum diversion rate on any given day is almost certainly lower than this aggregate authorized maximum rate). Approximately 60 of the 720 water rights in this reach authorize diversions in excess of 10 cfs. Most of these larger diversions are clustered in the reach between the King Hill and CJ Strike Dam (Figure 26). Most of the irrigation diversions between Milner Dam and the Murphy Gaging Station are authorized under (1) water rights senior to the IWRB's minimum flow water rights and (2) water rights to which the hydropower rights are subordinate.[22] As such, most of the irrigation diversions between Milner Dam and the Murphy Gaging Station cannot be called out for curtailment during times of shortage by the holders of hydropower or minimum flow partial decrees listed in Section 1.1.

Diversions from the Snake River between Milner Dam and the Murphy Gaging Station have a direct influence on flows in this reach. In addition, thousands of authorized groundwater diversions in the area tributary to this reach (i.e., authorized under water rights in the Trust Area) also have an impact on flow in the Milner Dam to Murphy Gaging Station reach, although, depending on proximity to the reach, the effects of these diversions may not be realized for a long time.

The USGS developed an approach for estimating pumped irrigation-water withdrawals during the early 1990s based on electrical power data (Maupin, 1999). More recently, IDWR formed Water District 02 to expand measurement and reporting of diversions in Administrative Basin 02 (which includes the Snake River between Milner Dam and the Murphy Gaging Station).[23] Water users within the district are required to install measurement devices, record diversions, and report diversion data to IDWR by the 2016 irrigation season.

[22] Conditions in the partial decrees for the hydropower water rights provide they are subordinated to water rights senior in priority to October 25, 1984 (unless otherwise indicated on the face of the right), and to water rights dismissed from Ada County Case No. 81375 (*Idaho Power Co. v. State of Idaho*) on February 16, 1990, most if not all of which also are senior in priority to October 25, 1984.

[23] Preliminary Order signed on May 1, 2012.

4. HYDROPOWER FACILITIES

4.1. Overview

There are eight hydroelectric-generating facilities operated by Idaho Power on the Snake River between (and including) Milner Dam and Swan Falls Dam (Figure 27). In aggregate, these facilities have a maximum generating capacity of approximately 430 megawatts (MW). The following subsections describe these facilities and their effects on Snake River flows.

4.2. Reservoir Terminology

The following terms are used in this section:

- "Total storage" is the entire volume held in a reservoir or pool. Total storage includes active and inactive storage.
- "Active storage" is the portion of the reservoir that can be drained through a dam's outlet works.
- "Inactive storage" is the reservoir volume that cannot be drained through a dam's outlet works.
- "Usable storage" is the active storage that can be used to generate electricity.
- "Operational storage" is the storage defined by the maximum reservoir-elevation change allowed under a Federal Energy Regulatory Commission (FERC) license.
- "Load-following" is the process of increasing or decreasing flows (thereby adjusting power output) to meet changes in electrical-system demand.
- "Pondage" is reservoir storage of limited magnitude that provides only daily or weekly regulation of streamflow (United States Inter-Agency Committee on Water Resources, 1965).
- "Run-of-river project" is a hydroelectric power plant utilizing pondage or the flow of the river as it occurs (United States Inter-Agency Committee on Water Resources, 1965).
- "Run-flat" conditions refers to the operation of hydroelectric facilities with relatively constant reservoir levels.
- "Tail water ramping" is the rate at which reservoir discharge may change; may be described in terms of the rate at which a reservoir can be raised or lowered.

- “Block-loaded operations” (or “block-loading”) refers to the generation of electricity in “blocks” corresponding with the use of multiple turbines at a given facility. Block-loaded operations results in reservoir discharge varying in response to the number of turbines in operation.

4.3. Idaho Power Facilities

All of the following Idaho Power hydroelectric projects (Table 3) are licensed by FERC and are considered run-of-river projects. However, the operations of some of the projects involve fluctuation of the pondage behind the dam. Pondage fluctuations result in a change in flow below the project and are therefore considered fluctuations resulting from operation of Idaho Power facilities.

4.3.1. Milner Dam

Milner Dam is an earth-filled structure located at river mile 639.1. The dam was originally built in 1905, rebuilt in 1932, and rebuilt again in 1992. The facility was originally constructed with two generating units; an additional powerhouse was constructed at river mile 638.0 in 1992. The current capacity of the hydroelectric project is 59 MW. While the dam itself is owned by Milner Dam Inc., Idaho Power owns and operates the hydroelectric projects associated with the dam. Milner Dam is operated primarily for irrigation purposes with power production and recreation as secondary uses.

4.3.2. Twin Falls Dam

The Twin Falls Hydroelectric Project, located at river mile 617.4, was originally built in 1935 and is owned and operated by Idaho Power. A new powerhouse and second generating unit were added in 1995. The dam is a concrete gravity structure; pooled water is used primarily for hydroelectric generation and secondarily for recreation. The facility’s two hydroelectric units are capable of producing 54 MW. The pondage created by the dam covers approximately 85 acres and stores approximately 955 AF. Of this amount, 85 AF is considered operational storage.

4.3.3. Shoshone Falls

The Shoshone Falls Hydroelectric Project was built in 1907 at river mile 614.7. The reservoir is maintained by a concrete gravity structure owned and operated by Idaho Power for hydroelectric generation. Two generating units were part of the initial construction and a third unit was added in 1921. The pondage behind Shoshone Falls Dam covers approximately 86 acres and is capable of storing 1,500 AF (with 86 AF of operational storage). The facility has three generating units capable of producing up to 13 MW.

4.3.4. Upper Salmon Falls Dam

The Upper Salmon Falls Hydroelectric Project is owned and operated by Idaho Power. The “A” Plant was built in 1947 at river mile 579.6. The “B” Plant was built in 1947 at River mile 580.8. An upper canal delivers water from the diversion dam to the “B” Plant, while a lower canal spills approximately 500 cfs into what is known as Dolman Rapids, which then feeds into the “A” Plant. Flows in excess of plant capacity are spilled to a north channel around the diversion dam. The Upper Salmon Falls facility has no pondage, and contains four generating units capable of producing up to 39 MW.

4.3.5. Lower Salmon Falls Dam

The Lower Salmon Falls Dam is a concrete gravity structure located at river mile 573.0. Built in 1910, and rebuilt in 1949, the facility is owned and operated by Idaho Power. The pondage created by this dam covers approximately 748 acres. It is capable of storing 10,900 AF (with approximately 1,496 AF of operational storage). Pooled water is used primarily for power production and secondarily for recreation. The facility has four generating units capable of producing up to 70 MW. Lower Salmon Falls operations are constrained by the FERC license. Tail water ramping is limited to 2.5 feet per hour and five feet per day, and the instantaneous minimum discharge is 3,500 cfs or inflow, whichever is less.

4.3.6. Bliss Dam

The Bliss Dam is a concrete gravity structure built in 1950. Located at river mile 560.3, the facility is owned by Idaho Power and is capable of producing up to 80 MW. The pondage created by the Bliss Dam covers approximately 255 acres, with 8,415 AF of storage (510 AF of which is operational storage). Bliss Dam operations are constrained by the FERC license: tail water ramping is limited to three feet per hour and six feet per day, and the instantaneous minimum discharge is 4,500 cfs or inflow, whichever is less.

4.3.7. CJ Strike Dam

CJ Strike Dam, at river mile 494, creates the largest reservoir in the Milner Dam to Murphy Gaging Station reach. At full pool, the CJ Strike pond covers approximately 7,500 acres and stores about 247,000 AF (11,250 AF of which is operational storage). Constructed in 1952, the CJ Strike Hydroelectric Project is owned and operated by Idaho Power. It is used primarily for power production but also for recreational purposes and is capable of producing up to 89 MW. CJ Strike operations are constrained by the FERC license. Tail water ramping is limited to 2.5 feet per hour and 4 feet per day, and the instantaneous minimum discharge is 3,900 cfs or inflow, whichever is less.

4.3.8. Swan Falls Dam

Swan Falls Dam is a concrete gravity structure located at river mile 457.7. The Swan Falls Hydroelectric Project, built in 1901, is owned and operated by Idaho Power. Additional generating units were added in 1918. The dam was rebuilt in 1986, and a new powerhouse was constructed in 1994.

The pondage covers approximately 1,525 acres. The total volume stored behind Swan Falls Dam is 7,425 AF (6,100 AF of which is operational storage). It is used primarily for power production but also for recreational purposes and is capable of producing up to 26 MW. Swan Falls operations are constrained by the FERC license. Tail water ramping is limited to one foot per hour and three feet per day, and the instantaneous minimum discharge is 3,900 cfs (irrigation season) and 5,600 cfs (non-irrigation season) or inflow, whichever is less.

4.4. Fluctuations Resulting from Idaho Power Operations

Idaho Power operations influence Snake River flow at the Murphy Gaging Station in two ways. First, flows purchased, leased, owned, or otherwise acquired by Idaho Power add to flow at the Murphy Gaging Station and are considered fluctuations resulting from Idaho Power operations. Second, changes in reservoir storage at Idaho Power facilities result in downstream flow fluctuations; such changes in reservoir storage are the result of Idaho Power operations.

For purposes of distributing water under the partial decrees listed in Section 1.1, the unadjusted average daily flow at the Murphy Gaging Station must be adjusted to account for fluctuations caused by Idaho Power operations. The following sections describe how the unadjusted average daily flow at the Murphy Gaging Station is adjusted to account for releases of storage water owned or rented by Idaho Power above Milner Dam (Section 4.4.1) and flow fluctuations resulting from changes in reservoir storage at Idaho Power facilities below Milner Dam (Section 4.4.2).

4.4.1. Releases Above Milner Dam of Storage Water Owned or Rented by Idaho Power Company

The partial decrees for the water rights listed in Section 1.1 provide that flows from water leased, purchased, owned, or otherwise acquired by Idaho Power from upstream sources and conveyed through the Milner Dam to the Murphy Gaging Station reach shall be considered “fluctuations resulting from the operation of Idaho Power Company facilities.” Thus, for the purposes of water distribution under the partial decrees listed in Section 1.1, the unadjusted average daily flow at the Murphy Gaging Station must be reduced to account for releases past Milner Dam resulting from such flows.

Releases of storage water owned or rented by Idaho Power from reservoirs above Milner Dam may take several days to arrive at the Murphy Gaging Station.[24] The impact on flow at the Murphy Gaging Station in response to an upstream release depends on the magnitude of the release, duration of the release, and the amount of base flow to which the release is added (see Section 4.5 below). It may take several days for releases upstream of Milner Dam to reach the Murphy Gaging Station, and it may take several days after such a release ends for the residual effect at Murphy Gaging Station to subside. Thus, the adjustment must take into account the travel time for such releases to arrive at the Murphy Gaging Station and the time for the impacts to dissipate.

4.4.2. Reservoir Fluctuations Below Milner Dam

Of the eight hydroelectric facilities that Idaho Power operates between (and including) Milner Dam and Swan Falls Dam (Section 3.3 and Figure 27), Twin Falls Dam (with approximately 85 AF of operational storage)[25], Shoshone Falls Dam (with approximately 86 AF of operational storage), and Upper Salmon Falls Dam (with no operational storage) have a relatively small impact on flows at the Murphy Gaging Station compared to other reservoirs. In contrast, fluctuations from changes in storage in the Lower Salmon Falls, Bliss, CJ Strike, and Swan Falls reservoirs can have a larger impact on flow at the Murphy Gaging Station.

Increases in reservoir storage at these facilities require that the unadjusted average daily flow at the Murphy Gaging Station be adjusted upward for purposes of distributing water under the partial decrees for the water rights identified in Section 1.1. Conversely, decreases in reservoir storage (i.e., reservoir discharge in excess of inflows) require a downward adjustment in the unadjusted average daily flow at the Murphy Gaging Station.

Changes in storage in CJ Strike and Swan Falls reservoirs have greater potential to impact flows at the Murphy Gaging Station than other dams in the Milner Dam to Murphy Gaging Station reach. This is because CJ Strike and Swan Falls reservoirs have substantially larger operational storage volumes than the Lower Salmon Falls, and Bliss dams (Table 3). Potential flow fluctuations resulting from releasing (or retaining) the entire operational storage volume in CJ Strike and Swan Falls reservoirs (11,250 AF and 6,100 AF, respectively) in a 24-hour period are approximately 5,670 cfs and 3,070 cfs, respectively (Table 4). Furthermore, changes in flows from Idaho

[24] Released storage water from reservoirs between Milner Dam and the Murphy Gaging Station may also take several days to arrive at the Murphy Gaging Station.

[25] The maximum impact associated with a 24-hour release of 85 AF is approximately 43 cfs This impact is likely fully or partially attenuated as the release moves down the Snake River through downstream reservoirs to the Murphy Gaging Station.

Power's upstream reservoirs are somewhat attenuated in CJ Strike and Swan Falls reservoirs.

In practice, fluctuations as a result of reservoir operations are typically lower than the potential maximum fluctuations, especially during low-flow conditions**.** For example, CJ Strike Reservoir is typically operated within 0.5 feet of full pool and during very low flow conditions (less than 4,500 cfs) the reservoir level typically is held as constant as practical[26] (representing a "run-flat" condition). Swan Falls Reservoir is also typically operated as flat as practical under very low flow conditions. However, cessation of block-loaded operations at low flows reduces (but does not eliminate) fluctuations observed in the unadjusted and adjusted average daily flow at the Murphy Gaging Station.

4.4.3. FERC Minimum Flows

Federal Energy Regulatory Commission (FERC) requirements require that Idaho Power operate facilities in such a way that FERC minimum flows are maintained[27]:

> "The licensee shall provide an instantaneous minimum flow downstream of Swan Falls dam of 3,900 cubic feet per second (cfs) from April 1 to October 31 and 5,600 cfs from November 1 to March 31…"

The FERC license requires that minimum flows are maintained on instantaneous basis (not on a daily or multi-day average basis). Furthermore, these FERC minimum-flow requirements do not distinguish between unadjusted and adjusted average daily flows, whereas the partial decrees listed in Section 1.1 specify an adjusted average daily flow.

Should the instantaneous daily flow fall below the FERC-established minimum flows, Idaho Power may release water from its facilities (e.g., CJ Strike or Swan Falls reservoirs) on a short-term basis to keep from breaching the FERC minimum flow.[28] However, if reservoir inflows remain less than minimum flows at the Swan Falls gaging station, Idaho Power will discharge flow consistent with inflows. In other words, the minimum discharge from Idaho Power reservoirs will be the FERC instantaneous minimum flow or reservoir inflows, whichever are less. Idaho Power facilities would be operated in a run-of-river fashion during periods when inflows are less than minimum flows.

[26] Jon Bowling, Idaho Power.
[27] FERC License, Article 402, issued September 28, 2012.

[28] Per Jon Bowling, Idaho Power.

4.5. Evaporation and Bank Storage

The presence and operation of Idaho Power reservoirs results in evaporative losses (consumptive) and changes in bank storage (non-consumptive). Evaporative losses occur from each of the Idaho Power reservoirs (which, in aggregate, cover 10,249 acres – see Table 3). Increases in bank storage (when reservoir levels rise) reduce flow in the Snake River; decreases in bank storage (when reservoir levels fall) increases flow in the Snake River. Neither evaporative losses nor the effects of changes in bank storage were quantified in this effort to account for fluctuations associated with Idaho Power operations.

4.6. Travel Times and Flow Attenuation

Fluctuations from Swan Falls operations directly influence the flow measured at the Murphy Gaging Station, which is located just 4.2 miles downstream from the Swan Falls Dam. However, fluctuations from operations at the Lower Salmon Falls, Bliss, or CJ Strike facilities (which are located upstream of the Swan Falls Dam) are attenuated with river distance (Figure 28) and by storage in Bliss, CJ Strike, and/or Swan Falls reservoirs.

Travel time is dependent on river distance (i.e., the distance between the dam creating the fluctuation to the Murphy Gaging Station) and flow velocities. The flow velocity depends, in part, on hydraulic gradient, wetted perimeter, channel roughness, and water level. Mean flow velocities are greater at higher flows (Figure 29).

"Rule-of-thumb" travel times (based on empirical observations by Idaho Power facility operators) between Idaho Power facilities are shown in Table 5. For example, the "rule–of-thumb" travel time for water to travel from CJ Strike Reservoir to the Murphy Gaging Station at a Snake River flow of approximately 5,000 cfs is approximately 10 hours.[29] Travel times are less at higher flows and greater at lower flows.

Fluctuations caused by upstream facilities are conveyed through downstream reservoirs. However, fluctuations (either an increase or decrease in discharge from one of upper reservoirs as a result of change in reservoir storage) may not *immediately* pass through lower reservoirs – they are attenuated as they passed through the lower reservoirs. For example, operators at CJ Strike or Swan Falls dams may not immediately reduce releases in response to a reduction at Lower Salmon Falls for Bliss reservoirs. This is, in part, because releases from some of the reservoirs occur in "blocks" corresponding with generating capacity; individual facilities have different generating capacities. Also contributing to attenuation are increases in bank storage (with increasing river stage) and decreases in bank storage (with decreasing river stage).

[29] Jon Bowling, Idaho Power.

In summary, fluctuations resulting from Idaho Power reservoir operations below Milner Dam but above CJ Strike will be "dampened" and spread out by the time the effects reach the Murphy Gaging Station. Storage releases from Lower Salmon Falls or Bliss reservoirs will be attenuated to a greater degree by the time they reach the Murphy Gaging Station than storage releases from CJ Strike and Swan Falls.

5. Quantifying the Effects of Idaho Power Operations on Snake River Flows

5.1. Introduction

The partial decrees for the water rights listed in Section 1.1 provide that the "average daily flow … shall be based upon actual flow conditions" and that "all flows actually present at the Murphy Gaging Station constitute actual flow conditions," with the "sole exclusion" of "[f]luctuations resulting from Idaho Power's operations." Thus, unadjusted average daily flow at the Murphy Gaging Station must be adjusted to account for Idaho Power operations, which include (1) changes in Lower Salmon Falls, Bliss, CJ Strike, and Swan Falls reservoir storage (Section 4.4.2) and (2) water that Idaho Power purchases, leases, owns, or otherwise acquires and releases from sources upstream of its power plants (Section 3.4.1).

In general, accounting for the effects of Idaho Power operations is most important at times of low flow relative to the partial decree provisions for flows of 3,900 cfs from April 1 to October 31 and 5,600 cfs from November 1 to March 31. Historically, flows approaching the partial decree minimums (see Section 3.3.4) have occurred in late March (just prior to the end of the 5,600 cfs period) and early- to mid-July (about halfway through the 3,900 cfs period).

This section describes two approaches for calculating the adjusted average daily flow at the Murphy Gaging Station. The first method – the Reservoir-Stage Method – is based on measuring the change in storage at Idaho Power facilities and converting the storage change to a flow adjustment that is routed to the Murphy Gaging Station. The second method – the Flow Method – is based on measuring and accounting for inflows and outflows to Idaho Power reservoirs between Milner Dam and the Murphy Gaging Station below Milner Dam.

5.2. Reservoir-Stage Method

5.2.1. Description

The Reservoir-Stage Method consists of calculating fluctuations in flow resulting from Idaho Power operations based on calculated changes in reservoir volume derived from measured reservoir water-level changes. The change in reservoir discharge associated with the change in reservoir volume (i.e., increased discharge if reservoir stage is decreasing, or decreased discharge if reservoir stage is increasing) is then tracked (routed) to the Murphy Gaging Station. The increased or decreased discharge associated with changes in reservoir stage (i.e., fluctuations associated with reservoir operations) is, after routing, added to or subtracted from the average daily flow at the Murphy Gaging Station to calculate the adjusted average daily flow for purposes of distribution of water under the partial decrees.

The fundamental assumption in this approach is that, absent Idaho Power storage facilities, all changes in Snake River flows – and tributary inflows between Milner Dam and the Murphy Gaging Station – would pass unhindered to the Murphy Gaging Station. It is therefore assumed that all fluctuations resulting from changes in reservoir storage are caused by Idaho Power operations. The effects of changes in reservoir storage caused by diversions, precipitation, evaporation, tributary inflows within the reservoir area are ignored.

Accounting for flow fluctuations resulting from Idaho Power operations at the Murphy Gaging Station consists of the following steps:

1. Compile the unadjusted average hourly flow for the Murphy Gaging Station;[30]
2. Compile average hourly flow data for flows passing by Milner Dam; identify releases of storage owned or rented by Idaho Power upstream of its hydropower facilities (e.g., storage water conveyed from above Milner Dam) from releases that are not the result of Idaho Power releases;
3. Calculate hourly change in reservoir storage based on reservoir stage measurements in Bliss, Lower Salmon Falls, CJ Strike, and Swan Falls reservoirs;[31]
4. Convert an hourly changes in reservoir storage to calculated changes in hourly reservoir discharge;
5. Route hourly flow fluctuations attributed to Idaho Power operations (i.e., calculated changes in discharge corresponding with changes in storage and/or releases over Milner Dam) to the Murphy Gaging Station;

[30] Unadjusted average daily flows at the Murphy Gaging Station are reported by Idaho Power on a daily basis (http://www.idahopower.com/OurEnvironment/WaterInformation/StreamFlow/maps/streamFlowsDataTable.cfm?id=972666). Compiled data are subsequently reported by the USGS National Water Information System (http://waterdata.usgs.gov/nwis).

[31] Because of limited operational storage, storage fluctuations at Idaho Power's Twin Falls (Section 4.3.2), Shoshone Falls (Section 4.3.3), and Upper Salmon Falls (Section 4.3.4) facilities were not included in the calculation of adjusted average daily flow at the Murphy Gaging Station.

6. Compute the adjusted average hourly flow at the Murphy Gaging Station by (a) adding lagged reservoir storage accruals to and subtracting lagged reservoir storage releases from the unadjusted flow at the Murphy Gaging Station and (b) subtracting lagged releases of Idaho Power storage water from above Milner Dam from the unadjusted flow at the Murphy Gaging Station.
7. Calculate the adjusted average daily flow at the Murphy Gaging Station for purposes of distributing water under the partial decrees listed in Section 1.1 by averaging the adjusted hourly flows over 24-hour periods (i.e., midnight to midnight).

5.2.2. Wind-Loading Effects on Reservoir Levels

Wind loading and wave action can confound reservoir-stage measurements, particularly in long reservoirs that are exposed to strong winds (such as in CJ Strike and Swan Falls reservoirs). Wind moving across a reservoir can create a water-surface slope, resulting in higher stage at the down-wind end of a reservoir than the up-wind end (USGS, 2012). Stage measurements in long reservoirs (such as CJ Strike reservoir) may require multiple gages at different locations.

Wind speeds during typical July low-flow conditions in the Snake River are relatively mild (Appendix A). A review of wind data from the Grandview, Mountain Home Air Force Base, and CJ Strike Reservoir weather stations during the summer low-flow period (e.g., early July) indicate low to moderate wind speeds, especially at night (Vidmar et al., 2013).

5.2.3. Data

The Reservoir-Stage Method relies exclusively on reservoir water-level measurements to determine change in storage (not measurements of reservoir inflows and outflows). The method requires accurate bathymetry between operational reservoir elevations[32] (to quantify changes in volume with unit changes in stage) and accurate stage measurements.

Data needed to implement this method include the following:

1. Unadjusted flow data from the Murphy Gaging Station (available from Idaho Power). These hourly data are reported by Idaho Power to the USGS as average daily flows (NWIS Station Number 13172500[33]);

[32] Bathymetry is the measurement of water depth at various places in a body of water. In this case, the change in reservoir storage volume associated with reservoir-stage fluctuations depends, in part, on accurate bathymetry.

[33] http://waterdata.usgs.gov/nwis/dv/?site_no=13172500&agency_cd=USGS&referred_module=sw.

2. Release records of Idaho Power owned and/or leased storage water passing through Milner Dam;
3. Hourly (at a minimum) reservoir-stage measurements within each measured reservoir (reservoir-stage measurement locations are shown in Figure 31 through Figure 33);
4. Reservoir volume per unit change in water level[34] (which enables quantification of changes in reservoir volume with unit changes in stage);
5. Wind intensity and duration at a minimum of three locations in CJ Strike Reservoir and one location each in Bliss Reservoir, Lower Salmon Falls Reservoir, and Swan Falls Reservoir;
6. Quantification of flow lag times between individual reservoirs and the Murphy Gaging Station; and
7. Factors or coefficients to account for travel time and attenuation of discharge fluctuations resulting from Idaho Power operations.

5.3. Flow Method

5.3.1. Description

The Flow Method for calculating the effects of reservoir fluctuations at the Murphy Gaging Station requires measuring inflows and outflows at each of Idaho Power's reservoirs capable of causing flow fluctuations at the Murphy Gaging Station (i.e., Lower Salmon Falls Reservoir, Bliss Reservoir, CJ Strike Reservoir, and Swan Falls Reservoir). Implementation of this method would require the installation (if not already installed), monitoring, and maintenance of streamflow gages at both the upstream and downstream ends of individual reservoirs. It would also require accounting for non-river inflows and outflows (such as tributary inflows, irrigation diversions, irrigation returns, precipitation, other reach gains/losses, etc.).

This method differs from the Reservoir-Stage Method in one important way. Change in reservoir volume is estimated based on the difference between reservoir inflows and outflows, not on changes in reservoir stage. Thus, accounting for flow fluctuations resulting from Idaho Power operations at the Murphy Gaging Station using the Flow Method consists of calculating the differences between reservoir inflow and outflow based on Snake River flow data above and below each reservoir, accounting for tributary inflows, irrigation diversions, irrigation return flows, precipitation, evaporation, and channel seepage. As with the Reservoir-Stage Method, changes in flow resulting

[34] Volume per unit change in water level can be calculated using accurate reservoir surface-area data over the range of reservoir operating levels.

from reservoir storage changes are then routed to the Murphy Gaging Station, accounting for travel time and attenuation.

Ideally, inflows and outflows at each reservoir are determined with streamflow gages above and below each reservoir. However, ideal measurement locations are not available above and below each reservoir. For example, a relatively low-error measurement location at lower flows above CJ Strike Reservoir may have low-velocity reservoir backwater (having high measurement error) at higher flows. Measurement locations that are sufficiently upstream of a reservoir to avoid high-pool conditions may include more irrigation diversions. These irrigation diversions must also be measured to calculate changes in reservoir storage, which adds additional potential measurement error.

Other inflows to, and outflows from, a reservoir reach must be measured to quantify the effect of Idaho Power operations on changes in reservoir storage (e.g., diversions, return flows, evaporation, seepage, etc.). Ideally, these inflows and outflows would be measured at the same time interval (e.g., an hourly or daily time interval) at which changes in storage are being calculated. Such measurements require time, resources, and, and more importantly, introduce measurement error and/or data uncertainty (by virtue of additional measurement points).

5.3.2. Data Components

Data components needed to implement the Flow Method include the following:

1. Unadjusted average hourly flow data for the Murphy Gaging Station. These data are currently collected and reported by Idaho Power (NWIS Station Number 13172500);
2. Hourly release records of Idaho Power owned and/or leased storage water passing through Milner Dam;
3. Hourly flow measurements collected above and below the Lower Salmon Falls, Bliss, CJ Strike, and Swan Falls reservoirs;
4. Hourly tributary inflow measurements into reservoir reaches (e.g., Bruneau River);
5. Hourly (or at a minimum, daily) irrigation diversion rates from (and returns to) pooled and free-flowing sections of the Snake River between Milner Dam and the Murphy Gaging Station;[35]
6. Precipitation rates, evaporation rates, channel seepage rates, and other reach gains/loss data for reservoir reaches; and

[35] Ideally, measurements of diversions and return flows would be at the same frequency as the average daily flow data being compiled above and below each Snake River reservoir.

7. Factors or coefficients to account for travel time and attenuation of discharge fluctuations resulting from Idaho Power operations.

5.4. Discussion

The Reservoir-Stage and the Flow Methods are conceptually similar, in that they both produce a calculation of change in reservoir storage volume. The difference is the manner in which changes in reservoir storage volumes are quantified. The Reservoir-Stage Method is used to calculate changes in storage based on reservoir-stage measurements and reservoir bathymetry. The Flow Method is used to calculate changes in reservoir storage based on inflow-outflow measurements and estimates.

The Reservoir-Stage Method is conceptually straightforward and easier to implement than the Flow Method because it relies on direct measurements of reservoir stage to calculate changes in reservoir storage. The Reservoir-Stage Method does not require a detailed, real-time accounting of reservoir inflows and outflows (such as tributary flows, irrigation diversions, irrigation return flows, seepage, precipitation, evaporation, etc., measurements potential bias and data uncertainty). Further, reservoir-stage measurements are not vulnerable to some of the factors that contribute error to flow measurements, such as changes in channel morphology, changes in aquatic growth, and other factors that affect flow measurements. On the other hand, reservoir-stage measurements are vulnerable to inaccurate bathymetry data, the effects of wind loading, and wave action.

