B O N N E V I L L E   P O W E R   A D M I N I S T R A T I O N

2020 Level Modified Streamflow

1928-2018

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2020 Level Modified Streamflow: 1928-2018

Lead Authors:
Abdullah Dakhlalla, Steve Hughes, Ann McManamon, Erik Pytlak, Travis R. Roth, and
Rick van der Zweep
Bonneville Power Administration, Department of Energy, Portland, OR

Agency Contributors:
Bonneville Power Administration: Milli Chennell, Arun Mylvahanan
Bureau of Reclamation: Jennifer Johnson, Peter Cooper, Joel Fenolio and Bob Lounsbury
The Department of Biological Systems Engineering at Washington State University: Kirti Rajagopalan Jennifer Adam, Karen Hills, Mingliang Liu, Roger Nelson, Matthew Pruett, Fabio Scarpare, and Claudio Stockle
US Army Corps of Engineers: Angela Duren, Thomas Chisholm and Bill Proctor

Other Contributors:
Edwin Welles, Deltares, USA

Project Data Providers:
BC Hydro
Chelan County PUD
Douglas PUD
Eugene Water and Electric Board
Energy Keepers Incorporated
Energy Northwest
Environment and Climate Change Canada
FortisBC
Idaho Power Company
Natural Resources Conservation Service
Northwest Power Pool
Northwestern Energy
PacifiCorp
Pend Oreille PUD
Portland General Electric
Puget Sound Energy
Seattle City Light
Statistics Canada
Tacoma Power
US Bureau of Reclamation
US Geological Survey
US Department of Agriculture
US Army Corps of Engineers

Editorial and Data Quality Control Assistance:
BC Hydro, US Army Corp of Engineers, Bureau of Reclamation, Columbia River Intertribal Fish Commission, Idaho Power Company

Editorial Assistance:
Elizabeth Baron and Stacey Williams, Bonneville Power Administration

Preface

The Bonneville Power Administration is pleased to publish this latest set of modified streamflows for the Columbia River Basin, coastal basins of Washington and Oregon, and most of the closed basins in eastern Oregon.

Building upon a comprehensive review of the calculation process in 2014 by HDR Inc., this version of Modified Flows incorporates four major process improvements:

- A standardized, annual PNCA hydrologic data submittal process,
- New data quality control processes and tools,
- Modernized hydrologic modeling systems at BPA and Reclamation; and
- A complete overhaul of the irrigation depletion process.

Implementation of the data submittal process could not have occurred without the enthusiastic support of the Pacific Northwest Coordination Agreement (PNCA) data submitters and supporting agencies. New data quality control tools, and expanded use of BPA's Community Hydrologic Prediction System (CHPS) was enabled through the considerable efforts by Deltares USA. Simultaneously, transition to the Riverware modeling system at Reclamation enabled the direct production of daily regulated flows for the first time at the outflow points of the upper Snake, Yakima and Deschutes Basins. With financial support from BPA and the PNCA, The Department of Biological Systems Engineering at Washington State University developed a state-of-the-science irrigation depletion calculation process, which improved both the accuracy and utility of the depletion dataset. Their efforts have yielded a much better understanding of irrigation extent and patterns across the Columbia River Basin.

We are, of course, grateful for the hard working and exceptional BPA team that worked over two years to compile and recalculate this enormous and complicated dataset:

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P.O. Box 3621
Portland, OR 97208-3621
library@bpa.gov

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Section 1 Introduction

Modified flows are defined as the historical streamflows that would have been observed if current irrigation depletions (as of year 2018 for this publication) existed in the past, and if the effects of river regulation were removed; except at the upper Snake, Deschutes, and Yakima basins where current upstream reservoir regulation practices are included. Irrigation practices have changed significantly over time, so the observed historical streamflows have been adjusted to account for current levels of irrigation depletions. This 2020 Modified Flow study includes 90 years of flows (1928-2018) adjusted to irrigation depletions in 2018.

The Bonneville Power Administration (BPA), the United States Army Corps of Engineers (USACE) and the U.S. Bureau of Reclamation (USBR) perform numerous hydroregulation studies of the Columbia River basin for hydropower, environmental, flood control, operations planning, and downstream benefit calculation studies. Also, a wide range of other regional organizations, including indigenous tribes, the Northwest Power and Conservation Council, Northwest Power Pool, Pacific Northwest and British Columbia power agencies and utilities, fishery agencies and organizations, universities, research organizations, contractors, and public interest groups have a need for a consistent and accepted regional streamflow dataset normalized to the most recent level of irrigation.

1.1 Study History

This report is the sixth in a series that has been compiled about once every ten years (Table 1-1.), beginning in 1970, as required by the Pacific Northwest Coordination Agreement (PNCA) and Columbia River Treaty (PNCA, 1997). An Interagency Depletions Task Force of the Columbia River Water Management Group compiled the 1970 and 1980 Modified Flow Reports. The first report, the *1970 Modified Streamflow Report*, contained the monthly streamflow data for various sites in the Columbia River Basin and coastal tributaries in the Northwest for the 40-year period 1928 to 1968 adjusted to the 1970 level of irrigation development. The second report, the *1980 Modified Streamflow Report*, contained the monthly streamflow data for various sites in the Columbia River Basin and coastal tributaries in the Northwest for the 50-year period 1928 to 1978 adjusted to the 1980 level of irrigation development. The third report, the *1990 Modified Streamflow Report*, was contracted by BPA to A.G. Crook Co. and contained two periods per month of streamflow data for various sites in the Columbia River Basin and coastal tributaries in the Northwest for the 61-year period 1928 to 1989 adjusted to the 1990 level of irrigation development. The fourth study and report was prepared for BPA by independent contractors in coordination with other federal and state agencies, Canadian authorities, and Northwest electric utilities. It contained daily streamflow data for various sites in the Columbia River Basin and semi-monthly data for coastal tributaries in the Northwest for the 71-year period 1928 to 1999 for the 2000 level of irrigation development. The fifth study included 80 years of flows for the period 1928-2008 adjusted to the 2010 level of irrigation development. It contained daily streamflow data for the Columbia and Willamette Basins and semi-monthly data (split as day 1-15 and day 16-last day) for the Puget Sound and Coastal Basins. This sixth study includes 90 years of flows for the period 1928-2018 adjusted to the 2020 level of irrigation development. It also contains daily streamflow data for the Columbia and Willamette Basins and semi-monthly data for the Puget Sound and Coastal Basins.

Table 1-1. Study History

Study 1	1928 – 1968	40 Years--1970 Level of Development	Monthly Flows
Study 2	1928 – 1978	50 Years – 1980 Level of Development	Monthly Flows
Study 3	1928 – 1989	61 Years – 1990 Level of Development	2 Periods/Month
Study 4	1928 – 1999	71 Years – 2000 level of Development	Daily Flows
Study 5	1928 – 2008	80 Years – 2010 Level of Development	Daily Flows
Study 6	1928 – 2018	90 Years – 2020 Level of Development	Daily Flows

1.2 The Region

The region of study includes the Canadian portion of the Columbia River Basin, and the U.S. portion of the Columbia River Basin in Washington, Oregon, Idaho, western Montana, and small parts of Wyoming, Utah and Nevada. This study also includes the coastal and Puget Sound drainages in Washington; and the coastal and closed basins in Oregon.

The climate across the region is quite variable. Annual precipitation ranges from less than 10 inches in the Columbia and Snake River Plateaus to well over 150 inches in the Coast Mountains and Cascade Ranges. Winter minimum daily average temperatures along the Pacific Coast usually range between 35 to 45°F, and summer maximums are between 65 and 75°F. Inland, the seasonal temperature fluctuations are more extreme. In the Columbia and Snake River Plateaus, winter temperatures below 0°F and summer temperatures above 100°F are common. The region is centered in the zone of prevailing westerly atmospheric flow. In the winter, the westerly flow often brings strong storm systems and associated atmospheric rivers to the region. Uplift of these air masses caused by the Coast, Cascade, and Rocky Mountain Ranges results in even heavier orographic precipitation on windward slopes, but lighter precipitation on the lee sides. This pattern is most pronounced in winter. Summers are characteristically dry across most of the region, except for isolated thunderstorms concentrated near mountains.

The region’s runoff falls into two general categories: (1) the snowmelt-dominated regime of the interior drainages east of the Cascade Range; and (2) the rainfall-dominated regime of the coastal drainages west of the Cascade Range.

East of the Cascades, which includes the bulk of the Columbia Basin, most of the runoff occurs during the snowmelt period in April through July. Streamflows gradually rise over a period of a month or more reaching a peak discharge in either late May or early June. Streamflow fluctuations are caused by variations in solar radiation, air temperature, humidity, and wind. Rain on the snowpack can add significantly to the runoff. Streamflow recessions following the peak runoff are prolonged by high elevation snowmelt and ground water outflow.

Streams west of the Cascades are dominated by rainfall during the winter months. Tributary streams respond to precipitation within a few hours. Peak discharges near the mouth of the Willamette Basin, which drains more than 11,000 square miles, occur within four days of the corresponding rainfall. The majority of the runoff from these areas occurs in the winter period, October through March, but moderate streamflows continue through the spring and early summer months fed by late snowmelt from mountain peaks and ground water outflows. Streamflow recession continues into the fall until the return of the wet season in October.

1.3 Data Types

The data types used in the process of calculating modified flows are listed in Table 1-2. The data types are discussed in detail in Section 2, and data sources are listed in Section 3.

Table 1-2. Hydrologic Data Types

ID	Data Types
H	Average daily observed streamflow or project outflow, cfs
S	Average daily observed storage change at projects, cfs
	(This includes storage change during initial fill of the projects)
A	Average daily inflow into projects - either provided by the project owners
	or calculated as: Inflow (A) = Outflow (H) + Storage Change (S), cfs
L	Average daily local flow (incremental flow between adjacent stations or projects), cfs
P	Average daily diversion to Banks Lake from Franklin Delano Roosevelt Lake (FDR)
	(via pumping), cfs
G	Average daily diversion from Banks Lake to Franklin Delano Roosevelt Lake (FDR)
	(for generation), cfs
ARF	Average daily unregulated flow based on Streamflow Synthesis and Reservoir
	Regulation (SSARR) routing, cfs
E	At site evaporation, cfs
D	At site irrigation depletion, cfs
EE	Accumulated evaporation for all upstream points, cfs
DD	Accumulated depletions for all upstream points, cfs
M	Average daily modified flow, cfs
R	Regulated flow provided by the Bureau of Reclamation, cfs

A full list of all the modified flow points and the various types of data for each point can be found throughout Section 3, and in Appendix A. .

1.4 Naming Conventions

Each project and site has been given a three-character identifier. The fourth character in the identifier is the study number. The 50-year study was number “2”. The 61-year study was number “3”. The 71-year study is “4”. The 80-year study is “5”. This study, the 90-year study, is “6”. The fifth, sixth and seventh characters of each project identifier define the type of data. The data types are defined in Section 1.3.

In some instances, references are made to the data type in general rather than indicating any particular study. In these cases, a "_" was used as the fourth character rather than the study number.

A few examples of project identifiers are:

LIB1A	Libby Dam Inflow, Study No. 1 (1928-1968)
LIB2A	Libby Dam Inflow, Study No. 2 (1928-1978)
LIB3A	Libby Dam Inflow, Study No. 3 (1928-1989)
LIB4A	Libby Dam Inflow, Study No. 4 (1928-1999)
LIB5A	Libby Dam Inflow, Study No. 5 (1928-2008)
LIB_A	Libby Dam Inflow

HGH6S	Hungry Horse Reservoir Change of Storage Content, Study No. 6
CFM6ARF	Columbia Falls Routed Flows, Study No. 6
MCD6E	Incremental Reservoir Evaporation at Mica Dam, Study No. 6
UPC6D	Irrigation Depletions Upper Columbia Basin above Mica Dam, Study 6
GCL6DD	Accumulated Irrigation Depletions above Grand Coulee Dam, Study No. 6
TDA6M	Average Daily Modified Flows at The Dalles Dam, Study No. 6

Section 2 Process

The framework for computing modified flows is similar to previous publications, but with several technical advances implemented for this 2020 analysis. For this study data from multiple sources are ingested into the operational database of BPA's implementation of the Community Hydrologic Prediction System (CHPS) (NOAA, 2020). CHPS is a collection of software packages developed by the National Weather Service (NWS) to meet the River Forecast Centers (RFCs) operational requirements. In general: it comprises a set of infrastructure software, a specific suite of hydrologic and hydraulic software models, and a set of custom configurations. As such, CHPS is a series of system components including the OHD-CORE hydrologic models, and the infrastructure software developed by Deltares NL as the Flood Early Warning System (FEWS) (https://oss.deltares.nl/web/delft-fews).

The suite of visualization and analysis tools available in CHPS is used to display and quality control streamflow, reservoir and irrigation depletions data. Equations that compute, summate and route flow downstream to calculate modified flows, are coded into CHPS's configuration files. The process is flexible enough to allow for annual analysis of raw reservoir and streamflow data, and more frequently updating of modified flows if updated irrigation depletions data are available. Previous studies relied upon a manually intensive spreadsheet process which lacked a central database, data analysis tools and flexible data visualization capabilities.

In order to demonstrate that this new way of computing the modified flow data set could develop comparable results to the previous technique, the entire modified flows record is recomputed back to July 1, 1928, using daily data from the originating entity where possible. Where data from the originating entity is not available, data used in previous modified flow studies is often utilized, with some quality-control corrections made as needed. This study also took greater advantage of quality controlled streamflow data from the United States Geological Survey (USGS). Because the routing routines and parameters are slightly different in this study and because of these enhanced data sets, the time series data in the earlier years is comparable to the previous set; but in many cases is not an exact match with earlier modified flows datasets including inflow and outflow values.

It is important to note that each time modified flows are recalculated, the entire streamflow record is recomputed based on the current level of irrigation. Therefore, differences between this 2020 Modified Flows study and previous studies appear throughout the entire record. To identify methodological inconsistences in previous efforts, the various time series types computed in 2010 Modified Flows were ingested and displayed in CHPS for comparison to the newly generated record extending to 2018. Where newly computed flows differ from the previous study, the causes of the inconsistencies are identified, and most accurate methodology is selected for the resulting time series.

The entire mean daily streamflow record from the Columbia River Basin from U.S. Geological Survey (USGS) is posted to the CHPS database. Having the entire historical streamflow record readily available for analysis allows for more accurate computation of time series used to compute modified flows. Additional daily streamflow data for the lower Snake River drainages is obtained from Idaho Power, which has assumed maintenance responsibilities for numerous stations discontinued by the USGS.

Daily reservoir outflow, inflow, pool elevation and reservoir storage data is provided by the various project owners in the basin. These data are submitted annually by Avista, BC Hydro, Chelan PUD, Douglas PUD, Energy Keepers, Energy Northwest, Idaho Power, Northwestern Energy, PacifiCorp, Pend Oreille PUD, Portland General Electric, Puget Sound Energy, Seattle City Light, Tacoma Power, the U.S. Army Corps of Engineers, and the U.S. Bureau of Reclamation.

Washington State University (WSU), under contract with BPA, computes the irrigation depletions for this study. Details are in the attached Washington State University Supplemental Report.

At some modified flow locations, the various flows may be calculated differently than discussed in this section or may have some special characteristics and considerations. These locations are discussed in detail by region within Section 3.

2.1 H

Data type *H* is defined as average daily observed streamflow or project outflow. Stream gaging stations recording daily flow data may or may not be located at a project site, and may or may not cover all of the 90-year study period. When the record is missing for all or a part of the 90-year period, the record for the stream gaging site is estimated using linear regression from a nearby station or stations. When the gaging site is not at the project location, it is necessary to move the record either upstream or downstream to the project site. To accomplish this, gaging records are generally obtained both upstream and downstream from the project, and the project flow is determined as the upstream flow, plus a portion of the incremental flow of the ungaged portion based on a drainage area ratio. While this is the general case, gaging records are also extended at project site locations by correlations with nearby stations or other adjustments as required on a site-by-site determination. Schematic diagrams for each site (shown in Section 3 and Appendix B) illustrate computational procedures for historical streamflow. When the gaging station location and the project site are extremely close, with no incremental inflow from side streams, the project flow is taken as the gaged flow with no adjustment.

The streamflow data obtained from the various sources often has obvious errors or missing data. Within the BPA's CHPS environment flow data is plotted and quality controlled to identify errors. The errors and small amounts of missing data are corrected by linear interpolation between the good data points. At many locations multiple sources of data sources are used to compute *H* flows. Streamflow gaging station records obtained from U.S. Geological Survey (USGS) are used as the primary source of data for streamflow. Where USGS gaging stations are located immediately downstream of reservoirs, the USGS data is compared with reservoir outflow data provided by the dam operator. The methodology used by the USGS to compute streamflow is considered more accurate than those used to compute reservoir outflow, so generally when there are differences USGS gage data is considered the more accurate source.

2.2 S

Data type *S* is the average daily observed storage change at project sites, and includes the storage change during the initial fill of the projects. *S* values can therefore be positive or negative. Dams were constructed to store water for various purposes such as irrigation, hydroelectric power production, flood control, recreation, and other purposes. Water is stored during periods of abundant flow so that it is available to either safely release a flood flow at a later time, or to augment flows during low flow periods. A few reservoirs were in existence prior to the beginning of the study period of July 1, 1928 but most were constructed afterward up through the 1970s.

For the last ten years, storage change in lakes and reservoirs, or reservoir elevations, were obtained from sources such as the USGS, the USACE, and project owners. In a departure from previous modified flows studies, project storage change was calculated and provided, for the most part, by the projects owners rather than relying on storage-elevation tables. The data was reviewed for errors and missing values, which the project owners corrected, as needed. Data prior to 2008 was obtained from 2010 Modified Flows or from the USGS. This storage data was also reviewed, and was found to be relatively free of errors.

Erroneous storage data typically falls into two general categories. An individual incorrect observation is generally corrected by deleting the incorrect point and using linear interpolation to estimate the deleted value. The other typical errors are found during low flow periods when fluctuating pool elevations result in the computation of negative inflow values. Negative inflows occur when storage changes exceed reservoir outflow. These negative inflows during low flow periods are corrected by smoothing the change in storage values, while preserving volume and mass balances.

In locations where reservoir pool data is only available as pool elevation, such as from the USGS, the data is converted to storage using the storage/elevation tables which were used in 2010 Modified Flows. Where questionable change in storage values are identified for these locations, forebay elevations are corrected and storage values recalculated.

2.2.1 Average Daily Storage Change Calculation

When storage data is unavailable from the project owner or USGS, lake elevations are converted to storage content using the most recent available storage/elevation tables. All elevation readings are instantaneous ones collected at midnight Local Time. The storage/elevation tables are obtained from the project owners, and can be found in Appendix D. Daily change in storage, in cfs, was calculated using:

$$\Delta S = (S_n - S_{n-1})\ (43{,}560\ \text{ft}^2\ /\ \text{ac})\ (1\ \text{day}\ /\ 86{,}400\ \text{s})$$

where,

$$\Delta S \text{ – daily change in storage, cfs}$$
$$S_n \text{ – Storage at midnight, ac ft}$$
$$S_{n\text{-}1} \text{ – Storage at midnight of previous day, ac ft}$$

2.2.2 Initial Fill

Storage change adjustments were made at project sites to account for the initial or first-time filling, of the reservoir. This initial fill storage adjustment was identified in previous modified flows studies as "*F*" type data, but is now included as part of the *S* data.

2.2.3 Grand Coulee Dam – Banks Lake (P and G)

The reservoir created by the Grand Coulee Dam project is called the Franklin D. Roosevelt Lake (FDR). The irrigation holding reservoir at Grand Coulee Dam is called Banks Lake. The diversion to Banks Lake by pumping from Franklin D. Roosevelt Lake is included as a storage change rather than an irrigation diversion, and is identified as a "*P*". Diversions from Banks Lake to Franklin D. Roosevelt Lake for generation are identified by a "*G*". The pumping plant at Grand Coulee diverts water from Franklin D. Roosevelt Lake to Banks Lake which provides temporary storage of irrigation flows for the USBR Columbia Basin Project, which supplies approximately 671,000 acres of cropland. Flow is also returned from Banks Lake to Franklin D. Roosevelt Lake for power generation. These diversions to and returns from Banks Lake are treated as change-of-content in the computation of *A* and *ARF* flows.

2.3 A

Daily project inflow *A* is either calculated from project outflow and project storage change, provided directly by the project owner, or computed from USGS streamflow gaging stations upstream of the reservoir. At projects where outflow and change in storage are provided, project inflow is calculated with the following formula (all values are in cfs):

$$A = H + S$$

Due to erroneous project data, calculated project inflows are sometimes negative. Most of the time negative inflows are incorrect, so *S*, the change in storage, is assumed to be the source of error contributing towards the negative values. This is because *S* is determined from reservoir elevation measurements (using storage/elevation tables) and any small discrepancies in these elevation measurements can result in large errors in the corresponding storage, and hence change in storage values. Section 2.2 provides a description on how storage data was corrected.

2.4 L and ARF

Local flows *L* are the flows that enter the river system between two projects or between a project and a gaging station. Routing is required to compute these local flows. To accomplish this, the outflow at the upstream project is routed either by the USACE's Streamflow Synthesis and Reservoir Regulation (SSARR) model (USACE, 1991) or the Lag and K Model (LagK) (Lindsay et al., 1975) to the downstream project, and subtracted from either the observed inflow at the downstream point if the downstream point is a dam or from the gaged flow if the downstream point is a gage. In other words:

Between two dams:

Local flow (6L) = Downstream point Inflow (6A) – Upstream point Outflow (6H) routed down

OR

Between an upstream dam and downstream gaging station:

Local flow (6L) = Downstream point gaged flow (6H) – Upstream point Outflow (6H) routed down

These calculated local flows are plotted to determine if they have a logical hydrological shape. If these calculated values appear reasonable, they are accepted as final local flow values and are used toward the calculation of adjusted routed flows (*ARF*). However, most of the time, the calculated local flows had erratic spikes or negative values. In some cases, the calculated values are negative for entire months. Explanations for why local flows are sometimes negative and how these negative or unreasonable local flow values are handled is discussed in Sections 2.4.2 and 2.4.3.

Adjusted routed flows, denoted as *ARF*, represent what flows at a given location would be if the upstream dams did not exist. At headwater locations, or locations where there are no upstream dams there are no *ARF* values, only *A* values. At all other locations (where dams are present upstream), *ARF* is calculated as local flows (*L*) added to upstream *A* or *ARF* values that have been routed down.

For example, the *ARF* at Revelstoke Dam (RVC) is calculated as shown below. RVC is the modified flow point immediately downstream of the headwater project, Mica (MCD).

RVC6ARF = (MCD6A routed to RVC) + RVC6L

The *ARF* at Arrow Dam (ARD), the next point downstream of Revelstoke, is calculated as:

ARD6ARF = (RVC6ARF routed to ARD) + ARD6L

A full list of equations used to calculate *ARF* values can be found throughout Section 3 as well as in Appendix B. *ARF* flows are basic to the development of modified flows because they will be modified for irrigation diversion and evaporation to the 2020 level of development.

2.4.1 Routing

Beginning with the 2000 Modified Flows study, daily flow data was calculated in addition to the monthly and semi-monthly data provided in prior studies. Previously, when flows were provided as monthly/semi-monthly data, the time taken for water to flow from an upstream to downstream point was not accounted because the travel time was insignificant compared to the monthly/semi-monthly time-step of the data. However, on a daily time-step, it is necessary to route the streamflow and reservoir change-of-content downstream to account for the time it takes for water to travel from one point to another.

In hydrology, routing is a technique used to predict the change in the shape of a hydrograph as water moves through the river channel, recognizing that water in one portion of the Columbia River drainage does not instantly appear in another section of the drainage, but rather has a certain travel time between the two locations. This travel time varies depending upon a variety of characteristics such as rainfall pattern, flow in the river, basin shape, channel slope and roughness, and the distance between the two points.

As with the two previous studies (2000 and 2010 Modified Flows), the SSARR routing model is used to route flow downstream, with the exception of several locations where the Lag and K routing model was used to maintain consistency with the BPA short-term modeling procedures. Prior to routing streamflows downstream, the mean daily flow data is converted to instantaneous flow on a 6-hour time step. The resulting routed flow is then converted back to mean daily flow.

2.4.1.1 SSARR Routing Method

The routing characteristics used in the 2020 Modified Flows are obtained from the BPA's CHPS implementation for short-term river forecasting. These are the same characteristics that are used by the Northwest River Forecast Center (NWRFC) and were originally obtained from the SSARR model when it was integrated into the National Weather Service River Forecast System. These should be the same characteristics which were used in the two previous studies as the routing routines have not required updating since the original calibration. Specific routing characteristics used in this study can be found in Appendix C.

The SSARR routing method is a "cascade of reservoirs" technique, wherein the lag and attenuation of the streamflow hydrograph is simulated through successive increments of lake type storage (USACE, 1991). A channel can be visualized as a series of small "lakes" which represent the natural delay of runoff from upstream to downstream points. The user specifies the routing characteristics of the prototype "lake" as well as the number of "lake" increments. The user specified routing characteristics are the same as those used for real-time streamflow forecasting at both the BPA and the NWRFC. There are slight differences with in the 2010 Level study (BPA, 2010).

2.4.1.2 Lag and K Routing

The Lag K routing method provides a computerized solution to a procedure which was initially developed as a graphical routing technique (see Linsley, Kohler and Paulhus, 1975, Section 9.9). Operationally, Lag and K has been and continues to be a practical and widely-used method of storage routing between flow-points. This technique recognizes that water flowing from one point to a downstream point is likely to be delayed (or lagged) and also to be a slightly different flatter shape (or attenuated, the "k" parameter). It is a very flexible method of routing since both the Lag and K elements can be either constant or variable. Examination of historical flood hydrographs of varying magnitude provides a basis for establishing Lag and K relationships within a reach. The first process in a normal operation is to lag or delay in hours an inflow hydrograph in order to create what is called a lagged inflow graph. The K part of the operation is then used to attenuate the lagged inflow graph in order to create an outflow hydrograph at the downstream flow-point. Though normally used together, Lag and K can also be used separately to account for lag with no attenuation or attenuation with negligible lag.

2.4.1.3 Routing Details

Within the CHPS implementation of modified flows the Columbia River Basin is divided into seven sub-basins:

- the Upper Columbia Basin including the Kootenai,
- the Middle Columbia Basin,
- the Lower Columbia Basin,
- the Lower Snake River Basin from Brownlee to Ice Harbor,
- the Pend Oreille River Basin,
- the Spokane River Basin and,
- the Willamette River Basin.

Two routings are performed in the development of *ARF*. The initial routing objective is to compute the local or incremental flow between two adjacent stations. To accomplish this, the outflow at the upstream project is routed to the downstream project and subtracted from the inflow at the downstream project. As an example refer to Appendix B.

For example, the local flows at Columbia Falls (CFM) gaging station were determined as:

CFM6L = CFM6H – HGH6H routed to CFM

Note that because CFM is a gaging station, and not a dam, the local is calculated by subtracting the Hungry Horse Dam (HGH) routed outflow from a 6*H* value (streamflow gaging station), rather than a more typical 6*A* value (calculated project inflow), as shown with KER below.

And at the next point downstream, Seli'š Ksanka Qlispe' (KER):

KER6L = KER6A – CFM6H routed to KER

These procedures are continued downstream to determine the local flows throughout the basin.

The second routing objective is to compute the Adjusted Routed Flow (*ARF*) at each of the project locations that are downstream of a storage project. HGH, for example, is a headwater dam with no other dams above it. The inflow to HGH is the sum of the project outflow and the change of reservoir content:

HGH6A = HGH6H + HGH6S

For headwater projects such as Mica and Hungry Horse Dams, no SSARR routing is required, so *ARF* is not applicable. *ARF* is equal to *A* for the headwater projects.

Routing is required for all projects located downstream of headwater projects. For example:

CFM6ARF = HGH6A routed to CFM + CFM6L.

where CFM6L is calculated as shown above, and:

KER6ARF = CFM6ARF routed to KER + KER6L.

These procedures are continued downstream in determining the unregulated flows throughout the basin. Appendix B shows the routing details for all basins in the form of diagrams as well as equations, while Appendix C shows the routing coefficients used.

2.4.2 Negative Local Flows

Negative local flows are often invalid, but in some situations can be accurate. There are several reasons for these negative flows to occur:

(1) Surface Water – Groundwater Interconnections

When surface water and groundwater are hydraulically connected, water can travel between a stream or other surface water body and the surrounding groundwater. For example, in a "losing reach" of a stream, the stream tends to leak water into the groundwater. In a "gaining reach," groundwater tends to seep into the stream. Aquifers act as natural storage sources that are recharged annually in varying degrees. Except for spring runoff, the majority of water from streams comes from groundwater discharge. Discharge to the streams is controlled by the water pressure or "head" in the aquifer. Reduced head results from withdrawal by wells and reduced recharge. Reduced head in the aquifer results in lower stream flows. Examples of projects where negative flows attributed to surface water-groundwater interconnections occur include: Noxon Rapids and Cabinet Gorge on the Clark Fork; and Upper Falls on the Spokane River.

USGS documentation of negative flow at Noxon Rapids Dam on the Clark Fork River is contained in the 2018 Surface Water Records Remarks paragraph for USGS Stream Gage Station #12391400—Clark Fork below Noxon Rapids Dam.

USGS documentation of surface water and groundwater interaction along the Spokane River and the underlying Spokane Valley-Rathdrum Prairie was obtained (Kahle et al., 2005). The paper describes numerous interactions between the Spokane River and the underlying Spokane Valley-Rathdrum Prairie aquifer.

(2) Evaporation
Reservoir evaporation during summer low flow months can exceed the local or incremental flow that occurs between two adjacent stations. An example where this occurs is Fern Ridge and Dorena Reservoirs located in the Willamette Valley. These reservoirs have very low inflow during the warm summer months, with lake evaporation frequently exceeding the local inflow, resulting in negative local inflows.

(3) Diversionary Water Uses
Diversionary water uses are those that divert or pump water away from its source and consume all or a portion of the water. Diversionary water uses include irrigation, residential or domestic, and municipal uses. Irrigation is by far the largest consumptive water use in the Columbia River Basin. However, the magnitude of the irrigation diversion is not large enough to result in negative local flows on most river reaches.

(4) Inaccurate Project Data
Observed reservoir elevations are sometimes inaccurate due to wind and wave action. For example, using the observed Flathead Lake elevation data can translate to calculated negative local flows for the reach on the Flathead River between gaging stations at Columbia Falls, MT and the Flathead River near Polson, MT. Flathead Lake is a large reservoir which is located between these two gaging stations. At full pool, the lake's surface area covers 126,000 acres, or 197 square miles. A change of 0.01 feet in observed reservoir elevation results in a daily computed local inflow change of 635 cfs. Wind and wave action at Flathead Lake can easily result in observed reservoir elevation differences of several tenths of a foot or more. During summer months, inflow to Flathead Lake averages 400 to 600 cfs, so even minor fluctuations in reservoir elevation readings result in local inflow calculations that are negative or erratic. To obtain more realistic local flow values at large, wind-affected reservoirs, "smoothing or indexing" is applied (Section 2.4.3).

In a few locations and river reaches, project outflow data is the only discharge value available, and is not accurate at certain locations and projects. Reaches where project outflows are notably inaccurate are in the Middle and Lower Columbia River due to poorly calibrated spillways or other project flow routes. In such cases, stream gaging data from tributary streams is sometimes used in lieu of project discharge data to compute local inflow. These situations are explained in Section 3 of this report.

2.4.3 Indexing Local Flows

Indexing of the local flow is performed to smooth daily flow values so that the computed local flow has a more reasonable hydrologic shape. This is feasible when stream gaging stations are located on tributaries within or adjacent to the local flow drainage area.

The indexing steps are:

1. Compute the monthly average of the daily local flows.
2. Compute the monthly average of the daily flows for the index station or if more than one station is utilized compute the monthly average of the combined index station flows.
3. Compute the ratio of the local monthly sum to the index monthly sum or local sum/index sum = F. This is computed for each month and the resulting F is used for that month.
4. Daily local or incremental flows are computed for each month by multiplying the F times the daily index flow.
5. If the computed monthly local flow volume is negative, the negative volume is converted to an average daily negative flow for the entire month.

The details of indexing for specific sites can be found in Section 3 and Appendix B

2.5 D and DD

2.5.1 Introduction

Irrigation in the Columbia River Basin began prior to 1840. Through the rest of the 19^{th} and 20^{th} Centuries, total irrigated acres increased significantly before leveling off, and in many cases, declining slightly since 2000. In addition to changes in irrigated acres, there have been several changes in the irrigation methods and the types of crops grown.

In the late 1920s through 1940s, gravity or field flooding was the primary irrigation method, and is still used today on about nineteen percent of irrigated acreage across the Columbia and Willamette Basins. This method involves applying water directly to the field which is then distributed by gravity.

Sprinkler irrigation, which uses pipes or nozzles operated under pressure to form a spray pattern, was first implemented around 1950. It has since become the predominant irrigation method across the basin (about 78 percent of irrigated acreage), although sprinkler efficiency has increased somewhat over time.

Since the early 2000s, micro irrigation methods, which include surface or root zone drip irrigation, has come into use in parts of the Columbia Basin. While this irrigation method was found to be negligible in 2010 Modified Flows, it gained wider acceptance in the 2010s due to lower evaporation losses and better suitability for some crop types. For this 2020 study, micro irrigation is occurring on about three percent of total acreage across the basin and is now a large enough scale to be considered in depletion calculations.

The cornerstone of modified flows development is the accurate depiction and calculation of consumptive water use. Irrigation is by far the largest source of consumptive use in the Columbia and Willamette River systems, followed be aquifer recharge in the upper Snake River Basin. Local municipal consumptive use is also present near larger towns and cities. However, these municipal withdrawals remain negligible compared to base streamflows and the other two consumptive uses. It is also important to note that more water is withdrawn from river systems than is needed by crops themselves because some water is lost via evaporation, deep groundwater percolation, nonproductive vegetation or runoff as it is applied to the field. These inefficiencies are also taken into account.

In the five previous modified flows studies and reports, irrigation depletions were calculated using methods developed in the 1950s and 1960s (e.g. Blaney and Criddle, 1950). Both the 2000 and 2010 Modified Streamflow reports describe the process in detail, and most of the terminology, outputs, and summary tables are the same for the 2020 effort. The modernized calculation method developed and used for this 2020 dataset is detailed in the attached report: *Calculation of 2020 Irrigation Depletions for 2020 Level Modified Streamflow Irrigation Depletions* (WSU Supplemental Report).

Because of the large changes in irrigation demand and application methods over time, it is necessary to also adjust historical flows all the way back to the beginning of the dataset to represent current irrigation conditions. To accomplish this, incremental irrigation depletions (D) are calculated. Incremental depletions are an estimate of the differences between the actual depletion for a given year and the estimated depletion at the current level. The actual, historical depletions are inherently observed in the historic flow record. To calculate the increment from historic to current depletions, though, the difference between historic irrigated acres and current levels of irrigated acres is multiplied by the current estimate of depletion per acre. This can be represented as:

$$Di = da * (\Delta I)$$

where,

Di = incremental depletion, cfs
da = depletion per unit area, cfs/1000 acres
ΔI = incremental irrigated acres, 1000 acres

This method assumes that all previous years were irrigated with the same crop distribution and method of water application as existed in 2017-2018.

At-site estimates of incremental depletions (D) reflect the effects of irrigation changes within a particular subarea of the Columbia basin. These effects carry downstream from subarea to subarea. To measure the net effect of all the upstream D, it is necessary to accumulate the incremental depletions to create a total depletion at each site (DD). Refer to equations throughout the WSU Supplemental Report for more details.

Depletion values are initially calculated as flow per unit area (cfs per 1000 acres), and vary according to the methods of irrigation used in a subarea. They vary because of the different application efficiencies of the three irrigation methods. Depletions are calculated on a monthly time-step because the data for the amount of water required by the various crop types was available on a monthly time-step:

$$\text{Depletion (cfs)} = \text{Diversion (cfs)} + \text{Return Flow (cfs)}$$

Diversion is a negative value that denotes the amount of water removed from the river for irrigation. Return Flow is a positive value that denotes the amount of water unused by the crops which is returned to the river.

Diversions for crop irrigation usually occur between March and October each year, whereas returns to the river occur throughout the year. In most locations, during the months of May through September, the amount diverted from the river is typically more than the amount returned, and therefore the depletion values will be negative for these months.

The depletions values (cfs per 1000 acres) are then multiplied with the incremental irrigated acreage to produce incremental depletions in cfs. All calculations for finding irrigation depletions, are made on a subarea basis, and are monthly values which are later converted to daily values.

The Columbia River Basin is divided into subareas where depletions per unit area can be considered uniform, yet conform to the geography of hydrologic subbasins. Up through 2000 Modified Flows, crop acreage extent was provided almost exclusively by county and state extension services, with some cross-checking using other data sources (CRWMG, 1988; CRWMG, 1980). In the 2010 Modified Flows effort, though, subbasin delineations were cross checked using satellite imagery and ArcGIS software, and corrected where possible. In most of the basin, the GIS-based corrections improved acreage estimates, and are confirmed in this 2020 Modified Flows study.

Depletions per unit area are estimated from the water requirements of the various crops in the subarea and the method that the water is delivered to the crops. A wide range of crops are grown in the Columbia and Willamette Basins, with each crop type requiring different amounts of water at different times of the growing season. In the five previous modified flows publications, the amount of water and crop consumptive uses were estimated using the Irrigation Water Requirement (IWR) software program from the Soil Conservation Service (SCS, 1967; SCS 1976), which eventually became the National Resource Conservation Service (NRCS).

2.5.2 Request for Proposals and Irrigation Method Development

At the conclusion of the 2010 Modified Flows process, the project team and PNCA parties recommended a top-to-bottom review of the calculation process be conducted to look for efficiencies and modernization opportunities. BPA contracted with HDR to independently review the modified flows calculation process, with the goal of identifying process and methodological improvements. The report presented to BPA (HDR, 2014) detailed several process improvements which were adapted for this study, including a standardized and more frequent data submittal process to facilitate streamlined data quality control, and moving the quality control and calculation process out of spreadsheet environments.

The HDR evaluation also found that the irrigation calculation process used in previous studies was no longer state-of-the-art. While the IWR software was found to be useful for many purposes, the region's complex irrigation patterns, numerous crop and irrigation data sources, different levels of quality control, and increasing use of new and more efficient irrigation delivery methods all supported the development of a more sophisticated irrigation calculation process. Moreover, GIS-based irrigation estimates derived from Moderate Resolution Imaging Spectroradiometer (MODIS) satellite imagery were becoming widely available. New irrigation software and calculation methods were also in development which were advancing the state-of-the-science, and could improve irrigation depletion estimates throughout the basin.

Using the HDR report as a guide, and incorporating technical ideas from Reclamation and other PNCA parties, BPA issued a Request for Proposals (RFP) in 2017 for developing a modernized, state-of-the-science irrigation depletion methodology for the Umatilla River Basin. If successful in this particularly complex, but relatively data-rich agricultural area, the RFP included an option to expand the methodology to the rest of the Columbia and Willamette River Basins. More specifically, the RFP Statement of Work requested that competing entities develop an improved method which is:

- More accurate than current methodology compared to actual flow information,
- Applicable to all watersheds in modified flow dataset,
- Cost effective in wide-scale and out-year application,
- Can be applied in a timely manner (comparable to current methods), and
- Allows for open source use of methodology by BPA in the future and with other vendors.

Through the competitive RFP process, which included technical evaluators from BPA and Reclamation, Washington State University was selected to develop, test and evaluate its methodology. Throughout 2018, BPA and Reclamation subject matter experts reviewed WSU's project progress, and in October 2018, the test basin project was completed (WSU, 2018). In the report, WSU not only showed convincingly that their calculation method could be scaled up to the entire basin, but that it was superior to previous modified flows efforts, and even corrected inadvertent basin delineation errors using more recent satellite mapping and ground truth information.

Based on that project success, the option to contract with WSU for the rest of the modified flows subbasins was exercised, with financial support from BPA and the PNCA. In addition, the project team was encouraged to evaluate calculation methods in the Columbia River Basin Project for their quality, *vis-à-vis* the methodology they developed and were about to employ across the rest of the basin.

In April, 2020, Washington State University completed the irrigation depletions used in *2020 Level Modified Streamflow*. The project report, *Calculation of 2020 Irrigation Depletions for 2020 Level Modified Streamflow*, is included as a Supplemental Report. The report details the methodology, changes in irrigation acreage and crop water demands compared to the 2008 report and previous studies, and outlines the advantages of this modernized calculation method.

2.6 E and EE

The construction of dams, with their reservoirs, increases the water surface area and provides greater opportunity for evaporation to occur. Part of the post-dam evaporation is offset by the evaporation from the pre-dam river surface. The area between the pre-dam river surface and the post-dam reservoir surface historically contained vegetation that removed water from downstream use through evapotranspiration. The at-site evaporation, due to the construction of a dam, is the difference between the post-dam reservoir evaporation and the pre-dam sum of river surface evaporation and vegetation evapotranspiration, in cfs.

Incremental evaporation adjustments (*E*) were computed to adjust streamflows to a condition as if existing dams had all been constructed and evaporating water for the entire 90-year period 1928-2018. This evaporation adjustment was for the period July 1928 up to the time the reservoir first filled to 50 percent of usable storage capacity, and was the difference between post-dam reservoir evaporation and the pre-dam sum of river evaporation and vegetation transpiration. After initial filling, the reservoir evaporation is reflected in the observed streamflows.

Incremental evaporation adjustments (*E*) reflect the effects of evaporation changes at a specific site. These effects carry downstream from site to site. To measure the net effect of the upstream *E*, it is necessary to accumulate the incremental evaporation adjustments to create a total evaporation at each site (*EE*). Refer to equations within Section 3 for more details.

2.7 M

Modified flows (*M*) are flows which have been adjusted to a common level of irrigation development and evaporation in upstream reservoirs and lakes, and reflect no regulation by dams. The most significant of these adjustments is the irrigation depletion adjustments. The 2020 level modified flows were computed at most locations by the addition of the depletion adjustments (*D*, *DD*) and the evaporation adjustments (*E*, *EE*) to the adjusted routed flows (*ARF*). At headwater locations, the adjustments (*D and E*) are added to the inflows (*A*) rather than to *ARF* because there is no routing and hence no *ARF* at the headwaters. At some locations, where there are no *D*, *DD*, *E* or *EE* values, modified flows simply equal the *A* or *ARF* values. Refer to equations throughout Section 3 for more details.

At certain locations, modified flow values can be negative during instances when the evaporation (*E*, *EE*) and/or irrigation adjustments (*D*, *DD*) are larger than the calculated inflows (*A*) or routed flows (*ARF*). In these cases, it is likely that current levels of irrigation require more water than was historically observed.

Section 3 Discussion by Region

The Columbia basin is divided into nine sections:

1. The Columbia and Kootenay in Canada and Kootenai in the U.S.,
2. The Pend Oreille-Clark Fork and Spokane River Basins,
3. The Columbia River from the mouth of the Pend Oreille to the mouth of the Snake River,
4. The Snake River above Brownlee Dam,
5. The Snake River Basin from Brownlee to the mouth,
6. The Columbia River from the mouth of the Snake River to Bonneville, and the Closed Basin in Oregon,
7. The Willamette Basin,
8. The Lower Columbia tributaries, the Puget Sound drainage, and Coastal Streams in Western Washington, and
9. The Klamath and Coastal Streams in Oregon

For the nine sections listed above, pertinent data related to the calculation of modified flows is provided. These data include:

- An overview of the basin characteristics
- A map of the sub-basin with dams and gaging stations highlighted
- A list of data points
- Details about unique points
- The equations used to calculate *L*, *ARF*, *DD*, *EE* and *M* for each point

3.1 Upper Columbia and Kootenay Basins

The area described in this section includes the Columbia-Kootenay drainage above the mouth of the Pend Oreille River, near Trail, British Columbia. The Columbia drainage discussed in this section is located entirely within Canada. The Kootenay River (Kootenai in the U.S.) has its source in southeast British Columbia, enters the U.S. in northwest Montana, and then flows back into Canada from northern Idaho. The drainage area of these two river basins above Trail, B.C., is 34,000 square miles; 28,000 in Canada and 6,000 in the U.S. See Section 3.1.1 for a map of the area.

Most of the irrigated land in these two basins is located adjacent to the major rivers, lakes and principal tributaries, especially in the Kootenay Basin. Irrigation acreage and surface water depletions in these two subbasins have historically been an order of magnitude smaller than elsewhere in the Columbia Basin, which has continued into the 2010s. Irrigation acreage estimates, using methods documented in previous studies increased from 20,700 acres in 1928 to 36,600 acres in 2008. However, the WSU study concluded that irrigated acreage in 2018 is actually quite a bit lower than previous estimates -- around 13,300 acres, with virtually all irrigated acreage in the US portion of the Kootenai Basin. Since irrigation depletion estimates in earlier decades were already small, the corrected acreage estimate has minimal impact on modified flows calculations. In 2018, approximately 66 percent of the irrigated lands use sprinkler systems in the Kootenay Basin. See the WSU Supplemental Report for additional details.

For the areas described above, irrigation depletion was computed based on water from surface sources. Except for a small segment of the Kootenai River in extreme northern Idaho, groundwater is not a significant source of irrigation in this basin, and groundwater and surface water sources are not connected.

Below is the list of areas where depletion adjustments were computed as described in Appendix B:

(1) The Columbia above Mica, BC;
(2) The Columbia from Mica to Keenleyside, BC;
(3) The East Kootenay above Newgate, BC;
(4) The Kootenai in Montana;
(5) The Kootenai in Idaho;
(6) The West Kootenay from the Idaho Border to Corra Linn, BC;
(7) The Slocan Basin; and
(8) The Columbia from Keenleyside, BC to the mouth of the Pend Oreille.

Equations used to arrive at *L*, *ARF*, *DD*, *EE* and *M* are shown in Section 3.1.4. A schematic diagram depicting where and how the various irrigation adjustments are applied, and the data used to calculate irrigation depletions can be found in the WSU Supplemental Report.

3.1.1 Regional Map

Figure 3-1. Upper Columbia and Kootenay Basin Map

3.1.2 List of Points

Table 3-1. Upper Columbia and Kootenay Basin Points

ID	Name	Basin	H	S	A	L	ARF	D	DD	E	EE	M
MCD	Mica	Upper Columbia	x	x	x				x	x		x
RVC	Revelstoke	Upper Columbia	x	x	x	x	x		x	x	x	x
ARD	Hugh Keenleyside	Upper Columbia	x	x	x	x	x	x	x	x	x	x
LIB	Libby	Kootenay	x	x	x				x	x		x
BFE	Bonners Ferry	Kootenay	x			x	x		x			x
DCD	Duncan	Kootenay	x	x	x					x		x
COR	Corra Linn	Kootenay	x	x	x	x	x		x		x	x
CAN	Kootenay Canal	Kootenay										x
UBN	Upper Bonnington	Kootenay										x
LBN	Lower Bonnington	Kootenay										x
SLO	Slocan	Kootenay										x
BRI	Brilliant	Kootenay	x			x	x	x	x			x
MUC	Murphy Creek	Upper Columbia	x			x	x		x		x	x
UPC	Upper Columbia above Mica	Upper Columbia						x				
CTR	Columbia at Trail	Upper Columbia						x	x			
EKO	East Kootenay above Newgate	Kootenay						x				
KMT	Kootenai-Montana	Kootenay						x				
KID	Kootenai-Idaho	Kootenay						x				
WKO	West Kootenay	Kootenay						x				

3.1.3 Special Characteristics

Modified flow points that are calculated differently from the methodology described in Appendix B, and points that have other special characteristics are discussed in this section.

Mica, and Revelstoke, BC (MCD, RVC) - British Columbia Hydro and Power Authority (BCHydro) made revisions to historic flow data at all Canadian projects for 2020 Modified Flows. This revised historical data, as well as the most recent ten years of data, were provided by BCHydro and consist of outflows, storage, and calculated local flows. inflows (Mica/Duncan) and local flows (Revelstoke/Keenleyside) for the four projects are provided back to July 1928 by BCHydro. This improved data translates in rather sizable changes in daily routed flows downstream to Arrow, BC, and into the US portion of the Columbia Basin, but only small changes in semi-monthly, monthly and seasonal volumes.

Arrow, BC (ARD) – The earliest of these data revisions began with January 1, 1961 at Arrow Dam, so Canadian flows were recalculated and rerouted from October, 1, 1960 (WY 1961) through 2018. The Arrow local inflows provided by BCHydro do not include inflows into Whatshan Dam, which is located between the Upper and Lower Arrow Lakes. Instead, its inflow is added to the local flows provided by BCHydro to create the total Arrow local flows:

Total Arrow Local flow (ARD6L) = Arrow Local flow from BCHydro + Whatshan Inflow.

Whatshan Dam inflow data provided by BCHydro from January 1974 to September 2018. Prior to those dates, data from 2010 Modified Flows is used.

For quality control purposes, local flows were calculated separately to evaluate the local flow calculations provided by BCHydro:

ARD6L = ARD6A – RVL6H routed to ARD

where,

ARD6A = ARD6S (Upper plus Lower Arrow Lake storage) + ARD6H.

The local flow calculations provided by BCHydro were comparable to this evaluation, and were accepted as-is for 2020 Modified Flows calculations.

Duncan, BC (DCD) -- as with other BCHydro projects, all of the required data was provided by BCHydro, either from the previous modified flow study or recent submittals. Details are provided in Appendix B.

Corra Linn, BC (COR) – Corra Linn outflow data was developed using data from two gages from Environment and Climate Change Canada prior to 2008. After that date, BCHydro provided all project data, along with local flows into Corra Linn which included the entire area above Corra Linn but below Duncan and Libby Dams. Because the BCHydro-provided local flow extends upstream to the Kootenai River at Bonners Ferry, ID, it was necessary to disaggregate the flows into two pieces above and below Bonners Ferry using:

MF_COR_local = BCHydro_COR_local – MF_BFE_local.

This process yielded realistic results for 2009-2018. For data prior to 2009, though, the computation resulted in inconsistent local flows and periods of unrealistic negative flow. To resolve this issue, the COR local flow prior to 2008 was computed independent of BCHydro's COR local, using the alternative equation:

MF_COR_local = MF_COR_inflow – MF_DCD_outflow – MF_BFE_streamflow.

This is the same approach for computation of this local as the 2010 Modified Flows study. For the entire record both methods were within 0.1% of the volume of the 2010 results. Neither method yields a significant bias or volume discontinuity in the overlapping 80-year period between the studies (Figure 3-2).

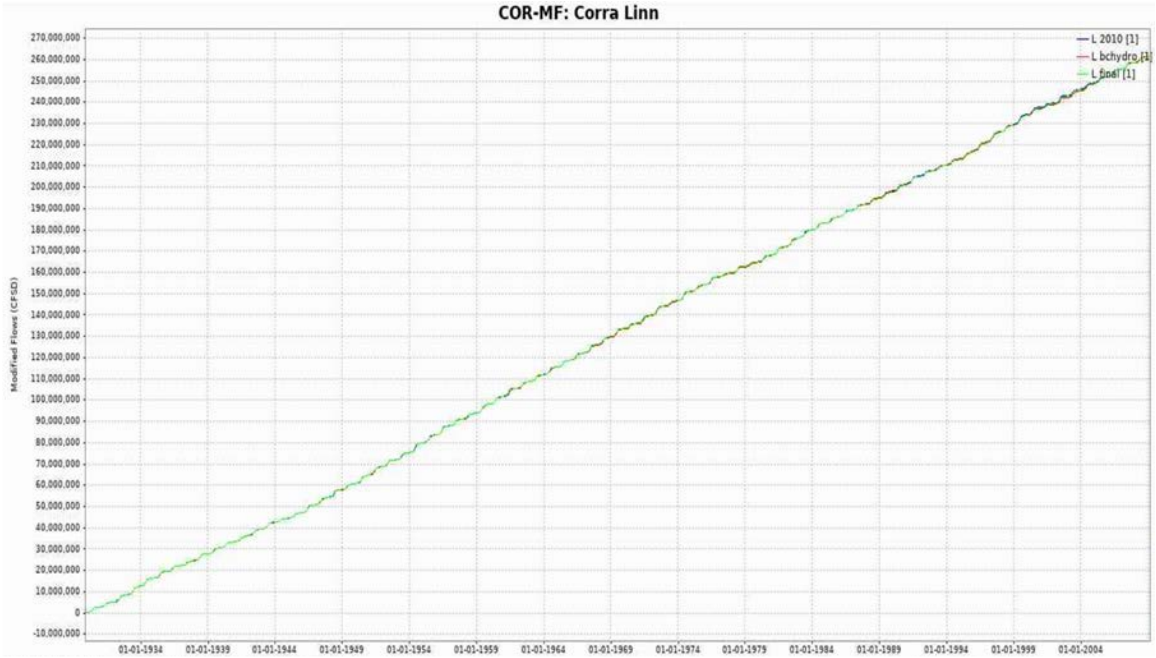

Figure 3-2. Accumulated Corra Linn (COR) Modified Flow.

Bonners Ferry, MT (BFE) – Typically, the observed flow at Bonners Ferry (BFE6H) is used in calculating local flow (BFE6L). However, BFE6H are unreliable due to back water effects from Kootenay Lake. Therefore, BFE6L is instead calculated using the gage at Kootenai River at Bonners Ferry prior to 1960 when backwater effects begin to influence the gage. From 1960 to 2002, the outflow is estimated using the Kootenai River at Leonia and an estimate for the local based on the gage at Moyie River at Eastport. After 2002, the flow set equal the observed flow recorded at USGS gage 12310100 (Kootenai River at Tribal Hatchery near Bonners Ferry). This gage is an acoustic Doppler velocity meter which is not affected by backwater from Kootenay Lake. It appears that the 2010 method of estimated flow values at BFE tended to be too high between 2002 and 2008 when compared with observations at the Tribal Hatchery site as shown in Figure 3-3.

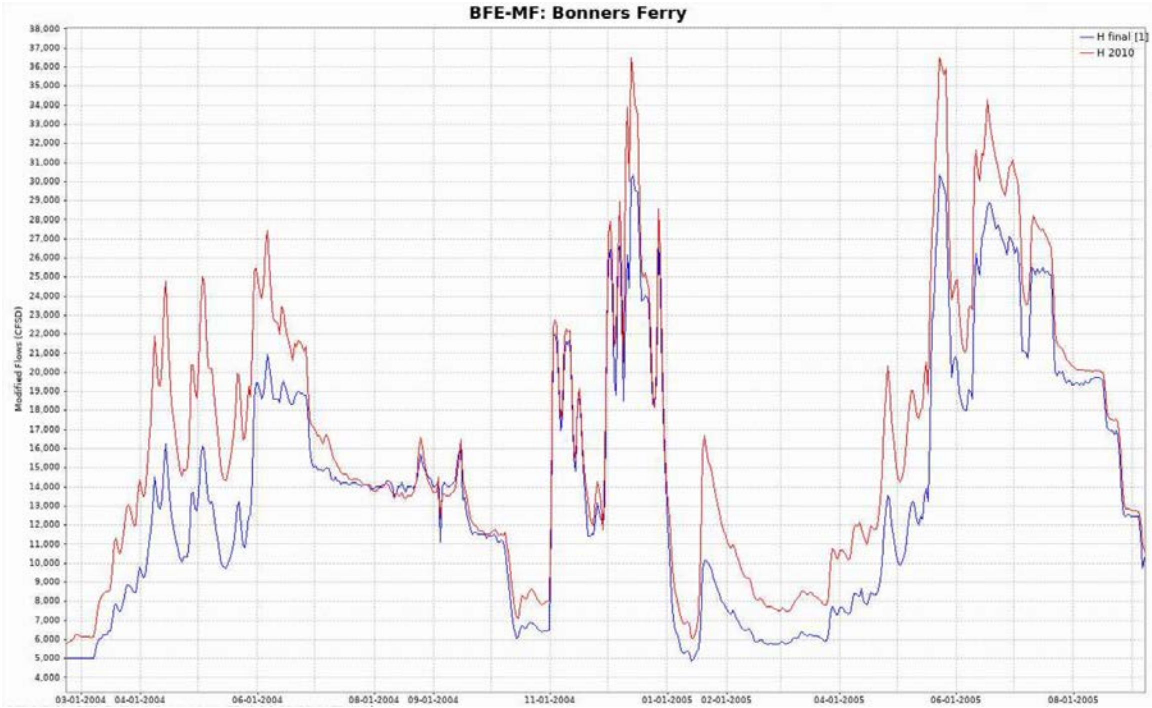

Figure 3-3. Comparison of Bonners Ferry (BFE) Modified Flows from 2010 (red) and 2020 (blue).

Murphy Creek, BC (MUC) – The Columbia River at Murphy Creek is located several miles downstream of the confluence of the Kootenay and Columbia rivers, near Birchbank, BC. Initially, the local flow contribution for this short reach was computed from the difference of MUC6H minus the sum of ARD6H and BIR6H, but the resulting local flow differed significantly from the 2010 values between 1961 and 1991 (Figure 3-4).

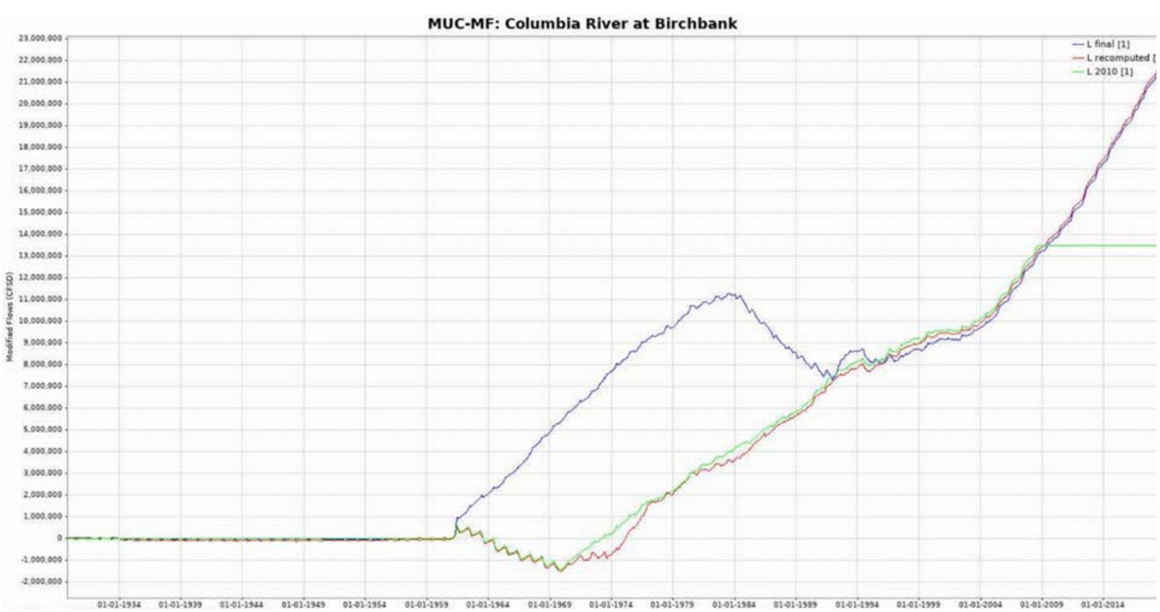

Figure 3-4. Murphy Creek (MUC) accumulated Local Flow from 2010 Modified Flows (green), 2020 Modified Flows (red), and as initially calculated 2020 Modified Flows from BCHydro ARD outflow data submittal (blue).

An inconsistency between the submitted ARD outflow and the ARD local inflow and storage is causing the unusual behavior with the MUC local. To preserve the mass balance ARD outflow was computed using:

$$ARD6H = MCD6H + RVC6L - RVC6S + ARD6L - ARD6S.$$

The resulting local flow more closely resembles the local flow in 2010 Modified Flows, indicating that a similar approach was used to address the issue. The computed Arrow inflow using this equation is only applied for the computation of the MUC local flow. The published ARD6H values are those submitted by BCHydro. Though these values deviate slightly between 1961 and 1991, as shown in Figure 3-5, the total volume of runoff during the 90-year record is virtually identical for both the submitted and calculated inflow.

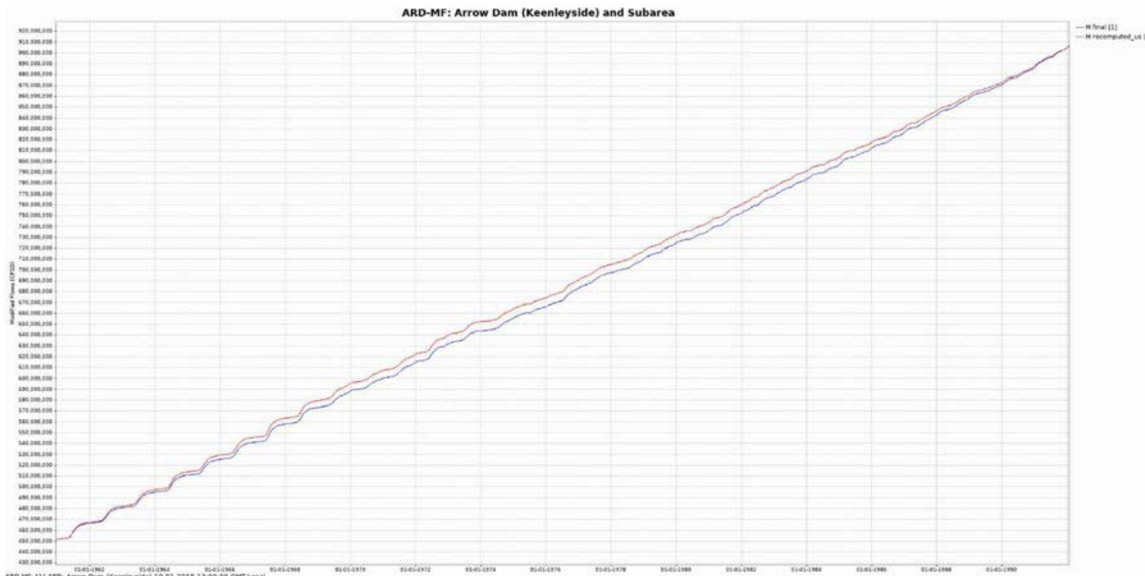

Figure 3-5. Accumulated Arrow ARD_BCH flow (blue line) and ARD6H (red line) outflow, 1961-1991

3.1.4 Equations

The equations used in the calculation of local flows, adjusted routed flows, accumulated depletions, accumulated evaporations and modified flows are shown below. For more details on the indexing of certain local flows, and about the routing involved in determining local and adjusted routed flows, refer to the Routing Diagram in Appendix C.

A full list of abbreviations can be found in Section 3.1.2 and Appendix B. Data type definitions can be found in Section 1.3.

Local Flows (*L*):

RVC6L = BCHydro provided quality controlled data
ARD6L = BCHydro provided quality controlled including Whatshan Dam
MUC6L = MUC6H – [(ARD6H + BRI6H) routed to MUC]
BFE6L = BFE6H - (LIB6H routed to BFE)
COR6L = COR6A – [(BFE6H routed to COR) + DCD5H]
BRI6L = BRI6H – COR6H

Adjusted Routed Flows (*ARF*):

RVC6ARF = (MCD6A routed to RVC) + RVC6L
ARD6ARF = (RVC6ARF routed to ARD) + ARD6L + WGS (Whatshan)
MUC6ARF = [(ARD6ARF + BRI6ARF) routed to MUC] + MUC6L
BFE6ARF = (LIB6A routed to BFE) + BFE6L
COR6ARF = (BFE6ARF routed to COR) + DCD6A + COR6L
BRI6ARF = COR6ARF + BRI6L

Accumulated Depletions (*DD*):

MCD6DD = UPC6D
RVC6DD = UPC6D + (0.35) ARD6D
ARD6DD = UPC6D + ARD6D
LIB6DD = EKO6D + (0.85) KMT6D
BFE6DD = EKO6D + KMT6D
COR6DD = EKO6D + KMT6D + KID6D + WKO6D
BRI6DD = COR6DD + BRI6D
MUC6DD = ARD6DD + BRI6DD + (0.45) CTR6D
CTR6DD = ARD6DD + BRI6DD + CTR6D

Accumulated Evaporation (*EE*):

RVC6EE = RVC6E + MCD6E
ARD6EE = RVC6EE + ARD6E
COR6EE = LIB6E + DCD6E
MUC6EE = ARD6EE + COR6EE

Modified Flows (*M*):

MCD6M = MCD6A + MCD6DD + MCD6E
RVC6M = RVC6ARF + RVC6DD + RVC6EE
ARD6M = ARD6ARF + ARD6DD + ARD6EE
LIB6M = LIB6A + LIB6DD + LIB6E
BFE6M = BFE6ARF + LIB6E + KMT6D + EKO6D
DCD6M = DCD6A + DCD6E
COR6M = COR6ARF + COR6DD + COR6EE
CAN6M = COR6M
UBN6M = COR6M
LBN6M = COR6M
SLO6M = COR6M
BRI6M = BRI6ARF + BRI6DD + COR6EE
MUC6M = MUC6ARF + MUC6DD + MUC6EE

3.2 Pend Oreille and Spokane Basins

The area described in this section includes the Pend Oreille River and the Spokane River Basins. Both of these rivers are major tributaries to the Columbia River above the Grand Coulee Dam. The Pend Oreille-Clark Fork basin drains 25,800 square miles in Montana, Idaho, Washington, and British Columbia. The Spokane River drains 6,200 square miles in Idaho and Washington. See Section 3.2.1 for a map of the area.

Irrigation is concentrated in the valleys of the Flathead, Bitterroot, Clark Fork above St. Regis, MT, and Spokane Rivers. Irrigation supplied by surface water in the area increased from 317,000 acres in 1928 to around 400,000 acres in the early 2000s before declining to around 353,000 acres in 2018 (with total acreage using both surface and groundwater sources at around 420,000 acres). Most of the irrigation is for hay and pasture, although some irrigation supports grain, sugar beet, potato, fruit and vegetable cultivation. Use of sprinklers has increased markedly since the 1990s, with about 75 percent of irrigated acreage under this form of application in 2018. Approximately 25 percent of the acreage uses gravity methods, with a very small amount of micro irrigation.

Since 2010 Modified Flows, a key basin hydroelectric project changed ownership. In 2015, the Confederated Salish-Kootenai Tribe completed the purchase of Kerr Dam, and renamed it Seli'š Ksanka Qlispe' Dam. River Keepers Incorporated (EKI), which is a wholly owned tribal subsidiary, was established to oversee project operations and management. In some publications, the identifier SKQ is growing into greater acceptance in recognition of this name change. However, because many data feeds and computational systems are difficult to update when identifiers are changed, 2020 Modified Streamflows retains to previous KER designation until other hydroregulation systems can be updated.

In the Spokane Basin, groundwater is basically an underground river that interfaces with the Spokane River. Thus all irrigated lands in this basin, regardless of water supply source, were included in the determination of the irrigation adjustment. The Spokane River and the underlying Spokane Valley-Rathdrum Prairie Aquifer are highly interconnected with water flowing back and forth between the two along numerous reaches of the Spokane River (USGS, 2005). The water supply source for irrigation has essentially been converted from surface water, via the Rathdrum Prairie and Spokane Valley Farms canals, to groundwater pumping. Streamflow modifications are computed by adding historical canal diversions and subtracting 2020 level adjustments. Early in the century, the Spokane Valley Farms canal was installed to divert water from the Spokane River for irrigation downstream from Lake Coeur d'Alene. Monthly diversions averaged about 250 cfs from June to August and somewhat smaller amounts in May and September. In 1946, the Rathdrum Prairie Canal began diverting water to the first unit of the Rathdrum Prairie Project. These diversions averaged 45 cfs in June, July and August, and 25 cfs in May and September. In 1968, the Spokane Valley Farms Canal was abandoned and the irrigation project was supplied by groundwater pumping. Adjustment for irrigation in the Spokane Basin is made by adding back the historical diversions from the Spokane Valley Farms Canal and the Rathdrum Prairie Canal for the entire period of record and subtracting the 2020 level of adjustment.

Below is the list of areas where depletion adjustments were computed as described in Appendix B.

(1) The Upper Clark Fork and Blackfoot River Basins above Missoula
(2) The Bitterroot River Basin
(3) The Lower Clark Fork from Missoula to Lake Pend Oreille
(4) Privately developed land upstream from the Flathead Indian Reservation
(5) The Flathead Reservation from Flathead Lake to Plains
(6) The Pend Oreille Basin in Idaho and Washington from Cabinet Gorge to the Canadian border
(7) The Salmon River (tributary to the Pend Oreille) in British Columbia; the Pend d'Oreille River in British Columbia, Canada
(8) The Spokane River Basin from Lake Coeur d'Alene to the Columbia River

Equations used to arrive at *L*, *ARF*, *DD*, *EE* and *M* are shown in Appendix B. A schematic diagram depicting where and how the various irrigation adjustments are applied, and the data used to calculate irrigation depletions can be found in the WSU Supplemental Report.

3.2.1 Regional Map

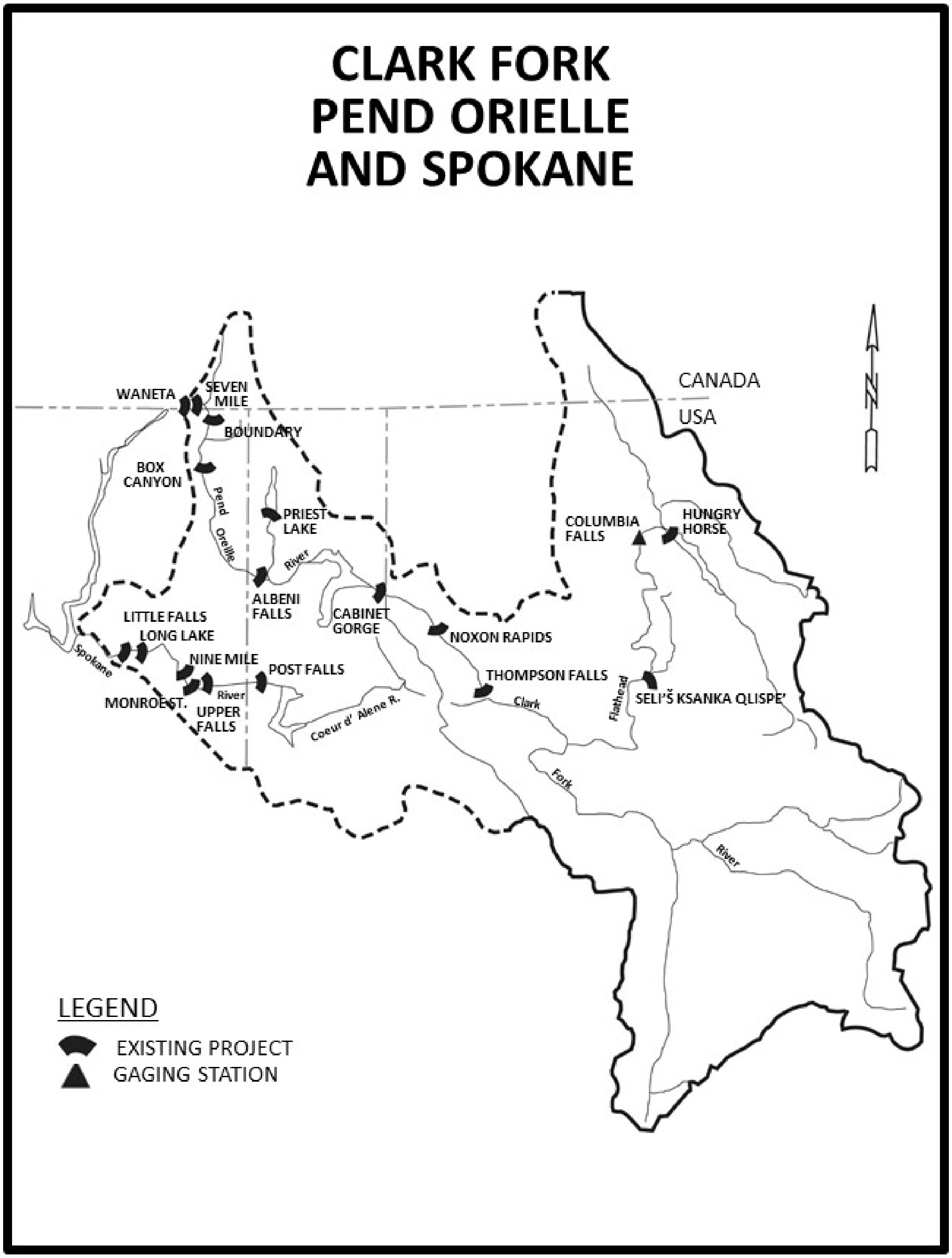

Figure 3-6. Pend Oreille and Spokane Basin Map

3.2.2 List of Points

Table 3-2. Pend Oreille and Spokane Basin Points

ID	Name	Basin	H	S	A	L	ARF	D	DD	E	EE	M
HGH	Hungry Horse	Pend Oreille	x	x	x					x		x
CFM	Columbia Falls	Pend Oreille	x			x	x					x
KER	Seli'š Ksanka Qlispe'	Pend Oreille	x	x	x	x	x		x			x
TOM	Thompson Falls	Pend Oreille	x	x	x	x	x		x			x
NOX	Noxon Rapids	Pend Oreille	x	x	x	x	x		x	x	x	x
CAB	Cabinet	Pend Oreille	x	x	x	x	x		x			x
PSL	Priest Lake	Pend Oreille	x	x	x							x
ALF	Albeni Falls	Pend Oreille	x	x	x	x	x		x			x
BOX	Box Canyon	Pend Oreille	x	x	x	x	x		x			x
BDY	Boundary	Pend Oreille	x	x	x	x	x		x			x
SEV	Seven Mile	Pend Oreille	x	x	x	x	x		x			x
WAT	Waneta	Pend Oreille	x	x	x		x					x
COE	Coeur D'Alene	Spokane	x	x	x				x			x
PFL	Post Falls	Spokane										x
UPF	Upper Falls	Spokane	x				x		x			x
MON	Monroe Street	Spokane										x
NIN	Nine Mile	Spokane	x				x					x
LLK	Long Lake	Spokane	x	x	x		x					x
LFL	Little Falls	Spokane										x
SUV	Sullivan Lake	Pend Oreille			x							x
FLT	Upper Flathead	Pend Oreille						x				
FID	Flathead Irrigation District	Pend Oreille						x				
BIT	Bitterroot	Pend Oreille						x				
UCF	Upper Clark Fork	Pend Oreille						x				
LCF	Lower Clark Fork	Pend Oreille						x				
PEN	Pend Oreille	Pend Oreille						x				
POC	Pend Oreille in Canada	Pend Oreille						x				
RAT	Rathdrum Prairie Canal	Spokane						x				
SPV	Spokane Valley	Spokane						x				
SPO	Spokane Valley Farms Canal	Spokane						x				

3.2.3 Special Characteristics

Modified flow points that are calculated differently from the methodology described in Appendix B and points that have other special characteristics are discussed in this section.

Seli'š Ksanka Qlispe', MT (KER) – The inflow values submitted by Energy Keepers for the 2020 Modified Flows are extremely noisy, due in large part to considerable wave action on Flathead Lake (see Section 2.4.2), and very often included negative values. Prior modified flow studies smoothed the inflows to remove the negative values. For 2020 Modified Flows, and for the period October 1, 1998 through September 30, 2018, the submitted inflows are used as a starting point, but are indexed using the USGS gaging site 12370000, Swan River near Bigfork, MT. Using this indexing procedure removes the negatives and greatly smooths the local values, while at the same time conserving the overall volumes. The indexed local flows are then added back to the routed Columbia Falls flow (CFM) to arrive at a realistic inflow.

Thompson Falls Dam, MT (TOM) – Early (prior to 1999) outflow data (H) is adjusted by factor of 1.045 times USGS gage Clark Fork near Plains. This factor was based on the ratio of volumetric adjusted runoff past the Plains and Thompson Falls gages during the concurrent period of record.

Cabinet Gorge Dam, ID (CAB) - In the 2010 Modified Flows, the outflow is estimated using the observed flow at Clark Fork at Whitehorse Rapids (12392000) minus 800 cfs to account for ground water inflow between stream gage and project site. For the 2020 modified flows, Avista submitted actual outflow from the project dating back to January 1986.

Sullivan Lake, WA (SUV) – Inflow (*A*) into Sullivan Lake was calculated for the period July 1928 through September 2018 using a linear relationship between Priest Lake inflows and estimated Sullivan Lake inflows provided by Pend Oreille PUD. The lake inflows were available for the periods 1961-1971 and 1994-2002. This period was used to develop the linear relationship to calculate the inflow into Sullivan Lake. These correlation factors required some minor adjustments so that the annual calculated volume better matched the annual outflow gage. Using Priest Lake inflow as an index to Sullivan resulted in numerous negative inflow values. For the period up to and including 2008, the negative flows and very small flows below 10 cfs were replaced with the mean flow for that day of year based on the Pend Oreille PUD inflows. A different approach was taken to remove the unwanted negative flows for 2008-18. For this period, the Priest Lake inflows were smoothed to remove the negative values, thereby ensuring that the indexed inflows into Sullivan Lake also remained positive

Priest Lake, ID (PSL) – Inflows were calculated based on flow from USGS gage '12394000 Priest River near Coolin, ID'. Since this gauge is downstream of the project, the flow at this USGS gage was reduced to better match the expected outflow at the project. The equation used was:

Outflow at Priest Lake = USGS 12394000 – 0.134*(USGS12394000 – USGS 12395000).

USGS gage '12395000 Priest River near Priest River, ID' is located downstream of USGS 12394000, and the 0.134 factor is the ratio of the drainage area between Priest Lake to 12394000 and 12394000 to 12395000.

Also to note, gage 12394000 was discontinued at the end of the 2006 water year. To calculate inflows for the remaining period of 1 October 2006 through 30 September 2018, a monthly correlation was performed to extend the record at gage 12394000. Table 3-3 shows the results of this correlation.

Table 3-3. Priest Lake Regression Coefficients

USGS 1239400 = USGS 12395000*a + b

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
a	0.943	0.848	0.714	0.652	0.574	0.572	0.621	0.772	0.872	0.885	0.829	0.934
b	-83.2	-54.3	-0.7	23.1	104.1	-14.9	-8.6	120.7	-94.6	-129.6	-80.6	-115.1

These same regression coefficients are used in the latest period, October 1, 2008 to September 30, 2018, to estimate the outflow from Priest Lake. During periods of low flow, small fluctuations in the Priest Lake elevation gage, USGS 12393000, causes the inflow calculations to often become negative. These minor lake elevation changes were smoothed in order to remove the negative inflows, while attempting to conserve volumes by smoothing unrealistic flow spikes.

Box Canyon and Boundary, WA (BOX, BDY) – Local flows at Box Canyon, WA, and Boundary, WA, were determined to be incorrect when calculated from project data. When positive local flow values were observed at one site, it was common to observe negative local flows of a similar magnitude at the other site. To avoid using the erroneous project data at both Box Canyon and Boundary, local flows were calculated by routing outflow from Albeni Falls (ALF) directly to BDY, bypassing BOX, and then creating an ALF to BDY local flow. This total local flow was then proportioned into a BOX local and BDY local by using the percentage of their drainage areas to the total of the drainage area between BDY and ALF (0.7 for BOX, 0.3 for BDY). This methodology is applicable for the most recent nineteen years of data (1999-2018). Therefore, from 1999-2018, observed project outflow values at BOX, and the corresponding inflow values, were not used in the calculation of BOX or BDY locals as was done in the past.

Seven Mile, BC (SEV) – Outflow data from Seven Mile, BC was not available so it was calculated from change in storage data and inflow into the project:

SEV5H = SEV5A – SEV5S,

where

SEV5A = USGS 12398600 + Water Survey Canada 08NE074.

Inflow was estimated as the sum of USGS gage #12398600 Pend Oreille River at International Boundary, and Water Survey of Canada gage #08NE074. In previous modified flows studies, the USGS gage #12398600 was used for the Seven Mile project although the gage is located upstream of Seven Mile.

From October 1, 2008 to September 30, 2018, outflow and change in storage were provided by BCHydro for SEV. The inflow was then derived using the outflow plus the change in storage.

Spokane River at Coeur D'Alene, ID (COE) - Between July 1 and October 7 each year, the change in storage values are smoothed using a 7-day moving average. This adjustment impacts the entire period of record, not just the most recent ten years. This is necessary because reservoir storage fluctuations during the summer low inflow period causes numerous erroneous negative inflow spikes.

Spokane Valley Irrigation, WA (SPV, RAT and SPO) – Irrigation depletions in the Spokane Valley, north and west of Post Falls Dam, are accounted in three depletion datasets: SPV6D, RAT6D and SPO6D. The incremental depletion values in SPV6D are determined as described in the WSU Supplemental Report. RAT5D and SPO6D are records of historical diversions from the Spokane River which are obtained from gaged USGS data.

RAT5D is the historical diversion from the Spokane River to the first unit of the Rathdrum Prairie Project in the Spokane Valley. The data is obtained from USGS Gage #12418000 (Rathdrum Prairie Canal near Huetter, ID), which was in place from April 1946 to September 1992. SPO6D is the historical diversion from Spokane River for the Spokane Valley Farm area. This data is obtained from USGS Gage #12418500 (Spokane Valley Farms Canal at Post Falls, ID), which was in service from July 1928 to September 1966.

Spokane River at Nine Mile Dam, WA (NIN) – The local for NIN, which extends upstream to the outlet of Upper Falls Dam (UPF), is indexed to a streamflow gaging gage within the contributing area to smooth out fluctuations. The streamflow record measured at the USGS Hangman Creek at Spokane (12424000) is used as the indexing gage. There is a relatively complete record back to 1948. Prior to that, the Little Spokane at Dartford, WA (12431000) and Colville River at Kettle Falls, WA (12409000) are used to reconstruct the streamflow record back to 1928. Figure 3-7 shows the reduction in daily variability in the local flow from indexing and the virtually elimination.

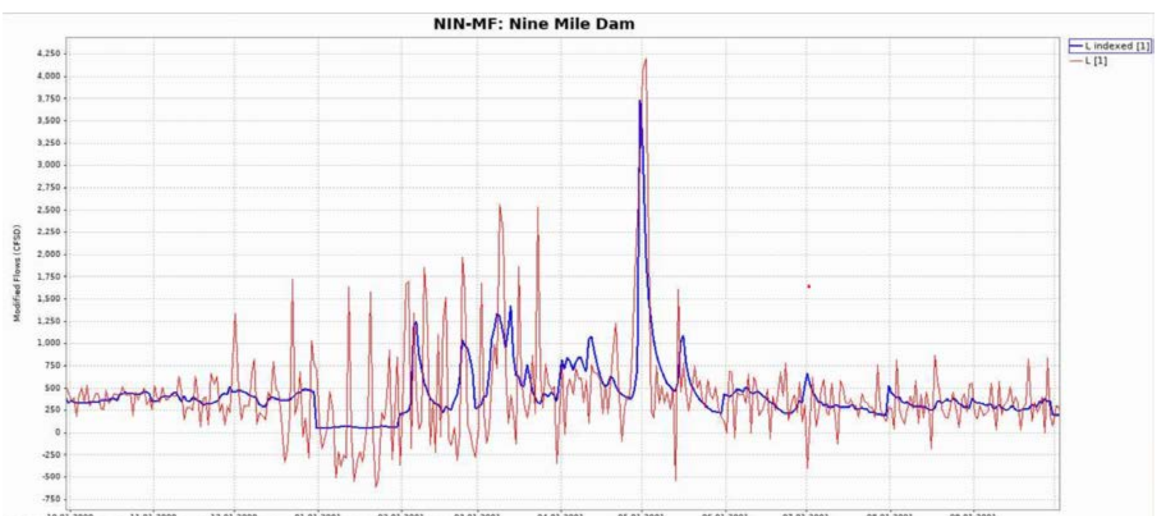

Figure 3-7. Comparison of raw (red) and indexed (blue) local flows for Spokane River at Nine Mile Dam.

Spokane River at Long Lake Dam (LLK) – Similar issues are present with the LLK local, which extends upstream to the outlet of Nine Mile Dam (NIN). The local is indexed to a streamflow gaging gage within the contributing area to smooth out fluctuations. The streamflow record measured at the USGS Little Spokane at Dartford, WA (12431000) is used as the indexing gage. There is complete record back to 1947. The Colville River at Kettle Falls, WA (12409000) is used to reconstruct the streamflow record back to 1928.

3.2.4 Equations

The equations used in the calculation of local flows, adjusted routed flows, accumulated depletions, accumulated evaporations and modified flows are shown below. For more details on the indexing of certain local flows, and about the routing involved in determining local and routed flows, refer to the Routing Diagram in Appendix B.

A full list of abbreviations can be found in Section 3.2.2 and in Appendix A. Data type definitions can be found in Section 1.3.

Local Flows (*L*):

CFM6L = CFM6L – (HGH6L routed to CFM6L)
KER6L = KER6A – (CFM6L routed to KER)
TOM6L = TOM6L – (KER6L routed to TOM)
NOX6L = NOX6A – (TOM6L routed to NOX)
CAB6L = CAB6A – (NOX6L routed to CAB)
ALF6L = ALF6A – ((CAB6L + PSL6L) routed to ALF)
(BOX + BDY)6L = BDY6A – (ALF6L routed to BDY)
BOX6L = 0.7 * (BOX + BDY)6L
BDY6L = 0.3 * (BOX + BDY)6L
SEV6L = Salmo River near Salmo
UPF6L = UPF6L – (COE6L routed to UPF)
NIN6L = NIN6L – (UPF6L routed to NIN)
LLK6L = LLK6A – (NIN6L routed to LLK)

Adjusted Routed Flows (*ARF*):

CFM6ARF = (HGH56 routed to CFM) + CFM6L
KER6ARF = (CFM6ARF routed to KER) + KER6L
TOM6ARF = (KER6ARF routed to TOM) + TOM6L
NOX6ARF = (TOM6ARF routed to NOX) + NOX6L
CAB6ARF = (NOX6ARF routed to CAB) + CAB6L
ALF6ARF = ((CAB6ARF + PSL6A) routed to ALF) + ALF6L
BOX6ARF = (ALF6ARF routed to BOX) + BOX6L
BDY6ARF = (BOX6ARF routed to BDY) + BDY6L
SEV6ARF = BDY6ARF + SEV6L
WAT6ARF = SEV6ARF + WAT6S
UPF6ARF = (COE6A routed to UPF) + UPF6L
NIN6ARF = (UPF6ARF routed to NIN) + NIN6L
LLK6ARF = (NIN6ARF routed to LLK) + LLK6L

Accumulated Depletions (*DD*):

KER6DD = FLT6D + FID6D
TOM6DD = FLT6D + FID6D + UCF6D + BIT6D + (0.84) LCF6D
NOX6DD = TOM6DD + (0.16) LCF6D
CAB6DD = NOX6DD
ALF6DD = CAB6DD + (0.72) PEN6D
BOX6DD = CAB6DD + PEN6D
BDY6DD = BOX6DD
SEV6DD = BDY6DD + POC6D
COE6DD = RAT6D + SPO6D
UPF6DD = COE6DD + SPV6D

Accumulated Evaporation (*EE*):

NOX6EE = NOX6E + HGH6E

Modified Flows (*M*):

HGH6M = HGH6A + HGH6E
CFM6M = CFM6ARF + HGH6E
KER6M = KER6ARF + KER6DD + HGH6E
TOM6M = TOM6ARF + TOM6DD + HGH6E
NOX6M = NOX6ARF + NOX6DD + NOX6EE
CAB6M = CAB6ARF + CAB6DD + NOX6EE
PSL6M = PSL6A
ALF6M = ALF6ARF + ALF6DD + NOX6EE
BOX6M = BOX6ARF + BOX6DD + NOX6EE
SUV6M = SUV6A
BDY6M = BDY6ARF + BDY6DD + NOX6EE
SEV6M = SEV6ARF + SEV6DD + NOX6EE
WAT6M = WAT6ARF + SEV6DD + NOX6EE
COE6M = COE6A + COE6DD
PFL6M = COE6M
UPF6M = UPF6ARF + UPF6DD
MON6M = UPF6M
NIN6M = NIN6ARF + UPF6DD
LLK6M = LLK6ARF + UPF6DD
LFL6M = LLK6M

3.3 Mid-Columbia Basin

The mid-Columbia region consists of lands in and around Grand Coulee Dam to Priest Rapids Dam, including the Okanagan and Kettle basins in British Columbia, and the Columbia Basin Project.

Irrigation from surface water in the Okanagan, Similikameen and Kettle Rivers in Canada, like in the upper Columbia-Kootenay Basins, is quite small compared to elsewhere in the Columbia Basin. In this 2020 study, irrigated acreage in these subbasins is around 44,000 acres, compared to the estimate of 79,000 acres in 2010 Modified Flows. There was also a reduction in irrigated acreage in the Ferry, Stevens, Methow and Okanogan basins on the US side of the border, with 63,000 irrigated acres in 2010 decreasing to 25,000 in 2020 (42,000 acres when both surface and ground water sources are taken into account). This part of the basin is a prime orchard and winery region, interspersed with hay and pasture lands mostly on the US side of the international border. Over 90 percent of this acreage is irrigated via sprinklers, with the reminder irrigated with micro/drip systems.

The remaining irrigated land area is referred to as the Big Bend Area. This is the area that is east and south of the Columbia River, where the river makes its “Big Bend”. Lands within the “Big Bend” are: The Columbia Basin Project, lands west of Banks Lake (mentioned above), and lands east of the Columbia Basin Project, herein called Big Bend East.

Irrigated lands in the Big Bend East area are located on the high plateau east of the Columbia Basin Project. Water supply in this area is derived from mostly groundwater sources. The surface/groundwater barrier is generally impermeable in this area, so groundwater pumping is considered as water mining. Little, if any, surface water is withdrawn in this area with most streams discontinuous and ephemeral. Irrigation in this area does not have return flow or depletion impacts on the Columbia River flows, and thus are not included in the study.

Lands irrigated in the area west of Banks Lake, on the other hand, are located along the Columbia River, so diversions and return flows are treated as if the Columbia was the direct water source. Irrigation west of Banks Lake is combined with the irrigation in the Chelan, Entiat and Wenatchee Basins, with the total irrigation depletions applied between Chief Joseph and Rock Island Dams. As noted in the WSU Supplemental Report, a sizeable irrigated acreage correction has been made in this 2020 study, with total irrigation from surface water sources at around 42,000 acres (51,000 acres when both surface and groundwater sources). A wide variety of grain and orchard crops are grown in this region. About 75 percent of this area is irrigated via sprinkler systems.

Below is the list of areas where depletion adjustments were computed as described in the WSU Supplemental Report. Apart from these areas, the Yakima Basin and Columbia Basin Project Area also affect the irrigation depletion in this basin:

(1) The Kettle River in Canada
(2) The Okanagan River in Canada
(3) The Ferry-Stevens counties above Grand Coulee Dam
(4) The Methow and Okanogan Basins
(5) The Chelan, Entiat and Wenatchee Basins along with the area “West of Banks Lake”

The 2010 Modified Flows report presented a change in the methodology used to calculate local flows joining the Columbia River between Chief Joseph and Priest Rapids Dams. This report follows the same methodology and is discussed in detail in Section 3.3.4 of the 2010 report.

Irrigation is extensively practiced in the Yakima Basin, and largely regulated by the Bureau of Reclamation as detailed in the Yakima Basin Supplemental Report. Irrigated acreage from surface water sources increased from around 333,000 acres in 1928 to around 465,000 acres in 2008 before declining slightly through 2018. About 65 percent of this area is irrigated via sprinkler systems. Like in previous studies, Reclamation calculated the set of regulated modified streamflows at the mouth of the Yakima River. The Yakima River observed flows (6H) are subtracted from the regulated flows (6R) provided from the USBR to arrive at a depletion adjustment for the Yakima River. This adjustment is applied to the modified flows at McNary Dam.

The Columbia Basin Project supplies irrigation water for over 671,000 acres across central and eastern Washington. Water is pumped from Franklin D. Roosevelt (FDR) Lake behind Grand Coulee into the equalizing reservoir Banks Lake. From there, water is routed through the project distribution system. Return flows from the northern portion of the project flow to the Potholes Reservoir, where they are reused to irrigate other project lands. Return flows from the project re-enters the main river system into Wanapum (WRF6D), Priest Rapids (PRF5D), and McNary (MRF6D) Reservoirs. Details on this complex irrigation project are included in Appendix F of the WSU Supplemental Report.

Equations used to arrive at *L*, *ARF*, *DD*, *EE* and *M* are shown in Section 3.3.5. A schematic diagram depicting where and how the various irrigation adjustments are applied, and the data used to calculate irrigation depletions can be found in the WSU Supplemental Report.

3.3.1 Regional Map

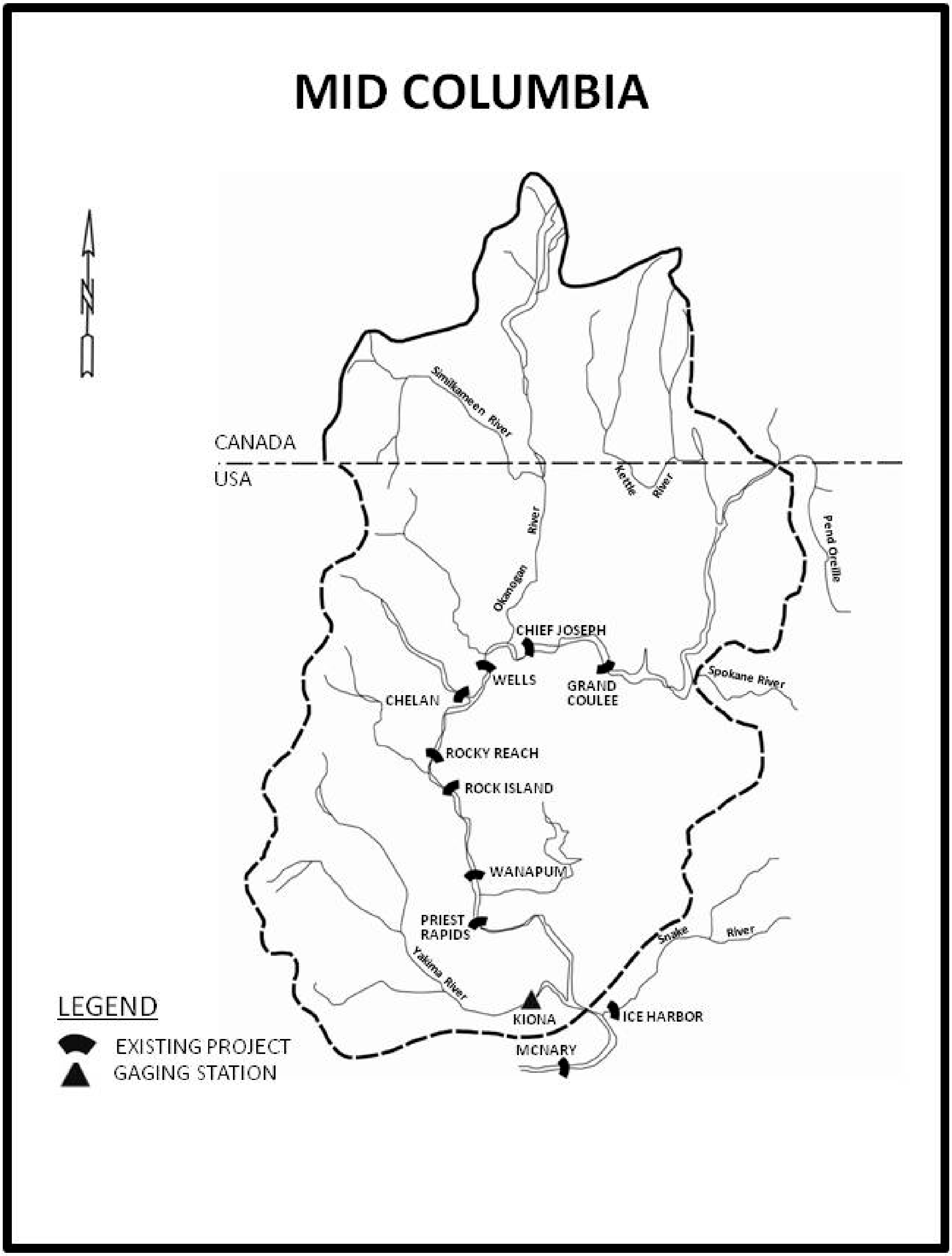

Figure 3-8. Mid-Columbia Basin Map

3.3.2 *List of Points*

Table 3-4. Mid-Columbia Basin Points

ID	Name	Basin	H	S	A	L	ARF	D	DD	E	EE	M
GCL	Grand Coulee	Mid-Columbia	x	x	x	x	x	x	x	x	x	x
CHJ	Chief Joseph	Mid-Columbia	x	x	x	x	x			x	x	x
WEL	Wells	Mid-Columbia	x	x	x	x	x		x	x	x	x
CHL	Chelan	Mid-Columbia	x	x	x							x
RRH	Rocky Reach	Mid-Columbia	x	x	x	x	x		x	x	x	x
RIS	Rock Island	Mid-Columbia	x	x	x	x	x		x			x
WAN	Wanapum	Mid-Columbia	x	x	x		x		x	x	x	x
PRD	Priest Rapids	Mid-Columbia	x	x	x	x	x		x	x	x	x
YAK*	Yakima	Mid-Columbia	x						x			x
FDR**	Franklin D. Roosevelt Lake	Mid-Columbia										
OKA	Okanagon in Canada	Mid-Columbia						x				
OKM	Methow-Okanagan	Mid-Columbia						x				
KET	Kettle	Mid-Columbia						x				
FER	Ferry-Stevens	Mid-Columbia						x				
CEW	Chelan-Entiat-Wenatchee-West of Banks Lake	Mid-Columbia						x				
WRF	Wanapum Return Flow	Mid-Columbia						x				
PRF	Priest Rapids Return Flow	Mid-Columbia						x				

***YAK has an additional data type, *R*, which is flow data provided by the USBR (Supplemental Report)**
****FDR has two additional data types: *G* and *P*, which are generation and pumping flow data (Section 3.3.3)**

3.3.3 *Special Characteristics*

Modified flow points that are calculated differently from the methodology described in Appendix B. and points that have other special characteristics are discussed in this section.

Grand Coulee, WA (GCL) – The Keyes Pumping Plant diverts flow from the reservoir behind Grand Coulee Dam, Franklin D. Roosevelt Reservoir, into Banks Lake, where it is stored to provide about 2.8 million acre feet of irrigation water for the Reclamation Columbia Basin Project. Water is also returned periodically from Banks Lake to Franklin D. Roosevelt Reservoir through the Keyes Plant for power generation. The datasets which contain the Grand Coulee diversion (pumping) and return flow from power generation are FDR6P and FDR6G, respectively. FDR6P values are positive while FDR6G values are negative. The pumping and generation are accounted in the calculation of inflows into Grand Coulee Dam as:

$$GCL6A = GCL6H + GCL6S + FDR6P + FDR6G$$

With the total Grand Coulee depletion represented as:

$$GCL6D = FDR6P - FDR6G$$

Irrigation depletions at Grand Coulee Dam are, in effect, the net water removed from the river for the irrigation that occurs in the Columbia Basin Project. An estimated 2020 Level diversion schedule of water exchange between Franklin D. Roosevelt Reservoir and Banks Lake was derived by averaging pumping from October 2009 to September, 2018, which included a range of wet, average and dry years. However, the averages excluded periods when maintenance outages caused abnormal pumping schedules. Because irrigation schedules change significantly within the months of April and August, which in turn can impact flows in these key times of the year, Reclamation calculated split-month diversion schedules for April and August for 2020 Modified Flows. Details are included in Appendix F of the WSU Supplemental Report. Table 3-5 details differences between 2010L and 2020L average depletions for GCL.

Table 3-5. Average daily net pumping rate (cfs) for 14-periods, and differences between 2010 (5D) and 2020 (6D) Modified Flows. Negative pumping indicates average return flow back into FDR Reservoir due to pump-generation at the Keys Pumping Plant.

Month	GCL5D (cfs)	GCL6D (cfs)	Diff. (cfs)
Jan	-85	-52	33
Feb	-186	129	315
Mar	1349	1364	15
Apr 1-15	5913	5932	19
Apr 16-30	5913	6527	614
May	7696	7097	-599
Jun	7258	7208	-50
Jul	8961	8972	11
Aug 1-15	5744	6734	990
Aug 16-31	5744	4708	-1036
Sep	6910	5811	-1099
Oct	2995	2647	-348
Nov	543	352	-191
Dec	98	185	87

Chelan, WA (CHL) -- Inflows at Chelan Dam (CHL6A) were calculated as:

$$CHL6A = CHL6S + CHL6H,$$

but this yielded noisy and unrealistic hydrographs. Therefore, inflows were indexed against a neighboring stream gage, the USGS Gage Stehekin River at Stehekin, WA (#12451000). Due to its long period of record, indexing was done for all the years from 1928 until 2018 to smooth the Chelan flows to more realistic values.

Wells, Rocky Reach, Rock Island, Wanapum, and Priest Rapids, WA: Locals, Inflows and Outflows (WEL, RRH, RIS, WAN, PRD) – This 2020 study follows the same methodology, with some slight variations, as the 2010 study to calculate local flows in the river reach between Chief Joseph and Priest Rapids Dams. The differences are explained in detail in Section 3.3.4.

Yakima, OR (YAK) – Regulated “modified” flows at Yakima are provided by Reclamation (Supplemental Report) and are denoted as data type YAK6R. Irrigation depletions are already accounted in YAK6R, but are not available from Reclamation as a separate dataset.

The following calculation was used to create a YAK6DD record. YAK6DD is created because it is a component in the calculation of MCN6DD.

$$YAK6DD = YAK6R - YAK6H$$

where YAK5H is data from USGS gage Yakima River at Kiona WA,12510500.

YAK6DD is one of the three locations where *DD* values should not be compared directly with the 6DD values at other sites in the Columbia River Basin because they are calculated differently. The other two locations with different *DD* calculations include BRN6DD and ROU6DD.

3.3.4 Mid-Columbia Locals Methodology

3.3.4.1 Introduction

Local flows in the mid-Columbia River reach between Chief Joseph, WA (CHJ) and Priest Rapids, WA (PRD), are calculated as described in Appendix B. Numerous issues with negative flows, unrealistic flow shapes and atypical flow magnitudes in previous Modified Flows studies were corrected using the methodology described in the *2010 Level Modified Streamflow* report. However in the 2010 study, the corrections were only applied to the 1960-2018 period.

For 2020 Modified Flows, this superior local flow calculation methodology is extended to the entire 90-year record because it removes almost all negative local flows and creates more realistic hydrographs while preserving hydrologic mass balance. Because of this improvement, though, daily local flows for 1928-1960 are significantly different between 2010 and 2020 Modified Flows, even though average semi-monthly and monthly flows and volumes are similar between the two studies as mass balance is maintained.

In addition to this calculation improvement, quality control updates to gaged side streams within this reach are also applied for 2020 Modified Flows, which in turn prompted an update to the indexing linear regressions used to calculate some local flows.

This section provides the details for each local calculation within the mid-Columbia river reach, and the subsequent impacts to inflows, outflows, routed flows, and modified flows at the following mid-Columbia points:

- Wells, WA (WEL),
- Rocky Reach, WA (RRH),
- Rock Island, WA (RIS),
- Wanapum, WA (WAN), and

- Priest Rapids, WA (PRD).

3.3.4.2 Local Flow Calculation Methodology

The principal reason for switching to the alternate local flow calculation method in the 2010 Modified Flows was that most of larger the side streams flowing into the mid-Columbia projects are gaged. In addition, because reliable mainstem gage data within this reach is lacking, project outflow estimates are particularly difficult in this heavily regulated portion of the basin.

The active storage at these mid-Columbia projects is small compared to the magnitude of the river flow. Because of this, project outflow was chosen as the parameter that required modification in most cases. The observed change in content provided by the project owner or USACE is accepted as being correct. Local inflow for each project is assumed to be the gaged flow of the tributary streams. The change of reservoir content is assumed to be observed change-of-content, and the project outflow is revised to be consistent with these values.

The starting point of the alternate method is Chief Joseph Dam, with the ending point at Priest Rapids Dam. The observed outflow at Chief Joseph (CHJ6H) and Priest Rapids (PRD6H) are assumed correct. All the inflows and outflows of the dams between Chief Joseph and Priest Rapids are calculated based on the method of computing locals as described as follows:

Wells Local Flow:

Two major tributaries flow into the stretch of river between Chief Joseph Dam and Wells Dam, the Okanogan and Methow Rivers. Unfortunately, these two streams were not continuously gaged at a single site for the entire 90-year record. However, multiple locations were gaged that covered the period of concern, so linear regression indexing is performed for each stream segment to obtain a reasonable estimate of flows for each river, resulting in:

WEL6L = Okanogan River + Methow River.

Okanogan River:

from July 1928 – Sept 1928:

Methow River at Twisp (USGS #12449500) correlated via linear regression with Okanogan River near Tonasket (USGS #12445000)

from October 1928 – April 1929:

Observed flow from Similkameen River near Nighthawk, WA (USGS #12442500)

from May 1929 – September, 2018:

Observed flow from Okanagan River near Tonasket, WA (USGS #12449950).

Table 3-6. Okanogan Regression Coefficients

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
a	1.626	2.055	2.977	2.527	2.727	1.479	1.437	1.338	1.577	1.762	2.545	2.758
b	583.28	519.21	153.19	375.78	354.19	698.1	555.02	2282.15	1425.78	565.35	120.44	227.29

Methow River:

from July, 1928 – September, 1928:

Observed flow from Methow River at Twisp (USGS #12449500)

from October, 1928 – September, 1933:

Stehekin River at Stehekin (USGS #12451000) linearly correlated with Methow River near Pateros (USGS #12449950)

from October, 1933 – March, 1959:

Observed flow from Methow River at Twisp (USGS #12449500)

from April, 1959 – September, 2018:

Observed flow from Methow River near Twisp (USGS #12449950).

Table 3-7. Methow Regression Coefficients

USGS 12445000 = USGS 12449500a +b

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
a	0.26	0.23	0.35	0.26	0.39	0.86	1.28	1.55	1.54	0.94	0.54	0.35
b	326.01	389.25	300.25	309.31	257.48	116.31	-61.86	-220.92	-752.17	-420.71	-12.34	194.13

Wells Inflow and Outflow:

WEL6A = (CHJ6H routed to WEL) + WEL6L
WEL6H = WEL6A – Observed WEL6S

Rocky Reach Local Flow:

The main tributary between Wells Dam and Rocky Reach Dam is the Entiat River. Similar to WEL6L, the local contributions are constructed through overlapping gaging station records at differing locations along the Entiat River through linear correlations.

RRH6L = Entiat River

from July, 1928 – September, 1951:

Stehekin River at Stehekin (USGS #12451000) linearly correlated with Entiat River near Entiat (USGS #12452990)

from October, 1951 – September, 1958:

Entiat River at Entiat (USGS #12453000)

from October, 1958 – March, 1996:

Entiat River near Ardenvoir (USGS #1242800) from March, 1996 – September, 2018:

Entiat River near Entiat (USGS #12452990)

Table 3-8. Entiat River Regression Coefficients

USGS 12449950 = USGS 12451000a +b

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
a	0.1	0.16	0.23	0.14	0.3	0.3	0.37	0.38	0.42	0.31	0.24	0.12
b	91.34	97.92	64.38	109.22	61.11	92.07	26.9	90.39	-140.88	-136.29	-42.81	60.39

Rocky Reach Inflow and Outflow

RRH6A = (CHL6H + WEL6H routed to RRH) + RRH6L

RRH6H = RRH6A – Observed RRH6S

Rock Island Local Flow:

The main tributary between Rocky Reach Dam and Rock Island is the Wenatchee River. As with RRH6L, the local contributions are constructed through overlapping gaging station records at differing locations along the Wenatchee River and through linear correlations.

RIS6L = Wenatchee River

from July, 1928 – February, 1929:

Wenatchee River at Plain (USGS #12457000) linearly correlated with Wenatchee River at Monitor (USGS #12462500)

from March, 1929 – September, 1962:

Wenatchee River at Peshastin (USGS #12459000) linearly correlated with Wenatchee River at Monitor (USGS #12462500)

from October, 1962 – September, 2018:

Wenatchee River at Monitor (USGS #12462500).

Table 3-9. Wenatchee River at Plain Regression Coefficients

USGS 12457000 = USGS 12462500a +b

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
a	1.03	1.11	1.11	1.11	1.15	1.15	1.09	1.1	1.1	1.05	1.03	1.05
b	11.16	-68.69	-26.54	-0.42	-23.65	2.67	39.12	-265.32	-373.66	-186.03	-110.15	-65.74

Table 3-10. Wenatchee River at Peshastin Regression Coefficients

USGS 12459000 = USGS 12462500a +b

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
a	1.348	1.57	1.56	1.59	1.603	1.73	1.534	1.535	1.518	1.414	1.378	1.404
b	5.359	-129.852	-57.113	-53.385	-12.032	-97.101	-6.9	-391.969	-574.999	-339.456	-231.048	-146.564

Rock Island Inflow and Outflow
The nearest Columbia River gage above Rock Island Dam was used for RIS_H values up until it was removed in 1959. After this date RIS_H was calculated using the routed RRH_H data, the main tributary of the reach (RIS_L), and RIS_S.

RIS6H = RRH6H routed to RIS) + RIS6L - Observed RIS6S
RIS6A = RIS6H + RIS6S

Wanapum Local Flow
No major tributaries are present and therefore local flows into this section of the reach is negligible.

Wanapum Inflow and Outflow

WAN6A = RIS6H routed to WAN
WAN6H = WAN6A – Observed WAN6S

Priest Rapids Local Flow, Inflow and Outflow:
The local flow at Priest Rapids is primarily used to balance the net local area contribution within the reach from Chief Joe Dam to Priest Rapids Dam. This is the same approach used in the 2010 Modified Flows study to account for local flow within this reach, though the specific methodology has changed with the current modified flows study. As described earlier, the locals for WEL, RRH and RIS are calculated using USGS observed values of the major tributaries within each reach. This approach does not fully account for all local flow contributions because not all of the contributing area is gaged, and there are some inherent inaccuracies in measuring discharge.

To account for these issues and to maintain the water balance, the PRD local is computed as the difference between PRD outflow and the summation of CHJ outflow, the locals at WEL, RRH and RIS, and the change in storage at WEL, RRH, RIS, WAN and PRD. The accumulated flow is routed to PRD using the SSARR model before being subtracted from the observed PRD outflow. The resulting local time series is extremely noisy, so it is smoothed using an eleven day moving average to reduce the day to day fluctuations. This is a more appropriate method of smoothing the local flow compared to indexing to a USGS time series of an adjacent tributary since actual local inflow is insignificant within this reach.

The current PRD local differs from the 2010 Modified Flows local flow calculation in two primary ways. First, the current methodology balances the flow on each day. In 2010 the water balance was evaluated at the end of the record, and an average daily miscellaneous flow was computed and added to each day of the PRD local time series. The second difference is that the methodology introduced in 2010 Modified Flows was extended to the beginning of the study period. In 2010 this methodology was only used from 1960 to 2008. These changes dramatically changed the shape of the PRD local, and this is best portrayed in the accumulated flow plot (see Figure 3.9).

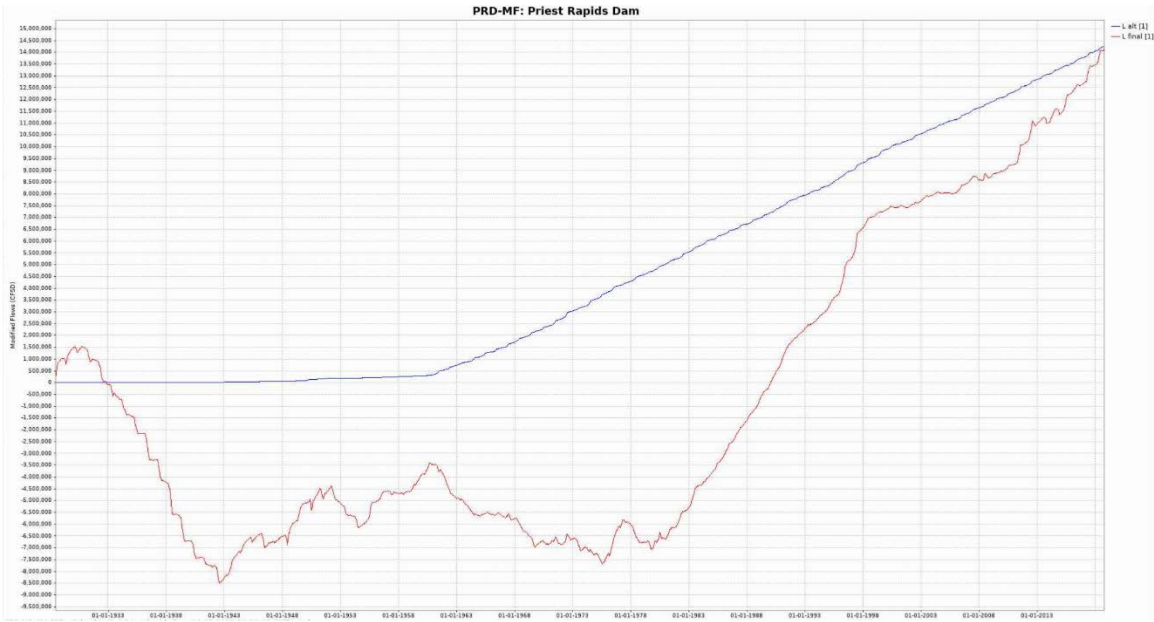

Figure 3-9. Accumulated local flow at PRD, 2010 (blue) and 2020 (red).

Both methodologies show a net accumulation of water within the PRD local but the 2020 local shows higher day to day variation and net negative flow during the 1930s. The negative local flows during the 1930s appear to compensate for a net increase in locals at WEL, RRH and RIS during the period prior to 1960. Overall, the new methodology better accounts for the net water balance within the middle Columbia reach.

3.3.5 Equations

The equations used in the calculation of local flows, inflows, routed flows, accumulated depletions, accumulated evaporations and modified flows are shown below. For more details on the indexing of certain local flows, and about the routing involved in determining local and routed flows, refer to the Routing Diagram in Appendix B

A full list of abbreviations can be found in Section 3.3.2 and in Appendix A. Data type definitions can be found in Section 1.3.

As discussed in the previous section, because local flows at Wells, Rocky Reach, Rock Island, and Priest Rapids are now based on gaged side stream data rather than calculated values, the equations usually used to calculate locals are not applicable at these locations. In this stretch of the river, local flows are observed values while the inflows into the projects are calculated based on these local flows. Because these inflows were not determined the typical way, equations that show how they were calculated are included.

Locals (*L*):

CIB = Columbia River at International Boundary. Refer to Appendix B

GCL_L = GCL_A – (CIB_H routed to GCL) – LLK_H
CHJ_L = CHJ_A – (GCL_H routed to CHJ)

WEL_L = Gaged Sidestreams
RRH_L = Gaged Sidestreams
RIS_L = Gaged Sidestreams
PRD_L = PRD_A – (WAN_H routed to PRD)

Inflows (*A*):

GCL_A = GCL_H + GCL_S + FDR_P + FDR_G
CHJ_A = CHJ_H + CHJ_S
WEL_A = WEL_L + (CHJ_H routed to WEL)
CHL_A = CHL_H + CHL_S
RRH_A = RRH_L + ((WEL_H routed to RRH) + CHL_H)
RIS_A = RIS_H + RIS_S
PRD_A = PRD_H + PRD_S

Adjusted Routed Flows (*ARF*):

GCL_ARF = (CIB_ARF routed to GCL) + GCL_L + LLK_ARF
CHJ_ARF = (GCL_ARF routed to CHJ) + CHJ_L
WEL_ARF = (CHJ_ARF routed to WEL) + WEL_L
RRH_ARF = (WEL_ARF routed to RRH) + RRH_L + CHL_A
RIS_ARF = (RRH_ARF routed to RIS) + RIS_L
WAN_ARF = RIS_ARF routed to WAN
PRD_ARF = (WAN_ARF routed to PRD) + PRD_L

Accumulated Depletions (*DD*):

GCL6DD = CTR6DD + SEV6DD + UPF6DD + KET6D + FER6D + GCL6D
WEL6DD = GCL6DD + OKA6D + OKM6D + (0.01) CEW6D
RRH6DD = GCL6DD + OKA6D + OKM6D + (0.4) CEW6D
RIS6DD = GCL6DD + OKA6D + OKM6D + CEW6D
WAN6DD = RIS6DD + WRF6D*
PRD6DD = WAN6DD + PRF6D*
YAK6DD = YAK6R** – YAK6H

*details in WSU Supplemental Report
**details in Reclamation Yakima Supplemental Report

Accumulated Evaporation (*EE*):

GCL6EE = MUC6EE + NOX6EE + GCL6E
CHJ6EE = GCL6EE + CHJ6E
WEL6EE = CHJ6EE + WEL6E
RRH6EE = WEL6EE + RRH6E
WAN6EE = RRH6EE + WAN6E
PRD6EE = WAN6EE + PRD6E

Modified Flows (*M*):

GCL6M = GCL6ARF + GCL6DD + GCL6EE
CHJ6M = CHJ6ARF + GCL6DD + CHJ6EE
WEL6M = WEL6ARF + WEL6DD + WEL6EE
CHL6M = CHL6A
RRH6M = RRH6ARF + RRH6DD + RRH6EE
RIS6M = RIS6ARF + RIS6DD + RRH6EE
WAN6M = WAN6ARF + WAN6DD + WAN6EE
PRD6M = PRD6ARF + PRD6DD + PRD6EE

3.4 Upper and Central Snake Basins

The Snake River and its tributaries drain about 72,500 square miles upstream of Brownlee Reservoir on the Idaho-Oregon border. Surface water diversions provide an average of 14 to 16 million acre-feet of water each year to around 3.4 million acres above Brownlee Dam, while groundwater supplies provide an additional 3.5 to 7.5 million acre-feet. Less than 50 percent of diverted streamflow is consumptively used; the remainder returns to the river as surface flow or recharges the groundwater aquifer. Because of this complexity, regulation studies were again completed by the US Bureau of Reclamation (Supplemental Report) to reflect the net effect on streamflow by successive stages of irrigation and storage development. The regulation studies adjust the flows for the 1928 to 2018 period to reflect current irrigation and aquifer recharge requirements, along with other reservoir operation objectives such as providing flow augmentation for salmon habitat.

The end product of the Reclamation regulation studies of the Snake River above Brownlee Reservoir is a regulated “modified” flow. The regulated “modified” flows above Brownlee Reservoir, denoted as BRN5R, do not remove the effect of dam storage whereas the modified flows defined in this report do. For this reason, it is not appropriate to compare modified flows generated by Reclamation with modified flows generated in this 2020 level study. This study also incorporates several process and modeling improvements, including flood control operations, better irrigation and groundwater estimates and return flows, and daily flows calculated by newly implemented Riverware software. More details are in the attached Reclamation Supplement Report.

The area in this section includes: (1) the upper Snake Basin above King Hill (map shown in Section 3.4.1) which is a drainage area of about 36,000 square miles, encompassing parts of Idaho, Wyoming, Utah and Nevada, (2) the Central Snake Basin – King Hill to Brownlee, which is an area of about 36,800 square miles, encompassing parts of Idaho, Nevada and Oregon.

(1) Upper Snake:

The Upper Snake Basin above King Hill interfaces with groundwater (the Snake Plain aquifer), surface water, and storage to serve irrigated lands. Major storage in the Upper Snake is located on the main stem, and the entire system is coordinated and operated on a forecast basis. To model diversions, other characteristics, and distinctive features, the Upper Snake is divided into six sub-areas: South Fork, Henry’s Fork, Heise-Neeley, Neeley-Milner, North Streams, and West Streams.

Irrigation practice in the subareas includes both gravity and sprinkler applications and is modeled accordingly, together with groundwater pumping. All aspects of existing operation criteria are utilized in study simulations to meet irrigation needs together with the many additional uses performed by the river system.

(2) Central Snake:

In the Central Snake Basin from King Hill to Brownlee, major storage reservoirs are located on the tributaries, and the Snake River serves mostly as a drainage way for the highly developed tributary streams. The Central Snake River drainage is modeled in eight sub-areas: Bruneau, Boise, Payette, Weiser, Owyhee, Malheur, Burnt, and Powder Rivers. Each basin is operated on a forecast basis, and coordination of the Central Snake system focuses on the diversity of basin runoff.

Between the Boise and Payette Rivers, some basin water exchanges are made. Irrigation practices (gravity, sprinkler, and groundwater pumping) are modeled accordingly. In addition to the irrigation system as modeled for surface and groundwater supplies, about 800,000 acre-feet is pumped seasonally for irrigation from the main stem of the river (Buhl, ID to Weiser, ID). This development started in about 1965, and has grown steadily to its present level. Since direct river pumping quantities are not measured, diversions are estimated by utilizing actual generation records of the energy used to pump the water by procedures developed by the Idaho Power Company and Reclamation.

3.4.1 Regional Maps

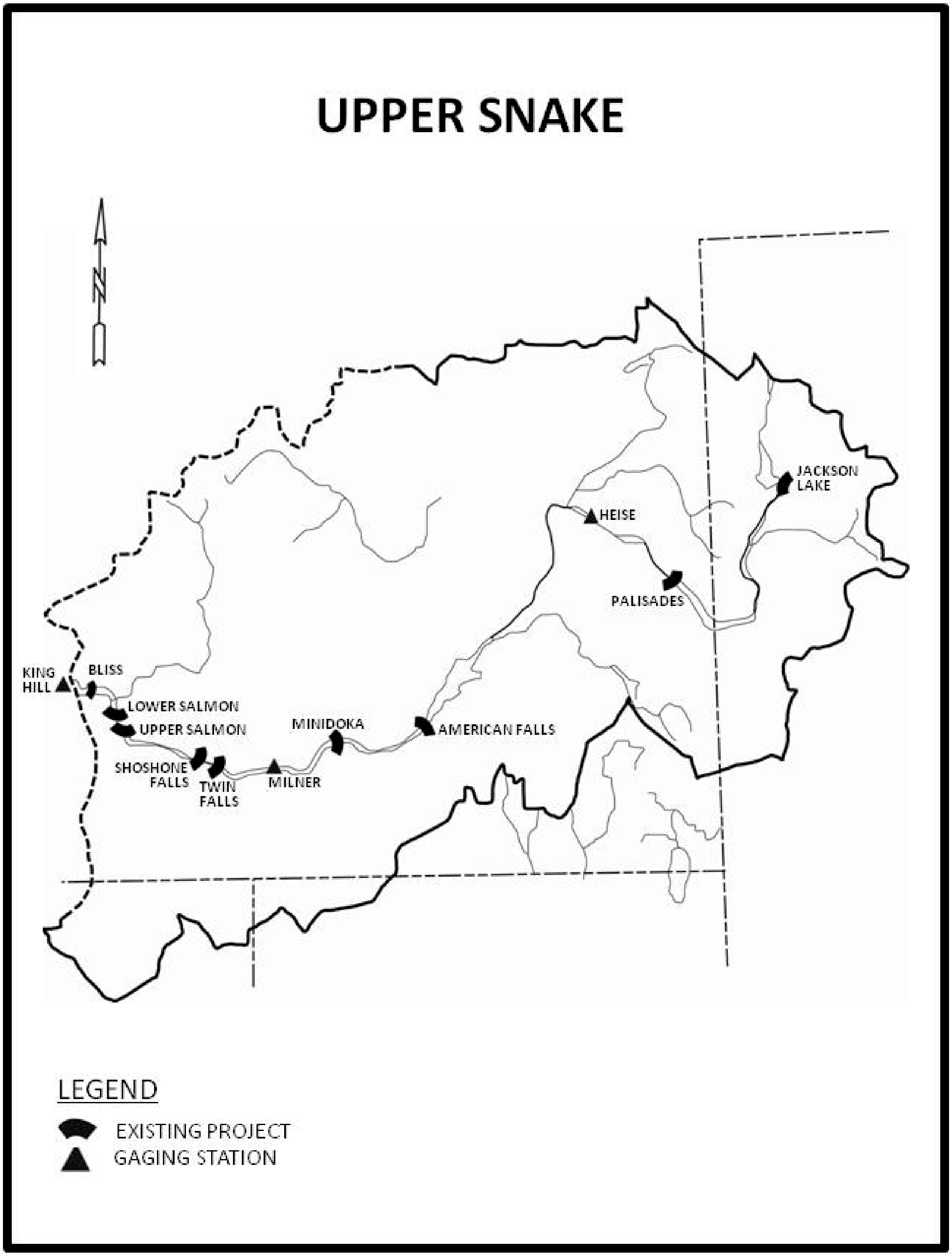

Figure 3-10. Upper Snake Basin Map

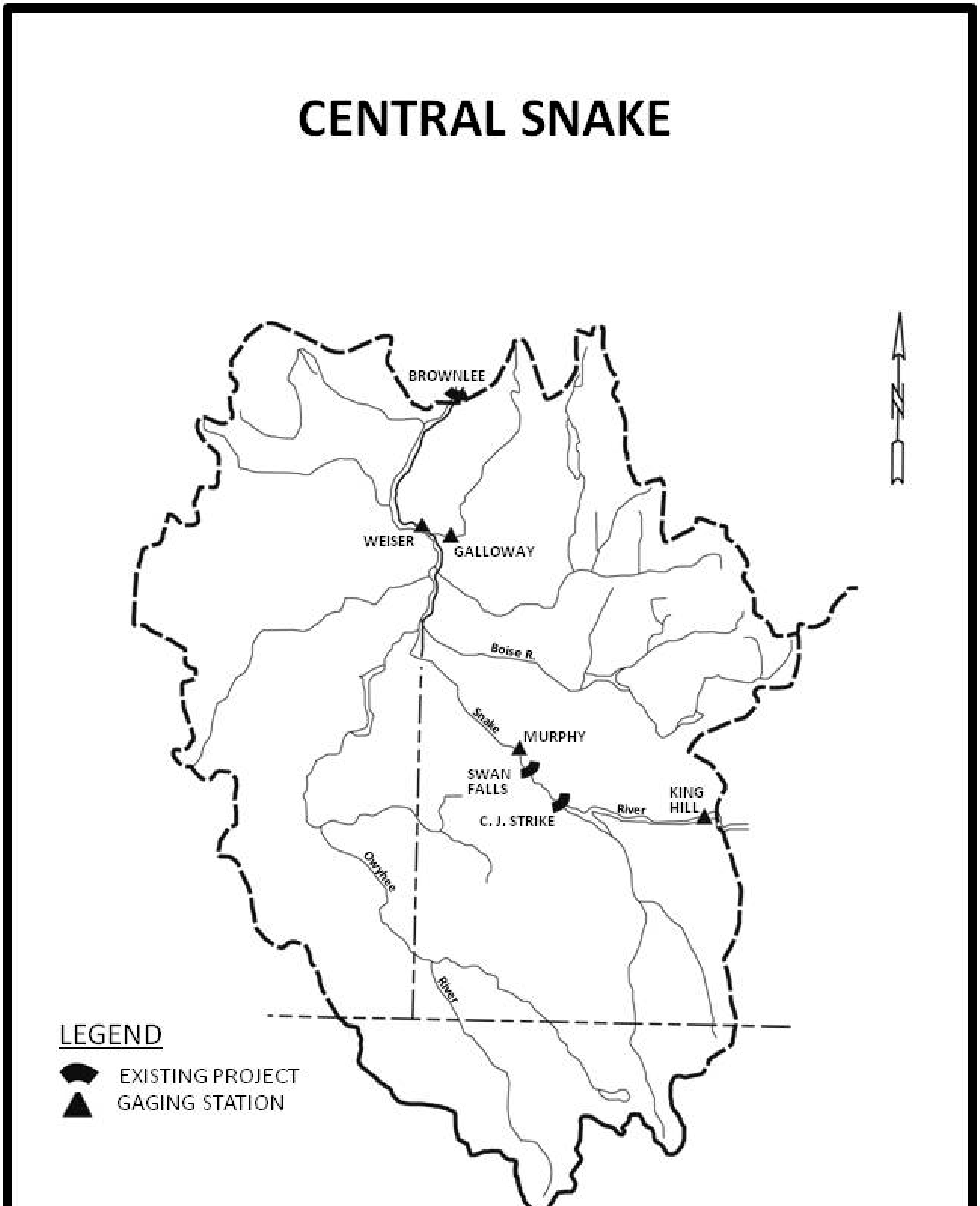

Figure 3-11. Central Snake Basin Map

3.5 Lower Snake Basin

The area contained in this section includes the Salmon, Clearwater, Grande Ronde, and Palouse River Basins, and the main stem Snake River from Brownlee Dam to the confluence with the Columbia River. The Salmon River drains 14,100 square miles on the east side of the Snake River Basin. Meanwhile, the Clearwater River drains 8,300 square miles, the Grande Ronde River drains 3,412 square miles, and the Palouse-Lower Snake collect the runoff from the remaining 10,598 square miles. See Section 3.5.1 for a map of the area.

Irrigation is concentrated in the Upper Salmon, Grande Ronde, and Palouse-Lower Snake areas. Irrigation from surface water increased from about 223,000 acres in 1928 to 272,000 acres by the late 1990s, before diminishing to around 216,000 acres by 2018 (although total acreage under irrigation from both surface and ground water sources was closer to 269,000 acres in 2018). In the Salmon River Basin, about 50 percent of the irrigated lands are supplied by sprinkler, while the Grande Ronde Basin has about 62 percent of its irrigated acreage under sprinkler application.

In the Clearwater and Palouse-Lower Snake Basins, and unlike much of the Columbia basin, estimates of acreage under sprinkler irrigation have declined from near 100 percent in the late 1990s to around 65 percent in 2018. In the Palouse subbasin, micro irrigation has also recently emerged as an application method, with about 3% of acreage irrigated using drip systems. These subareas are also notable in that almost a quarter of all irrigation water used in the Clearwater Basin comes from groundwater sources, while the Palouse-Lower Snake irrigation draws over 40% from groundwater.

Below is the list of areas where depletion adjustments were computed as described in Appendix B.

(1) The Upper Salmon River Basin
(2) The Lower Salmon River Basin
(3) The Grande Ronde River Basin
(4) The Clearwater River Basin
(5) The Palouse–Lower Snake River Basins

Apart from the above basins, irrigation depletions in the Upper and Central Snake River basins were derived from a special study by the USBR (upper Snake Supplemental Report). The representative accumulated depletion value for those basins are applied at Brownlee Dam, which is the location where the Lower Snake basin begins.

Equations used to arrive at *L*, *ARF*, *DD*, *EE* and *M* are shown in Section 3.5.4. A schematic diagram depicting where and how the various irrigation adjustments are applied, and the data used to calculate irrigation depletions can be found in the WSU Supplemental Report.

3.5.1 Regional Map

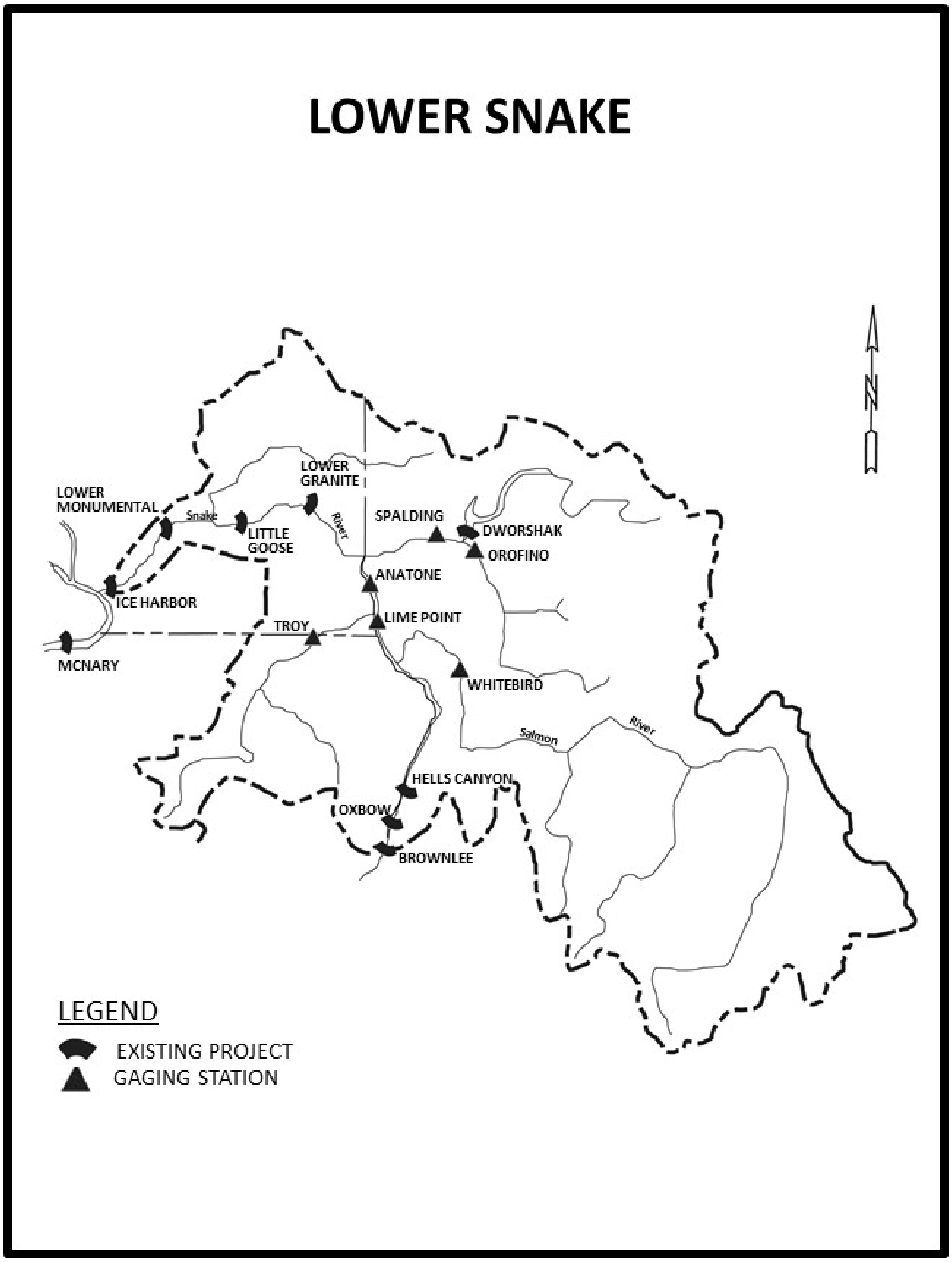

Figure 3-12. Lower Snake Basin Map

3.5.2 *List of Points*

Table 3-11. Lower Snake Basin Points

ID	Name	Basin	H	S	A	L	ARF	D	DD	E	EE	M
BRN*	Brownlee	Lower Snake	x	x	x				x	x		x
OXB	Oxbox	Lower Snake										x
HCD	Hells Canyon	Lower Snake	x	x	x	x	x			x	x	x
WHB	Whitebird	Lower Snake	x									x
LIM	Lime Point	Lower Snake	x			x	x					x
TRY	Troy	Lower Snake	x									x
ANA	Anatone	Lower Snake	x			x	x		x			x
ORO	Orofino	Lower Snake	x									x
DWR	Dworshak	Lower Snake	x	x	x					x		x
SPD	Spalding	Lower Snake	x			x	x					x
LWG	Lower Granite	Lower Snake	x	x	x	x	x		x	x	x	x
LGS	Little Goose	Lower Snake	x	x			x			x	x	x
LMN	Lower Monumental	Lower Snake	x	x	x	x	x		x	x	x	x
IHR	Ice Harbor	Lower Snake	x	x			x			x	x	x
UPS	Upper Salmon	Lower Snake						x				
LWS	Lower Salmon	Lower Snake						x				
WEN	Grande Ronde	Lower Snake						x				
CLR	Clearwater	Lower Snake						x				
PLS	Palouse-Lower Snake	Lower Snake						x				

***BRN has an additional data type, *R*, which is flow data provided by the USBR (Supplemental Report).**

3.5.3 *Special Characteristics*

Modified flow points that are calculated differently from the methodology described in Appendix B. and points that have other special characteristics are discussed in this section.

Brownlee, ID/OR (BRN) – Regulated "modified" flows at Brownlee are provided by Reclamation, as documented in the upper Snake Supplemental Report, are denoted as data type BRN6R. Note that these flows are computed differently because several large dams in this basin are multi-year storage reservoirs with considerable ranges in storage carryover from year-to-year. Irrigation depletions are already accounted in BRN6R and calculated by BPA, but are not available from the Reclamation as a separate dataset. As a result, BRN6DD is one of the three *DD* datasets in which values should not be compared directly with the 6DD values at other sites in the Columbia River Basin. The other two locations with regulated *DD* calculations include the Yakima River (YAK6DD) and the Deschutes River (ROU6DD).

Cumulative depletions from the Snake River above Brownlee Reservoir (BRN6DD) are computed from the BRN6R time series provided by the USBR. BRN6DD is created because it is a component in the calculation of *M* values at downstream modified flow locations:

BRN6DD = BRN6R – BRN6A

where BRN6A is inflow into Brownlee calculated from flow measured at USGS gaging stations.

In the 2010 study, Brownlee inflow was calculated by adding the change in storage (BRN6S) to the observed outflows at Brownlee dam (BRN6H). However, for the 2020 study, a new methodology for computing inflow is used to reduce the inaccuracies caused by inherent fluctuations in pool storage computations. Because reservoir inflow was computed from outflow and change in storage, additional errors in Brownlee inflow calculations resulted from an inaccurate estimation of Brownlee outflow using USGS gaging stations miles downstream and below Oxbow and Hells Canyon Dams. The new methodology uses USGS gaging stations upstream of the Brownlee reservoir with the Snake River at Weiser (13269000) contributing most of the flow. USGS gaging stations on Eagle Creek and the Burnt and Powder Rivers are used to compute inflow from the local area between the Snake River at Weiser gage and Brownlee Dam (Refer to Appendix B for additional details). Although, inaccuracies were observed throughout the year, they were most prevalent during the summer low flow periods as shown in Figure 3-13.

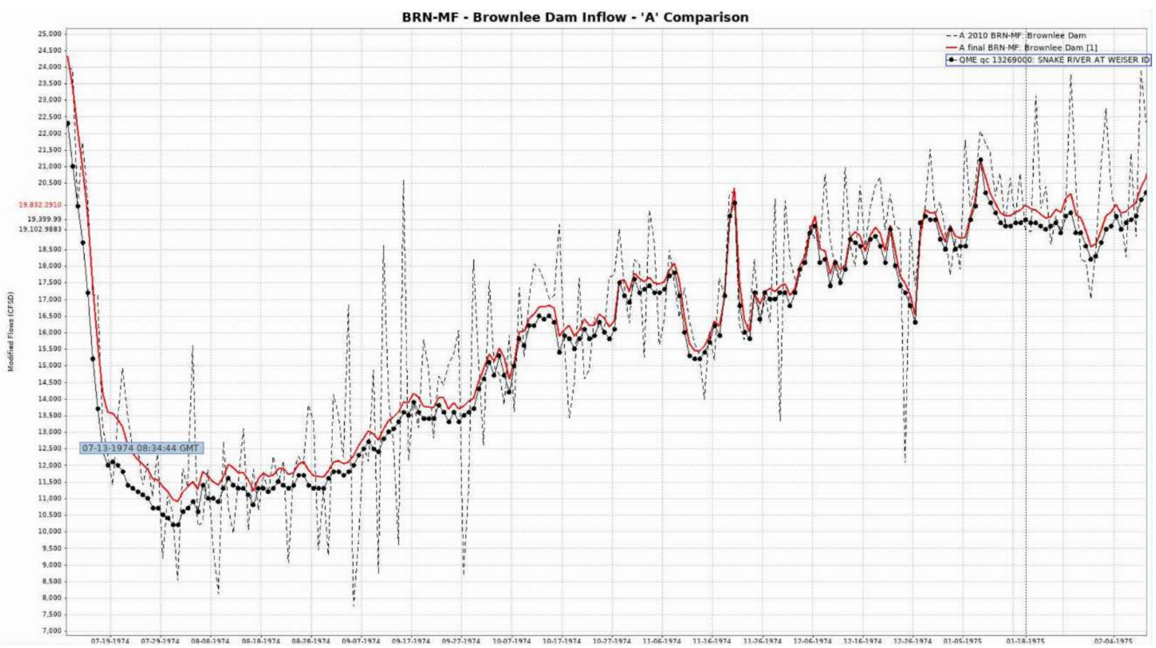

Figure 3-13. Comparison of 2010 and 2020 inflow at Brownlee Dam, ID/OR. Black dashed lines represent flows derived from Brownlee Reservoir elevations. Red line is the recalculated Brownlee inflow indexed to the USGS gage for the Snake River at Weiser, ID (USGS #13269000).

Even though the new method uses different time series to compute Brownlee inflow, the calculated and observed volumes are very similar. A mass comparison of the two methodologies shows that the total runoff volume computed using the new method is only 0.33 percent less for the overlapping July 1928 to September 2008 period. The smoother, more realistic, reservoir inflow record provides a better initial time series for the computation of downstream *ARF* and *M* flows.

Computation of reservoir outflow is now computed as:

BRN6H = BRN6A – BRN6S

Unfortunately, the Brownlee Reservoir outflow time series contains inaccuracies caused by fluctuating reservoir elevation and storage, which then translates to unrealistic swings in reservoir outflow. Brownlee outflow is subsequently used to compute the Hells Canyon local flow, which translates these unrealistic spikes and drops into the entire period-of-record. Indexing the resulting local flow to the USGS gage below Pine Creek at Oxbow (USGS #13290200) yields a smoother, more realistic time series while preserving mass balance.

Hells Canyon, ID/OR (HCD) – Hells Canyon Dam outflow is computed using the same general methodology used in 2010. However, a correction in estimating missing Pine Creek streamflow records between July 1928 and July 1965 is made, as the method used in previous Modified Flows studies which caused a mass balance discontinuity of as much as five percent. As discussed in the Brownlee section, the resulting Hells Canyon local (HCD6L) is different because of changes to Brownlee outflow. Like previous studies, indexing is again performed on the local flow. However, unlike 2010 when the Imnaha River at Imnaha (USGS #13292000) time series was used, flows in 2020 are indexed with the reconstructed Snake River below Pine Creek at Oxbow (USGS #13290200) time series. The resulting local flow is similar to the 2010 local flows, but indexing to a gage within the contributing area yielded a more realistic data fit. Hells Canyon Dam inflow is computed using these newly developed outflows and the change in storage. When comparing these results to the previous modified flow studies, one will see similar differences to the previously published inflow time series.

Lime Point, ID/OR (LIM) – Lime Point, which is located downstream of Hells Canyon Dam between the confluences of the Grande Ronde and Salmon Rivers with the Snake River, has historically been an important location as it relates to navigation of the Snake River. As early as June of 1944, there were requests that an adequate water channel be dug through Lewiston to allow lime, copper and iron ore to be shipped downstream to Portland Oregon. Idaho Power is currently required to meet a minimum discharge at Lime Point 95% of the time. However, no gaging stations were installed at Lime Point, so flow at this location was still computed from relatively distant gaging sites. However, in 2003, a gage in close proximity (within eight miles) to Lime Point was established on the Snake River: USGS Gage #13317660 (Snake River below McDuff Rapids at China Gardens, ID). As with the 2010 study, data from this relatively new gage is used directly to compute Lime Point from October, 2003 through September, 2018.

Prior to the installation of the USGS gage at China Gardens, ID, streamflow at Lime Point was computed as the sum of flows measure at the Salmon River at Whitebird, ID, the Imnaha River at Imnaha, OR, and the Snake River below Hells Canyon Dam. In the

2010 study, Lime Point flow was computed from the flows of the Snake River at Anatone, WA, minus the Grande Ronde River at Troy, OR, between October, 1999 and October, 2003. In this study, this computation method was applied from July 1958 through October 2003 since both the Anatone and Troy gaging records extend back to 1958, and this calculation tracked the China Gardens gaging record better than the summation of the three upstream gages.

Using the downstream Anatone and Troy streamflow records to compute Lime Point discharge gives a better accounting of water within the Lime Point local. The net water balance of the Snake Basin remains the same with the change in methodology. However, water has shifted out of the Anatone local and into the Lime Point local between 1958 and 1999 (See Figures 3-14 and 3-16). Shifting of water between the two locals provides a more accurate depiction of the flow gains within both of these reaches. There is still too little flow within the Lime Point local prior to 1958 due to the upstream gages that are used to compute the *H* flow at that location (See Figure 3-15). This water ultimately is accounted in the Lower Granite local. This behavior also existed in the 2010 study. No procedures to correct this imbalance are proposed in this analysis.