Both methods require tracking (i.e., routing) of flows from water leased, purchased, owned, or otherwise acquired by Idaho Power from upstream sources and conveyed through Milner Dam to the Murphy Gaging Station reach. Furthermore, both methods require the tracking of fluctuations at the Murphy Gaging Station associated with storage releases at Milner Dam and storage changes in Lower Salmon Falls, Bliss, CJ Strike, and Swan Falls reservoirs.

Both methods have some inherent error and uncertainty (see Section 7 below), a result of measurement uncertainty, uncertainty in travel time estimates, lack of attenuation data, etc. The TWG therefore recommends use of multi-day averaging in the calculation of the average daily flow at the Murphy Gaging Station under the partial decrees. Multi-day averaging (such as a rolling 3-day average of the adjusted average daily flow) reduces the effects of short-term fluctuations associated with these factors.

6. INITIAL IMPLEMENTATION OF RESERVOIR-STAGE METHOD

6.1. Overview

This section presents the adjusted average daily flow at the Murphy Gaging Station for the water years 2011 through 2013. These calculations of adjusted average daily flows represent an initial implementation of the reservoir-stage method (see Section 5.2). It is anticipated that the method will be refined as data from additional measuring points (e.g., additional reservoir-stage data) become available.

A spreadsheet model was constructed by IDWR to calculate the adjusted average daily flows at the Murphy Gaging Station.[36] The adjusted average daily flows are calculated using hourly or sub-hourly data. Use of hourly data is necessary because travel times between individual reservoirs and the Murphy Gaging Station do not coincide with 24-hour or daily periods. The adjusted average daily flow was then calculated as an average of adjusted average hourly flows for the previous 24-hour period.

Any method for estimating adjusted average daily flows has some level of inherent uncertainty. The uncertainty in this implementation of the Reservoir-Stage Method reflects reservoir-stage and river-stage measurement error, imprecise travel-time estimates, and other factors (see Section 7 below).

While not perfect, the Swan Falls Technical Working Group (Section 1.5) recommends the Reservoir-Stage Method as presented herein for calculating adjusted average daily flows at the Murphy Gaging Station at this time (in part because of less anticipated uncertainty and in part because flow data required for the flow method are not yet available). The TWG recommends that the Reservoir-Stage Method be implemented on a trial basis for the 2014 irrigation season, and that method be reviewed – and, if necessary, refined – based on analysis of the 2014 implementation.

6.2. Spreadsheet Implementation

A spreadsheet model used to calculate adjusted average daily flows at the Murphy Gaging Station includes four worksheets. The first worksheet (“ReadMe”) describes the basic methodology, lists data sources, and lists assumptions. The second worksheet (“Adjusted Avg Daily Flow”) lists primary data and calculates adjusted average daily flows. The “Headwater Data” worksheet contains hourly and averaged

[36] A current version of the spreadsheet is available from David Hoekema, IDWR.

reservoir-stage data. Finally, the “Graphs” worksheet contains the figures that are presented in this report.

The adjusted average daily flows at the Murphy Gaging Station were calculated as follows:

1. Unadjusted flow data collected at the Murphy Gaging Station were provided by Idaho Power in 15-minute intervals. These data were then averaged into hourly data for calculating adjusted average hourly flow at the Murphy Gaging Station. Averaging reservoir-stage data over short periods of time reduces the short-term reservoir-surface fluctuations caused by wave action, boat wakes, wind-loading, and power plant flow fluctuations.

2. Hourly flows passing Milner Dam from the release of storage water owned or leased by Idaho Power were identified for 2012 and 2013 based on release records provided by Idaho Power.

3. Hourly reservoir-stage data were obtained from Idaho Power. Idaho Power measures reservoir stage (instantaneous readings) on an hourly basis at the Lower Salmon Falls, Bliss, and Swan Falls reservoirs (gage-site locations are shown in Figure 30, Figure 31, and Figure 33, respectively). To calculate the adjusted average hourly flow at the Murphy Gaging Station, the hourly data were averaged over a 3-hour period (i.e., averaged using three readings) to reduce the impact of short-term perturbations inherent to instantaneous measurements.

4. CJ Strike Reservoir (Figure 32) stage data are collected by Idaho Power at 5-second intervals in CJ Strike Reservoir. Idaho Power provided these data in the form of averages of 120 measurements taken over 10-minute periods. The 10-minute averages coinciding with the top of the hours were used to calculate the adjusted average hourly flows at the Murphy Gaging Station. The 10-minute averages provide a more accurate estimate of head than an instantaneous measurement that may be impacted by waves, wind, etc. (Figure 34).

5. Changes in reservoir storage were calculated as the product of reservoir surface area (see Table 3) and changes in reservoir-stage elevations. It was assumed that reservoir sides are vertical over the reservoir-fluctuation interval. For example, a two-foot fluctuation in CJ Strike Reservoir, which covers 7,500 surface acres, was assumed to represent a 15,000 AF volume change. In reality, reservoir sides between the full-pool elevation and the minimum-pool elevation (Table 3) are not vertical, but bathymetry data enabling a more precise calculation are not yet available.

6. Changes in reservoir storage were converted to flows on hourly basis. For example, a 0.1-foot increase in reservoir-stage elevation over one hour in

Swan Falls Reservoir represents a decrease in flow below the reservoir of 461 cfs, i.e.,

$$Q = 1,525\ acres * \frac{0.1\ foot\ change}{1\ hr} * \frac{43{,}560\ ft^3}{AF} * \frac{1\ hr}{60\ min} * \frac{1\ min}{60\ sec} = 1{,}845\ cfs$$

7. Changes in flow attributed to Idaho Power operations (including Idaho Power releases over Milner Dam) were then "tracked" (i.e., routed) to the Murphy Gaging Station using empirical travel-time estimates provided by Idaho Power (Table 5). These are empirical travel-time estimates (see Section 4.5) that apply to "low flows" (i.e., approximately 5,000 cfs).

   Changes in flow as a result of reservoir operations also attenuate with distance (see Section 4.5 and Figure 28). However, data describing attenuation rates are not available, and were therefore not included in these calculations of adjusted average daily flow rates.

8. The adjusted average hourly flow at the Murphy Gaging Station was then calculated based on the following equation:

$$Q_{AAHF,Murphy\ (t)} = Q_{Murphy\ (t)} - Q_{Mil\ (t-74)} + \Delta S_{LSF(t-24)} + \Delta S_{Bli\ (t-22)} + \Delta S_{CJ\ (t-10)} + \Delta S_{SF\ (t-2)}$$

Where,

$Q_{AAHF,Murphy\ (t)}$ is the adjusted average hourly flow at the Murphy Gaging Station at a given time;

$Q_{Murphy\ (t)}$ is the unadjusted average hourly flow at the Murphy Gaging Station;

$Q_{Mil\ (t-74)}$ is the flow released by Idaho Power over Milner Dam 74 hours prior to the given time;

$\Delta S_{LSF(t-24)}$ is the flow resulting from change in storage 24 hours prior to the given time;

$\Delta S_{Bli\ (t-22)}$ is the flow resulting from change in storage 22 hours prior to the given time;

$\Delta S_{CJ\ (t-10)}$ is the flow resulting from change in storage 10 hours prior to the given time; and

$\Delta S_{SF\ (t-2)}$ is the flow resulting from change in storage two hours prior to the given time.

A storage accrual is added to the unadjusted flow at the Murphy Gaging Station. A storage release is subtracted from the unadjusted flow at the Murphy Gaging Station.

9. Finally, the adjusted average *daily* flow at the Murphy Gaging Station was calculated as the average of the adjusted *hourly* flows for the 24-hour period prior to midnight of any given day.

6.3. Results and Discussion

6.3.1. Adjusted Average Daily Flows at the Murphy Gaging Station

Comparisons of adjusted and unadjusted average daily flows at the Murphy Gaging Station are shown in Figure 35 through Figure 37 for water years ("WY") 2011-2013. At this scale, the adjusted average daily flows at the Murphy Gaging Station are similar to the unadjusted average daily flows, with the exception of Idaho Power releases over Milner Dam (Figure 36 and Figure 37).

In 2011, 2012, 2013, adjusted average daily flows at the Murphy Gaging Station ranged from a high of 30,054 cfs (on June 2, 2011) to 4,230 cfs (on June 18, 2013). This lowest adjusted average daily flow was 330 cfs above the seasonal minimum flow of 3,900 cfs established in the above-listed partial decrees (Figure 37).

Between 2011 and 2013, the adjusted and unadjusted average daily flow values came closest to the minimum flows in late March of 2013 (Figure 37 and Figure 38). Between March 1 and March 20, the adjusted average daily flow at the Murphy Gaging Station was approximately 6,850 cfs (1,250 cfs greater than the minimum flow). However, flows began dropping on about March 22; the adjusted average daily flow at the Murphy Gaging Station averaged 5,880 cfs between March 26 and March 31. The lowest adjusted average daily flow during this period was 5,727 cfs on March 30, 2013 (127 cfs greater than the 5,600 cfs minimum flow). Decreases in flows between about March 22 and March 31 likely reflect the startup of seasonal irrigation diversions from the Snake River between Milner Dam and Swan Falls Dam.

Flows in early April 2013 remained lower than March levels. The unadjusted average daily flow on March 27 and 28, 2013 was 6100 cfs, and dropped sharply on April 1, 2013 (from 6,110 cfs on March 31, 2013 to 5,280 cfs). The average of the unadjusted average daily flow in the first week of April was 5,610 cfs; the average adjusted average daily flow during this period was 5,730 cfs.

6.3.2. Flow Fluctuations at the Murphy Gaging Station

The initial implementation (described herein) of the Reservoir-Stage Method to account for Idaho Power operations removes some – but not all – of the flow fluctuations observed at the Murphy Gaging Station. A portion of the variability observed in the adjusted average daily flow at the Murphy Gaging Station is (1) variability not explained by Idaho Power operations and/or (2) not removed by the Reservoir-Stage Method as implemented here. Remaining fluctuations likely reflect flow variations as a result of (1) changes in inflows, changes in irrigation diversion rates, and natural flow variability, and/or (2) effects of Idaho Power operations that were not fully removed using this implementation of the Reservoir-Stage Method (in part because of incomplete representation of travel times and attenuation).

For example, removal of Idaho Power operational effects in this implementation of the Reservoir-Stage Method results in less hydrograph fluctuations in early April 2013 (Figure 38), but substantial flow variability at other times. In general, variability appears to be greatest during winter months and at higher flows (Figure 36 through Figure 38) when Idaho Power responds to fluctuating electrical demand and operates turbines in stages for maximum efficiency. In general, fluctuations during the summer months (e.g., June and July) of a low-flow year such as 2013 (Figure 37) are less than in higher-flow years such as 2011 (Figure 35) and 2012 (Figure 36), possibly reflecting the “run-flat” operations (i.e., cessation of load-following operations – see Section 4.4.2) during times of low flow.

Some of the hydrograph variability likely reflects variations in seasonal inflows from tributary basins (e.g., May flows in Figure 38). However, the adjusted average daily flow at the Murphy Gaging Station still fluctuates when variations in tributary inflows are minimal (e.g., July), likely reflecting (in part) fluctuations in irrigation withdrawals in the Snake River reach between Milner Dam and Swan Falls Dam.

Fluctuations in the adjusted average daily flow at the Murphy Gaging Station may also reflect error inherent to this implementation of the Reservoir-Stage Method. Error associated with (1) attenuation effects (which were neglected in this initial implementation), (2) tracking (i.e., routing) of flow changes from Idaho Power operations, (3) reservoir-stage measurements, (4) assumptions used to translate changes in storage to changes in discharge rates, and (5) unadjusted average daily flow measurements at the Murphy Gaging Station could explain a portion of the fluctuations in the adjusted average daily flow at the Murphy Gaging Station. These potential sources of error are further discussed below.

Some of the apparent fluctuations in adjusted average daily flow can be reduced by averaging the adjusted average daily flow over multiple days. A rolling average can be calculated as a “trailing” multi-day average or a “centered” multi-day average. The trailing multi-day average for a given day is calculated based on an average of past adjusted average daily flow values (Table 8). The centered multi-day average is calculated based on an average of past and future days.

The use of trailing and centered multi-day averages of the adjusted average daily flow at the Murphy Gaging Station does not completely “smooth” large-scale fluctuations (Figure 39).[37] However, 3-, 5-, and 7-day trailing and centered averages reduce apparent day-to-day fluctuations in the adjusted average daily flow record (Figure 40 through Figure 43). Trailing averages, by definition, lag the non-averaged adjusted average daily flow (Figure 40 and Figure 42). Centered averages are more consistent in time with the adjusted average daily flow (Figure 41 and Figure 43).

The trailing multi-day average can be calculated for any given day in real time, because the trailing average depends on previous days. In contrast, the centered average cannot be calculated in real time, because the centered multi-day average relies on the adjusted average daily flow values for at least 1 day after the day of interest.

[37] Note also the sharp decrease in flow beginning on approximately March 20, 2013 presumably in response to the start of seasonal irrigation diversions.

7. SOURCES OF MEASUREMENT ERROR AND DATA UNCERTAINTY

This section describes sources of measurement error and uncertainty using the Reservoir-Stage Method and Flow Method.

7.1. Murphy Gaging Station Flow Measurements

The unadjusted average daily flow at the Murphy Gaging Station is based on river-stage measurements (i.e., water-level measurements) and a stage-discharge relationship. The stage-discharge relationship was developed based on multiple streamflow measurements at the Murphy Gaging Station conducted at various flow levels. The stage-discharge relationship is used to interpolate streamflow at river levels that were not measured in preparation of the stage-discharge relationship. Snake River water-level measurements (i.e., stage measurements) are collected at 15-minute intervals. These stage measurements are converted to streamflow estimates based on the stage-discharge relationship. Streamflows calculated on 15-minute intervals are averaged over a 24-hour period to calculate the unadjusted average daily flow.

Sources of measurement error include (1) random measurement error (reflecting natural short-term variations in flow), (2) measurement bias (which could be caused by instrument malfunction), and/or (3) bias in the computed streamflow based on the stage-discharge rating, which can be caused by changes in channel morphology (e.g., scour or fill) or aquatic vegetation growth. Thus, uncertainty can arise from (1) initial streamflow measurements to establish the stage-discharge relationship, (2) subsequent streamflow measurements conducted to check and refine the stage-discharge relationship, and (3) changes in channel characteristics (as a result of changes in channel morphology or aquatic vegetation growth) that affect the stage-discharge relationship between actual streamflow measurements.

Idaho Power (which operates the gage) has rated the Murphy Gaging Station as "good."[38] The USGS also classified the gage as "good" in the last year that the USGS operated the gage (USGS, 2001). A "good" rating indicates that 95% of the daily discharges based on automated measurements and use of a rating curve are within 10% of the true value (Kennedy, 1983). This rating is a subjective determination, based on quality of measurements, data continuity, etc. (Sauer and Meyer, 1992). The USGS continues to review Idaho Power data from this gage, in part to satisfy FERC licensing requirements.

[38] http://www.idahopower.com/pdfs/ourEnvironment/waterResourcesdata/WaterResourcesData2011.pdf (pg 37).

The lowest achievable uncertainty for *manual* streamflow measurements made at the Murphy Gaging Station is likely in the 1-2 percent range, based on a preliminary analysis of streamflow measurements made during a seepage run in November 2012 (Wood et al., *in preparation*). Two Snake River streamflow measurements were made at the Murphy Gaging Station during the 2012 seepage run. The first measurement consisted of 12 transects (i.e., passes across the river); the second measurement consisted of four transects. The USGS assigned uncertainties of 1.1 percent and 4.4 percent, respectively, to the two November 2012 streamflow measurements at the Murphy Gaging Station. The level of uncertainty is based on a preliminary assessment of the measurements' coefficients of variation and potential sources of error.

However, uncertainty increases when scaling a manual measurement at one flow to other flows. That is why manual streamflow measurements should be conducted on a frequent basis at the Murphy Gaging Station if Snake River flows approach the flows provided in the partial decrees for the water rights listed in Section 1.1. Increased frequency of streamflow measurements will help reduce bias associated with the effects of aquatic growth or changes in channel morphology, and will thus reduce the level of uncertainty associated with use of the stage-discharge relationship during low flow periods.

Streamflow measurements with more transects (i.e. passes) reduce the random error portion of the uncertainty. As a result, measurements made at the Murphy Gaging Station during low flow periods should consist of at least 12 transects. Instrument bias is not expected to be significant, but this should be verified through periodic check measurements made with a second instrument.

7.2. Reservoir-Stage Method

Sources of measurement error and uncertainty for the Reservoir-Stage Method include the following:

1. Wave action (from boat wakes, for example) can impact reservoir-stage measurements. This potential error is reduced substantially by taking the average of 120 measurements over a 10-minute period to estimate the reservoir-stage (see Section 6.2). Better quantification of uncertainty associated with reservoir-stage measurements is recommended during the 2014 water year.

2. Sustained, high-intensity winds can create wind-loading effects (see Section 5.2.2). Reservoir-stage measurements taken under infrequent, high-wind conditions may reflect wind-loading effects. Averaging reservoir-stage measurements may reduce this source of error. In addition, winds are generally of low or moderate intensity during low-flow periods in early July when Snake River flows are closest to the summertime minimum flow.

3. Error associated with reservoir bathymetry impacts the rate of flow associated with a change in reservoir volume. The magnitude of this error has not yet been quantified.

7.3. Flow Method

At this point, lack of all necessary inflow gages and the ability to track agricultural diversions prevents utilization of this method. However, sources of measurement error and uncertainty with this method (assuming that all data are available) include the following:

1. Not all of the reservoirs currently have upstream and downstream gages, nor do all reservoirs have ideal gaging sites above and below each reservoir. Suitable gage locations are limited by channel characteristics, property ownership, physical access, and flow characteristics at various reservoir stages.
2. Typical streamflow estimates based on stage-discharge relationships have uncertainties on the order of ± 10%. At 4,000 cfs, an error of ± 10% translates to a potential uncertainty of plus or minus 400 cfs. Moreover, flow estimates based on multiple-transect streamflow measurements at the Murphy Gaging Station typically have an uncertainty of approximately ± 2% (see Section 7.1).
3. Stage-discharge relationships change as a result of channel scour, channel deposition, and/or aquatic growth. These processes can impact streamflow measurements on an intra-seasonal and seasonal basis.
4. Incomplete measurements of all diversions from the Snake River, standard error in individual measurements (± 5%) and incomplete temporal data (e.g., totalizing flowmeters do not provide daily data) create measurement uncertainty. This is compounded by the number of diversions between Milner Dam and the Murphy Gaging Station (see Section3.5).
5. A portion of irrigation diversions returns to the Snake River. Unless measured, the magnitude and variability of these return flows, is uncertain.
6. Seepage gains and losses impact the quantification of flow through a reservoir. Although seepage gains and losses likely do not vary substantially on a daily basis, they may affect reservoir mass-balance estimates.

7.4. Routing and Attenuation

“Rule-of-thumb” travel time estimates (Table 5), which are based on empirical observations by Idaho Power personnel, are simplistic, do not apply to all flows, and have not been well documented. Because of lack of data, attenuation rates are not factored into the above-described calculations of adjusted average daily flow. Routing and attenuation error adds uncertainty to the calculation of the adjusted average daily flow at the Murphy Gaging Station. Multi-day averaging of the adjusted average daily flow reduces the effects of error associated with routing and attenuation uncertainty.

7.5. Summary: Error and Uncertainty

The magnitude of error and uncertainty associated with the adjusted average daily flow at the Murphy Gaging Station depends, in part, on the Snake River channel conditions (e.g., aquatic growth effects measurements based on rating curves), flow rate (e.g., travel times and attenuation are influenced by flow rate), wind conditions (i.e., wind-loading in Idaho Power reservoirs influences stage measurements), etc. Error and uncertainty associated with the reservoir-stage method to calculate the adjusted average daily flow at the Murphy Gaging Station has not been fully quantified. The following measures could serve to help reduce (or better quantify) error and uncertainty associated with the reservoir-stage method:

1. Conduct frequent manual measurements of Snake River flows at the Murphy Gaging Station at times when Snake River flows approach the minimum flows established in the partial decrees listed in Section 1.1 (e.g., when Snake River flows are – or are anticipated to be – within approximately 5% of the minimum flows)
2. Monitor wind conditions at reservoir-stage gaging locations at the Murphy Gaging Station at times when Snake River flows approach the minimum flows established in the partial decrees listed in Section 1.1. Quantify wind-loading effects during times of high wind conditions and/or do not use reservoir-stage method to quantify adjusted average daily flow at the Murphy Gaging Station during periods of high winds.
3. Better quantify error associated with reservoir bathymetry over the range of reservoir operating levels.
4. Better quantify estimates of water travel times at various flow rates to more accurately track (i.e. route) changes in discharge associated with Idaho Power reservoir operations.
5. Better quantify attenuation of changes in discharge associated with Idaho Power reservoir operations at various flow levels.
6. Continue to develop the Flow Method as a means of checking Reservoir-Stage Method components, especially at times when Snake River flows approach the minimum flows established in the partial decrees listed in Section 1.1.
7. Review potential error and uncertainty in the 2014 adjusted average daily flow data for the Murphy Gaging Station.

Idaho Power is planning to construct a river-flow model that can be used to improved travel-time estimates and quantify attenuation effects. This effort is currently in the budgeting process; a completed model is not anticipated prior to 2015.[39]

Multi-day averaging of the adjusted average daily flow would serve to reduce error and uncertainty associated with the adjusted average daily flow until the above-listed measures have been fully implemented. Some of the short-term variability observed in the 2010-2013 adjusted average daily flow hydrographs is the result of natural-flow variability, variability in irrigation diversions and/or returns, and other physical factors. However, some of the variability is also likely the result of error associated with reservoir-stage method measurements, travel-time estimate errors, and attenuation errors. Multi-day averaging of the adjusted average daily flows at the Murphy Gaging Station would serve to reduce the impact of these errors.

[39] Jon Bowling, TWG Meeting, March 13, 2014.

8. Summary and Recommendations

This document presents a measurement and monitoring plan for determining and tracking adjusted average daily flow at the Murphy Gaging Station for the purpose of distribution of water to the partial decrees listed in Section 1.1. Specific conclusions and recommendations in this plan include the following:

1. Two approaches were identified for determining adjusted average daily flow in the Snake River at the Murphy Gaging Station as provided in the partial decrees for the hydropower water rights listed in Section 1.1: the Reservoir-Stage Method and the Flow Method.
2. The Reservoir-Stage Method was implemented for water years 2011-2013, and is recommended for use in 2014 on a trial basis as the primary approach for determining for the adjusted average daily flow at the Murphy Gaging Station. This method requires only reservoir-stage measurements to quantify changes in reservoir storage. By comparison, the Flow Method requires multiple streamflow measurements above and below each reservoir and measurements of other inflows and outflows (such as tributary flows, irrigation diversions, irrigation return flows, seepage, precipitation, evaporation, etc.). Instrumentation for these measurements are not yet fully installed. Furthermore, each of these additional measurements introduces potential bias and uncertainty.
3. Reservoir-Stage Method accuracy may be reduced during times of substantial wind-loading. Although the region experiences generally mild wind conditions during low-flow periods in July, intense and shifting winds may temporarily limit the use of this method. The Reservoir-Stage Method may also be impacted by wave action and error associated with quantification of reservoir bathymetry. Additional work is needed to quantify error associated with substantial wind loading.
4. A spreadsheet tool was created for calculating the effects of Idaho Power operations on adjusted average daily flows at the Murphy Gaging Station. The spreadsheet tool was used to calculate the adjusted average daily flows at the Murphy Gaging Station for the years 2011, 2012 and, 2013.
5. The TWG recommends use of this spreadsheet model for calculating the adjusted average daily flow at the Murphy Gaging Station during the 2014 water year. The TWG also recommends that the implementation of this method be reviewed at the end of 2014, with possible changes and improvements to be implemented for 2015 and beyond.

6. The TWG recommends that any possible failure to satisfy the minimum-flow water rights held by the IWRB and the hydropower water rights held by Idaho Power as indicated by the adjusted average daily flow calculations using this spreadsheet model trigger a careful review of measurements, calculations, and potential sources of error and uncertainty during the time that the minimum-flow water rights and the hydropower water rights are not satisfied.
7. The TWG recommends use of a multi-day rolling average (minimum 3-day rolling average) of the adjusted average daily flow to reduce the effects of natural flow variability, measurement error, and method (e.g., routing and attenuation) uncertainty. The multi-day centered average provides a better average for a given day; the trailing multi-day average lags actual fluctuations but can be monitored on a real-time basis. Use of the multi-day rolling average should be used whether or not the minimum-flow water rights held by the IWRB and the hydropower water rights held by Idaho Power are not satisfied.
8. The TWG also recommends frequent manual flow measurements at the Murphy Gaging Station if Snake River flows approach established minimum flows provided in the partial decrees for the water rights listed in Section 1.1. The manual streamflow measurements will help reduce bias associated with the effects of aquatic growth or changes in channel morphology, thus reducing the level of uncertainty associated with use of the stage-discharge relationship during low flows.
9. Both the Reservoir-Stage and Flow Measurement Methods require "routing" (or tracking) changes in reservoir storage from where they occur downstream to the Murphy Gaging Station. Routing assumptions for calculating travel time are currently based on "rule-of-thumb" empirical information. Travel times and attenuation rates have not been fully quantified at various flow rates. The TWG recommends that current travel time assumptions be tested and better quantified through analysis of historical data, modeling, and/or tracer studies.
10. Similarly, TWG recommends analyses of historical flow data and channel hydraulics to quantify how changes in flow caused by Idaho Power operations are attenuated as they move downstream.
11. The TWG recommends quantification of the effects of (and error associated with) wind-loading in Idaho Power reservoirs under different wind conditions.
12. The Flow Method cannot be recommended at the current time because instrumentation for this method is not yet fully established. Some of the required streamflow measurement stations have not yet been installed and

Water District 02 requirements to fully measure and report irrigation diversions will not be fully implemented until 2016.

Efforts should continue to implement the Flow Method as a backup to the Reservoir-Stage Method. Streamflow measurements made as part of the Flow Method can (and should) be used to verify conclusions drawn using the Reservoir-Stage Method.

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10. FIGURES

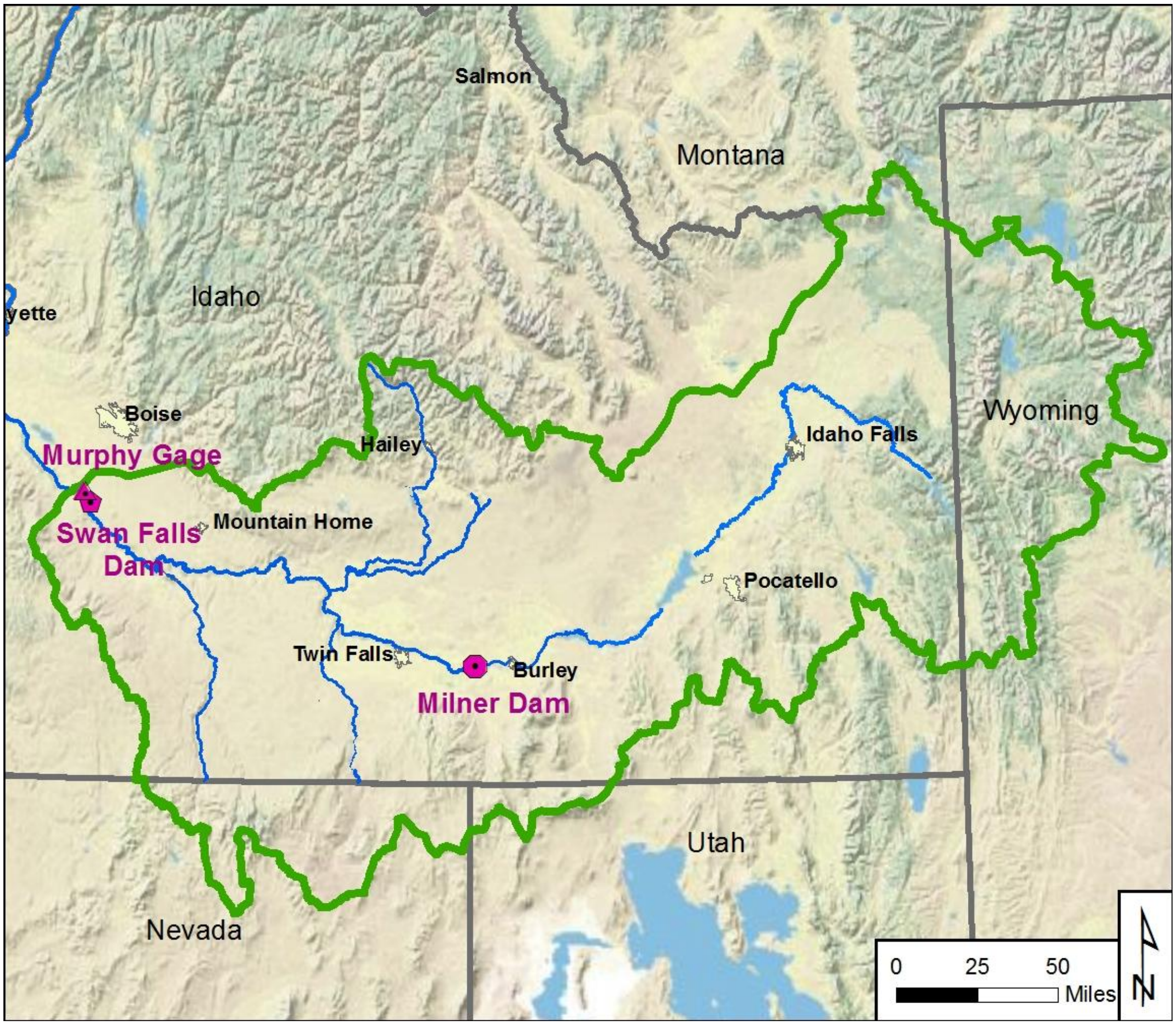


Figure 1. Snake River Basin.