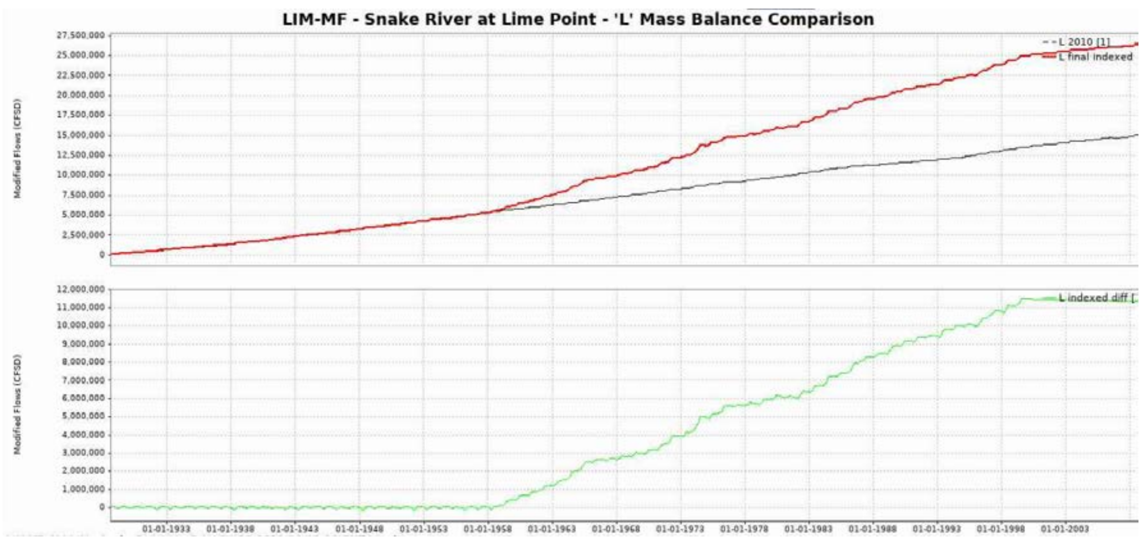

Figure 3-14. Snake River at Lime Point Local Mass Balance

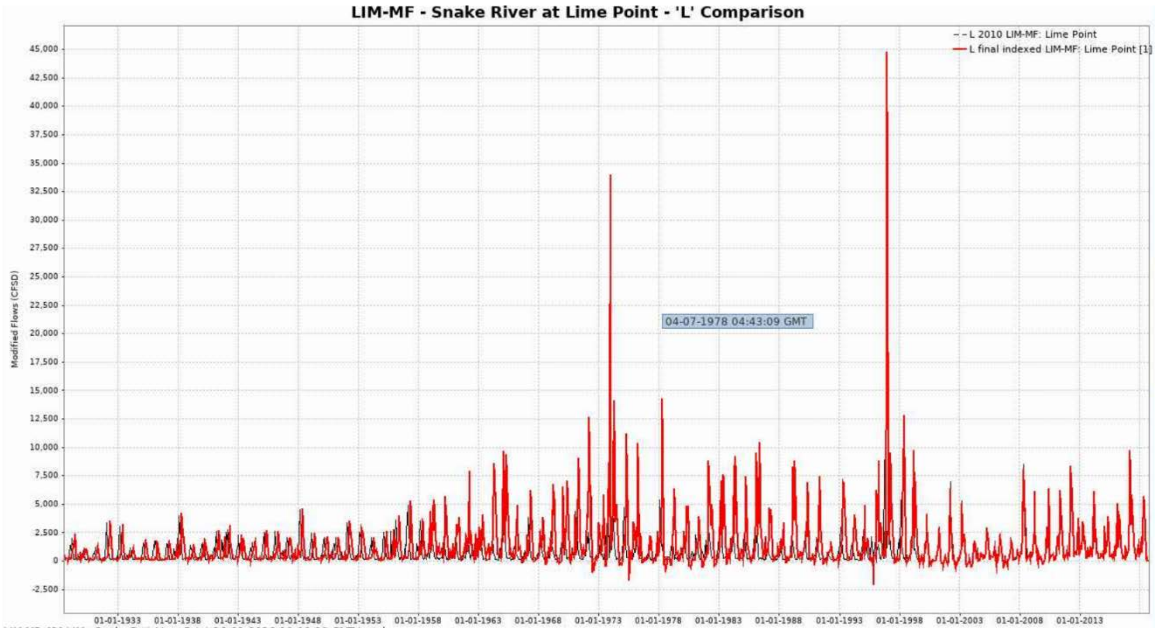

Figure 3-15. Snake River at Lime Point Local Flow (LIM6L)

Anatone, WA (ANA) – The Anatone gaging station was established in 1958. Prior to 1958, flow was estimated by summing the routed streamflow from the Snake River at Hells Canyon, Salmon River at White Bird and the Imnaha River at Imnaha, OR. Flow calculations are performed using the same methodology from 2010. The only difference is with the local flow (see Figure 3-16) which is lower than the 2010 values as a result of changes to the *H* flow computation at Lime Point.

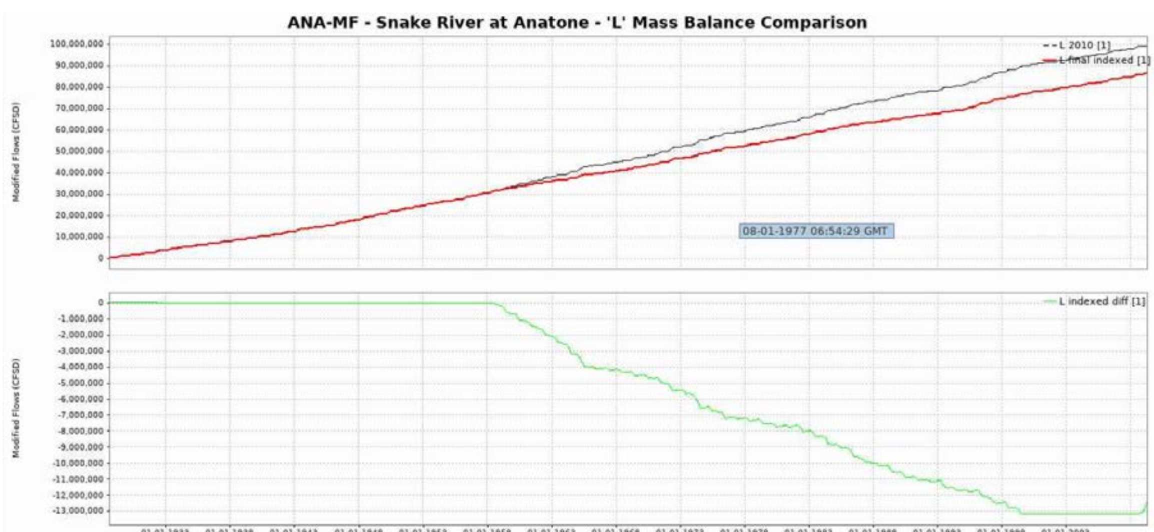

Figure 3-16. Snake River at Anatone Local Mass Balance

Dworshak, ID (DWR) – For this study observed outflow provided by the USACE is used. In the 2010 Dworshak outflow values were calculated from USGS streamflow gages upstream and downstream from confluence of the North Fork Clearwater River. Outflow was calculated as:

DWR5H = Clearwater River near Peck (USGS #13351050) – Clearwater River at Orofino (USGS #13340000)

Outflow is computed using this methodology again in this study, but a comparison of the USACE submitted outflow with the outflow computed from the USGS gages showed that the submitted data appeared from USACE to be more accurate with better quality control.

Lower Granite (LWG), Lower Monumental (LMN) and Ice Harbor (IHR), WA: Due to unrealistic and unreliable data reported at these sites due to a variety of reporting and hydraulic factors, the outflows from each of these dams are calculated using different methods that were used in 2010 and previous studies. USGS gaging stations immediately downstream from dams typically provide a more accurate measurement of streamflow than outflow computations made at the dam. Unfortunately, there are no USGS streamflow gaging stations currently maintained on the Snake River from Lower Granite Dam to the confluence with the Columbia River, with the only gage located below Ice Harbor Dam (USGS #13353000) discontinued in 2000.

In this study USGS gaging station data is used to compute Lower Granite inflow as it was in the 2010 study. However, in this study, downstream project flows are computed using available gage data, plus the project's change in reservoir storage and local flows. Listed below are specific details about how flows were computed for the lower Snake River dams.

Lower Granite, WA (LWG) – Inflows into Lower Granite Dam (LWG6A) are calculated as either the flow in the Snake River at Clarkston, ID (13343500) or the sum of the flows from the three upstream river reaches – the Snake River, the Clearwater River and Asotin Creek:

LWG6A = Clearwater River at Spalding (USGS #13352500) + Snake River at Anatone (USGS #13335300) + Asotin Creek at Asotin (USGS #13335050)

and

LWG6H = LWG6A – LWG6S.

Flows from Spalding, ID, and Anatone, WA, are not routed, as was done in the 2010 study, due to the short distance between the gages and Lower Granite.

The USGS gage Asotin Creek at Asotin, WA (#13335050) is used to provide flow contributions from Asotin Creek, as it was done in the previous study. However, discharge from Asotin Creek was recalculated back to 1928 and missing periods were estimated using different gages and for different periods than used it previous studies. Appendix B provides details about the new computations.

Little Goose, WA (LGS) – For the entire record LGS inflow is estimated from the routed LWG outflow. From 1928 to 2008 LGS outflow is computed from inflow plus change in storage. After 2008 outflow data submitted by the USACE is used:

LSG6A = routed LWG6H.

Lower Monumental, WA (LMN) – From 1928 to 2008 inflow to Lower Monumental is equal to the routed outflow from Little Goose Dam plus the streamflow from the Palouse River at Hooper (13351000) and from the Tucannon River near Starbuck (13344500).

LMN6A = Routed LGS6H plus Palouse River at Hooper (USGS #13351000)
plus Tucannon River near Starbuck (USGS #13344500)

LMN outflow is computed from the inflow plus the change in storage between 1928 and 2008. After 2008 outflow submitted by the USACE is used.

Ice Harbor, WA (IHR) –The USGS gaging station below Ice Harbor Dam (USGS #13353000) is used to compute outflow when available. During other periods routed outflow from Lower Monumental Dam (LMN6H) minus Ice Harbor storage is used. After 2008 IHR outflow submitted by the USACE is used. As discussed earlier, this value is ultimately derived from the USGS gaging stations on the Clearwater at White Bird and the Snake River at Anatone, WA. During periods when the USGS gaging station is used to compute IHR outflow, a discontinuity in the water balance occurs. A new local for IHR is created to account imbalance caused by changing the method for computing IHR outflow. No local was created for IHR in 2010 because LMN outflow was set equal to IHR outflow plus IHR change in storage, which caused the LMN local to implicitly account for the IHR water imbalance.

The resulting IHR local is smoothed using an eleven day moving average to reduce the day to day fluctuations. This is a more appropriate method of smoothing the local than indexing to the USGS time series of an adjacent tributary because there is insignificant actual local inflow within this reach.

3.5.4 Equations

The equations used in the calculation of local flows, adjusted routed flows, accumulated depletions, accumulated evaporations and modified flows are shown below. For more details on the indexing of certain local flows, and about the routing involved in determining local and routed flows, refer to the Routing Diagram in Appendix B.

A full list of abbreviations can be found in Section 3.5.2 and in Appendix A. Data type definitions can be found in Section 1.3.

<u>Local Flows (*L*):</u>
HCD6L = HCD6A – (BRN6H routed to HCD)
LIM6L = LIM6H – (HCD6H routed to LIM) – (WHB6H routed to LIM)
ANA6L = ANA6H – LIM6H
SPD6L = SPD6H – [(DWR6H + ORF6H) routed to SPD)]
LWG6L = LWG6A – [(SPD6H + ANA6H) routed to LWG)]
LMN6L = LMN6A – (LGS6H routed to LMN)
IHR6L = IHR6A – (LMN6H routed to LMN)

<u>Adjusted Routed Flows (*ARF*):</u>
HCD6ARF = (BRN6A routed to HCD) + HCD6L
LIM6ARF = (HCD6ARF routed to LIM) + (WHB6H routed to LIM) + LIM6L
ANA6ARF = LIM6ARF + ANA6L
SPD6ARF = [(DWR6A + ORF6H) routed to SPD] + SPD6L
LWG6ARF = [(SPD6ARF + ANA6ARF) routed to LWG] + LWG6L
LGS6ARF = LWG6ARF routed to LGS
LMN6ARF = (LGS6ARF routed to LMN) + LMN6L
IHR6ARF = LMN6ARF routed to IHR + IHR6L

<u>Accumulated Depletions (*DD*):</u>
BRN6DD = BRN6R** – BRN6A
ANA6DD = BRN6DD + UPS6D + LWS6D + WEN6D
LWG6DD = ANA6DD + CLR6D
LMN6DD = LWG6DD + PLS6D

**details in Reclamation Supplemental Report

<u>Accumulated Evaporation (*EE*):</u>
HCD6EE = BRN6E + HCD6E
LWG6EE = HCD6EE + DWR6E + LWG6E
LGS6EE = LWG6EE + LGS6E
LMN6EE = LGS6EE + LMN6E
IHR6EE = LMN6EE + IHR6E

<u>Modified Flows (*M*):</u>
BRN6M = BRN6A + BRN6DD + BRN6E
OXB6M = BRN6M
HCD6M = HCD6ARF + BRN6DD + HCD6EE
WHB6M = WHB6H + UPS6D + LWS6D
LIM6M = LIM6ARF + UPS6D + LWS6D + BRN6DD + HCD6EE
TRY6M = TRY6H + WEN6D
ANA6M = ANA6ARF + ANA6DD + HCD6EE
ORO6M = ORO6H
DWR6M = DWR6A + DWR6E
SPD6M = SPD6ARF + DWR6E
LWG6M = LWG6ARF + LWG6DD + LWG6EE
LGS6M = LGS6ARF + LWG6DD + LGS6EE
LMN6M = LMN6ARF + LMN6DD + LMN6EE
IHR6M = IHR6ARF + LMN6DD + IHR6EE

3.6 Lower Columbia Basin

This area includes the portion of the Closed Basin that lies in Oregon, and the portion of the Columbia River drainage that extends from the mouth of the Snake River downstream through Bonneville Dam. See Section 3.6.1 for a map of the area.

The Oregon portion of the Closed Basin encompasses 17,900 square miles and includes most of Harney and Lake Counties in the south-central portion of the state. This area is not included in this study because flows do not reach the Columbia River.

Previous modified flows studies reported that irrigation from surface water in this portion of the basin increased from 245,000 acres in 1928 to 551,000 acres in 2008. Using the more sophisticated Washington State University methods revealed that irrigated acreage from surface water sources is around 443,000 acres. In this part of the basin, groundwater is also a considerable irrigation source. Combining the two sources, total irrigated acreage in this part of the basin is around 642,000 acres. About 80 percent of this region is irrigated with sprinklers. Micro irrigation emerged as a sizeable application method in the 2010s, reaching 7 percent of total acreage by 2018.

The larger irrigation projects are those north and south of the Columbia River that pump directly from the river and the Deschutes Project near Bend, OR. Other irrigated lands are located in the valleys of the Walla Walla, Umatilla, Willow Creek, John Day, White, Hood, Klickitat, and White Salmon Rivers.

Below is the list of areas where depletion adjustments were computed as described in Appendix B and WSU Supplemental Report:

(1) Return flow from the Kennewick Project
(2) Walla Walla River Basin
(3) McNary pool direct pumping to the North Side
(4) McNary pool direct pumping to the Umatilla sub-area
(5) Umatilla River/Willow Creek Basins
(6) John Day pool direct pumping to the North Side
(7) John Day pool direct pumping to Morrow/Gilliam Counties sub-area
(8) John Day River Basin
(9) White River/Wapinita Project
(10) Klickitat River Basin
(11) White Salmon River Basin
(12) Hood River Basin

Apart from the above basins, special studies were completed to determine the irrigation in the Upper Deschutes Basin and the Columbia Basin Project.

Irrigation in the Upper Deschutes Basin, associated with the Bureau of Reclamation's Deschutes Project, is extensive. The irrigated land has grown from 75,500 acres in 1928 to approximately 118,000 acres in 2008 before leveling off at around this same acreage as of 2018. Because of the use of storage reservoirs and intensive water use, a special study was conducted by Reclamation to determine the irrigation adjustments to be applied at Round Butte and Pelton Dams, and downstream to the confluence with the Columbia River behind The Dalles Dam. The output of this study was a set of 2020 Level regulated inflows to Round Butte and to Pelton Dams. The calculated inflows into Round Butte (observed outflows plus change in storage), were subtracted from the Round Butte regulated inflows. This adjustment was then applied at-site and downstream. Additional information on this study is contained in the Reclamation Supplemental Report for the Deschutes Basin.

The other special study in the basin is the Columbia Basin Return Flow Study, which was comprehensively reviewed and updated in the attached WSU University Supplemental Report. Several corrections to return flow points were made using GIS information and information provide by Reclamation (Appendix F of the supplemental report).

Equations used to arrive at *L*, *ARF*, *DD*, *EE* and *M* are shown in Section 3.6.4. A schematic diagram depicting where and how the various irrigation adjustments are applied, and the data used to calculate irrigation depletions can be found in the WSU Supplemental Report.

3.6.1 Regional Map

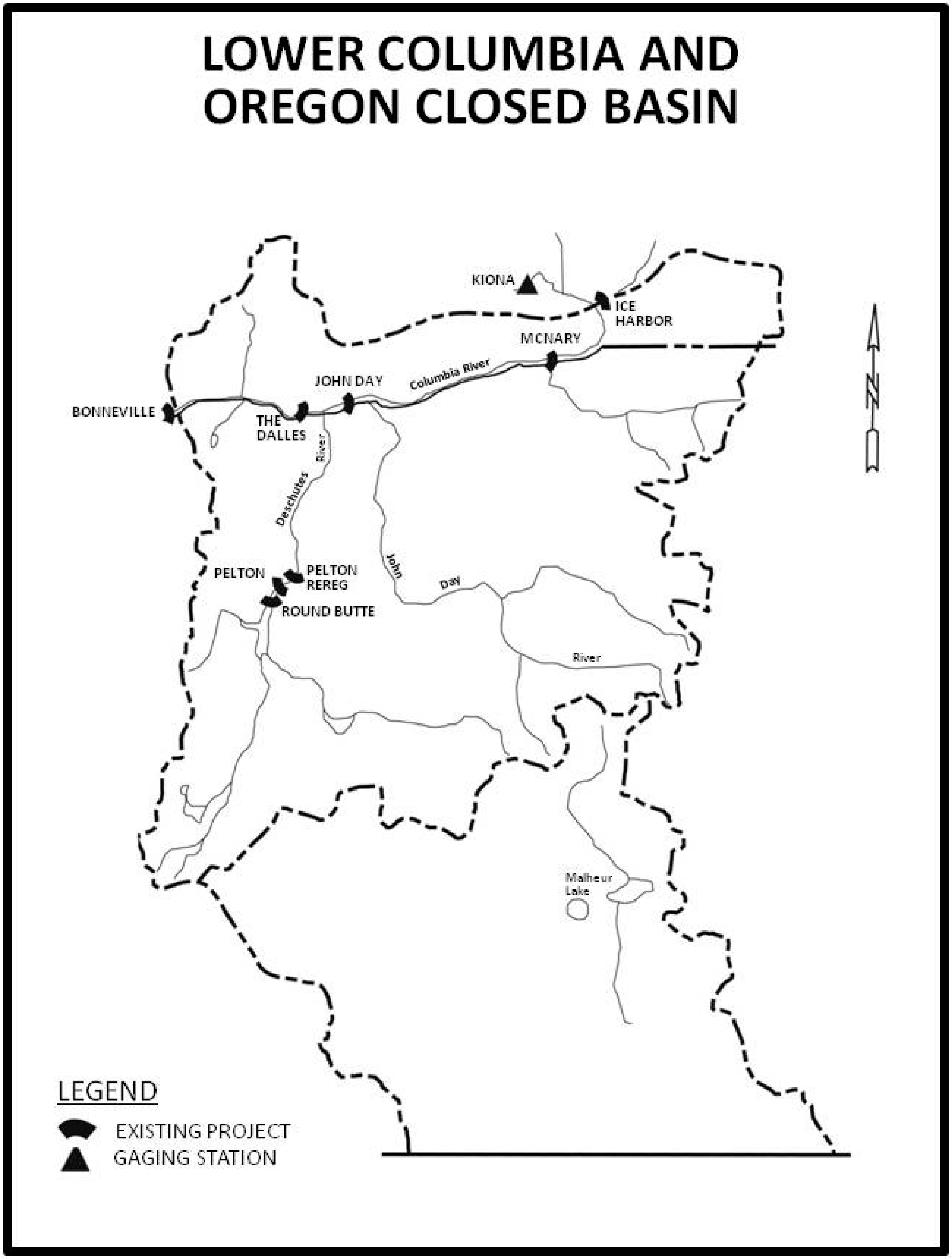

Figure 3-17. Lower Columbia Basin Map

3.6.2 List of Points

Table 3-12. Lower Columbia Basin Points

ID	Name	Basin	H	S	A	L	ARF	D	DD	E	EE	M
MCN	McNary	Lower Columbia	x	x	x	x	x		x	x	x	x
JDA	John Day	Lower Columbia	x	x	x	x	x	x	x	x	x	x
ROU*	Round Butte	Lower Columbia	x	x	x				x	x		x
PEL	Pelton	Lower Columbia	x						x			x
RER	Pelton Rereg	Lower Columbia										x
TDA	The Dalles	Lower Columbia	x	x	x	x	x		x	x	x	x
BON	Bonneville	Lower Columbia	x	x	x	x	x		x			x
B23	Pump to Blocks 2 & 3	Lower Columbia						x				
MRF	McNary Return Flow	Lower Columbia						x				
KEN	Kennewick	Lower Columbia						x				
WWA	Walla Walla	Lower Columbia						x				
NSM	Pumping from McNary to Northside	Lower Columbia						x				
NSR	Return flow from McNary pumping to Northside	Lower Columbia						x				
UMP	Pumping from McNary to Umatilla	Lower Columbia						x				
UMR	Return flow from McNary pumping to Umatilla	Lower Columbia						x				
UMW	Umatilla River and Willow Creek	Lower Columbia						x				
NSJ	Pumping from John Day to Northside + Returns	Lower Columbia						x				
JDP	Pumping from John Day to Morrow/Gilliam + Returns	Lower Columbia						x				
WHT	White River - Wapinitia	Lower Columbia						x				
KLC	Klickitat	Lower Columbia						x				
HOD	Hood River	Lower Columbia						x				
WHS	White Salmon	Lower Columbia						x				

***ROU has an additional data type, *R*, which is flow data provided by the USBR (Supplemental Report)**

3.6.3 Special Characteristics

In this heavily irrigated part of the basin, modified flows that are calculated differently from the methodology described in Chapter 2, and points that have other special characteristics are discussed in this section. Many of these changes involve the location and amount of irrigation return flows in eastern Oregon and southeast Washington (UMP, UMR, JDP, NSM, NSR, NSJ), which are documented in the WSU Supplemental Report.

Repartitioning of Subareas 32 and 36 – There were two changes to the boundaries of Subareas 32 and 36. While these changes allowed for more accurate computation of irrigation depletions, it did not have an effect on the net depletions from the John Day reservoir. The portion of subarea 32b that was south of the Columbia River was moved from NSM into subarea 36b (JDP). Refer to Section 4.4.1 of the WSU irrigation depletions report for more information.

Kennewick, WA (KEN) – Return flows from pumps 12-1, 12-1A and 12-2 are not included in KEN6D calculations because they are already accounted for in MRF6D. Flow from these pumps appeared to have been double counted in the 2010 study. More details are available in the WSU Supplemental Report.

The Dalles and John Day, OR/WA (TDA, JDA) – The Dalles local flows are often negative when calculated from project data, so the measured flow on the only major stream to flow into the Columbia between the two dams, the Deschutes River (USGS gage #14103000), is used for TDA6L. Since JDA outflow is unreliable due to backwater effects from TDA, the John Day outflow was calculated as TDA6A – TDA6L.

Round Butte, OR (ROU) – Regulated inflows at Round Butte Reservoir are provided by Reclamation (Supplemental Report) and are denoted as data type ROU6R. Note that these flows are different from 6M values. Irrigation depletions are already accounted in ROU6R, but are not available from the Bureau as a separate dataset. The following calculation was used to create a ROU6DD record:

ROU6DD = ROU6R – ROU6A

where ROU6A is the inflow into Round Butte calculated by adding the change in storage (ROU6S) to the observed outflows at Round Butte dam (ROU6H). ROU6R data is not available prior to October 1928, so DD values cannot be computed back to July 1928. The initial value of 319 cfs is extrapolated back to July 1928. ROU6DD is one of the three locations where *DD* values may not be compared directly with the 6DD values computed at other sites in the Columbia River Basin because they are calculated differently. The other two locations are YAK6DD and BRN6DD.

Pelton, OR (PEL) – Outflow from springs located between Pelton and Round Butte dams resulting primarily from the extensive irrigation in the Deschutes Basin have been estimated to contribute a constant flow of 200 cfs. This estimated 200 cfs of irrigation return flow is added to the Round Butte accumulated depletions to compute the Pelton accumulated depletions. This is reflected in the equations in Section 0.

3.6.4 Equations

The equations used in the calculation of local flows, adjusted routed flows, accumulated depletions, accumulated evaporations and modified flows are shown below. For more details on the indexing of certain local flows, and about the routing involved in determining local and routed flows, refer to the Routing Diagram in Appendix B.

A full list of abbreviations can be found in Section 3.6.2 and in Appendix A. Data type definitions can be found in Section 1.3.

<u>Local Flows (*L*):</u>
CP_H = (PRD_H routed to Pasco) + (YAK_H routed to Pasco) + IHR_H
CP = Control Point used for routing, at Pasco, Washington. Refer to Appendix B.

MCN_L = MCN_A – (CP_H routed to MCN)
JDA_L = JDA_A – (MCN_H routed to JDA)
TDA_L = Deschutes River near Madras

BON_L = BON_A – (TDA_H routed to BON)

Adjusted Routed Flows (*ARF*):

CP_ARF = IHR_ARF + (PRD_ARF routed to Pasco) + (YAK_H routed to Pasco)
CP = Control Point used for routing, at Pasco, Washington. Refer to Appendix B.

MCN_ARF = (CP_ARF routed to MCN) + MCN_L
JDA_ARF = (MCN_ARF routed to JDA) + JDA_L
TDA_ARF = (JDA_ARF routed to TDA) + TDA_L
BON_ARF = (MCN_ARF routed to BON) + BON_L

Accumulated Depletions (*DD*):

MCN6DD = YAK6DD + PRD6DD + MRF6D* + B236D* + LMN6DD + NSM6D + KEN6D + (0.4) NSR6D + UMP6D + WWA6D
JDA6DD = MCN6DD + NSJ6D + UMW6D + UMR6D + (0.6) NSR6D + JDP6D + JDA6D
ROU6DD = ROU6R** – ROU6A
PEL6DD = ROU6DD + 200 CFS RETURN FLOW
TDA6DD = JDA6DD + PEL6DD + WHT6D
BON6DD = TDA6DD + HOD6D + WHS6D + KLC6D
*details in WSU Supplemental Report **Error! Reference source not found.**
**details in Reclamation Deschutes Supplemental Report

Accumulated Evaporation (*EE*):

MCN6EE = PRD6EE + IHR6EE + MCN6E
JDA6EE = MCN6EE + JDA6E
TDA6EE = JDA6EE + ROU6E + TDA6E

Modified flows (*M*):

MCN6M = MCN6ARF + MCN6DD + MCN6EE
JDA6M = JDA6ARF + JDA6DD + JDA6EE
ROU6M = ROU6A + ROU6DD + ROU6E
PEL6M = ROU6A + PEL6DD + ROU6E
RER6M = PEL6M
TDA6M = TDA6ARF + TDA6DD + TDA6EE
BON6M = BON6ARF + BON6DD + TDA6EE

3.7 Willamette Basin

The area covered by this section is the Willamette River Basin in Oregon. See Section 3.7.1 for a map of the area

The Willamette River Basin drains 11,154 square miles. Although agriculture developed rapidly in the basin, irrigation of these lands developed slowly. About 1,000 acres were irrigated by 1910, 3,000 acres by 1920, 5,000 acres by 1930, and 27,000 acres by 1940. The period of significant irrigation increase came in the 1930s during the recovery period after the depression. During World War II, acreage under irrigation remained almost static due largely to shortages of metal for sprinkler pipe systems, which have been used almost exclusively on newly irrigated lands since the 1930s. After World War II, irrigation growth was significant, reaching 220,000 acres using surface water sources by 1980 before declining to around 175,000 acres in 2008. The Washington State University study indicates that about 187,000 acres are irrigated from surface water sources, with 290,000 acres irrigated using both surface and ground water. Sprinkling application is used on over 95 percent of irrigated acres, with only a few plots irrigated using micro/drip systems. One interesting development in this region is the emergence of landscape sod cultivation, which has become the second largest crop type in this region, and generally has higher water demands earlier in the summer compared to the pasture, fruit and grain crops historically grown in this fertile valley.

The vast majority of the irrigated land is located along the Willamette River between Eugene and Oregon City, OR, and along the lower reaches of tributary streams. Most of the irrigation (93%) in the Willamette basin is located above T. W. Sullivan Dam near Oregon City, and below the vast majority of dams. Therefore. irrigation depletions are only applied at Fern Ridge, Albany, Salem and T.W. Sullivan.

Equations used to arrive at *L*, *ARF*, *DD*, *EE* and *M* are shown in Section 3.7.4. A schematic diagram depicting where and how the various irrigation adjustments are applied, and the data used to calculate irrigation depletions can be found in the WSU Supplemental Report.

3.7.1 Regional Map

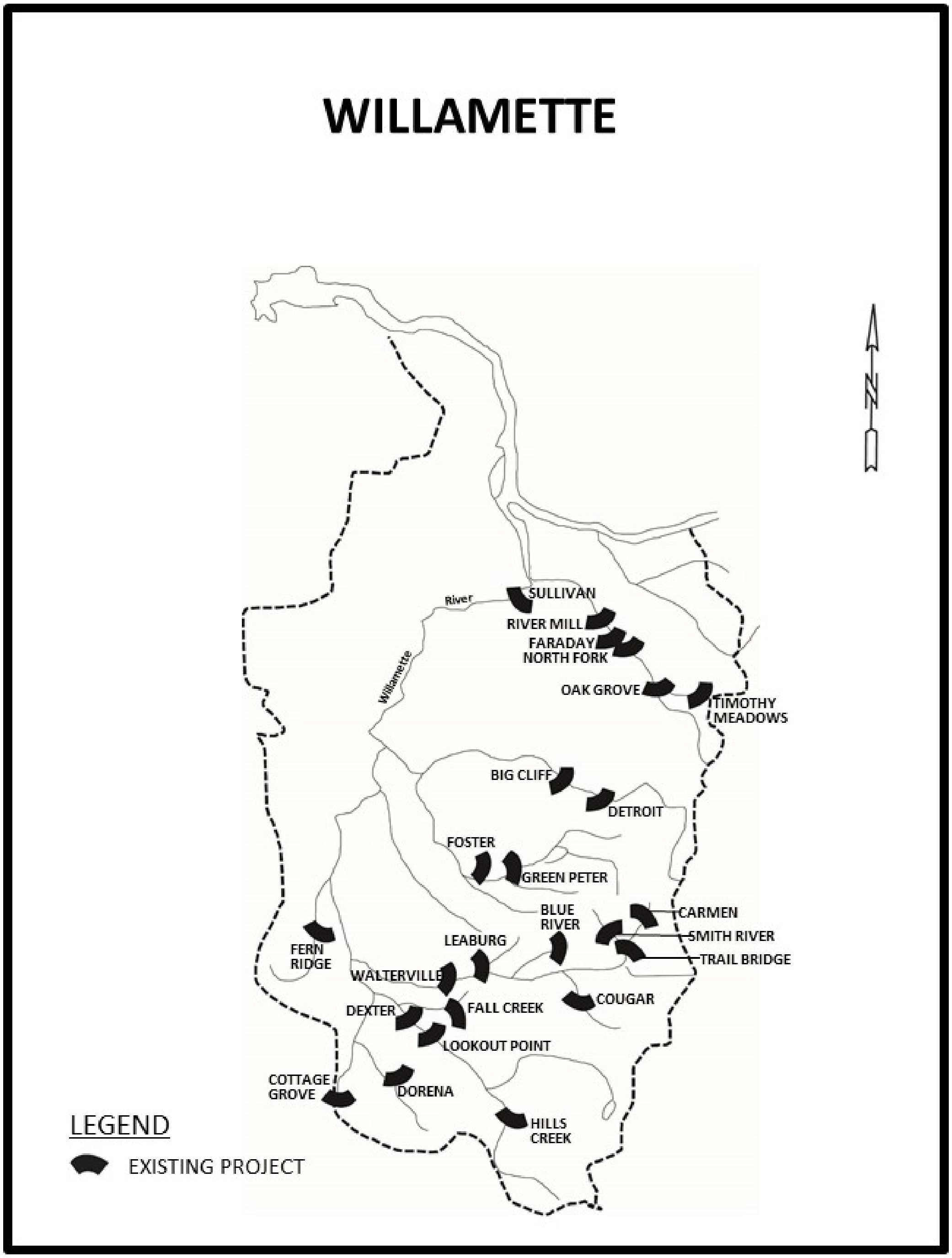

Figure 3-18. Willamette Basin Map

3.7.2 List of Points

Table 3-13. Willamette Basin Points

ID	Name	Basin	H	S	A	L	ARF	D	DD	E	EE	M
HCR	Hills Creek	Willamette	x	x	x							x
LOP	Lookout Point	Willamette	x	x	x		x			x		x
DEX	Dexter	Willamette										x
FAL	Falls Creek	Willamette	x	x	x							x
COT	Cottage Grove	Willamette	x	x	x							x
DOR	Dorena	Willamette	x	x	x							x
CAR	Carmen Diversion	Willamette	x									x
SMH	Smith R. Reservoir	Willamette			x							x
C_S	Carmen-Smith PP inflow	Willamette			x							x
TRB	Trail Bridge	Willamette	x			x	x					x
CGR	Cougar	Willamette	x	x	x							x
BLU	Blue River	Willamette	x	x	x							x
LEA	Leaburg	Willamette	x		x	x	x					x
WAV	Walterville	Willamette	x		x	x	x					x
FRN	Fern Ridge	Willamette	x	x	x			x		x		x
ALB	Albany	Willamette	x			x	x		x			x
DET	Detroit	Willamette	x	x	x							x
BCL	Big Cliff	Willamette	x				x					x
GPR	Green Peter	Willamette	x	x	x							x
FOS	Foster	Willamette	x	x	x	x	x					x
SLM	Salem	Willamette	x			x	x		x			x
SVN	T.W. Sullivan	Willamette	x			x	x		x		x	x
TMY	Timothy Meadows	Willamette	x	x	x							x
OAK	Oak Grove	Willamette	x		x							x
NFK	North Fork	Willamette	x	x	x							x
FAR	Faraday	Willamette										x
RML	River Mill	Willamette										x
HYD	Carmen Div. Max 630 cfs	Willamette			x							
WMT	Willamette	Willamette						x				

3.7.3 Special Characteristics

Modified flow points that are calculated differently from the methodology described in Appendix B, and points that have other special characteristics are discussed in this section.

The routing routines are slightly different from the previous study, so routing is redone from July 1928 through September 2018. In 2010 Modified Flows, many of the early years were reshaped to daily values from the 1990 level monthly flows. For this study, they are computed by developing relationships with nearby streams to extend the records for times prior to the project’s completion. There is very good agreement with the prior study, but some slight differences can be found which are more representative of the flows during the early period of record. For this study, USACE project data from the last ten years is used rather than estimated from downstream gages.

Lookout Point, OR (LOP) – The outflow for LOP is defined as the outflow from Dexter Dam (DEX) and the change in storage at LOP is defined as the combined change in storage at LOP and DEX. In effect, this method treats the two projects as one combined project.

Fall Creek, OR (FAL) – The early part of the inflow and outflow record had previously been a shaped version of the 1990 flows. For this study, we estimate the early period inflows (prior to 1935) by developing a relationship between overlapping historical records of the local gage (Fall Creek below Winberry Creek) and a nearby gage (MF Willamette River below North Fork at Oakridge) with a longer record. The parameters of that relationship are detailed in Appendix B, Section 3.7.

Carmen Smith, OR (CAR, HYD, SMH, C_S) – A diversion tunnel and a penstock connect the McKenzie and Smith rivers at two separate locations for power generation. Water is diverted through the Carmen Diversion Tunnel from McKenzie River to Smith River Reservoir, and after combining with flows from the Smith River, is diverted back to the McKenzie River through the Smith Power Tunnel and penstock to the Carmen powerhouse.

Flow that is diverted from McKenzie River into the Smith River comprises the CAR6H dataset. The diversion tunnel through which the water flows (HYD6A) has an upper capacity limit of 630 cfs. This diverted flow (HYD6A) along with flow in the Smith River (SMH6A) combine to create the C_S6A dataset, which then flows back into the McKenzie River through the penstock to the Carmen powerhouse. Refer to River Schematics in Appendix A for more details.

Most of the historical record of the Carmen Smith inflows and outflows are recalculated with new relationships between representative USGS gages, and is extended or filled in as needed with nearby gages with longer and more consistent records. The specific sites, dates and correlation factors are detailed in Appendix B.

Trail Bridge, OR (TRB) – The early part of the inflow and outflow record had previously been a shaped version of the 1990 flows. For this study, the early period inflows (prior to 1960) is estimated by developing a relationship between overlapping historical records of the local gage (McKenzie River at outlet of Clear Lake, OR)) and a nearby gage (McKenzie River near McKenzie Bridge) with a longer record. The parameters of that relationship are detailed in Appendix B section 3.7.

Dorena, OR (DOR) – Summer inflow is often very low and during warm summers, reservoir evaporation can result in negative inflows during August and September. This same phenomenon was noted in 2010 Modified Flows

Fern Ridge, OR (FRN) – Inflow is often low, and due to the large surface area of the reservoir, evaporation can result in negative calculated inflows, particularly in the summer. There were several changes to storage tables during the previous study described in 2010 Modified Flows. This same storage information is used for this 2020 study, including usage of a new storage table from November 2005 through 2018. Data for the latest ten years is provided by the USACE. As was found in previous studies, modified flows (FRN6M) and inflows (FRN6A) are often negative during the summer and fall months due to the high evaporation relative to low flows and irrigation depletion adjustments.

Cougar, OR (CGR) –. There were several changes to storage tables during the previous study described in the 2010 Modified Flows report. These same storage data are used for this study, with storage data from October 2008 through 2018 is provided by the USACE.

Blue River, OR (BLU) – Summer inflow is often very low and during warm summers, reservoir evaporation can result in negative inflows during August and September. This same phenomenon was noted in 2010 Modified Flows.

Leaburg, OR (LEA) – Prior to this study, the project outflow was estimated by a number of different relationships all of which are detailed in Appendix B. There is little storage in this reach and the inflow is set to outflow. This is a change from previous studies where storage at Blue River and Cougar were taken into account.

Detroit, OR (DET) – Prior to October 1999, the outflow at Big Cliff Dam (BCL) was used for the DET outflow and the storage change at DET was equal to the combined storage change at DET and BCL. In effect, this method treats the two projects as one combined project. After 1999, BCL is not combined with DET and instead DET information is used to compute all but BCL storage

T.W. Sullivan, OR (SVN) – The derivation of the outflow from T.W. Sullivan Dam was unique because it was computed by the addition of seven different components which all contribute to flows at this location. For more details, refer to River Schematics in Appendix A. One change with this study is that the component from the Tualatin River at West Linn no longer includes the Oswego Canal (USGS 14207000) which enters the Willamette River below the T. W. Sullivan generation station. This change has been made for the entire record.

3.7.4 Equations

The equations used in the calculation of local flows, routed flows, accumulated depletions, accumulated evaporations and modified flows are shown below. For more details on the indexing of certain local flows, and about the routing involved in determining local and routed flows, refer to the Routing Diagram in Appendix B.

A full list of abbreviations can be found in Section 3.7.2 and in Appendix A. Data type definitions can be found in Section 1.3.

Local Flows (*L*):

LOP_L = LOP_A – (HCR_H routed to LOP)
TRB_L = TRB_A – CAR_H
LEA_L = LEA_A – [(CAR_H + TRB_H + CGR_H + BLU_H) routed to LEA]
WAV_L = WAV_A – LEA_H
ALB_L = ALB_H – [(LOP_H + FAL_H + COT_H + DOR_H + WAV_H + FRN_H) routed to ALB]
FOS_L = FOS_A – GPR_H

SLM_L = SLM_H – [(ALB_H + FOS_H + DET_H) routed to SLM]
SVN_L = SVN_H – (SLM_H routed to SVN)

<u>Adjusted Routed Flows (*ARF*):</u>

LOP_ARF = (HCR_A routed to LOP) + LOP_L
TRB_ARF = CAR_A + TRB_L
LEA_ARF = [(TRB_ARF + CGR_A + BLU_A) routed to LEA] + LEA_L
WAV_ARF = LEA_ARF + WAV_L
ALB_ARF = [(LOP_ARF + FAL_A + COT_A + DOR_A + WAV_ARF + FRN_A) routed to ALB] + ALB_L
FOS_ARF = GPR_A + FOS_L
SLM_ARF = [(ALB_ARF + FOS_ARF + DET_A) routed to SLM] + SLM_L
SVN_ARF = (SLM_ARF routed to SVN) + SVN_L

<u>Accumulated Depletions (*DD*):</u>

ALB6DD = (0.25) WMT6D
SLM6DD = (0.4) WMT6D
SVN6DD = (0.93) WMT6D

<u>Accumulated Evaporation (*EE*):</u>

SVN6EE = LOP6E + FRN6E

<u>Modified Flows (*M*):</u>

HCR6M = HCR6A
LOP6M = LOP6ARF + LOP6E
DEX6M = LOP6M
FAL6M = FAL6A
DOR6M = DOR6A
COT6M = COT6A
CAR6M = CAR6H
SMH6M = SMH6A
C-S6M = C-S6A
TRB6M = TRB6ARF
CGR6M = CGR6A
BLU6M = BLU6A
LEA6M = LEA6ARF
WAV6M = WAV6ARF
FRN6M = FRN6A + FRN6D + FRN6E
ALB6M = ALB6ARF + ALB6DD + SVN6EE
DET6M = DET6A
BCL6M = DET6A
GPR6M = GPR6A
FOS6M = FOS6ARF
SLM6M = SLM6ARF + SLM6DD + SVN6EE
SVN6M = SVN6ARF + SVN6DD + SVN6EE
TMY6M = TMY6A
OAK6M = OAK6A
NFK6M = NFK6A
FAR6M = NFK6A
RML6M = NFK6A

3.8 Western Washington Basins

This section includes the lands in western Washington which are located west of the Cascade Range. Section 3.8.1 contains a map of this section showing those sites where streamflows were developed. Like previous studies, irrigated lands were not estimated in this region because all irrigated land in these basins is located downstream from the hydropower sites.

3.8.1 Regional Map

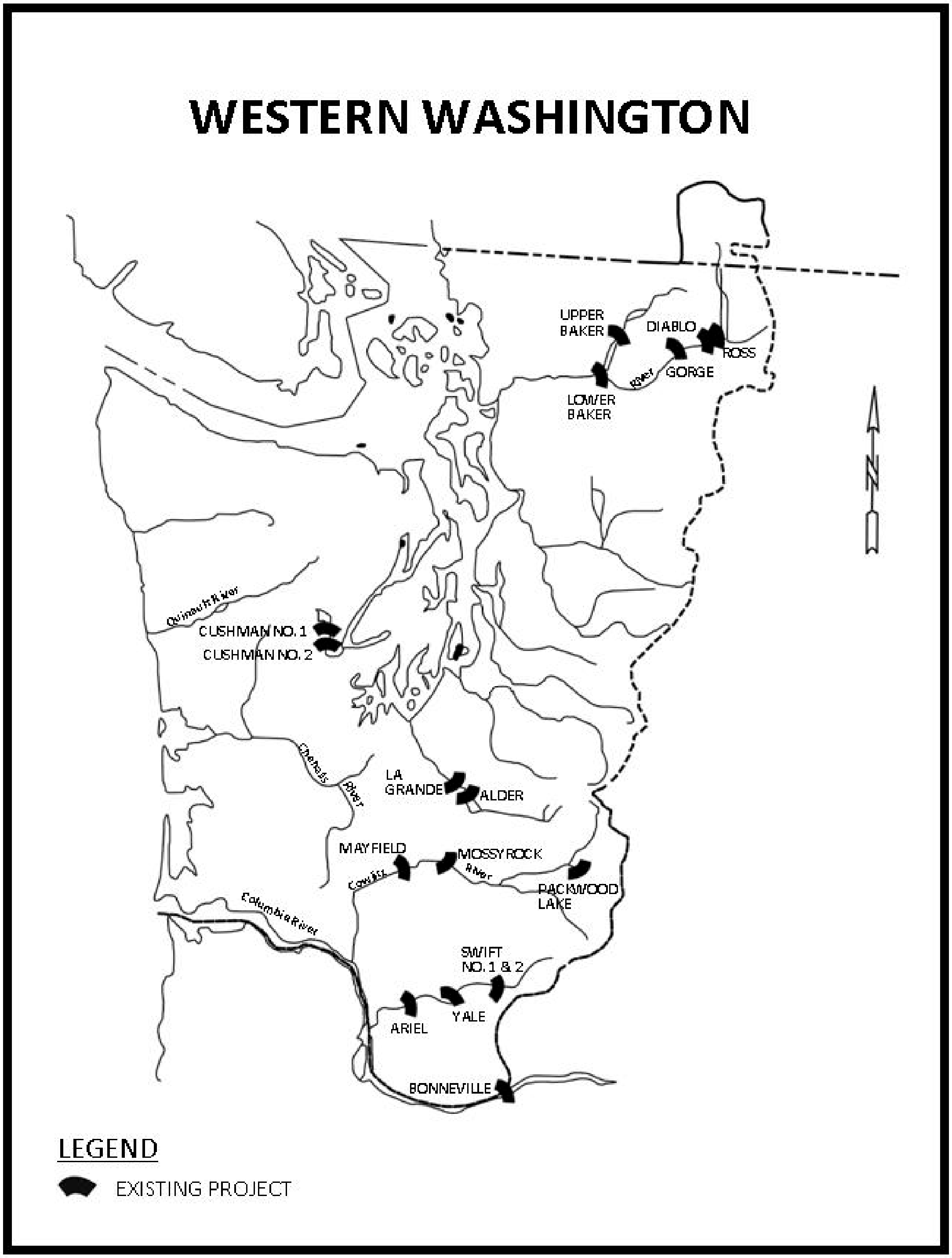

Figure 3-19. Western Washington Basin Map

3.8.2 List of Points

Table 3-14. Western Washington Basin Points

ID	Name	Basin	H	S	A	L	ARF	D	DD	E	EE	M
SWF	Swift 1	Western Washington			x							x
SW2	Swift 2	Western Washington										x
YAL	Yale	Western Washington			x							x
MER	Aerial (Merwin)	Western Washington	x		x							x
PAK	Packwood Lake	Western Washington		x	x							x
MOS	Mossyrock	Western Washington	x	x	x					x		x
MAY	Mayfield	Western Washington	x	x	x							x
CS1	Cushman 1	Western Washington			x							x
CS2	Cushman 2	Western Washington			x							x
LAG	Lagrande	Western Washington	x		x							x
ALD	Alder	Western Washington		x								x
ROS	Ross	Western Washington			x					x		x
DIA	Diablo	Western Washington			x							x
GOR	Gorge	Western Washington			x							x
UBK	Upper Baker	Western Washington			x							x
SHA	Lower Baker	Western Washington			x							x

3.8.3 Data Submittal and Quality Control

Swift 1 and Swift 2, WA (SWF and SW2) – Daily inflows for October 1, 2008-September 30, 2018 were submitted by Pacific Corps. No quality control changes were needed for this data.

Yale, WA (YAL) – Daily inflows from October 1, 2008-September 30, 2018 were submitted by Pacific Corps. No quality control changes were needed for this data.

Aerial, WA (MER) – Daily inflows from October 1, 2008-September 30, 2018 were submitted by Pacific Corps. No quality control changes were made to the data. The observed streamflows from the Lewis River at Ariel USGS gauge (14220500) is used as the outflows for this project.

Packwood Lake, WA (PAK) – Daily inflows from October 1, 2008-September 30, 2018 were submitted by Energy Northwest. Any time periods that had missing data for longer than a week are filled by using daily streamflows from the Cowlitz River at Packwood USGS gauge (14226500). Linear interpolation is used to fill in the other time periods of missing data that are shorter than a week. Daily reservoir elevation data from October 1, 2008-September 30, 2018 were also submitted by Energy Northwest. The elevation data and capacity table provided by Energy Northwest were used to compute the change in reservoir storage data.

For the 2020 Modified Flows study, the Packwood inflow is computed using daily streamflows at USGS gauges instead of the method in previous modified flows studies using outflow plus the change in storage. The older method computed inflow at the monthly time scale, while the new method using the USGS gauges is at the daily time scale. The list of USGS gauges used are listed in Appendix B.

Mossyrock, WA (MOS) – Daily inflows from October 1, 2008-September 30, 2018were submitted by Tacoma Power. There were nine days with missing inflow in the submitted dataset, which are filled by linear interpolation.

The inflows from 1928 to 2018 are recomputed using a different method compared to previous modified flows reports. For this report, USGS gauges plus PAK6S are used to compute the Mossyrock inflows. The old method relied on semi-monthly inflow data from the 1990 Modified Flows report, while the new method computes the inflow at the daily time scale. The list of USGS gauges used are listed in Appendix B.

The outflow is computed using the Mossyrock inflow minus the Mossyrock change in storage minus the Packwood change in storage. There is a gap in the outflow submitted by Tacoma Power from October 1,2008 to June 30, 2012, so this calculation method is also used to estimate the unavailable outflow data.

Mayfield, WA (MAY) – Daily local flow data from October 1, 2008-September 30, 2018 were submitted by Tacoma Power. The Mayfield local flows are added to the Mossyrock inflows to obtain the inflows into Mayfield. Like the inflows for Mossyrock, there are nine dates missing Mayfield inflow data points which are filled using linear interpolation.

Semi-monthly flows from the 1990 Modified Flows study were used in the 2010 and 2020 studies to estimate the outflow from July 1, 1928 to March 31, 1934. For this study, we use daily streamflow data from nearby USGS gauges to estimate the Mayfield outflow during that time period. The USGS gauges are listed in Appendix B.

Cushman 1 and Cushman 2, WA (CS1 and CS2) – Daily inflows from October 1, 2008-September 30, 2018 were submitted by Tacoma Power. Negative inflow values are corrected to positive values through linear interpolation. These corrections do not result in a significant increase in the overall volume at CS1, with only a 0.41 percent difference in volumes between the uncorrected and the corrected inflow datasets. Any corrections to the inflow data were coordinated with Tacoma Power. It is important to note that the inflows prior to 10/1/2008 are at a bimonthly timescale, while the data after October 1, 2008 are at a daily scale.

LaGrande and Alder, WA (LAG and ALD) – The inflow at LAG from October 1, 2008-September 30, 2018 are estimated based on the outflow plus the change in storage at ALD. The outflow from October 1, 2008-September 30, 2018 are estimated from the streamflow at the Nisqually River at LaGrande USGS gauge station (12086500). Prior to 10/1/1943, the Nisqually River near Alder and the Little Nisqually River near Alder USGS gauge stations (12084000 and 12084500) were used to estimate the outflow at LAG. However, there was no observed streamflow available at the Little Nisqually River near Alder USGS gauge station (12084500) after 5/31/1943, so the observed LAG outflow from the 2010 modified flow study is used to fill in the gap from June 1 to September 30, 1943. The elevation data at ALD from October 1, 2008-September 30, 2018 provided by USACE. Any questionable elevation data in the dataset were adjusted using the elevation data from the Alder Reservoir at Alder, WA USGS gauge station (12085000).

Ross (ROS), Diablo (DIA), and Gorge, WA (GOR) - Daily inflow data from October 1, 2008-September 30, 2018 were submitted by Seattle City Light. Only two days had questionable inflow data, which are corrected by linear interpolation.

Upper Baker, WA (UBK) – Daily inflow data from October 1, 2008-September 30, 2018 were submitted by Puget Sound Energy. No quality control changes were needed for this data.

Lower Baker, WA (SHA) – Because the inflow from October 1, 2008-September 30, 2018 at SHA is very noisy and questionable, due to several hydrologic and hydraulic factors below the Upper Baker project, the UBK daily inflows were multiplied by 125 percent. This calculation was coordinated with Puget Sound Energy, and yielded realistic flow results.

3.8.4 Equations

Because no routing was done for the modified flow points in this region, local flows and adjusted routed flows were not computed. Irrigation depletions and accumulated evaporations were not computed.

A full list of abbreviations can be found in 3.8.2 and in Appendix B.. Data type definitions can be found in Section 1.3.

Modified Flows (*M*):

SWF6M = SWF6A
SW26M = SWF6A
YAL6M = YAL6A
MER6M = MER6A
PAK6M = PAK6A
MOS6M = MOS6A + MOS6E
MAY6M = MAY6A + MOS6E
CS16M = CS16A
CS26M = CS26A
LAG6M = LAG6A
ALD6M = LAG6M
ROS6M = ROS6A + ROS6E
DIA6M = DIA6A + ROS6E
GOR6M = GOR6A + ROS6E
UBK6M = UBK6A
SHA6M = SHA6A

3.9 *Western Oregon Basins*

This section includes the lands along the Oregon Coast west of the Coast Range, and the Klamath River drainage extending downstream to Iron Gate, California. Section 3.9.1 shows a map of the area showing those sites where streamflows were developed.

The Oregon Coast area consists of two sub-areas: the Coastal Strip and the Rogue Basin. The Coastal Strip supports agriculture in a narrow band no more than a few miles wide.

The Rogue Basin is one of the major pear-growing regions of the nation. Apple, peach, and livestock production are also important. All of the irrigation occurs downstream from the Lost Creek Project, and thus no irrigation adjustments were computed for the Lost Creek Project.

The Klamath River Basin above Iron Gate, California, is located in south central Oregon and northeastern California. The Oregon portion of the basin covers about 3.6 million acres, and there are about 1.5 million acres in California. Almost all of the approximately irrigated 400,000 acres are supplied from surface sources with the water applied mostly by gravity distribution.

There is considerable private irrigation development above Upper Klamath Lake, and irrigation development primarily from the USBR's Klamath Project is downstream from Upper Klamath Lake. Irrigation development in the basin began early, and the development above Upper Klamath Lake was essentially stable from 1928 to 2018, thus no irrigation adjustment was computed for this upper portion of the basin.

The Klamath Project receives water from both Upper Klamath Lake via the "A" canal, and from the Lost River. The Lost River is a closed basin and does not empty into the Klamath River. At certain times of the year, excess water is evacuated from the Lost River reservoirs for flood control purposes and dumped into the Klamath River via the Lost River Diversion Canal. During the growing season, supplemental water is supplied from the Klamath River to the Klamath Project via both the Lost River diversion canal and the Midland Canal. The southern end of the project is a sump, and the pumps remove excess water and pump it back into the Klamath River.

Irrigation in the Klamath Project increased until about 1950 when it essentially stabilized. PacificCorp computed and furnished incremental irrigation adjustments for the period 1928-1950. Observed streamflows since 1950 are all considered to represent a current (2020) level of irrigation development. These adjustments apply at two sites: Link River Dam and Keno gaging station.

The equations used to calculate the modified flows (*M*) are shown in Section 3.9.3.

3.9.1 Regional Map

Figure 3-20. Western Oregon Basin Map

3.9.2 *List of Points*

Table 3-15. Western Oregon Basin Points

ID	Name	Basin	H	S	A	L	ARF	D	DD	E	EE	M
LOS	Lost Creek	Western Oregon	x	x	x							x
LNK	Link R.	Western Oregon	x		x							x
KLA	Klamath Lake	Western Oregon		x								x
JCB	John C. Boyle	Western Oregon	x	x	x							x
ACL	"A" Canal Diversion	Western Oregon	x					x				
PPL	"A" Canal Depletion	Western Oregon						x				

3.9.3 *Special Characteristics*

Modified flow points that are calculated differently from the methodology described in Appendix B. and points that have other special characteristics are discussed in this section.

"A" Canal Depletions (ACL and PPL) – The Klamath Project receives irrigation water from Upper Klamath Lake via the "A" canal, and also from the Lost River. This irrigation water data is represented by two datasets: ACL6D and PPL6D.

$$ACL6D = - ACL6H$$

where ACL6H data is collected as described in the River Schematics in Appendix A:

July 1928 -- September 1981: USGS
October 1981 – September 2018: USBR Klamath Falls office.

PPL6H data was provided by the PacificCorp, and has data only through September 1950. This is because irrigation in the Klamath Project increased until about 1950 when it essentially stabilized. PacificCorp computed and furnished incremental irrigation adjustments for the period 1928-1950.

John C. Boyle (JCB) – Streamflow on the Klamath River below the power plant (11507500) is available from the USGS back to Jan 1959. Previous studies only used this gaging data after Oct 1960 and prior to that date JCB outflow was estimated from the nearby USGS gage 11510500. For the current study streamflow data from USGS gage 11507500 is used to compute JCB6H back to Jan 1959.

3.9.4 *Equations*

Because no routing was done for the modified flow points in this region, local flows and adjusted routed flows were not computed.

A full list of abbreviations can be found in Section 3.9.2 and in Appendix B. Data type definitions can be found in Section 1.3.

Modified flows (*M*):

LOS6M = LOS6A
LNK6M = LNK6A + ACL6D + PPL6D
KLA6M = LNK6M
JCB6M = JCB6A + ACL6D + PPL6D

Section 4 Results

This study utilizes several methods to estimate and incorporate the effect of irrigation so that the 90 years of Columbia River Basin flows from 1928 to 2018 are normalized to a 2018 level of irrigation development. The irrigated acres, depletions, and modified flows generated in this study are compared with data from the 2010 Modified Flows study to highlight changes in calculated flows.

It is important to note that several key factors impact the overall changes in calculated modified flows between the 80- and 90-year sets. Not only do flow differences between 2010 and 2020 Modified Flows include changes in irrigation depletions, but also changes to the depletion calculations, improvements in quality-control processes, and new hydrologic modeling systems. This 90-year dataset also incorporates several notably wet water years (2011, 2012, 2017, 2018) but only two notable dry ones (2010, 2015), which even with such a long period of record can impact mean flows and volumes. Because of developing and evolving regional climate change, non-stationarity in the long-term record is also evaluated.

4.1 Changes in Depletion: 2010 Level vs 2020 Level

A complete summary of changes in irrigation depletions are in WSU Supplemental Report. In it, a comparison of the common 80 years (1929-2008) of depletions between the 2010 and 2020 studies explicates the differences between flow sets resulting from updating depletions to current levels of irrigation. Across most of the basin, irrigated acreage is lower in this 2020 study compared to 2010. This is partially the result of better acreage estimates from satellite and ground truth data. However, this also continues a trend noted in the 2010 report in which slight declines in irrigated acreage and surface water withdrawals since the early 2000s, which has also been noted by the Northwest Power and Conservation Council (Harrison, 2020).

4.2 Comparison of 2020 vs. 2010 Modified Flows

The 2010 Modified Flows are compared with the 2020 Modified Flows to illustrate the total effect changes in irrigation depletions, adding ten years of observed streamflows, better quality control practices, and upgrades to hydrologic modeling capabilities at both BPA and Reclamation.

4.2.1 *Upper Columbia and Kootenay*

The 2020 Modified Flows compared to the 2010 Modified Flows at Murphy Creek (near Birchbank), BC, in the upper Columbia River are slightly higher (Figure 4-1, Table 4-1). The 2020 Modified Flows are about two to four percent higher in the low-flow winter months and five percent higher for March. Meanwhile, August flows are a little over one percent lower. No change in peak streamflow timing is noted.

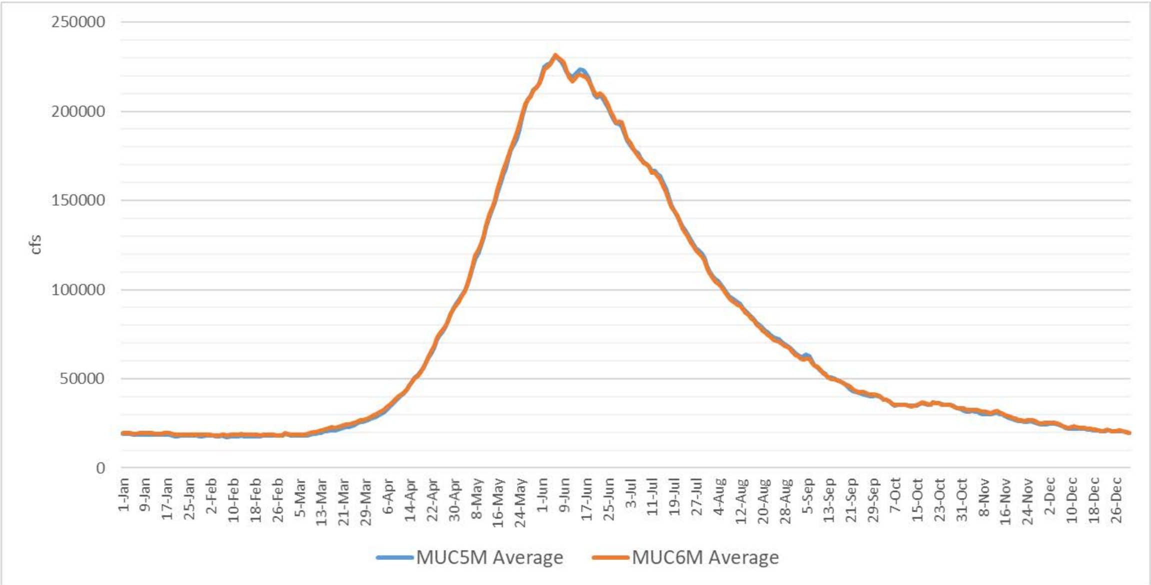

Figure 4-1. Upper Columbia Basin at Murphy Creek Dam Average Daily 5M (2010 Modified Flows) vs. 6M (2020 Modified Flows)

Table 4-1. Upper Columbia Basin at Murphy Creek Dam Average Monthly 5M vs. 6M

Month	MUC5M (cfs)	MUC6M (cfs)	Diff. (cfs)	% Change
Jan	18401	19132	732	4.0
Feb	17864	18515	652	3.6
Mar	21378	22445	1066	5.0
Apr	52518	53114	597	1.1
May	154144	155180	1036	0.7
Jun	215302	215196	-106	0.0
Jul	152233	151596	-637	-0.4
Aug	85789	84754	-1036	-1.2
Sep	50606	50618	12	0.0
Oct	35860	35935	75	0.2
Nov	28625	29443	818	2.9
Dec	21900	22333	433	2.0

4.2.2 Pend Oreille and Spokane

Like the upper Columbia Basin, 2020 Modified Flows at Seven Mile, BC, which is at the terminus of the Pend Oreille Basin, are slightly higher than the 2010 Modified Flows (Figure 4-2, Table 4.2), most notably in February-May. However, unlike the upper Columbia, August flows are also notably higher in this subbasin. While some of the late spring and summer increases could be related to a slight decrease in irrigation depletions relative to the 2010 calculations, the largest increase in average flow, relative to average, is in the month of March when irrigation withdrawals are negligible.

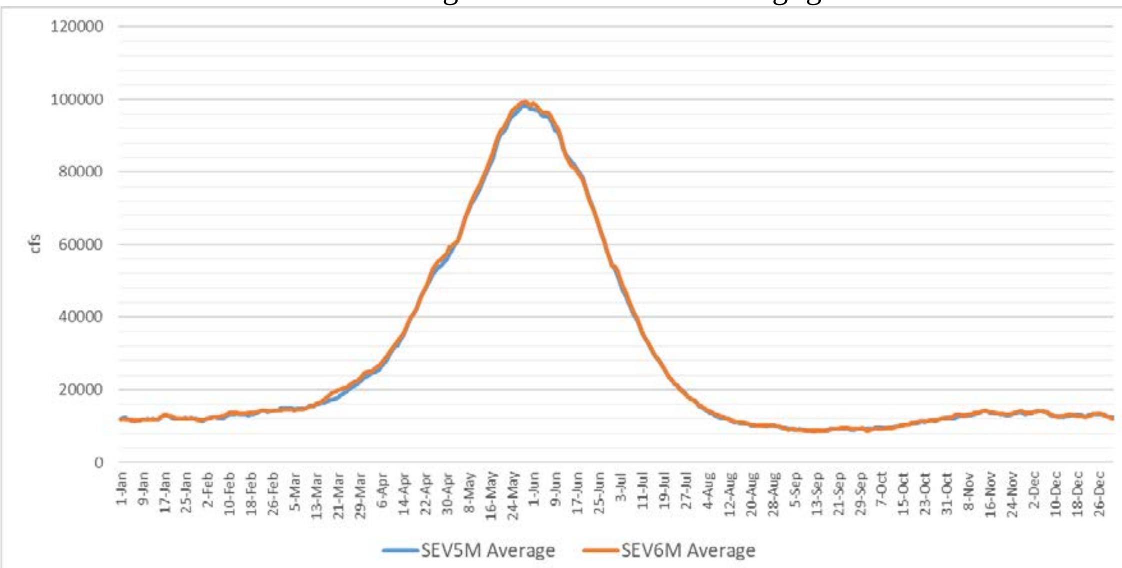

Figure 4-2. Pend Oreille Basin at Seven Mile Dam Average Daily 5M vs. 6M

Table 4-2. Pend Oreille Basin at Seven Mile Dam Average Monthly 5M vs. 6M

Month	SEV5M (cfs)	SEV6M (cfs)	Diff. (cfs)	% Change
Jan	11982	11943	-38	-0.3
Feb	13183	13389	206	1.6
Mar	17397	18018	621	3.6
Apr	38539	39324	785	2.0
May	81091	82027	936	1.2
Jun	80461	80664	203	0.3
Jul	31195	31475	280	0.9
Aug	11485	11663	178	1.6
Sep	9031	9076	45	0.5
Oct	10461	10396	-65	-0.6
Nov	13196	13412	216	1.6
Dec	13060	13052	-7	-0.1

The 2020 Modified Flows at Little Falls Dam, WA, which is toward the lower end of the Spokane River Basin, are slightly higher in January-April, but slightly lower in the summer and fall seasons when compared to the 2010 Modified Flows (Figure 4-3, Table 4-3). Average August and September flows are slightly lower compared to the 2010

Modified Flows. Since this part of the basin also has slightly lower irrigation depletions compared to the 2010 study, the decrease in summer flows appear to be the result of other factors, including climate.

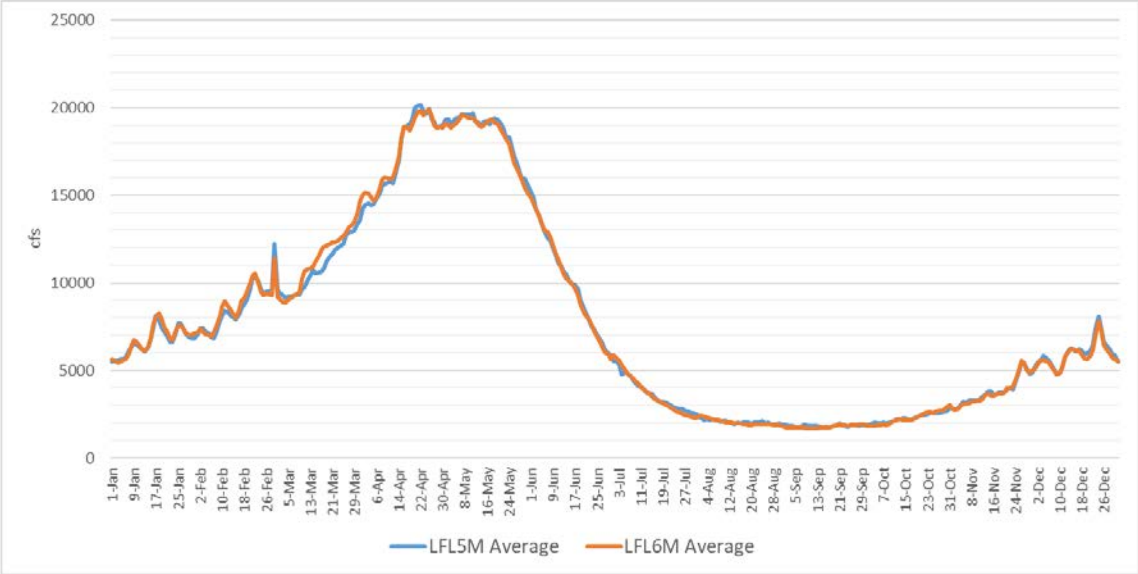

Figure 4-3. Spokane Basin at Little Falls Dam Average Daily 5M vs. 6M

Table 4-3. Spokane Basin at Little Falls Dam Average Monthly 5M vs. 6M

Month	LFL5M (cfs)	LFL6M (cfs)	Diff. (cfs)	% Change
Jan	6655	6731	77	1.2
Feb	8462	8600	138	1.6
Mar	10906	11305	399	3.7
Apr	17436	17527	91	0.5
May	18616	18406	-210	-1.1
Jun	10097	10022	-75	-0.7
Jul	3678	3645	-33	-0.9
Aug	2050	2027	-22	-1.1
Sep	1826	1781	-44	-2.4
Oct	2276	2265	-11	-0.5
Nov	3800	3777	-23	-0.6
Dec	5966	5832	-134	-2.3

4.2.3 Mid-Columbia

The 2020 Modified Flows at Priest Rapids, WA, (Figure 4-4, Table 4-4) are slightly higher compared to 2010 Modified Flows, especially in the February-June period. The largest average monthly flow increases are observed in March and May.

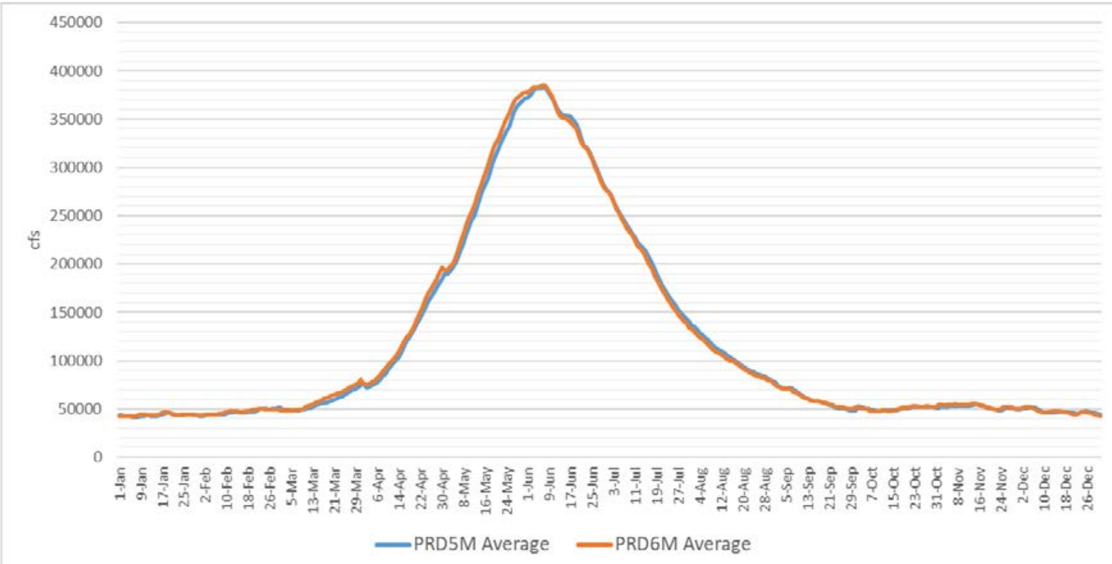

Figure 4-4. Mid-Columbia Basin at Priest Rapids Dam Average Daily 5M vs. 6M

Table 4-4. Mid-Columbia Basin at Priest Rapids Dam Average Monthly 5M vs. 6M

Month	PRD5M (cfs)	PRD6M (cfs)	Diff. (cfs)	% Change
Jan	43394	44372	978	2.3
Feb	46927	47951	1024	2.2
Mar	58004	60539	2535	4.4
Apr	121794	123318	1524	1.3
May	286006	288242	2236	0.8
Jun	342169	344039	1870	0.5
Jul	199723	200109	386	0.2
Aug	102020	101145	-874	-0.9
Sep	59504	60477	973	1.6
Oct	50467	50486	20	0.0
Nov	51865	53200	1335	2.6
Dec	47204	47565	361	0.8

4.2.4 *Lower Snake*

The 2020 Modified Flows are notably higher in the spring and summer months at Ice Harbor, WA, when compared to the 2010 Modified Flows (Figure 4-5). The largest monthly percentage increases in average monthly flows are in July through September (Table 4-5), although the largest increase by volume is in April and May. The increase is primarily the result of changes in Reclamation-calculated flows at Brownlee Dam between 2010 and 2020 Modified Flows (see Reclamation Supplemental Report), in addition to less irrigation withdrawals and higher flows originating from the Clearwater and Salmon River Basins compared to 2010 Modified Flows.