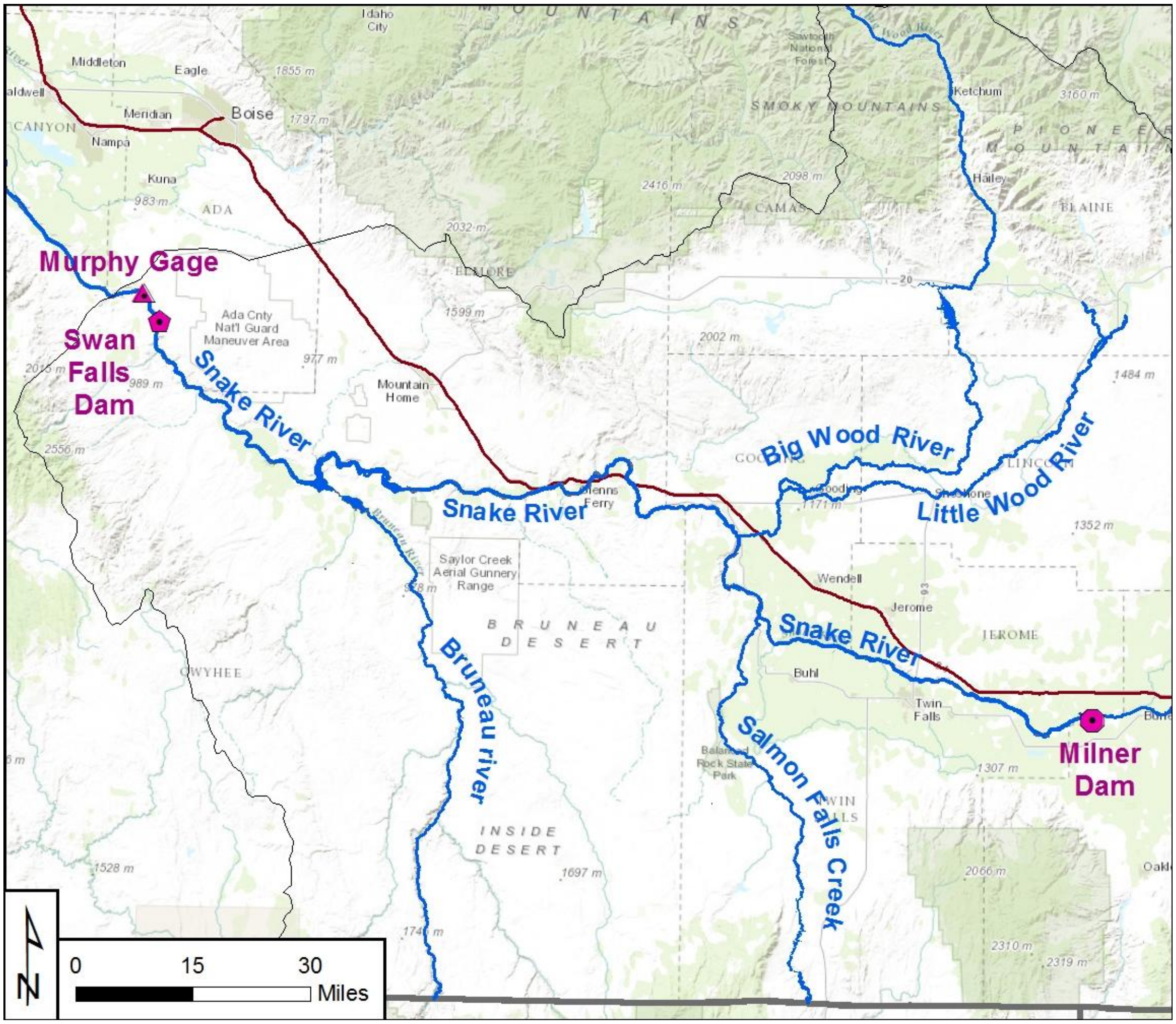
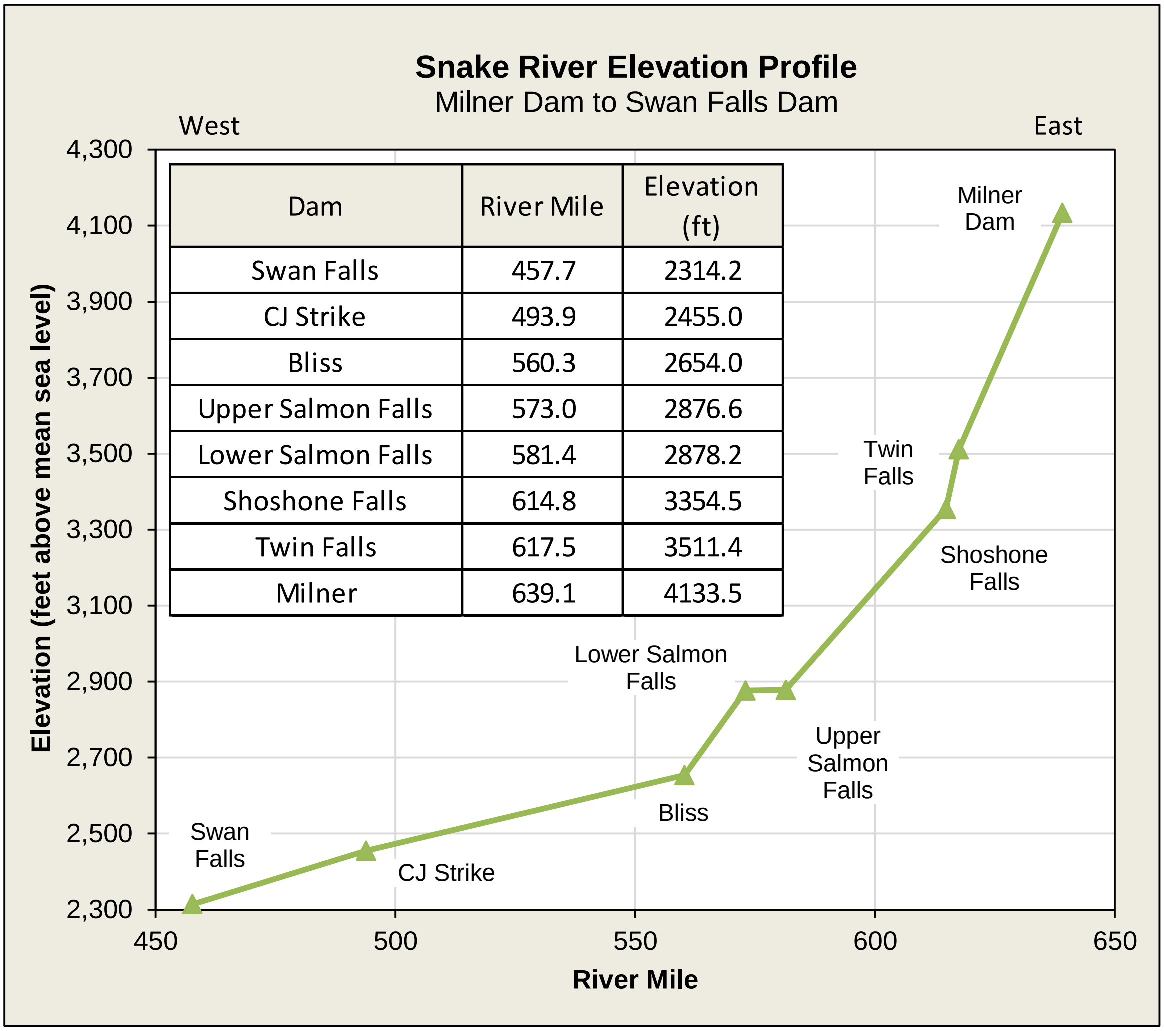
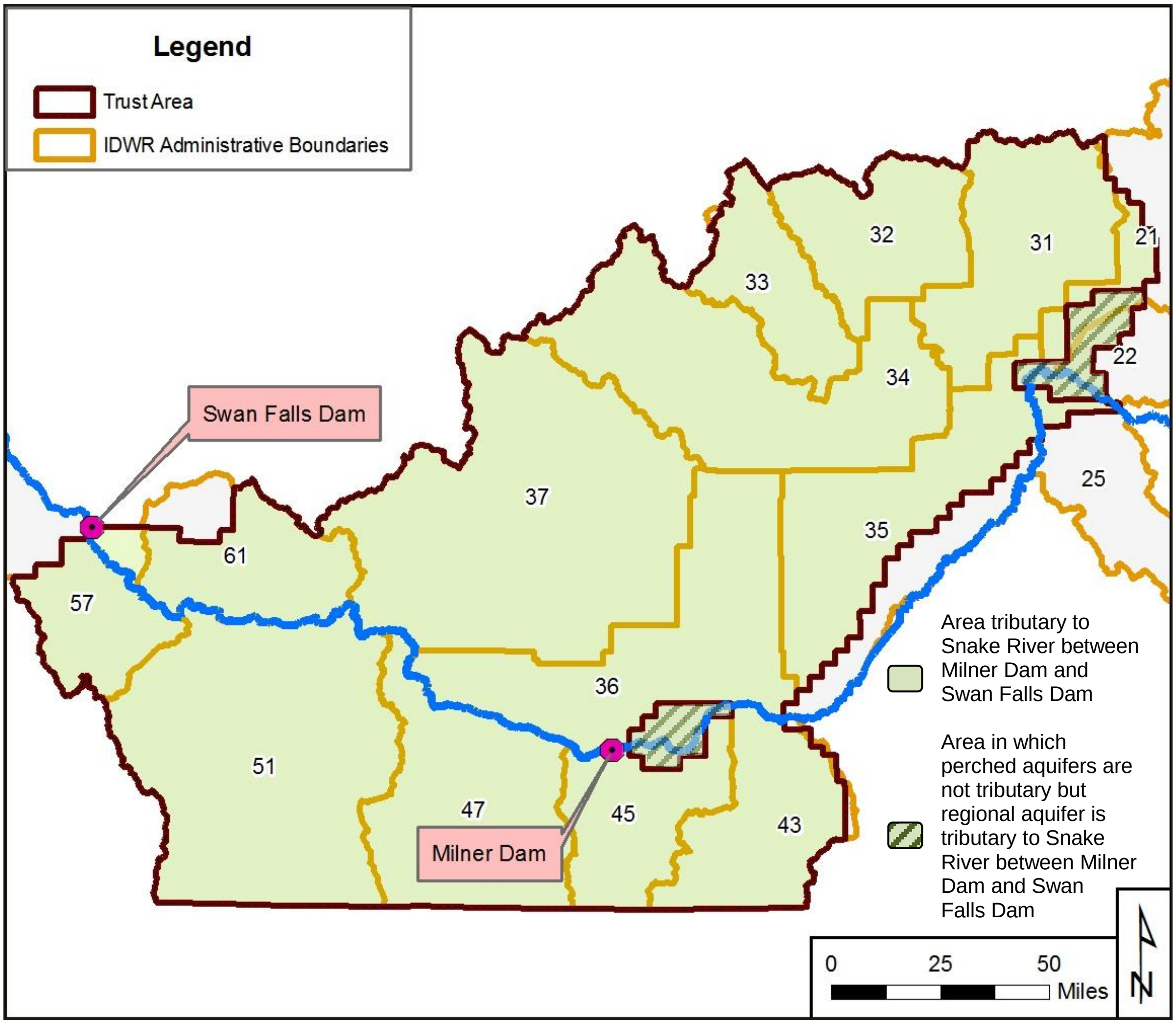


Figure 2. Snake River between Milner Dam and the Murphy Gaging Station.



Dam	River Mile	Elevation (ft)
Swan Falls	457.7	2314.2
CJ Strike	493.9	2455.0
Bliss	560.3	2654.0
Upper Salmon Falls	573.0	2876.6
Lower Salmon Falls	581.4	2878.2
Shoshone Falls	614.8	3354.5
Twin Falls	617.5	3511.4
Milner	639.1	4133.5

Figure 3. Snake River elevation profile.



Source: IDAPA 37.03.08.030 and IDWR GIS shapefiles.

Figure 4. Eastern Snake River Plain administrative basins and Trust Area.

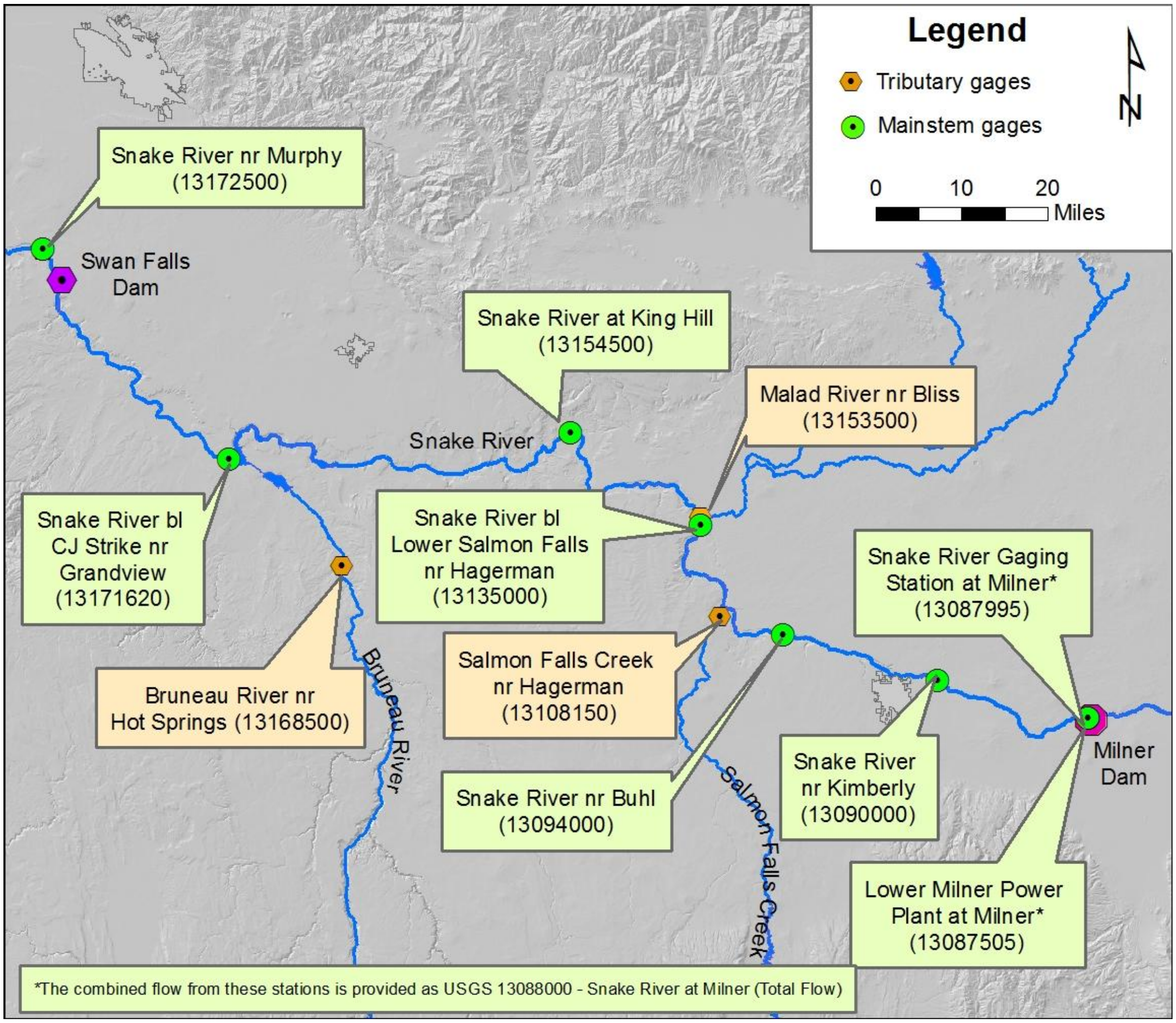


Figure 5. Snake River streamflow gaging locations, Milner Dam to Murphy Gaging Station.

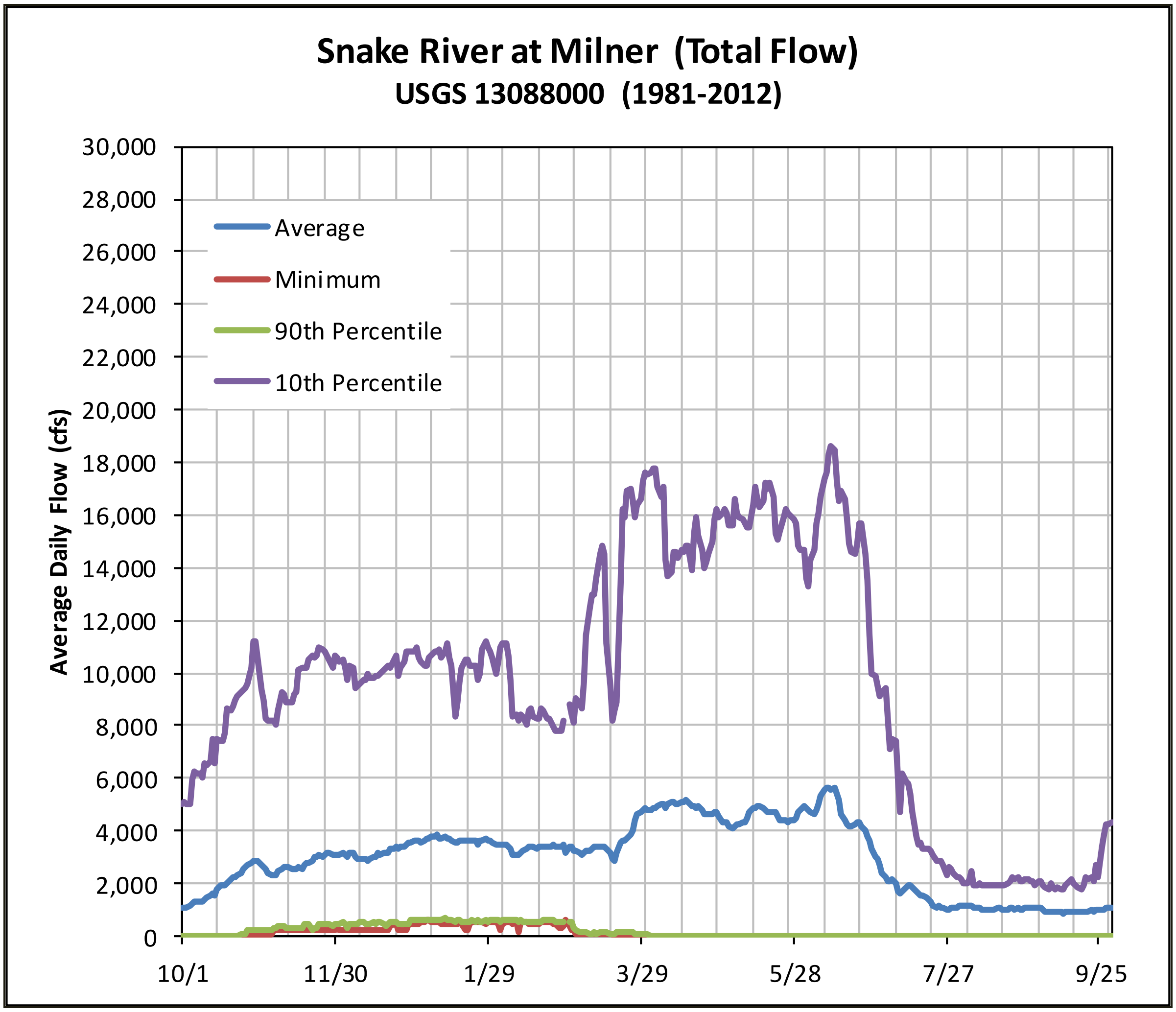


Figure 6. Snake River streamflow below Milner Dam, 1981-2012.

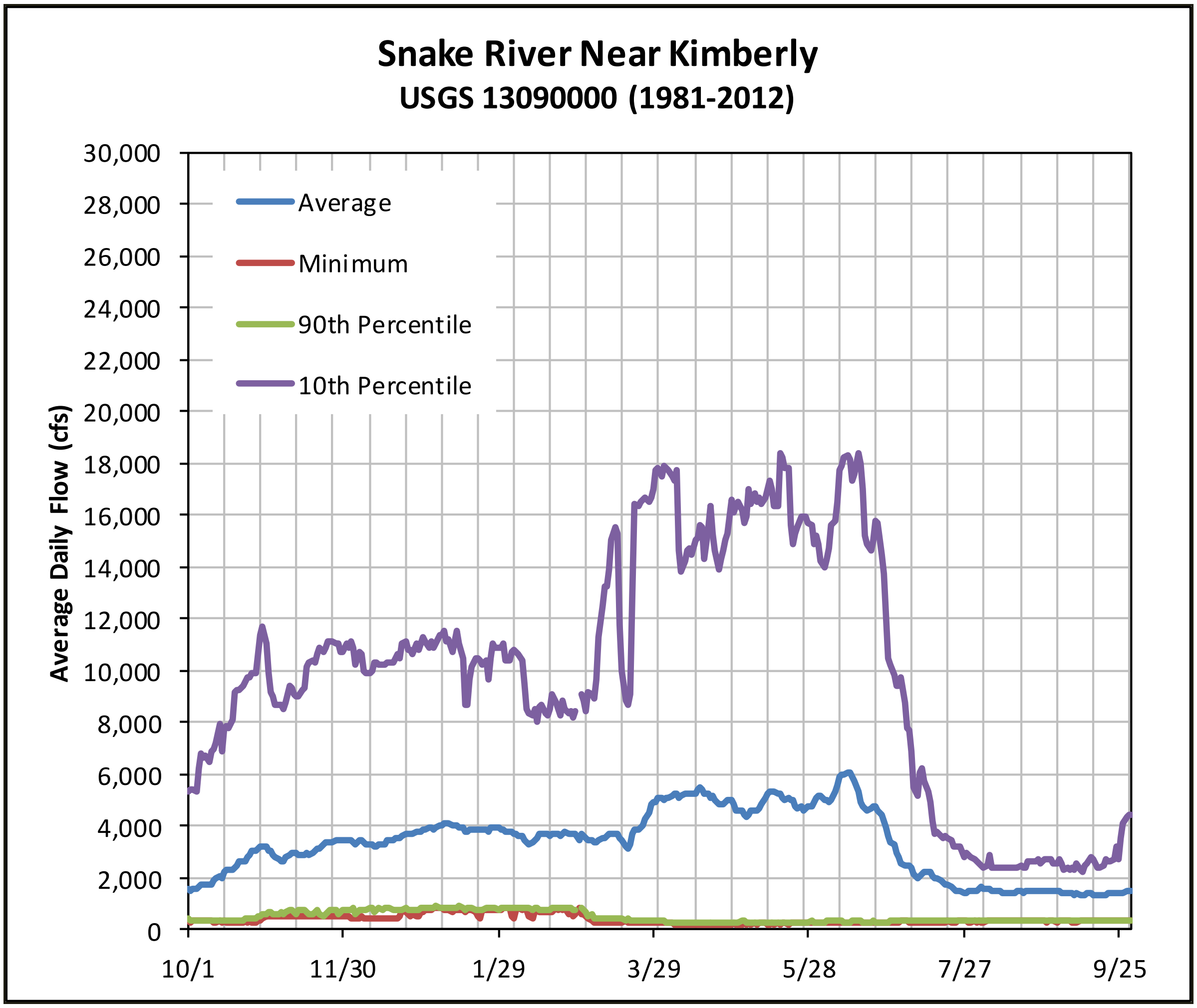


Figure 7. Snake River streamflow near Kimberly, 1981-2012.

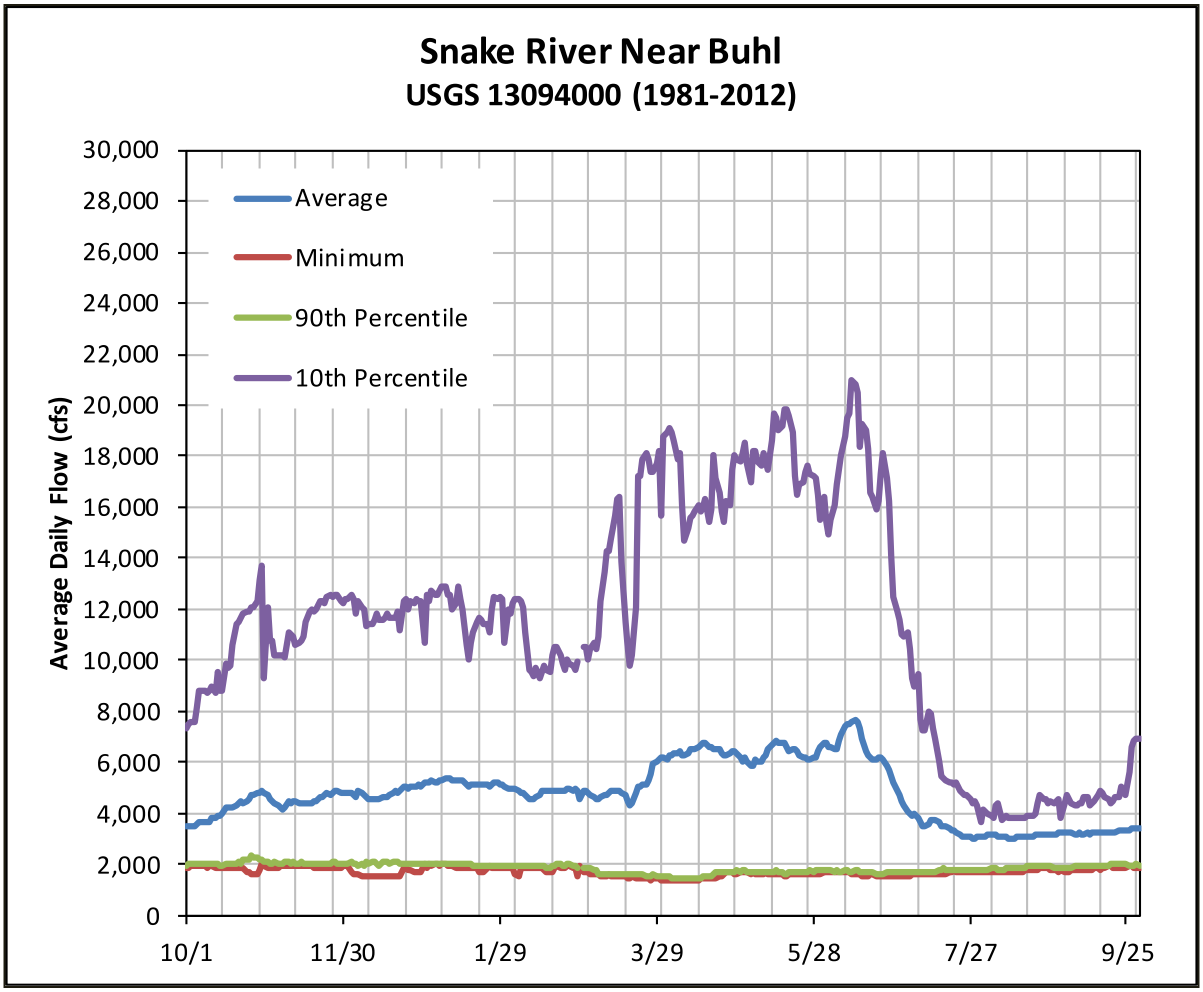


Figure 8. Snake River streamflow near Buhl, 1981-2012.