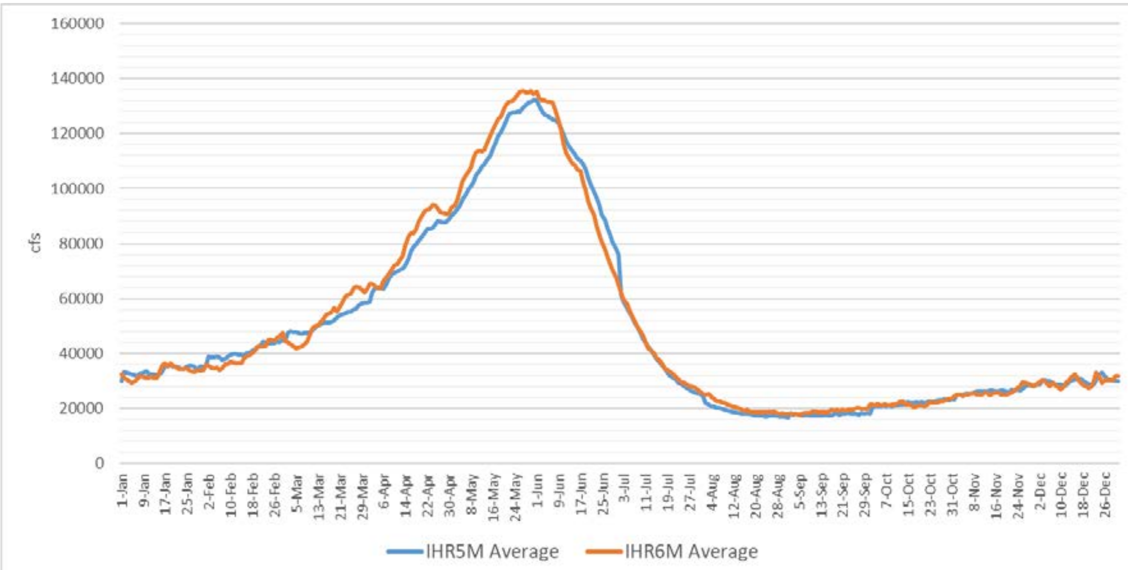

Figure 4-5. Lower Snake Basin at Ice Harbor Dam Average Daily 5M vs. 6M

Table 4-5. Lower Snake Basin at Ice Harbor Dam Average Monthly 5M vs. 6M

Month	IHR5M (cfs)	IHR6M (cfs)	Diff. (cfs)	% Change
Jan	33873	32911	-962	-2.8
Feb	40944	39099	-1845	-4.5
Mar	52056	53074	1018	2.0
Apr	76744	80095	3350	4.4
May	115121	119445	4324	3.8
Jun	107514	105673	-1841	-1.7
Jul	38185	40270	2085	5.5
Aug	18397	20399	2003	10.9
Sep	17745	18884	1139	6.4
Oct	21908	21685	-224	-1.0
Nov	26484	26000	-484	-1.8
Dec	29915	29678	-237	-0.8

4.2.5 Lower Columbia

Although The Dalles Dam is not the most downstream point in the Lower Columbia Basin, results are shown because it is an important point to many users and planning purposes. Overall, average 2020 Modified Flows are slightly higher compared to 2010, with higher March-May flows working downstream from the middle and upper Columbia, and higher July-September flows working downstream from the Snake Basin (Figure 4-6, Table 4-6).

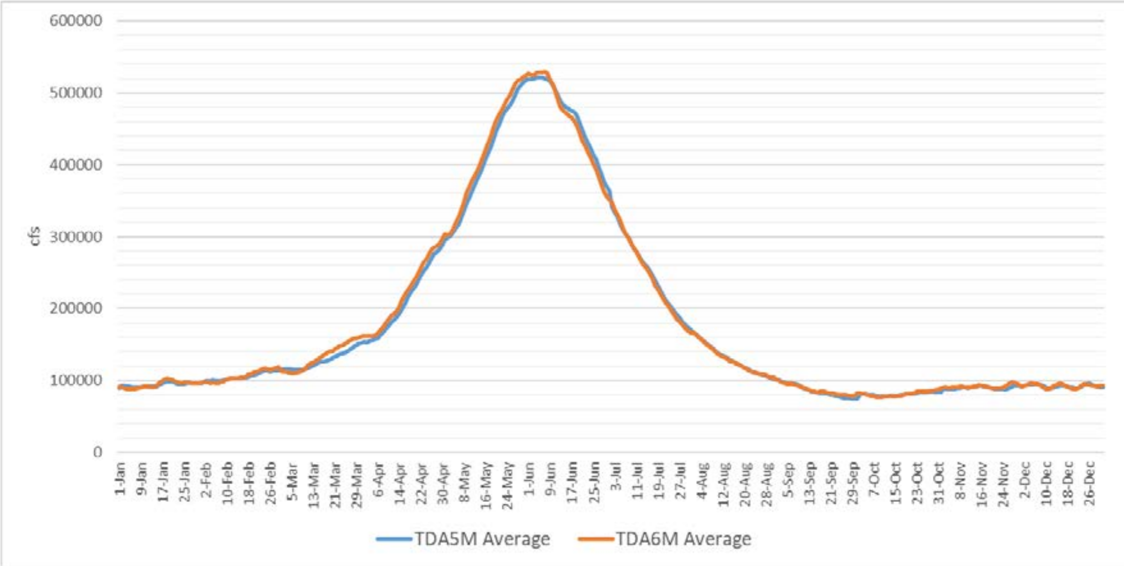

Figure 4-6. Lower Columbia Basin at The Dalles Dam Average Daily 5M vs. 6M

Table 4-6. Lower Columbia Basin at The Dalles Dam Average Monthly 5M vs. 6M

Month	TDA5M (cfs)	TDA6M (cfs)	Diff. (cfs)	% Change
Jan	93995	94311	316	0.3
Feb	105614	105539	-74	-0.1
Mar	128973	132790	3817	3.0
Apr	215168	219399	4231	2.0
May	414075	418360	4285	1.0
Jun	464102	463901	-201	0.0
Jul	245739	249710	3971	1.6
Aug	127019	128723	1704	1.3
Sep	84943	87160	2217	2.6
Oct	80915	81021	107	0.1
Nov	89738	91398	1660	1.8
Dec	91953	92269	316	0.3

Results at Bonneville Dam are also shown as it is the most downstream point in the Lower Columbia Basin. Since Bonneville Dam is the next downstream point below The Dalles Dam, the results are essentially the same as at The Dalles (Table 4-7, Figure 4-7). However, flow differences between the two are greatest in the winter and early spring. Larger tributaries like the Hood, Klickitat and White Salmon Rivers can at times contribute considerable winter inflow in the Bonneville Reservoir since they originate in the Cascade Mountains where winter precipitation historically falls more frequently as rain versus snow (or, as rain on snowpack) compared to points above The Dalles.

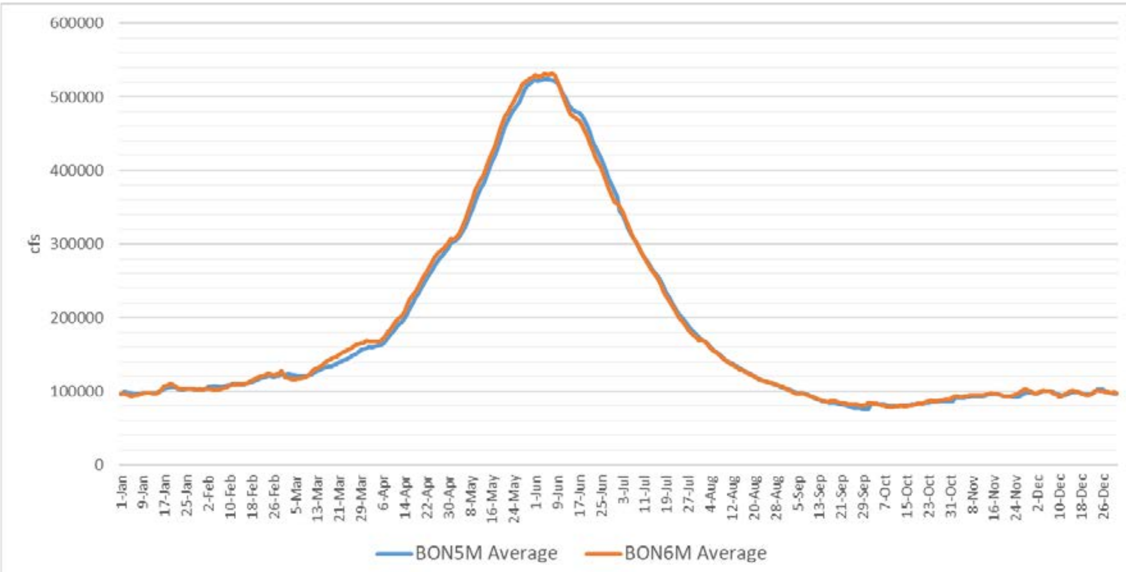

Figure 4-7. Lower Columbia Basin at Bonneville Dam Average Daily 5M vs. 6M

Table 4-7. Lower Columbia Basin at Bonneville Dam Average Monthly 5M vs. 6M

Month	BON5M (cfs)	BON6M (cfs)	Diff. (cfs)	% Change
Jan	101089	100913	-176	-0.2
Feb	112937	112333	-604	-0.5
Mar	135494	139143	3648	2.7
Apr	221155	224971	3817	1.7
May	417802	421487	3685	0.9
Jun	466483	466075	-408	-0.1
Jul	249247	253250	4002	1.6
Aug	129994	131646	1652	1.3
Sep	86887	89116	2229	2.6
Oct	83054	83211	157	0.2
Nov	94156	95601	1444	1.5
Dec	98219	98128	-91	-0.1

4.2.6 Willamette

The average 2020 Modified Flows at Sullivan Dam on the Willamette River are slightly higher in the spring and slightly lower in the winter compared to the 2010 report (Table 4-8, Figure 4-8). The largest percent differences are observed in October and April, when flows are about three percent higher than in 2010 Modified Flows.

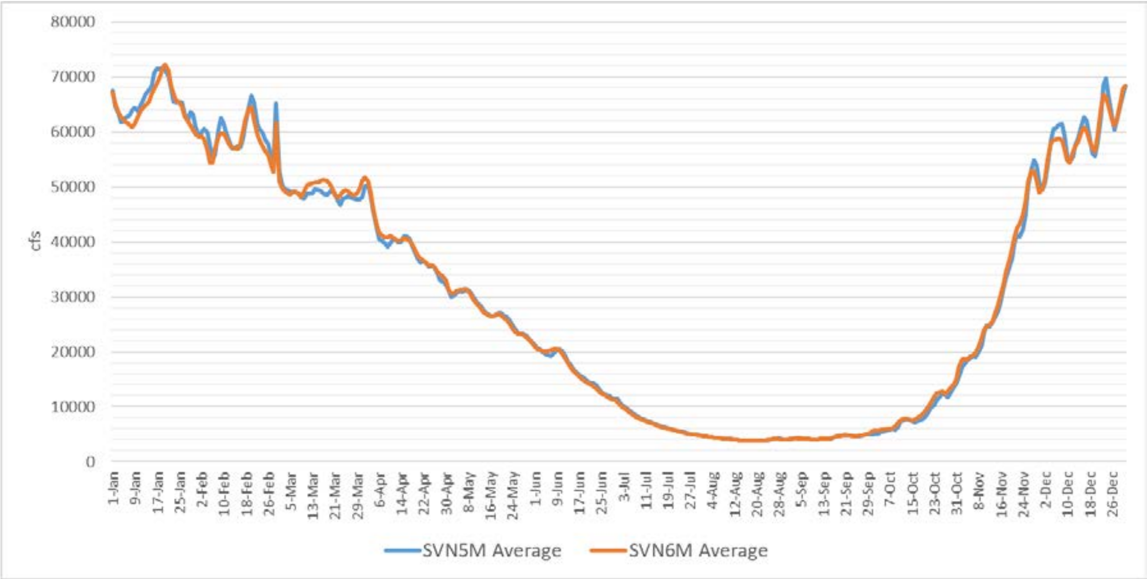

Figure 4-8. Willamette Basin at T.W. Sullivan Dam Average Daily 5M vs. 6M

Table 4-8. Willamette Basin at T.W. Sullivan Dam Average monthly 5M vs. 6M

Month	SVN5M (cfs)	SVN6M (cfs)	Diff. (cfs)	% Change
Jan	65520	64937	-583	-0.9
Feb	59195	58295	-900	-1.5
Mar	48693	49637	944	1.9
Apr	38720	39879	1159	3.0
May	26988	27152	164	0.6
Jun	16299	16492	193	1.2
Jul	6815	6879	64	0.9
Aug	4050	4083	33	0.8
Sep	4424	4428	4	0.1
Oct	8733	8982	249	2.9
Nov	33047	32568	-479	-1.5
Dec	60782	59619	-1162	-1.9

4.3 Reclamation Special Studies

Special modified flows studies were again conducted by the US Bureau of Reclamation for three of the areas within the Columbia Basin which have extensive irrigation and groundwater-surface water interchange. A comparison of the routed flows between the 2010 and 2020 studies is shown in Table 4-9. Despite the major change in models and methods, Reclamation found that average annual flows changed only slightly between 2020 and 2010 Modified Flows over the 1929-2008 period.

However, as the Reclamation Supplemental reports note, intra-annual flows in some basins did change appreciably in some years and decades. Annual flow volumes in the more recent 1999-2008 period are four to six percent higher for 2020 Modified Flows in the upper Snake Basin due to better unregulated flow estimates, better estimates of how much water is withdrawn for groundwater recharge, and how much groundwater returns to the river channel. Meanwhile, for the same period, flows are five percent lower for the Yakima River at Kiona, which is consistent with slightly lower depletions noted by the Washington State University study elsewhere in the mid-Columbia Basin. Finally, little change in water demand is noted by Reclamation in the Deschutes basin since 2010 Modified Flows.

Table 4-9. USBR Special Study Points

	Average Annual *R* Flows (WY 1929-2008, cfs)		
Reclamation Study Points	**2010L**	**2020L**	**Difference (cfs)**
Snake River above Brownlee	16921	16934	12
Yakima River above Kiona	3312	3610	298
Deschutes River above Round Butte	4497	4312	-185

4.4 Recent Trend Analyses

An analysis is included to test and compare whether statistically significant, non-stationary trends are apparent in in this updated long-term streamflow record -- possibly associated with regional climate change. If non-stationarity does exist, it may be more appropriate, depending on the context in which Modified Flows are utilized, to use a more recent and shorter period-of-record for long term planning purposes. This section discusses the statistical approach to analyze long-term trends, and presents the results at a few key locations within the basin.

Non-stationary trends in this dataset can come from sources other than climate change. For example, modified flows include the effects of irrigation on streamflows, including both changes and uncertainties in irrigation calculations. Thus changes in both the depletions, and calculations of the depletions, can yield a non-stationary signal. Because of this, non-stationarity tests were conducted on both the Adjusted Routed Flows (*ARF*) and Modified Flows (*M*), keeping in mind that both *ARF* and *M* flows include regulated flows which are routed downstream from the Yakima, Deschutes and upper Snake Basins. Because the main purpose for calculating modified flows is to normalize flows with current irrigation practices, changes in previous irrigation practices going back to

1928 are at least partially taken into account. However, the trends identified here using *M* flows are very similar to those found when assessing non-stationary trends in *ARF* (which do not normalize for current levels of irrigation).

4.4.1 30-year Mean Streamflow Trends

This analysis compared the mean daily modified flows for nine, 30-year moving periods. Daily mean flows were calculated for WY 1929-1958; WY 1939-1968; WY 1949-1978; etc.). With these groupings of mean daily flows, hydrographs at key locations: The Dalles (TDA), Grand Coulee (GCL), and Ice Harbor (IHR) can be compared for signal identification (Figures 4-8 to 4-11).

The 30-year mean flows at The Dalles showed a distinct reduction in peak flows and an earlier date of peak flow over time (Figure 4-9). The reduction in peak flow is first apparent in the period WY1969-1998 and gradually amplify through the most recent 30-year period. Similarly, a reduced summer flow pattern emerges for those same time periods, along with an increase in March and April flows, which may be driven by a trend for earlier snowmelt in the basin.

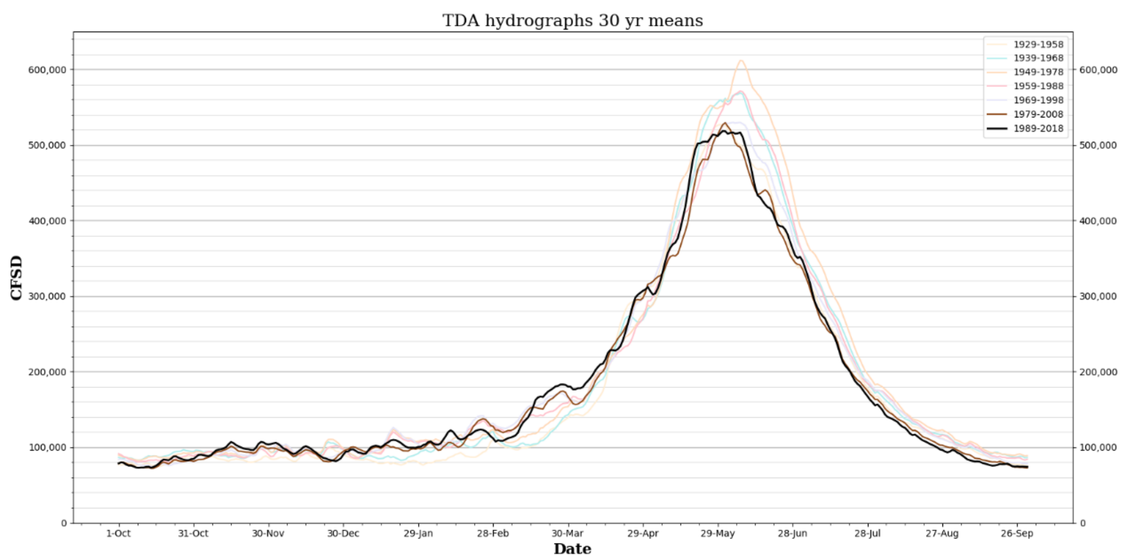

Figure 4-9. The Dalles (TDA) 30-year mean daily Modified Flows.

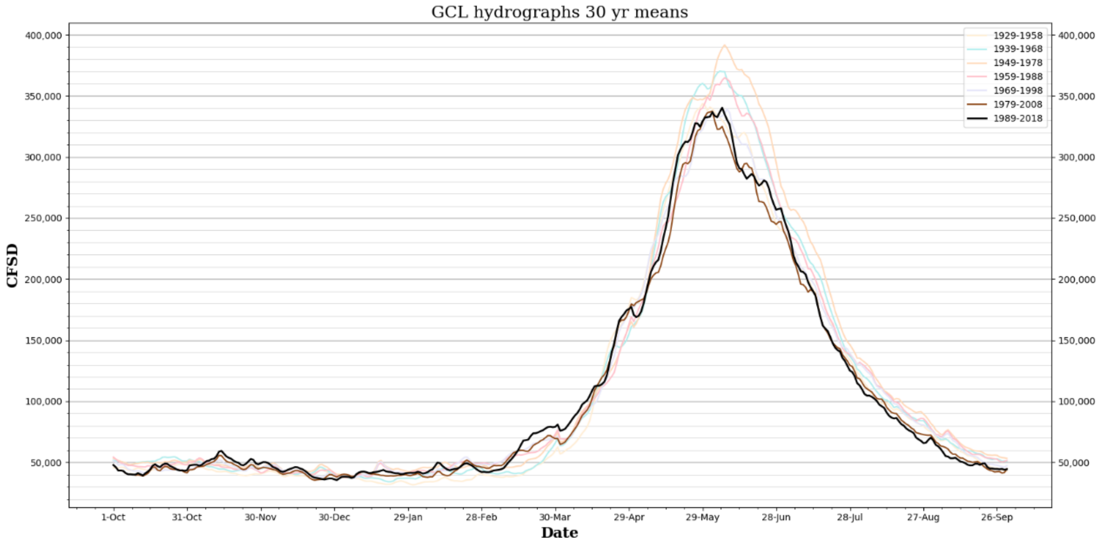

Figure 4-10. Grand Coulee (GCL) 30-year mean daily Modified Flows.

Data at Grand Coulee shows similar trends as at TDA: earlier spring streamflow, reduced peak streamflows, and lower summer flows for more recent periods (Figure 4-10). Considering that GCL provides the bulk of seasonal streamflow that passes through TDA, it is expected to see similar trends at both locations.

The hydrograph at Ice Harbor on the Snake River showed a more erratic signal in the fall and winter periods (Figure 4-11). One cause may be that the Snake River Basin is warmer and more arid, with lower mean annual volume, more significant flow spikes relative to base flows, and greater interannual variability. However, several trends are apparent with earlier and lower peak streamflow and reduced summer flow being the most notable. Mean peak streamflows were two to four weeks earlier in the two most recent periods relative to all other periods. The first period (1929-1958) is more similar to the most recent periods due to the exceptionally dry and cold period of the 1930s, which is evident at all locations across the Columbia Basin. This is believed to have driven the reduced flows for the 1929-1958 period.

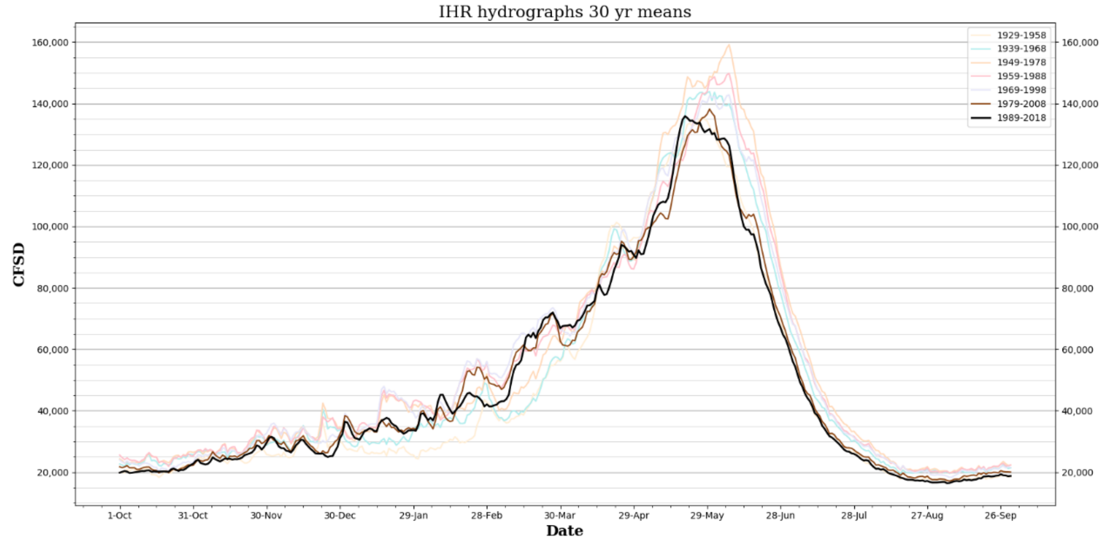

Figure 4-11. Ice Harbor (IHR) 30-year mean daily Modified Flows.

4.4.2 Statistical Analysis

Important sub-seasonal volume and shape changes can provide context of a larger climate signal on streamflows as shifts in runoff timing can be masked within a seasonal volume framework. Further analysis focuses on the sub-seasonal modified flow volumes at The Dalles during three main periods: 1929-1958; 1959-1988; 1989-2018 (Figure 4-11). Sub-seasons are defined as Fall (October-November), Winter (December-February), Spring (March-June) and Summer (July-September). The four-month spring period was chosen to encompass the spring melt season, which peaks earlier in the warmer Snake basin (March to May), compared to the colder Canadian portion of the Basin (May-June).

For the Fall, Winter, and Summer seasons there was minimal difference between periods with regards to the runoff pattern, with the exception of the 1929-1958 (red line), which was driven by the anomalously dry and cold 1930s, as noted above. A noticeable volume reduction for the Summer period, at least visually, is evident for the most recent period (green line). The Spring period showed a shift in runoff timing earlier for the most recent period (green line) compared to the other periods, with little accompanying change in overall volume (Figure 4-12).

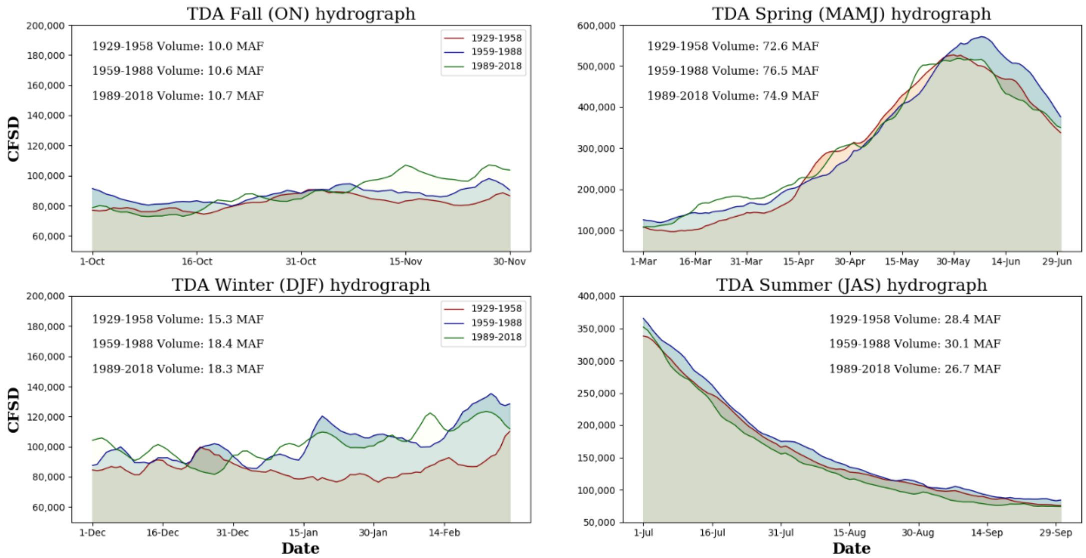

Figure 4-12. Sub-seasonal mean Modified Flows for three periods at The Dalles. Y-axis for each subplot are on different scales to highlight lower flow seasons, e.g. Fall and Winter.

To determine if these difference had statistical significant. Z-score analyses of sub-seasonal modified flows is conducted. The periods 1929-1988 and 1929-2018 are compared against the most recent 30-year record (1989-2018). Results at The Dalles for both periods show a statistically significant increase in winter volume (p-value = >0.99) when compared to the most recent 30-year record (Table 4-10). Comparing the first 60 years (1929-1988) with the most recent period, an increase in fall volumes and reduction in summer volume is also indicated, although the difference is not quite statistically significant. A similar trend at Grand Coulee (Table 4-11) are consistent with what was found at TDA: statistically significant increases in winter volumes, coupled with a non-significant increase in fall volumes and reduction in summer volumes.

Table 4-10. Sub-seasonal mean volumes Z-score statistical analysis at The Dalles. Statistically significant findings (p-value >=0.95) are shown in bold/italic

TDA	Fall (ON)	Winter (DJF)	Spring (MAMJ)	Summer (JAS)	Annual
1929-2018 vs 1989-2018					
Vol. Difference (kaf)	245.6	***891.9***	775.2	-1725.1	187.7
Z-score	0.98	***3.59***	0.22	-0.90	0.04
p-Value	0.84	***>0.99***	0.59	0.18	0.52
1929-1988 vs 1989-2018					
Vol. Difference (kaf)	368.4	***1337.9***	1162.8	-2587.7	281.5
Z-score	1.492	***5.191***	0.305	-1.272	0.062
p-Value	0.93	***>0.99***	0.62	0.10	0.52

Table 4-11. Sub-seasonal mean volumes Z-score statistical analysis at Grand Coulee. Statistically significant findings (p-value >=0.95) are shown in bold/italic.

GCL	Fall (ON)	Winter (DJF)	Spring (MAMJ)	Summer (JAS)	Annual
1929-2018 vs 1989-2018					
Vol. Difference (kaf)	112.0	***217.8***	-193.7	-1274.5	-1138.5
Z-score	1.07	***2.60***	-0.07	-0.89	-0.44
p-Value	0.86	***>0.99***	0.47	0.19	0.33
1929-1988 vs 1989-2018					
Vol. Difference (kaf)	168.0	***326.6***	-290.6	-1911.7	-1707.7
Z-score	1.556	***3.758***	-0.101	-1.257	-0.618
p-Value	0.94	***>0.99***	0.46	0.10	0.27

At IHR, though, a somewhat different picture emerges (Table 4-12). Unlike GCL and TDA where winter volumes have exhibited a statistically significant increase in the most recent 30 years, there is little change in winter volumes indicated at IHR when comparing both 1929-2018 and 1929-1988 seasonal volumes with 1989-2018 seasonal volumes. However, a statistically significant decrease in fall volumes is noted, along with a non-significant decrease in summer volumes similar to TDA and GCL. As noted earlier, the Snake River basin has historically exhibited greater volume volatility and higher standard deviations, which may make signal detection more difficult using standard Z-score comparisons. However, a reduction in summer and fall flows in the most recent 30 years compared to the previous 60 years, whether they are statistically significant or not, may be a noteworthy signal when paired with other trend analyses.

Table 4-12. Sub-seasonal mean volumes Z-score statistical analysis at Ice Harbor. Statistically significant findings (p-value <0.05) are shown in bold/italic.

IHR	Fall (ON)	Winter (DJF)	Spring (MAMJ)	Summer (JAS)	Annual
1929-2018 vs 1989-2018					
Vol. Difference (kaf)	***-146.8***	29.4	-158.7	-279.6	-555.7
Z-score	***-2.17***	0.21	-0.23	-1.01	-0.65
p-Value	***0.01***	0.58	0.41	0.16	0.26
1929-1988 vs 1989-2018					
Vol. Difference (kaf)	***-220.2***	44.1	-238.1	-419.4	-833.5
Z-score	***-3.113***	0.302	-0.314	-1.389	-0.908
p-Value	***<0.01***	0.62	0.38	0.08	0.18

Finally, to test for non-stationarity within the 90-year record, a statistical assessment of the streamflow record is performed using two statistical trend analyses. Inspection of the 30-year moving average daily flows, and in addition to the statistical subseasonal volume analyses, suggested an earlier streamflow peak may be present. To test this hypothesis, a Mann-Kendall statistical test is first performed. The Mann-Kendall approach is a widely used test for hydrological trend analysis due to its ease of use, non-parametric nature, and few underlying assumptions. A Mann-Kendall test can determine if a dataset exhibits a monotonic increasing or decreasing trend over time. Similarly, a Spearman's Rank Correlation is a rank-based test that measures the strength and direction of a monotonic trend of variables over time. The more positive or negative the correlation coefficient (ρ) is, the stronger the monotonic trend.

Useful indicators of changing hydrologic regimes are metrics that remove the dependence of volume, particularly in the Columbia Basin where large interannual variability can obscure climate signals that may be present. The *M* dataset was used to calculate the date during the water year when 50 percent of water year volume has passed a given location for each year in the 90-year record.

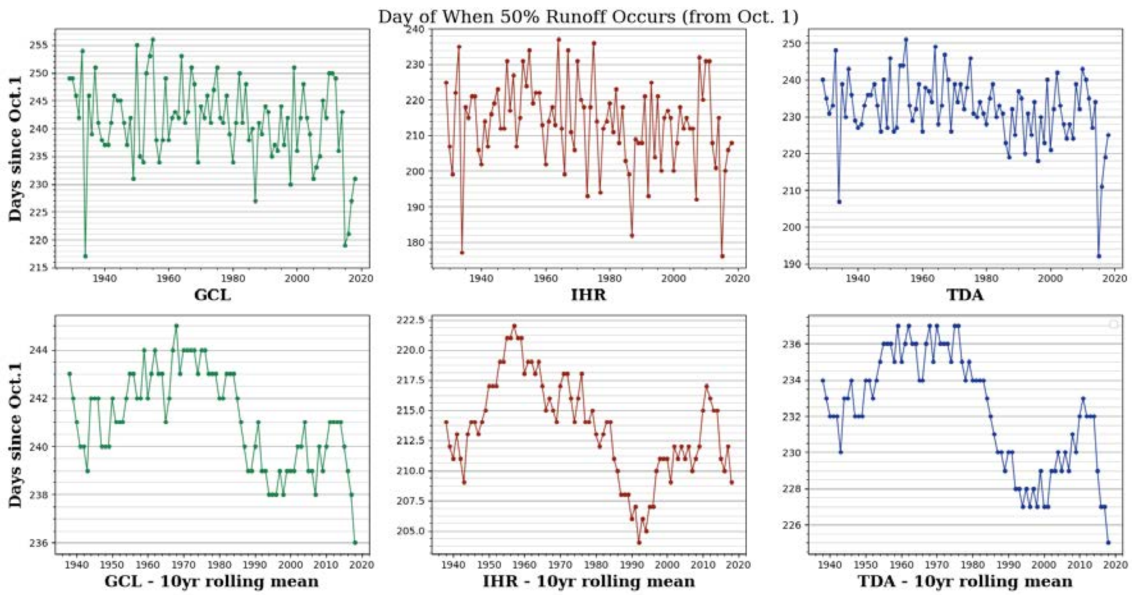

Figure 4-13. Date since October 1 of when 50% of Modified Flow runoff passes GCL, IHR, and TDA (top), and 10-year running mean (bottom), 1929-2018.

All three sites chosen for this analysis showed a significant decreasing trend for both tests, e.g. earlier in the water year when 50% of seasonal runoff passes. For GCL the Mann-Kendall statistics show a significant decreasing trend (p-value = 0.02) of three days earlier (Table 4-13). Additionally, Spearman's Rank Correlation shows a significant decreasing trend with ρ = -0.23 with a p-value of 0.03. For IHR, the decreasing trend is also three days (p-value = 0.04) for the Mann-Kendall and a Spearman's ρ of -0.21 (p-value = 0.04). For TDA, a similar trend is present with the Mann-Kendall test showing a strong decreasing trend (p-value = <0.01) of three days earlier when 50% runoff occurs. Spearman's ρ for TDA is -0.29 and is significant (p-value <0.01).

Table 4-13. Statistical trends for each location with associated p-values for each test. Statistically significant findings (p-value <0.05) are shown in bold.

	Mann-Kendall z	p-value	Spearman's ρ	p-value
GCL	-2.26	**0.02**	-0.23	**0.03**
IHR	-2.05	**0.04**	-0.21	**0.04**
TDA	-2.72	**<0.01**	-0.28	**<0.01**

4.4.3 Conclusions

Although these analyses are not comprehensive for the entire Columbia River Basin, the dataset does suggest that non-stationary trends exist in this 90-year streamflow dataset, particularly in the more recent past. Moreover, at The Dalles, Grand Coulee and Ice Harbor Dams, the trends are consistent with the RMJOC-II climate change study (RMJOC, 2018) and other regional climate change projections, and have begun to emerge in the last 30 to 40 years. Those expected trends in this study include: higher flows in the winter December to March, lower flows in July to September, and a slightly earlier, but statistically significant, trend in peak spring flows.

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Appendix A- List of Points

ID	Name	Basin	Section	H	S	A	L	ARF	D	DD	E	EE	M
ACL	"A" Canal Diversion	Western Oregon	3.9	x					x				
ALB	Albany	Willamette	3.7	x			x	x		x			x
ALD	Alder	Western Washington	3.8		x								x
ALF	Albeni Falls	Pend Oreille	3.2	x	x	x	x	x		x			x
ANA	Anatone	Lower Snake	3.5	x			x	x		x			x
ARD	Hugh Keenleyside	Upper Columbia	3.1	x	x	x	x	x	x	x	x	x	x
B23	Pump to Blocks 2 & 3	Lower Columbia	3.6, 4.1						x				
BCL	Big Cliff	Willamette	3.7	x				x					x
BDY	Boundary	Pend Oreille	3.2	x	x	x	x	x		x			x
BFE	Bonners Ferry	Libby	3.1	x			x	x		x			x
BIT	Bitterroot	Pend Oreille	3.2						x				
BLU	Blue River	Willamette	3.7	x	x	x							x
BON	Bonneville	Lower Columbia	3.6	x	x	x	x	x		x			x
BOX	Box Canyon	Pend Oreille	3.2	x	x	x	x	x		x			x
BRI	Brilliant	Kootenay	3.1	x			x	x	x	x			x
BRN *	Brownlee	Lower Snake	3.5, 4.2	x	x	x				x	x		x
C_S	Carmen-Smith PP inflow	Willamette	3.7			x							x
CAB	Cabinet	Pend Oreille	3.2	x	x	x	x	x		x			x
CAN	Kootenay Canal	Kootenay	3.1										x
CAR	Carmen Diversion	Willamette	3.7	x									x
CEW	Chelan-Entiat-Wenatchee-West of Banks Lake	Mid-Columbia	3.3						x				
CFM	Columbia Falls	Pend Oreille	3.2	x			x	x					x
CGR	Cougar	Willamette	3.7	x	x	x							x
CHJ	Chief Joseph	Mid-Columbia	3.3	x	x	x	x	x			x	x	x
CHL	Chelan	Mid-Columbia	3.3	x	x	x							x
CLR	Clearwater	Lower Snake	3.5						x				
COE	Coeur D'Alene	Spokane	3.2	x	x	x				x			x
COR	Corra Linn	Kootenay	3.1	x	x	x	x	x		x		x	x
COT	Cottage Grove	Willamette	3.7	x	x	x							x
CS1	Cushman 1	Western Washington	3.8			x							x
CS2	Cushman 2	Western Washington	3.8			x							x
CTR	Columbia at Trail	Upper Columbia	3.1						x	x			
DCD	Duncan	Kootenay	3.1	x	x	x					x		x
DET	Detroit	Willamette	3.7	x	x	x							x
DEX	Dexter	Willamette	3.7										x
DIA	Diablo	Western Washington	3.8			x							x
DOR	Dorena	Willamette	3.7	x	x	x							x
DWR	Dworshak	Lower Snake	3.5	x	x	x					x		x
EKO	East Kootenay abv Newgate	Kootenay	3.1						x				
FAL	Falls Creek	Willamette	3.7	x	x	x							x
FAR	Faraday	Willamette	3.7										x
FDR**	Franklin D. Roosevelt Lake	Mid-Columbia	3.3										
FER	Ferry-Stevens	Mid-Columbia	3.3						x				
FID	Flathead Irrigation District	Pend Oreille	3.2						x				
FLT	Upper Flathead	Pend Oreille	3.2						x				
FOS	Foster	Willamette	3.7	x	x	x	x	x					x
FRN	Fern Ridge	Willamette	3.7	x	x	x			x		x		x
GCL	Grand Coulee	Mid-Columbia	3.3	x	x	x	x	x	x	x	x	x	x
GOR	Gorge	Western Washington	3.8			x							x
GPR	Green Peter	Willamette	3.7	x	x	x							x
HCD	Hells Canyon	Lower Snake	3.5	x	x	x	x	x			x	x	x
HCR	Hills Creek	Willamette	3.7	x	x	x							x
HGH	Hungry Horse	Pend Oreille	3.2	x	x	x					x		x
HOD	Hood River	Lower Columbia	3.6						x				
HYD	Carmen Div. Max 630 cfs	Willamette	3.7			x							

ID	Name	Basin	Section	H	S	A	L	ARF	D	DD	E	EE	M
IHR	Ice Harbor	Lower Snake	3.5	x	x			x			x	x	x
JCB	John C. Boyle	Western Oregon	3.9	x	x	x							x
JDA	John Day	Lower Columbia	3.6	x	x	x	x	x	x	x	x	x	x
JDP	Pumping/Returns from John Day to Morrow/Gilliam	Lower Columbia	3.6						x				
KEN	Kennewick	Lower Columbia	3.6						x				
KER	Seli'š Ksanka Qlispe'	Pend Oreille	3.2	x	x	x	x	x		x			x
KET	Kettle	Mid-Columbia	3.3						x				
KID	Kootenai-Idaho	Kootenay	3.1						x				
KLA	Klamath Lake	Western Oregon	3.9		x								x
KLC	Klickitat	Lower Columbia	3.6						x				
KMT	Kootenai-Montana	Kootenay	3.1						x				
LAG	Lagrande	Western Washington	3.8	x		x							x
LBN	Lower Bonnington	Kootenay	3.1										x
LCF	Lower Clark Fork	Pend Oreille	3.2						x				
LEA	Leaburg	Willamette	3.7	x		x	x	x					x
LFL	Little Falls	Spokane	3.2										x
LGS	Little Goose	Lower Snake	3.5	x	x			x			x	x	x
LIB	Libby	Kootenay	3.1	x	x	x				x	x		x
LIM	Lime Point	Lower Snake	3.5	x			x	x					x
LLK	Long Lake	Spokane	3.2	x	x	x		x					x
LMN	Lower Monumental	Lower Snake	3.5	x	x	x	x	x		x	x	x	x
LNK	Link R.	Western Oregon	3.9	x		x							x
LOP	Lookout Point	Willamette	3.7	x	x	x		x			x		x
LOS	Lost Creek	Western Oregon	3.9	x	x	x							x
LWG	Lower Granite	Lower Snake	3.5	x	x	x	x	x		x	x	x	x
LWS	Lower Salmon	Lower Snake	3.5						x				
MAY	Mayfield	Western Washington	3.8	x	x	x							x
MCD	Mica	Upper Columbia	3.1	x	x	x				x	x		x
MCN	McNary	Lower Columbia	3.6	x	x	x	x	x		x	x	x	x
MER	Aerial (Merwin)	Western Washington	3.8	x		x							x
MON	Monroe Street	Spokane	3.2										x
MOS	Mossyrock	Western Washington	3.8	x	x	x					x		x
MRF	McNary Return Flow	Lower Columbia	3.6, 4.1						x				
MUC	Murphy Creek	Upper Columbia	3.1	x			x	x		x		x	x
NFK	North Fork	Willamette	3.7	x	x	x							x
NIN	Nine Mile	Spokane	3.2	x				x					x
NOX	Noxon Rapids	Pend Oreille	3.2	x	x	x	x	x		x	x	x	x
NSJ	Pumping/Returns from John Day to Northside	Lower Columbia	3.6						x				
NSM	Pumping from McNary to Northside	Lower Columbia	3.6						x				
NSR	Return flow from McNary pumping to Northside	Lower Columbia	3.6						x				
OAK	Oak Grove	Willamette	3.7	x		x							x
OKA	Okanagon in Canada	Mid-Columbia	3.3						x				
OKM	Methow-Okanagan	Mid-Columbia	3.3						x				
ORO	Orofino	Lower Snake	3.5	x									x
OXB	Oxbox	Lower Snake	3.5										x
PAK	Packwood Lake	Western Washington	3.8		x	x							x
PEL	Pelton	Lower Columbia	3.6	x						x			x
PEN	Pend Oreille	Pend Oreille	3.2						x				
PFL	Post Falls	Spokane	3.2										x
PLS	Palouse-Lower Snake	Lower Snake	3.5						x				
POC	Pend Oreille in Canada	Pend Oreille	3.2						x				
PPL	"A" Canal depletion	Western Oregon	3.9						x				
PRD	Priest Rapids	Mid-Columbia	3.3	x	x	x	x	x		x	x	x	x
PRF	Priest Rapids Return Flow	Mid-Columbia	3.3, 4.1						x				
PSL	Priest Lake	Pend Oreille	3.2	x	x	x							x
RAT	Rathdrum Prairie Canal	Spokane	3.2						x				
RER	Pelton Rereg	Lower Columbia	3.6										x
RIS	Rock Island	Mid-Columbia	3.3	x	x	x	x	x		x			x

ID	Name	Basin	Section	H	S	A	L	ARF	D	DD	E	EE	M
RML	River Mill	Willamette	3.7										x
ROS	Ross	Western Washington	3.8			x					x		x
ROU*	Round Butte	Lower Columbia	3.6, 4.2	x	x	x				x	x		x
RRH	Rocky Reach	Mid-Columbia	3.3	x	x	x	x	x		x	x	x	x
RVC	Revelstoke	Upper Columbia	3.1	x	x	x	x	x		x	x	x	x
SEV	Seven Mile	Pend Oreille	3.2	x	x	x	x	x		x			x
SHA	Lower Baker	Western Washington	3.8			x							x
SLM	Salem	Willamette	3.7	x			x	x		x			x
SLO	Slocan	Kootenay	3.1										x
SMH	Smith R. Reservoir	Willamette	3.7			x							x
SPD	Spalding	Lower Snake	3.5	x			x	x					x
SPO	Spokane Valley Farms Canal	Spokane	3.2						x				
SPV	Spokane Valley	Spokane	3.2						x				
SUV	Sullivan Lake	Pend Oreille	3.2			x							x
SVN	T.W. Sullivan	Willamette	3.7	x			x	x		x		x	x
SW2	Swift 2	Western Washington	3.8										x
SWF	Swift 1	Western Washington	3.8			x							x
TDA	The Dalles	Lower Columbia	3.6	x	x	x	x	x		x	x	x	x
TMY	Timothy Meadows	Willamette	3.7	x	x	x							x
TOM	Thompson Falls	Pend Oreille	3.2	x	x	x	x	x		x			x
TRB	Trail Bridge	Willamette	3.7	x			x	x					x
TRY	Troy	Lower Snake	3.5	x									x
UBK	Upper Baker	Western Washington	3.8			x							x
UBN	Upper Bonnington	Kootenay	3.1										x
UCF	Upper Clark Fork	Pend Oreille	3.2						x				
UMP	Pumping from McNary to Umatilla	Lower Columbia	3.6						x				
UMR	Return flow from McNary pumping to Umatilla	Lower Columbia	3.6						x				
UMW	Umatilla River and Willow Creek	Lower Columbia	3.6						x				
UPC	Upper Columbia above Mica	Upper Columbia	3.1						x				
UPF	Upper Falls	Spokane	3.2	x				x		x			x
UPS	Upper Salmon	Lower Snake	3.5						x				
WAN	Wanapum	Mid-Columbia	3.3	x	x	x		x		x	x	x	x
WAT	Waneta	Pend Oreille	3.2	x	x	x		x					x
WAV	Walterville	Willamette	3.7	x		x	x	x					x
WEL	Wells	Mid-Columbia	3.3	x	x	x	x	x		x	x	x	x
WEN	Grande Ronde	Lower Snake	3.5						x				
WHB	White Bird	Lower Snake	3.5	x									x
WHS	White Salmon	Lower Columbia	3.6						x				
WHT	White River - Wapinitia	Lower Columbia	3.6						x				
WKO	West Kootenay	Kootenay	3.1						x				
WMT	Willamette	Willamette	3.7						x				
WRF	Wanapum Return Flow	Mid-Columbia	3.3, 4.1						x				
WWA	Walla Walla	Lower Columbia	3.6						x				
YAK*	Yakima	Mid-Columbia	3.3, 4.2	x						x			x
YAL	Yale	Western Washington	3.8			x							x

***BRN, ROU, and YAK have an additional data type, *R*, which is flow data provided by the Reclamation (Supplemental Reports)**
****FDR has two additional data types: *G* and *P*, which are generation and pumping flow data (Section 3.3.3)**

Appendix B– River Schematics

The following section presents the data sources or methods used in the gathering of *H*, *S*, and *A* data at each modified flow project or point. The table includes the period of record of the data source, the source of that data, and any special comments about the data used. A schematic of the modified flow point along with the historical and current gages is provided. Presented alongside each streamflow gage in the schematic is the site's period of record and the drainage area (denoted in schematics as "DA") above the site. River miles are shown for each dam site and gaging station. The modified flow points are listed in upstream to downstream order.

Upper Columbia and Kootenay Basins (Section 3.1)

MICA (MCD)

COLUMBIA RIVER	River Mile 1018	Drainage Area: 8290 sq. mi

Site	Period	Source	Comments
MCD6H	07/01/1928 – 11/30/1976		Outflows used from 2010 Modified Flows. How those were created are described in Footnote 1
	12/01/1976 - 12/31/1983	BCHydro	Project discharge from BCHydro
	01/01/1984 - 09/30/2008	BCHydro	Used PDSS data furnished by BC Hydro with following exceptions where data from USACE was used instead: 05/01/1985 to 05/10/1985 08/11/1986 to 08/20/1986
	10/01/2008 – 09/30/2018	BCHydro	
MCD6S	03/01/1973 - 09/30/2008	BCHydro	Reservoir storage data was used to compute daily change-of-content
	10/01/2008 – 09/30/2018	BCHydro	
MCD6A	07/01/1928 – 09/30/2018	BCHydro	Data for entire period of record was submitted by BCHydro

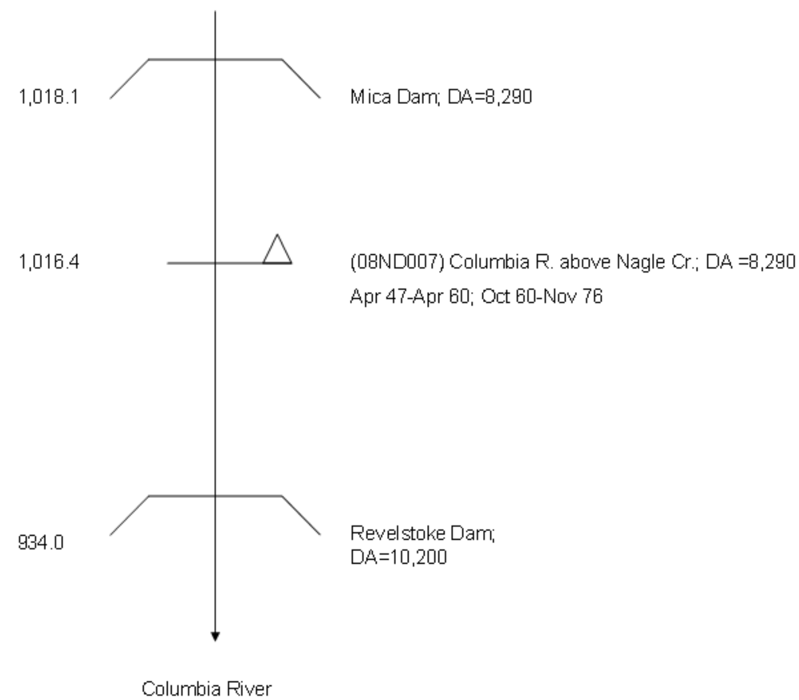
Footnote 1 -- Computations from 2010 Modified Flows for period prior to December 1976 are as follows:

<u>July 1928 – August 1928</u> -- Used the 1990 Modified Flows study average monthly flow of 62,900 & 41,760 cfs for July and August, respectively. Average daily flows were developed by using these monthly flow volumes and the daily flow shape of 08NA002 (Columbia River at Nicholson).

<u>September 1928 through March 1947</u> –Developed correlation with 08ND007 (Columbia River above Nagle Creek)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	0.514	0.468	0.449	0.656	0.711	0.737	0.695	0.625	0.590	0.565	0.611	0.495
b	930	1077	1144	-35	-2732	-3075	4317	7445	4419	2059	600	1149

<u>April 1947 through November 1976</u> -- Observed flows of 08ND007 (Columbia River above Nagle Creek)

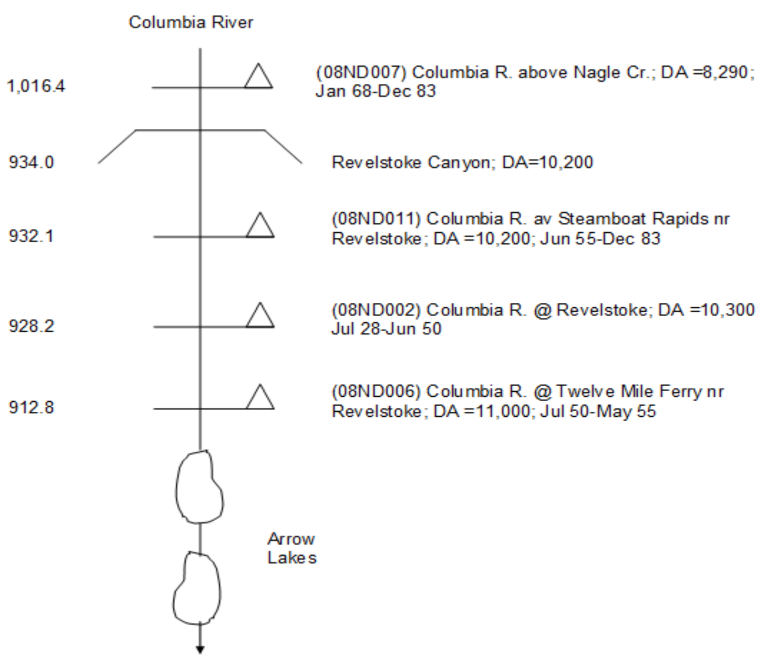


1,018.1
Mica Dam; DA=8,290
1,016.4
(08ND007) Columbia R. above Nagle Cr.; DA =8,290
Apr 47-Apr 60; Oct 60-Nov 76
934.0
Revelstoke Dam;
DA=10,200
Columbia River

REVELSTOKE CANYON (RVC)

COLUMBIA RIVER River Mile 934 Drainage Area: 10200 sq. mi

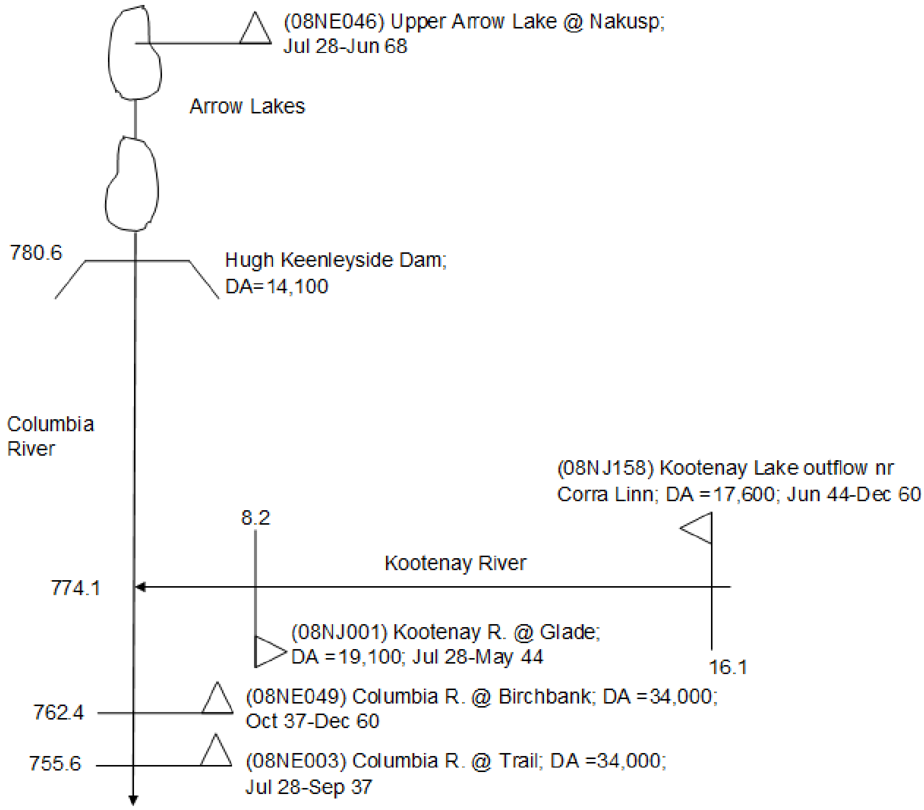
Site	Period	Source	Comments
RVC6H	07/01/1928 – 12/31/1984	2010 Modified Flows	
	01/01/1984 – 09/30/2018	BCHydro	All outflow data provided by BCHydro
RVC6S	10/01/1983 - 12/31/1984	USACE Data query	Used Corps of Engineers data base
	01/01/1985 - 09/30/2008	BCHydro	Used BCHydro PDSS midnight storage data except for 05/01/85 to 05/11/85 used USACE data base because of missing record. RVC4S not used after 1/1/84 because BCHydro furnished quality controlled flows for 1/1/84 to 9/30/99.
	10/01/2008 – 09/30/2018	BCHydro	
RVC6L	07/01/1928 – 09/30/2018	BCHydro	Entire record provided by BCHydro
RVC6A	07/01/1928 – 09/30/2018		MCD_H + RVC_L



KEENLEYSIDE (ARROW) (ARD)

COLUMBIA RIVER River Mile 780.6 Drainage Area: 14100 sq. mi

Site	Period	Source	Comments
ARD6H	07/01/1928 - 09/30/2018	BCHydro	Outflow data provided by BCHydro, and published as provided. Note that flows are not routed downstream to Murphy Creek/Birchbank, BC. See MUC below and Section 3.1.3.
ARD6S	07/01/1928 - 09/30/2008	2010 Modified Flows	
	10/01/2008 – 09/30/2018	BCHydro	Change in storage for Lower Lake generated from Fauquier gage.
ARD6L	07/01/1928 - 09/30/2018	BCHydro	Data provided directly by BCHydro
WGS_L	07/01/1928 – 02/04/1974		Used Whatshan flows from 2010 Modified Flow study
	02/05/1974 – 09/30/2018	BCHydro	
ARD6A	07/01/1928 – 09/30/2018		RVC_H + ARD_L + WGS_L


(08NE046) Upper Arrow Lake @ Nakusp;
Jul 28-Jun 68
Arrow Lakes
780.6
Hugh Keenleyside Dam;
DA=14,100
Columbia
River
(08NJ158) Kootenay Lake outflow nr
Corra Linn; DA =17,600; Jun 44-Dec 60
8.2
Kootenay River
774.1
(08NJ001) Kootenay R. @ Glade;
DA =19,100; Jul 28-May 44
16.1
762.4
(08NE049) Columbia R. @ Birchbank; DA =34,000;
Oct 37-Dec 60
755.6
(08NE003) Columbia R. @ Trail; DA =34,000;
Jul 28-Sep 37

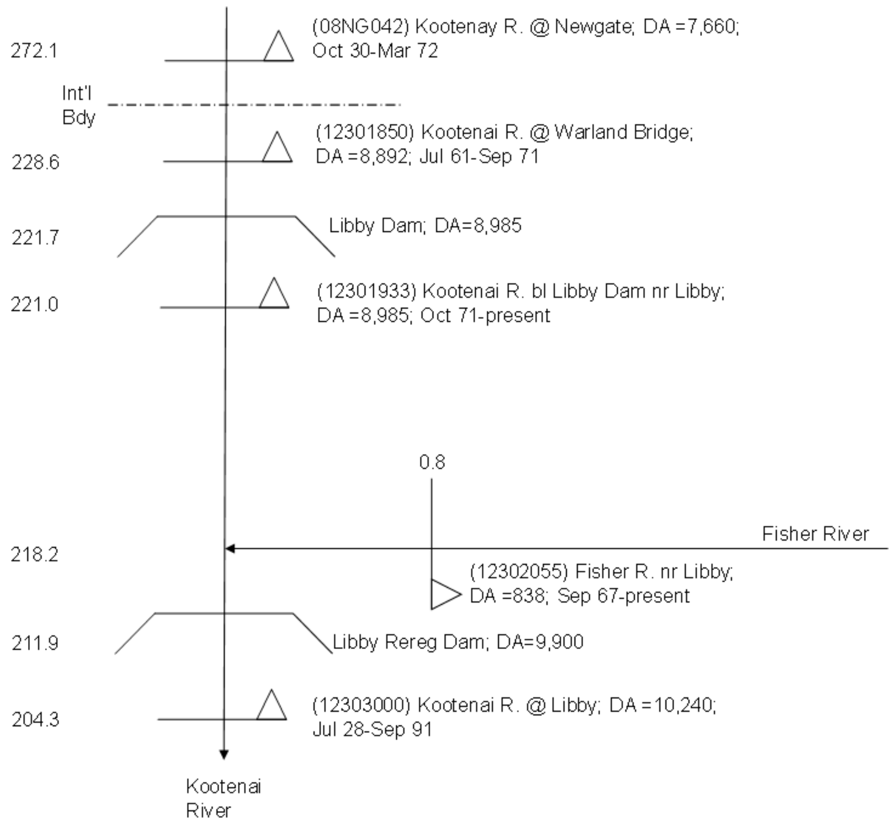
LIBBY (LIB)

KOOTENAI RIVER　　River Mile 221.7　　Drainage Area: 8985 sq. mi

Site	Period	Source	Comments
LIB6H	07/01/1928 - 09/30/1930	USGS 12303000	Linear correlation with 12303000 (Kootenai River at Libby). See Footnote 2.
	10/01/1930 - 06/30/1961	USGS 12303000 & 08NG042	Observed flow of 08NG042 (Kootenay River at Newgate) plus [.5136 times 12303000 (Kootenai River at Libby) minus 08NG042 (Kootenay River at Newgate)]
	07/01/1961 - 09/30/1971	USGS 12303000 & 12301850	Observed flow of 12301850 (Kootenay River at Worland Bridge) plus .069 times [USGS 12303000 (Kootenay River at Libby) minus USGS 12301850 (Kootenai River at Worland Bridge)]
	10/01/1971 - 09/30/2018	USGS 12301933	Observed flow of 12301933 (Kootenai River below Libby Dam near Libby)
LIB6S	10/01/1972 - 09/30/1999	USGS 12301920	Reservoir elevations USGS 12301920 (Lake KOOCANUSA Near Libby) and USACE capacity table
	10/01/1999 - 09/30/2018	USACE	
LIB6A	07/01/1928 - 09/30/2018	LIB_H + LIB_S	

Footnote 2 – Linear interpolation equation variables for Libby inflow:

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
a	0.909	0.88	0.765	0.752	0.754	0.751	0.873	0.959	0.961	0.97	0.963	0.956
b	189.3	166.0	480.9	461.8	401.0	392.8	-389.3	-1351.3	-215.7	-206.0	-42.4	-3.1


272.1
(08NG042) Kootenay R. @ Newgate; DA =7,660;
Oct 30-Mar 72
Int'l
Bdy
228.6
(12301850) Kootenai R. @ Warland Bridge;
DA =8,892; Jul 61-Sep 71
221.7
Libby Dam; DA=8,985
221.0
(12301933) Kootenai R. bl Libby Dam nr Libby;
DA =8,985; Oct 71-present
0.8
Fisher River
218.2
(12302055) Fisher R. nr Libby;
DA =838; Sep 67-present
211.9
Libby Rereg Dam; DA=9,900
204.3
(12303000) Kootenai R. @ Libby; DA =10,240;
Jul 28-Sep 91
Kootenai
River

BONNERS FERRY (BFE)

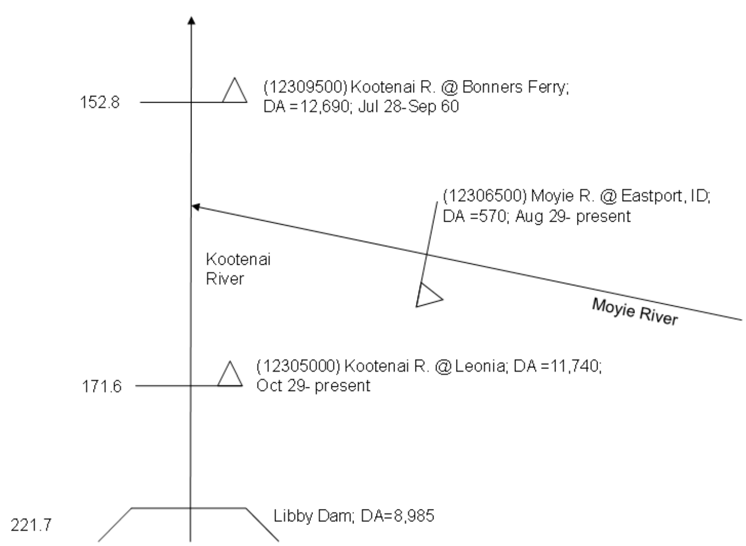
KOOTENAI RIVER | River Mile 152.8 | Drainage Area: 12690 sq. mi

Site	Period	Source	Formula
BFE6H	07/01/1928 - 09/30/1960	USGS 12309500	Observed flows of 12309500 (Kootenai River at Bonners Ferry).
	10/01/1960 - 09/30/2002	USGS 12305000 & USGS 12306500	Observed flows of USGS 12305000 (Kootenai River at Leonia) routed by SSARR plus estimated local based on correlation with USGS 12306500 (Moyie River at Eastport)[3]
	10/01/2002 - 09/30/2018	USGS 12310100	Observed flow of USGS 12310100 (Kootenai River at Tribal Hatchery near Bonners Ferry)
BFE6L	07/01/1928 – 09/30/2018		BFE_H – LIB_H (routed) using SSARROUTE
BFE6ARF	07/01/1928 - 09/30/2018		LIB_A (routed using SSARROUTE and CHPS system) + BFE_L

Footnote 3 – Estimation of local inflow at Bonners Ferry, ID.

Bonners Ferry and Leonia = USGS 12306500*a + b
where USGS 12306500 = Moyie River at Eastport, ID

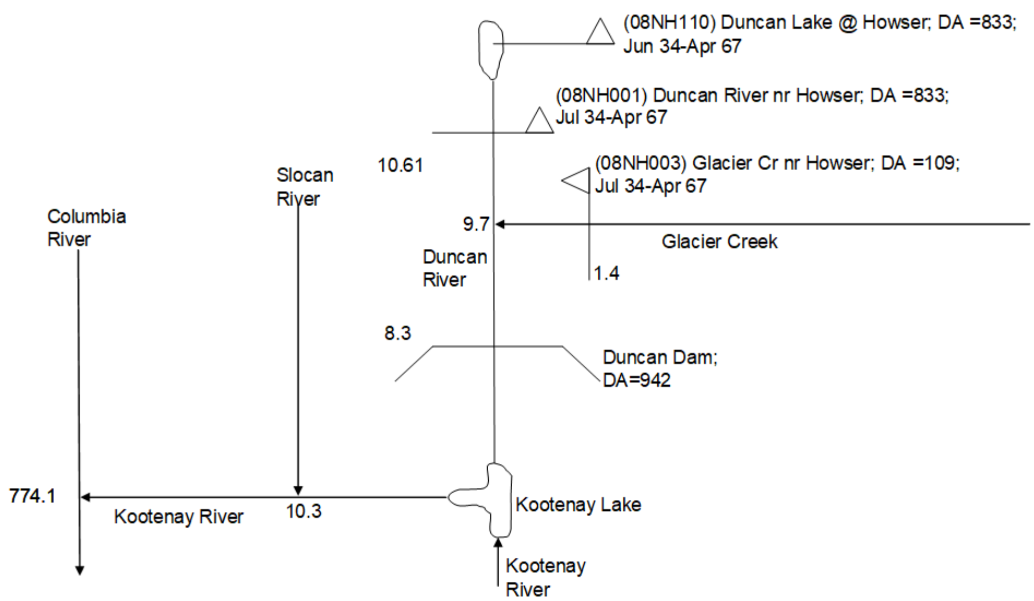
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
a	1.387	1.601	1.399	1.753	2.139	1.437	1.327	1.066	1.289	1.732	1.73	1.382
b	55.8	42.7	105.6	37.3	-21.1	98.1	266.1	986.8	582.4	250.8	25.9	30.2



DUNCAN (DCD)

DUNCAN RIVER | River Mile 8.3 | Drainage Area: 942 sq. mi

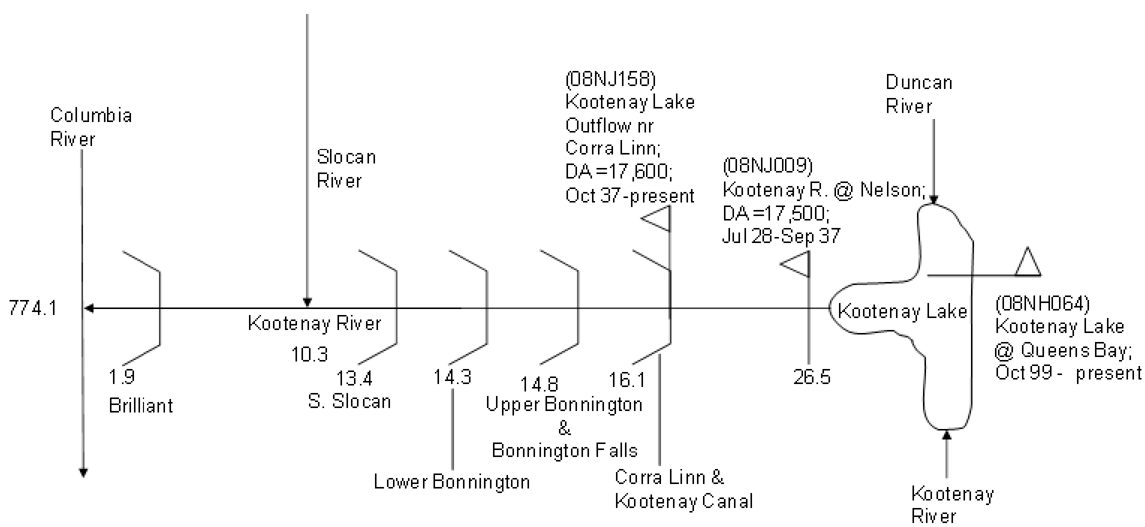
Site	Period	Source	Comments
DCD6H	07/01/1928 - 09/30/2008		Used data from previous 2010 Modified Flows
	10/01/2008 - 09/30/2018	BCHydro	
DCD6S	07/01/1928 - 09/30/2008		Used data from previous 2010 Modified Flows
	10/01/2008 09/30/2018		Project storage data provided by BCHydro
DCD6A	07/01/1928 - 09/30/2018	BCHydro	



CORRA LINN (COR)

KOOTENAY RIVER | River Mile 16 | Drainage Area: 17700 Sq. Mi.

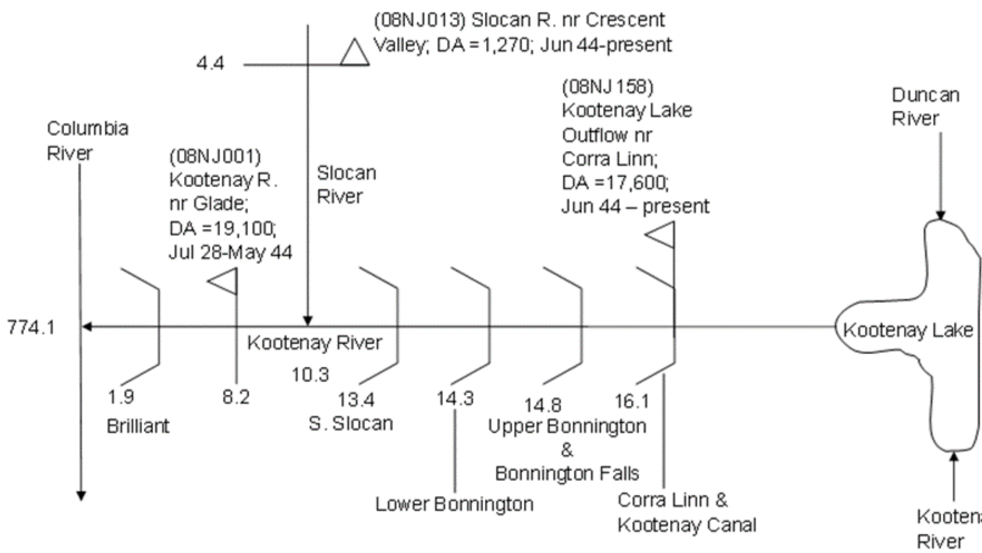
Site	Period	Source	Comments
COR6H	07/01/1928 - 09/30/1937	08NJ009	Observed flow of 08NJ009 Kootenay River at Nelson.
	10/01/1937 - 09/30/2018	08NJ158	Observed outflow from gage 08NJ158 Kootenay Lake near Corra Linn.
COR6S	10/01/1928 - 09/30/2008		Storage data used from 2010 Modified Flows
	10/01/2008 - 09/30/2018	BCHydro	
COR6ARF	07/01/1928 - 09/30/2018		COR_L + DCD_A + BFE_ARF (routed using SSARROUTE)
COR6A	07/01/1928 – 09/30/2018		COR_H + COR_S



SLOCAN BASIN (BRI)

KOOTENAI RIVER River Mile 2 Drainage Area: 19300 sq. mi.