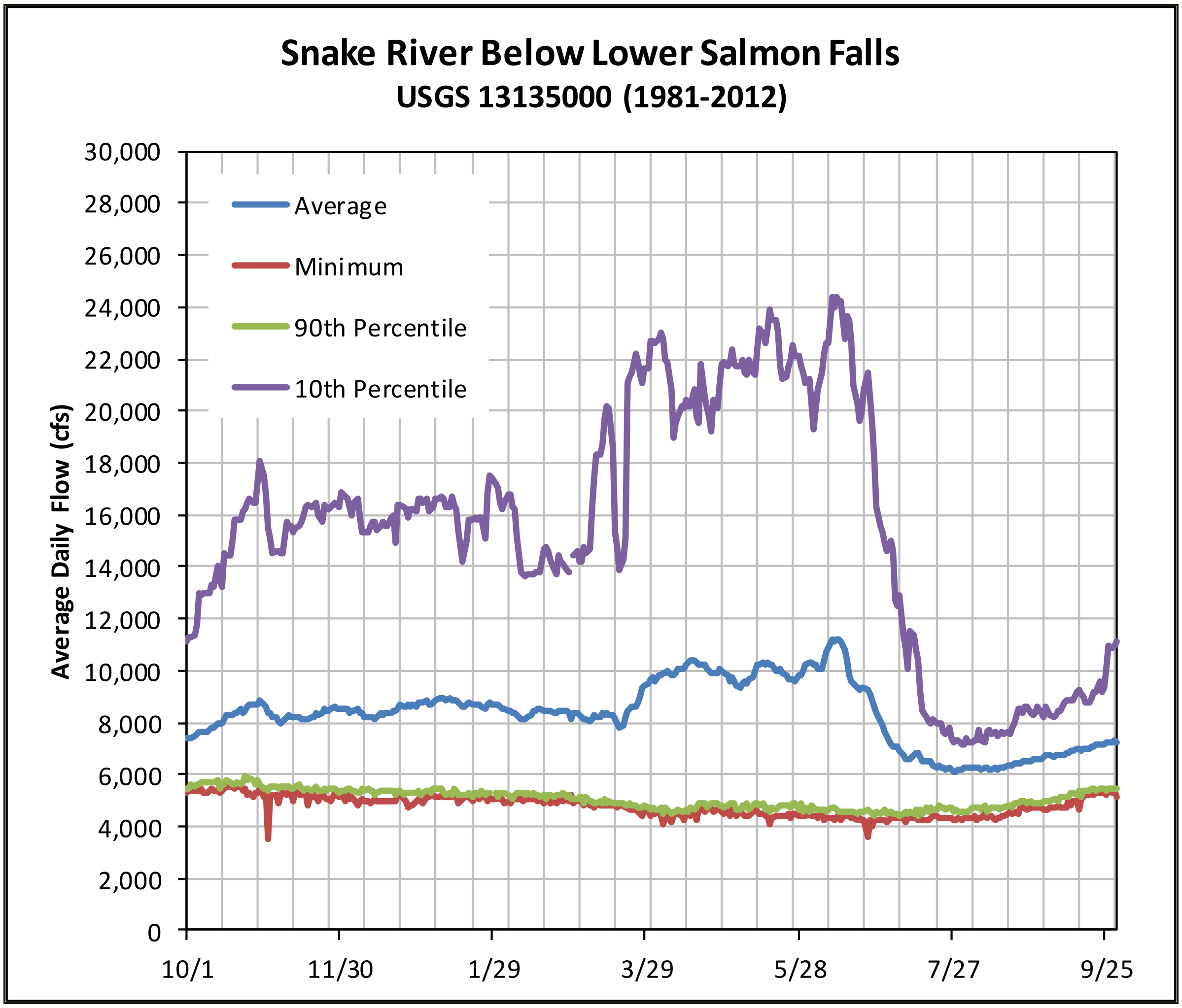


Figure 9. Snake River streamflow below Lower Salmon Falls near Hagerman, 1981-2012.

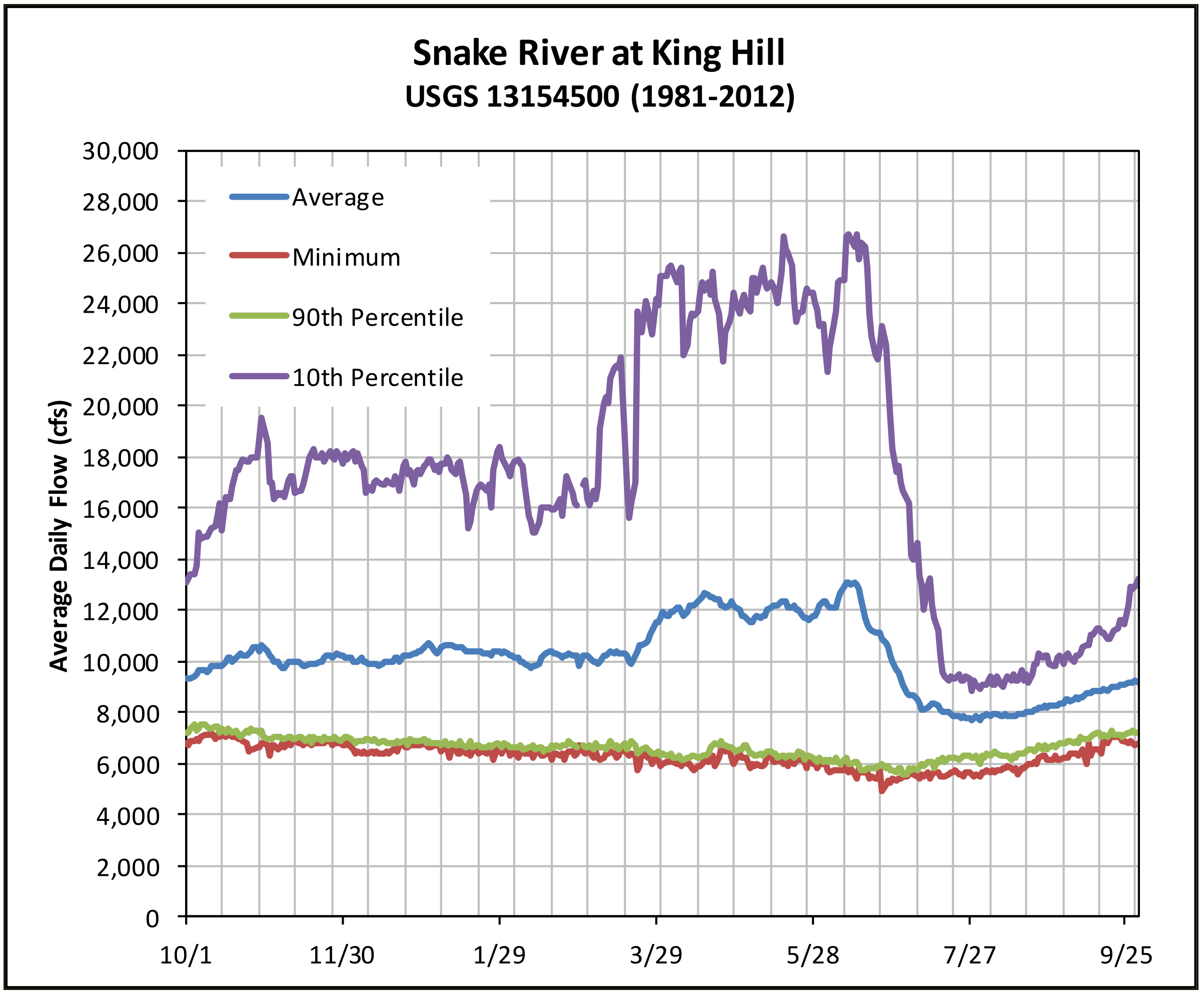


Figure 10. Snake River streamflow at King Hill, 1981-2012.

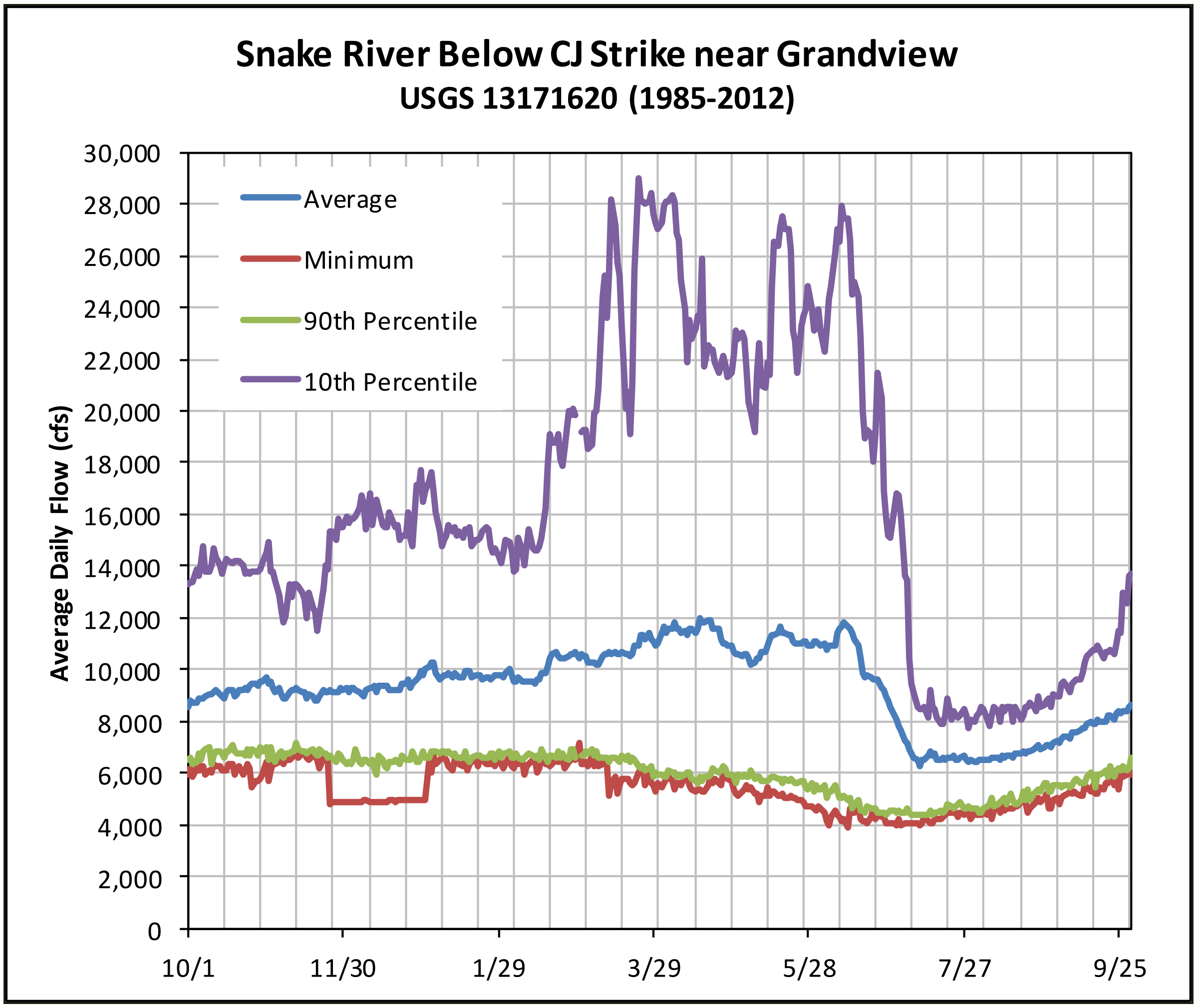


Figure 11. Snake River streamflow below CJ Strike near Grandview, 1981-2012.

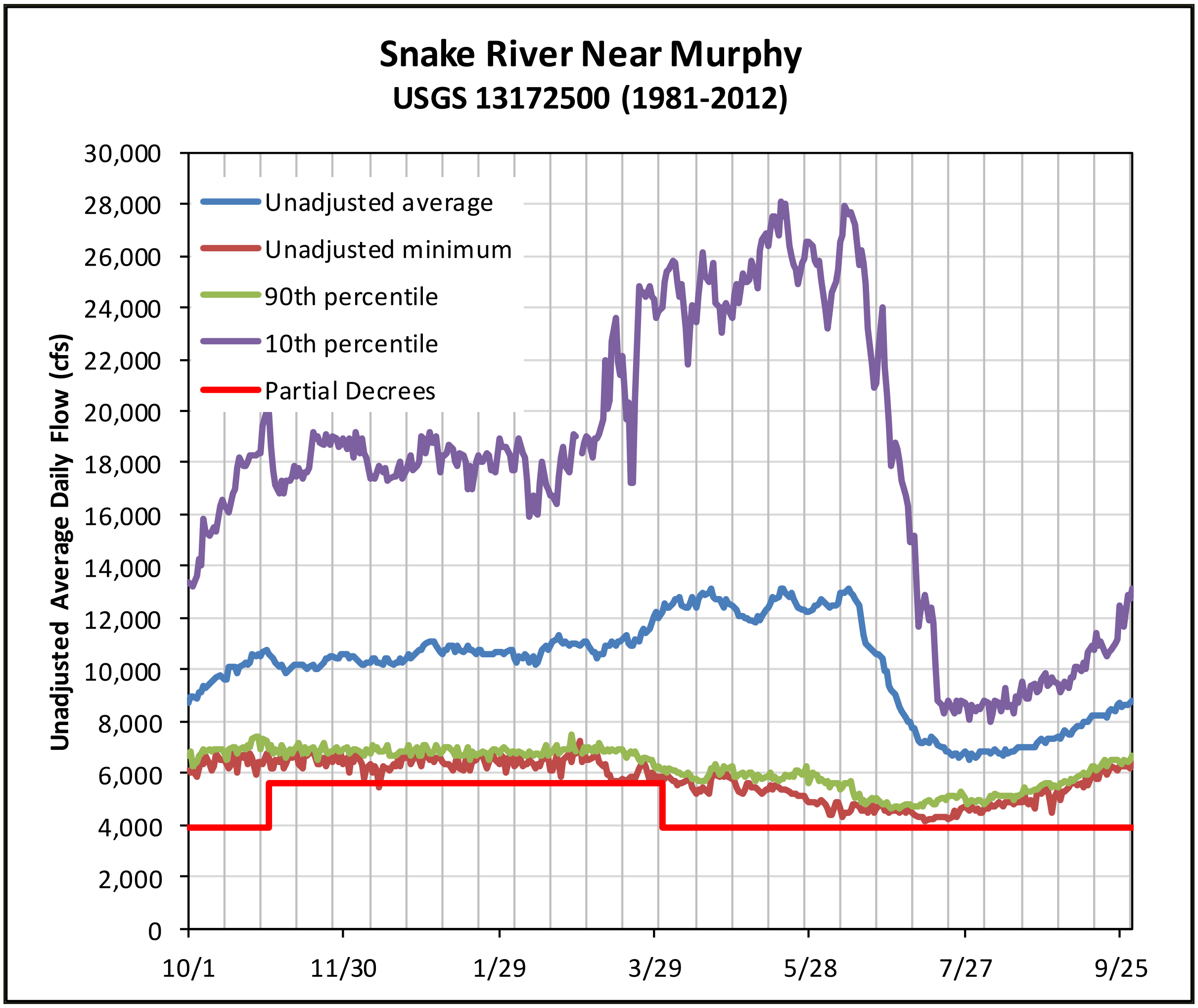


Figure 12. Snake River streamflow near Murphy (i.e., Murphy Gaging Station), 1981-2012 (full scale).

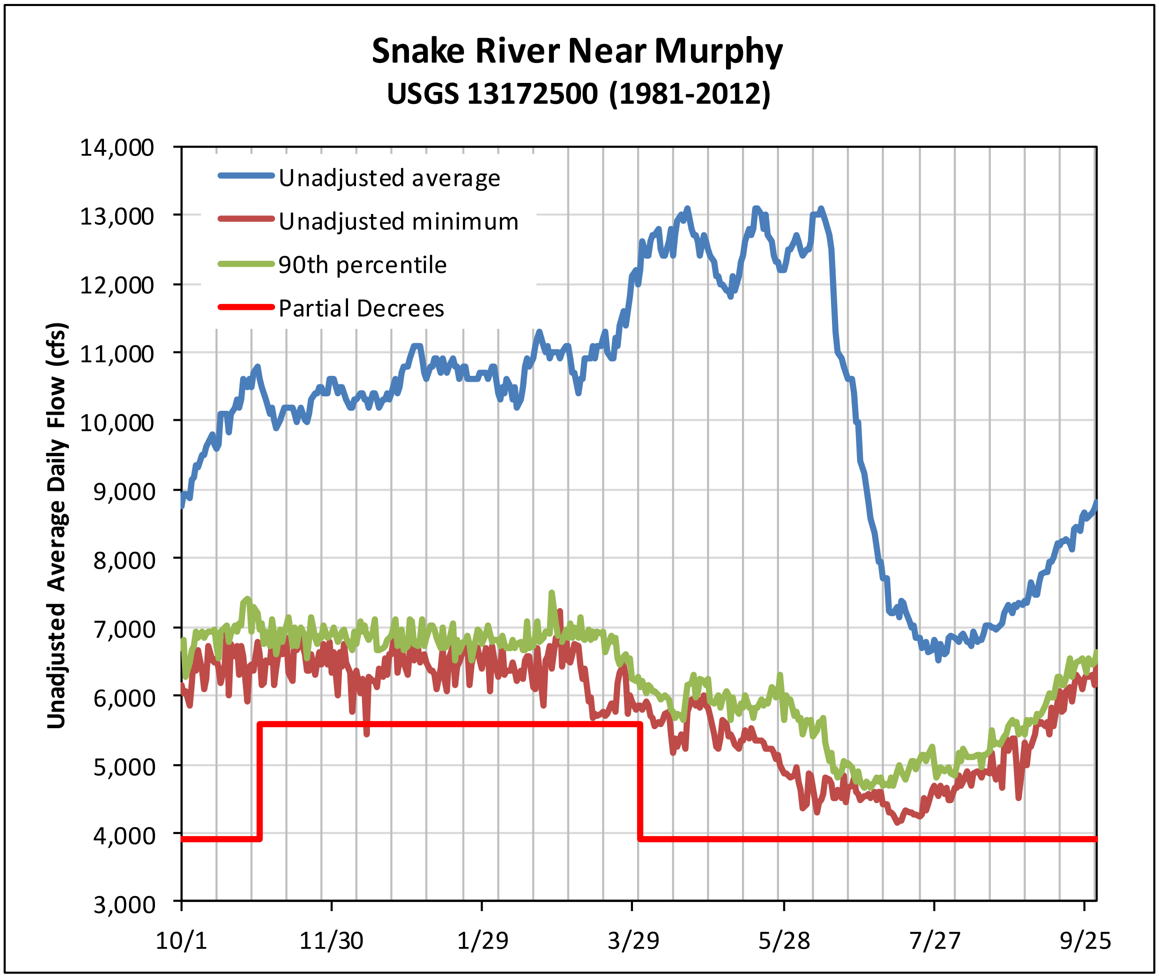


Figure 13. Snake River streamflow near Murphy (i.e., Murphy Gaging Station), 1981-2012 (partial scale).

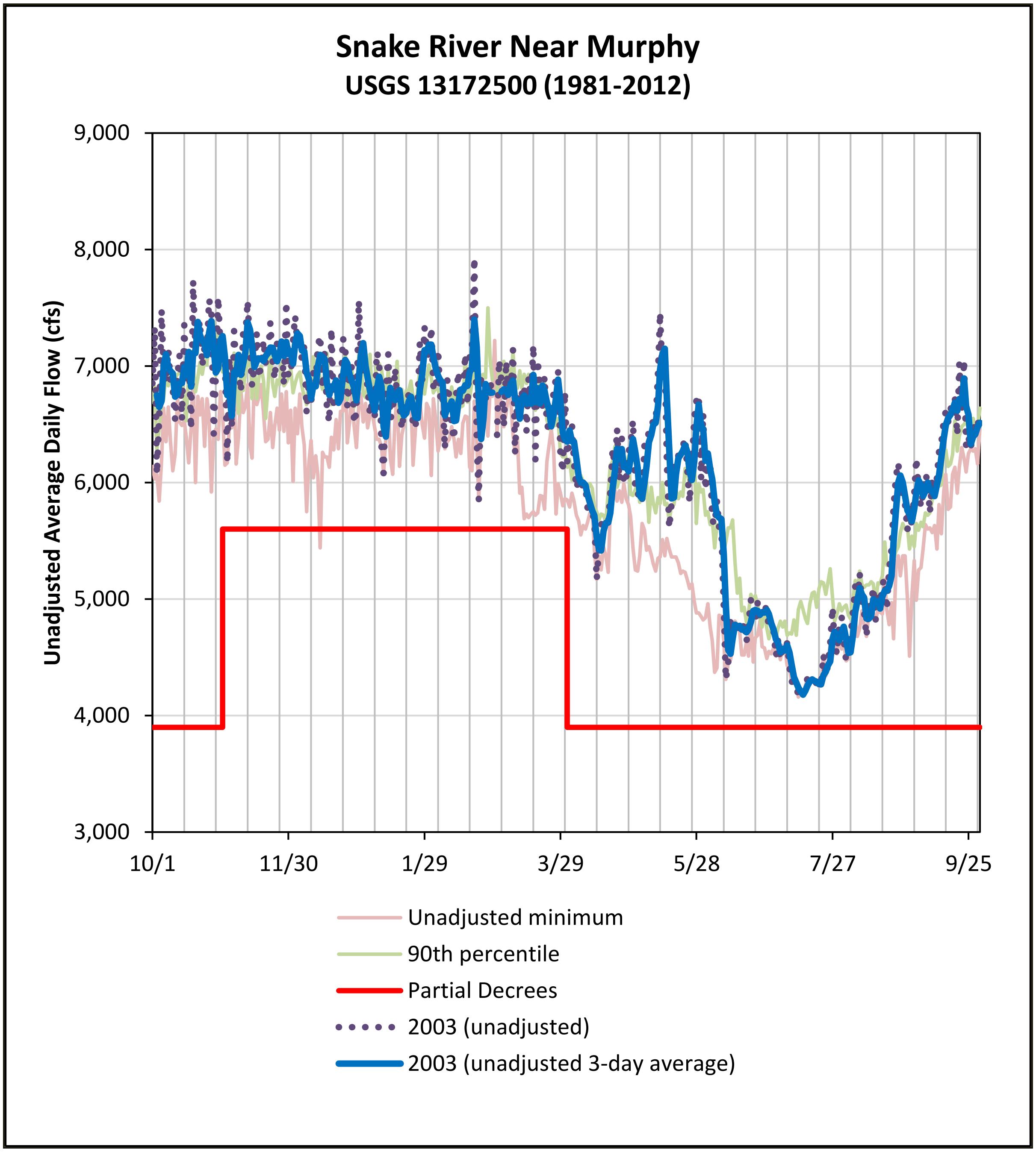


Figure 14. Snake River streamflow near Murphy, 2003 (with 1981-2012 90th percentile and minimum flows).

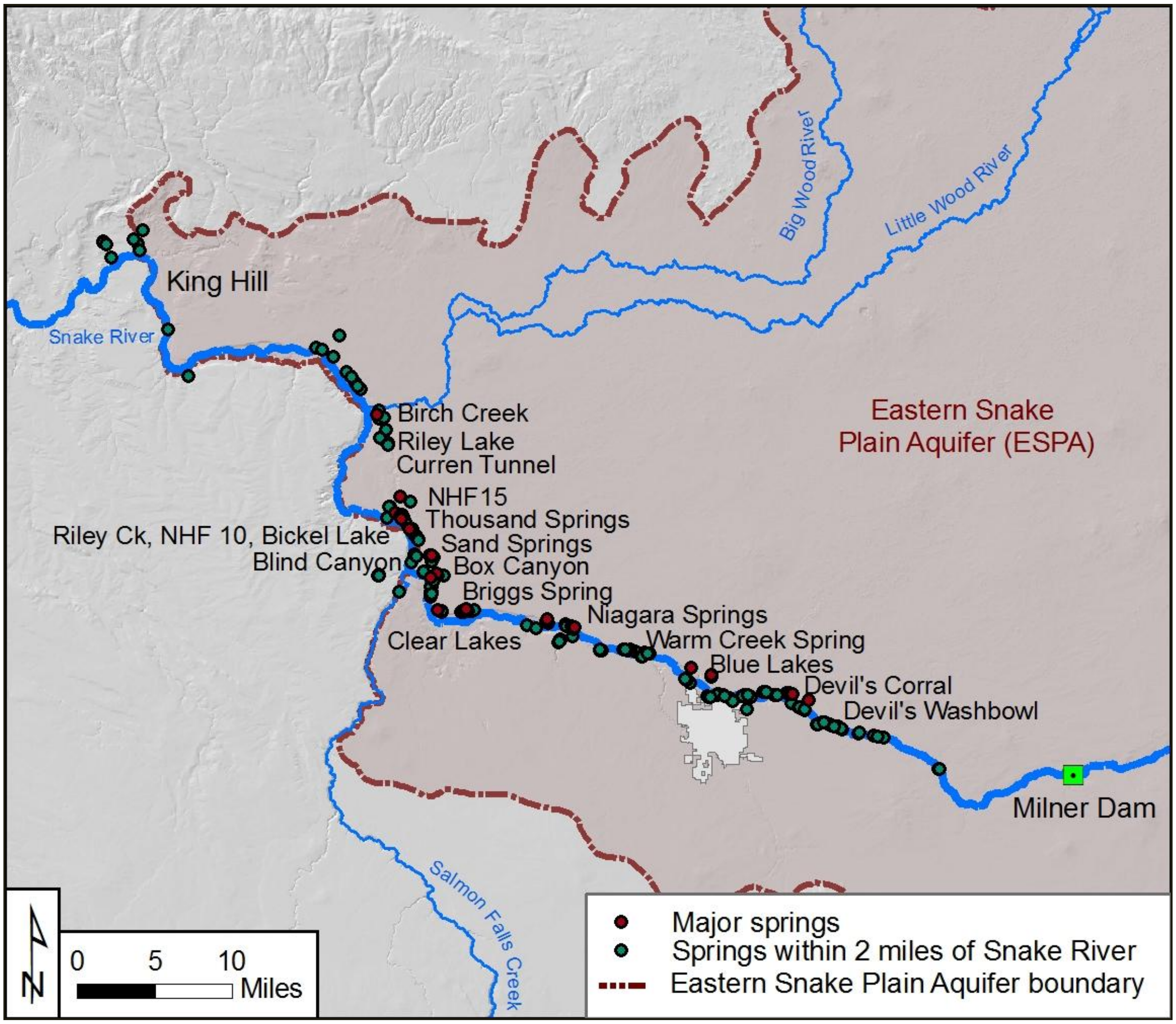


Figure 15. Major springs in the Milner Dam to King Hill reach of the Snake River.

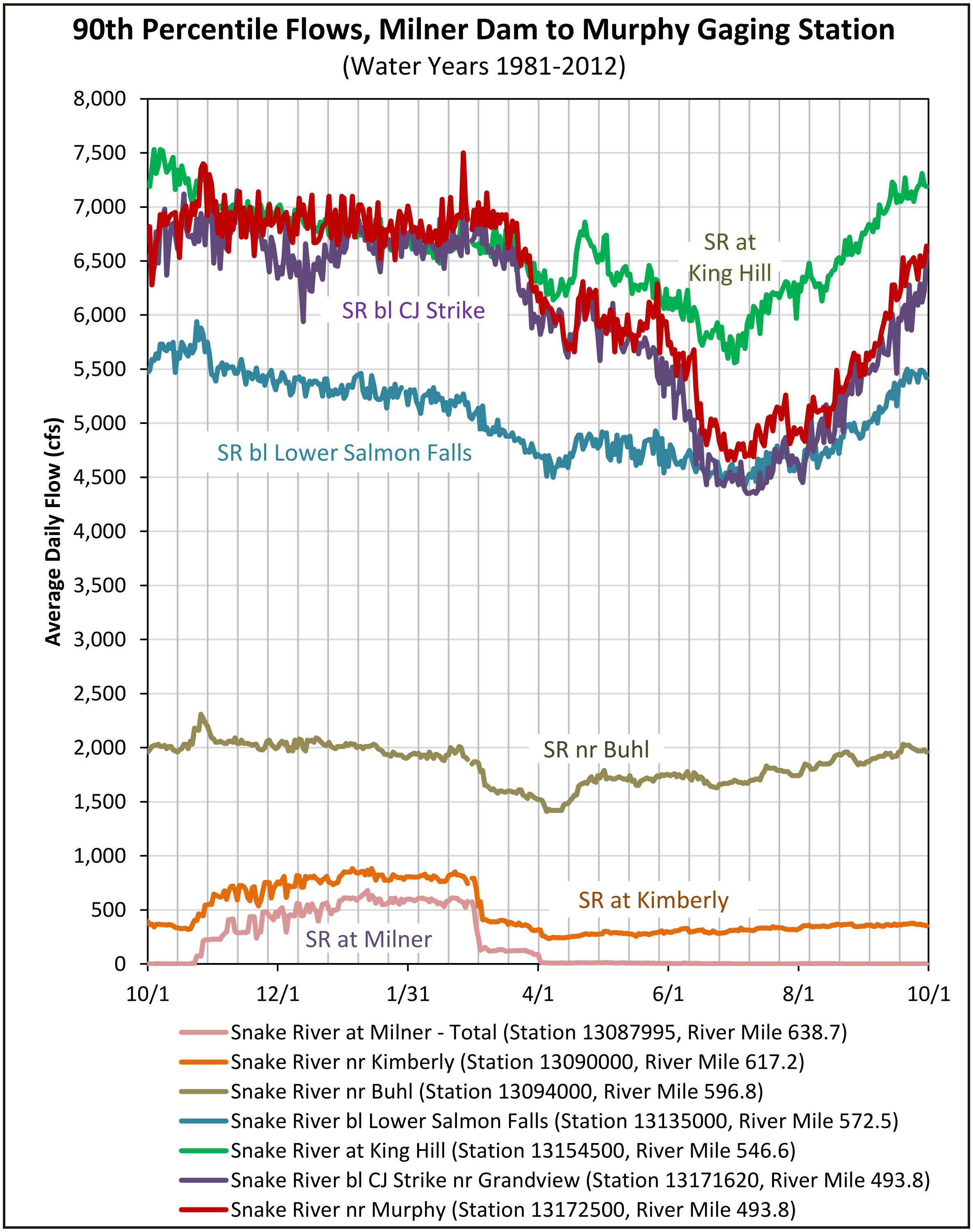


Figure 16. 90th percentile streamflow, Milner Dam to Murphy Gaging Station, water years 1981-2012.