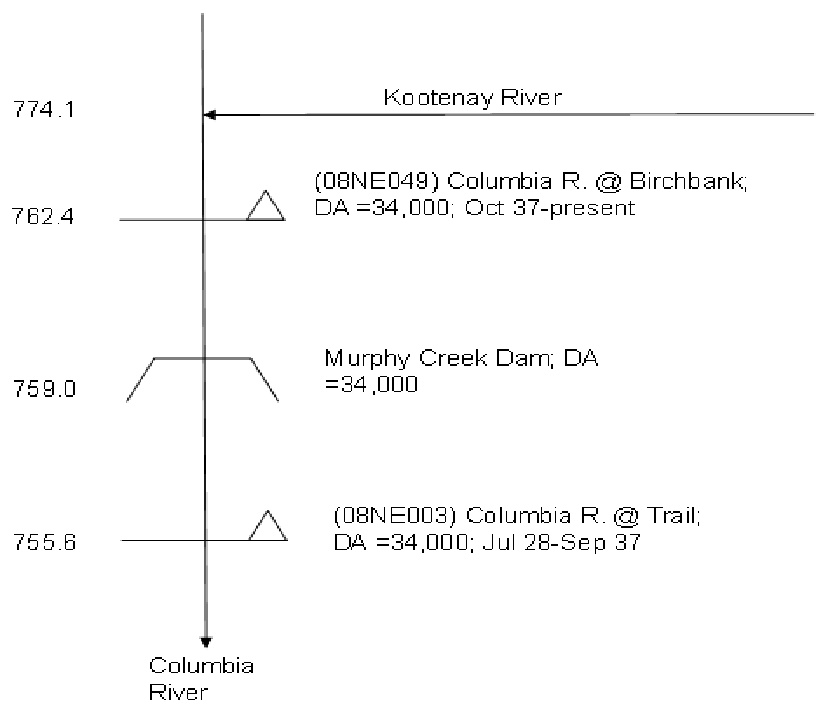
Site	Period	Source	Comments
BRI6H	07/01/1928 - 05/31/1944	08NJ001	Observed flow of 08NJ001 (Kootenay River near Glade)
	06/01/1944 - 09/30/2018	08NJ158 & 08NJ013	Observed flow of 08NJ158 Kootenay Lake outflow near Corra Linn plus observed flow of 08NJ013 Slocan River near Crescent Valley
BRI6L	07/01/1928 - 09/30/2018		BRI_H – routed COR_H (routed using SSARROUTE)
BRI6ARF	07/01/1928 - 09/30/2018		BRI_L + COR_ARF (COR routed using SSARROUTE and CHPS System)



MURPHY CREEK (MUC)

COLUMBIA RIVER River Mile 759 Drainage Area: 34000 sq. mi

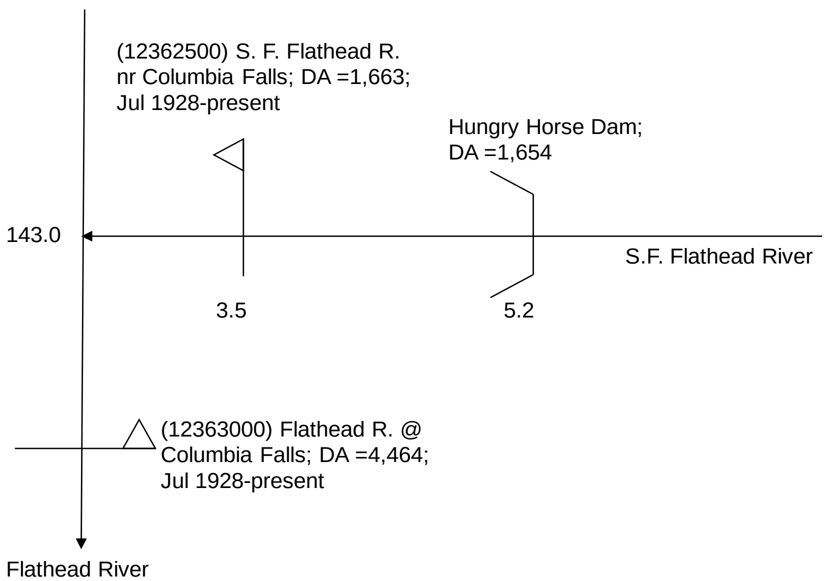
Site	Period	Source	Formula
MUC6H	07/01/1928 - 09/30/1937	08NE003	Observed flow of 08NE003 (Columbia River at Trail)
	10/01/1937 - 09/30/2018	08NE049	Observed flow of 08NE049 (Columbia River at Birchbank)
MUC6L			MUC_H – [routed(MCD_H + REV_L + REV_S + ARD_L + ARD_S) + routed BRI_H] Routing done using SSARROUTE. Refer to Sections 3.1.3 for more details.
MUC6ARF	07/01/1928 - 09/30/2018		MUC_L + routed ARD_ARF + routed BRI_ARF



HUNGRY HORSE (HGH)

SF FLATHEAD RIVER River Mile 5 Drainage Area: 1654 sq. mi

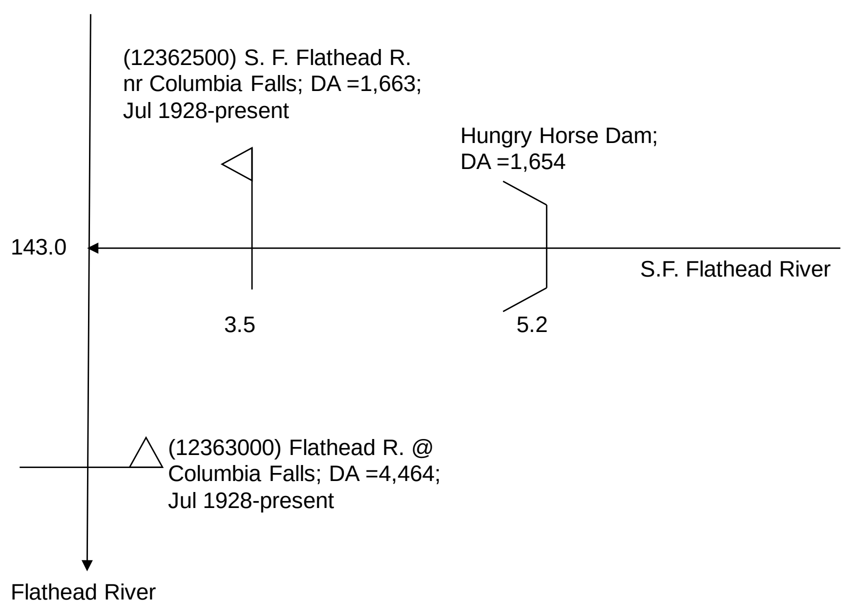
Site	Period	Source	Comments
HGH6H	07/01/1928 - 9/30/2018	USGS 12362500	Observed flows of 12362500 SF Flathead River near Columbia Falls.
HGH6S	09/21/1951 - 09/30/2008 10/01/2008 – 09/30/2018	USGS 12362000 USBR	Observed USGS 12362000 reservoir elevations and Capacity table from USACE. Reservoir storage provided.
HGH6A	07/01/1928 - 09/30/2018	HGH_H + HGH_S	Some revision of outflow and reservoir change of content required to obtain realistic Hungry Horse inflows and remove negative inflow readings.



COLUMBIA FALLS (CFM)

FLATHEAD RIVER River Mile 143 Drainage Area: 4464 sq. mi

Site	Period	Source	Comments
CFM6H	07/01/1928 - 09/30/2018	USGS 12363000	Observed flow of 12363000 Flathead River at Columbia Falls
CFM6L	7/01/1928- 09/30/2018	USGS 12363000 & HGH_H	USGS 12363000 (Flathead River at Columbia Falls, MT) minus HGH_H routed
CFM6ARF	07/01/1928 - 09/30/2018	CHPS	Unregulated flows derived by SSARR model

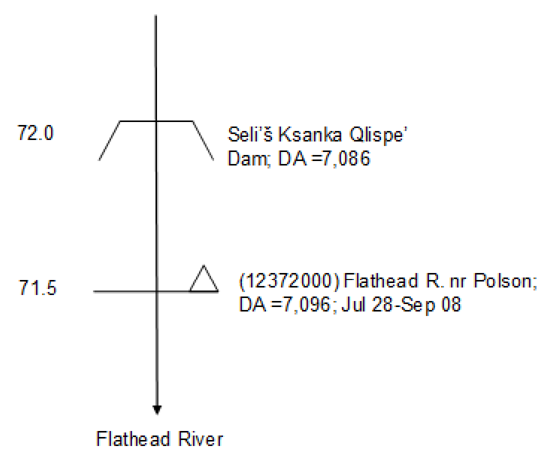


SELI'Š KASNKA QLISPE' (KER)

FLATHEAD RIVER | River Mile 72 | Drainage Area: 7086 sq. mi

Site	Period	Source	Comments
KER6H	07/01/1928 - 09/30/2018	USGS 12372000	Observed flow of 12372000 Flathead River near Polson, MT
KER6S[1]	07/01/1928 - 11/30/1928	USGS 12371550	Observed lake elevations and capacity table
	12/01/1928 - 01/31/1929	USACE Data query	Corps data base elevations and capacity table
	02/28/1929 - 09/30/1999	USGS 12371550	Observed lake elevations and capacity table
	10/01/1999 - 09/30/2008	USACE Data query	Corps database elevations and capacity table
	10/01/2008 - 09/30/2018	Energy Keepers	Observed storage submitted by Energy Keepers
KER6L	07/01/1928 - 09/30/2018	KER_A, CFM_H	KER_A minus CFM_H routed to Seli'š Ksanka Qlispe'. Index the resulting local to USGS 12370000. (Swan River near Big Fork, MT
KER6ARF	07/01/1928 - 09/30/2018	CHPS	Unregulated flows derived by SSARR model

Footnote 1 - Some revision of reservoir elevations and change of content required to obtain realistic Flathead Lake daily inflow.

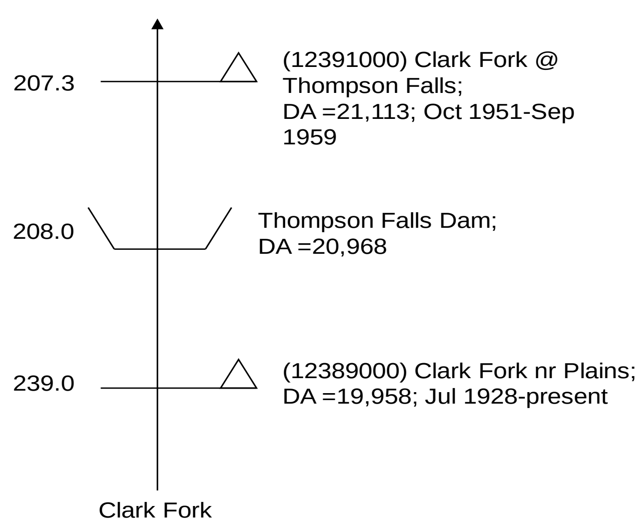


THOMPSON FALLS (TOM)

CLARK FORK RIVER | River Mile 208 | Drainage Area: 20,986 sq. mi

Site	Period	Source	Comments
TOM6H	07/01/1928 - 09/30/1951	USGS 12389000	(USGS 12389000 plus KER_S)*1.0405 minus KER_S
	10/01/1951 - 09/30/1959	USGS 12391000	Observed flow of 12391000 Clark Fork at Thompson Falls
	10/01/1959 - 09/30/1999	USGS 12389000	(USGS 12389000 plus KER_S)*1.0405 minus KER_S
	10/01/1999 - 09/30/2018	PPL / NW Energy	
TOM6S	07/01/1928 - 09/30/2008	2010 Modified Flows	
	10/01/2008 - 09/30/2018	PPL Montana	
TOM6L	07/01/1928 - 09/30/2018	TOM_A, KER_H	TOM_A minus KER_H routed to Thompson Falls. Index the resulting local to USGS 12370000 (Swan River near Bigfork, MT)
TOM6ARF[2]	07/01/1928 - 09/30/2018	CHPS	Unregulated flows derived by SSARR model.

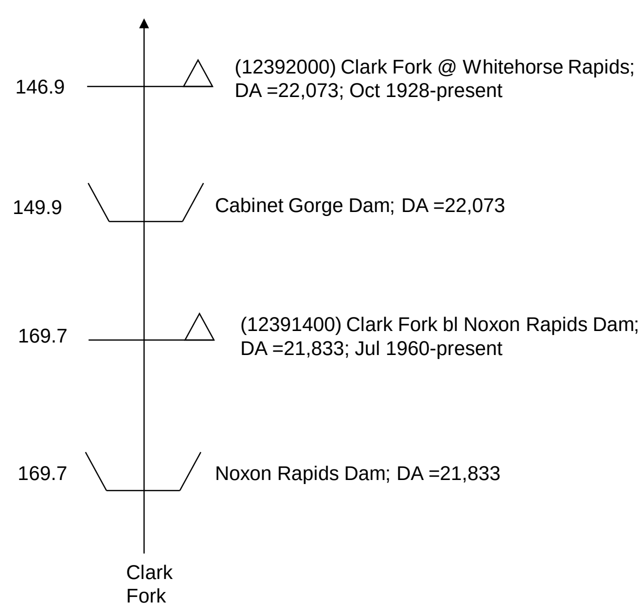
Footnote 2 – Factor of 1.0405 was based on ratio of volumetric adjusted runoff past the Plains and Thompson Falls gages during the concurrent period of record.



NOXON RAPIDS (NOX)

CLARK FORK RIVER River Mile 170 Drainage Area: 21,833 sq. mi

Site	Period	Source	Comments
NOX6H	07/01/1928 - 09/30/1928	USGS 12395500	Used 1990 monthly flow volume shaped to USGS 12395500 (Pend Oreille River at Newport, MT).
	10/01/1928 - 05/31/1960	USGS 12392000	Used 1990 monthly flow volume shaped to USGS 12392000 (Clark Fork at Whitehorse Rapids, MT).
	06/01/1960 - 09/30/2018	USGS 12391400	Used observed flow of 12391400 (Clark Fork below Noxon Rapids Dam).
NOX6S	04/01/1959 - 09/30/1999	USACE & Avista databases	Reservoir elevation data obtained from Avista and USACE data bases and capacity table.
	10/01/1999 - 09/30/2018	USACE Data query	Reservoir elevation data obtained from USACE database and capacity table.
NOX6L	07/01/1928 - 09/30/2018	NOX_A, TOM_H	NOX_A minus TOM_H routed to Noxon. Index the resulting local to USGS 12390700 (Prospect Creek at Thompson Falls, MT
NOX6ARF	07/01/1928 - 09/30/2018	CHPS	Unregulated flows derived by SSARR model



CABINET GORGE (CAB)

CLARK FORK RIVER River Mile 150 Drainage Area: 22,067 sq. mi

Site	Period	Source	Comments
CAB6H	07/01/1928 – 12/31/1986	USGS 12392000	Observed flow of 12392000 Clark Fork at Whitehorse Rapids minus 800 cfs to account for ground water inflow between stream gage and project site. [3]
	01/01/1986-09/30/2018	AVISTA	Obtained outflow from AVISTA
CAB6S	08/10/1952 - 09/30/2008	2010 Modified Flows	
	10/01/2008 - 09/30/2018	AVISTA	Obtained storage measurements from AVISTA
CAB6L	07/01/1928 - 09/30/2018	CAB_A, NOX_H	CAB_A minus NOX_H routed to Cabinet Gorge. Index the resulting local to USGS 12390700 (Prospect Creek at Thompson Falls, MT
CAB65ARF	07/01/1928 - 09/30/2018	CHPS	Unregulated flows derived by SSARR model

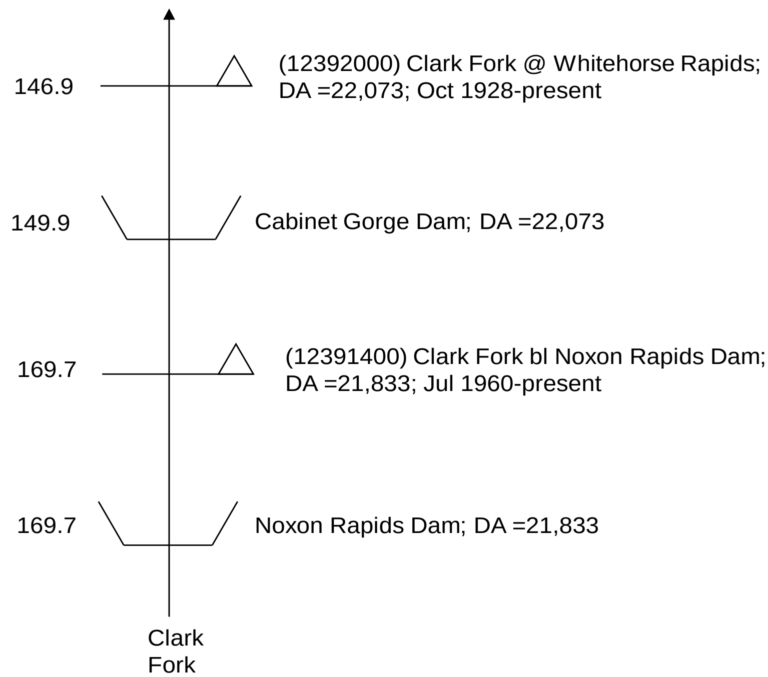
Footnote 3 – Estimation of missing streamflow for the Clark Fork River at Whitehorse Rapids.

Monthly linear regression coefficients for estimating 12392000 (Clark Fork R. at Whitehorse Rapids) from flow measured at 12389000 (Clark Fork R. near Plains):

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	-	-	-	-	-	-	1.11	1.08	1.08	-	-	-
b	-	-	-	-	-	-	492.	683.	118.	-	-	-

$Q1 = a*Q2 + b$

Periods Estimated	
Start Date	**End Date**
07/01/1928	09/30/1928


146.9
(12392000) Clark Fork @ Whitehorse Rapids; DA =22,073; Oct 1928-present
149.9
Cabinet Gorge Dam; DA =22,073
169.7
(12391400) Clark Fork bl Noxon Rapids Dam; DA =21,833; Jul 1960-present
169.7
Noxon Rapids Dam; DA =21,833
Clark Fork

PRIEST LAKE (PSL)

PRIEST RIVER River Mile 43 Drainage Area: 572 sq. mi

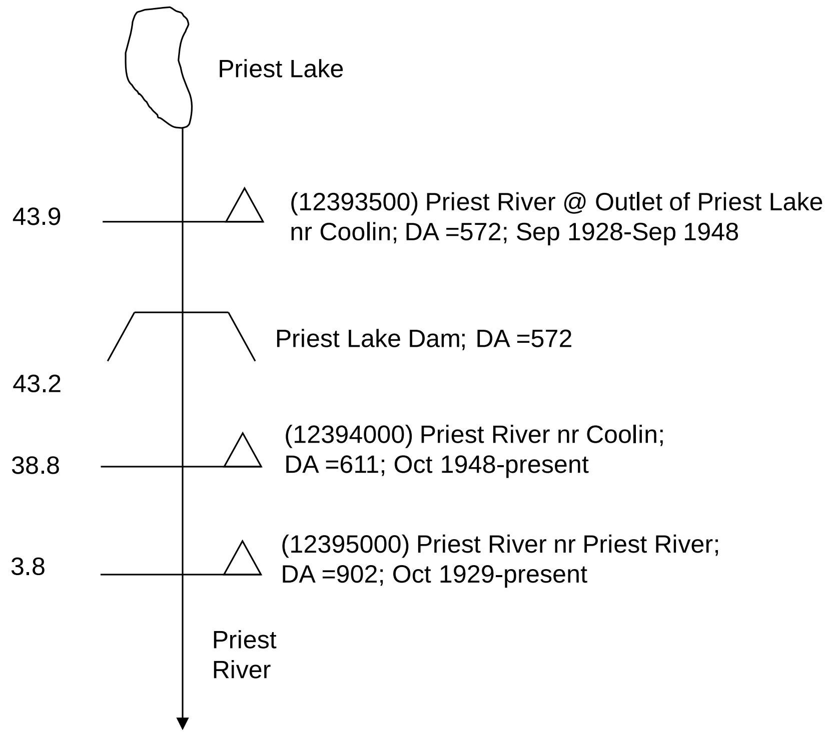
Site	Period	Source	Comments
PSL6H	07/01/1928 - 09/30/1948	USGS 12393500	Observed flow of 12393500 (Priest River at outlet of Priest Lake near Coolin, ID).
	10/01/1948 - 09/30/2006	USGS 12394000 USGS 12395000	Observed flow of 12394000 (Priest River near Coolin) minus 0.134 times [(12394000 (Priest R near Coolin) minus 12395000 (Priest R near Priest R)]
	10/01/2006 – 09/30/2018	USGS 12394000 & USGS 12395000 & USGS 12394000	Linear correlation between USGS 12394000 (Priest River near Coolin) and USGS 12395000 (Priest River near Priest River, ID) Then USGS 12394000 –[0.134 * USGS 12395000 – estimate of USGS 12394000)][4]
PSL6S	07/01/1928 – 09/30/1929	USGS 12393000	Used storage information from 2010 Modified Flows, which were based on USGS 12393000 reservoir elevation data paper records and PSL capacity table
	10/01/1929 - 09/30/2018	USGS 12393000	Observed USGS electronic reservoir elevation data and capacity table PSL datum of gage is 2434.64. Add the datum to gage height from 1239000 to get the latke elevation.
PSL6A	07/01/1928 - 09/30/1929	PSL_H + PSL_S	Used PSL_A time series form 2010 Modified Flows
	10/01/1929 - 09/30/2018		PSL_H + PSL_S

Footnote 4 – Estimation of missing streamflow for Priest River near Coolin.
The USGS gaging station on Priest River near Priest is used to estimate streamflow for Priest River near Coolin.

Monthly linear regression coefficients for estimating 12394000 (Priest River near Coolin) from 12394000 (Priest River near Priest) are:

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
a	0.94	0.85	0.71	0.65	0.57	0.57	0.62	0.77	0.87	0.89	0.83	0.93
b	-83.2	-54.3	-0.7	23.1	104.1	-14.9	-8.6	120.7	-94.6	-129.6	-80.6	-115

$Q1 = a*Q2 + b$

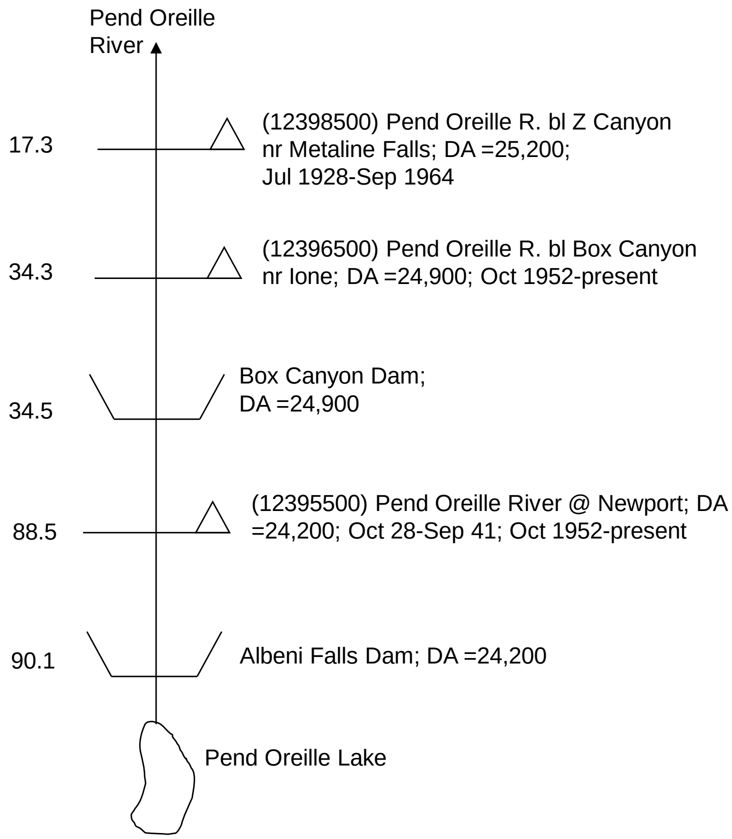

Priest Lake
43.9
(12393500) Priest River @ Outlet of Priest Lake nr Coolin; DA =572; Sep 1928-Sep 1948
Priest Lake Dam; DA =572
43.2
(12394000) Priest River nr Coolin; DA =611; Oct 1948-present
38.8
(12395000) Priest River nr Priest River; DA =902; Oct 1929-present
3.8
Priest River

ALBENI FALLS (ALF)

PEND OREILLE RIVER River Mile 90 Drainage Area: 24,200 sq. mi

Site	Period	Source	Comments
ALF6H	07/01/1928 - 09/30/1928	USGS 12398500	2010 Modified Flows monthly values shaped to 12398500 (Pend Oreille River below Z Canyon near Metaline Falls) to obtain daily values
	10/01/1928 - 09/30/1941	USGS 12395500	Observed flow of 12395500 (Pend Oreille River at Newport).
	10/01/1941 - 09/30/1952	USACE Data query	2010 Modified Flows. Project discharges determine by SSARR model regulation using Hope reservoir gage. USGS 12395500 is missing for this period
	10/01/1952 - 09/30/2018	USGS 12395500	Observed flow of 12395500 (Pend Oreille River at Newport).
ALF6S	07/01/1928 - 09/30/1929	USGS 12392500	Storage data from 2010 Modified Flows. Data not available in electronic form so USGS reservoir elevation data paper records were scanned and capacity table was used to obtain daily change of content.
	10/01/1929 - 09/30/2008	USGS 12392500	Reservoir elevation data and capacity table was used to obtain daily change of content.[5]
	10/01/2008 – 09/30/2018		USACE data submittal
ALF6A	07/01/1928 – 09/30/2008		ALF_H + ALF_S
	10/01/2008 – 09/30/2018		USACE data submittal
ALF6L	07/01/1928 - 09/30/2018	ALF_A, CAB_H, PSL_H	ALF_A minus (CAB_H + PSL_H) routed to Albeni Falls
ALF6ARF	07/01/1928 - 09/30/2018	CHPS	Unregulated daily flows derived by SSARR model

Footnote 5 - Data missing from 12/01/39-1/31/40 & 4/01/45-4/31/45 was obtained from USACE.


Pend Oreille
River
17.3
(12398500) Pend Oreille R. bl Z Canyon
nr Metaline Falls; DA =25,200;
Jul 1928-Sep 1964
34.3
(12396500) Pend Oreille R. bl Box Canyon
nr Ione; DA =24,900; Oct 1952-present
34.5
Box Canyon Dam;
DA =24,900
88.5
(12395500) Pend Oreille River @ Newport; DA
=24,200; Oct 28-Sep 41; Oct 1952-present
90.1
Albeni Falls Dam; DA =24,200
Pend Oreille Lake

BOX CANYON (BOX)

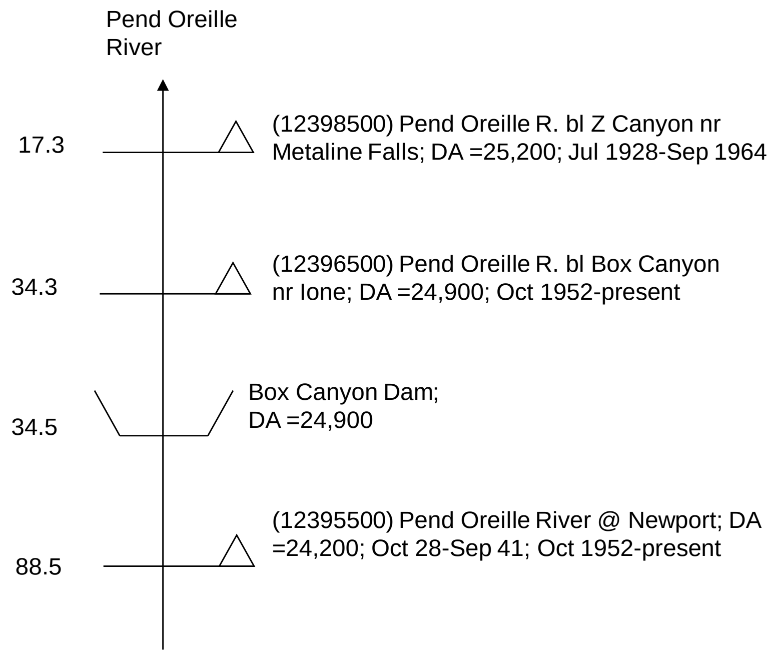
PEND OREILLE RIVER River Mile 35 Drainage Area: 24,900 sq. mi

Site	Period	Source	Comments
BOX6H	07/01/1928 – 09/30/1928	USGS 12389000 & USGS 12395500	(USGS 1238900 + 12395500) / 2.0 Average of USGS 12389000 (Pend Oreille River below Z Canyon) and USGS 12395500 (Pend Oreille River at Newport) Missing data estimated with Footnote 6
	10/01/1928 – 09/30/1941	USGS 12389000 & USGS 12395500	(USGS 1238900 + 12395500) / 2.0 Average of USGS 12389000 (Pend Oreille River below Z Canyon) and USGS 12395500 (Pend Oreille River at Newport)
	10/01/1941 - 09/30/1952	USGS 12395500	(USGS 1238900 + 12395500) / 2.0 Average of USGS 12389000 (Pend Oreille River below Z Canyon) and USGS 12395500 (Pend Oreille River at Newport). Missing data estimated with Footnote 6
	10/01/1952 - 09/30/2018	USGS 12396500	Observed flow of USGS 12396500 (Pend Oreille R below Box Canyon)
BOX6F	06/11/55 - 06/12/55		Initial fill of Box Canyon
BOX6S	06/12/1955 - 09/30/2008	2010 Modified Flows	
	10/01/1999 - 09/30/2018	USACE Data query	Storage data was available and corrected via indexing.
BOX6L	07/01/1928- 09/30/1999	2010 Modified Flow Study	
	10/01/1999- 09/30/2018	BDY_A, ALF_H	BDY_A minus ALF_H routed to Boundary multiplied by 0.7. Index the resulting local to USGS 12395000 (Priest River near Priest River, ID)
BOX6ARF	07/01/28 - 09/30/2018	CHPS	Unregulated flows derived by SSARR model

Footnote 6 – Estimation of missing streamflow for the Pend Oreille River below Z Canyon. Monthly linear regression coefficients for estimating 12398500 (Pend Oreille River below Z Canyon) from 12395500 (Pend Oreille River at Newport):

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
a	0.95	0.95	0.93	0.93	0.92	0.91	0.95	0.96	0.98	0.92	0.92	1.01
b	115	120	115	124	80	253	-494	340	-1889	184	90	-514

Q1 = a*Q2 + b


Pend Oreille
River
17.3
(12398500) Pend Oreille R. bl Z Canyon nr
Metaline Falls; DA =25,200; Jul 1928-Sep 1964
34.3
(12396500) Pend Oreille R. bl Box Canyon
nr Ione; DA =24,900; Oct 1952-present
34.5
Box Canyon Dam;
DA =24,900
88.5
(12395500) Pend Oreille River @ Newport; DA
=24,200; Oct 28-Sep 41; Oct 1952-present

BOUNDARY (BDY)

PEND OREILLE RIVER River Mile 17 Drainage Area: 25,200 sq. mi

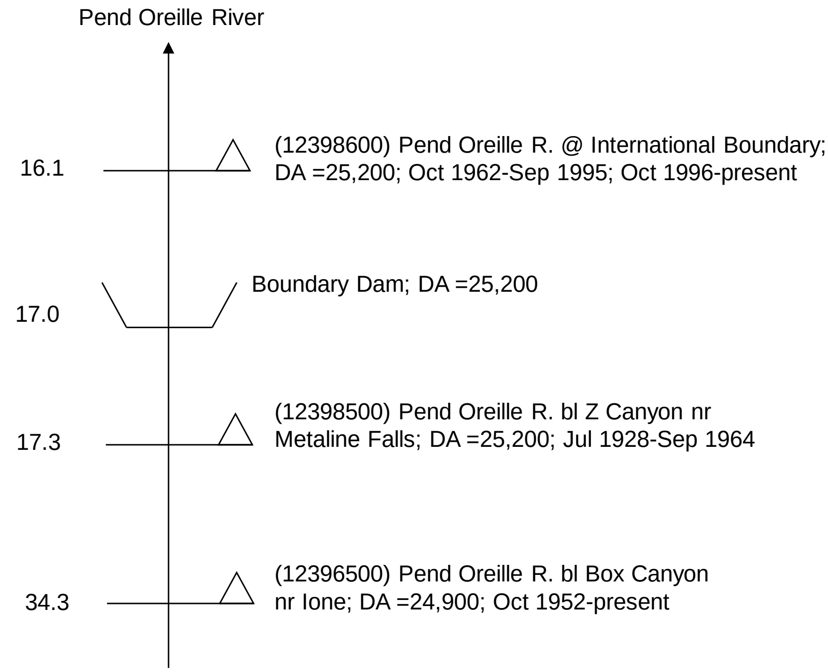
Site	Period	Source	Comments
BDY6H	07/01/1928 - 09/30/1964	USGS 12398500	Observed flows of 12398500 (Pend Oreille R below Z Canyon near Metaline Falls
	10/01/1964 – 09/30/1995	USGS 12398600	Observed flows of 12398600 (Pend Oreille River at International Boundary)
	10/01/1995 – 09/30/1996	USGS 12398600 & USGS 12396500	Linear relationship developed between USGS 12398600 (Pend Oreille River at International Boundary) and USGS 12396500 (Pend Oreille Below Box Canyon) [7]
	10/01/1996 - 09/30/2018	USGS 12398600	Observed flows of 12398600 (Pend Oreille River at International Boundary)
BDY6S	10/01/1999 - 09/30/2008	USACE Data query	Storage data was available and corrected via indexing
BDY6F	07/01/1967 - 08/19/1967		Boundary Initial Fill
BDY6L	07/01/1928-09/30/1999	2010 Modified Flow Study	
	10/01/1999-09/30/2018	BDY_A, ALF_H	BDY_A minus ALF_H routed to Boundary multiplied by 0.3. Index the resulting local to USGS 12395000 (Priest River near Priest River, ID)
BDY56RF	07/01/1928 - 09/30/2018	CHPS	Unregulated daily flows derived by SSARR model

Footnote 7 – Estimation of missing streamflow for the Pend Oreille River at International Boundary.

Monthly linear regression coefficients for estimating 12398600 (Pend Oreille River at International Boundary) from 12396500 (Pend Oreille below Box Canyon:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	0.99	1.04	0.99	0.98	1.01	1.01	0.98	1.02	1.02	1.01	0.99	1.01
b	485	-469	370	423	-46	267	951	371	-49	98	219	-78

$Q1 = a*Q2 + b$


Pend Oreille River
16.1
(12398600) Pend Oreille R. @ International Boundary;
DA =25,200; Oct 1962-Sep 1995; Oct 1996-present
Boundary Dam; DA =25,200
17.0
17.3
(12398500) Pend Oreille R. bl Z Canyon nr
Metaline Falls; DA =25,200; Jul 1928-Sep 1964
34.3
(12396500) Pend Oreille R. bl Box Canyon
nr Ione; DA =24,900; Oct 1952-present

SEVEN MILE (SEV)

PEND O'REILLE RIVER River Mile 6 Drainage Area: 25,700 sq. mi

Site	Period	Source	Comments
SEV6H	07/01/1928 - 09/30/1928	2010 Modified Flows	
	10/01/1928 – 03/31/1936	USGS 12398500 & 08NE044 & SEV_S	USGS 12398500 (Pend Oreille River below Z Canyon near Metaline Falls + estimated 08NE044 (Salmo River near Waneta- Storage at SEV[8]
	04/01/1936 - 09/30/1946	USGS 12398500 & 08NE044 & SEV_S	Observed flow of 12398500 (Pend Oreille R below Z Canyon near Metaline Falls) plus observed flow of 08NE044 (Salmo R near Waneta)[8] minus change in storage data from BCHydro
	10/01/1946 – 02/28/1949		USGS 12398500 (Pend Oreille River below Z Canyon near Metaline Falls + estimated 08NE044 (Salmo River near Waneta - Storage at SEV[8]
	03/01/1949 - 09/30/1964	USGS 12398500 & 08NE074	Observed flow of 12398500 (Pend Oreille R below Z Canyon near Metaline Falls) plus observed flow of 08NE074 (Salmo River near Salmo) minus change in storage data from BCHydro
	10/01/1964 - 09/30/1995	USGS 12398600 & 08NE074	Observed flow of 12398600 (Pend Oreille River at International Boundary)[8] plus observed flow of 08NE074 (Salmo River near Salmo) minus change in storage data from BCHydro
	10/01/1995 – 09/30/1996	08NE074 & USGSG12398600	Observed flow of 08NE074 (Salmo River near Salmo) + estimated flow for 12398600 (Pend Oreille River at International Boundary – SEV_S[9]
	10/01/1996 - 09/30/2008	USGS 12398600 & 08NE074	Observed flow of 12398600 (Pend Oreille River at International Boundary) plus observed flow of 08NE074 (Salmo River near Salmo) minus change in storage data from BCHydro
	10/01/2008 – 09/30/2018	BCHydro	BCHydro provided Seven Mile reservoir outflow data
SEV6S	12/11/1979 - 09/30/2018	BCHydro	BCHydro provided Seven Mile reservoir elevations and storage capacity formula
SEV6ARF	07/01/1928 - 09/30/2018	CHPS	Unregulated daily flows derived by SSARR model

Footnote 8 – Estimation of missing streamflow for the Salmo River near Waneta.
No nearby locations were available to estimate streamflow for the Salmo River between Jul 1928 and Sep 1928, so values were set to the monthly average flows of: Jul=2124 cfs, Aug=274 cfs, Sep = 267 cfs.

After October 1, 1928 a USGS gaging station established on the Kettle River is used to estimate Salmo River streamflow. Monthly linear regression coefficients for estimating 08NE044 (Salmo R near Waneta) from 12401500 is the Kettle River near Ferry, Washington:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	0.807	1.19	0.79	0.39	0.44	0.63	0.51	0.40	039	0.52	0.76	1.16
b	112.	38.8	183.	848.	1190.	61.5	220.	150.	134.	121.	145.	62.0

Q1 = a*Q2 + b

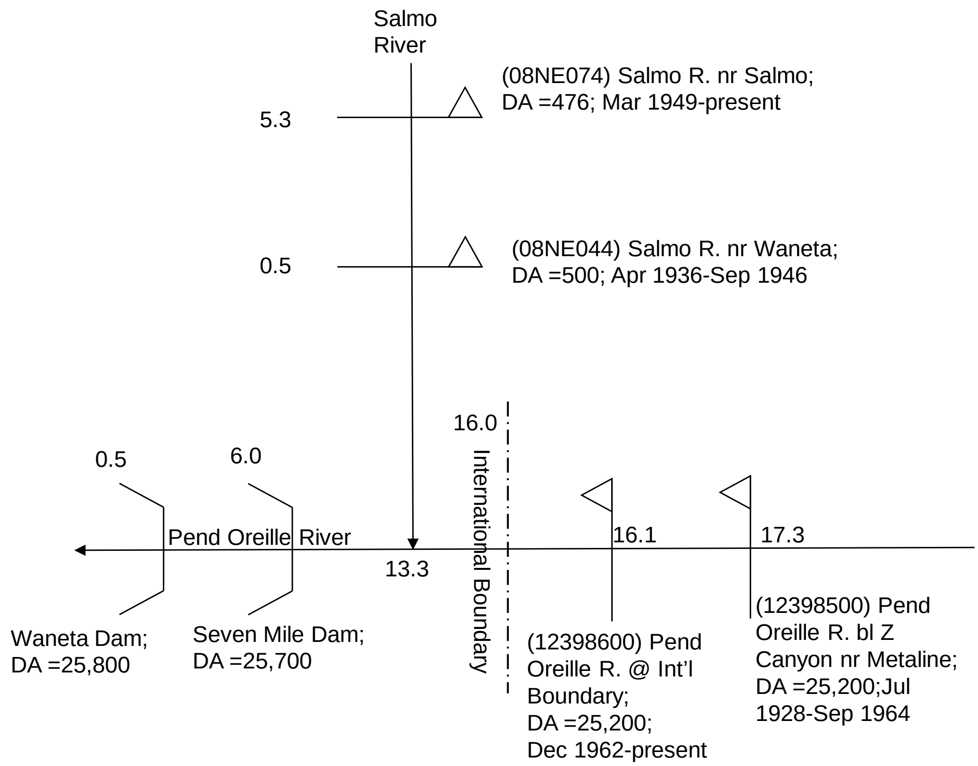
Periods Estimated	
Start Date	**End Date**
10/01/1928	03/30/1936
10/01/1946	02/28/1949

Footnote 9 – Estimation of missing streamflow for the Pend Oreille River at International Boundary.
The USGS gaging station on the Pend Oreille River below Box Canyon is used to estimate streamflow at International Boundary. Monthly linear regression coefficients for estimating 12399500 (Pend Oreille R. at International Boundary) from 12396500 (Pend Oreille R below Box Canyon near Ione) are:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	0.98	1.01	1.00	0.98	1.02	1.02	1.01	0.99	1.01	0.99	1.04	0.99
b	423.	-46.2	267.	951.	371.	-48.9	98.4	219.	-77.7	485.	-469.	370.

Q1 = a*Q2 + b

Periods Estimated	
Start Date	**End Date**
10/01/1995	09/30/1996



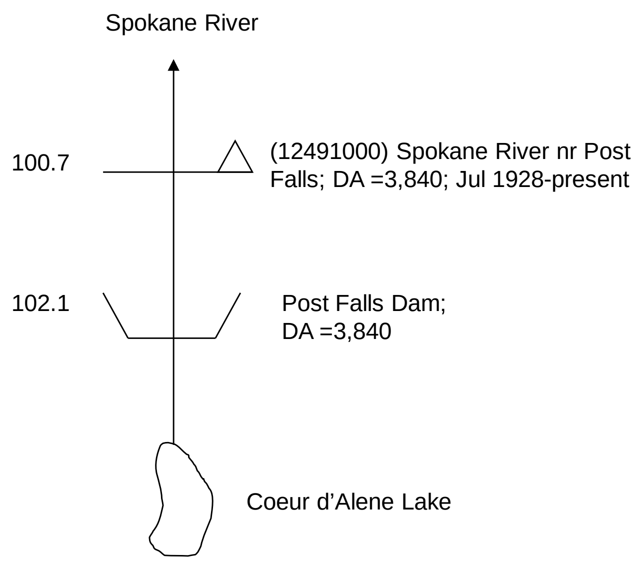
Salmo
River
(08NE074) Salmo R. nr Salmo;
DA =476; Mar 1949-present
5.3
(08NE044) Salmo R. nr Waneta;
DA =500; Apr 1936-Sep 1946
0.5
16.0
0.5
6.0
International Boundary
Pend Oreille River
16.1
17.3
13.3
Waneta Dam;
DA =25,800
Seven Mile Dam;
DA =25,700
(12398600) Pend
Oreille R. @ Int'l
Boundary;
DA =25,200;
Dec 1962-present
(12398500) Pend
Oreille R. bl Z
Canyon nr Metaline;
DA =25,200;Jul
1928-Sep 1964

COEUR D'ALENE (COE)

SPOKANE RIVER | River Mile 102 | Drainage Area: 3840 sq. mi

Site	Period	Source	Comments
COE6H	07/01/1928 - 09/30/2018	USGS 12419000	Observed flow of 12419000 (Spokane River near Post Falls)
COE6S	07/01/1928 - 09/30/2018	USGS 12415500	Observed USGS 1215500 reservoir elevations and capacity table from 2010 Modified Flows[10]
COE6A	07/01/1928 - 09/30/2018	COE_H + COE_S	

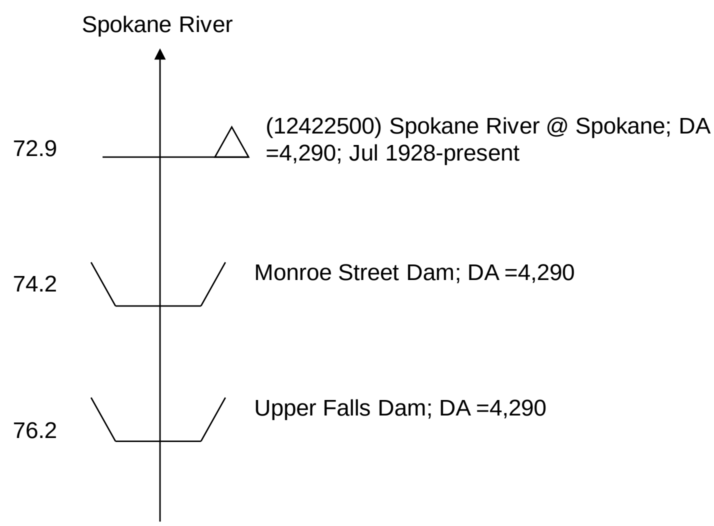
Footnote 10 – Smoothing of Coeur D'Alene reservoir storage data.
Between July 1st and October 7th the change in storage values are smoothed using a 7 day moving average. This is necessary because reservoir storage fluctuations during the summer low inflow period causes numerous erroneous negative inflow spikes.



UPPER FALLS (UPF)
MONROE STREET (MON)

SPOKANE RIVER River Mile 76 Drainage Area: 4290 sq. mi
SPOKANE RIVER River Mile 74 Drainage Area: 4290 sq. mi

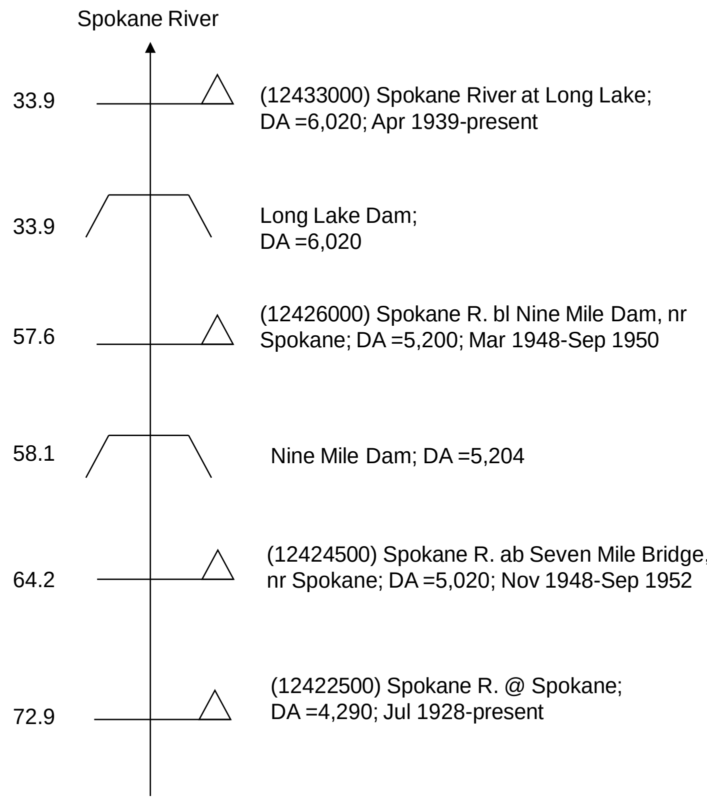
Site	Period	Source	Comments
UPF6H	07/01/1928 - 09/30/2018	USGS 12422500	Observed flow of 12422500 Spokane River at Spokane
UPF6ARF	07/01/1928 - 09/30/2018	CHPS	Unregulated flows derived by SSARR model



NINE MILE (NIN)

SPOKANE RIVER River Mile 58.1 Drainage Area: 5204 sq. mi

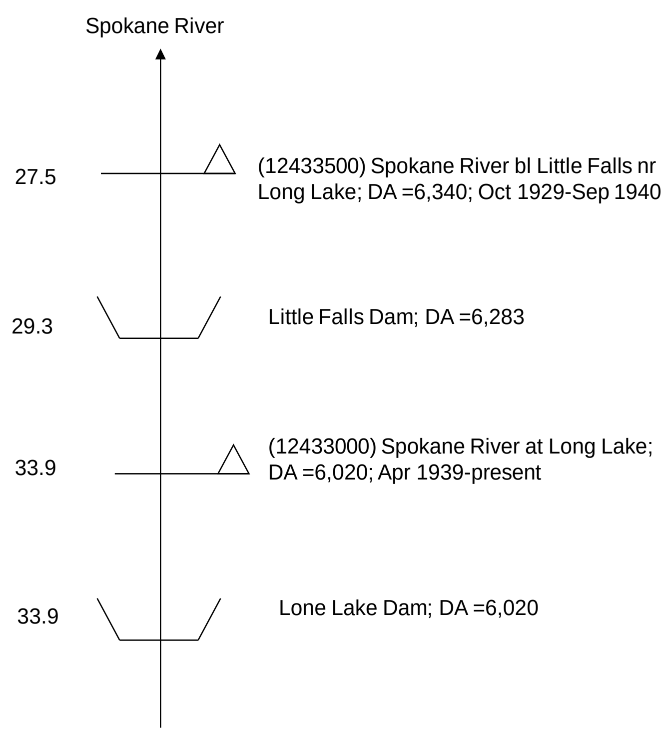
Site	Period	Source	Comments
NIN6H	07/01/1928 - 03/31/1939	USGS 12422500 12433500 LLK6S	Average of 12422500 (Spokane River at Spokane) and 12433500 (Spokane River below Little Falls near Long Lake) plus change of content of Long Lake
	04/01/1939 - 03/01/1948	USGS 12422500 12433500 LLK6S	Average of 12422500 (Spokane River at Spokane) and 12433000 (Spokane River at Long Lake) plus change of content of Long Lake
	03/01/1948 - 09/30/1950	USGS 12426000	Observed flow of 1242600 (Spokane R. below Nine Mile Dam, near Spokane).
	10/01/1950 - 09/29/1952	USGS 12424500	Observed flow of 12424500 (Spokane R. above Seven Mile Bridge, near Spokane).
	09/30/1952 - 09/30/2018	USGS 12422500 12433000 LLK6S	Average of 12422500 (Spokane River at Spokane) and 12433000 (Spokane River at Long Lake) plus change of content of Long Lake
LLK6S	07/01/1928 - 09/30/1977	2010 Modified Flows	Semi-monthly values used as daily values because daily data was not available
	10/01/1977 - 09/30/0201	USGS 12432500	Reservoir elevations USGS 12432500 and capacity table from 2010 Modified Flows
NIN6ARF	07/01/1928 - 09/30/2018	CHPS	Unregulated flows derived by SSARR model


Spokane River
33.9
(12433000) Spokane River at Long Lake; DA =6,020; Apr 1939-present
33.9
Long Lake Dam; DA =6,020
57.6
(12426000) Spokane R. bl Nine Mile Dam, nr Spokane; DA =5,200; Mar 1948-Sep 1950
58.1
Nine Mile Dam; DA =5,204
64.2
(12424500) Spokane R. ab Seven Mile Bridge, nr Spokane; DA =5,020; Nov 1948-Sep 1952
72.9
(12422500) Spokane R. @ Spokane; DA =4,290; Jul 1928-present

LONG LAKE (LLK)
LITTLE FALLS (LFL)

SPOKANE RIVER River Mile 34 Drainage Area: 6020 sq. mi
SPOKANE RIVER River Mile 29 Drainage Area: 6283 sq. mi

Site	Period	Source	Comments
LLK6H	07/01/1928 - 03/30/1939	USGS 12433500	Observed flow of 12433500 (Spokane River below Little Falls, near Long Lake)
	04/01/1939 - 09/30/2018	USGS 12433000	Observed flow of 12433000 (Spokane River at Long Lake)
LLK6S	07/01/1928 - 09/30/1977	1990 Modified Flows	Used bi-monthly values from 1990 Modified Flows because daily reservoir elevations were not available
	10/01/1977 - 09/30/2018	USGS 12432500	Observed daily reservoir elevations and capacity table from 2010 Modified Flows
LLK6A	07/01/28 - 09/30/08	LLK_H + LLK_S	
LLK6ARF	07/01/28 - 09/30/2018	CHPS	Unregulated daily flows derived by SSARR model

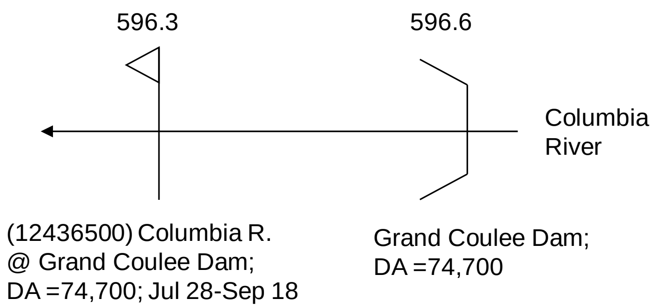


Mid-Columbia Basin (Section 3.3)

GRAND COULEE (GCL)

COLUMBIA RIVER | River Mile 597 | Drainage Area: 74700 Sq. Mi.

Site	Period	Source	Comments
GCL6H	07/01/1928 - 09/30/2008	USGS 12436500	Observed flow of USGS 12436500 (Columbia River at Grand Coulee dam)
	10/01/2008 - 09/30/2018	USBR	Submitted flows
GCL6S	05/01/1938 - 09/30/2008	2010 Modified Flows	
	10/01/2008 - 9/30/2018	USBR	Submitted Elevation Data
GCL6A	07/01/1928 - 9/30/2018	CHPS	GCL6H + GCL6S + FDR6P + FDR6G
GCL6L	07/01/1928 - 9/30/2018	CHPS	GCL6A - CIB6H (routed) - LLK6H + CIB6L then indexed to USGS 12409000 (07/01/1928 - 08/30/1929) and USGS 12404500 (09/01/1929 - 10/01/2018)
GCL6ARF	07/01/1928 - 09/30/2018	CHPS	CIB6ARF (routed) + LLK6ARF + GCL6L



GRAND COULEE PUMP and GENERATION (FDR)

COLUMBIA RIVER River Mile 597 Drainage Area: 74700 Sq. Mi.

Site	Period	Source	Comments
FDR6P	05/01/1951 – 09/30/2008	2010 Modified Flows	
	10/01/2008 – 10/01/2018	USGS 12435500	Observed positive flow of USGS 12435500 (Feeder Canal at Grand Coulee, WA)
FDR6G	05/01/1952 - 09/30/2008	2010 Modified Flows	
	10/01/2008 – 10/01/2018	USGS 12435500	Observed negative flow of USGS 12435500 (Feeder Canal at Grand Coulee, WA)

CHIEF JOSEPH (CHJ)

COLUMBIA RIVER | River Mile 545 | Drainage Area: 75400 Sq. Mi.

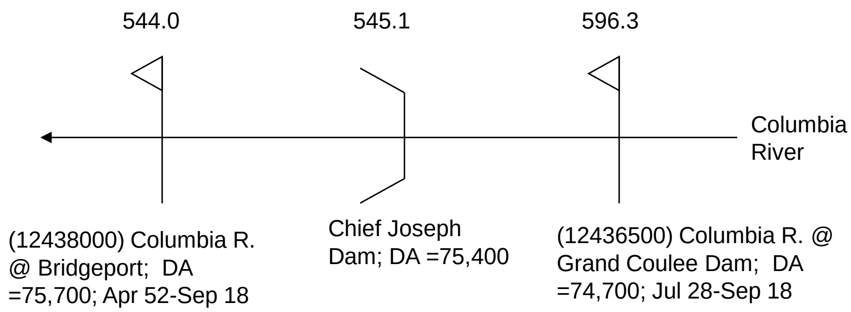
Site	Period	Source	Comments
CHJ6H	07/01/1928 - 03/31/1952	USGS 12436500	Observed flow of USGS 12436500 (Columbia River at Grand Coulee Dam).
	04/01/1952 - 09/30/2018	USGS 12438000	Observed flow of USGS 12438000 (Columbia River at Bridgeport).
CHJ6S	11/01/1954 – 09/30/2008	2010 Modified Flows	
	10/01/2008 – 10/01/2018	USACE	Submitted Elevation Data
CHJ6L	04/01/1952 - 10/01/2018	CHPS	CHJ6A - GCL6H (routed) then indexed to USGS 12449500B[1] (07/01/1928 - 09/30/1928) and USGS 12442500 (10/01/1928 - 10/01/2018)
Okanogan R. 12449500B[1]		CHPS	Linear correlation of USGS 12445000 and USGS 12449500 with daily shape of USGS 12449500
CHJ6A	07/01/1928 - 09/30/2018	CHPS	CHJ6H + CHJ6S
CHJ6ARF	07/01/1928 - 09/30/2018	CHPS	CHJ6L + GCL6ARF (routed)

Footnote 1 – Estimation of missing streamflow record for the Okanogan River near Tonasket, WA (USGS 12445000).

While there are no gaged tributaries between Grand Coulee Dam and Chief Joseph Dam there are multiple small channels that when combined produce a measureable increase in flow to the Columbia River. The difference between the inflow at Chief Joseph and the routed outflow from Grand Coulee is then indexed to the nearest long term gaged sidestream the Similkameen River near Nighthawk, WA (USGS 1242500)

Monthly linear regression coefficients for estimating the Okanogan River neat Tonasket (USGS 12445000 from the Methow River at Twisp (USGS 12449500):

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
a	1.67	2.06	2.98	2.53	2.727	1.48	1.44	1.34	1.58	1.76	2.55	2.76
b	583.1	519.2	153.2	375.8	354.2	699.0	555.0	2282.2	1425.8	565.4	120.4	227.3


544.0
545.1
596.3
Columbia River
(12438000) Columbia R. @ Bridgeport; DA =75,700; Apr 52-Sep 18
Chief Joseph Dam; DA =75,400
(12436500) Columbia R. @ Grand Coulee Dam; DA =74,700; Jul 28-Sep 18

WELLS (WEL)

COLUMBIA RIVER River Mile 515.8 Drainage Area: 86100 Sq. Mi.

Site	Period	Source	Comments
WEL6H	07/01/1928 - 09/30/2018	CHPS	WEL6A - WEL6S
WEL6S	05/01/1967 - 09/30/2008	2010 Modified Flows	
	10/01/2008 – 10/01/2018	USACE	Submitted Elevation Data
WEL6L	07/01/1928 - 10/01/2018	CHPS	Local flows calculated as the sum of major side streams the Okanogan[2] and the Methow[3] rivers. Calculations for each stream are outlined below.
Okanogan[2] River	07/01/1928 - 09/30/1928	USGS 12445000	Linear correlation of USGS 12449500 with USGS 12445000 with daily shape of USGS 12445000.
	10/01/1928 - 04/30/1929	USGS 12442500	Observed flow of USGS 12442500 (Silmilkameen River near Nighthawk)
	05/01/1929 - 10/01/2018	USGS 12445000	Observed flow of USGS 12445000 (Okanogan River near Tonasket)
Methow[3] River	07/01/1928 - 09/28/1928	USGS 12449500	Observed flow of USGS 12449950 (Methow River at Twisp)
	09/29/1928 - 09/30/1933	USGS 12449950	Linear correlation of USGS 12451000 with USGS 12449950 with daily shape of USGS 12449950.
	10/01/1933 - 03/31/1959	USGS 12449500	Observed flow of USGS 12449500 (Methow River at Twisp)
	04/01/1959 - 10/01/2018	USGS 12449950	Observed flow of USGS 12449950 (Methow River near Pateros)
WEL6A	07/01/1928 - 09/30/2018	CHPS	WEL6L + CHJ6H (routed)
WEL6ARF	07/01/1929 - 10/01/2018	CHPS	WEL6L + CHJ6ARF (routed)

Footnote 2 – Estimation of missing streamflow record for the Okanogan River near Tonasket, WA (USGS 12445000).

The earliest gage on the Okanogan River starts in May 1929 near Tonasket (USGS 12445000). However, a major tributary to the Okanogan river, the Similkameen River near Nighthawk, WA (USGS 12442500) is gaged from Oct 1928. The time period from July 1928 until Oct 1928 is estimated from the Methow River at Twisp (USGS 12449500).

Monthly linear regression coefficients for estimating the Okanogan River near Tonasket (USGS 12445000) from the Methow River at Twisp (USGS 12449500):

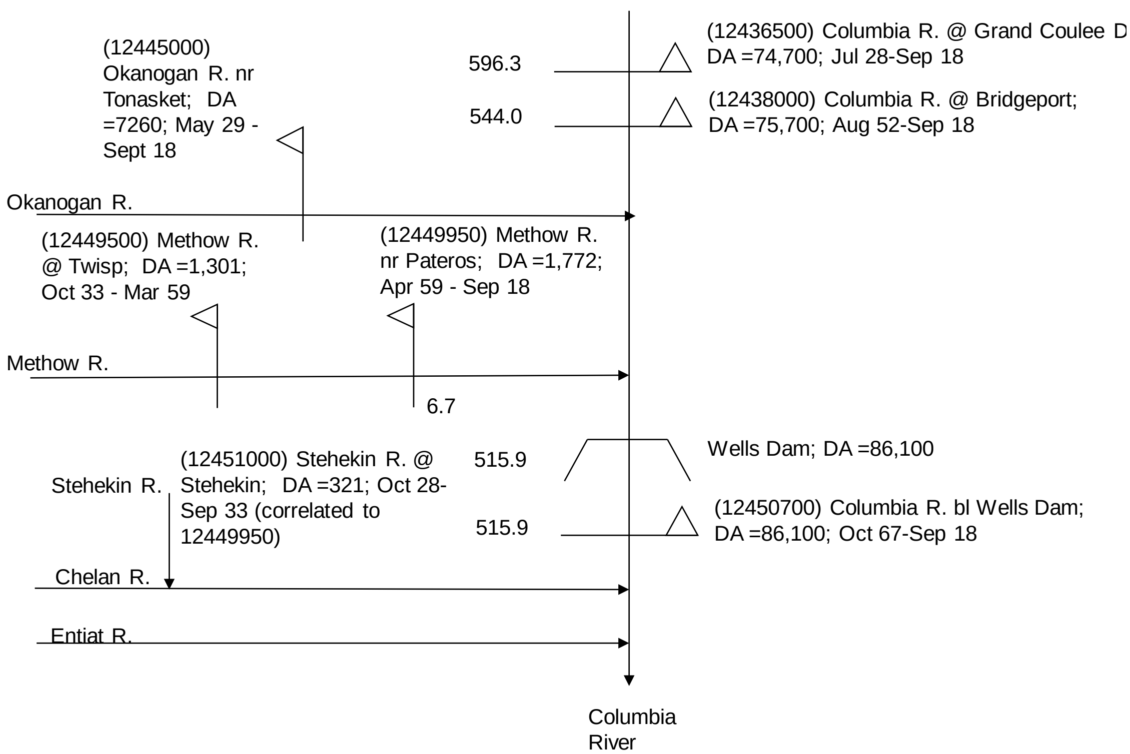
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
a	1.63	2.06	2.98	2.53	2.73	1.48	1.44	1.34	1.58	1.76	2.55	2.76
b	583.3	519.2	153.2	375.8	354.2	69.90	555.0	2282.2	1425.8	565.4	120.4	227.3

Footnote 3 – Estimation of missing streamflow record for the Methow River at Twisp, WA (USGS 12449500).

The gage at the Methow River at Twisp (USGS 12449950) has a 5-year gap from Oct 1928 – Sept 1933. This time period was estimated using the nearby Stehekin River at Stehekin, WA (USGS 12451000).

Monthly linear regression coefficients for estimating the Methow River at Twisp (USGS 12449500) from the Stehekin River at Stehekin (USGS 12451000):

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
a	0.26	0.23	0.35	0.26	0.39	0.86	1.28	1.55	1.54	0.94	0.54	0.35
b	326.0	389.3	300.3	309.3	257.5	116.3	-61.9	-220.9	-752.2	-420.7	-12.3	194.1



CHELAN (CHL)

CHELAN RIVER River Mile 4 Drainage Area: 924 Sq. Mi.

Site	Period	Source	Comments
CHL5H	07/01/1928 - 09/30/2018	USGS 12452500	Observed flow of USGS 12452500 (Chelan River at Chelan)
CHL5S	07/01/1928 - 09/30/2008	2010 Modified Flows	
	10/01/2008 - 10/01/2018	USACE	Submitted elevation data
CHL5A	07/01/1928 - 09/30/2018	CHPS	CHL6H + CHL6S then indexed to USGS 12451000 (Stehekin River at Stehekin)

ROCKY REACH (RRH)

COLUMBIA RIVER | River Mile 474 | Drainage Area: 87800 Sq. Mi.

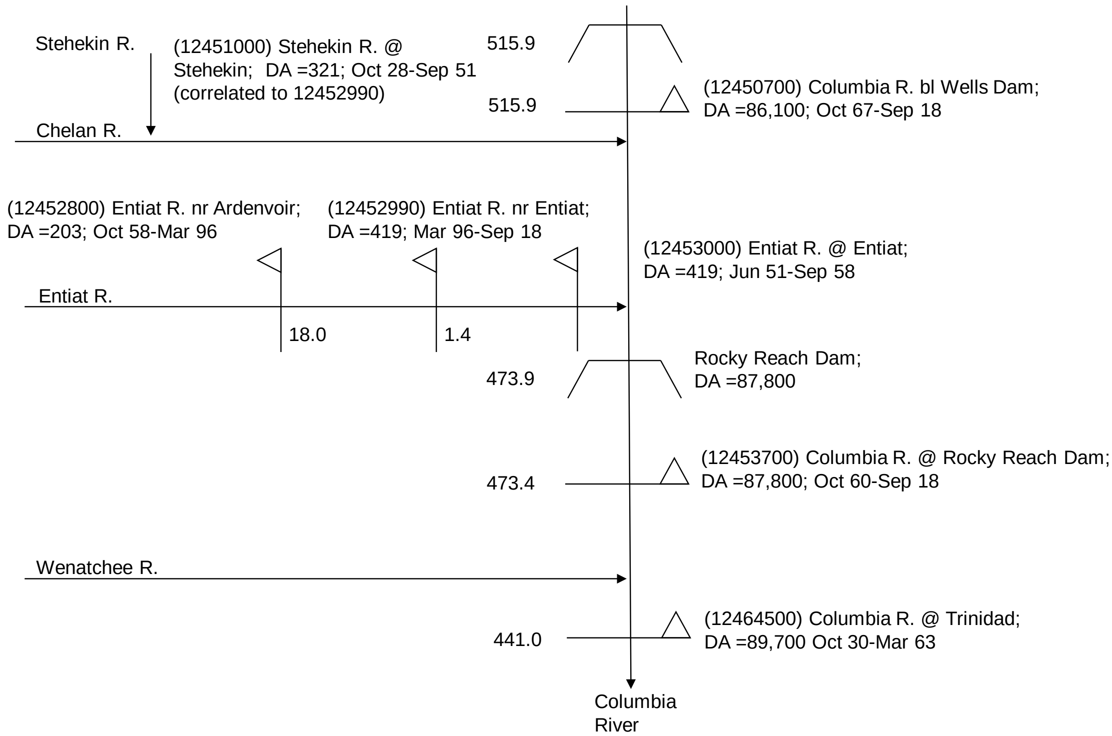
Site	Period	Source	Comments
RRH6H	07/01/1928 - 03/31/2018	CHPS	RRH6A - RRH6S
RRH6A	07/01/1928 - 03/31/2018	CHPS	WEL6H (routed) + CHL6H + RRH6L
RRH6S	07/01/1961 - 09/30/2008	2010 Modified Flows	
	10/01/2008 - 10/01/2018	USACE	Submitted Elevation Data
RRH6L	07/01/1928 - 09/30/1951	USGS 12451000[4]	Linear correlation of USGS 12451000 with USGS 12452990 with daily shape of USGS 12452990
	10/01/1951 - 09/30/1958	USGS 12453000	Observed flow of USGS 12453000 (Entiat River at Entiat)
	10/01/1958 - 03/14/1996	USGS 12452800	Observed flow of USGS 12452800 (Entiat River near Ardenvoir)
	03/15/1996 - 10/01/2018	USGS 12452990	Observed flow of USGS 12452990 (Entiat River near Entiat)
RRH5ARF	07/01/1928 - 10/01/2018	CHPS	WEL6ARF (routed) + RRH6L + CHL6A

Footnote 4 – Estimation of missing streamflow record for the Entiat River near Entiat, WA (USGS 12452990).

The main tributary into the Rocky Reach Dam is the Entiat River. The earliest known gage on the river, however, is from Oct. 1951. To estimate the period from 1928-1951 we linearly correlated the Stehekin River at Stehekin (USGS 12451000) with the Entiat River near Entiat (USGS 12452990).

Monthly linear regression coefficients for estimating the Entiat River near Entiat (USGS 12452990) from the Stehekin River at Stehekin (USGS 12451000):

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
a	0.1	0.16	0.23	0.14	0.3	0.3	0.37	0.38	0.42	0.31	0.24	0.12
b	91.3	97.9	64.4	109.2	61.1	92.1	26.9	90.4	-140.9	-136.3	-42.8	60.4


Stehekin R.
(12451000) Stehekin R. @ Stehekin; DA =321; Oct 28-Sep 51 (correlated to 12452990)
515.9
515.9
(12450700) Columbia R. bl Wells Dam; DA =86,100; Oct 67-Sep 18
Chelan R.
(12452800) Entiat R. nr Ardenvoir; DA =203; Oct 58-Mar 96
(12452990) Entiat R. nr Entiat; DA =419; Mar 96-Sep 18
(12453000) Entiat R. @ Entiat; DA =419; Jun 51-Sep 58
Entiat R.
18.0
1.4
473.9
Rocky Reach Dam; DA =87,800
473.4
(12453700) Columbia R. @ Rocky Reach Dam; DA =87,800; Oct 60-Sep 18
Wenatchee R.
441.0
(12464500) Columbia R. @ Trinidad; DA =89,700 Oct 30-Mar 63
Columbia River

ROCK ISLAND (RIS)

COLUMBIA RIVER River Mile 453 Drainage Area: 89400 Sq. Mi.

Site	Period	Source	Comments
RIS6H	07/01/1928 - 09/30/1930	USGS 12436500[5]	Linear correlation of USGS 12436500 with USGS 12464500 with daily shape of USGS 12464500
	10/01/1930 - 09/30/1959	USGS 12464500	Observed flow of USGS 12464500 (Columbia River at Trinidad)
	10/01/1959 - 10/01/2018		RRH6H (routed) + Wenatchee[4] - RIS6S
Wenatchee[6,7]		USGS	No single river gage on the Wenatchee river extends over the 90-year record so we merged three USGS gages on the river that do extend over the 90-year record
	07/01/1928 - 02/28/1929	USGS 12457000[6]	Linear correlation of USGS 12457000 with USGS 12462500 with daily shape of USGS 12462500
	03/01/1929 - 09/30/1962	USGS 12459000[7]	Linear correlation of USGS 12459000 with USGS 12462500 with daily shape of USGS 12462500
	10/01/1962 - 10/01/2018	USGS 12462500	Observed flow of USGS 12462500 (Wenatchee R. at Monitor)
RIS6S	08/01/1960 - 09/30/2008	2010 Modified Flows	
	10/01/2008 - 10/01/2018	Chelan PUD	Submitted Reservoir data
RIS6A	07/01/1928 - 10/01/2018	CHPS	RIS6H + RIS6S
RIS6L	07/01/1928 - 10/01/2018	USGS	Wenatchee[4] (see above)
RIS6ARF	07/01/1928 - 10/01/2018	CHPS	RRH6ARF (routed) + RIS6L

Footnote 5 – Estimation of missing streamflow record for the Columbia River at Trinidad (USGS 12464500).

Outflow prior to the construction the Rock Island Dam was calculated using the Columbia River at Trinidad (USGS 12464500). However, that record only goes back to Oct. 1930. To estimate the period from 1928-1930 we linearly correlated the Columbia River at Grand Coulee (USGS 12436500) with the Columbia River at Trinidad (USGS 12464500).

Monthly linear regression coefficients for the Columbia River at Trinidad (USGS 12464500) from the Columbia River at Grand Coulee (USGS 12436500):

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
a	1.05	1.08	1.06	1.05	1.08	1.08	1.09	1.09	1.1	1.11	1.08	1.01
b	2952.6	2387.9	3176.4	3156.9	1719.6	1391.4	210.2	1371.8	-3061.2	-6609.4	-665.3	5539.8

Footnote 6 and 7 – Estimation of missing streamflow record for the Wenatchee River at Monitor, WA (USGS 12462500).

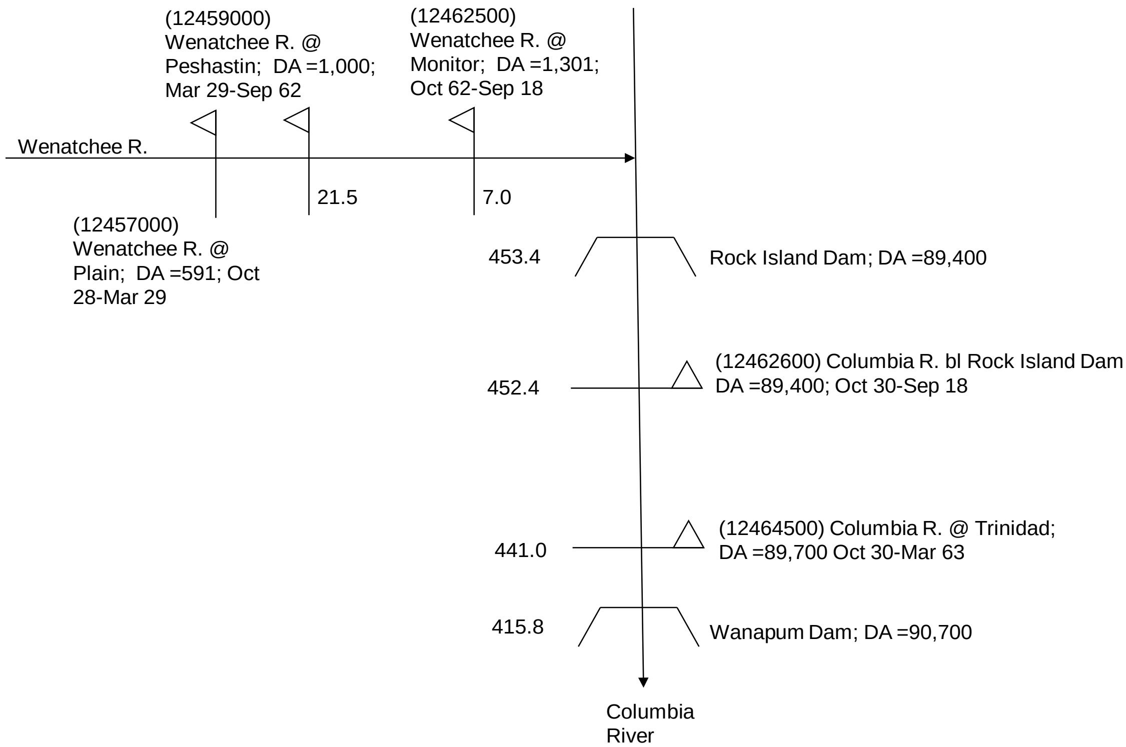
The main tributary into the Rock Island Dam is the Wenatchee River. There are three gages on the Wenatchee River that span the entire period of record. However, none span the entire range so to obtain a full record a linear correlation was performed to provide estimates of the gage nearest to the confluence with the Columbia River, Wenatchee River at Monitor, WA (USGS 12462500). The first period that is estimated is from July 1928 through Feb, 1929 using the Wenatchee River at Plain, WA (USGS 12457000). While the second estimation period runs from Mar. 1929 through Sept. 1962 using the Wenatchee River at Peshastin, WA (USGS 12459000).

Monthly linear regression coefficients for estimating the Wenatchee River at Monitor, WA (USGS 12462500) from the Wenatchee River at Plain, WA (USGS 12457000)[6]:

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
a	1.03	1.11	1.11	1.11	1.15	1.15	1.09	1.1	1.1	1.05	1.03	1.05
b	11.2	-68.7	-26.5	-0.4	-23.7	2.7	39.1	-265.3	-373.7	-186.0	-110.2	-65.7

Monthly linear regression coefficients for estimating the Wenatchee River at Monitor, WA (USGS 12462500) from the Wenatchee River at Peshastin, WA (USGS 12459000)[7]:

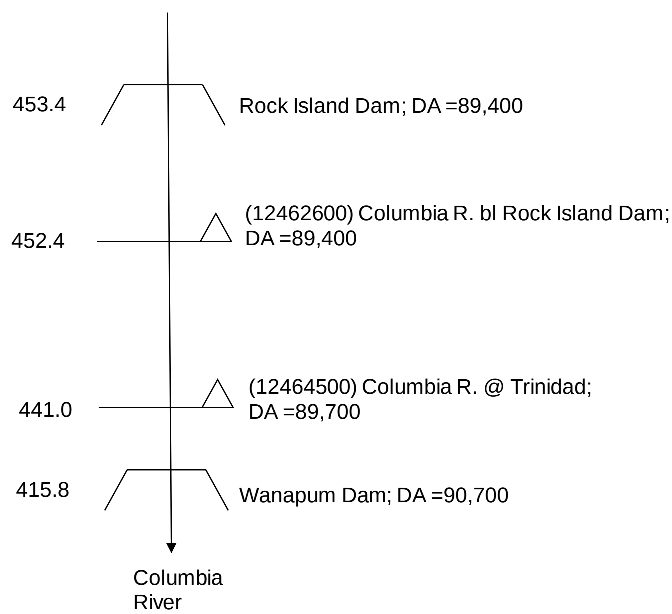
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
a	1.35	1.57	1.56	1.59	1.60	1.73	1.53	1.54	1.52	1.41	1.38	1.44
b	5.4	-129.9	-57.1	-53.4	-12.0	-97.1	-6.9	-392.0	-575.0	-339.5	-231.1	-146.6


(12459000)
Wenatchee R. @
Peshastin; DA =1,000;
Mar 29-Sep 62
(12462500)
Wenatchee R. @
Monitor; DA =1,301;
Oct 62-Sep 18
Wenatchee R.
21.5
7.0
(12457000)
Wenatchee R. @
Plain; DA =591; Oct
28-Mar 29
453.4
Rock Island Dam; DA =89,400
452.4
(12462600) Columbia R. bl Rock Island Dam;
DA =89,400; Oct 30-Sep 18
441.0
(12464500) Columbia R. @ Trinidad;
DA =89,700 Oct 30-Mar 63
415.8
Wanapum Dam; DA =90,700
Columbia
River

WANAPUM (WAN)

COLUMBIA RIVER River Mile 416 Drainage Area: 90700 Sq. Mi.

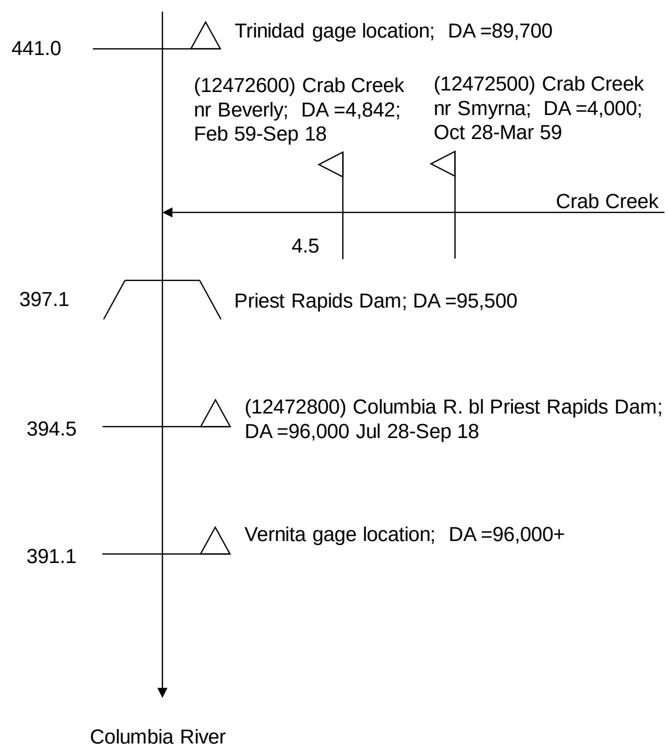
Site	Period	Source	Comments
WAN6H	07/01/1928 - 10/01/2018	CHPS	WAN6A - WAN6S
WAN6S	08/01/1960 - 09/30/2008	2010 Modified Flows	
	10/01/2008 - 10/01/2018	USACE	Submitted Elevation Data
WAN6A	07/01/1928 - 10/01/2018	CHPS	RIS6H (routed)
WAN6ARF	07/01/1928 - 10/01/2018	CHPS	RIS6ARF (routed)



PRIEST RAPIDS (PRD)

COLUMBIA RIVER River Mile 397 Drainage Area: 95500 Sq. Mi.

Site	Period	Source	Comments
PRD6H	07/01/1928 - 09/30/2018	USGS 12472800	Observed flow of 12472800 (Columbia River below Priest Rapids)
PRD6S	03/01/1960 - 09/30/2008	2010 Modified Flows	
	10/01/2008 - 10/01/2018	USACE	Submitted Elevation Data
PRD6A	07/01/1928 - 10/01/2018	CHPS	PRD6H + PRD6S
PRD6L	07/01/1928 - 09/30/2018	CHPS	PRDH6A – WAN6H (routed)
PRD6ARF	07/01/1928 - 10/01/2018	CHPS	WAN6ARF (routed) + PRD6L



Lower Snake Basin (Section 3.5)

BROWNLEE DAM (BRN)

SNAKE RIVER River Mile 285 Drainage Area: 72590 sq. mi

Site	Period	Source	Comments
BRN6A	07/01/1928 - 03/08/1958	USGS 13290000	Observed flow of 13290000 (Snake River at Oxbow)
	03/09/1958 - 04/18/2005	USGS 13269000 13275000 13286700 13288200	Observed flow of 13269000 (Snake Rv at Weiser) plus 1.25[1] times the sum (13275000 (Burnt Rv at Hunnington[2] plus: 13286700 (Powder Rv at Richland) plus 13288200 (Eagle Ck abv Skull Ck near New Bridge[3])
	04/16/1999 - present	USGS 13269000 13275000 13286700 13288300	Observed flow of 13269000 (Snake Rv at Weiser) plus 1.25[1] times the sum (13275000 (Burnt Rv at Hunnington[2] plus: 13286700 (Powder Rv at Richland) plus 13288300 (Eagle Ck abv Skull Ck at Richland))

Footnote 1 - Estimation of flow from ungaged portion of Brownlee local.

Brownlee Reservoir inflow is computed by summing the streamflow measurements from the major tributaries that were collected at USGS gages. The primary source of inflow is the Snake River and the three gages downstream of the Snake River at Weiser gage (13269000) contribute approximately 75% of the Brownlee local flow. To account for runoff from the ungaged portion of the basin the runoff from the gaged portion of the local is multiplied by 1.25. This assumes that the runoff characteristics of the ungaged portion of the local are similar to the gaged portion.

Site	Area
	(sq. mi.)
BRN	72,590
Snake River at Weiser (13269000)	69,200
Total Local	3390

Site	Area
	(sq. mi.)
Burnt River (13275000)	1093
Powder River (13286700)	1310
Eagle Creek (13288200)	156
Total Gaged Local	2559

Footnote 2 – Estimation of missing streamflow record the Burnt River at Huntington, Oregon.
The historical streamflow records in the Burnt River drainage is of poorer quality than the other two drainages. Fortunately, it contributes less runoff than the other two basins so flow inaccuracies have a limited impact on the calculation of Brownlee local flow. Currently, Idaho Power maintains the Burnt River at Huntington (13275000) gaging station but the record contains several periods where measurements were discontinued. The discontinued upstream gage at Hereford, Oregon (13273000) is used to estimate missing Huntington flows prior to 9/29/1997. Unfortunately, the drainage area of the Hereford site (309 sq. mi.) is less than a third of the total area of the Huntington station (1093 sq. mi.), so correlation during the months of July and August was poor because streamflow being diverted for irrigation between the two gaging sites.

Monthly linear regression coefficients for estimating 13275000 (Burnt River at Huntington) from flow measured at 13273000 (Burnt River at Hereford):

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	1.67	1.30	1.36	1.36	1.68	1.28	0.55	0.36	0.48	0.58	1.11	1.36
b	60.8	105.	106.	84.4	-72.3	-28.3	16.3	27.1	36.2	54.1	48.9	49.1

Periods Estimated	
Start Date	**End Date**
09/29/1932	10/01/1956
09/29/1959	06/08/1962
10/02/1980	09/29/1997

Between 1997 and 2005 there are no historical streamflow records in the Burnt River drainage, so flow from a gage in the adjacent Powder River drainage is used.

Monthly linear regression coefficients for estimating 13275000 (Burnt Rv at Huntington) from flow measured at 13286700 (Powder Rv at Richland):

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	0.228	0.340	0.504	0.730	0.467	0.144	0.205	0.733	0.977	0.415	0.215	0.224
b	33.7	33.2	-3.96	8.09	57.6	67.0	53.5	30.9	18.6	41.9	45.3	37.9

Period Estimated	
Start Date	**End Date**
09/29/1997	4/18/2005

Footnote 3 – Estimation of missing streamflow record the Eagle Ck abv Skull Ck near New Bridge, Oregon.
Eagle Creek has a relatively small drainage area but contributes a disproportionately large amount of runoff to the Brownlee local because its drainage encompasses part of the high elevation Wallowa Mountains. The USGS gaging station at Eagle Creek above Skull Creek (13288200) provides a good streamflow record from Oct. 1957 to the end of 1997. Missing periods were estimated using streamflow records from the nearby Imnaha River which also drains from the Wallowa Mountains. After 1997 the gage on Eagle Creek was moved several miles downstream near the confluence with the Powder River at Richland, Oregon. Eagle Creek at Richland (13288300) is currently maintained by Idaho Power. Little additional flow

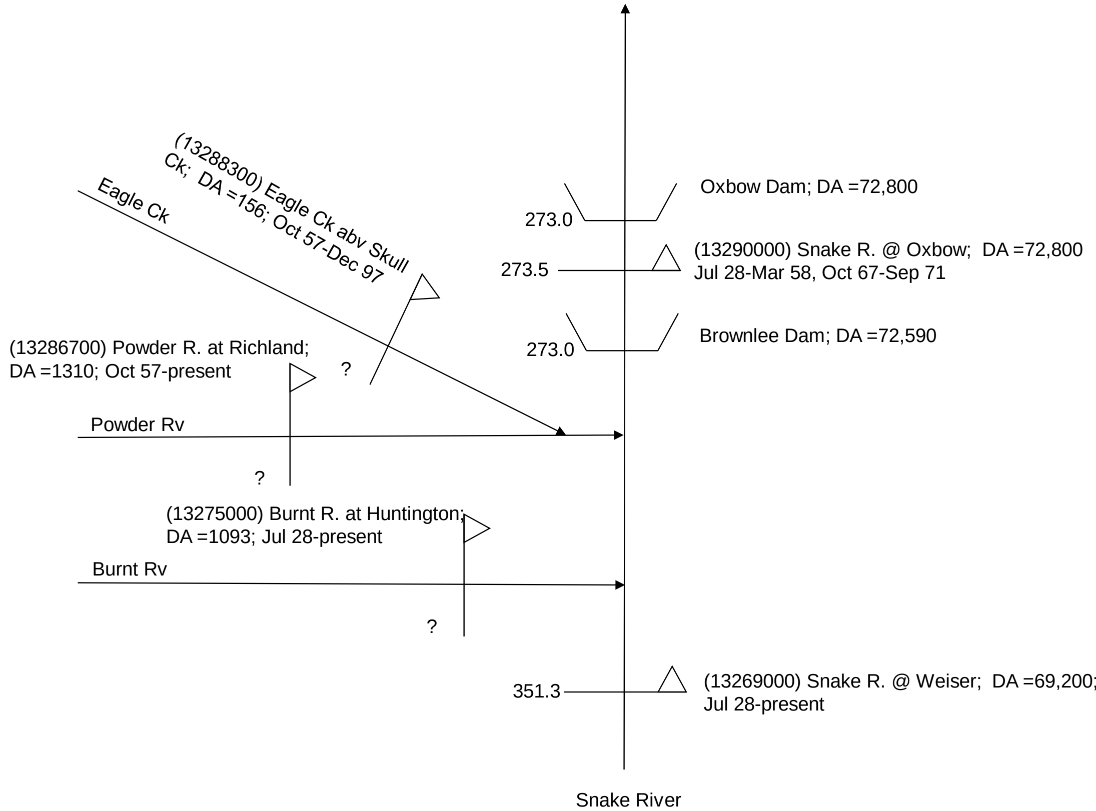
accumulates in the lower reaches of Eagle Creek so the streamflow record of 13288200 is extended until present using 13288300 data without modification.

Monthly linear regression coefficients for estimating 13288200 (Eagle Ck abv Skull Ck near New Bridge) from flow measured at 13292000 (Imnaha River at Imnaha):

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	0.36	0.30	0.234	0.42	0.49	0.66	0.83	0.366	0.20	0.83	0.998	0.21
b	41.0	56.2	108.	-3.52	42.7	-24.3	-193.	-49.9	-16.2	-82.5	-62.1	65.0

Periods Estimated	
Start Date	**End Date**
07/01/1928	10/01/1957
12/31/1997	04/16/1999
08/08/2000	11/15/2001

BRN6S	05/05/58 - 09/30/2008	2010 Modified Flows	
	10/01/2008 - 09/30/2018	Idaho Submittal	
BRN6H	07/01/28 - 09/30/2018	BRN_A - BRN_S	


(13288300) Eagle Ck abv Skull Ck; DA =156; Oct 57-Dec 97
Eagle Ck
Oxbow Dam; DA =72,800
273.0
273.5
(13290000) Snake R. @ Oxbow; DA =72,800
Jul 28-Mar 58, Oct 67-Sep 71
273.0
Brownlee Dam; DA =72,590
(13286700) Powder R. at Richland;
DA =1310; Oct 57-present
?
Powder Rv
?
(13275000) Burnt R. at Huntington;
DA =1093; Jul 28-present
Burnt Rv
?
351.3
(13269000) Snake R. @ Weiser; DA =69,200;
Jul 28-present
Snake River

OXBOW DAM (OXB)

SNAKE RIVER River Mile 273 Drainage Area: 72800 sq. mi

Site	Period	Source	Formula
OXB6M	07/01/28 - 09/30/2018	BRN6M	

HELLS CANYON DAM (HCD)

SNAKE RIVER River Mile 248 Drainage Area: 73300 sq. mi

Site	Period	Source	Formula
HCD6H	07/01/28 - 01/31/58	USGS 13290000 13290190	Observed flow of 13290000 (Snake R at Oxbow) plus 2.17[4] times the flow of 13290190 (Pine Cr. Near Oxbow)[5]
	02/01/58 - 07/31/65	USGS 13290200 13290190	Observed flow of 13290200 (Snake River below Pine Cr. at Oxbow) plus .65 times the flow of 13290190 (Pine Cr. near Oxbow)[5]
	08/01/65 - 09/30/18	USGS 13290450	Observed flow of 13290450 (Snake River at Hells Canyon Dam).

Footnote 4 - Flow Adjustment due to change of gaging stations.

The USGS established a new gaging station (13290450) along this reach of the Snake River in August of 1965 because construction of Hells Canyon Dam would inundate the existing gaging station located below Pine Creek (13290200). The new site located immediately downstream of Hells Canyon Dam had a larger drainage area than the two former gaging stations. An area weighting of the Pine Creek (13290190) streamflow record is used to estimate the change in discharge due to the change in gaging locations.

Site	Total Area	Area Difference	Ratio to Pine Ck
	(sq. mi.)	(sq. mi.)	
Snake River at Oxbow (13290000)	72,800	500	2.17
Snake River Below Pine Ck (13290200)	73,150	150	0.65
Snake River at Hells Canyon Dam (13290450)	73,300	-	-
Pine Ck nr Oxbow (13290190)	230	-	-

Footnote 5 – Estimation of missing streamflow record for Pine Creek near Oxbow, Oregon. Pine Creek is the only drainage within the Hells Canyon local where streamflow has been measure for any length of record. Flow was measure for about thirty years between 1966 and 1996. Periods of overlapping streamflow data with two stations in nearby drainages allows reconstruction of the Pine Creek record. The long, continuous record at the Imnaha River at Imnaha (13292000) site provides the best estimate for Pine Creek, in fact this was the gage used in 2010 to index the Hells Canyon local.

Monthly linear regression coefficients for estimating 13290190 (Pine Creek near Oxbow) from flow measured at 13292000 (Imnaha River at Imnaha):

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	1.12	1.84	1.05	0.573	0.547	0.712	0.464	0.216	0.543	0.626	0.691	1.16
b	17.2	-98.2	120.	162.	34.4	-207.	-90.0	2.31	-33.4	-29.0	-6.97	-23.4

Periods Estimated	
Start Date	**End Date**
10/01/1928	11/01/1966
07/23/1996	Present

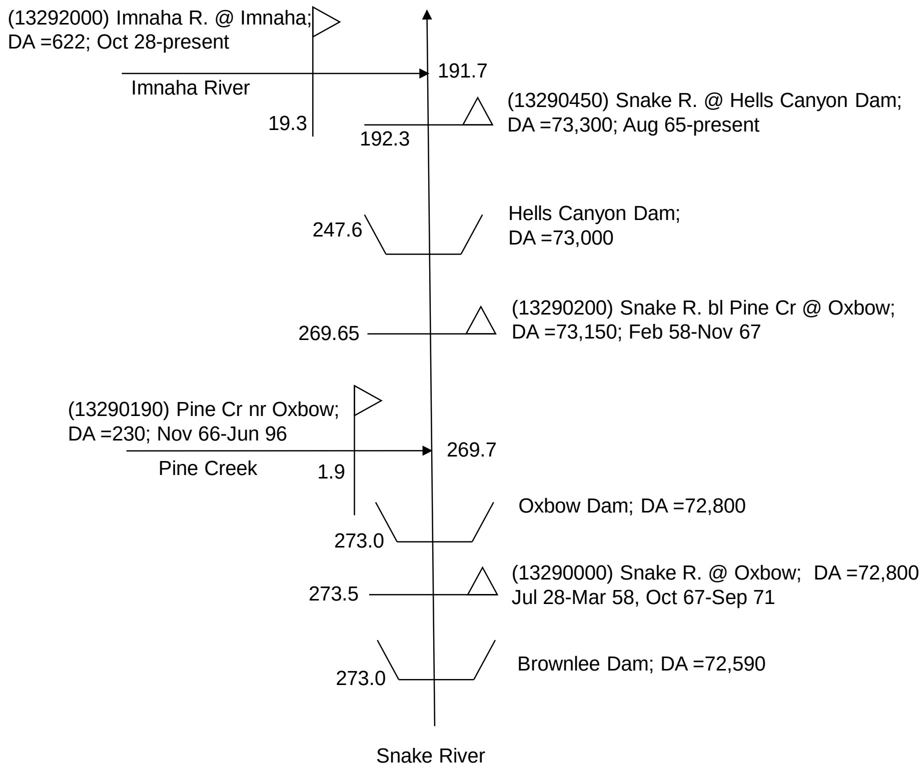
The streamflow record at the Imnaha River at Imnaha does not extend back to the beginning of the modified flow analysis period so another gage needed to be identified for this earlier period. Records are rather sparse this early but a location on the north slope of the Wallowa Mountains existed during this period

Monthly linear regression coefficients for estimating 13290190 (Pine Creek near Oxbow) from flow measured at 13330500 (Bear Creek near Wallowa):

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	4.94	4.46	6.06	2.74	1.84	1.91	1.60	1.79	1.79	1.03	1.54	2.60
b	15.0	136.	177.	326.	312.	43.0	3.10	13.3	25.4	51.6	74.7	111.

Periods Estimated	
Start Date	**End Date**
07/01/1928	09/30/1928

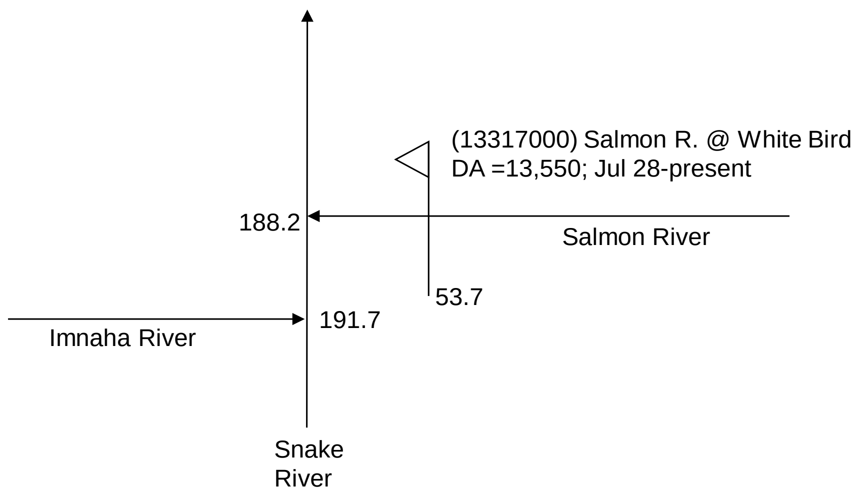
HCD6S	10/01/1967 - 09/30/2008	USACE	Storage data from USACE
	10/01/2008 - 09/30/2018	Idaho Power	Storage data from Idaho Power
HCD6ARF	07/01/1928 - 09/30/2018	CHPS	Unregulated flows routed using the SSARR model


(13292000) Imnaha R. @ Imnaha;
DA =622; Oct 28-present
191.7
Imnaha River
(13290450) Snake R. @ Hells Canyon Dam;
DA =73,300; Aug 65-present
19.3
192.3
247.6
Hells Canyon Dam;
DA =73,000
(13290200) Snake R. bl Pine Cr @ Oxbow;
DA =73,150; Feb 58-Nov 67
269.65
(13290190) Pine Cr nr Oxbow;
DA =230; Nov 66-Jun 96
269.7
Pine Creek
1.9
Oxbow Dam; DA =72,800
273.0
(13290000) Snake R. @ Oxbow; DA =72,800
Jul 28-Mar 58, Oct 67-Sep 71
273.5
Brownlee Dam; DA =72,590
273.0
Snake River

WHITE BIRD (WHB)

SALMON RIVER   River Mile 53.7   Drainage Area: 13550 sq. mi.

Site	Period	Source	Comments
WHB6H	07/01/1928 - 09/30/2018	USGS 13317000	Observed flow of 13317000 (Salmon R. at White Bird).
WHB6A	07/01/1928 - 09/30/2018	WHB_H	



LIME POINT (LIM)

SNAKE RIVER | River Mile 172 | Drainage Area: 88000 sq. mi.

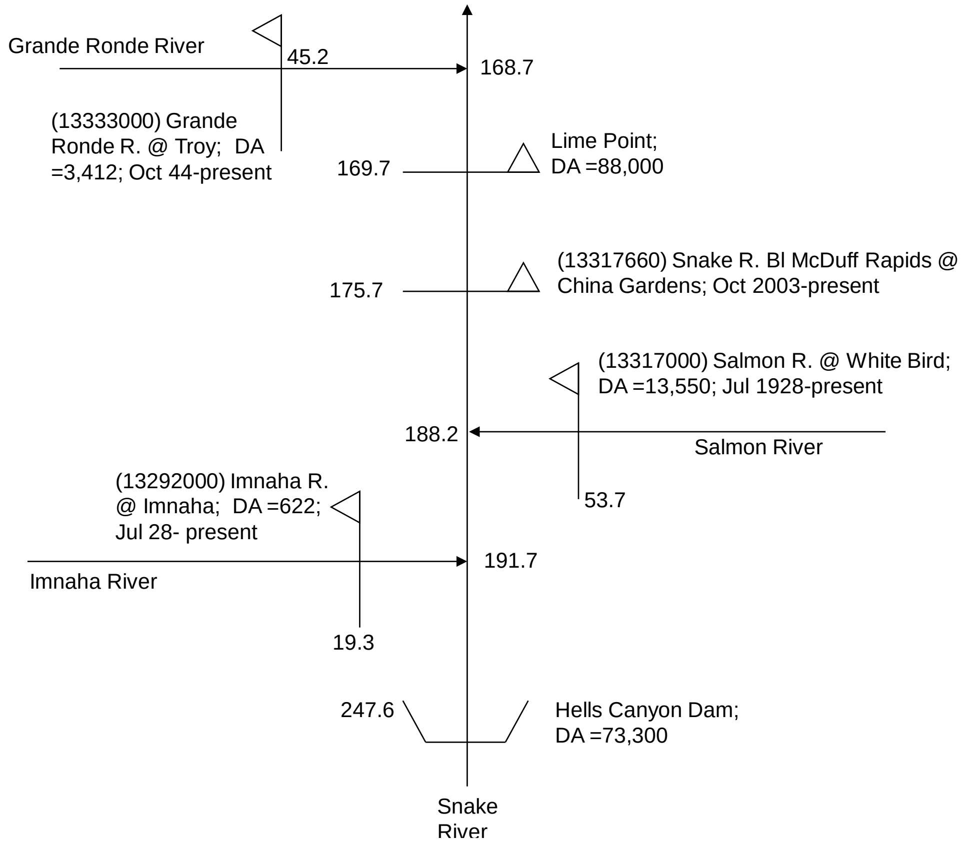
Site	Period	Source	Comments
LIM6H	07/01/1928 - 09/30/1957	USGS 13317000 13292000 HCD6H	Observed flow of 13317000 (Salmon R at White Bird) to Anatone plus 13292000 (Imnaha R at Imnaha)[6] routed to Anatone plus the historic flow from Hells Canyon Dam (see HCD6H for this derivation) routed to Anatone
	10/01/1999 - 09/30/2003	Calculated	USGS 13334300 (Snake River near Anatone) minus USGS 13333000 (Grande Ronde River at Troy) routed to Anatone
	10/01/2003 - 09/30/2018	USGS 13317660	Observed flow of 13317660 (Snake R below McDuff Rapids at China Gardens)
LIM6ARF	07/01/1928 - 09/30/2018	CHPS	Unregulated daily flows routed using the SSARR model

Footnote 6 – Estimation of missing streamflow record for Imnaha River near Imnaha, Oregon. The streamflow record at the Imnaha River at Imnaha does not extend back to the beginning of the modified flow analysis period. Records are rather sparse this early but a gaging site on the Lostine River existed during this period and is reasonably correlated.

Monthly linear regression coefficients for estimating 13292000 (Imnaha River at Imnaha) from flow measured at 13330000 (Lostine River near Lostine):

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	3.77	3.69	6.22	2.90	1.22	1.36	1.27	1.45	1.35	1.09	1.05	2.21
b	15.2	59.7	64.5	494.	962.	277.	73.3	71.0	77.9	99.9	119.	86.1

Periods Estimated	
Start Date	**End Date**
07/01/1928	09/30/1928



Grande Ronde River
45.2
168.7
(13333000) Grande Ronde R. @ Troy; DA =3,412; Oct 44-present
169.7
Lime Point; DA =88,000
(13317660) Snake R. Bl McDuff Rapids @ China Gardens; Oct 2003-present
175.7
(13317000) Salmon R. @ White Bird; DA =13,550; Jul 1928-present
188.2
Salmon River
53.7
(13292000) Imnaha R. @ Imnaha; DA =622; Jul 28- present
191.7
Imnaha River
19.3
247.6
Hells Canyon Dam; DA =73,300
Snake River

TROY (TRY)

GRAND RONDE | River Mile 45 | Drainage Area: 3412 sq. mi.

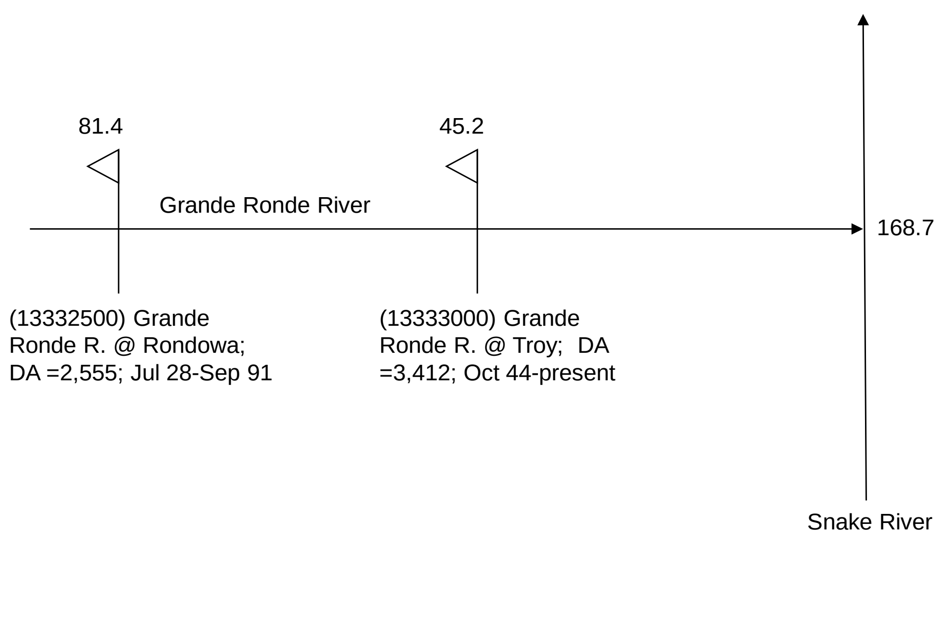
Site	Period	Source	Comments
TRY6H	07/01/1928 - 09/30/2018	USGS 13333000 13332500	Observed flow of 13333000 (Grande R at Troy)[7]

Footnote 7 – Estimation of missing streamflow record for Grand Ronde River at Troy, Oregon. The streamflow record at the Grand Ronde River at Troy only goes back to Oct. 1944 but there is a gage located further upstream with an overlapping record. The same gage, Grand Ronde at Rondowa, was used in the 2010 study but for this study the regression parameters were recomputed using data stored in CHPS.

Monthly linear regression coefficients for estimating 13333000 (Grand Ronde River at Troy) from flow measured at 13332500 (Grand Ronde River at Rondowa):

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	1.49	1.48	1.41	1.44	1.24	1.13	1.08	1.06	1.11	1.25	1.42	1.76
b	38.59	-5.86	111.	128.	226.	156.	224.	179.	153.	69.7	-5.01	-259.

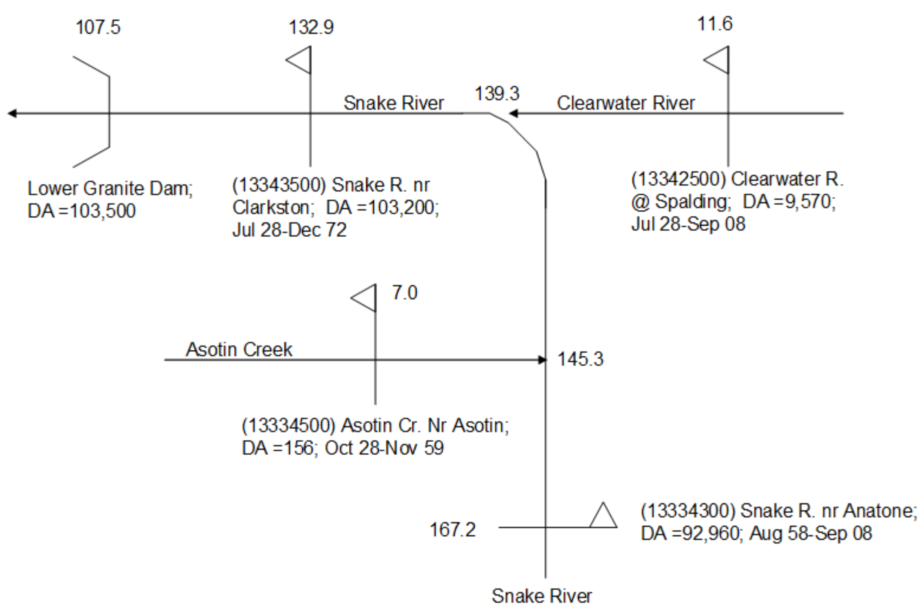
Periods Estimated	
Start Date	**End Date**
07/01/1928	09/30/1944



ANATONE (ANA)

SNAKE RIVER River Mile 167 Drainage Area: 92,9960 sq. mi.

Site	Period	Source	Formula
ANA6H	07/01/1928 - 07/31/1958	USGS 13317000 13292000 HCD6H	Observed flow of 13317000 (Salmon R at White Bird) to Anatone plus 13292000 (Imnaha R at Imnaha)[6] routed to Anatone plus the historic flow from Hells Canyon Dam (see HCD6H for this derivation) routed to Anatone
	08/01/1958 - 09/30/2018	USGS 13334300	Observed flow of 13334300 (Snake R near Anatone)
ANA6ARF	07/01/1928 - 09/30/2018	CHPS	Unregulated flows routed using the SSARR model



ORFINO (ORO)

CLEARWATER RIVER | River Mile 45 | Drainage Area: 5580 sq. mi.

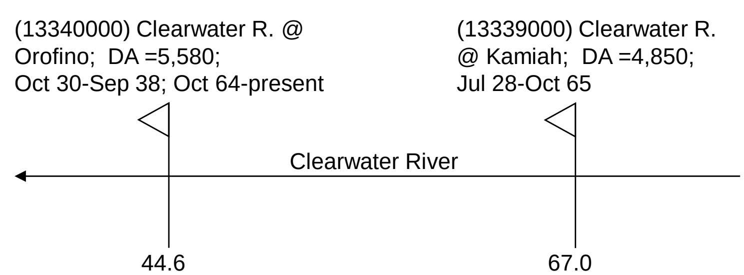
Site	Period	Source	Formula
ORO6H	07/01/1928 - 09/30/2018	USGS 133400001 3339000	Observed flow of 13340000 (Clearwater R at Orofino)[8]

Footnote 8 – Estimation of missing streamflow record for Clearwater River at Orofino, Idaho. The streamflow record at the Clearwater River at Orofino begins in Oct. 1930 and is currently maintained, but there was a 26-year period when the gage was inactive. During this period and the period prior to the installation of the gage, the Clearwater River at Kamiah (13339000) record is used to compute flows at Orofino.

Monthly linear regression coefficients for estimating 13340000 (Clearwater at Orofino) from flow measured at 13339000 (Clearwater at Kamiah) where 1334000=a*13339000+b:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	1.18	1.08	1.02	1.04	1.05	0.921	1.02	1.02	1.02	1.08	1.12	1.16
b	34	96	946	1240	-644	1380	86	46	50	-35	-34	-80

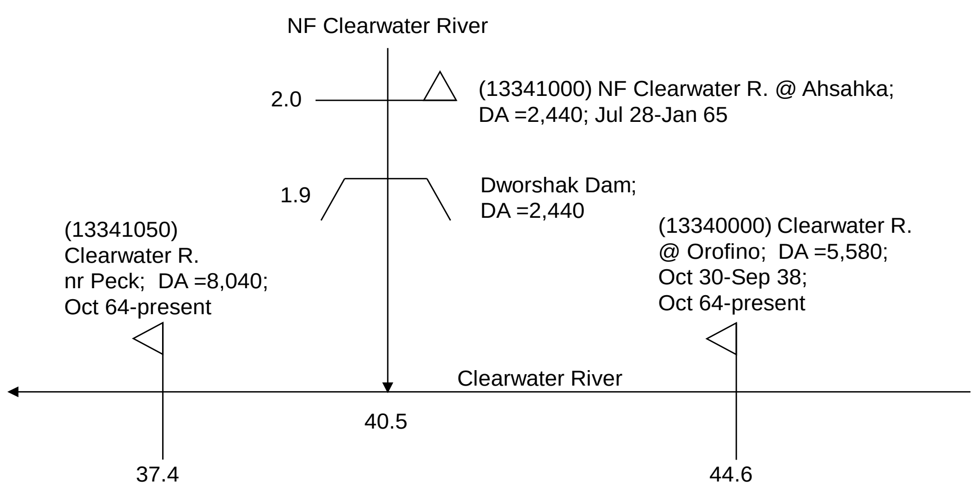
Periods Estimated	
Start Date	**End Date**
07/01/1928	09/30/1930
10/01/1938	09/30/1964



DWORSHAK (DWR)

NF CLEARWATER RIVER | River Mile 2 | Drainage Area: 2440 sq. mi.

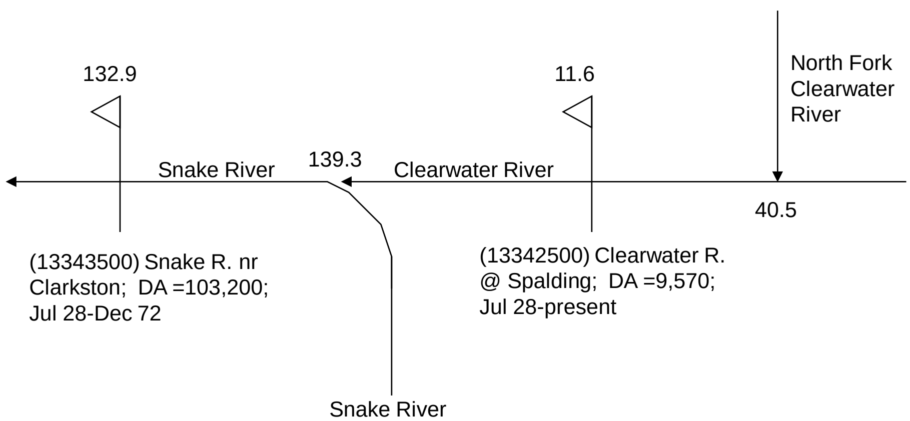
Site	Period	Source	Comments
DWR6H	07/01/1928 - 01/31/1965	USGS 13341000	Observed flow of 13341000 (NF Clearwater R near Ahsahka)
	02/01/1965 - 09/30/2008	USGS 13341050 & 13340000	Observed flow of 13341050 (Clearwater R near Peck) minus observed flow of 13340000 (Clearwater R at Orofino). Values taken from 2010 Modified Flows.
	10/01/2008-09/30/2018	USACE	Data Submittal
DWR6S	10/01/71 - 09/30/08	2010 Modified Flows	
	10/01/2008-09/30/2018	USACE	Data Submittal
DWR6A	07/01/28 - 09/30/08	DWR_S + DWR_H	
	10/01/2008-09/30/2018	USACE	Data Submittal



SPALDING (SPD)

CLEARWATER RIVER | River Mile 12 | Drainage Area: 9570 sq. mi.

Site	Period	Source	Comments
SPD6H	07/01/1928 - 09/30/2018	USGS 13342500	Observed flow of 13342500 (Clearwater River at Spalding)
SPD6ARF	07/01/1928 - 09/30/2018	CHPS	Unregulated daily flows derived by SSARR model.



LOWER GRANITE (LWG)

SNAKE RIVER | River Mile 108 | Drainage Area: 103,500 sq. mi.

Site	Period	Source	Comments
LWG6A	07/01/1928 - 07/31/1928	USGS 13342500 13334700 ANA6H	Observed flow of 13342500 (Clearwater River at Spalding) plus H flow at Snake River at Anatone plus observed and extended flow of 13334700 (Asotin Cr at Asotin)[9]
	08/01/1928 - 12/31/1972	USGS 13343500	Observed flow of 13343500 (Snake River at Clarkston).
	01/01/1973 - 09/30/2018	USGS 13342500 13334300 13335050	Observed flow of 13342500 (Clearwater River at Spalding) plus observed flow of 13334300 (Snake River at Anatone) plus observed and extended flow of 13335050 (Asotin Cr at Asotin) [9]

Footnote 9 – Estimation of missing streamflow record for Asotin Creek at Asotin, Washington. The streamflow records on Asotin Creek are quite fragmented. The current gage on Asotin Ck at Asotin (13335050) was established in Mar. 1991. The 27-year record provides a sufficient record to correlate with upstream or nearby gages. Estimated flow for this small tributary is required for the month of July, 1928, prior to the establishment of the Snake River at Clarkston (13342500) and after the station was closed.

For the period prior to the establishment of the Clarkston station, monthly linear regression coefficients for estimating 13335050 (Asotin Ck at Asotin) were obtained from flow measured at 13344000 (Tucannon River at Pomeroy) where 13335050=a*13344000+b:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	0.269	0.269	0.213	0.464	0.495	0.528	0.841	0.338	0.422	0.211	0.255	0.564
b	17.6	17.6	20.1	-3.76	13.1	9.11	-9.21	12.0	7.22	18.4	15.4	-7.08

Periods Estimated	
Start Date	**End Date**
07/01/1928	09/30/1928

Flow from Asotin Creek is not needed again to compute Lower Granite inflow until Jan 1973 when the Snake River at Clarkston gage was closed due to pending inundated resulting from the construction of Lower Granite Dam.

Monthly linear regression coefficients for estimating 13335050 (Asotin Ck at Asotin) from flow measured at 13330500 (Asotin Ck below Kearney Gulch):

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	1.51	1.20	1.46	2.30	1.58	1.56	2.28	1.03	1.15	0.742	0.925	1.25
b	-9.43	21.3	-1.88	-65.3	-26.4	-19.2	-39.2	1.85	-2.10	8.72	4.19	-2.49

Periods Estimated	
Start Date	**End Date**
10/01/1959	11/16/1982
10/01/1989	03/22/1991

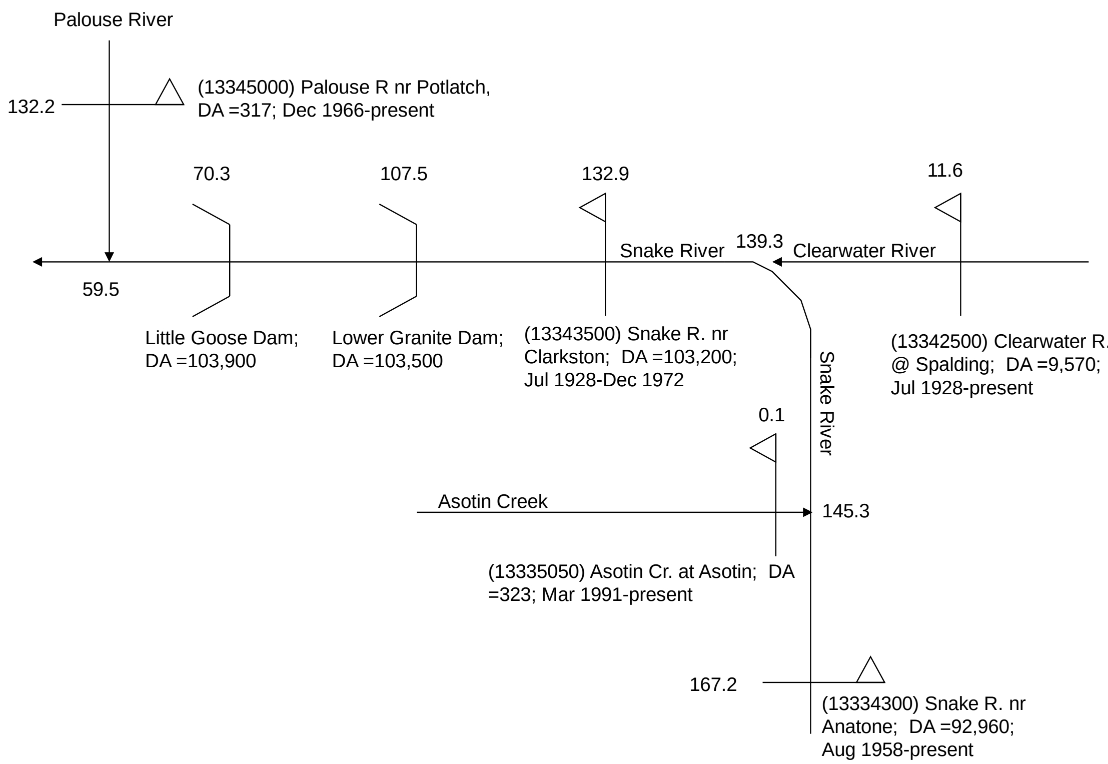
The Asotin Creek below Kearney Gulch was closed for seven years starting in Nov. 1982 and another gage within the adjacent Tucannon drainage is used to estimate flow at Asotin.

Monthly linear regression coefficients for estimating 13335050 (Asotin Ck at Asotin) from flow measured at 13330500 (Tucannon River near Starbuck):

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	0.204	0.286	0.371	0.440	0.445	0.5	0.374	0.258	0.180	0.129	0.412	0.305
b	27.2	13.8	0.874	-0.946	18.2	7.37	18.0	21.5	24.1	26.4	-0.65	12.5

Periods Estimated	
Start Date	**End Date**
11/17/1982	09/30/1989

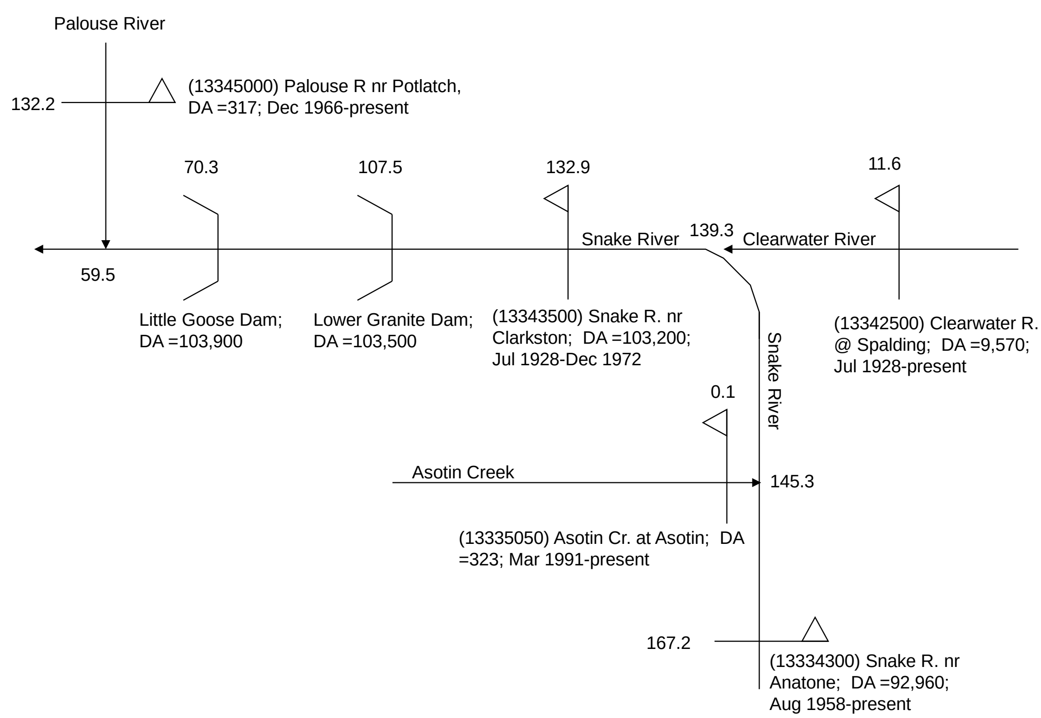
LWG6S	02/14/1975 - 09/30/2008	2010 Modified Flows	
	10/01/2008 - 09/30/2018	USACE	Reservoir data submittal
LWG6H	02/14/1975 - 09/30/2008	LWG6A & LWG6S	LWG6A plus LWG6S
	10/01/2008 - 09/30/2018	USACE	Reservoir data submittal
LWG6ARF	07/01/28 - 09/30/2018	CHPS	Unregulated daily flows derived by SSARR model


Palouse River
132.2
(13345000) Palouse R nr Potlatch,
DA =317; Dec 1966-present
70.3
107.5
132.9
11.6
Snake River
139.3
Clearwater River
59.5
Little Goose Dam;
DA =103,900
Lower Granite Dam;
DA =103,500
(13343500) Snake R. nr
Clarkston; DA =103,200;
Jul 1928-Dec 1972
(13342500) Clearwater R.
@ Spalding; DA =9,570;
Jul 1928-present
Snake River
0.1
Asotin Creek
145.3
(13335050) Asotin Cr. at Asotin; DA
=323; Mar 1991-present
167.2
(13334300) Snake R. nr
Anatone; DA =92,960;
Aug 1958-present

LITTLE GOOSE (LGS)

SNAKE RIVER River Mile 70 Drainage Area: 103,900 sq. mi.

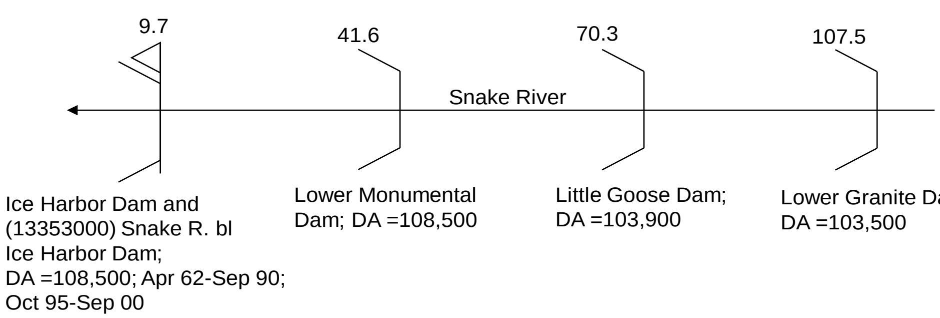
Site	Period	Source	Comments
LGS6H	07/01/1928 - 01/22/1970	LWG6H	Routed LWG6H
	01/23/1970 - 09/30/1999	LWG6H & LGS6S	Routed LWG6H minus LGS6S
	10/01/1999 - 09/30/2018	USACE	Data submittal
LGS6S	01/23/1970 - 09/30/2008	2010 Modified Flows	
	10/01/2008 - 09/30/2018	USACE	Data submittal
LGS6ARF	07/01/1928 - 09/30/2018	CHPS	Unregulated daily flows derived by SSARR model



LOWER MONUMENTAL (LMN)

SNAKE RIVER River Mile 42 Drainage Area: 108,500 sq. mi.

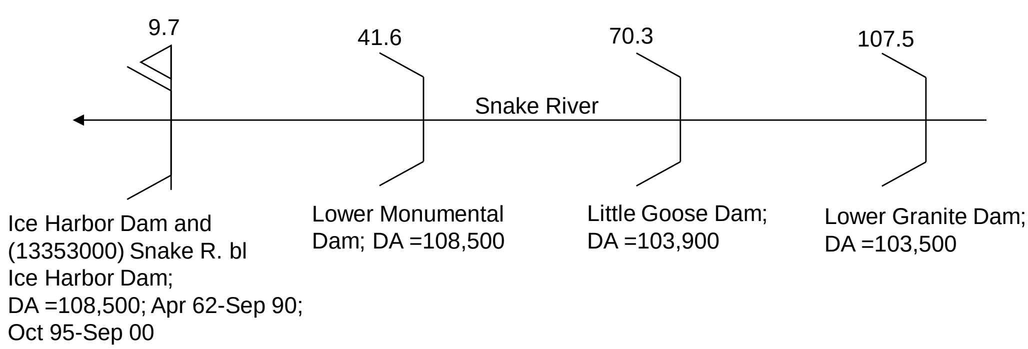
Site	Period	Source	Comments
LMN6A	07/01/1928 - 09/30/2018	USGS 13351000 13344500 LGS6H	Routed LGS6H plus Palouse R. at Hooper (13351000) plus Tucannon R. near Starbuck (13344500)
LMN6H	07/01/1928 - 10/30/1961	IHR6H	LMN6H = Derived IHR6H (see IHR6H)
	11/01/1961 - 09/30/1999	IHR6H & IHR6S	LMN6H = LMN6A – LMN6S
	10/01/1999 - 09/30/2008	USACE	Data submittal
LMN6S	11/27/1961 - 09/30/2008	2010 Modified Flows	
	10/01/2008 - 09/30/2018	USACE Dataquery	Elevation data from USACE Dataquery, and stor-elevation table from USACE.
LMN6ARF	07/01/1928 - 09/30/2018	CHPS	Unregulated daily flows derived by SSARR model



ICE HARBOR (IHR)

SNAKE RIVER   River Mile 10   Drainage Area: 108,500 sq. mi.

Site	Period	Source	Comments
IHR6H	07/01/1928 - 11/26/1961	LMN6H	Routed LMN6H
	11/27/1961 - 03/31/1962	LMN6H IHR6S	Routed LMN6H minus IHR6S
	04/01/1962 - 09/30/1990	USGS 13353000	Observed flow of 13353000 (Snake River below Ice Harbor Dam)
	10/01/1990 - 09/30/1995	LMN6H IHR6S	Routed LMN6H minus IHR6S
	10/01/1995 - 09/28/2000	USGS 13353000	Observed flow of 13353000 (Snake River below Ice Harbor Dam)
	10/01/1998 - 09/30/2008	LMN6H IHR6S	Routed LMN6H minus IHR6S
	10/01/2008 - 09/30/2018	USACE	Data submittal
IHR6S	11/27/1961 - 09/30/2008	2010 Modified Flows	
	10/01/2008 - 09/30/2018	USACE	Data submittal

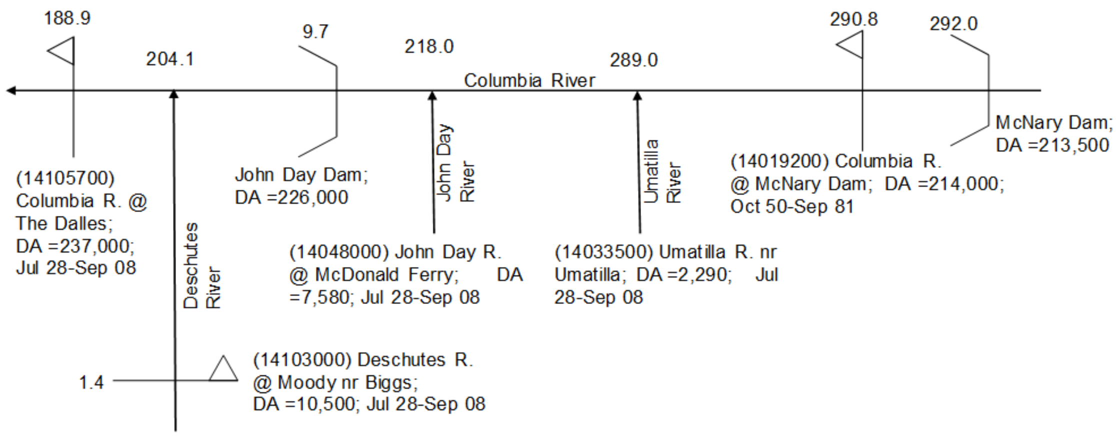


Lower Columbia Basin (Section 3.6)

McNARY (MCN)

COLUMBIA RIVER River Mile 292 Drainage Area: 213500 sq. mi

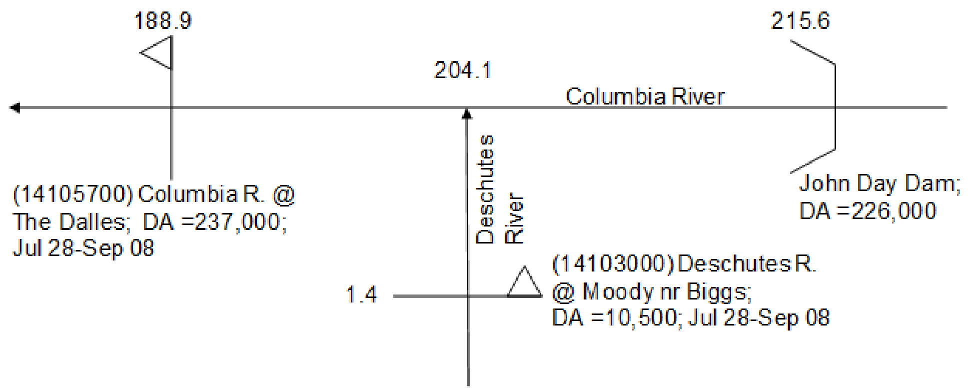
Site	Period	Source	Comments
MCN6H	07/01/1928 - 09/30/1950	USGS 14105700, 14103000, 14048000, and 14033500	Observed flow of USGS #12105700 (Columbia River at The Dalles) minus USGS #14103000 (Deschutes River at Moody) minus USGS #14048000 (John Day River at McDonald Ferry) minus 14033500 (Umatilla R near Umatilla)
	10/01/1950 - 09/30/1981	USGS 14019200	Observed flow of USGS #14019200 (Columbia River at McNary Dam)
	10/01/1981 - 09/30/2018	USACE Dataquery	Flow data from USACE Dataquery
MCN6S	04/19/1953 - 09/30/2018	USACE Dataquery	Elevation data from USACE Dataquery
MCN6A	07/01/1928 - 09/30/2018	MCN_H + MCN_S	
MCN6L	07/01/1928 - 09/30/2018	PRD_H, YAK_H, IHR_H, MCN_A	Route PRD_H and YAK_H to control point located at the confluence of the Columbia and Snake Rivers, then add IHR_H. MCN_L is calculated by subtracting MCN_A from control point outflow routed to MCN. Index the resulting local to 12018500 (Walla Walla River near Touchet) using a ratio of the monthly cumulative local flow to the cumulative monthly USGS flow
MCN6ARF	07/01/1928 - 09/30/2018	PRD_ARF, YAK_H, IHR_ARF	Route PRD_ARF and YAK_H to control point located at the confluence of the Columbia and Snake River, then add IHR_ARF. MCN_ARF is calculated by adding MCN_L plus the control point ARF routed to MCN.


188.9
204.1
9.7
218.0
Columbia River
289.0
290.8
292.0
McNary Dam;
DA =213,500
(14105700)
Columbia R. @
The Dalles;
DA =237,000;
Jul 28-Sep 08
John Day Dam;
DA =226,000
John Day
River
Umatilla
River
(14019200) Columbia R.
@ McNary Dam; DA =214,000;
Oct 50-Sep 81
Deschutes
River
(14048000) John Day R.
@ McDonald Ferry; DA
=7,580; Jul 28-Sep 08
(14033500) Umatilla R. nr
Umatilla; DA =2,290; Jul
28-Sep 08
1.4
(14103000) Deschutes R.
@ Moody nr Biggs;
DA =10,500; Jul 28-Sep 08

JOHN DAY (JDA)

COLUMBIA RIVER | River Mile 216 | Drainage Area: 226000 sq. mi

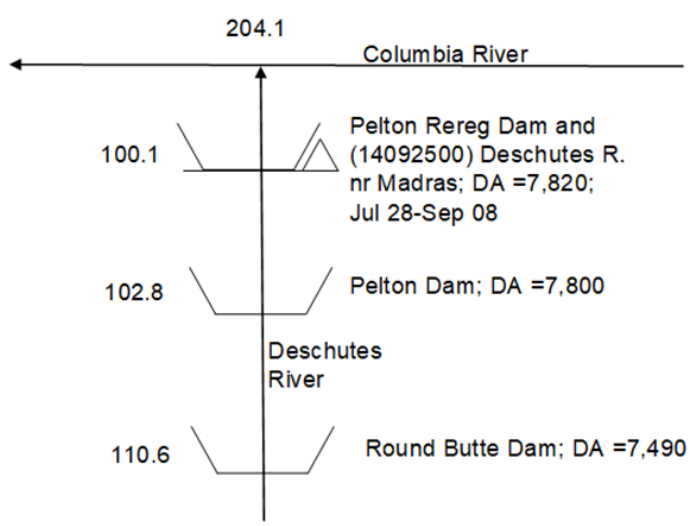
Site	Period	Source	Comments
JDA6H	07/01/1928 - 11/01/1960	USGS 14105700 & 14103000	Observed flow of 14105700 (Columbia River at The Dalles) minus observed flow of 14103000 (Deschutes R at Moody)
	11/2/1960 - 09/30/2018	USGS 14105700 & 14103000 TDA_S	Observed flow of 14105700 (Columbia River at The Dalles) minus observed flow of 14103000 (Deschutes R at Moody) plus TDA6S
JDA6S	11/02/1960 - 09/30/2018	USACE Dataquery	Elevation data from USACE Dataquery
JDA6A	07/01/1928 - 09/30/2018	JDA_H + JDA_S	
JDA6L	07/01/1928 - 09/30/2018	JDA_A - MCN_H	JDA_A minus MCN_H routed to John Day. Index the resulting local to USGS 12018500 (Walla Walla River near Touchet) using a ratio of the monthly cumulative local flow to the cumulative monthly USGS flow
JDA6ARF	07/01/1928 - 09/30/2018	JDA_L, MCN_ARF	JDA_L plus MCN_ARF routed to JDA



ROUND BUTTE (ROU)
PELTON (PEL)
PELTON REREG (RER)

DESCHUTES RIVER	River Mile 111	Drainage Area: 7490 sq. mi
DESCHUTES RIVER	River Mile 103	Drainage Area: 7800 sq. mi
DESCHUTES RIVER	River Mile 100	Drainage Area: 7820 sq. mi

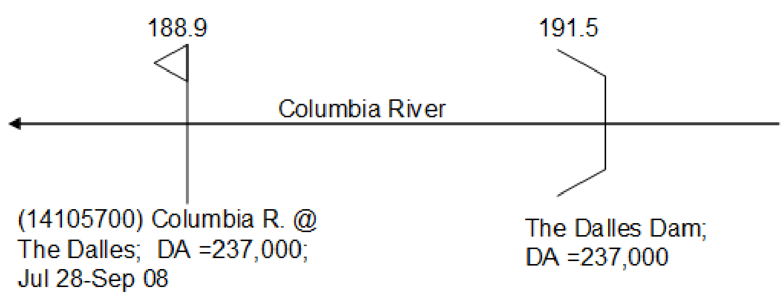
Site	Period	Source	Comments
ROU6H	07/01/1928 - 09/30/2018	USGS 14092500	Observed flow of USGS 14092500 (Deschutes R near Madras)
ROU6S	01/01/1964 - 09/30/1989	1990 Modified Flows	1990 Modified Flows semi-monthly data used as daily data
	10/01/1989 - 09/30/2018	PGE	PGE reservoir elevations and capacity table from USACE to compute daily change of content
ROU6A	07/01/1928 - 09/30/2018	ROU_H + ROU_S	



THE DALLES (TDA)

COLUMBIA RIVER River Mile 192 Drainage Area: 237000 sq. mi

Site	Period	Source	Comments
TDA6H	07/01/1928 - 09/30/2018	USGS 14105700	Observed flow of USGS 14105700 (Columbia River at The Dalles)
TDA6S	11/02/1960 - 09/30/2008	2010 Modified Flows	
	10/01/2008 - 09/30/2018	USACE	Data Submittal
TDA6A	07/01/1928- 09/30/2018	TDA_H + TDA_S	
TDA6L	07/01/1928 - 09/30/2018	USGS 14092500	Observed flow of USGS 14092500 (Deschutes R near Madras)
TDA6ARF	07/01/1928 - 09/30/2018	TDA_L, JDA_ARF	TDA_L plus JDA_ARF routed to TDA



BONNEVILLE (BON)

COLUMBIA RIVER River Mile 146 Drainage Area: 240000 sq. mi

Site	Period	Source	Comments
BON6H	07/01/1928 - 12/31/1960	USGS 14105700 + BON_L	Sum of the observed or extended flow of 14105700 (Columbia R at The Dalles) plus BON6L
	01/01/1961 - 09/30/2018	USACE Dataquery	Flow data from USACE Dataquery
BON6S	10/01/1999 - 09/30/2018	USACE Dataquery	Elevation data from USACE Dataquery
BON6A	07/01/1928 - 09/30/2018	BON_H + BON_S	
BON6L	07/01/1928 - 12/31/1960	USGS 14113000 & 14120000 & 14123500 & 14125500 & 14128500	Sum of the observed flow of 14113000 (Klickitat River near Pitt)[1] plus 14120000 (Hood River at Tucker Bridge)[2] plus 14123500 (White Salmon River near Underwood)[3] plus 14125500 (Little White Salmon River near Cook)[4] plus 14128500 (Wind River near Carson)[5]. No indexing done to this computation of the local.
	01/01/1961 - 09/30/2018	BON_A and TDA_H	BON_A minus TDA_H routed to BON. Index the resulting local to the sum of flow from USGS 14113000 (Klickitat near Pitt) and 14120000 (Hood River at Tucker Bridge) using a ratio of the monthly cumulative local flow to the cumulative monthly USGS flow
BON6ARF	07/01/1928 - 09/30/2018	BON_L and MCN_ARF	BON_L plus MCN_ARF routed to BON

Footnote 1 – Estimation of missing streamflow record at the Klickitat River near Pitt.
Only the first few months of the streamflow record are missing at the Klickitat River near Pitt (14113000) and they are estimated from flow measured at White Salmon River near Underwood (14123500) in the adjacent White Salmon drainage.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	1.91	1.99	1.90	1.93	1.89	1.68	1.40	1.07	0.951	1.06	1.06	1.48
b	-732.	-781.	-642.	-616.	-406.	-207.	-82.5	81.5	147.	91.7	94.6	-279.

14113000 = a * 14123500 + b

Periods Estimated	
Start Date	**End Date**
07/01/1928	09/30/1928

Footnote 2 – Estimation of missing streamflow record at the Hood River at Tucker Bridge.
Two different gages are used to estimate streamflow at 14120000 (Hood River at Tucker Bridge) before the gage was installed in 1965. Between July 1928 and September 1964 streamflow from the downstream gage, 14121001 (Hood River + PPEL Conduit near Hood River) is used directly to estimate streamflow for the Tucker Bridge location. During the three and a half months prior to installation of 14120000, streamflow is estimated from the upstream gage, 14118500 (West Fk Hood River near Dee). The linear coefficients are:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	1.53	1.62	1.63	1.57	1.74	1.83	2.37	2.34	1.65	1.21	1.43	1.63
b	226.	190.	164.	155.	60.3	66.7	-54.8	-37.2	76.9	163.	119.	73.0

14120000 = a * 14118500 + b

Periods Estimated	
Start Date	**End Date**
09/30/1964	01/15/1965

Footnote 3 – Estimation of missing streamflow record at the White Salmon River near Underwood.
The White Salmon near Underwood (14123500) gage has a relatively complete record. There is five-year period in the early 1930's where stream flow records are missing. The missing record is estimated from a gage in the adjacent watershed, the Klickitat River near Pitt (14113000). The linear coefficients are:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	0.453	0.443	0.46	0.415	0.44	0.513	0.624	0.775	0.808	0.797	0.83	0.563
b	515.	527.	489.	559.	437.	283.	165.	55.0	24.6	23.7	20.9	349.

14123500 = a * 14113000 + b

Periods Estimated	
Start Date	**End Date**
09/30/1960	08/31/1935

Footnote 4 – Estimation of missing streamflow record at the Little White Salmon River near Cook.
The Little White Salmon River near Cook (14125500) was established in October 1956. Streamflow prior to this period are estimated from records collected at a number of different gages. Starting from the beginning of the record, the White Salmon River near Underwood (14123500) is used to estimate 14125500 during two different periods. The linear coefficients are:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	0.557	0.606	0.581	0.501	0.255	0.271	0.386	0.411	0.276	0.362	0.644	0.64
b	98.2	-34.1	-70.5	-40.4	170.	135.	22.1	-53.6	-14.3	-86.7	-232.	-58.1

14125500 = a * 14123500 + b

Periods Estimated	
Start Date	**End Date**
07/01/1928	09/29/1930
09/01/1935	11/30/1944

The more distant Klickitat River near Pitt (14113000) is used to estimate 14125500 during the early 1930's when streamflow records at 14123500 were not collects. The linear coefficients are:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	0.206	0.29	0.312	0.244	0.109	0.122	0.223	0.311	0.245	0.321	0.527	0.346
b	534.	318.	157.	176.	291.	235.	100.	-31.0	-29.0	-105.	-208.	219.

14125500 = a * 14113000 + b

Periods Estimated	
Start Date	**End Date**
09/30/1930	08/31/1935

The upstream gage, Little White Salmon River at Willard (14124500) is used to estimate 14125500 during the late 1940's. The linear coefficients are:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	1.09	1.04	1.14	1.13	1.08	1.05	1.01	1.06	1.08	1.11	1.16	1.14
b	115.	187.	145.	124.	127.	118.	115.	103.	106.	103.	96.1	102.

14125500 = a * 14124500 + b

Periods Estimated	
Start Date	**End Date**
12/01/1944	08/31/1949

Another upstream gage, Little White Salmon River above Lapham Ck (14125000) is used to estimate 14125500 during the early 1950's. The linear coefficients are:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	0.953	1.02	1.06	0.983	0.977	0.967	0.961	0.988	0.991	0.991	1.05	0.999
b	67.4	34.6	45.3	81.0	68.6	53.9	52.6	42.1	46.6	47.3	30.5	45.0

14125500 = a * 14125000 + b

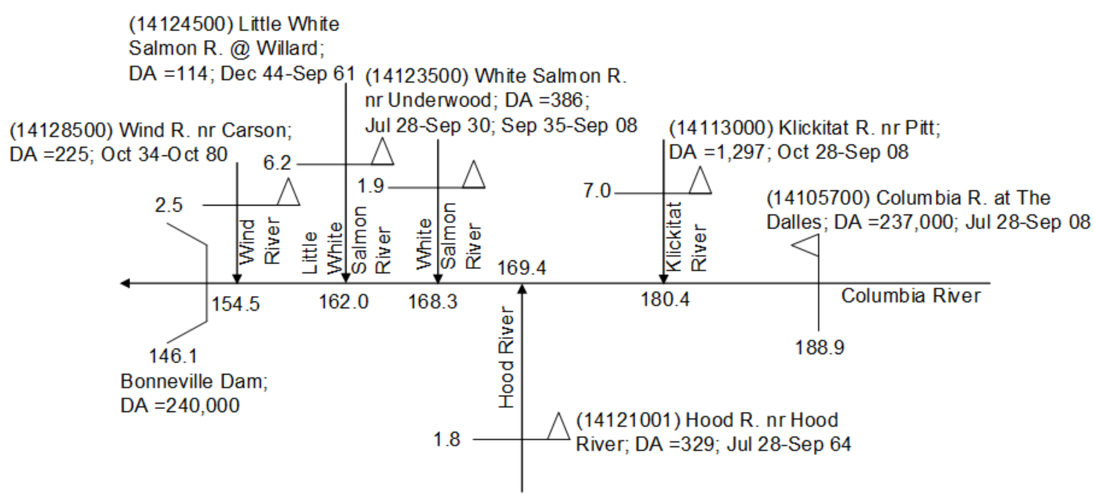
Periods Estimated	
Start Date	**End Date**
09/01/1949	09/30/1956

Footnote 5 – Estimation of missing streamflow record at Wind River near Carson.
The Wind River near Carson (14128500) was established in December 1934. Streamflow prior to this period are estimated from records from the Hood River + PPEL Conduit near Hood River (14121001) gage. The linear coefficients are:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	1.38	1.39	1.58	1.32	1.05	0.795	0.546	0.326	0.465	1.37	1.47	1.20
b	-143.	-224.	-521.	-261.	-184.	-85.7	30.1	104.	28.9	-399.	-288.	159.