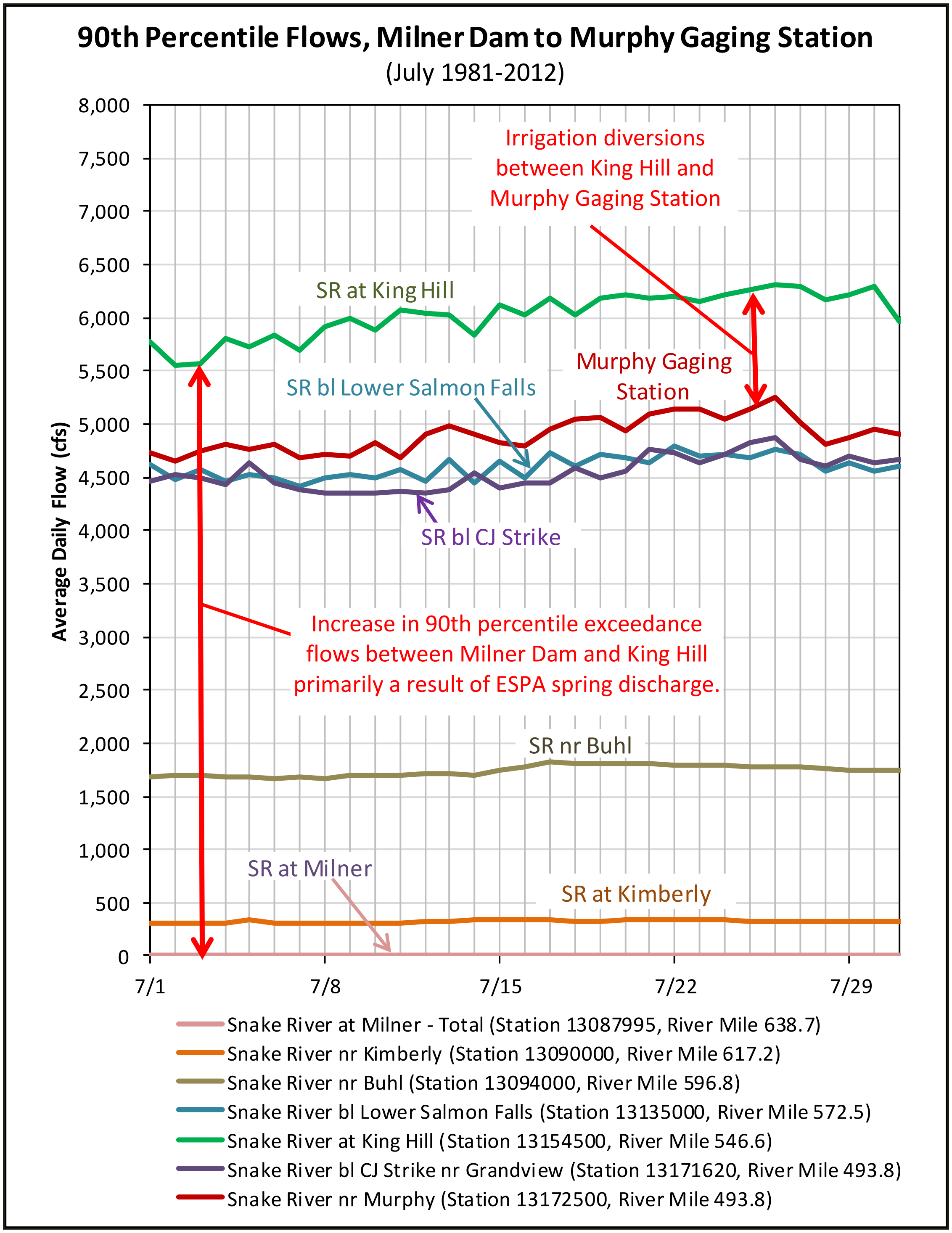


Figure 17. 90th percentile streamflow, Milner Dam to Murphy Gaging Station, July 1981-2012.

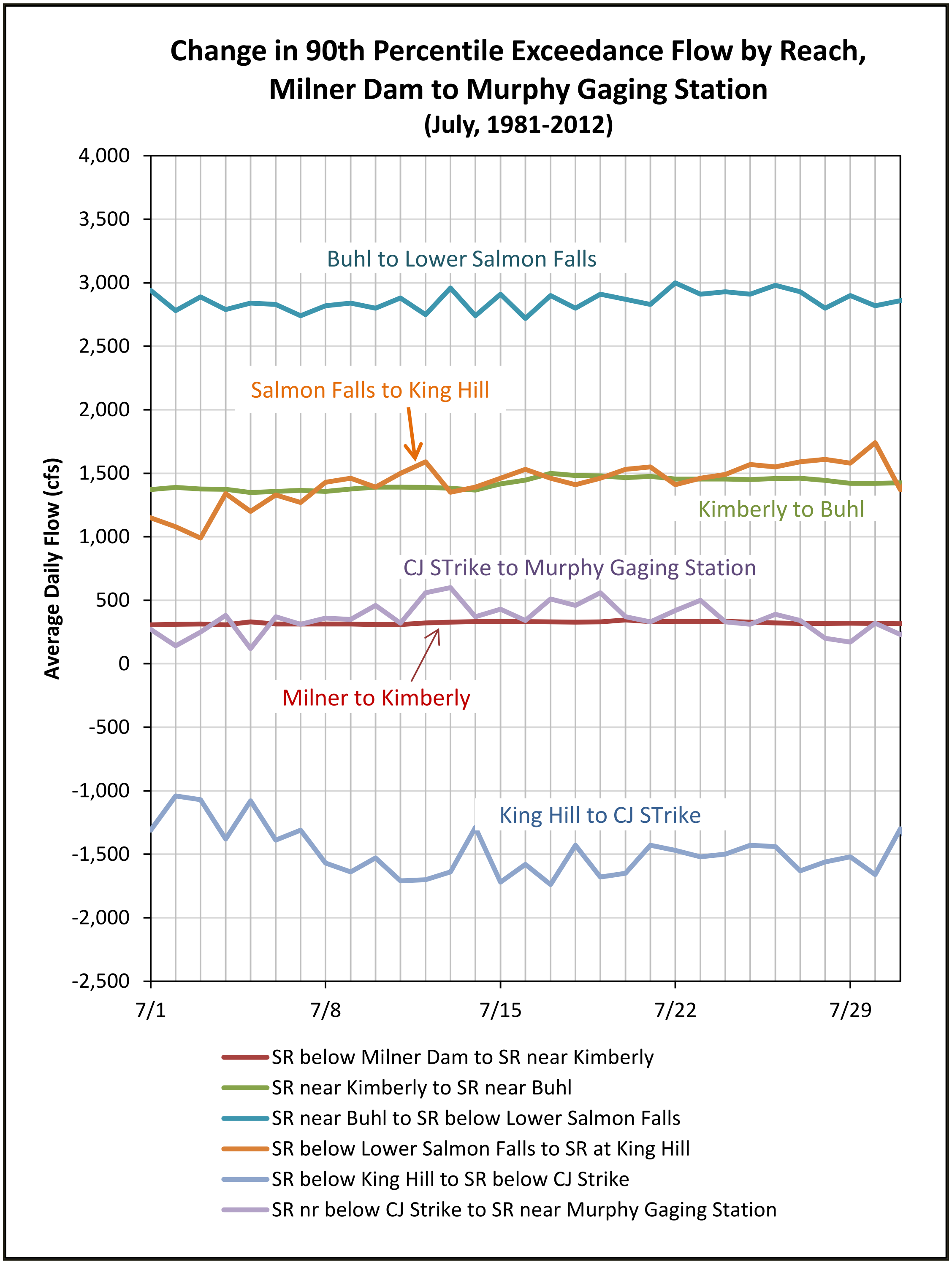
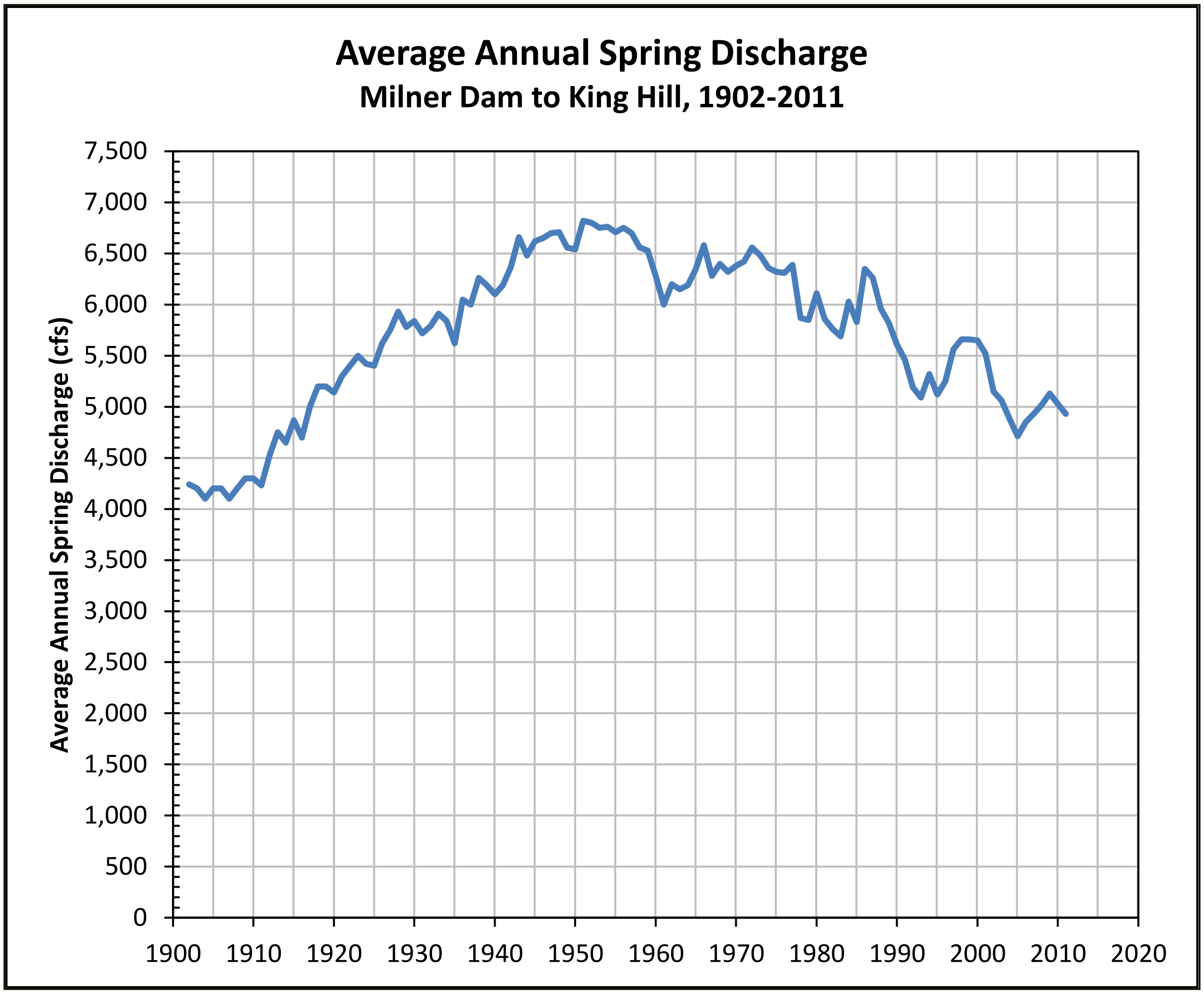


Figure 18. Change in 90th percentile exceedance flows by reach, Milner Dam to Murphy Gaging Station, 1981-2012.



IDWR data, based on Kjelstrom method (Kjelstrom, 1995).

Figure 19. Estimated annual spring discharge to Snake River between Milner Dam and King Hill.

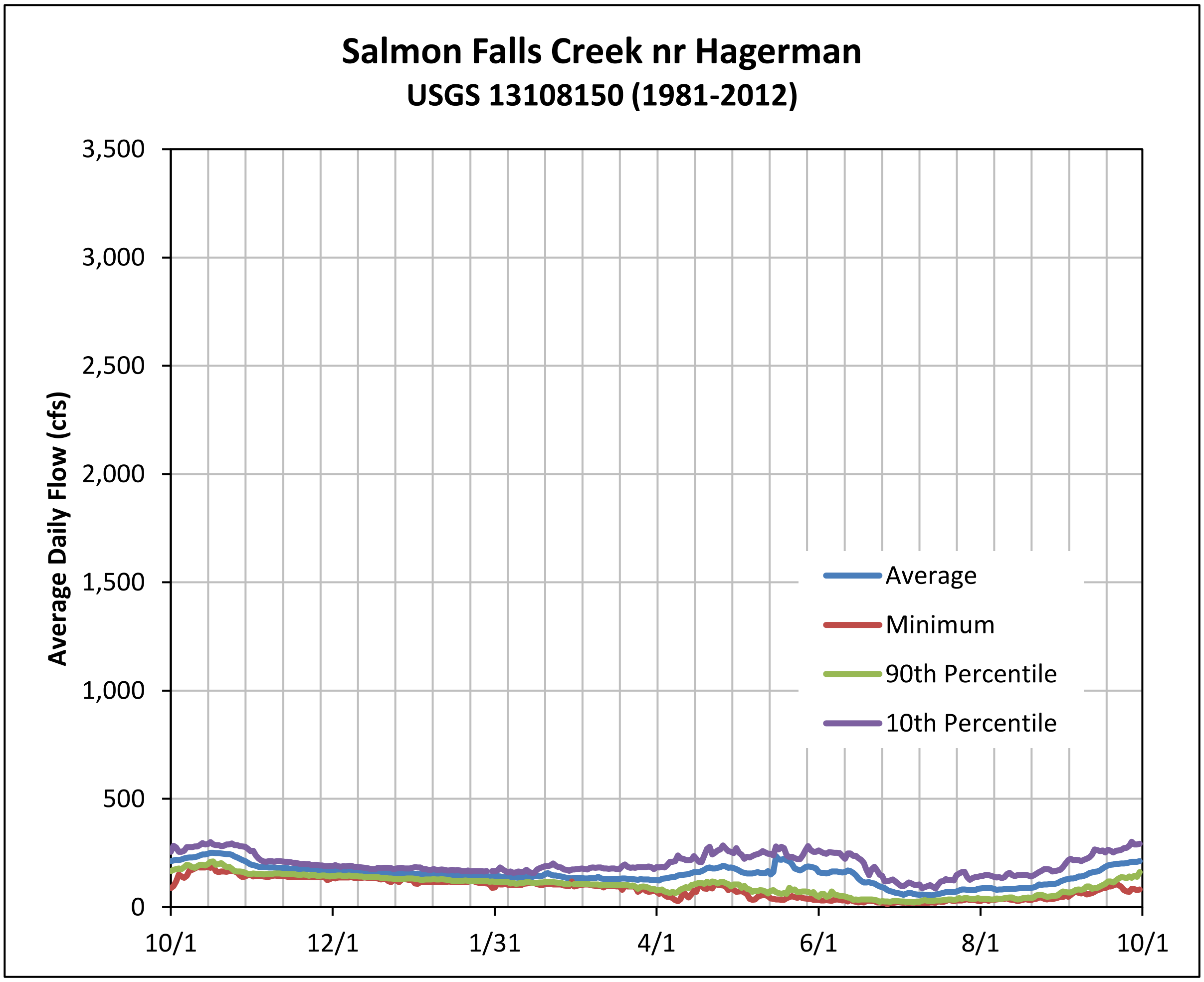


Figure 20. Salmon Falls Creek near Hagerman, 1981-2012.

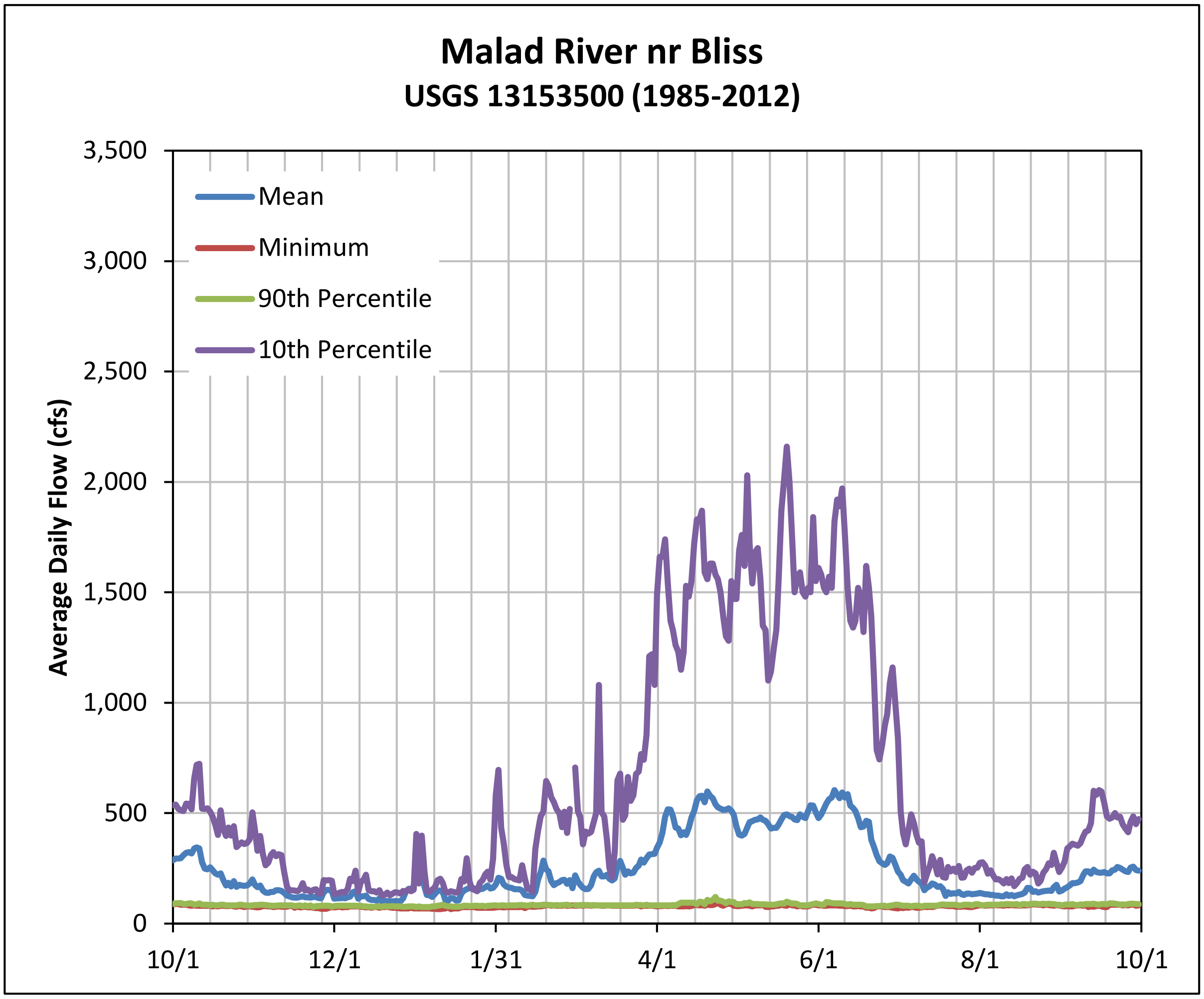


Figure 21. Malad River near Bliss streamflow, 1985-2012.

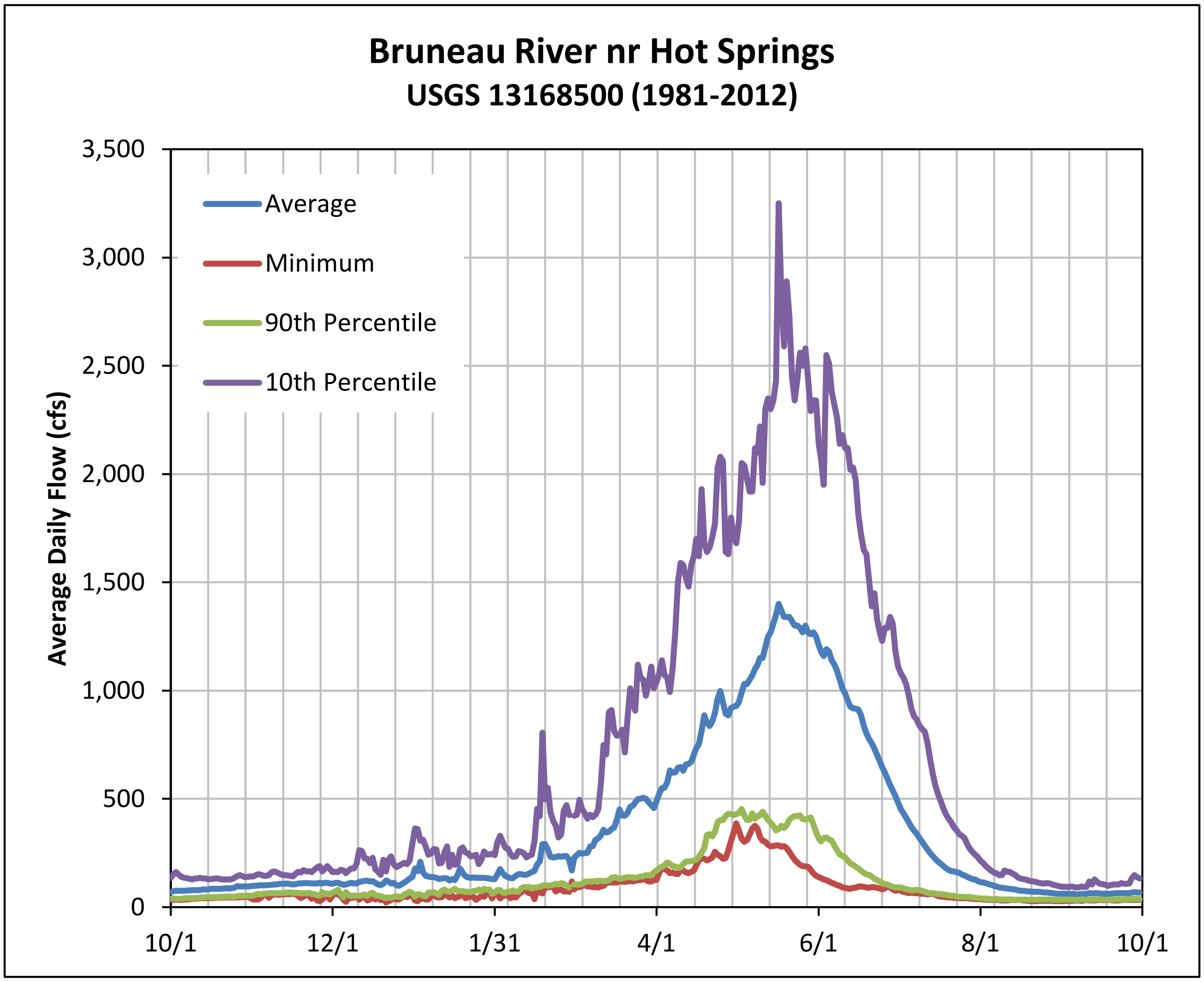
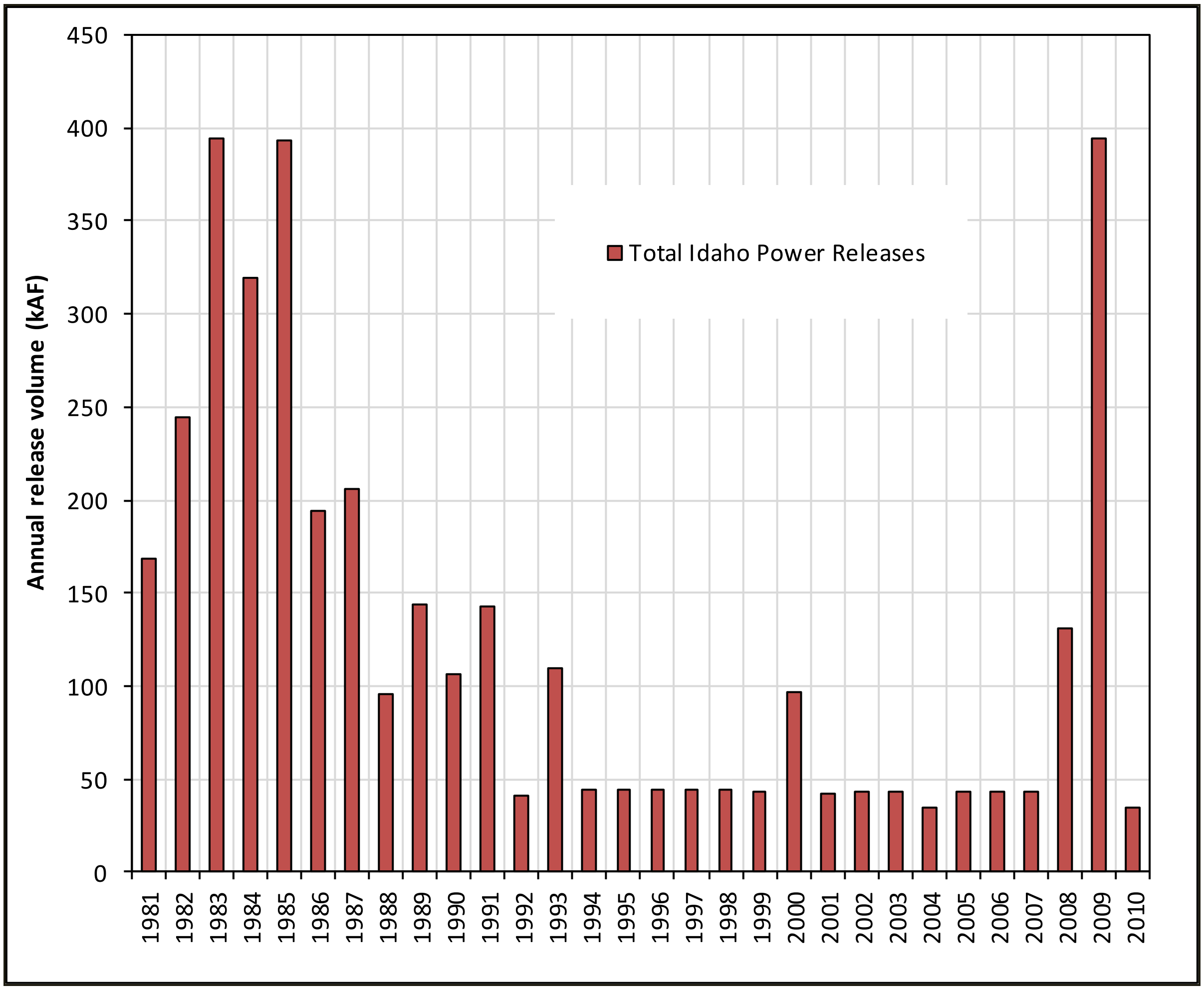
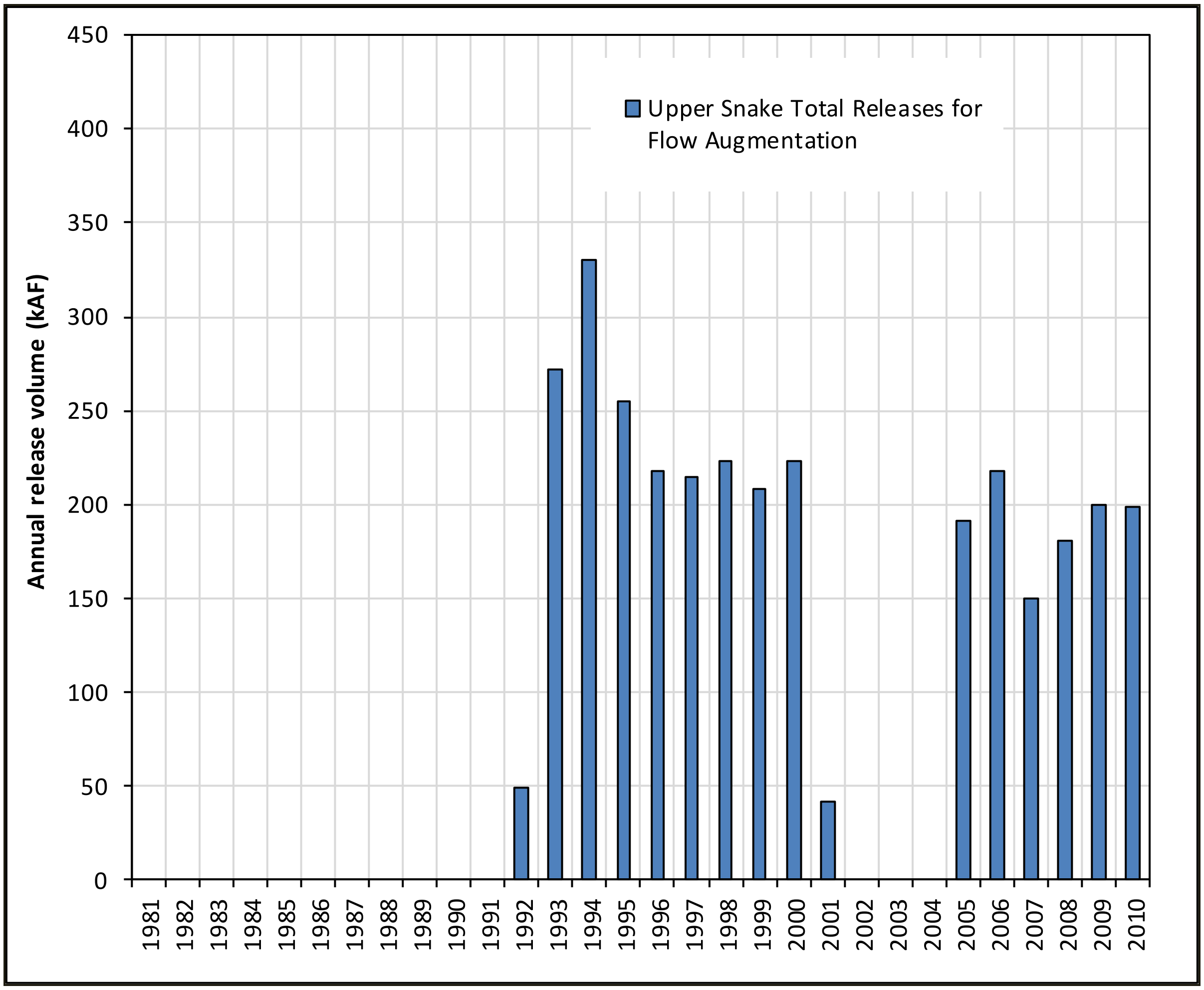


Figure 22. Bruneau River near Hot Springs streamflow, 1981-2012.



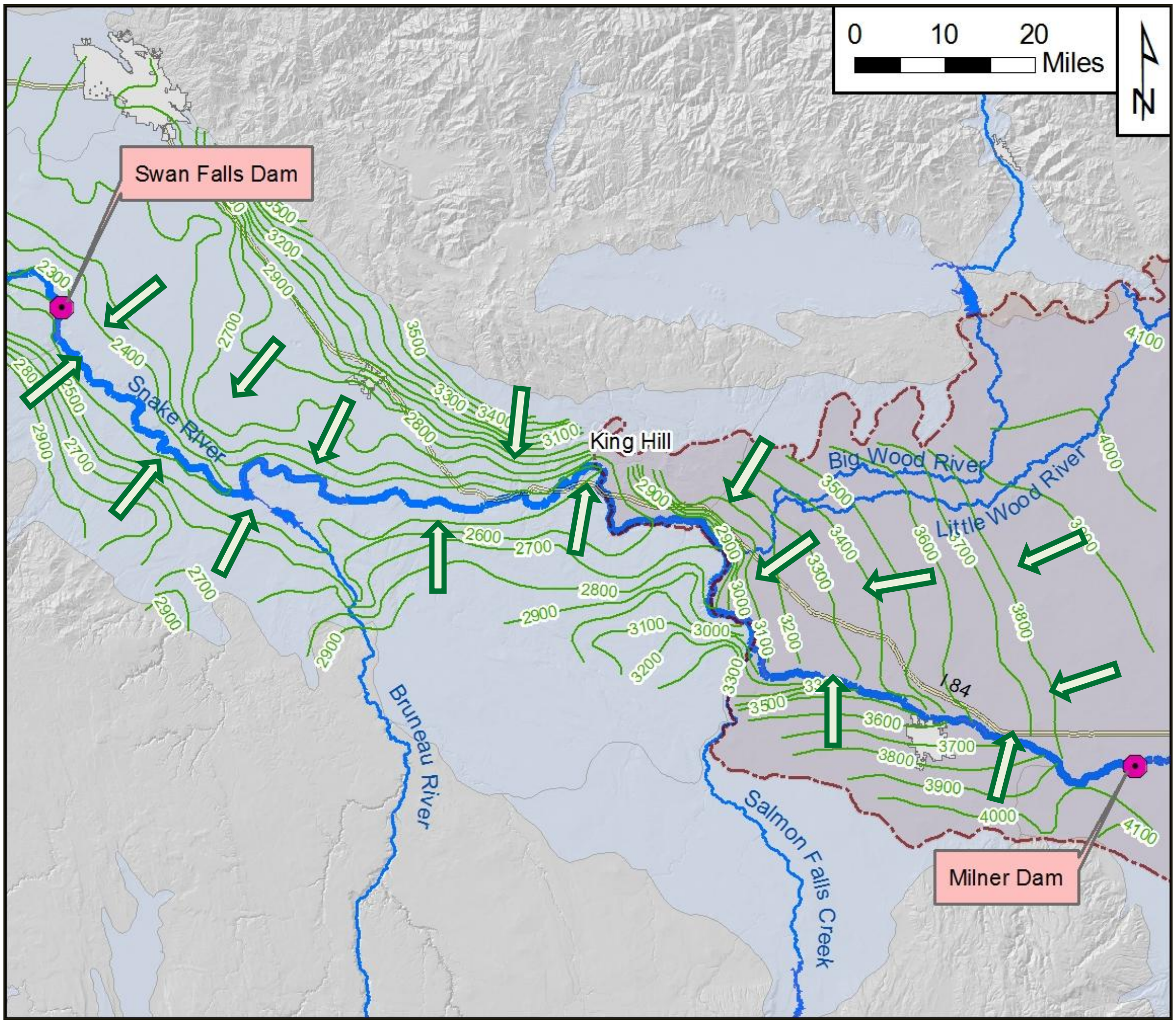
Note: Releases of the volumes shown in this graph are considered “fluctuations” resulting from Idaho Power operations.

Figure 23. Idaho Power releases from upstream of Milner Dam passing through the Milner Dam to Murphy Gaging Station reach, 1981-2010.



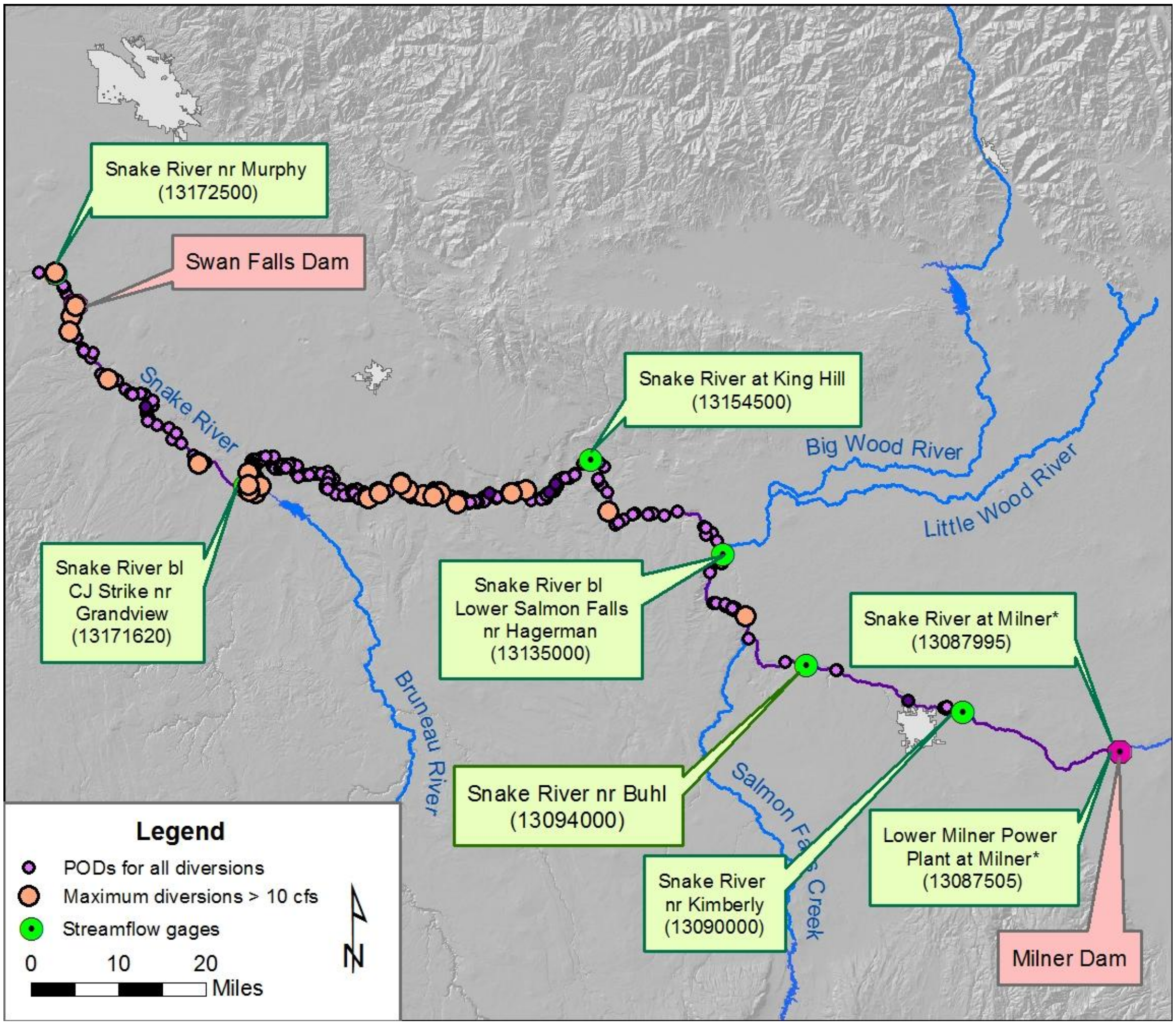
Note: these releases are *not* considered "fluctuations" resulting from Idaho Power operations.

Figure 24. Flow augmentation releases passing through the Milner Dam to Murphy Gaging Station reach, 1981-2010.



Groundwater-elevation contours adapted from Lindohlm et al. (1988).

Figure 25. Regional groundwater flow direction.



Note: Federal stock water rights authorizing diversions of 0.02 cfs or less are not displayed.

Figure 26. Snake River diversions between Milner Dam and Murphy Gaging Station.

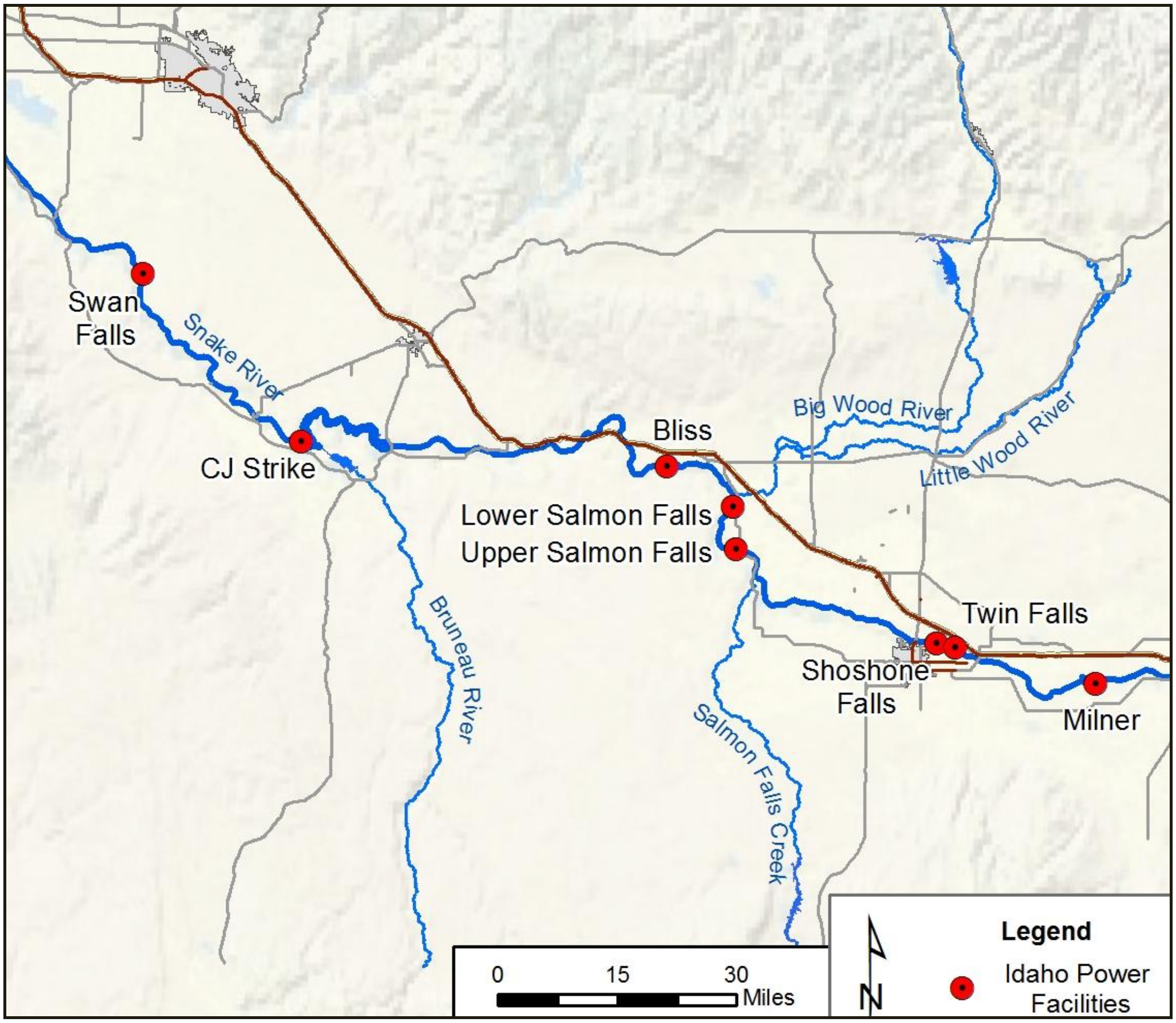
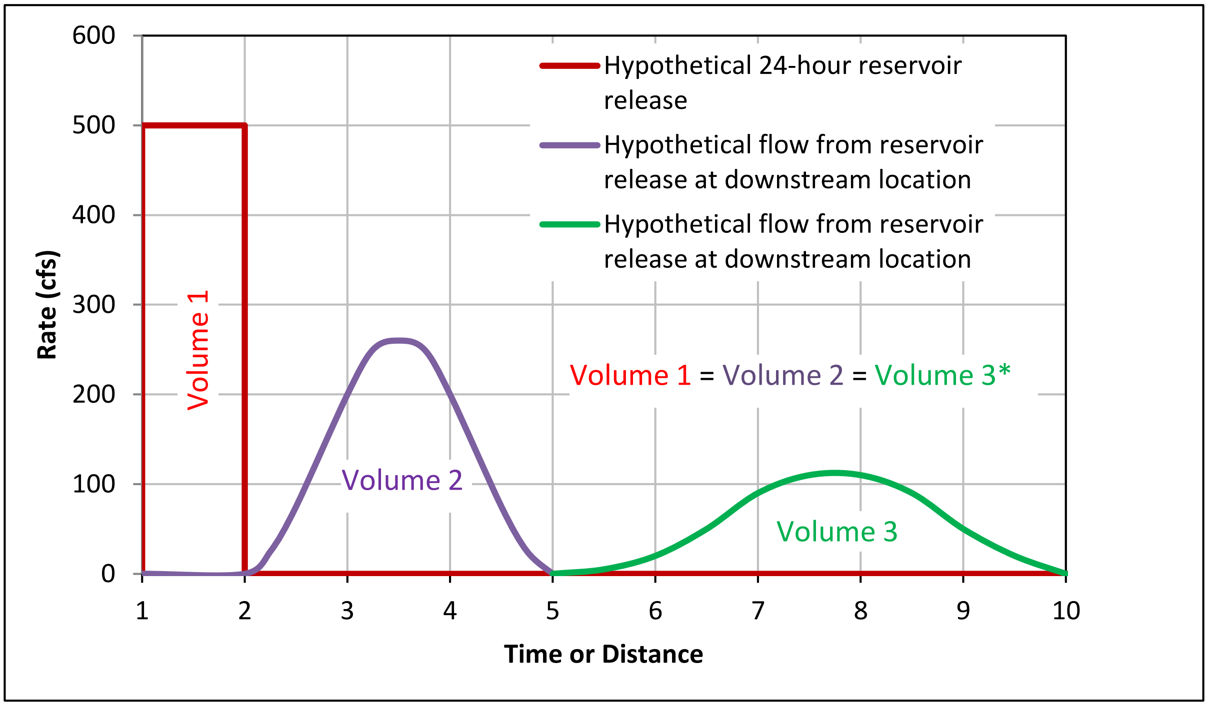


Figure 27. Map showing Idaho Power facilities along the Snake River between Milner Dam and Swan Falls Dam.



* Diversions and/or consumptive losses will reduce volume with time and distance. Also, bank storage effects may distort the hypothetical lag and attenuation illustrated above.

Figure 28. Hydrographs illustrating lag and attenuation of a hypothetical 500 cfs reservoir release.

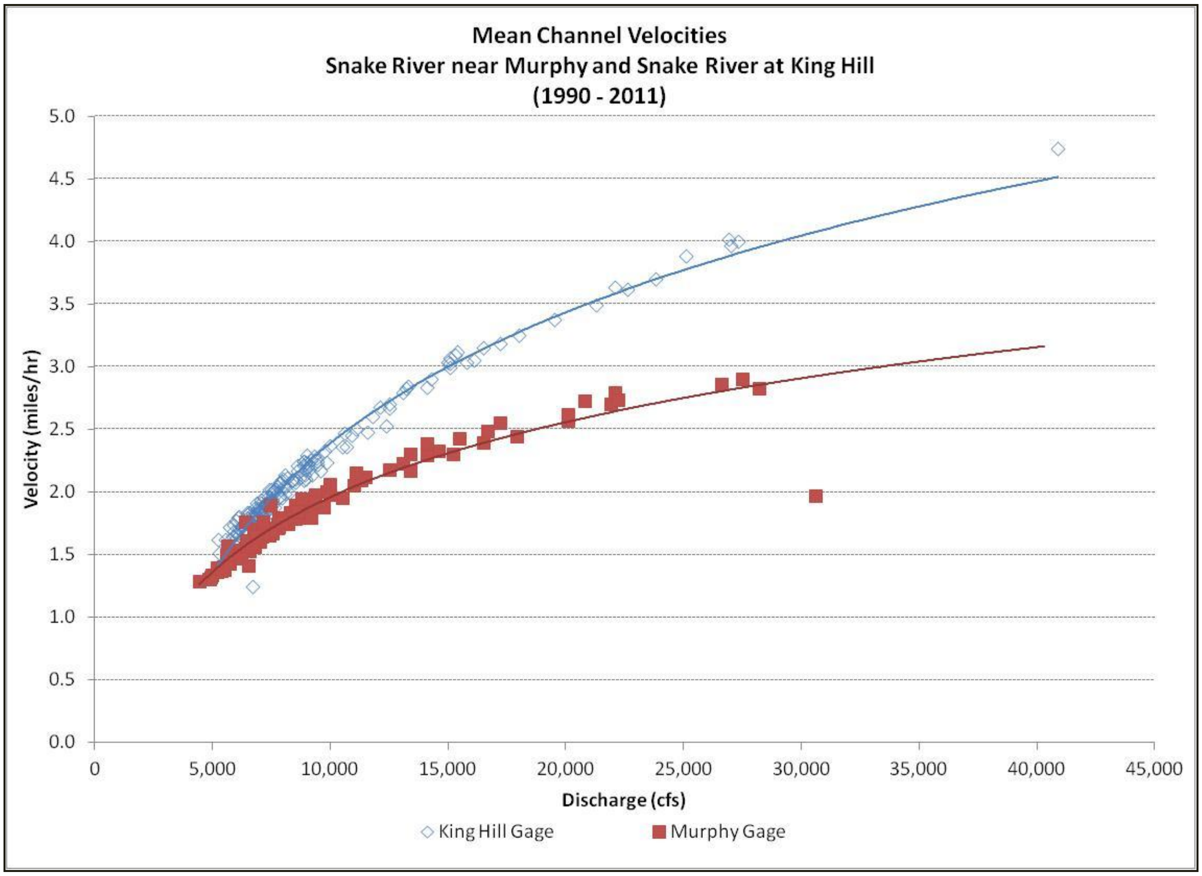


Figure 29. Mean channel velocity versus discharge at near Murphy and King Hill gages (Data provided by Kay Lehmann, USGS, Boise, Idaho).

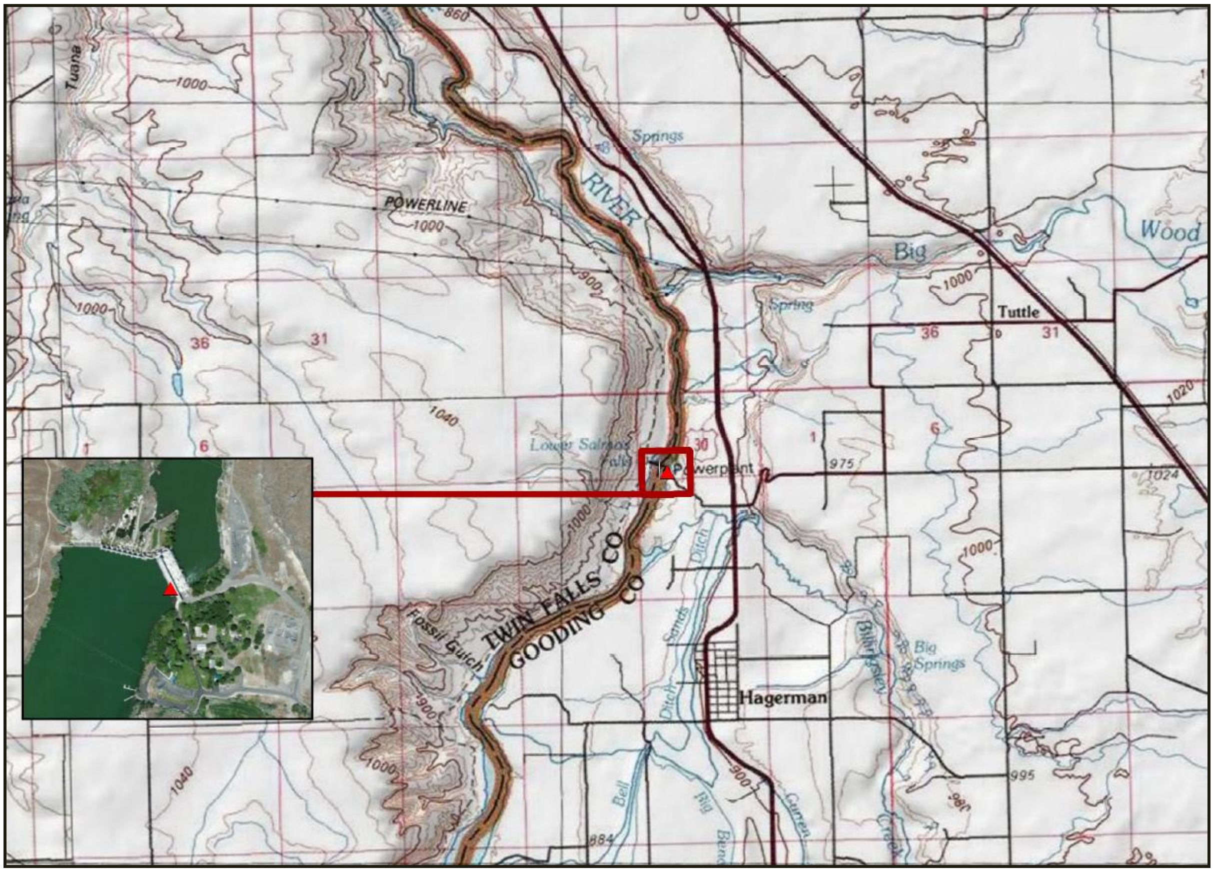


Figure 30. Reservoir stage-gaging location (Lower Salmon Reservoir).

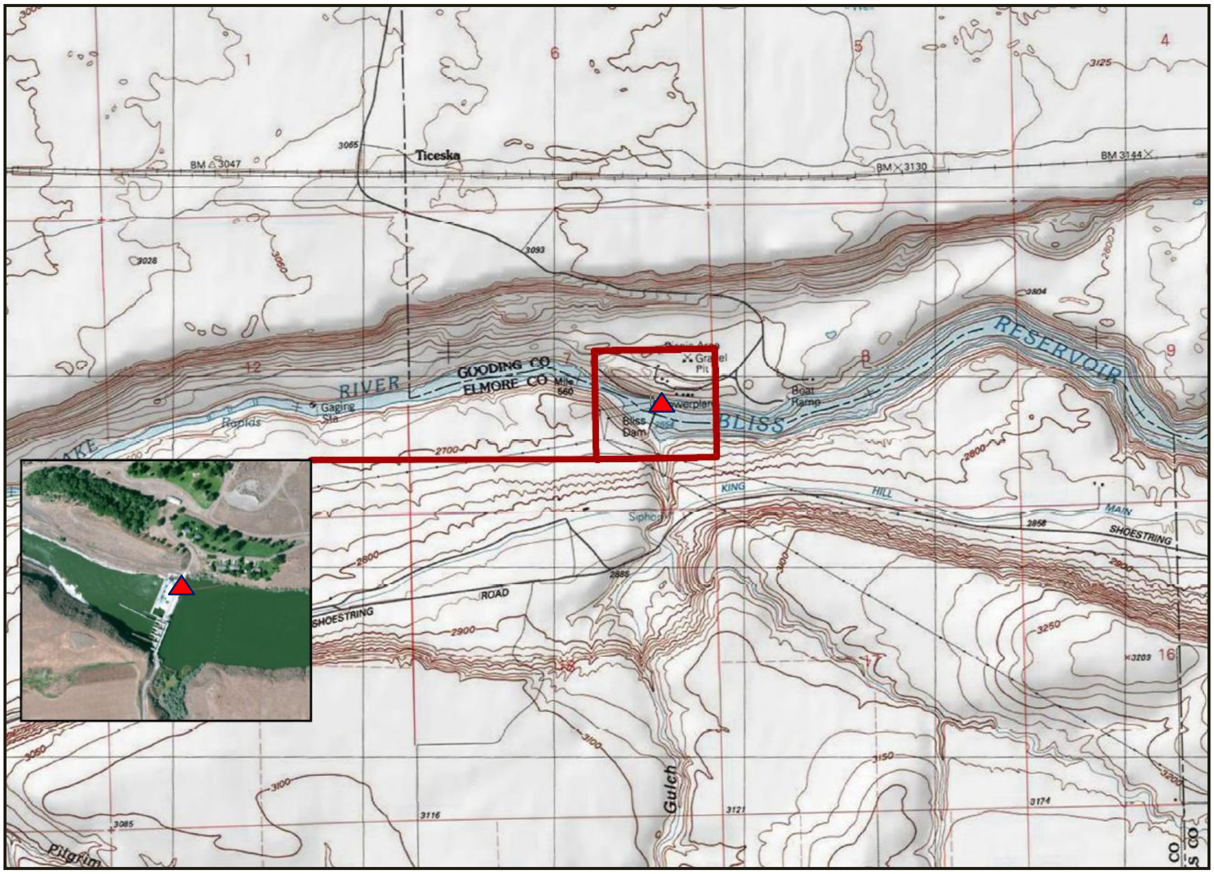


Figure 31. Reservoir stage-gaging location (Bliss Reservoir).