14128500 = a * 14121001 + b

Periods Estimated	
Start Date	**End Date**
07/01/1928	12/15/1934



Willamette Basin (Section 3.7)

HILLS CREEK (HCR)

MF WILLAMETTE RIVER | River Mile 233 | Drainage Area: 392 Sq. mi.

Site	Period	Source	Comments
HCR6H	07/01/1928 – 09/30/1935	USGS 14148000	Linear correlation of 14145500 (MF Willamette R above Salt Cr near Oakridge) and 14148000 (MF Willamette R below NF near Oakridge) with daily shape of USGS 14148000.[1]
	10/01/1935 - 09/30/2008	USGS 14145500	Observed flow of 14145500 (MF Willamette R above Salt Creek near Oakridge)
	10/01/2008- 09/30/2018	USACE Submittal	

Footnote 1 – Estimation of missing streamflow record at MF Willamette River above Salt Creek near Oakridge.

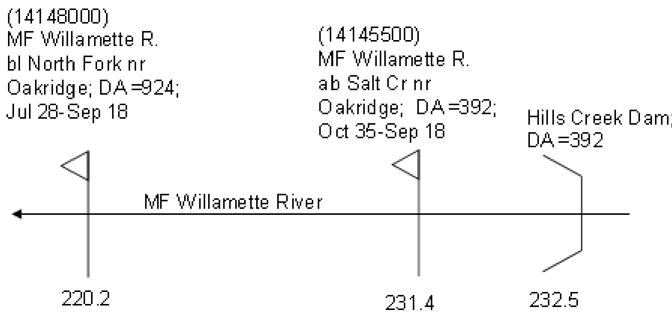
The MF Willamette River above Salt Creek near Oakridge gage (14144500) was established in October 1935. Streamflow prior to this period are estimated from records from the MF Willamette R below NF near Oakridge (14148000) The linear coefficients are:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	0.44	0.42	0.41	0.42	0.40	0.40	0.44	0.38	0.35	0.43	0.43	0.43
b	-122	-85	-93	-136	-2	18	-42	21	47	-46	-107	-136

14145500 = a * 1448000 + b

Site	Period	Source	Comments
HCR6S	08/30/1961 - 09/30/1965	USGS 14145100	Reservoir elevations USGS 14145100 and USACE capacity table
	10/01/1965 - 09/30/1974	USGS 14145100	Reservoir content from USGS 14145100
	10/01/1974 - 09/30/1999	USGS 14145100	Reservoir elevations USGS 14145100 and USACE capacity table
	10/01/1999 - 09/30/2008	USACE Data query	Reservoir elevations USACE Data query and USACE capacity table
	10/01/2008- 09/30/2018	USACE Submittal	

Site	Period	Source	Comments
HCR6A	07/01/1928 - 09/30/2008		HCR_H + HCR_S
	10/01/2008- 09/30/2018	USACE Submittal	


(14148000)
MF Willamette R.
bl North Fork nr
Oakridge; DA =924;
Jul 28-Sep 18
(14145500)
MF Willamette R.
ab Salt Cr nr
Oakridge; DA =392;
Oct 35-Sep 18
Hills Creek Dam;
DA =392
MF Willamette River
220.2
231.4
232.5

LOOKOUT POINT (LOP)
DEXTER (DEX)

MF WILLAMETTE RIVER River Mile 207 Drainage Area: 991 Sq. mi.
MF WILLAMETTE RIVER River Mile 204 Drainage Area: 1000 Sq. mi.

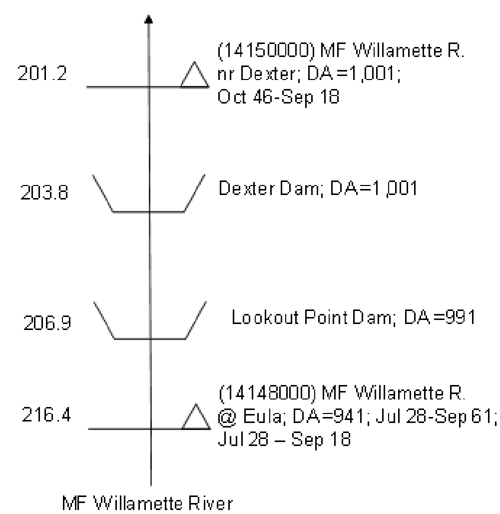
Site	Period	Source	Comments
LOP6H	07/01/1928 – 09/30/1946	USGS 14148000 USGS 1415000	Linear correlation of 1415000 (MF Willamette R near Dexter) and 14148000 (MF Willamette R below NF near Oakridge)[2]
	10/01/1946 - 09/30/2008	USGS 14150000	Observed flow of USGS 14150000 (MF Willamette R near Dexter)
	10/01/2008-09/30/2018	USACE Submittal	

Footnote 2 – Estimation of missing streamflow record at MF Willamette River near Dexter. The MF Willamette River near Dexter gage (14150000) was established in October 1946. Streamflow prior to this period are estimated from records from the MF Willamette R below NF near Oakridge (14148000) The linear coefficients are:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	1.06	1.1	1.15	1.05	1.08	1.08	1.10	1.08	0.98	1.07	1.12	1.11
b	127	1.3	-216	66	-98	-67	-87	-45	33	-27	-103	-108

Site	Period	Source	Comments
LOP6S	11/07/1953 - 09/30/1961	USGS 141490000	Observed reservoir content of USGS 14149000
	10/01/1961 - 09/30/1974	USGS 14149000	Reservoir content scanned from USGS paper publications
	10/01/1974 - 09/30/1999	USGS 14149000	USGS reservoir elevations and USACE capacity table.
	10/01/1999 - 09/30/2008	USACE Data query	Reservoir elevations USACE Data query and capacity table
	10/01/2008-09/30/2018	USACE Submittal	

Site	Period	Source	Comments
LOP6A	07/01/1928 - 09/30/2008		LOP_H + LOP_S
	10/01/2008- 09/30/2018	USACE Submittal	
Site	**Period**	**Source**	**Comments**
LOP6L	10/01/1960 - 09/30/2018		LOP_A – routed HCR_A flows
LOP6ARF	07/01/1928- 09/30/2018	SSARROUTE in CHPS	Unregulated daily flows derived using SSARR routing



Note: USGS 14148000 published as MF Willamette at Eula, 1928-1950 and MF Willamette below North Fork at Oakridge after 1950.

FALL CREEK (FAL)

FALL CREEK RIVER — River Mile 7 — Drainage Area: 186 Sq. mi.

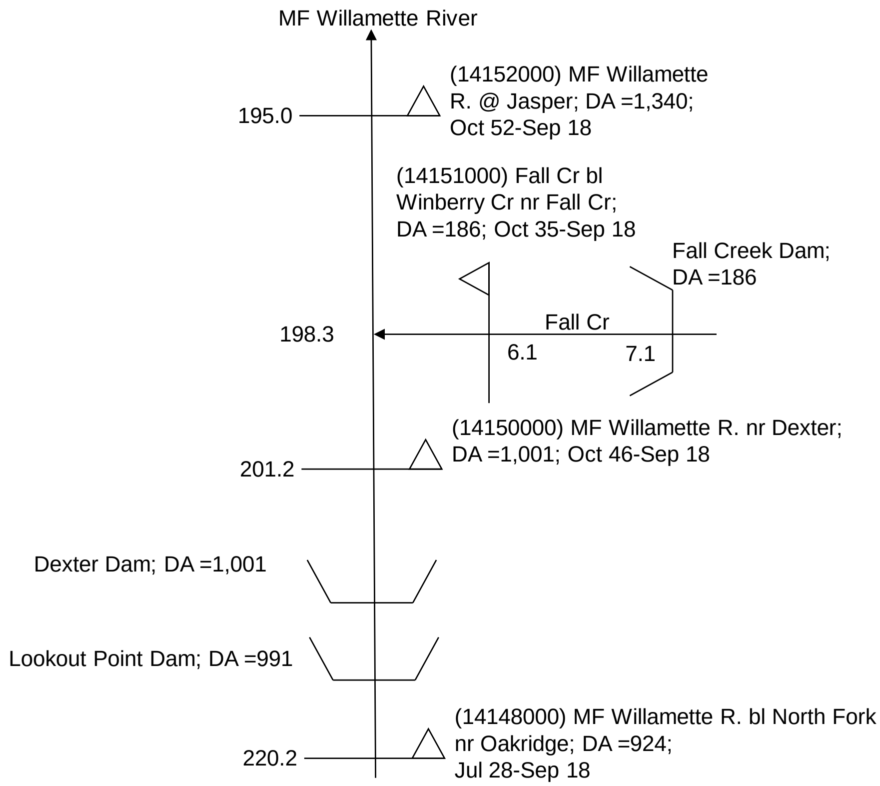
Site	Period	Source	Comments
FAL6H	07/01/1928 – 09/30/1935	USGS 14148000 USGS 1415100	Linear correlation between USGS 14148000 (MF Willamette R. below North Fork at Oakridge, and USGS 14151000 (Fall Creek below Winberry Creek)[3]
	10/01/1935 - 09/30/2008	USGS 14151000	Observed flow of 14151000 (Fall Creek below Winberry Creek)
	10/01/2008-09/30/2018	USACE Submittal	

Footnote 3 – Estimation of missing streamflow record at Fall Creek below Winberry Creek. The Fall Creek below Winberry Creek gage (14150000) was established in October 1935. Streamflow prior to this period are estimated from records from the MF Willamette R below NF near Oakridge (14148000) The linear coefficients are:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	0.28	0.28	0.31	0.22	0.17	0.13	0.09	0.06	0.09	0.25	0.28	0.26
b	-112	-100	-126	-130	-170	-59	-18	-2	-22	-111	-74	-40

Site	Period	Source	Comments
FAL6S	01/04/1966 - 09/30/1974	USGS 14150900	Observed reservoir content of USGS 14150900
	10/01/1974 - 09/30/1999	USGS 14150900	Observed reservoir elevations USGS 14150900 and USACE capacity table
	10/01/1999 - 09/30/2008	USACE Data query	Reservoir elevations USACE Data query and capacity table
	10/01/2008-09/30/2018	USACE Submittal	

Site	Period	Source	Comments
FAL6A	07/01/1928 - 09/30/2008		FAL_H + FAL_S
	10/01/2008-09/30/2018	USACE Submittal	



Note: USGS 14148000 published as MF Willamette at Eula, 1928-1950 and MF Willamette below North Fork at Oakridge after 1950.

COTTAGE GROVE (COT)

COAST FORK WILLAMETTE RIVER River Mile 30 Drainage Area: 104 Sq. mi.

Site	Period	Source	Comments
COT6H	06/23/1928 – 12/31/1938	USGS 14153500 & USGS 14157000	Linear correlation between USGS 14153500 (Coast Fork Willamette River below Cottage Grove) and USGS 14157000 (Coast Fork Willamette River at Saginaw)[4]
	01/01/1939 - 09/30/2008	USGS 14153500	Observed flow of 14153500 (Coast Fork Willamette River below Cottage Grove)
	10/01/2008- 09/30/2018	USACE Submittal	

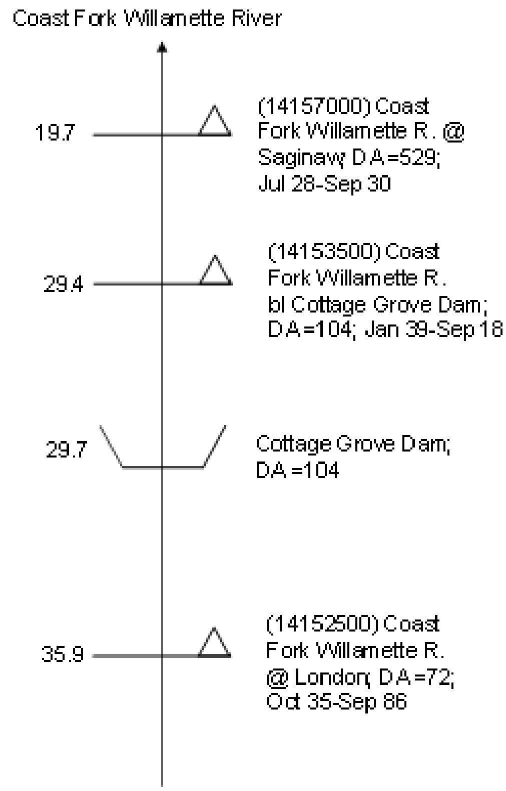
Footnote 4 – Estimation of missing streamflow record at Coast Fork Willamette River below Cottage Grove.

The Coast Fork Willamette River below Cottage Grove gage (14153500) was established in January 1939. Streamflow prior to this period are estimated from records from Coast Fork Willamette River at Saginaw (14157000) The linear coefficients are:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	0.18	0.18	0.2	0.16	0.14	0.20	0.15	0.27	0.86	0.21	0.14	0.13
b	107	11	-97	-25	31	1.5	17	10	-41	100	82	187

Site	Period	Source	Comments
COT6S	10/01/1942 - 09/30/1974	USGS 14153000	Scanned reservoir content from USGS paper records (electronic data not available)
	10/01/1974 - 09/30/1999	USGS 14153000	Observed reservoir elevations USGS 14153000 and USACE capacity table
	10/01/1999 - 09/30/2008	USACE Data query	Reservoir elevations USACE Data query and USACE capacity table
	10/01/2008- 09/30/2018	USACE Submittal	

Site	Period	Source	Comments
COT6A	07/01/1928 - 09/30/2008		COT_H + COT_S
	10/01/2008- 09/30/2018	USACE Submittal	


Coast Fork Willamette River
19.7
(14157000) Coast
Fork Willamette R. @
Saginaw; DA=529;
Jul 28-Sep 30
29.4
(14153500) Coast
Fork Willamette R.
bl Cottage Grove Dam;
DA=104; Jan 39-Sep 18
29.7
Cottage Grove Dam;
DA=104
35.9
(14152500) Coast
Fork Willamette R.
@ London; DA=72;
Oct 35-Sep 86

DORENA (DOR)

ROW RIVER River Mile 8 Drainage Area: 270 Sq. mi.

Site	Period	Source	Comments
DOR6H	06/23/1928 – 12/31/1938	USGS 14155500 & USGS 14157000	Linear correlation between USGS 14155500 (Row River Near Cottage Grove) and USGS 14157000 (Coast Fork Willamette R at Saginaw)[5]
	01/01/1939 - 09/30/2008	USGS 14155500	USGS 14154500 (Row River above Pitcher Creek near Dorena)
	10/01/2008- 09/30/2018	USACE Submittal	

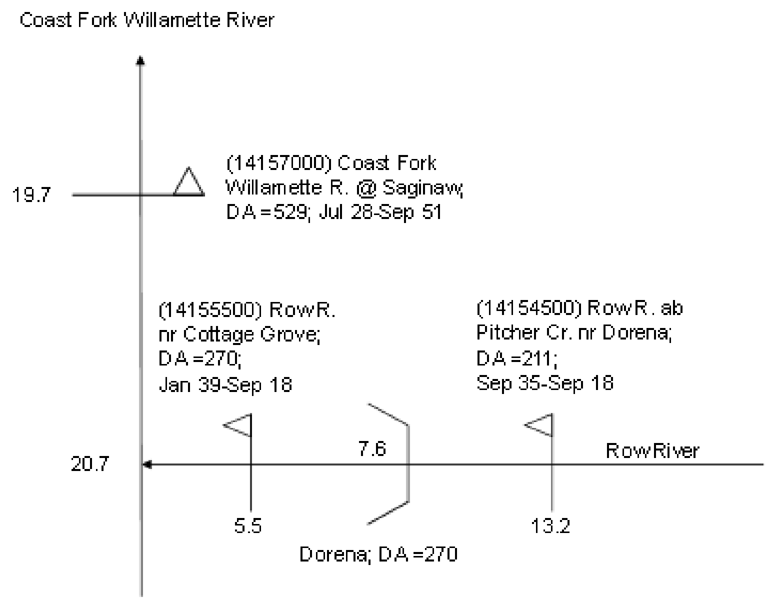
Footnote 5 – Estimation of missing streamflow record at Coast Fork Willamette River below Cottage Grove.

The Row River near Cottage Grove gage (14155500) was established in January 1939. Streamflow prior to this period are estimated from records from Coast Fork Willamette River at Saginaw (14157000) The linear coefficients are:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	0.42	0.38	0.41	0.48	0.50	0.49	0.46	0.38	0.07	0.38	0.45	0.46
b	-45	60	127	49	39	2.1	-3.2	1.2	27	-19	-8.8	-66

Site	Period	Source	Comments
DOR6S	10/01/1949 - 09/30/1999	USGS 14155000	Observed USGS 14155000 reservoir elevations and USACE capacity table
	10/01/1999 - 09/30/2008	USACE Data query	Reservoir elevations USACE Data query and capacity table
	10/01/2008- 09/30/2018	USACE Submittal	

Site	Period	Source	Comments
DOR6A	07/01/1928 - 09/30/2008		DOR_H + DOR_S
	10/01/2008- 09/30/2018	USACE Submittal	


Coast Fork Willamette River
19.7
(14157000) Coast Fork
Willamette R. @ Saginaw;
DA =529; Jul 28-Sep 51
(14155500) RowR.
nr Cottage Grove;
DA =270;
Jan 39-Sep 18
(14154500) RowR. ab
Pitcher Cr. nr Dorena;
DA =211;
Sep 35-Sep 18
20.7
7.6
RowRiver
5.5
13.2
Dorena; DA =270

CARMEN DIVERSION INFLOW (CAR)

MCKENZIE RIVER | River Mile 88 | Drainage Area: 146 Sq. mi.

Site	Period	Source	Comments
CAR6H	06/23/1928 – 09/30/1947	USGS 14158700 & USGS 14159000	Estimated using linear correlation of 14158700 (McKenzie River near Belknap Springs) with 14159000 (McKenzie River at McKenzie Bridge)[6]
	10/01/1947 - 09/30/1957	USGS 14158500	Estimated using linear correlation of 14158700 (McKenzie R near Belknap Springs) with 14158500 (McKenzie River at Outlet of Clear Lake)[6]
	10/01/1957 - 09/29/1962	USGS 14158700 & USGS 14158700	Observed flow of 14158700 (McKenzie River near Belknap Springs)
	10/01/1962- 09/30/2018	USGS 14158700 & USGS 14158500	Estimated using linear correlation of 14158700 (McKenzie R near Belknap Springs) with 14158500 (McKenzie River at Outlet of Clear Lake)[6]

Footnote 6 – Estimation of missing streamflow record at McKenzie River near Belknap Springs.
June 1928 – September 1947 - The McKenzie River at Belknap Springs gage (14158700) has a a relatively short record from 1957 to 1962. We have developed estimates of it across the period using a series of nearby gages. Streamflow from this period is estimated using records from McKenzie River at McKenzie Bridge (14159000). The linear coefficients are:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	0.27	0.31	0.23	0.34	0.35	0.44	0.44	0.46	0.19	0.22	0.23	0.16
b	134	87	184	104	118	-60	-68	-97	278	166	165	340

October 1947 – September 1957 - The McKenzie River at Belknap Springs gage (14158700) has a relatively short record from 1957 to 1962. Streamflow from this period is estimated using records from McKenzie River at Outlet of Clear Lake (14158500). The linear coefficients are:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	1.98	1.12	0.94	1.03	1.08	1.0	0.86	.0.78	0.57	0.93	1.08	1.0
b	180	111	199	147	117	178	214	243	286	194	159	175

October 1962 – September 2018 - The McKenzie River at Belknap Springs gage (14158700) has a relatively short record from 1957 to 1962. Streamflow from this period is estimated using records from McKenzie River at Outlet of Clear Lake (14158500). The linear coefficients are:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	1.98	1.12	0.94	1.03	1.08	1.0	0.86	.0.78	0.57	0.93	1.08	1.0
b	180	111	199	147	117	178	214	243	286	194	159	175

Site	Period	Source	Comments
HYD6A	07/01/1928 - 09/30/2018	CAR_H, max 630 cfs	Represents flow in the diversion tunnel shown in the schematic. This tunnel has a 630 cfs max limit. HYD_A = CAR_H < 630 cfs. All CAR_H values greater than 630 are replaced with 630 cfs.

Site	Period	Source	Comments
SMH6A	06/23/1928 – 08/31/1935	USGS 14158790 & USGS 14159000	Estimated using linear correlation of 14158790 (Smith River above Smith Reservoir near Belknap Springs) with 14159000 (McKenzie River at McKenzie Bridge)[7]
	09/01/1935 - 09/30/1957	USGS 14158790 & USGS14162000	Estimated using linear correlation of 14158790 (Smith River above Smith Reservoir near Belknap Springs) with 14162000 (Blue River at near Blue River, OR)[7]
	10/01/1957 – 09/30/1960	USGS 14158800	Observed flow of USGS 14158800 (Smith River Near Belknap Springs) times .70 (based on drainage area)
	10/01/1960 - 09/30/2018	USGS 14158790	Observed flow of USGS 14158790 (Smith R Reservoir near Belknap Springs) times*1.13
C_S6A	07/01/28 - 09/30/08	SMH_A + HYD_A	Carmen Smith Power Plant Inflow represents the power generation flow (shown in schematic) that flows back to the McKenzie River through a penstock and powerhouse.

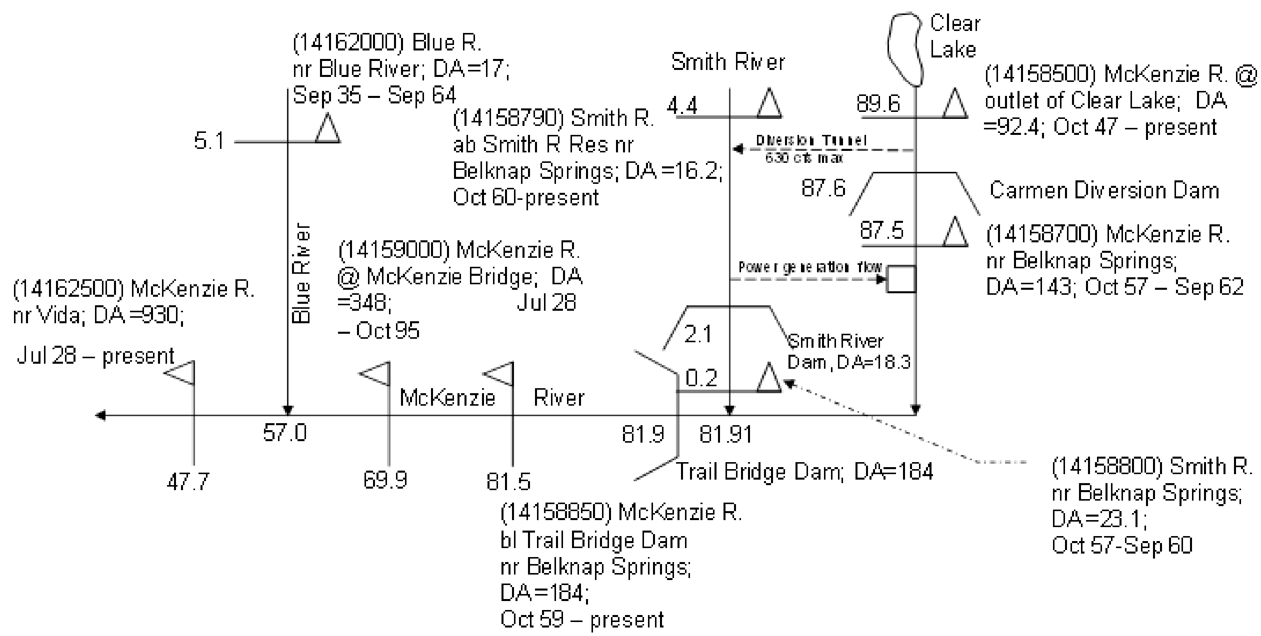
Footnote 7 – Estimation of missing streamflow record at Smith River Reservoir near Belknap Springs.

June 1928 – August 1935 - The Smith River Reservoir near Belknap Springs gage (14158790) has records stating in October 1960. We have developed estimates for the gage across the period using a series of nearby gages. Streamflow from this period is estimated using records from McKenzie River at McKenzie Bridge (14159000). The linear coefficients are:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	0.13	0.14	0.13	0.15	0.17	0.14	0.04	0.01	0.02	0.16	0.18	0.14
b	-149	-155	-144	-162	-183	-162	-40	-3.4	-9.8	-154	-169	-142

September 1935 – September 1957 - Streamflow from this period is estimated using records from Blue River near Blue River (14162000). The linear coefficients are:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	0.18	0.21	0.12	0.24	0.23	0.50	0.29	0.10	0.11	0.26	0.20	0.16
b	9.5	10.4	12.1	20.2	63	-16	-2.1	2.6	2.8	-0.2	15	31


Clear Lake
(14158500) McKenzie R. @ outlet of Clear Lake; DA =92.4; Oct 47 – present
89.6
Diversion Tunnel
630 cfs max
87.6
Carmen Diversion Dam
87.5
(14158700) McKenzie R. nr Belknap Springs; DA=143; Oct 57 – Sep 62
Power generation flow
Smith River
4.4
(14158790) Smith R. ab Smith R Res nr Belknap Springs; DA =16.2; Oct 60-present
2.1
Smith River Dam, DA=18.3
0.2
(14158800) Smith R. nr Belknap Springs; DA=23.1; Oct 57-Sep 60
81.91
81.9
Trail Bridge Dam; DA=184
(14158850) McKenzie R. bl Trail Bridge Dam nr Belknap Springs; DA=184; Oct 59 – present
McKenzie River
81.5
(14159000) McKenzie R. @ McKenzie Bridge; DA =348; Jul 28 – Oct 95
69.9
(14162000) Blue R. nr Blue River; DA=17; Sep 35 – Sep 64
5.1
Blue River
57.0
(14162500) McKenzie R. nr Vida; DA =930; Jul 28 – present
47.7

TRAIL BRIDGE (TRB)

MCKENZIE RIVER | River Mile 82 | Drainage Area: 184 Sq. mi.

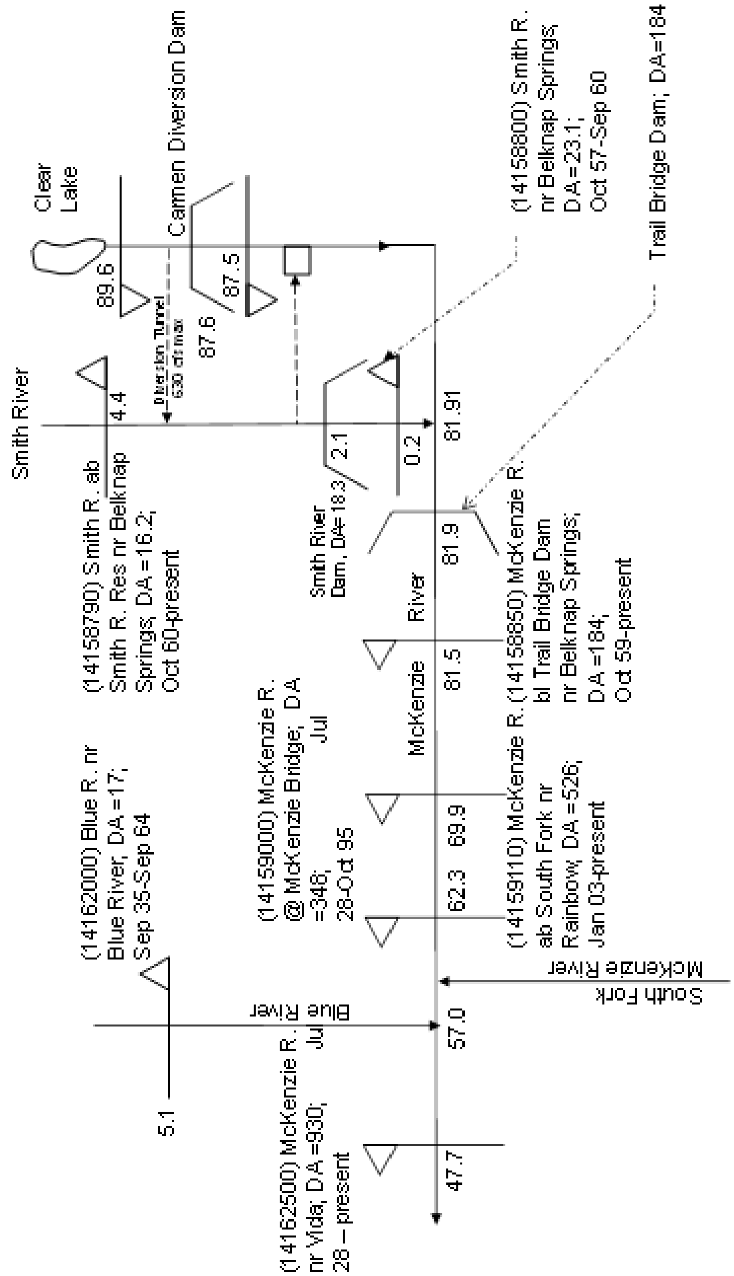
Site	Period	Source	Comments
TRB6H	06/23/1928 – 09/30/1960	USGS 14159000 & USGS 14158500	Linear correlation between USGSS 14159000 (McKenzie River at McKenzie Bridge) and 14158500 (McKenzie River at outlet of Clear Lake, OR)[8]
	10/01/1960 - 09/30/2018	USGS 14158850	Observed flow of 14158850 (McKenzie River at outlet of Clear Lake OR)

Footnote 8 – Estimation of missing streamflow record at McKenzie River at outlet of Clear Lake.

The McKenzie River at outlet of Clear Lake gage (14158850) was established in October 1960. Streamflow prior to this period are estimated from records from McKenzie River at McKenzie Bridge (14159000) The linear coefficients are:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	0.48	0.48	0.53	0.55	0.61	0.65	0.64	0.66	0.66	0.54	0.48	0.51
b	163	176	91	92	18	-57	-62	-63	-66	71	149	120

Site	Period	Source	Comments
TRB6L	06/23/1928 – 09/30/2018		TRB6H – CAR6H
TRB6ARF	07/01/1928 - 09/30/2018	SSARR model	Unregulated daily flows derived by SSARROUTE model using SSARR routing in CHPS



Clear Lake
Carmen Diversion Dam
89.6
87.5
87.6
Diversion Tunnel 630 cfs max
Smith River
4.4
2.1
0.2
81.91
(14158800) Smith R. nr Belknap Springs; DA=23.1; Oct 57-Sep 60
Trail Bridge Dam; DA=184
(14158790) Smith R. ab Smith R. Res nr Belknap Springs; DA=16.2; Oct 60-present
Smith River Dam, DA=18.3
81.9
River
81.5
McKenzie
(14158850) McKenzie R. bl Trail Bridge Dam nr Belknap Springs; DA=184; Oct 59-present
(14159000) McKenzie R. @ McKenzie Bridge; DA =348; Jul 28-Oct 95
69.9
62.3
(14159110) McKenzie R. ab South Fork nr Rainbow, DA=526; Jan 03-present
(14162000) Blue R. nr Blue River, DA=17; Sep 35-Sep 64
South Fork McKenzie River
Blue River
5.1
57.0
(14162500) McKenzie R. nr Vida; DA=930; Jul 28 – present
47.7

COUGAR (CGR)

SF MCKENZIE RIVER | River Mile 5 | Drainage Area: 208 Sq. mi.

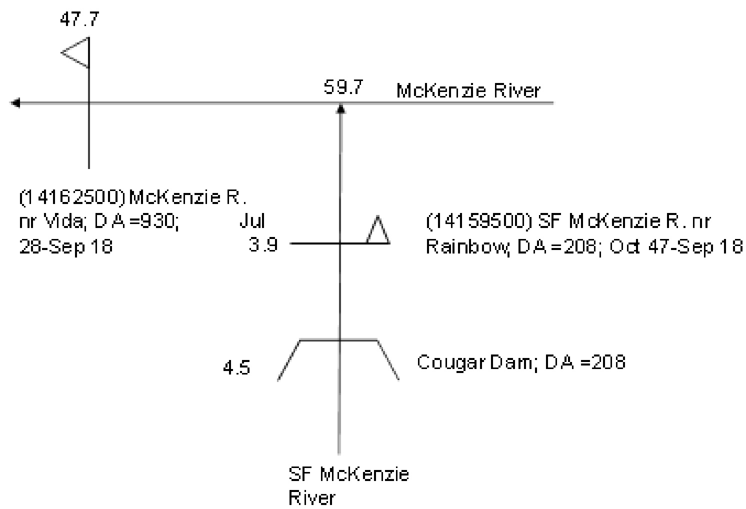
Site	Period	Source	Comments
CGR6H	06/23/1928 – 09/30/1947	USGS 14159500 & USGS 14162500	Linear correlation between USGS 14162500 (McKenzie River near Vida) and USGS 14159500 (SF McKenzie River near Rainbow.[9]
	10/01/1947 - 09/30/2008	USGS 14159500	Observed flow of USGS 14159500 (SF McKenzie River near Rainbow).
	10/01/2008 - 09/30/2018	USACE Submittal	

Footnote 9 – Estimation of missing streamflow record at SF McKenzie River at near Rainbow. The SF McKenzie River near Rainbow gage (14158850) was established in October 1947. Streamflow prior to this period are estimated from records from McKenzie River near Vida (14162500) The linear coefficients are:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	0.27	0.27	0.25	0.31	0.31	0.33	0.20	0.11	0.18	0.27	0.27	0.27
b	-373	-380	-300	-459	-402	-509	-150	56	83	-298	-347	-373

Site	Period	Source	Comments
CGR6S	10/01/1963 - 09/30/1999	USGS 14159400	Observed reservoir elevations and contents USGS 14159400 (Cougar Reservoir near Rainbow, OR) and USACE capacity table.
	10/01/1999 - 09/30/2008	USACE Data query	Reservoir elevations from USACE Data query and capacity table. Table updated in Feb. 2002
	10/01/2008 - 09/30/2018	USACE Submittal	

Site	Period	Source	Comments
CGR6A	07/01/1928 - 09/30/2008		CGR6H+CGR6S
	10/01/2008 - 09/30/2018	USACE Submittal	

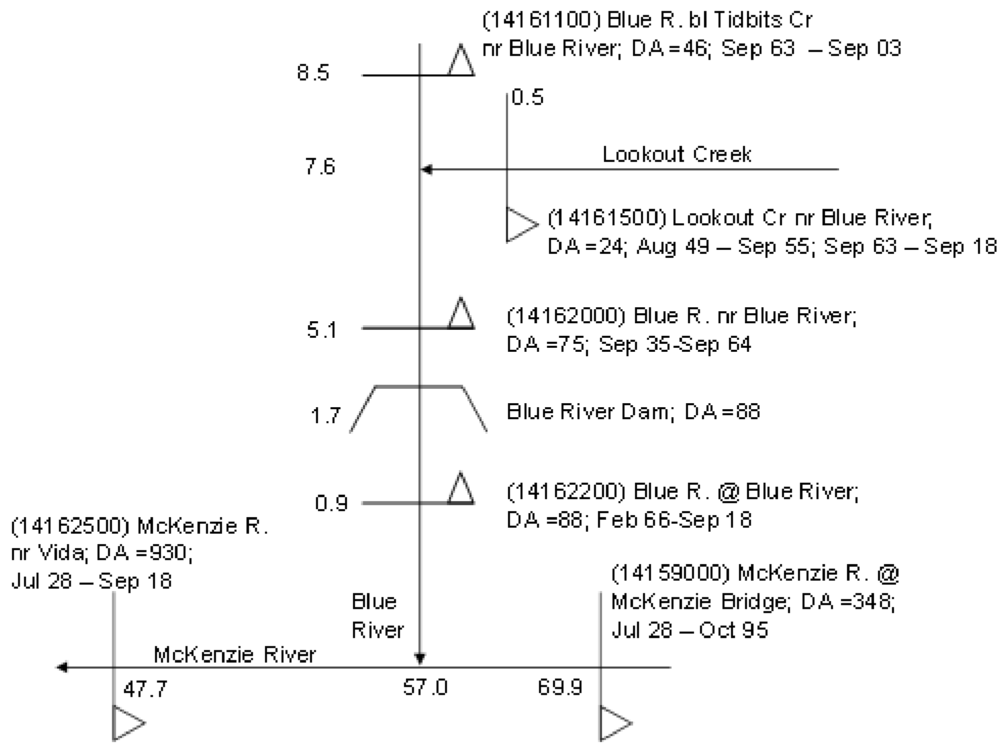


47.7
59.7
McKenzie River
(14162500) McKenzie R.
nr Vida; DA =930; Jul
28-Sep 18
3.9
(14159500) SF McKenzie R. nr
Rainbow; DA =208; Oct 47-Sep 18
4.5
Cougar Dam; DA =208
SF McKenzie
River

BLUE RIVER (BLU)

BLUE RIVER   River Mile 2   Drainage Area: 88 Sq. mi.

Site	**Period**	**Source**	**Comments**
BLU6H	06/23/1928 - 08/31/1935	USGS 14162500 & USGS 1415900	1.173 * (USGS 14162200 (Blue River at Blue River) - 14162500 (McKenzie River near Vida))
	09/01/1935 - 12/31/1964	USGS 14162000	1.173 * USGS 14162000 (Blue River near Blue River)
	01/01/1965 - 09/30/1966	USGS 14161500 & USGS 14161100	1.260 * (USGS 14161100 plus USGS 14161500)
	10/01/1966 - 09/30/2008	USGS 14162200	Observed flow of USGS 14162200 (Blue R at Blue R)
	10/01/2008 - 09/30/2018	USACE Submittal	
BLU6S	10/01/1968 - 09/30/1974	USGS 14162100	Reservoir daily storage scanned from USGS paper records and scanned
	10/01/1974 - 09/30/1999	USGS 14162100	Observed reservoir elevations USGS 14162100 and USACE capacity table.
	10/01/1999 - 09/30/2008	USACE Data query	Reservoir elevations USACE Data query and capacity table
	10/01/2008 – 09/30/2018	USACE Submittal	
BLU6A	07/01/1928 - 09/30/2008		BLU_H + BLU_S
	10-01-2008 - 09/30-2018	USACE Submittal	


(14161100) Blue R. bl Tidbits Cr
nr Blue River; DA =46; Sep 63 – Sep 03
8.5
0.5
Lookout Creek
7.6
(14161500) Lookout Cr nr Blue River,
DA =24; Aug 49 – Sep 55; Sep 63 – Sep 18
5.1
(14162000) Blue R. nr Blue River;
DA =75; Sep 35-Sep 64
1.7
Blue River Dam; DA =88
0.9
(14162200) Blue R. @ Blue River;
DA =88; Feb 66-Sep 18
(14162500) McKenzie R.
nr Vida; DA =930;
Jul 28 – Sep 18
Blue
River
(14159000) McKenzie R. @
McKenzie Bridge; DA =348;
Jul 28 – Oct 95
McKenzie River
47.7
57.0
69.9

LEABURG (LEA)

MCKENZIE RIVER River Mile 39 Drainage Area: 1000 Sq. mi.

Site	Period	Source	Comments
LEA6H	07/01/1928 - 09/30/1951	USGS gages 14162500 & 14163000 & 14159000	USGS 14162500 (McKenzie River near Vida) + 1.47 * USGS 14163000 (Gate Creek at Vida (estimated from 14162500 (McKenzie River near Vida)) – USGS 14159000 (McKenzie River at McKenzie Bridge)[10]
	10/01/1951 - 09/30/1957	USGS gages 14162500 & 14163000	USGS 14162500 (McKenzie R near Vida) + 1.47 * USGS 14163000 (Gate Creek at Vida).
	10/01/1957 – 12/31/1964	USGS gages 14162500 & 14163000	USGS 14162500 + 1.47 * USGS 14163000 (Gate Creek at Vida (estimated from 14152000 (Blue River near Blue River))[10]
	01/10/1965 – 09/30/1966	USGS gages 14162500 & 14163000 & 14159000	USGS 14162500 (McKenzie River near Vida) + 1.47 * (USGS14163000 (Gate Creek at Vida (estimated from USGS 14162500(McKenzie River near Vida) – USGS 14159000 (McKenzie River at McKenzie Bridge))[10]
	10/01/1966 - 09/29/1990	USGS gages 14162500 & 14163000	USGS 14162500 (McKenzie R near Vida) + 1.47 * USGS 14163000 (Gate Creek at Vida)
	09/39/1990 – 09/29/1994	USGS gages 14162500 & 14163000 & 14159000	USGS 14162500 (McKenzie River near Vida) + 1.47 * (USGS14163000 (Gate Creek at Vida (estimated from USGS 14162500 (McKenzie River near Vida)) – USGS 14159000 (McKenzie River at McKenzie Bridge))[10]
	09/30/1994 - 09/30/2018	USGS gages 14162500 & 14161500	USGS 14162500 (McKenzie River near Vida) + 1.47 * (USGS14163000 (Gate Creek at Vida (estimated from USGS 14161500 (Lookout Creek near Blue River)) – USGS 14159000 (McKenzie River at McKenzie Bridge))[10]
LEA6A	07/01/1928 – 09/30/2018		LEA6H (set inflow = outflow
LEA6L	07/01/1928 – 09/30/2018		LEA6A – (routed TRB6H + routed CGR6H + routed BLU6H)
LEA6ARF	07/01/1928 – 09/30/2018		LEA6L + (TRB6ARF + routed CGR6A + routed BLU6A)

Footnote 10 – Estimation of missing streamflow record for Gate Creek at Vida.
July 1928 – September 1951, January 1965 – September 1966 and September 1990 – September 1994 - The McKenzie River at Leaburg is a combination of the McKenzie River near Vida (14162500) The McKenzie River at McKenzie Bridge and Gate Creek at Vida gages (14163000). Gate Creek at Vida has a relatively short record and needs to be estimated using the McKenzie River near Vida gage from 1928 to 1951, 1965 to 1966 and then again from 190 to 1994. The linear coefficients for this period are:

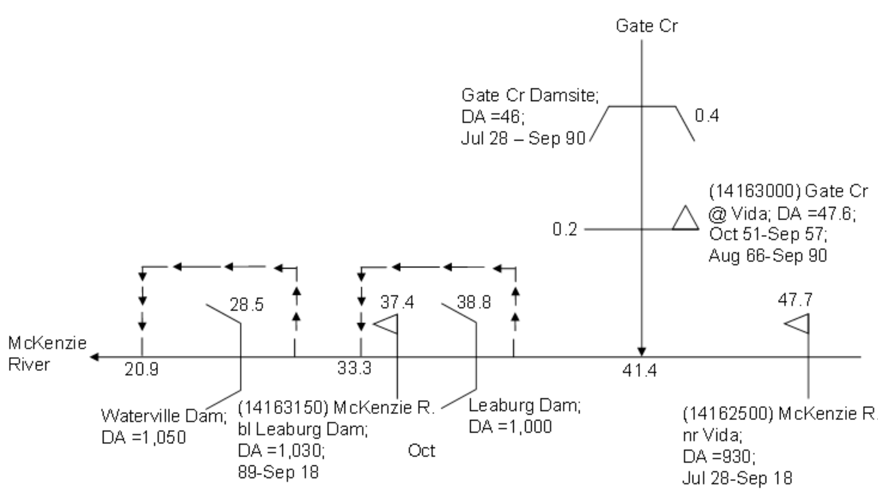
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	0.12	0.11	0.12	0.08	0.05	0.03	0.04	0.05	0.05	0.12	0.12	0.10
b	-39	-19	-14	22	-3.1	19	4.2	-10	-17	-62	44	-39

October 1957 – December 1964 - Gate Creek at Vida needs to be estimated for this period using records from Blue River near Blue River (14152000). The linear coefficients are:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	0.45	0.44	0.47	0.27	0.23	0.15	0.28	0.43	0.27	0.46	0.49	0.43
b	123	133	157	137	49	64	25	11	14	13	9.4	163

January 1994 – September 2018 - Gate Creek at Vida estimated from Lookout Creek near Blue River (USGS 14161500). The linear coefficients are:

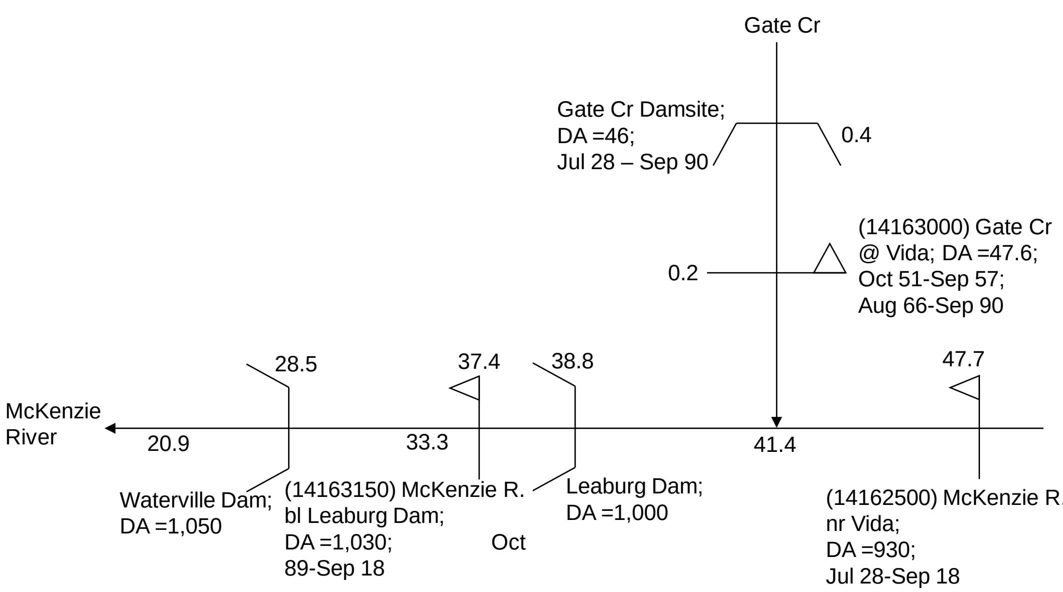
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	1.43	1.45	1.72	1.32	0.65	1.06	1.51	2.34	2.11	1.53	1.61	1.44
b	89	81	42	44	66	19	4.7	-7.5	-3.9	7.6	18	76



WALTERVILLE (WAV)

MCKENZIE RIVER | River Mile 29 | Drainage Area: 1050 Sq. mi.

Site	Period	Source	Comments
WAV6H	07/01/1928 - 09/30/2018	LEA_H	1.05 * LEA_H
WAV6A	07/01/1928 - 09/30/2018	WAV6H	No storage. Set inflow to outflow
WAV6L	07/01/1928 - 09/30/2018		WAV6A – LEA6H (essentially equal to 0.05 LEA6H)
WAV6ARF	07/01/1928 - 09/30/2018		WAV6L + LEA6ARF



FERN RIDGE (FRN)

LONG TOM RIVER | River Mile 26 | Drainage Area: 252 Sq. mi.

Site	Period	Source	Comments
FRN6H	06/23/1928 – 09/30/1939	USGS 14169001 & USGS 14170000	Linear correlation of USGS 141690001 (Long Tom River + Diversion to Coyote Creek near Alvadore) with USGS 14170000 (Long Tom R. at Monroe)[11]
	10/01/1939 - 09/30/1954	USGS 14169000	Observed flow of USGS 14169000 (Long Tom R near Alvadore)
	10/01/1954 - 09/30/1985	USGS 14169001	Observed flow of 14169001 (Long Tom River near Alavadore plus diversion to Coyote Cr)
	10/01/1985 - 09/30/2008	USGS 14169000	Observed flow of 14169000 (Long Tom River near Alavadore) plus 7 cfs diversion to Coyote Cr.
	10/01/2008 - 09/30/2018	USACE Submittal	

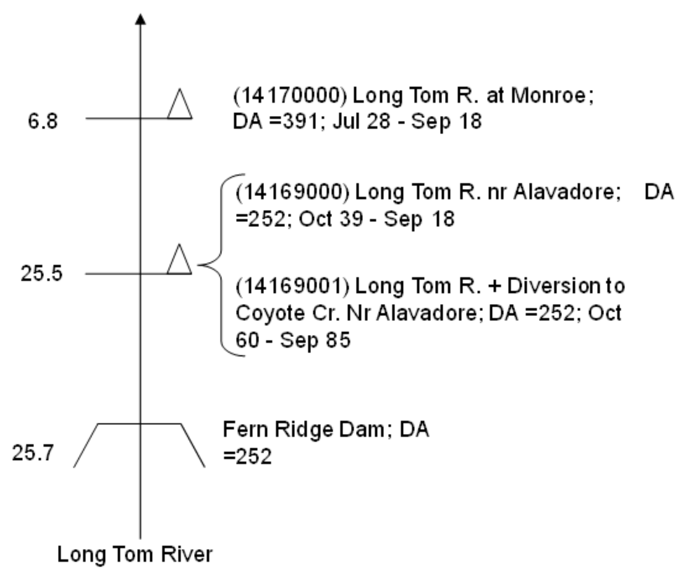
Footnote 11 – Estimation of missing streamflow record at Long Tom River plus diversion to Coyote Creek near Alvadore.

The Long Tom River plus diversion to Coyote Creek near Alvadore gage (14169001) was established in October 1954. Streamflow prior to this period are estimated from records from Long Tom River at Monroe (14170000) The linear coefficients are:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	0.67	0.70	0.65	0.71	0.72	0.08	0.49	1.01	0.94	0.94	0.68	0.65
b	-53	-158	-131	-85	-18	5.0	29	11	7.0	18	80	9.7

Site	Period	Source	Comments
FRN6S	11/15/1941 - 09/30/1974	USGS 14168000	USGS 14168000 observed change of content from USGS electronic & paper records.
	10/01/1974 - 09/30/1999	USGS 14168000	USGS 14168000 observed reservoir elevation data and USACE capacity table
	10/01/1999 - 09/30/2008	USACE Data query	Reservoir elevations USACE Data query and USACE capacity table
	10/01/2008 - 09/30/2018	USACE Submittal	

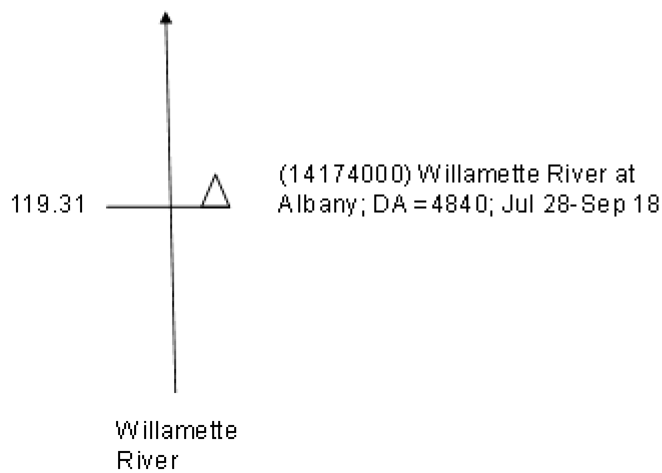
Site	Period	Source	Comments
FRN6A	07/01/1928 - 09/30/2008		FRN_H + FRN_S
	10/01/2008 - 09/30/2018	USACE Submittal	



ALBANY (ALB)

WILLAMETTE RIVER River Mile 119 Drainage Area: 4840 Sq. mi.

Site	Period	Source	Comments
ALB6H	07/01/1928 - 09/30/2018	USGS 14174000	Daily values from USGS 14174000 (Willamette River at Albany)
ALB6L	07/01/1928 - 09/30/2018		ALB_H – routed CORO_H
ALB6ARF	07/01/1928 - 09/30/2018	SSARR model	Unregulated daily flows derived using CHPS system and SSARR routing



DETROIT (DET)
BIG CLIFF (BCL)

N SANTIAM RIVER	River Mile 61	Drainage Area: 438 Sq. mi.
N SANTIAM RIVER	River Mile 58	Drainage Area: 453 Sq. mi.

Site	Period	Source	Comments
DET6H	07/01/1928 - 09/30/1931	USGS 14183000 & USGS 14181500	Linear correlation between USGS 14183000 (N. Santiam R. at Mehama) and USGS 14181500 (North Santiam River at Niagara)[12]
	10/01/1931 - 09/30/1938	USGS 14183000 & USGS 14182500	Relationship between 14183000 (N. Santiam R. at Mehama) minus 14182500 (North Santiam R. near Mehama).
	10/01/1938 - 09/30/2008	USGS 14181500	Observed flow of USGS 1418500 (North Santiam R at Niagara)
	10/01/2008 - 09/30/2018	USACE Submittal	

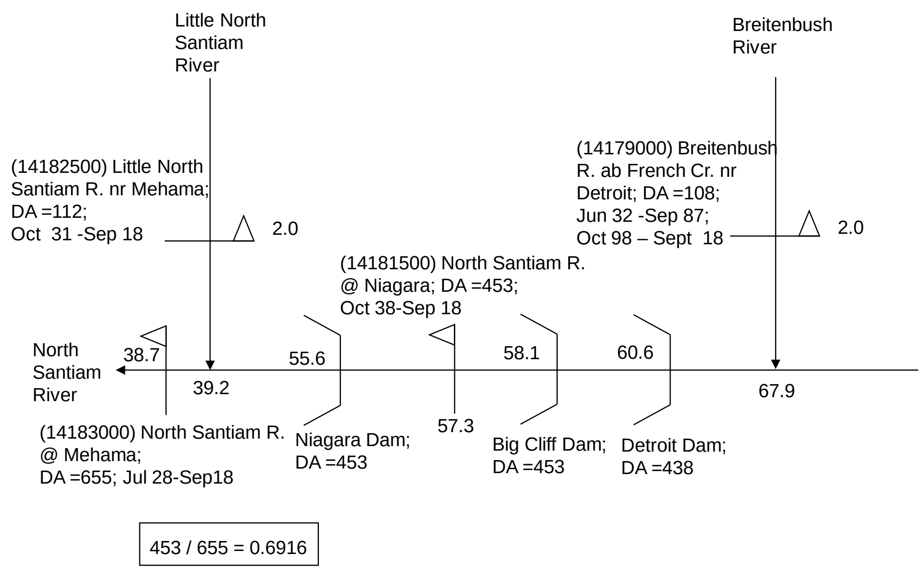
Footnote 12 – Estimation of missing streamflow record at North Santiam River at Niagara.
July 1928 – September 1931 - The North Santiam River at Niagara gage (14169001) was established in October 1938. Streamflow for this period are estimated from records from North Santiam River at Mehama (14183000) The linear coefficients are:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	0.54	0.54	0.55	0.66	0.62	0.72	0.73	0.85	0.49	0.53	0.57	0.58
b	239	290	279	96	377	104	129	28	270	179	83	109

October 1931 – September 1938 – A relationship was developed between N. Santiam R. at Mehama (14183000) minus North Santiam R. near Mehama (14182500). The linear coefficients are:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	0.75	0.76	0.78	0.88	0.82	0.93	0.89	0.94	0.84	0.76	0.80	0.80
b	177	174	113	-69	231	-29	46	4.8	66	132	20	44

Site	Period	Source	Comments
DET6S	01/01/1953 - 09/30/1974	USGS 14180500	Observed content from USGS 14180500 (Detroit Lake near Detroit)
	10/01/1974 - 08/03/2004	USGS 14180500	Observed reservoir elevations USGS 14180500 (Detroit Lake near Detroit) and USACE capacity table
	08/04/2004 - 09/30/2008	USACE Data query	Reservoir elevations USACE Data query and capacity table
	10/01/2008 - 09/30/2018	USACE Submittal	
BCL6S	11/1953	USACE	Initial Fill at Big Cliff Reregulation Reservoir
DET6A	07/01/1928 - 09/30/2008	DET_H + BCL_S + DET_S	
	10/01/2008 - 09/30/2018	USACE Submittal	
BCL_H	07/01/1928 - 09/30/2018		Set equal to DET_A



GREEN PETER (GPR)

M. SANTIAM RIVER | River Mile 6 | Drainage Area: 277 Sq. mi.

Site	Period	Source	Comments
GPR6H	07/01/1928 - 09/30/1931	USGS gages 14186500 & 14187500	Linear correlation between USGS 14187500 (South Santiam River at Waterloo) and USGS 14186500 (Middle Santiam River at mouth near Foster)[13]
	10/01/1931 - 09/30/1947	USGS 14186000	Observed flow of USGS 14186000 (Middle Santiam River near Foster).
	10/01/1947 - 09/30/1950	USGS gages 14186500 & 14187500	Linear correlation between USGS 14187500 (South Santiam River at Waterloo) and USGS 14186500 (Middle Santiam River at mouth near Foster)[13]
	10/01/1950 - 09/30/1966	USGS 14186500	Observed flow of USGS 14186500 (Middle Santiam River at mouth near Foster).
	10/01/1966 – 06/21/1967	USGS gages 14186500 & 14187500 & 14185000	Linear correlation between USGS14186500 (Middle Fork Santiam River) and (USGS 14187500(South Santiam River at Waterloo) minus USGS14185000 (South Santiam River below Cascadia))[14]
	06/22/1967 – 09/30/2018	USASCE Submittal	

Footnote 13 – Estimation of missing streamflow record Middle Santiam River at mouth near Foster.

July 1928 – September 1931 and October 1947 – September 1950- The Middle Santiam River at mouth near Foster gage (14186500) was established in October 1931 and records only go to September 1947. Streamflow for these periods are estimated from records from South Santiam River at Waterloo (14187500) The linear coefficients are:

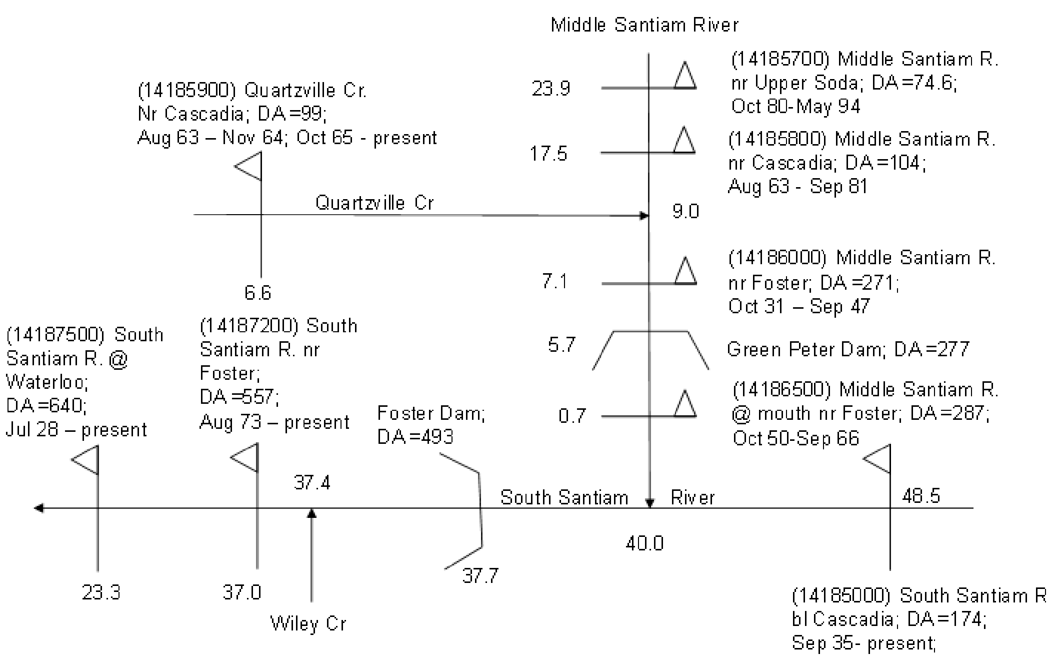
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	0.57	0.55	0.55	0.54	0.54	0.60	0.52	0.55	0.61	0.60	0.57	0.58
b	-210	-157	-103	43	19	-90	15	3.7	-8.1	2.3	-21	-174

Footnote 14 – Estimation of missing streamflow record Middle Fork Santiam River.

October 1966 – June 1967 - Linear correlation between the Middle Fork Santiam River (14186500) and South Santiam River at Waterloo (14187500) minus South Santiam River below Cascadia (14185000) The linear coefficients are:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	0.78	0.76	0.71	0.73	0.75	0.80	0.76	0.71	0.88	0.82	0.78	0.80
b	-240	-194	3.3	107	89	0.4	7.6	16	-12	3.9	-33	-239

Site	Period	Source	Comments
GPR6S	10/30/1966 - 09/30/1999	USGS 14186100	Reservoir contents from USGS publication for Water years 1967-1974. Reservoir elevations from USGS 14186000 for Water years 1975-1999 and USACE capacity table.
	10/01/1999 - 09/30/2008	USACE Data query	Reservoir elevations USACE Data query and capacity table
	10/01/2008 - 09/30/2018	USACE Submittal	
GPR6A	07/01/1928 - 09/30/2018		GPR_H + GPR_S



FOSTER (FOS)

S. SANTIAM RIVER | River Mile 38 | Drainage Area: 493 Sq. mi.

Site	Period	Source	Comments
FOS6H	06/23/1928 - 09/30/1935	USGS gages 14187500 & 14157000	USGS 14187500 (South Santiam at Waterloo) – local flow estimated from USGS 14157000 (Coast Fork Willamette at Saginaw).[15]
	10/01/1935 - 09/30/1966	USGS gages 14172000 & 14187500	USGS 14187500 (South Santiam River at Waterloo) – local flow (estimated from USGS 1417200 (Calapooia River at Holley)[16]
	08/01/1973 - 09/01/1973	USGS gages 14187200 & 14187100 & 14185900	USGS 14187200 (South Santiam R near Foster) minus USGS 14187100 (Wiley Creek at Foster (estimated from USGS 14185900A Quartzville Creek near Cascadia)[17]
	09/02/1973 - 09/30/1988	USGS 14187200 & USGS 14187100	USGS 14187200 (South Santiam R near Foster) minus USGS 14187100 (Wiley Cr. At Foster).
	10/01/1988 - 09/30/2008	USGS 14187200 & USGS 14187000	USGS 14187200 (South Santiam River near Foster) minus USGS 14187000 (Wiley Cr. Near Foster).
	10/01/2008 - 09/30/2018	USACE Submittal	

Footnote 15 – Estimation of missing streamflow local streamflow record near Foster.
July 1928 – September 1935 - The local flow for Foster is estimated from the Coast Fork Willamette at Saginaw (14157000). The linear coefficients are:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	0.20	0.16	0.68	0.12	0.17	0.25	0.25	0.32	0.03	0.21	0.21	0.18
b	139	289	362	234	41	9.9	-24	-5.9	11	28	134	211

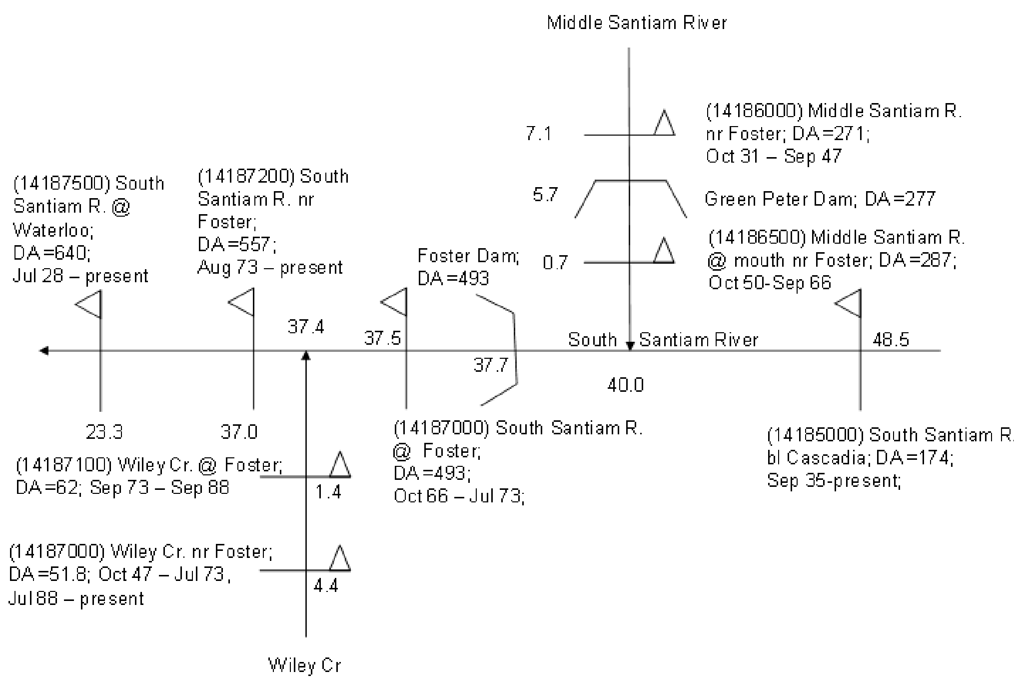
Footnote 16 – Estimation of missing streamflow local streamflow record near Foster.
October 1935 – September 1966 – The local flow for Foster is estimated from the Calapooia River at Holley (1417200). The linear coefficients are:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	0.77	0.67	0.51	0.75	1.00	1.03	1.09	0.86	0.44	0.68	0.78	0.70
b	44	186	268	87	-46	-48	-57	-44	-3.6	22	83	44

Footnote 17 – Estimation of missing streamflow for Wiley Creek near Foster.
October 1935 – September 1966 – Streamflow for these periods are estimated from records Quartzville Creek near Cascadia (14185900) The linear coefficients are:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	0.41	0.38	0.38	0.41	0.21	0.23	0.14	0.22	0.19	0.20	0.31	0.30
b	-2.8	58	77	5.02	71	1.6	9.8	-1.7	4.0	6.3	52	106

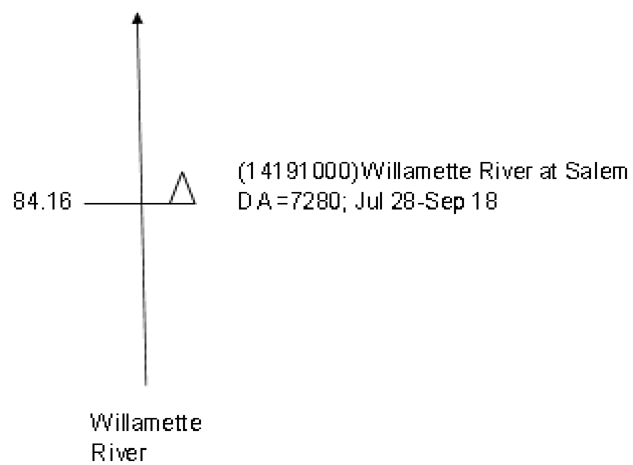
Site	Period	Source	Comments
FOS6S	12/17/1966 - 09/30/1974	USGS 14186600	Observed USGS reservoir contents
	10/01/1974 - 09/30/1999	USGS 14186600	Observed USGS elevations and capacity table FOS.CAP
	10/01/1999 - 09/30/2008	USACE Data query	Reservoir elevations USACE Data query and capacity table
	10/01/2008 - 09/30/2018	USACE Submittal	
FOS6A	06/23/1928 - 09/30/2008		FOS_H + FOS_S
	10/01/2008 - 09/30/2018	USACE Submittal	
FOS6L	06/23/1928 - 09/30/2018		FOS_A – GPR_H
FOS6ARF	07/01/1928 - 09/30/2018		GPR_A + FOS_L



SALEM (SLM)

WILLAMETTE RIVER River Mile 84 Drainage Area: 7280 Sq. mi.

Site	Period	Source	Comments
SLM6H	06/23/1928 - 09/30/2018	USGS 14191000	USGS # 14191000 (Willamette River at Salem)
SLM6ARF	07/01/1928 - 09/30/2008	SSARR model	Unregulated daily flows derived by CHPS system using SSARR routing



T.W. SULLIVAN (SVN)

WILLAMETTE RIVER River Mile 27 Drainage Area: 10100 Sq. mi.

Site	Period	Source	Comments
SVN6H			Streamflow for the entire period of record computed as the **sum** of the following **seven** components:
	07/01/1928 - 09/30/2018	USGS 14191000	1) Willamette River at Salem routed to TW Sullivan
		USGS 14194000	2) South Yamhill River at McMinnville routed to TW Sullivan
	06/23/1928 – 04/30/1934	USGS gages 14194000 & 14305500	Estimated from correlation with USGS 14305500 (Siletz River at Siletz)[18]
	05/01/1934 - 06/30/1940	USGS gages 14194000 & 14192500	Estimated from correlation with USGS 14192500 (South Yamhill River near Willamina)[19]
	07/01/1940 - 09/28/1991	USGS 14194000	USGS 14194000 (South Yamhill River near Whiteson)
	09/29/1991 - 09/28/1993	USGS gages 14194000 & 14192500	Estimated from correlation with USGS 14192500 (South Yamhill River near Willamina)[19]
	09/29/1993 - 09/28/1994	USGS gages 14194000 & 14305500	Estimated from correlation with USGS 14305500 (Siletz River at Siletz)[18]
	10/01/1994 - 09/30/2018	USGS gages 14194000 & 14192500	Estimate from correlation with USGS 14192500 (South Yamhill River near Willamina)[19]

Footnote 18 – Estimation of missing streamflow for South Yamhill River at McMinnville. July 1928 – April 1934 and October 1993 – September 1994 - The South Yamhill River at McMinnville is estimated from the Siletz River at Siletz (14305500). The linear coefficients are:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	0.89	1.19	1.07	1.06	0.78	0.48	0.65	0.21	0.37	0.49	0.59	0.86
b	1540	598	533	146	124	113	-32	18	5.4	22	672	1464

Footnote 19 – Estimation of missing streamflow for South Yamhill River at McMinnville. May 1934 – June 1940, October 1991 – September 1993 and October 1994 – September 2018 – The South Yamhill River at McMinnville is estimated from South Yamhill River near Willamina (14192500). The linear coefficients are:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	2.53	2.49	2.52	2.76	2.43	1.68	1.92	1.78	1.47	1.73	2.19	2.37
b	682	714	394	57	39	79	9.0	3.7	18	33	118	627

Site	Period	Source	Comments
SVN6H (cont)		USGS 14197000	3) USGS 14197000 (N Yamhill River at Pike) routed to TW Sullivan
	06/23/1928 – 05/31/1934	USGS gages 14197000 & 14305500	Estimated from USGS 14305500 (Siletz River at Siletz)[20]
	06/01/1934-09/30/1948	USGS gages 14197000 & 14193000	Estimate from correlation with USGS 14193000 (Willamina Creek near Willamina)[21]
	10/01/1948 – 09/28/1973		USGS 14194000 (South Yamhill River near Whiteson
	09/29/1973 – 09/28/1991	USGS gages 14197000 & 14193000	Estimate from correlation with USGS 14193000 (Willamina Creek near Willamina)[21]
	09/29/1991 – 09/30/2018	USGS gages 14197000 & 14203500	Estimated from correlation with USGS 14203500 (Tualatin River near Dilley)[22]

Footnote 20 – Estimation of missing streamflow for North Yamhill River at Pike.
July 1928 – May 1934 - The North Yamhill River at Pike is estimated from the Siletz River at Siletz (14305500). The linear coefficients are:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	0.15	0.16	0.15	0.12	0.09	0.05	0.05	0.04	0.03	0.06	0.11	0.16
b	76	65	80	54	37	30	9.8	7.1	6.7	-2.7	-9.5	-10.5

Footnote 21 – Estimation of missing streamflow for North Yamhill River at Pike.
June 1928 – September 1948 and October 1973 – September 1991 - The North Yamhill River at Pike is estimated from the Willamina Creek near Willamina (14193000). The linear coefficients are:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	0.86	0.95	0.87	0.87	0.85	0.64	0.83	0.57	0.56	0.73	0.83	0.85
b	30	-15	11.8	-9.9	-3.0	6.6	-5.7	0.15	0.7	-5.2	-5.9	7.8

Footnote 22 – Estimation of missing streamflow for North Yamhill River at Pike.
October 1991 – September 2018 - The North Yamhill River at Pike is estimated from the Tualatin River at Dilley (14203500). The linear coefficients are:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	0.54	0.54	0.51	0.49	0.55	0.58	0.50	0.40	0.60	0.63	0.58	0.50
b	23.1	19.9	45.6	19.4	10.2	6.1	8.5	6.8	3.1	-1.8	27.0	58.1

Site	Period	Source	Comments
SVN6H (cont)		USGS gages 14200000	USGS 14200000 (Molalla River near Canby
	06/23/1928 – 07/31/1928	USGS gages 14200000 & 14208000	Estimated using linear correlation with USGS 14208000 (Clackamas River at Big Bottom)[23]
	08/01/1928 – 09/28/1959		USGS 14200000 (Molalla River near Canby)
	09/29/1959 – 09/30/1963	USGS gages 14200000 & 14198500	Estimated using linear correlation with USGS 14198500 (Molalla River at Wilhoit)[24]
	10/01/1963 – 09/28/1978		USGS 14200000 (Molalla River near Canby)
	09/29/1978 – 09/28/1993	USGS gages 14200000 & 14198500	Estimated using linear correlation with USGS 14198500 (Molalla River at Wilhoit)[24]
	09/29/1993 – 09/30/1997	USGS gages 14200000 & 14202000	Estimated using linear correlation with USGS 14202000 (Pudding River at Aurora)[25]
	10/01/1997 – 09/30/2000	USGS gages 14200000 & 14201340	Estimate using linear correlation with USGS 14201340 (Pudding River near Woodburn)[26]
	10/01/2000 – 09/30/2018		USGS 14200000 (Molalla River near Canby)

Footnote 23 – Estimation of missing streamflow for Molalla River near Canby.
June 1928 – September 1928 - The Molalla River near Canby is estimated from the Clackamas River at Big Bottom (14208000). The linear coefficients are:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	4.15	3.81	4.15	2.87	1.22	1.26	1.28	0.85	1.03	5.83	5.42	3.82
b	-170	-138	-451	-360	208	-33.5	-184	-121	-137	-1235	-889	-97

Footnote 24 – Estimation of missing streamflow for Molalla River near Canby.
October 1959 – September 1963 and October 1978 – September 1993 - The Molalla River near Canby is estimated from the Molalla River at Wilhoit (14198500). The linear coefficients are:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	1.99	1.90	1.95	1.97	1.85	1.91	2.37	1.86	1.65	1.91	2.00	1.98
b	353	346	270	98.2	80.7	45. 8	-34.4	6.2	25.2	25.6	124	244

Footnote 25 – Estimation of missing streamflow for Molalla River near Canby.
October 1993 – September 1997 - The Molalla River near Canby is estimated from the Pudding River at Aurora (14202000). The linear coefficients are:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	0.75	0.70	0.84	0.59	1.32	1.27	1.10	0.97	1.57	0.97	0.78	0.78
b	101	151	142	635	-36	-1.5	32	35	-15	48	254	148

Footnote 26 – Estimation of missing streamflow for Molalla River near Canby.
October 1997 – September 2000 - The Molalla River near Canby is estimated from the Pudding River at Woodburn (14201340). The linear coefficients are:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	1.07	1.08	1.28	0.90	1.83	1.84	1.57	1.86	2.07	1.28	1.20	1.21
b	127	62	34	613	64	32	41	24	7.0	71	180	-22

Site	Period	Source	Comments
SVN6H (cont)		USGS 14202000	USGS 14202000 (Pudding River at Aurora)
	06/23/1928 – 07/31/1928	USGS gages 14202000 & 14208000	Estimated using linear correlation with USGS 14208000 (Clackamas River at Big Bottom)[27]
	08/01/1928 – 09/30/1928	USGS gages 14202000 &1420000	Estimated using linear correlation with USGS 14200000 (Molalla River near Canby)[28]
	10/01/1928 – 09/29/1964		USGS 14202000 (Pudding River At Aurora)
	09/30/1964 – 09/29/1978	USGS gages 14202000 &1420000	Estimated using linear correlation with USGS 14200000 (Molalla River near Canby)[28]
	09/30/1978 – 09/28/1993	USGS gages 14202000 & 14198500	Estimated using linear correlation with USGS 14198500 (Molalla River at Wilhoit)[29]
	09/29/1993 – 09/30/1997		USGS 14202000 (Pudding River At Aurora)
	10/01/1997 – 10/01/2002	USGS gages 14202000 & 14201340	Estimate using linear correlation with USGS 14201340 (Pudding River near Woodburn)[30]
	10/02/2002 – 09/30/2018		USGS 14202000 (Pudding River At Aurora)

Footnote 27 – Estimation of missing streamflow for Pudding River at Aurora.
June 1928 – July 1928 - The Pudding River at Aurora is estimated from the Clackamas River at Big Bottom (14208000). The linear coefficients are:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	3.31	3.16	3.06	2.03	0.38	0.54	0.61	0.18	0.31	3.24	3.39	2.99
b	821	857	524	252	608	131	-38	26	14	-597	-138	626

Footnote 28 – Estimation of missing streamflow for Pudding River at Aurora.
August 1928 – September 1928 and October 1964 – September 1978 - The Pudding River at Aurora is estimated from the Molalla River near Canby (14200000). The linear coefficients are:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	0.81	0.94	0.73	0.97	0.53	0.65	0.75	0.70	0.52	0.80	0.66	0.70
b	1062	607	775	79	275	88	-4.7	-10.1	22	29	468	1036

Footnote 29 – Estimation of missing streamflow for Pudding River at Aurora.