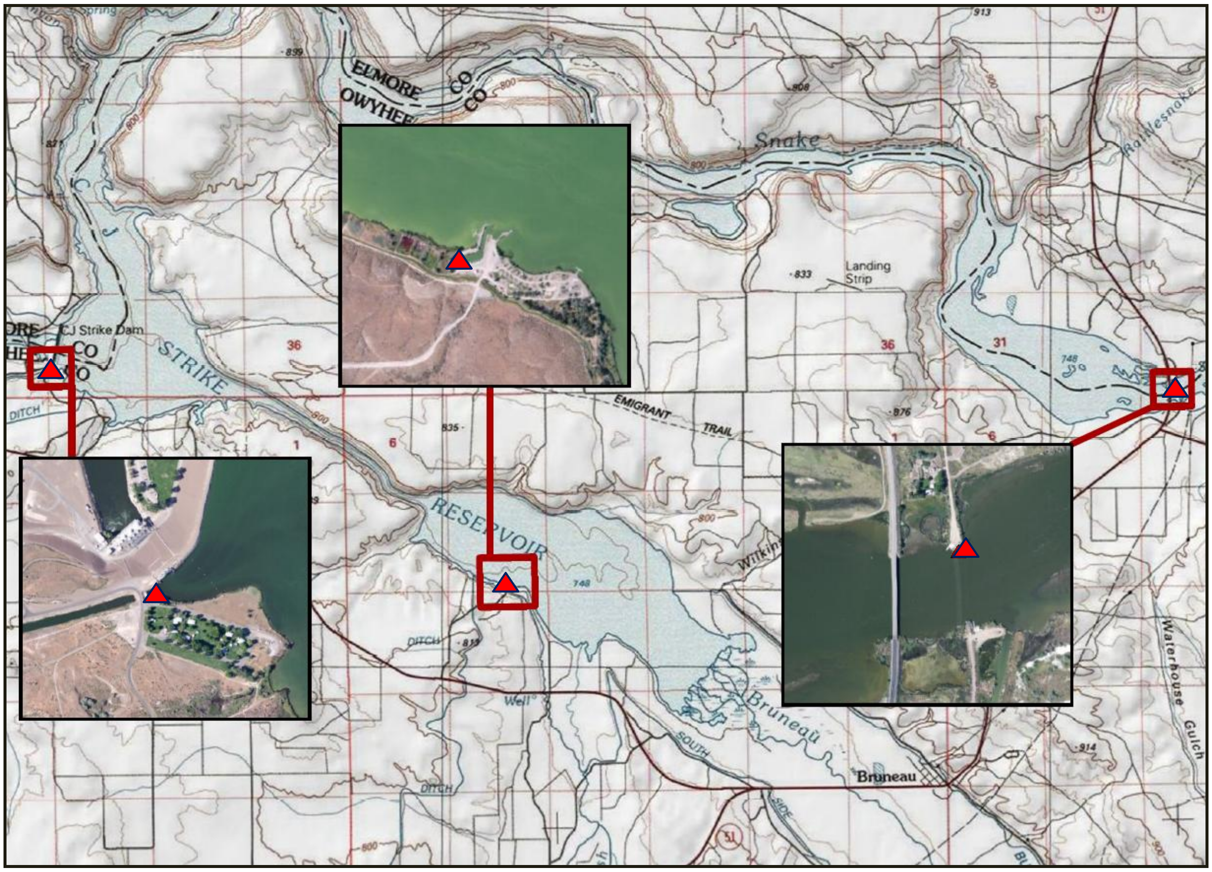


Figure 32. Reservoir stage-gaging locations (CJ Strike Reservoir).

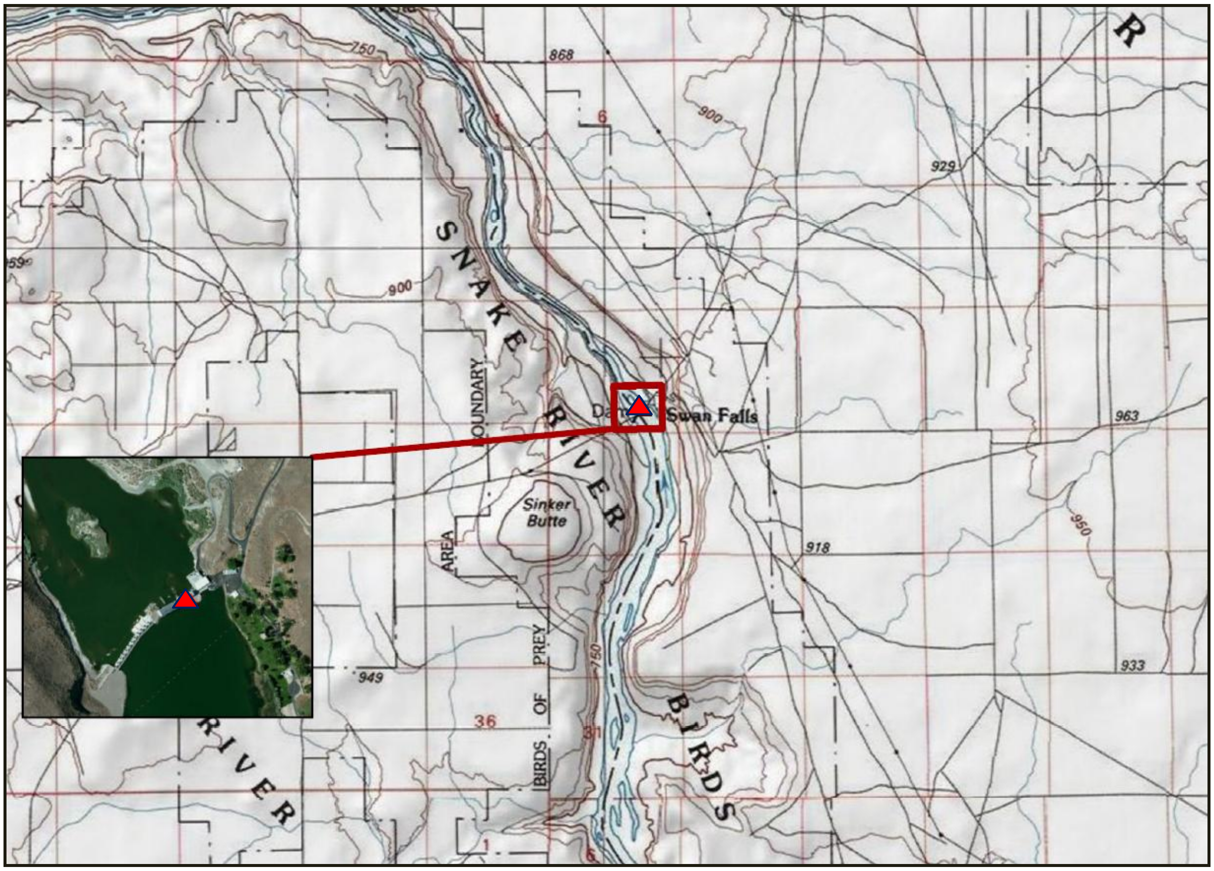


Figure 33. Reservoir stage-gaging location (Swan Falls Reservoir).

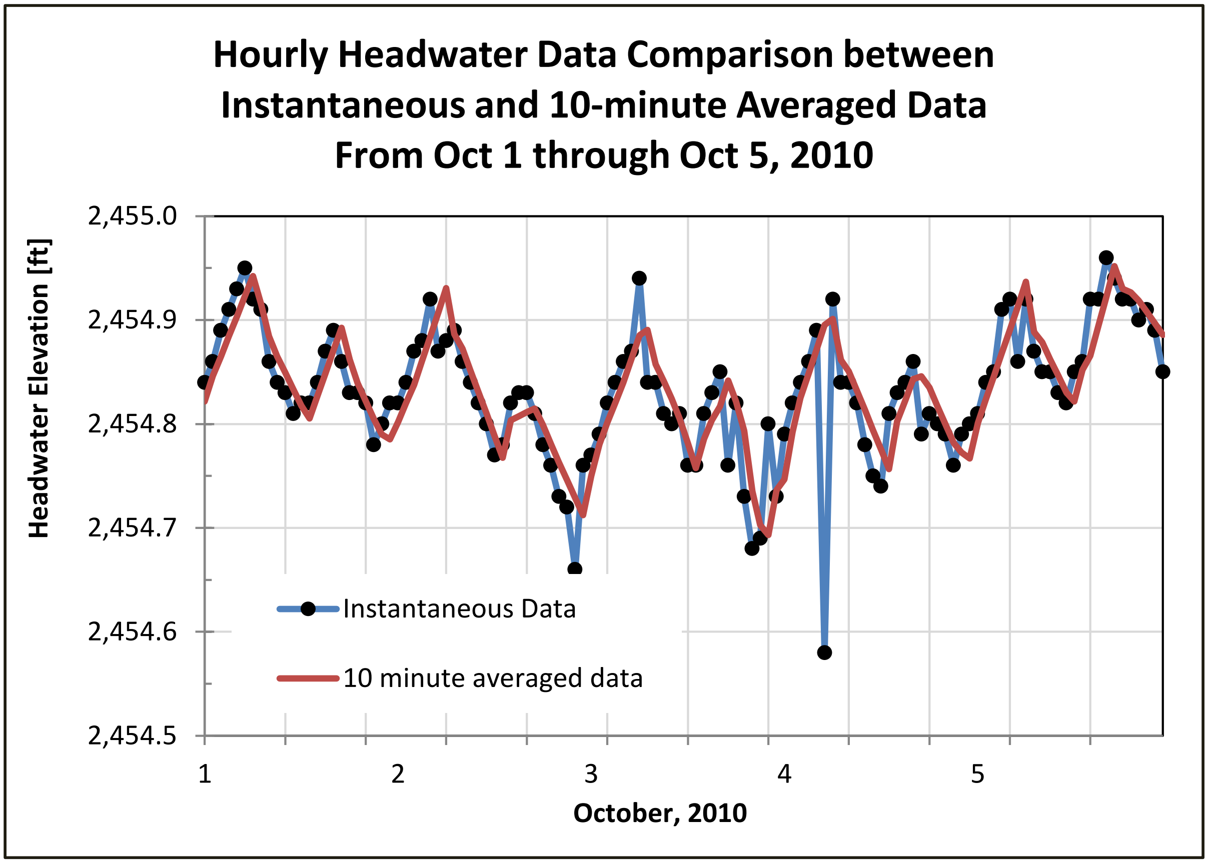


Figure 34. Headwater data comparison between instantaneous and 10-minute average data, CJ Strike Reservoir, October 1-October 5, 2010).

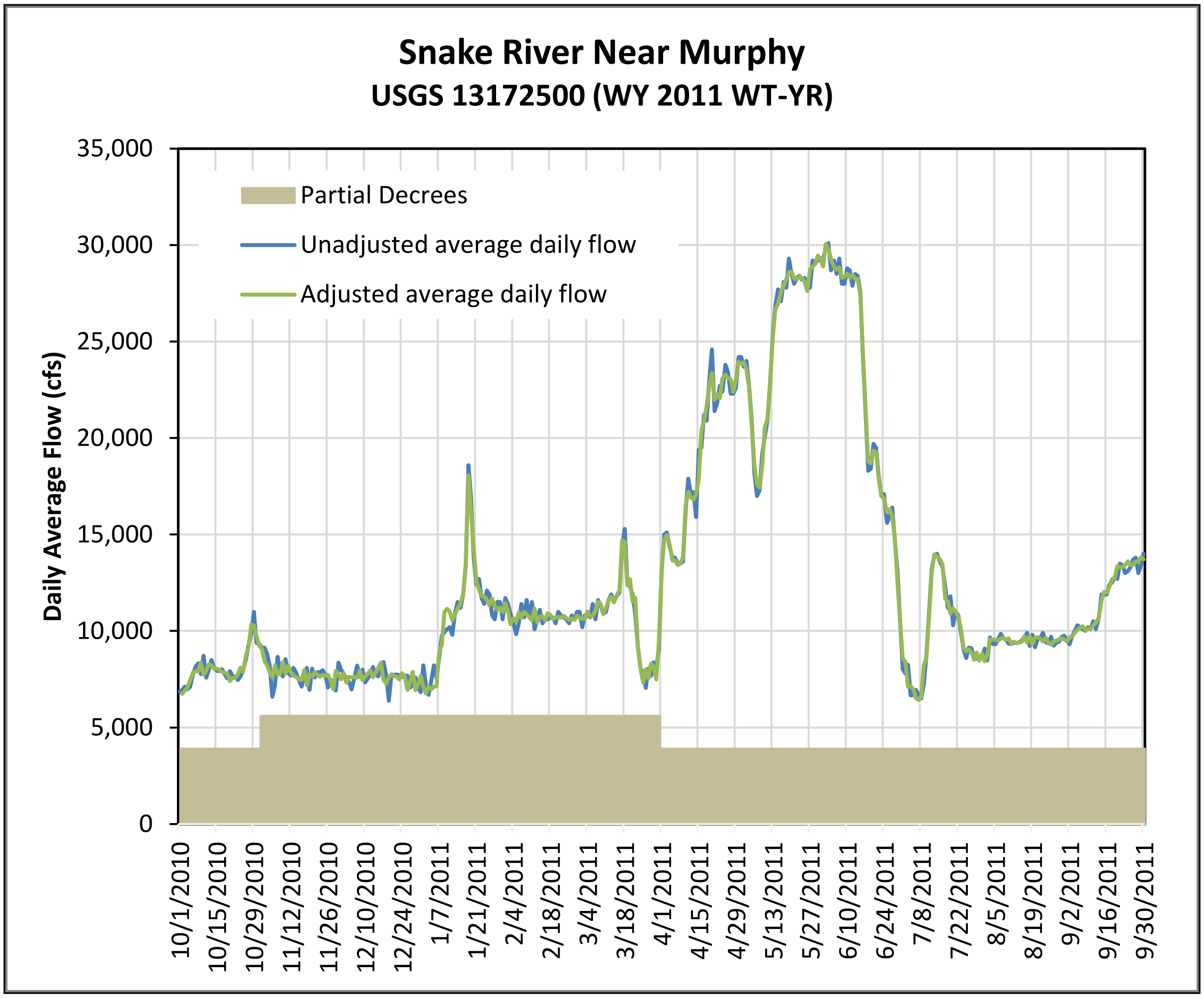


Figure 35. Adjusted and unadjusted average daily flow at the Murphy Gaging Station, water year 2011.

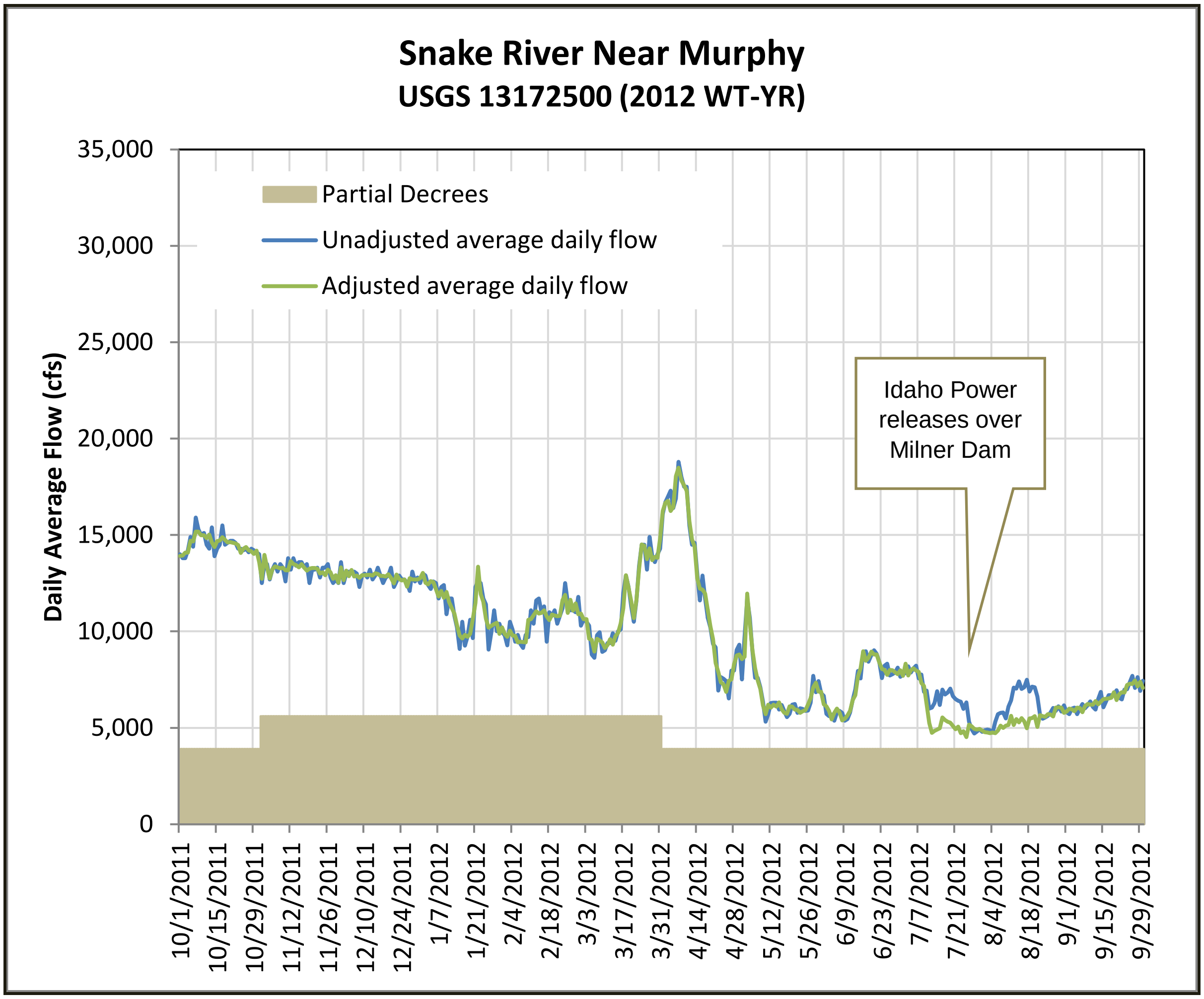


Figure 36. Adjusted and unadjusted average daily flow at the Murphy Gaging Station, water year 2012.

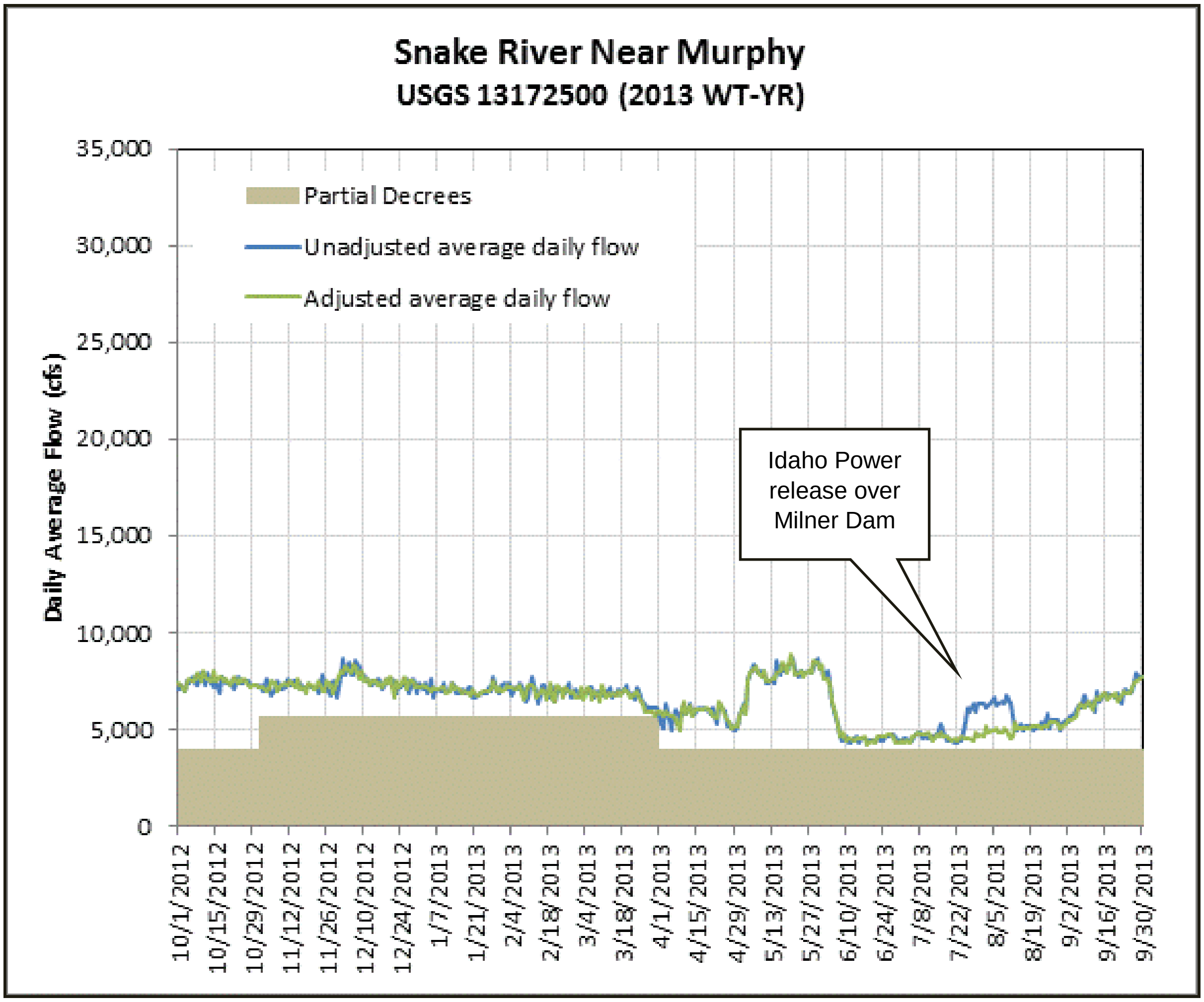


Figure 37. Adjusted and unadjusted average daily flow at the Murphy Gaging Station, water year 2013.

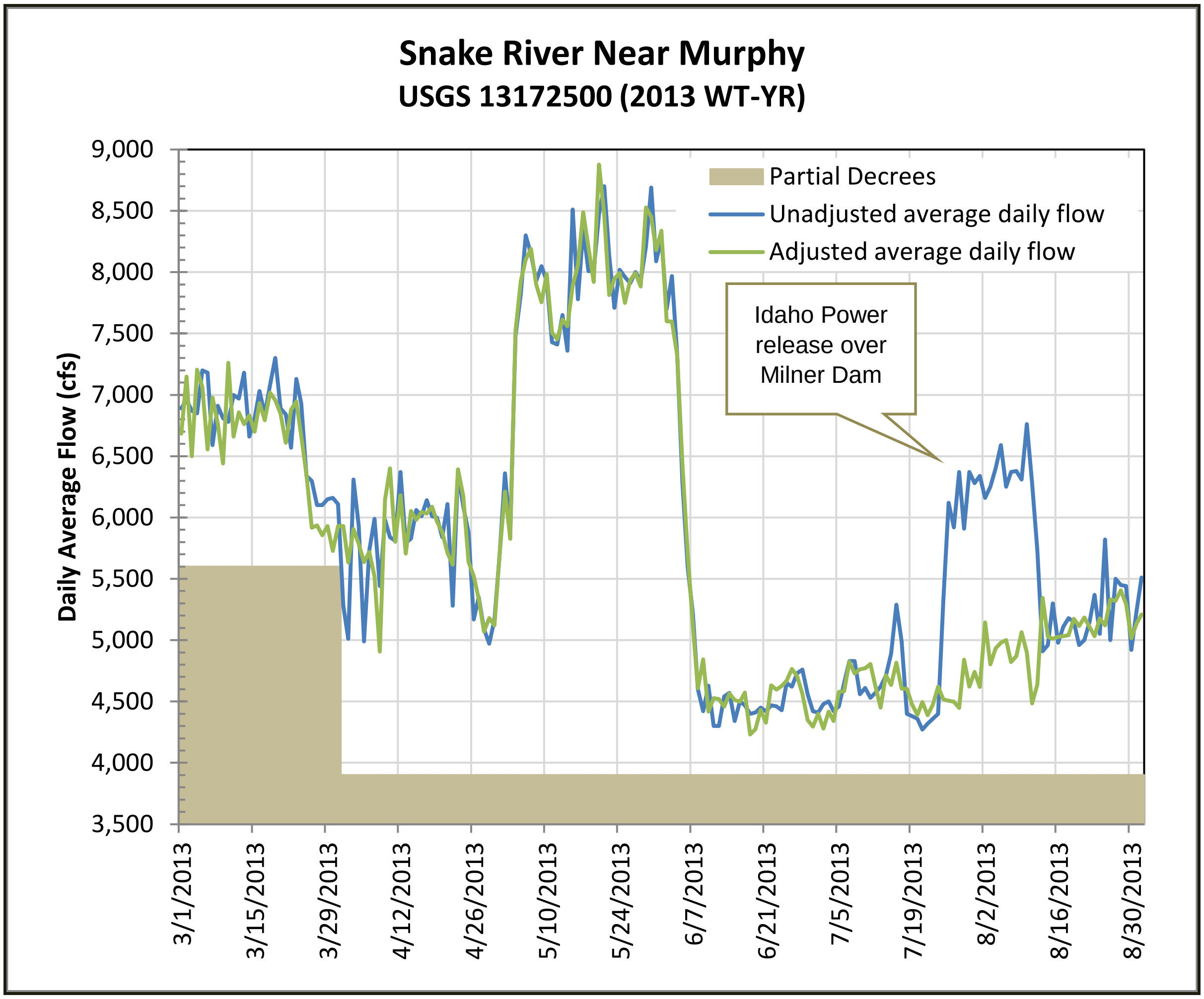


Figure 38. Adjusted and unadjusted average daily flow at the Murphy Gaging Station, March 1-August 30, 2013.

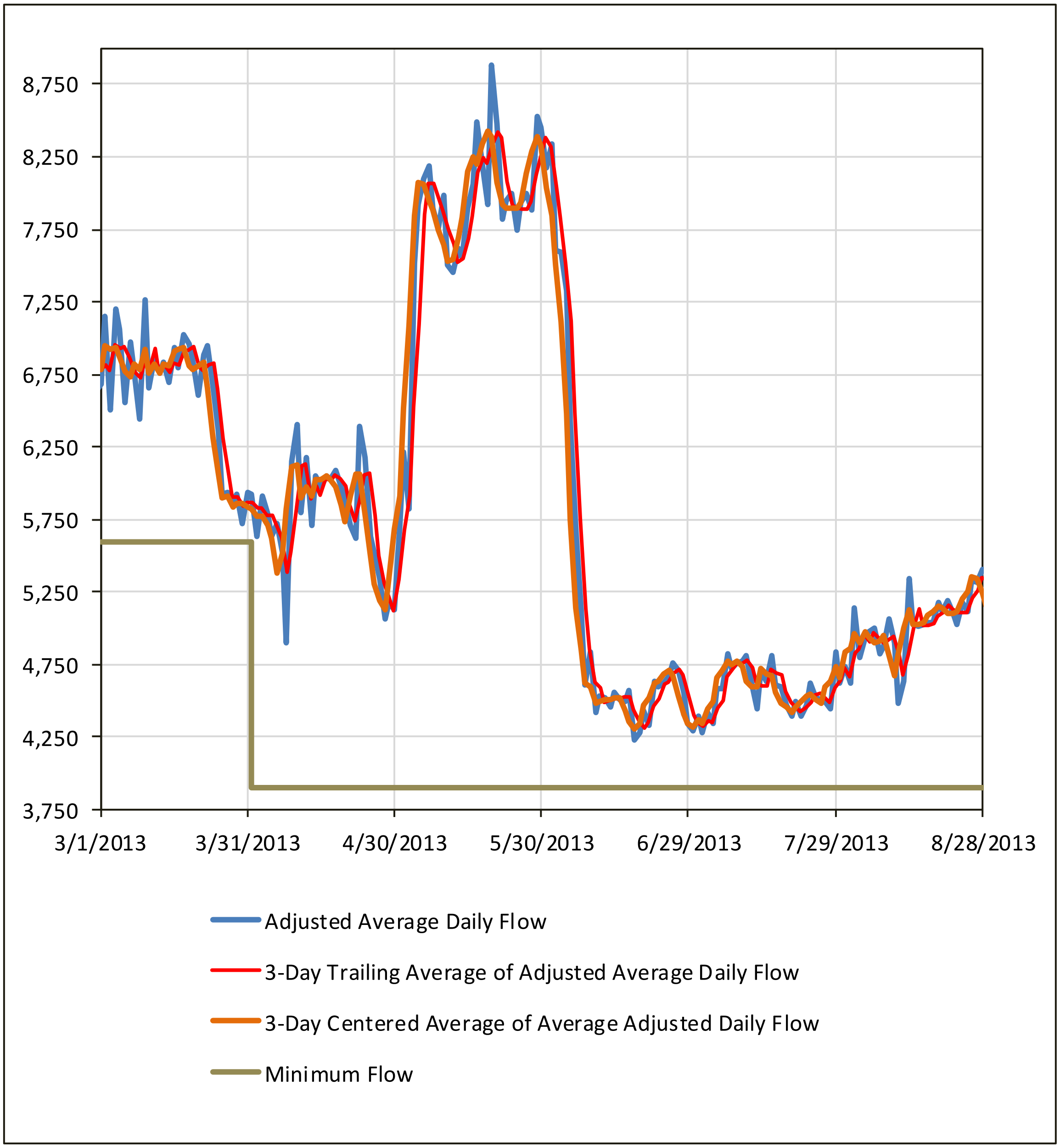


Figure 39. 3-day trailing and centered averages of adjusted average daily flow, March 20, 2013-August 30, 2013..

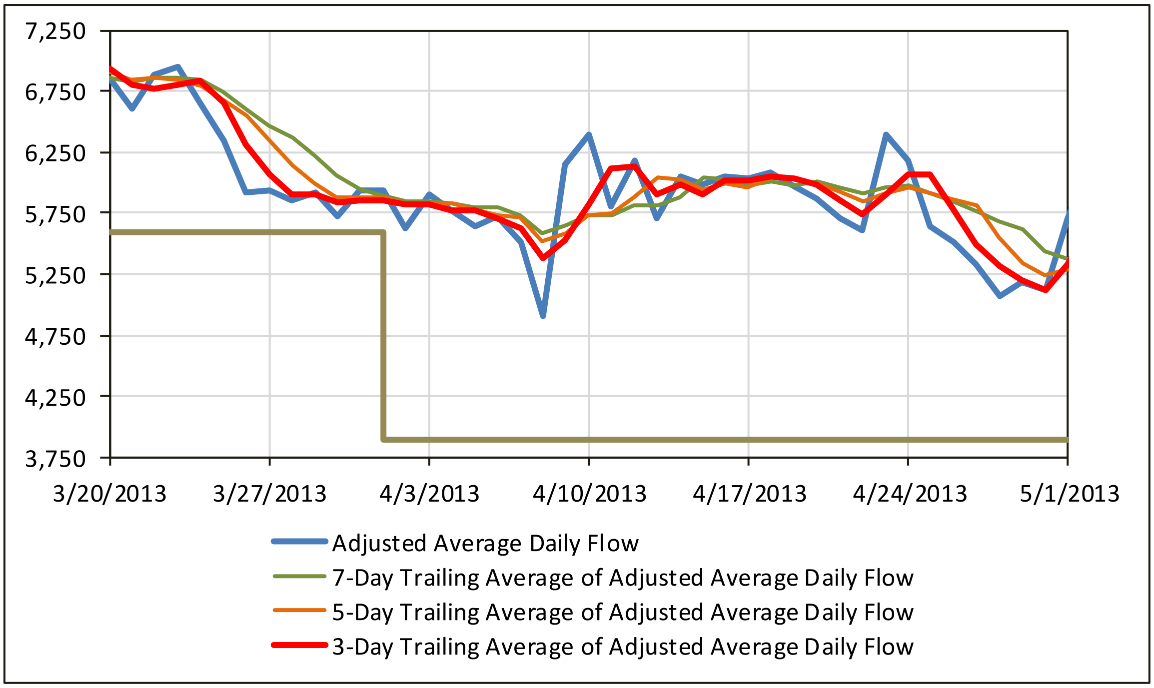


Figure 40. 3-, 5-, and 7-day trailing averages of adjusted average daily flow, 3/20/2013 – 5/1/2013.

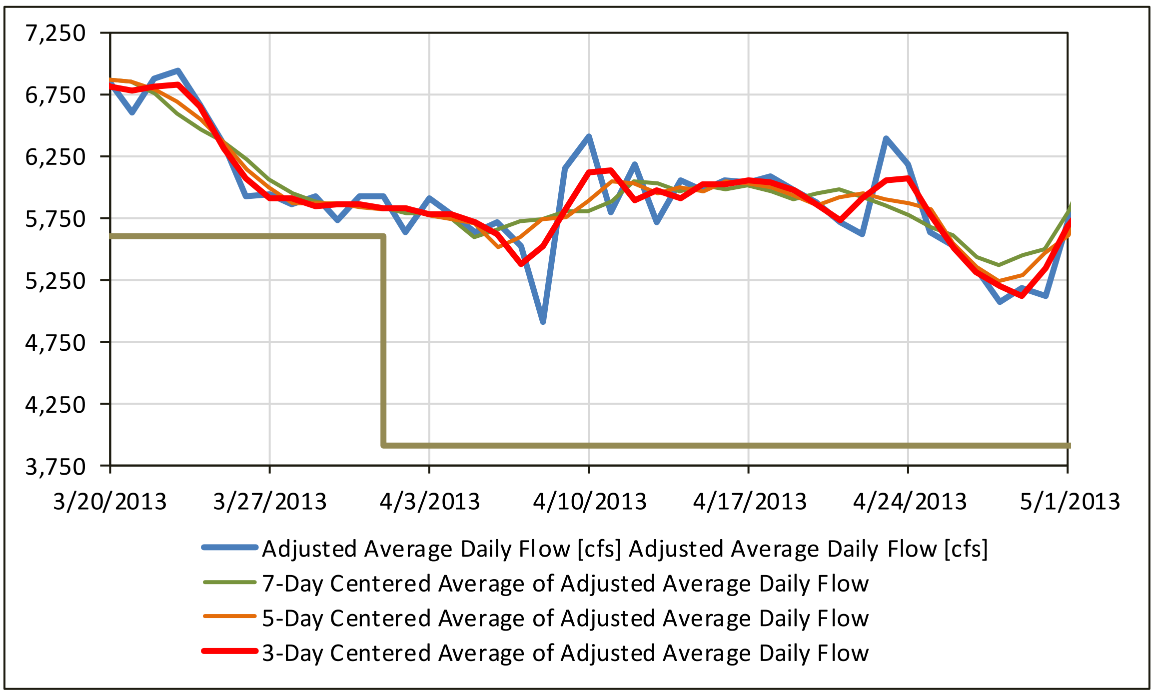


Figure 41. 3-, 5-, and 7-day centered averages of adjusted average daily flow, 3/20/2013 – 5/1/2013.

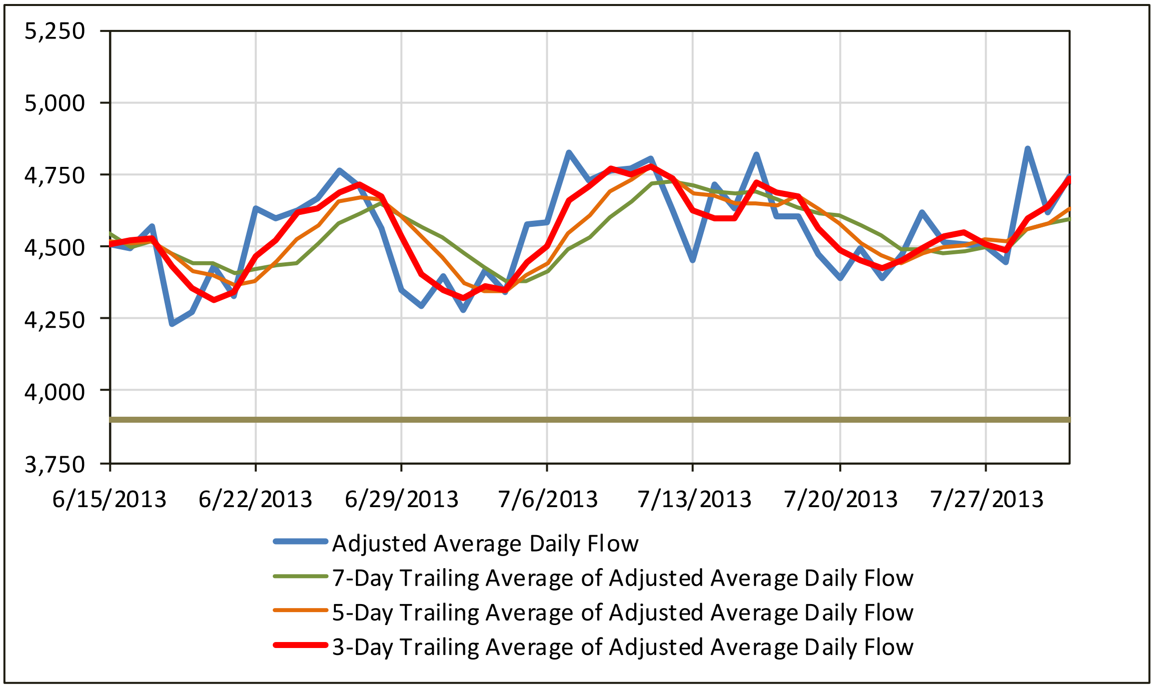


Figure 42. 3-, 5-, and 7-day trailing averages of adjusted average daily flow, 6/15/2013 – 7/29/2013.

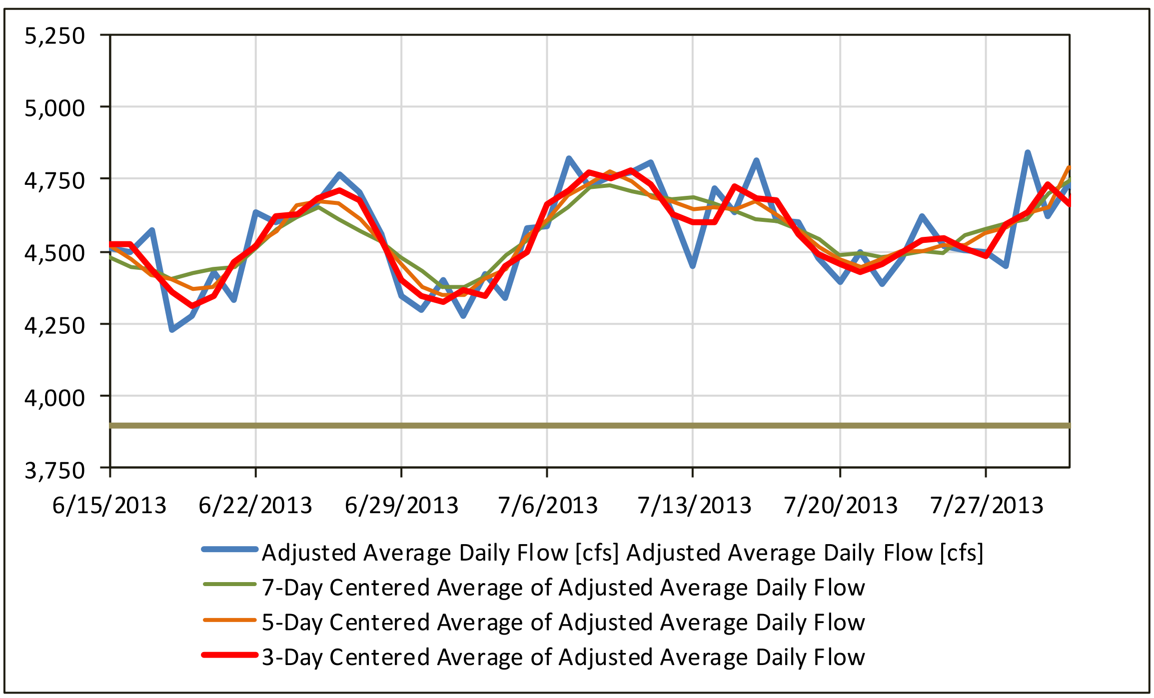


Figure 43. 3-, 5-, and 7-day centered averages of adjusted average daily flow, 6/15/2013 – 7/29/2013.

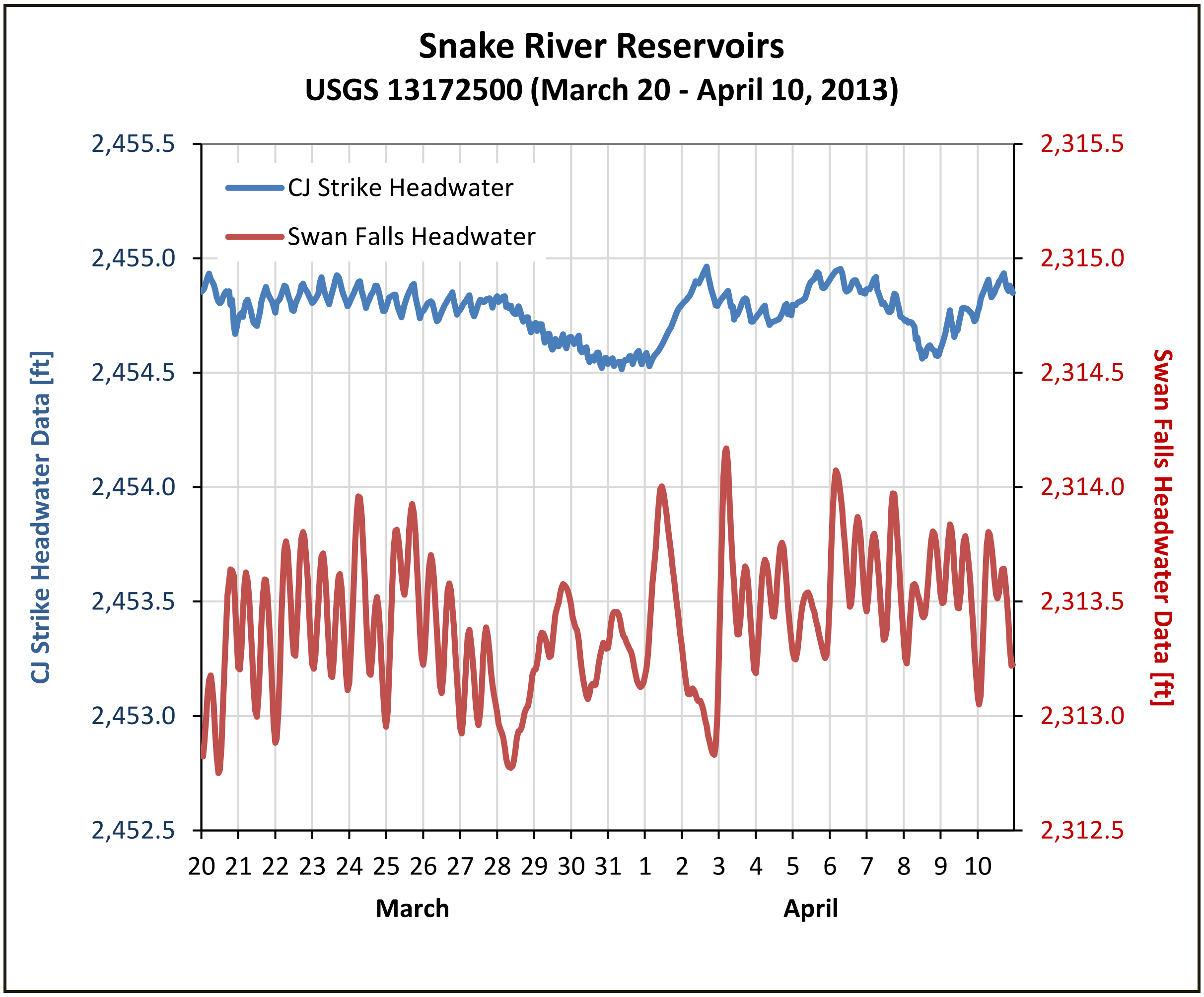


Figure 44. Headwater elevations in CJ Strike and Swan Falls reservoirs, March 20-April 10, 2013.

11. Tables

Snake River Hydropower and Minimum Stream Flow Rights between Milner Dam and the Murphy Gaging Station		
Water Right Number	**Purpose**	**Owner**
02-100	Power	Idaho Power
02-201	Minimum Stream Flow	Idaho Water Resource Board
02-223	Minimum Stream Flow	Idaho Water Resource Board
02-224	Minimum Stream Flow	Idaho Water Resource Board
02-2001A	Power	State of Idaho, Trustee
02-2001B	Power	State of Idaho, Trustee
02-2032A	Power	Idaho Power
02-2032B	Power	State of Idaho, Trustee
02-2036	Power	State of Idaho, Trustee
02-2056	Power	State of Idaho, Trustee
02-2057	Power	State of Idaho, Trustee
02-2059	Power	State of Idaho, Trustee
02-2060	Power	State of Idaho, Trustee
02-2064	Power	State of Idaho, Trustee
02-2065	Power	State of Idaho, Trustee
02-4000A	Power	Idaho Power
02-4000B	Power	State of Idaho, Trustee
02-4001A	Power	Idaho Power
02-4001B	Power	State of Idaho, Trustee
02-10135	Power	State of Idaho, Trustee
37-2128	Power	State of Idaho, Trustee
37-2472	Power	State of Idaho, Trustee
37-2471	Power	State of Idaho, Trustee
37-20710	Power	State of Idaho, Trustee
37-20709	Power	State of Idaho, Trustee
36-2013	Power	State of Idaho, Trustee
36-2018	Power	State of Idaho, Trustee
36-2026	Power	State of Idaho, Trustee

Table 1. Snake River hydropower and minimum streamflow rights between Milner Dam and the Murphy Gaging Station.

Stream Gage Summary, Milner to Swan Falls					
Station ID	Location	Maintained by	Date Established	Method	Instrumentation
13087505	Lower Milner Power Plant	USGS (1992-2001) IPCo (2001-present)	1992	Discharge measurements	Transit Time Flow Meter
13087995	Snake River at Milner	USGS	1992	Stage-discharge rating	Stage recorder with telemetry
13088000	Snake River at Milner (total)	Represents a combined total based on measurements at the Lower Milner Power Plant (13087505) and Snake River at Milner (13087995)			
13090000	Snake River nr Kimberly	USGS up to 2001; IPCo Maintained since 2001	1923	Stage-Discharge Rating	Stage and Temperature Recorder with Radio Telemetry
13094000	Snake River nr Buhl	USGS	1946	Stage-discharge rating	Stage recorder with telemetry
13108150	Salmon Falls Creek	USGS	Apr, 1970	Stage-discharge rating	Stage recorder with telemetry
13135000	Snake River below Lower Salmon Falls	USGS up to 2001; IPCo maintained since April 2001	1937	Stage-discharge rating curve	Stage recorder with telemetry
13154500	Snake River at King Hill	USGS	1909	Stage-discharge rating	Stage recorder with telemetry
13168500	Bruneau River nr Hot Springs	USGS	1943	Stage-discharge rating	Stage recorder with telemetry
13171620	Snake River below CJ Strike	IPCo maintained since 2001	4/1985	Velocity index with stage-area rating	ADVM with Stage recorder and telemetry
13172500	Snake River near Murphy	IPCO maintained since 2001	1912	Stage discharge rating	Stage recorder with telemetry

Table 2. Stream gages between Milner Dam and the Murphy Gaging Station.

Idaho Power Snake River Facilities[1]										
Facility	Storage Characteristics								Plant Information	
	River Mile (Dam)	Surface Acres	Total Volume (AF)	Usable Storage Volume (AF)	Operational Storage	Full Pool Elevation (ft)	Minimum Pool Elevation (ft)	Tailwater Elevation (ft)	Number of Units	Maximum Capacity (MW)
Milner	638.0	4,000	39,000	34,000	NA	4,134	1,449	3,975	3	59
Twin Falls	617.4	85	955	895	85	3,511	3,499	3,366	2	54
Shoshone Falls	614.7	86	1,500	375	86	3,355	3,350	3,150	3	13
Upper Salmon Falls	579.6	50	600	115	0	2,877	2,841	2,798	4	39
Lower Salmon Falls	573.0	748	10,900	4,100	1,496	2,798	2,792	2,739	4	70
Bliss	560.3	255	8,415	1,215	510	2,654	2,653	2,649	3	80
C. J. Strike	494.0	7,500	247,000	36,800	11,250	2,455	2,450	2,367	3	89
Swan Falls	457.7	1,525	7,425	6,745	6,100	2,314	2,310	2,290	2	26

Notes:
(1) Based on Idaho Power data.

Table 3. Idaho Power facilities between Milner Dam and the Murphy Gaging Station.

Potential Idaho Power Fluctuations						
Project	Twin Falls	Shoshone Falls	Lower Salmon	Bliss	CJ Strike	Swan Falls
FERC Minimum Flow (cfs)		300	3,500	4,500	3,900	3,900
Surface Acres	85	86	748	255	7,500	1,525
Operational Reservoir Stage (feet)	1	1	2	2	1.5	4
Operational Storage (2) (AF)	85	86	1,496	510	11,250	6,100
Estimated flow from 24-hour release/fill (3)	43	43	754	257	5,672	3,075

Notes:

1. Source: 2/28/2012 presentation by Jon Bowling to Technical Committee.
2. Operational volume reflects typical operations, not maximum possible usable volume.
3. Uniform flow rate generated by releasing (or retaining) operational volume in a 24-hour period.

Table 4. Potential 24-hour flow fluctuations resulting from the operation of Idaho Power facilities downstream of Milner Dam.

Distance and Approximate Low-Flow Water Travel Time (hours)								
Facility	**Parameter**	**Milner**	**Twin Falls**	**Lower Salmon Falls**	**Bliss**	**CJ Strike**	**Swan Falls**	**Murphy Gaging Station**
Milner	Distance (mi) →	—	21.6	57.7	78.8	145.2	181.4	185.6
	Travel Time (hrs) →	—	20	50	52	64	72	74
Twin Falls	Distance (mi) →	21.6	—	36.1	57.2	123.6	159.8	164.0
	Travel Time (hrs) →	20	—	30	32	44	52	54
Lower Salmon Falls	Distance (mi) →	57.7	36.1	—	21.1	87.5	157.1	161.3
	Travel Time (hrs) →	50	30	—	2	14	22	24
Bliss	Distance (mi) →	78.8	57.2	21.1	—	66.4	102.6	106.8
	Travel Time (hrs) →	52	32	2	—	12	20	22
CJ Strike	Distance (mi) →	145.2	123.6	87.5	66.4	—	36.2	40.4
	Travel Time (hrs) →	64	44	14	12	—	8	10
Swan Falls	Distance (mi) →	181.4	159.8	157.1	102.6	36.2	—	4.2
	Travel Time (hrs) →	72	52	22	20	8	—	2
Murphy Gaging Station	Distance (mi) →	185.6	164	161.3	106.8	40.4	4.2	—
	Travel Time (hrs) →	74	54	24	22	10	2	—

Source: Idaho Power data.

Table 5. Distance and approximate water travel times between Idaho Power facilities at a flow of about 5,000 cfs.

Annual Idaho Power Releases (acre-feet)			
Year	Idaho Power Storage Allocation	Idaho Power Rental	Total Idaho Power
1981	43,832	125,000	168,832
1982	44,059	200,000	244,059
1983	44,044	350,000	394,044
1984	44,030	275,000	319,030
1985	43,881	350,000	393,881
1986	44,031	150,000	194,031
1987	43,491	162,302	205,793
1988	43,608	51,849	95,457
1989	43,609	100,000	143,609
1990	43,690	63,000	106,690
1991	43,672	99,000	142,672
1992	40,959	0	40,959
1993	44,060	65,000	109,060
1994	43,782	0	43,782
1995	43,885	0	43,885
1996	43,910	0	43,910
1997	43,983	0	43,983
1998	43,942	0	43,942
1999	43,608	0	43,608
2000	42,926	53,325	96,251
2001	42,115	0	42,115
2002	43,388	0	43,388
2003	42,918	0	42,918
2004	34,827	0	34,827
2005	43,175	0	43,175
2006	43,336	0	43,336
2007	43,306	0	43,306
2008	43,085	87,336	130,421

Note: Releases of the volumes shown in this graph are considered “fluctuations” resulting from Idaho Power operations.

Table 6. Storage releases from the upper Snake River of water purchased, leased, owned, or otherwise acquired by Idaho Power.

Upper Snake Flow Augmentation Releases					
Year	Upper Snake Total Release Volume (AF)	Approximate Release Dates and Estimated Flow Rates			
		Release Start	Release End	No. Days	Estimated Flow Augmentation Rate (cfs)
1992	49,000	6/21/92	8/30/92		0
1993	271,619	6/21/93	8/30/93		0
1994	330,279	6/21/94	8/30/94		0
1995	255,235	7/2/95	9/29/95	89	1,446
1996	217,563	7/4/96	9/14/96	72	1,523
1997	214,219	7/9/97	9/18/97	71	1,521
1998	223,222	7/8/98	9/18/98	72	1,563
1999	208,221	7/2/99	9/8/99	68	1,544
2000	223,221	6/22/00	9/5/00	75	1,501
2001	41,439	5/10/01	6/2/01	23	908
2002	0	6/21/02	8/30/02	70	0
2003	0	6/21/03	8/30/03	70	0
2004	0	6/21/04	8/30/04	70	0
2005	190,987	6/20/05	8/10/05	51	1,888
2006	217,771	6/27/06	8/22/06	56	1,961
2007	149,649	6/20/07	8/15/07	56	1,347
2008	180,482	7/5/08	8/13/08	39	2,333
2009	199,758	7/5/09	7/31/09	26	3,874
2010	198,966	5/3/10	5/31/10	28	2,388
		6/30/10	7/14/10	14	
2011	207,500	7/28/11	8/26/11	29	3,607
2012	190,179	6/8/12	7/8/12	30	3,196
2013	154,885	5/1/13	6/2/13	32	2,440

Note: these releases are *not* considered “fluctuations” resulting from Idaho Power operations.

Table 7. Upper Snake flow augmentation releases.

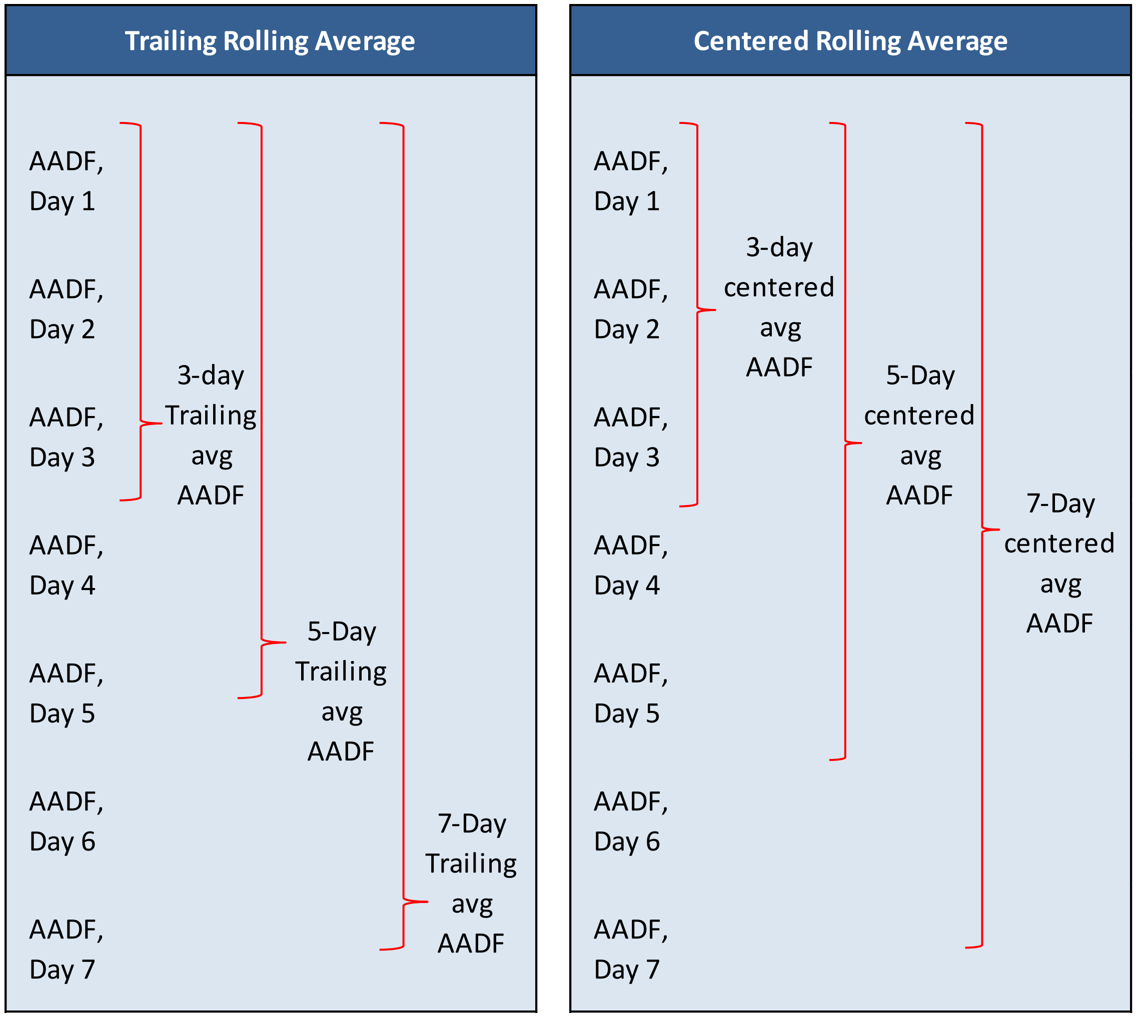


Table 8. Calculation of multi-day trailing and centered average of adjusted average daily flow (AADF) at the Murphy Gaging Station.

APPENDICES

Appendix A: Wind-Loading Analysis