October 1978 – September 1993 - The Pudding River at Aurora is estimated from the Molalla River at Wilhoit (14198500). The linear coefficients are:

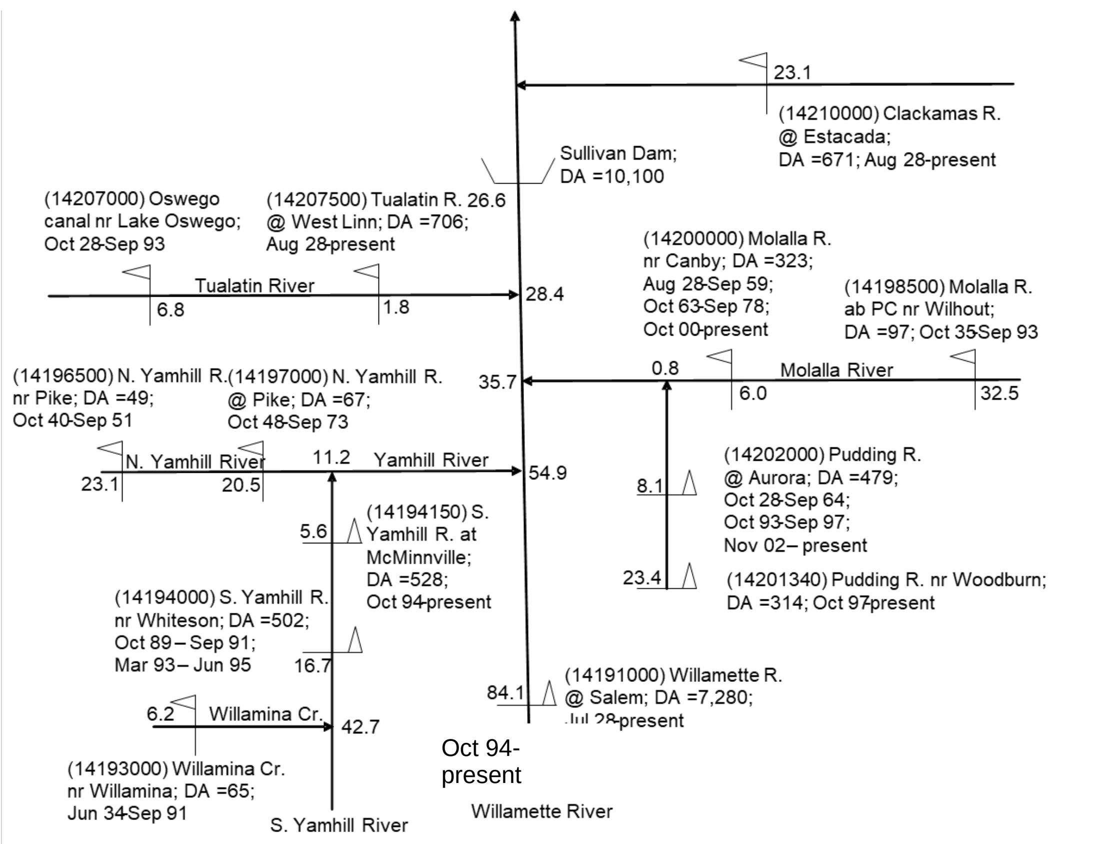
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	1.40	1.34	1.48	1.31	1.12	0.74	1.54	0.89	0.54	0.98	1.10	1.28
b	1439	1549	1011	581	258	189	-9.0	27	57	113	627	1170

Footnote 30 – Estimation of missing streamflow for Pudding River at Aurora.

October 1997 – September 2002 - The Pudding River at Aurora is estimated from the Pudding River near Woodburn (14201340). The linear coefficients are:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	1.41	1.53	1.49	1.47	1.40	1.45	1.49	1.79	1.21	1.28	1.43	1.52
b	90	-89	-41	-0.4	64	19	3.0	-7.3	19	26	-36	-140

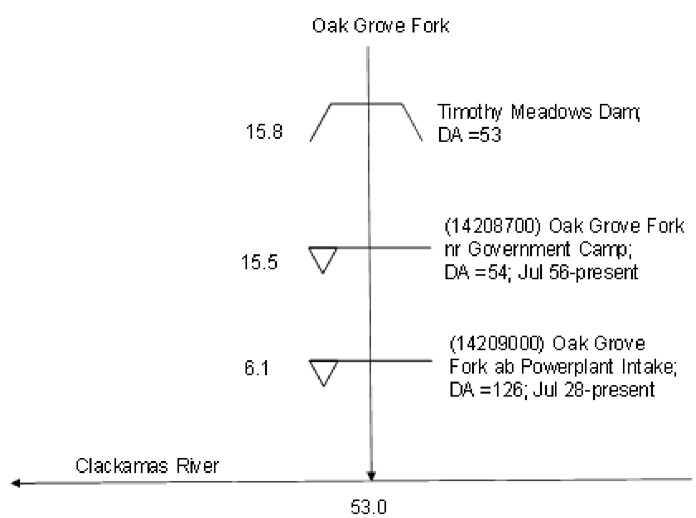
Site	Period	Source	Comments
SVN6H (cont)	06/23/1928 - 09/30/2018	USGS 14207500	USGS 14207500 (Tualatin River at West Linn)
			The Oswego Canal (14207000) is no longer included in the calculation because it enters the Willamette River downstream of the T.W. Sullivan generation station
	06/23/1928 - 09/30/2018		Ungauged streamflow contributions are computed using:
		USGS 142002000	May to October: 1.2 times USGS 14202000 (Pudding River at Aurora)
		USGS 14202000	November to April: 1.5 times USGS 14202000 (Pudding River at Aurora)
SVN6ARF	06/23/1928 - 09/30/2018	SSARR model	Unregulated daily flows derived using SSARR routing



TIMOTHY MEADOWS (TMY)

OAK GROVE FORK River Mile 16 Drainage Area: 53 Sq. mi.

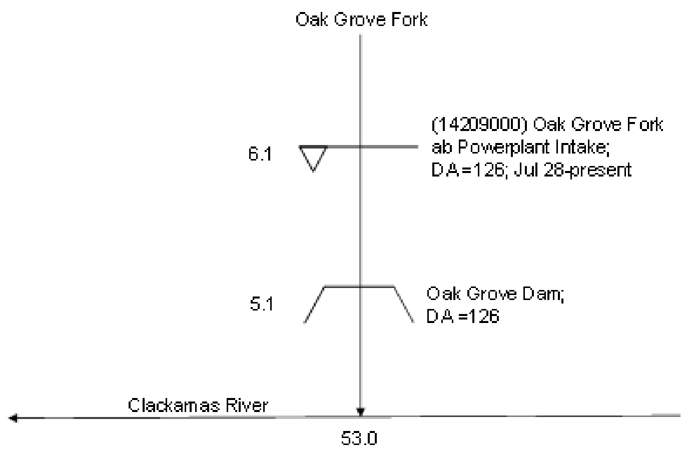
Site	Period	Source	Comments
TMY6H	06/23/1928 – 09/29/1929	USGS 14208500	USGS 14208500 (Oak Grove Fork at Timothy Meadows)
	10/01/1929 – 05/25/1956	USGS 14208500 & USGS 14209000	Linear correlation between USGS 14208500 (Oak Grove Fork at Timothy Meadows and USGS 14209000 (Oak Grove Fork above Powerplant Intake)
	05/26/1956 – 09/30/1956		Estimated flow at 20 cfs while project is constructed
	10/01/1956 - 09/30/2018	USGS 14208700	Observed flow of USGS 14208700 (Oak Grove Fork near Government Camp)
TMY6S	07/01/1928 - 09/30/1989	1990 Modified Flows	1990 Modified Flows semi-monthly values
	10/01/1989 - 09/30/2018	PGE	Timothy Lake reservoir elevations and USACE reservoir capacity table.
TMY6A	07/01/1928 - 09/30/2018		TMY_H + TMY_S



OAK GROVE (OAK)

OAK GROVE FK River Mile 5 Drainage Area: 126 Sq. mi.

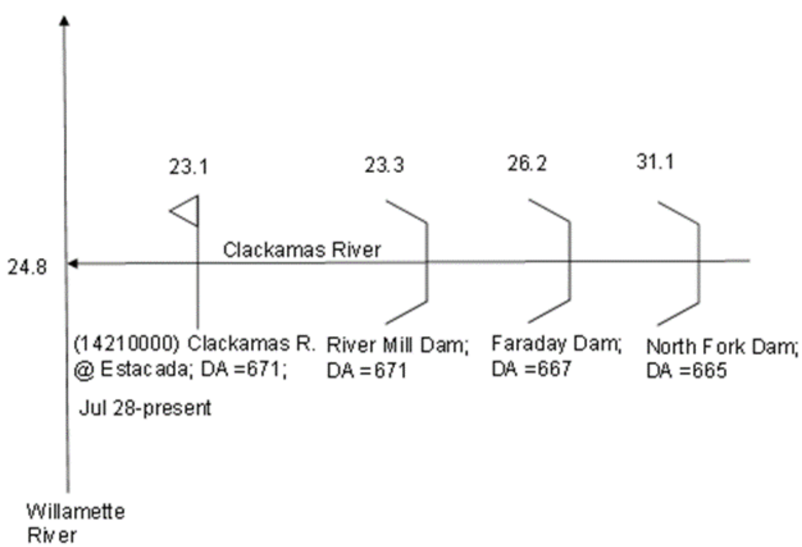
Site	Period	Source	Comments
OAK6H	07/01/1928 - 09/30/2018	USGS 14209000	Observed flow of USGS 14209000 (Oak Grove Fork above Power plant Intake)
OAK6A	07/01/1928 - 09/30/2018		Storage data provided by PGE OAK_H + TMY_S



NORTH FORK (NFK)
FARADAY (FAR)
RIVER MILL (RML)

CLACKAMAS RIVER	River Mile 31	Drainage Area: 665 Sq. mi.
CLACKAMAS RIVER	River Mile 26	Drainage Area: 667 Sq. mi.
CLACKAMAS RIVER	River Mile 23	Drainage Area: 671 Sq. mi.

Site	Period	Source	Comments
NFK6H	07/01/1928 - 09/30/2018	USGS 14210000	Observed flow of USGS 14210000 (Clackamas River at Estacada)
NFK6S	11/01/1958 - 06/30/1968	1990 Modified Flows	Monthly change in content for this period available from prior studies
	07/01/1968 - 09/30/1999	Unavailable	Reservoir change of content data not available for this period. Reservoir fluctuation is minor at this project.
	10/01/1999 - 09/30/2018	PGE	
NFK6A	07/01/1928 - 09/30/2018		NFK_H + NFK_S + TMY_S

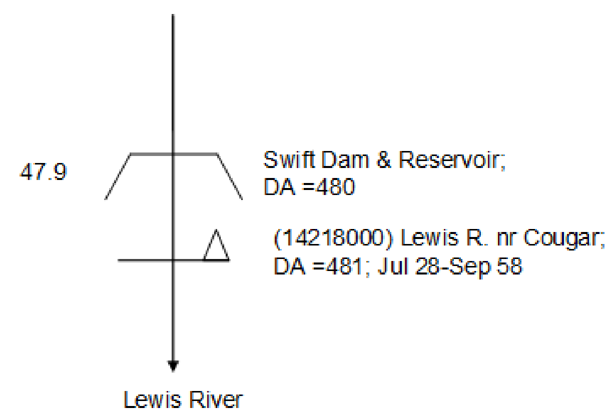


Western Washington Basins (Section 3.8)

SWIFT 1 (SWF)
SWIFT 2 (SW2)

LEWIS RIVER River Mile 48 Drainage Area: 480 Sq. Mi.
LEWIS RIVER River Mile 48 Drainage Area: 480 Sq. Mi.

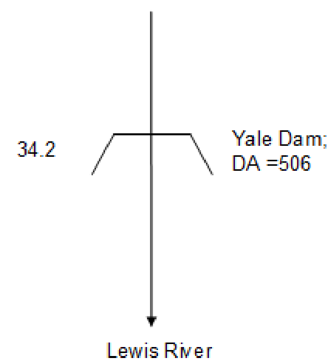
Site	Period	Source	Comments
SWF6A	07/01/28 - 09/30/58	USGS 14218000	Observed flow of USGS 14218000 (Lewis River near Cougar)
	10/01/58 - 09/30/18	PacifiCorp	Project Inflow provided by PacifiCorp



YALE (YAL)

LEWIS RIVER　　River Mile 34.2　　Drainage Area: 596 Sq. Mi.

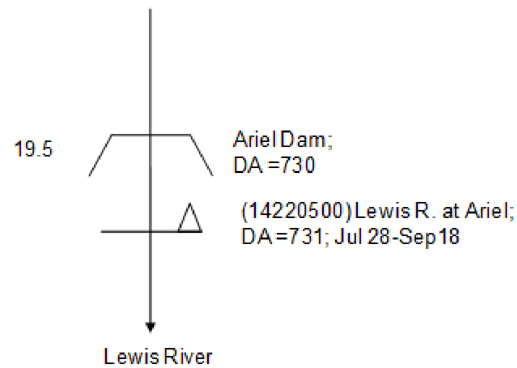
Site	Period	Source	Comments
YAL6A	07/01/28 - 09/30/58	1990 Modified Flows	Project flows furnished by PacifiCorp for the 1990 Modified Flows
	10/01/58 - 09/30/18	PacifiCorp	Daily project natural flows furnished by PacifiCorp.



ARIEL (MERWIN) (MER)

LEWIS RIVER | River Mile 19.5 | Drainage Area: 730 Sq. Mi.

Site	Period	Source	Comments
MER6H	07/01/28 - 09/30/18	USGS 14220500	Observed flow at USGS 14220500 (Lewis River at Ariel)
MER6A	07/01/28 - 09/30/18	PacifiCorp	Daily project natural flows furnished by PacifiCorp.

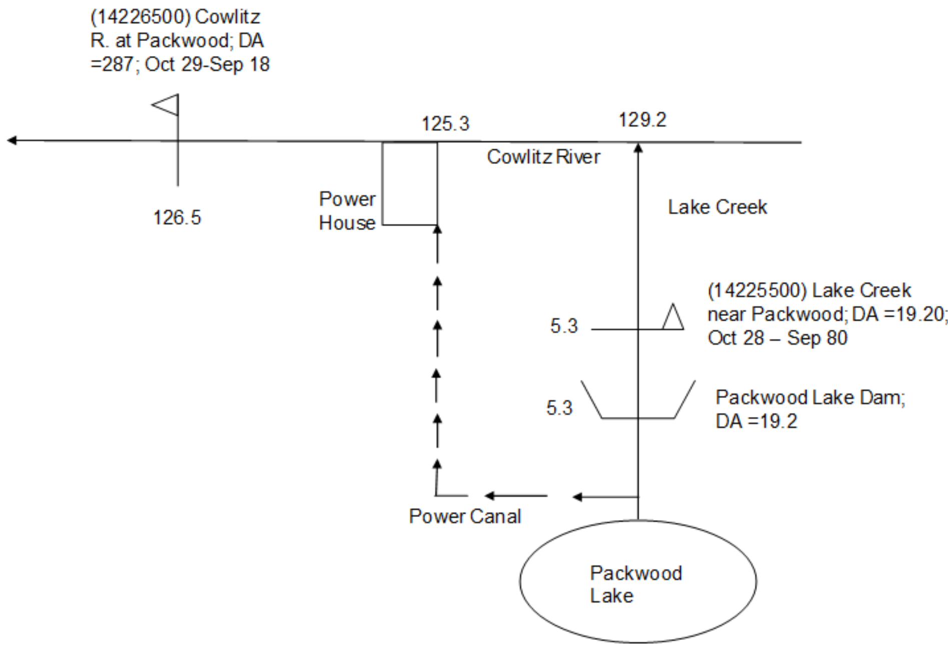


PACKWOOD LAKE (PKL)
PACKWOOD (PAK)

LAKE CREEK River Mile 5 Drainage Area: 19 Sq. Mi.

Site	Period	Source	Comments
PAK6S	09/01/59 - 09/30/73	1990 Modified Flows	Monthly data from the 1990 Modified Flows
	10/01/73 - 09/30/80	USGS 14225400	Daily reservoir elevations and USACE capacity table
	10/01/80 - 09/30/89	1990 Modified Flows	Monthly data from the 1990 Modified Flows
	10/01/89 - 09/30/18	Energy Northwest (formerly WPPSS)	Daily reservoir elevations and USACE capacity table
PAK6A	06/23/28 – 09/30/29	USGS 14110000	Observed flow at USGS 1411000 (Klickitat River near Glenwood, WA)
	10/01/29 – 08/31/30	USGS 14226500	Observed flow at USGS 14226500 (Cowlitz River at Packwood, WA)
	09/01/30 - 10/31/42	USGS 14225500	Observed flow at USGS 14225500 (Lake Creek near Packwood, WA)
	11/01/42 - 10/01/49	USGS 14226500	Observed flow at USGS 14226500 (Cowlitz River at Packwood, WA)
	10/02/49 – 04/30/54	USGS 14225500	Observed flow at USGS 14225500 (Lake Creek near Packwood, WA)
	05/01/54-09/01/59	USGS 14226500	Observed flow at USGS 14226500 (Cowlitz River at Packwood, WA)
	09/02/59 – 09/30/63	USGS 14225500	Observed flow at USGS 14225500 (Lake Creek near Packwood, WA)
	10/01/63 – 09/30/99	USGS 14226500	Observed flow at USGS 14226500 (Cowlitz River at Packwood, WA)

	10/01/99 – 09/30/01	Energy Northwest (formerly WPPSS)	Daily lake inflow data from Energy Northwest
	10/01/01 – 11/09/01	USGS 14226500	Observed flow at USGS 14226500 (Cowlitz River at Packwood, WA)
	11/10/01 – 09/13/09	Energy Northwest (formerly WPPSS)	Daily lake inflow data from Energy Northwest
	09/14/09 – 09/27/09	USGS 14226500	Observed flow at USGS 14226500 (Cowlitz River at Packwood, WA)
	09/28/09 – 01/17/12	Energy Northwest (formerly WPPSS)	Daily lake inflow data from Energy Northwest
	01/18/12 – 12/31/12	USGS 14226500	Observed flow at USGS 14226500 (Cowlitz River at Packwood, WA)
	01/01/13 – 09/30/18	Energy Northwest (formerly WPPSS)	Daily lake inflow data from Energy Northwest

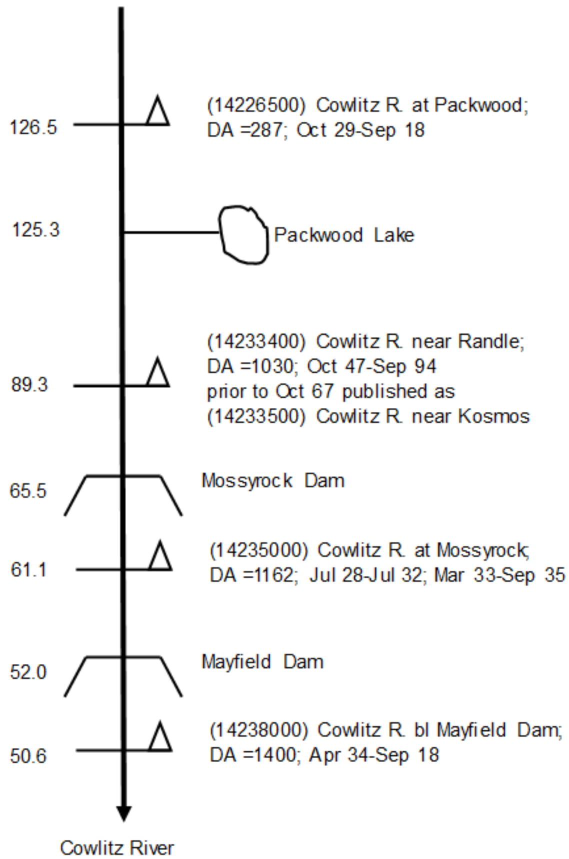


(14226500) Cowlitz R. at Packwood; DA =287; Oct 29-Sep 18
125.3
129.2
Cowlitz River
126.5
Power House
Lake Creek
(14225500) Lake Creek near Packwood; DA =19.20; Oct 28 – Sep 80
5.3
5.3
Packwood Lake Dam; DA =19.2
Power Canal
Packwood Lake

MOSSYROCK (MOS)

COWLITZ RIVER River Mile 65 Drainage Area: 1170 Sq. Mi.

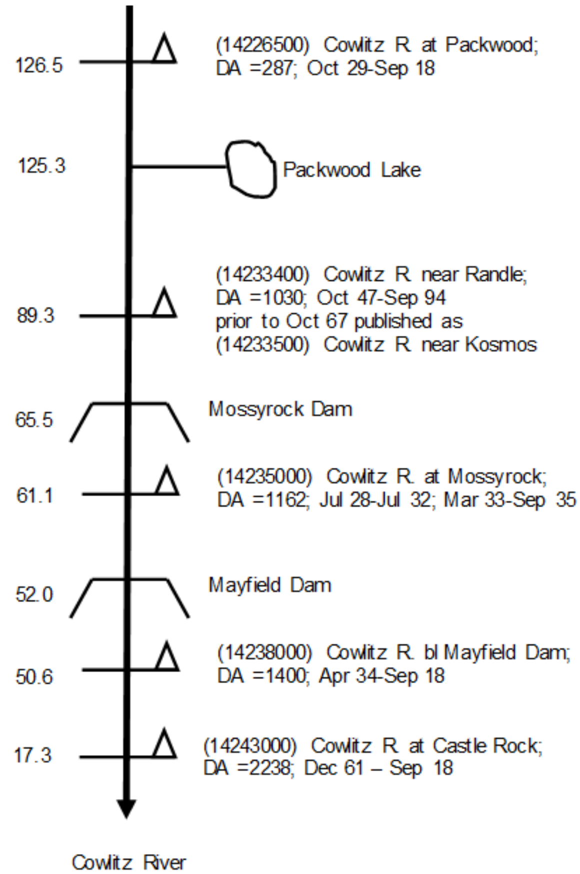
Site	Period	Source	Comments
MOS6S	10/01/99 - 09/30/18	USACE Dataquery	Storage (kaf) data from USACE Dataquery
MOS6A	06/23/28 – 09/30/32	USGS 14235000 and PAK_S	Observed flow at USGS 14235000 (Cowlitz River at Mossyrock, WA) plus PAK_S
	08/01/32 – 02/28/33	USGS 14226500 and PAK_S	Observed flow at USGS 14226500 (Cowlitz River at Packwood, WA) plus PAK_S
	03/01/33 – 09/29/35	USGS 14235000 and PAK_S	Observed flow at USGS 14235000 (Cowlitz River at Mossyrock, WA) plus PAK_S
	09/30/35 – 09/30/46	USGS 14238000 and PAK_S	Observed flow at USGS 14238000 (Cowlitz River below Mayfield Dam, WA) plus PAK_S
	10/01/46 – 09/29/59	USGS 14235000 and PAK_S	Observed flow at USGS 14235000 (Cowlitz River at Mossyrock, WA) plus PAK_S
	09/30/59 - 09/30/08	USGS 14233500 and PAK_S	Observed flow at USGS 14233500 (Cowlitz River near Kosmos, WA) plus PAK_S
	10/01/08 – 09/30/18	Tacoma Power	Daily inflow data from Tacoma Power
MOS6H	06/23/28 – 09/30/99	MOS_A – MOS_S – PAK_S	
	10/01/99 – 09/30/08	Tacoma Power	Daily outflow data from Tacoma Power
	10/01/08 – 06/30/12	MOS_A – MOS_S – PAK_S	
	10/01/12 – 09/30/18	Tacoma Power	Daily outflow data from Tacoma Power


126.5
(14226500) Cowlitz R. at Packwood;
DA =287; Oct 29-Sep 18
125.3
Packwood Lake
89.3
(14233400) Cowlitz R. near Randle;
DA =1030; Oct 47-Sep 94
prior to Oct 67 published as
(14233500) Cowlitz R. near Kosmos
65.5
Mossyrock Dam
61.1
(14235000) Cowlitz R. at Mossyrock;
DA =1162; Jul 28-Jul 32; Mar 33-Sep 35
52.0
Mayfield Dam
50.6
(14238000) Cowlitz R. bl Mayfield Dam;
DA =1400; Apr 34-Sep 18
Cowlitz River

MAYFIELD (MAY)

COWLITZ RIVER River mile 52 Drainage Area: 1400 Sq. Mi.

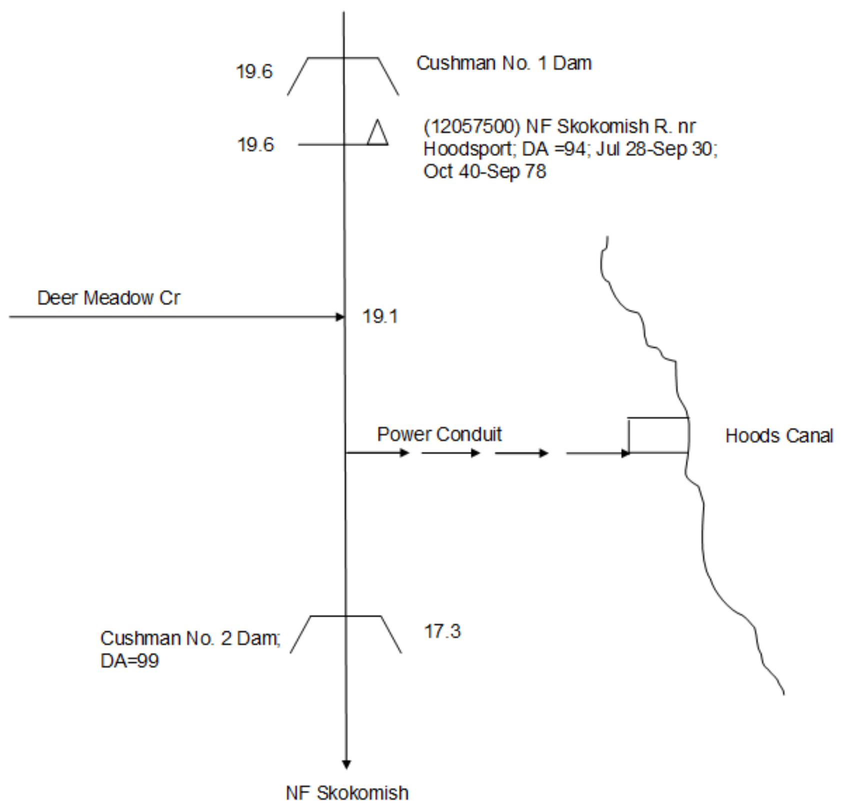
Site	Period	Source	Notes
MAY6H	06/23/28 – 07/25/32	USGS 14235000	Observed flow at USGS 14235000 (Cowlitz River at Mossyrock, WA)
	07/26/32 – 03/10/33	USGS 14243000	Observed flow at USGS 14243000 (Cowlitz River at Castle Rock, WA)
	03/11/33 – 03/31/34	USGS 14235000	Observed flow at USGS 14235000 (Cowlitz River at Mossyrock, WA)
	04/01/34 – 09/30/18	USGS 14238000	Observed flow at USGS 14238000 (Cowlitz River below Mayfield Dam, WA)
MAY6S	04/01/62 - 07/31/74	1990 Modified Flows	Monthly change of content from 1990 Modified Flows
	08/01/74 - 09/30/08	2010 Modified Flows	Daily change of content from 2010 Modified Flows
	10/01/08 – 09/30/18	Tacoma Power	Storage (kaf) data from Tacoma Power
MAY6A	07/01/28 - 09/30/08		MAY_H + MAY_S + MOS_S + PAK_S
	10/01/08 – 09/30/18	Tacoma Power	Mayfield local flow + MOS_A


126.5
(14226500) Cowlitz R. at Packwood;
DA =287; Oct 29-Sep 18
125.3
Packwood Lake
89.3
(14233400) Cowlitz R. near Randle;
DA =1030; Oct 47-Sep 94
prior to Oct 67 published as
(14233500) Cowlitz R. near Kosmos
65.5
Mossyrock Dam
61.1
(14235000) Cowlitz R. at Mossyrock;
DA =1162; Jul 28-Jul 32; Mar 33-Sep 35
52.0
Mayfield Dam
50.6
(14238000) Cowlitz R. bl Mayfield Dam;
DA =1400; Apr 34-Sep 18
17.3
(14243000) Cowlitz R. at Castle Rock;
DA =2238; Dec 61 – Sep 18
Cowlitz River

CUSHMAN 1 (CS1)

N. F. SKOKOMISH RIVER River Mile 20 Drainage Area: 94 Sq. Mi.

Site	Period	Source	Comments
CS16A	07/01/28 - 09/30/89	1990 Modified Flows	Semi-monthly data from 1990 Modified Flows
	10/01/89 - 9/30/08	Tacoma Power	Semi-monthly data from Tacoma Power
	10/1/08 – 09/30/18	Tacoma Power	Daily inflow data from Tacoma Power



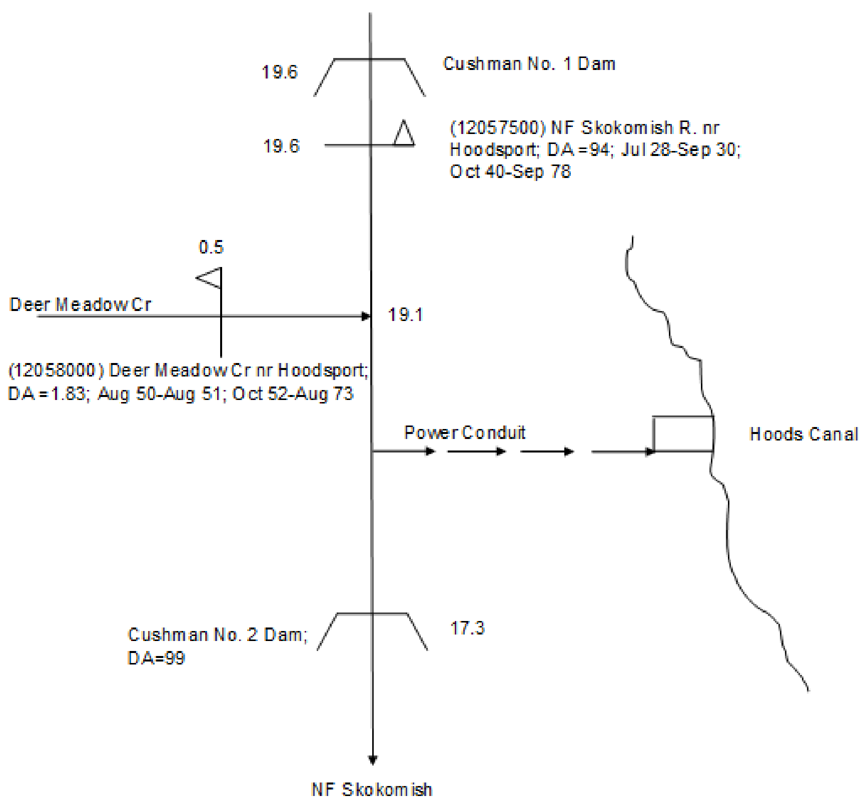
CUSHMAN 2 (CS2)

N. FK. SKOKOMISH RIVER River Mile 17 Drainage Area: 99 Sq. Mi.

Site	Period	Source	Comments
CS26A	07/01/28 - 09/30/18		CS16A flows plus adjustment. See below

Flows for Cushman 2 are computed by adding the flows for Cushman 1 plus the following monthly adjustments (in cfs) which are the estimated incremental flow between Cushman 1 and Cushman 2. These estimates are based on past record monthly trends from the Deer Meadow Creek gage.

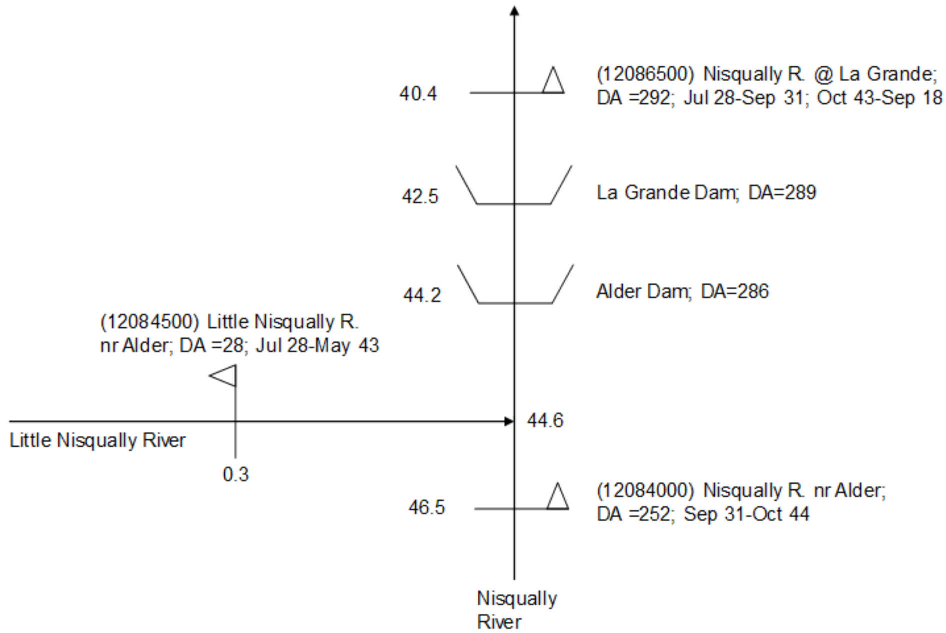
Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
3	10	15	18	15	11	6	4	3	1	0	1



LAGRANDE (LAG)
ALDER (ALD)

NISQUALLY RIVER River Mile 43 Drainage Area: 289 Sq. Mi.
NISQUALLLY RIVER River Mile 44 Drainage Area: 286 Sq. Mi.

Site	Period	Source	Comments
LAG6H	07/01/28 - 09/30/31	USGS 12086500	Observed flow of USGS 12086500 (Nisqually River at La Grande)
	10/01/31 – 05/31/43	USGS12084000 & USGS12084500	Observed flow of USGS 12084000 (Nisqually River near Alder) plus 1.315 times 12084500 (Little Nisqually River near Alder).
	06/01/43 - 09/30/43	2010 Modified Flows	Daily outflow from the 2010 Modified Flows
	10/01/43 - 09/30/18	USGS 12086500	Observed flow of USGS 12086500 (Nisqually River at La Grande)
ALD6S	11/01/44 - 01/31/45	1990 Modified Flows	Semi-monthly values from 1990 Modified Flows
	02/01/45 - 09/30/99	USGS 12085000	Reservoir content when provided and where reservoir elevations were provided, USACE capacity table was used
	10/01/99 - 09/30/18	USACE Dataquery	Elevation data from USACE Dataquery
LAG6A	07/01/28 - 09/30/18	LAG_H + ALD_S	

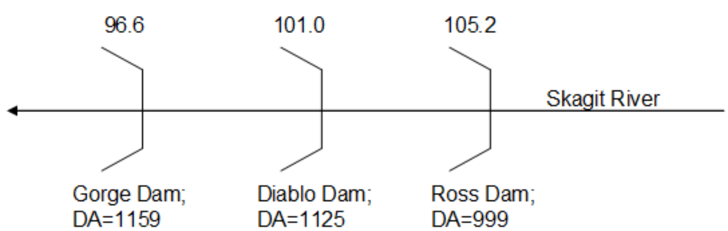


40.4
(12086500) Nisqually R. @ La Grande;
DA =292; Jul 28-Sep 31; Oct 43-Sep 18
42.5
La Grande Dam; DA=289
44.2
Alder Dam; DA=286
(12084500) Little Nisqually R.
nr Alder; DA =28; Jul 28-May 43
44.6
Little Nisqually River
0.3
46.5
(12084000) Nisqually R. nr Alder;
DA =252; Sep 31-Oct 44
Nisqually
River

ROSS (ROS)
DIABLO (DIA)
GORGE (GOR)

SKAGIT RIVER	River Mile 105	Drainage Area: 999 Sq. Mi.
SKAGIT RIVER	River Mile 101	Drainage Area: 1125 Sq. Mi.
SKAGIT RIVER	River Mile 97	Drainage Area: 1159 Sq. Mi.

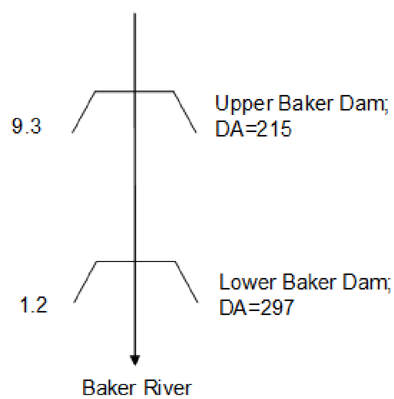
Site	Period	Source	Comments
ROS6A	07/01/28 - 09/30/89	1990 Modified Flows	Semi-monthly flow values provided by Puget Sound Power & Light for the 1990 Modified Flows
	10/01/89 - 09/30/18	Seattle City Light	Daily unregulated flow values provided by Seattle City Light



UPPER BAKER (UBK)

BAKER RIVER River Mile 9 Drainage Area: 215 Sq. Mi.

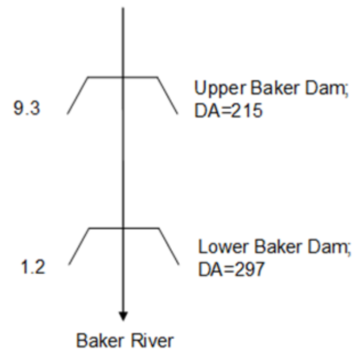
Site	Period	Source	Comments
UBK6A	07/01/28 - 09/30/89	1990 Modified Flows	Semi-monthly flow values provided by Seattle City Light for 1990 Modified Flows
	10/01/89 - 09/30/08	Data from Puget Sound Energy	Semi-monthly unregulated flow values provided by Puget Sound Energy
	10/01/08 – 09/30/18	Data from Puget Sound Energy	Daily unregulated flow values provided by Puget Sound Energy



LOWER BAKER (SHA)

BAKER RIVER River Mile 1 Drainage Area: 297 Sq. Mi.

Site	Period	Source	Comments
SHA6A	06/23/28 - 09/30/18	UBK6A	Inflow at Upper Baker multiplied by 1.25



LOST CREEK (LOS)

ROGUE RIVER River Mile 157 Drainage Area: 674 sq. mi

Site	Period	Source	Comments
LOS6H	07/01/1928 - 09/30/1967	USGS 14335000 14328000	Observed 14335000 (Rogue River below S. FK Rogue near Prospect)[1] times the monthly weighting factors[2] shown below.
	10/01/1967 - 09/30/2018	USGS 14337600 14337500	Observed flow of 14337600 (Rogue River near McLeod) minus observed flow of 14337500 (Big Butte Cr near McLeod) times the monthly weighting factors[3] shown below:
LOS6S	02/18/1977 - 9/30/2008	2010 Modified Flows	
	10/1/2008 - 9/30/2008	USACE	Submitted data
LOS6A	07/01/1928 - 09/30/2018	LOS_H + LOS_S	

Footnote 1 – Estimation of missing streamflow record the Rogue River above Prospect, Oregon.

Monthly linear regression coefficients for estimating 14335000 (Rogue River below S. FK Rogue near Prospect) from flow measured at 14328000 (Rogue River above Prospect):

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	2.00	1.88	1.73	1.63	1.66	1.748	2.13	2.12	2.02	1.64	1.75	1.93
b	232.	350.	474.	492.	436.	431.	165.	150.	168.	310.	241.	209.

Q1 = a*Q2 + b

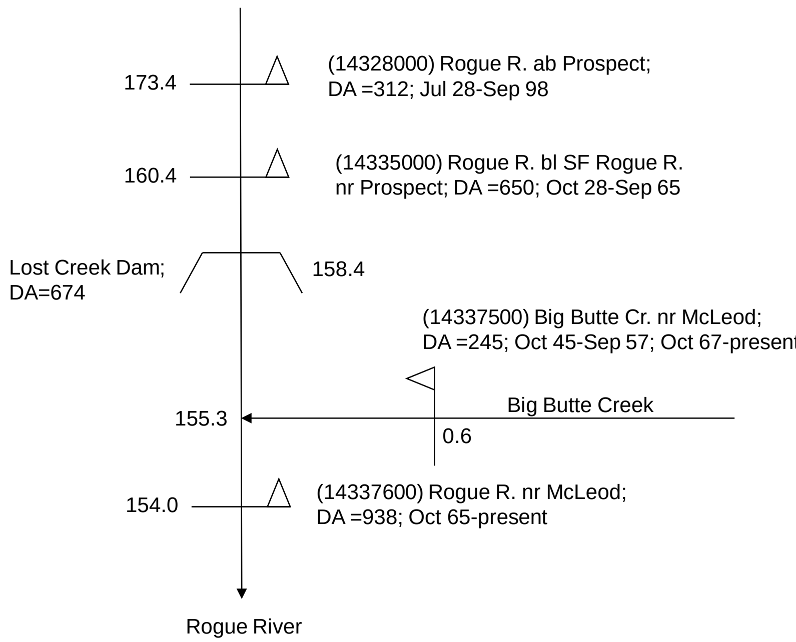
Periods Estimated	
Start Date	**End Date**
07/01/1928	09/30/1928
09/30/1965	00/30/1967

Footnote 2 – Monthly weighting Factors for the Rogue River above Prospect, Oregon.

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1.010	1.020	1.035	1.035	1.040	1.040	1.015	1.010	1.008	1.006	1.005	1.007

Footnote 3 – Monthly weighting Factors for the Rogue River near McLeod, Oregon.

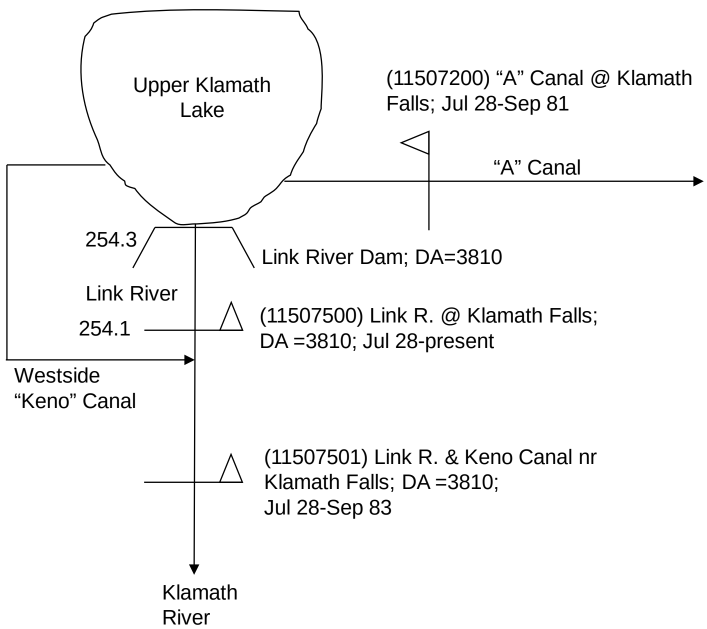
Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.992	0.984	0.973	0.973	0.969	0.969	0.988	0.992	0.994	0.996	0.997	0.995


173.4
(14328000) Rogue R. ab Prospect;
DA =312; Jul 28-Sep 98
160.4
(14335000) Rogue R. bl SF Rogue R.
nr Prospect; DA =650; Oct 28-Sep 65
Lost Creek Dam;
DA=674
158.4
(14337500) Big Butte Cr. nr McLeod;
DA =245; Oct 45-Sep 57; Oct 67-present
Big Butte Creek
155.3
0.6
154.0
(14337600) Rogue R. nr McLeod;
DA =938; Oct 65-present
Rogue River

“A” CANAL DIVERSION (ACL)

“A” CANAL River Mile 43 Drainage Area: 572 sq. mi

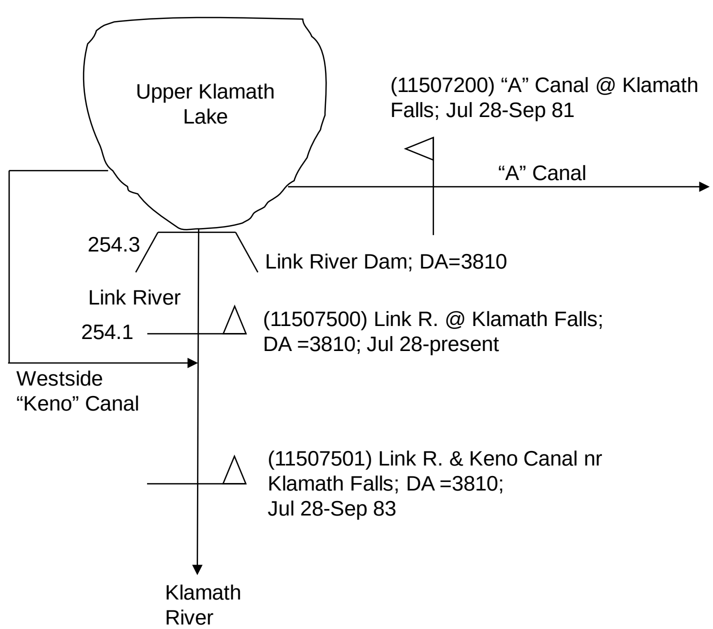
Site	Period	Source	Comments
ACL6H	07/01/1928 - 09/30/2018	USGS 11507200	Observed flow of USGS 11507200 (A Canal at Klamath Falls)



LINK RIVER (LNK)

KLAMATH RIVER | River Mile 254 | Drainage Area: 3810 sq. mi

Site	Period	Source	Comments
LNK6H	07/01/1928 - 09/30/1983	USGS 11507501	Observed flow of USGS 11507501 (Link River and Keno Canal near Klamath Falls)
	10/01/1983 - 09/30/2018	USGS 11507500 11507400 PacifiCorp	Observed flow of 11507500 (Link R at Klamath Falls) plus 11507400 (Westside Keno Canal) from PacifiCorp
KLA6S	07/01/1928 - 10/06/1974	2010 Modified Flows	
	10/07/1974 - 09/30/2018	USGS 11507001	Reservoir elevations from USGS 11507001 (Upper Klamath Lake near Klamath Falls)
LNK6A	07/01/1928 - 09/30/2018	LNK_H + KLA_S + ACL_H	
ACL6H	07/01/1928 - 09/30/2018	USGS 11507200	Observed flow of USGS 11507200 (A Canal at Klamath Falls)



JOHN C. BOYLE (JCB)

KLAMATH RIVER River Mile 225 Drainage Area: 4080 sq. mi

Site	Period	Source	Comments
JCB6H	07/01/1928 - 09/30/2018	USGS 11507500	Observed flow at 11510700 (Klamath R. below John C. Boyle Powerplant near Keno)[4]
JCB6S	03/01/1962 - 12/31/1962	2010 Modified Flows	
	10/01/2008 - 09/30/2018	PacifiCorp	Daily change of content from PacifiCorp
JCB6A	07/01/1928 - 09/30/2018	JCB_H + JCB_S + KLA_S + ACL_H	

Footnote 4 – Estimation of missing streamflow record for the Klamath River below John C. Boyle Power Plant near Keno, Oregon.

Monthly linear regression coefficients for estimating 11510700 ((Klamath R. below John C. Boyle Powerplant near Keno) from flow measured at 11510701 (Link R. below Keno Canal near Klamath Falls):

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	1.13	1.12	1.11	1.09	1.08	0.78	0.576	0.388	0.785	0.847	0.917	0.975
b	142.	457.	519.	225.	234.	115.	220.	613.	544.	578.	547.	501.

Q1 = a*Q2 + b

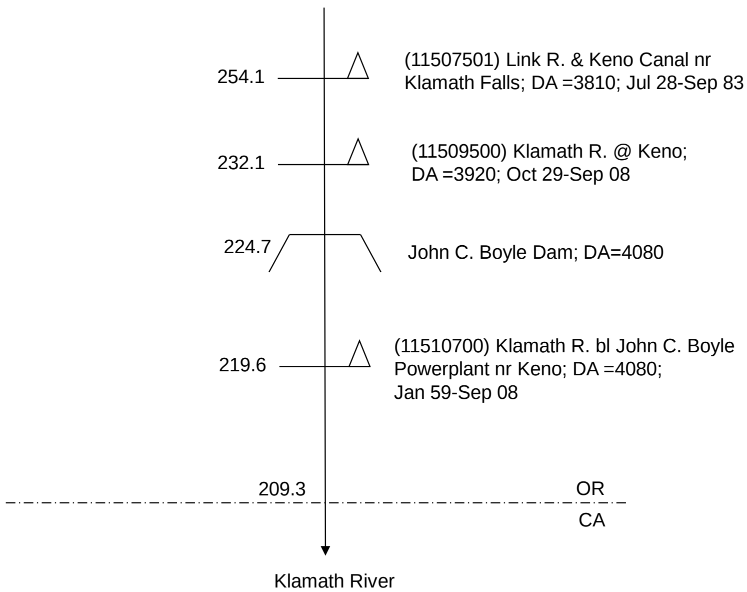
Periods Estimated	
Start Date	**End Date**
07/01/1928	09/30/1928

Monthly linear regression coefficients for estimating 11510700 ((Klamath R. below John C. Boyle Powerplant near Keno) from flow measured at 11510500 (Klamath R. at Keno):

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a	0.991	0.988	0.995	0.970	1.01	1.03	0.951	0.964	0.986	0.96	0.928	0.958
b	221.	220.	206.	299.	265.	244.	269.	267.	247.	267.	318.	279.

Q1 = a*Q2 + b

Periods Estimated	
Start Date	**End Date**
10/01/1929	12/31/1958


254.1
(11507501) Link R. & Keno Canal nr
Klamath Falls; DA =3810; Jul 28-Sep 83
232.1
(11509500) Klamath R. @ Keno;
DA =3920; Oct 29-Sep 08
224.7
John C. Boyle Dam; DA=4080
219.6
(11510700) Klamath R. bl John C. Boyle
Powerplant nr Keno; DA =4080;
Jan 59-Sep 08
209.3
OR
CA
Klamath River

Appendix C- Routing Characteristics

The SARR routing characteristics for calculating routed flows are shown in the following tables, where:

KTS:
n:
Phases:
Assume Q:
Phase Ts:
Total Ts:

They contain the values of the required characteristics for a specified channel flow for each of the Columbia River Basin reaches. The discharge value shown was selected for illustrative purposes only. This value changes daily. Channel routing using a defined specific discharge (Q) to time of storage (Ts) relationship was used for specific reaches.

Table C-1. Coefficients for Computing Routed Flows

Basin	Routing Reach	KTS	n	Phases	Assume Q	Phase Ts	Total Ts
Upper Columbia & Kootenai	MCD to RVC	5.0	0.2	3.0	20000	0.7	2.1
	RVC to ARD	10.0	0.2	2.0	20000	1.4	2.8
	LIB to LEO	See Table C-2					
	LEO to BFE	26.0	0.2	2.0	7000	4.4	8.9
	BFE to COR	10.0	0.2	4.0	20000	1.4	5.5
	COR to BRI	No routing in this reach					
	ARD + BRI to MUC	20.0	0.2	2.0	50300	2.3	4.6
	MUC to CIB	10.0	0.2	2.0	20000	1.4	2.8
Pend O'Reille	HGH to CFM	5.0	0.2	2.0	4000	1.0	1.9
	CFM to KER	26.0	0.2	4.0	9700	4.1	16.6
	KER to TOM	28.6	0.2	5.0	40000	3.4	17.2
	TOM to NOX	9.0	0.2	2.0	20000	1.2	2.5
	NOX to CAB	6.0	0.2	2.0	20000	0.8	1.7
	CAB+PSL to ALF	10.0	0.2	2.0	20000	1.4	2.8
	ALF to BOX	30.0	0.2	4.0	20000	4.1	16.6
	BOX to BDY	10.0	0.2	4.0	20000	1.4	5.5
	BDY to SEV/WAT	No routing in this reach					
	SEV/WAT to CIB	No routing in this reach					
Spokane	COE to UPF	See Table C-3					
	UPF to NIN	See Table C-4					
	NIN to LLK	See Table C-5					
	CIB+WAT+LLK to GCL	30.0	0.2	2.0	95900	3.0	6.1
Mid Columbia	GCL to CHJ	See Table C-6					
	CHJ to WEL	See Table C-7					
	WEL to RRH	See Table C-8					
	RRH to RIS	See Table C-9					
	RIS to WAN	See Table C-10					
	WAN to PRD	See Table C-11					
Snake	BRN to HCD	18.5	0.2	2.0	14200	2.7	5.5
	HCD to ANA	11.0	0.3	20.0	51600	1.3	25.1
	WHB to ANA	17.5	0.2	5.0	37350	2.1	10.7
	Imnaha to ANA	10.0	0.2	3	2130	2.2	6.5
	Troy to ANA	18.7	0.2	2	10450	2.9	5.9
	DWR to SPD	See Table C-12					
	ORO to SPD	7.0	0.2	5.0	5100	1.3	6.3
	ANA+SPD to LWG	No routing in this reach					
	LWG to LGS	6.0	0.3	20.0	54500	0.7	13.5
	LGS to LMN	6.0	0.3	20.0	54500	0.7	13.5
	LMN to IHR	5.0	0.2	4.0	50000	0.6	2.3
Lower Columbia	PRD to MCN	25.0	0.2	5.0	100000	2.5	12.5
	RICH to MCN (1928-1949)	See Table C-13					
	RICH to MCN (1950-1953)	See Table C-14					
	RICH to MCN (1954-present)	15.0	0.2	3.0	100000	1.5	4.5
	YAK to MCN	6.3	0.1	2.0	5000	1.1	2.3
	MCN to JDA	See Table C-15					
	JDA to TDA	See Table C-16					
	TDA to BON	See Table C-17					
Willamette	HCR to LOP	1.5	0.1	2.0	635	0.4	0.8
	LOP to DEX	No routing in this reach					
	FAL+DEX to JAS	3.0	0.2	5.0	2080	0.7	3.3
	COT+DOR to GOS	1.1	0.2	20.0	570	0.3	6.2
	GOS+JAS to EUG	3.0	0.2	5.0	2930	0.6	3.0
	CGR to VID	See Table C-18					
	BLU to VID	See Table C-19					
	VID to HAR	See Table C-20					
	EUG TO HAR	See Table C-21					
	FRN to MNR	5.0	0.2	5.0	370	1.5	7.7
	HAR+MNR TO COR	See Table C-22					
	COR to ALB	See Table C-23					
	DET to MEH	See Table C-24					
	MEH TO JEFF	7.0	0.2	5.0	1930	1.5	7.7
	FOS to WTL	3.5	0.2	5.0	1390	0.8	4.1
	WTL to JEFF	19.0	0.2	5.0	1520	4.4	21.9
	ALB+JEF TO SLM	See Table C-25					
	SLM to SVN	See Table C-26					

Table C-2. Libby routed to Leonia

Libby routed to Leonia Used WY 1928-present			
No. Phases	n	Discharge (cfs)	Ts (hours)
30	0	1	0.6
		6000	0.4
		9000	0.2
		20000	0.3
		100000	0.3
		200000	0.4
		9999999	0.4

Table C-3. Coeur D'Alene routed to Upper Falls

Coeur D'Alene routed to Upper Falls Used WY 1928-present			
No. Phases	n	Discharge (cfs)	Ts (hours)
5	0	1	1.1
		1000	1.1
		10000	1.0
		100000	0.9
		1000000	0.7

Table C-4. Upper Falls routed to Nine Mile

Upper Falls routed to Nine Mile Used WY 1928-present			
No. Phases	n	Discharge (cfs)	Ts (hours)
5	0	1	1.6
		7000	1.2
		10000	1.2
		100000	1.2
		1000000	1.2

Table C-5. Nine Mile routed to Long Lake

Nine Mile routed to Long Lake Used WY 1928-present			
No. Phases	n	Discharge (cfs)	Ts (hours)
5	0	1	1.6
		7000	1.2
		10000	1.2
		100000	1.2
		1000000	1.2

Table C-6. Grand Coulee routed to Chief Joseph

Grand Coulee routed to Chief Joe Used WY 1928-present			
No. Phases	n	Discharge (cfs)	Ts (hours)
10	0	1	0.3
		150000	0.3
		1000000	0.3

Table C-7. Chief Joe routed to Wells

Chief Joe to Wells Used WY 1928-present			
No. Phases	n	Discharge (cfs)	Ts (hours)
5	0	1	0.2
		100000	0.2
		500000	1.5
		900000	2.0
		1000000	2.6
		2000000	2.8
		9000000	2.9
		10000000	3.0

Table C-8. Wells routed to Rocky Reach

Wells to Rocky Reach Used WY 1928-present			
No. Phases	n	Discharge (cfs)	Ts (hours)
5	0	1	0.4
		100000	0.4
		500000	0.8
		900000	1.0
		1000000	1.4
		2000000	1.6
		10000000	1.6

Table C-9. Rocky Reach routed to Rock Island

Rocky Reach to Rock Island Used WY 1928-present			
No. Phases	n	Discharge (cfs)	Ts (hours)
5	0	1	0.2
		100000	0.2
		500000	0.4
		900000	0.8
		1000000	1.4
		2000000	1.6
		10000000	1.6

Table C-10. Rock Island routed to Wanapum

Rock Island to Wanapum Used WY 1928-present			
No. Phases	n	Discharge (cfs)	Ts (hours)
5	0	1	0.2
		100000	0.2
		500000	0.4
		900000	0.8
		1000000	1.0
		2000000	1.0
		10000000	1.0

Table C-11. Wanapum routed to Priest Rapids

Wanapum to Priest Rapids Used WY 1928-present			
No. Phases	n	Discharge (cfs)	Ts (hours)
5	0	1	0.2
		100000	0.2
		500000	0.5
		900000	0.8
		1000000	1.0
		2000000	1.0
		10000000	1.0

Table C-12. Dworshak routed to Spalding

Dworshak routed to Spalding Used WY 1928-present			
No. Phases	n	Discharge (cfs)	Ts (hours)
5	0	1	2.2
		1000	1.2
		2000	0.8
		5000	0.5
		10000	0.7
		20000	0.9
		50000	0.8
		1000000	0.7

Table C-13. Control Point (Richland) routed to McNary WY1929-1949

Control Point to McNary Used WY 1929-1949			
No. Phases	n	Discharge (cfs)	Ts (hours)
7	0	1	7.5
		40000	6.0
		100000	5.5
		450000	5.5
		550000	4.5
		750000	2.5
		800000	3.0
		1000000	4.0
		1250000	5.0
		1750000	6.5
		3000000	10.0

Table C-14. Control Point (Richland) routed to McNary WY1950-1953

Control Point to McNary Used WY 1950-1953			
No. Phases	n	Discharge (cfs)	Ts (hours)
7	0	1	3.5
		40000	3.0
		100000	2.5
		450000	2.0
		550000	1.5
		750000	1.0
		800000	1.5
		1000000	2.0
		1250000	2.5
		1750000	3.0
		3000000	4.0

Table C-15. McNary routed to John Day

McNary Routed to John Day Used WY 1929-present			
No. Phases	n	Discharge (cfs)	Ts (hours)
5	0	1000	1.2
		5000	1.1
		10000	1.1
		20000	1.0
		50000	0.8
		100000	0.7
		1000000	1.2
		10000000	1.2

Table C-16. John Day routed to The Dalles

John Day to The Dalles Used WY 1929-present			
No. Phases	n	Discharge (cfs)	Ts (hours)
5	0	1000	0.4
		5000	0.4
		10000	0.3
		20000	0.3
		50000	0.2
		100000	0.2
		500000	0.1
		1000000	0.1

Table C-17. The Dalles routed to Bonneville

The Dalles Routed to Bonneville Used Jul 1928-Present			
No. Phases	n	Discharge (cfs)	Ts (hours)
5	0	1000	0.6
		10000	0.6
		20000	0.5
		50000	0.5
		100000	0.4
		500000	0.3
		1000000	0.3

Table C-18. Cougar routed to Vida

Cougar to Vida Used WY 1928-present		
No. pairs	Flow (cfs)	Lag (hours)
5	0	10
	20000	10
	30000	10
	40000	10
	60000	16
No. pairs	Flow (cfs)	Attenuation (k)
5	100	1
	10000	1
	20000	2
	35000	2
	60000	2

Table C-19. Blue River routed to Vida

Blue River to Vida Used WY 1928-present		
No. pairs	Flow (cfs)	Lag (hours)
3	10	3
	500	2
	10000	2
No. pairs	Flow (cfs)	Attenuation (k)
3	10	1
	2000	2
	10000	6

Table C-20. Vida routed to Harrisburg

Vida routed to Harrisburg Used WY 1928-present		
No. pairs	Flow (cfs)	Lag (hours)
3	0	18
	2000	12
	10000	9

Table C-21. Eugene routed to Harrisburg

Eugene routed to Harrisburg Used WY 1928-present		
No. pairs	Flow (cfs)	Lag (hours)
5	0	16
	2000	10
	20000	4
	30000	4
	65000	6

Table C-22. Harrisburg/Monroe routed to Corvallis

Harrisburg/Monroe Routed to Corvalis Used WY 1928-present			
No. Phases	n	Discharge (cfs)	Ts (hours)
4	0	0	4.2
		1	4.2
		1000	3.5
		10000	2.5
		20000	2.2
		30000	2.8
		40000	4.1
		50000	5.8
		60000	5.6
		70000	5.5
		80000	4.8
		100000	4.6
		120000	4.2
		180000	2.7
		1000000	2.7

Table C-23. Corvallis routed to Albany

Corvallis routed to Albany Used WY 1928-present			
No. Phases	n	Discharge (cfs)	Ts (hours)
3	0	0	3.4
		1	3.4
		1000	3.0
		3000	2.6
		10000	2.3
		20000	2.2
		30000	1.7
		40000	1.5
		50000	1.6
		60000	2.0
		80000	2.0
		100000	2.0
		120000	2.1
		150000	2.0
		200000	2.3
		300000	2.2
		400000	1.8
		500000	1.7
		1000000	1.7

Table C-24. Detroit routed to Mehama

Detroit to Mehama Used WY 1928-present		
No. pairs	Flow (cfs)	Lag (hours)
3	0	3
	3000	3
	100000	3

Table C-25. Albany+Jefferson routed to Salem

Albany routed to Salem Used WY 1928-present			
No. Phases	n	Discharge (cfs)	Ts (hours)
3	0	0	3.3
		1000	3.3
		10000	2.7
		20000	2.2
		30000	1.6
		40000	1.4
		50000	1.2
		60000	1.3
		80000	1.4
		100000	2.3
		120000	2.8
		140000	3.0
		170000	3.1
		200000	2.8
		250000	2.2
		300000	1.8
		400000	1.8
		500000	1.7
		1000000	1.7

Table C-26. Salem routed to T.W.Sullivan

Salem routed to TW Sullivan Used WY 1928-present			
No. Phases	n	Discharge (cfs)	Ts (hours)
2	0	1	4.0
		50000	4.8
		100000	7.1
		150000	11.2
		200000	15.4
		250000	18.5
		300000	21.0
		350000	23.1
		400000	25.0
		1000000	30.0

Appendix D- Storage/Elevation Tables

D.1 Pend Oreille and Spokane

Noxon Rapids

Date of Table = 6/30/1960
Dates of use = Entire Period

Elevation (ft)	Storage (AF)
2270.1	357
2273	10711
2277	25785
2281	41653
2285	58314
2288	71405
2292	89653
2295	103934
2298	118810
2301	134281
2302	139636
2304	150744
2306	162248
2308	174149
2310	186446
2312	199141
2315	218777
2318	239008
2321	259835
2323	274116
2326	296132
2328	311207
2330	326678
2331	334612

Priest Lake at Outlet, near Coolin, ID

Date of Table = 6/23/1958
Date of use = Entire Period

Elevation (ft)	Storage (af)
2433.94	31860
2434.94	55360
2436.14	83680
2437.24	109750
2438.34	135930
2439.14	155050
2440.24	181450
2440.94	198320
2441.64	215260
2442	224008

Coeur d'Alene

Date of table = 9/29/1936
Dates of use = Entire period

Elevation (ft)	Storage (af)
1220	0
1220.5	13400
1221.4	37500
1223.2	86100
1224	107900
1225	135200
1226	162900
1226.6	181100
1227.4	211100
1227.6	219800
1228	238500
1228.4	257900
1228.8	277900
1229.4	308500
1230.2	350100
1231.5	419000
1233.5	527000
1233.9	549000
1234.1	559800

1235.3	625800
1235.5	636900
1236	664400
1236.5	692100
1237.3	736500
1238.6	809300
1238.9	826400
1239.1	837700
1240	889000
1241	947000
1242	1006000
1246	1246000

Long Lake

Date of table = 9/7/1961
Dates of use = Entire period

Elevation (ft)	Storage (af)
1500	0
1512.1	360
1514	7200
1517	18600
1518	22500
1519	26500
1521	34700
1522	38900
1524	47500
1526	56300
1529	70100
1530	74800
1532	84400
1534	94200
1536	104200
1537	109300

D.2 Mid-Columbia

Wells

Date of Table = Unknown
Dates of use = WY 2000 – 2008
Source = USACE

Elevation (ft)	Storage (af)
10	0
767	210000
769	223200
771	236600
773	252890
775	269900
777	288800
779	308900
781	331700

Lake Chelan

Date of table = 10/1/1927
Dates of use = Entire period

Elevation (ft)	Storage (af)
10	0
1079.1	3140
1080	31400
1081	62900
1082	94500
1083.5	142050
1085	189750
1088	285750
1090	350150
1093	447350
1097	577750
1097.3	587560
1100	676120

Rocky Reach

Date of Table = Unknown
Dates of use = WY 2000 - 2008
Source = USACE

Elevation (ft)	Storage (af)
10	0
592	0
600	2000
608	5000
624	13000
634	23000
638	29000
646	45000
650	55000
656	67000
664	103000
672	139000
676	159000
682	192000
688	228000
692	254000
696	283000
700	317000
703	344000
704	353000
706	372000
707	382000
710	412000

Rock Island

Date of table = Unknown
Dates of use = 07/1960 - 09/1999

Elevation (ft)	Storage (af)
10	0
603	0
615	29400

Date of table = Unknown
Dates of use = 10/1999 - 09/2008
Source = Chelan PUD; obtained in 2009

Elevation (ft)	**Storage (af)**
10	0
609	0
610	2900
611	5800
612	8700
613	11700

Wanapum

Dates of table = Unknown
Dates of use = WY 2000 – 2008
Source = USACE

Elevation (ft)	**Storage (af)**
10	0
500	28500
510	65000
520	122500
530	200000
540	294000
550	403500
559	518000
562	558500
565	600500
569	658500
578	793500

Priest Rapids

Date of table = Unknown
Dates of use = WY 2000 - 2008
Source = USACE

Elevation (ft)	**Storage (af)**
10	0
430	7200

440	23900
450	49500
460	81300
470	121300
480	171400
481	177100
483	189100
485	201900
487	215500
489	229900
490	237700
500	337700

D.3 Lower Snake

No storage tables were used in the Lower Snake

D.4 Lower Columbia

Round Butte

Date of table = 1/19/1964
Dates of use = WY 1978 - 2018

Elevation (ft)	Storage (af)
1860	260794
1870	286673
1880	314108
1890	343218
1900	374004
1910	406613
1920	441054
1930	477261
1940	515276
1945	534739
1950	555131

D.5 Willamette

No storage tables were used in the Willamette

D.6 Western Washington

Packwood Lake

Date of Table = Unknown
Dates of use = Entire Period

Elevation (ft)	Storage (af)
2843.5	0
2860	6981

Alder

Date of Table = Unknown
Dates of use = 02/1945 - 09/1999

Elevation (ft)	Storage (af)
940	0
1020	5000
1040	10000
1068	20000
1085	30000
1100	40000
1114	52300
1117	53700
1120	56465
1123	59044
1126	62217
1129	65391
1132	68366
1135	71540
1138	75110
1141	78283
1144	81844
1147	85622
1150	89193

1153	93160
1156	97126
1159	101688
1162	107044
1165	111804
1168	116961
1171	122912
1174	128862
1177	135011
1180	141755
1183	148300
1186	155639
1189	163049
1192	170317
1195	178647
1198	186979
1201	195705
1204	204631
1207	213756

D.7 Western Oregon

Klamath

Date of table = 1/1/1974
Dates of use = WY 1974 - 2018

Elevation (ft)	**Storage (af)**
4136	0
4137	61300
4138	127000
4139	193700
4140	262600
4141	335400
4142	414400
4143.3	523700
4144.3	583300
4145	668400