Appendix C

Truckee River Basin Historical Data Development Methodologies: Water Years 2001-2021

TRUCKEE RIVER BASIN HISTORICAL DATA DEVELOPMENT METHODOLOGIES:

WATER YEARS 2001-2021

To: U.S. Bureau of Reclamation,

Lahontan Basin Area Office

By: Precision Water Resources Engineering

DATE: October 19, 2017

REVISED: August 9, 2023

RE: Basin inflow computation

Precision Water Resources Engineering
720.261.7007 www.precisionwre.com
3401 County Road 16 ● Loveland, CO ● 80537

Table of Contents

FIGURES

TABLES

1 INTRODUCTION

Various stakeholders use the Truckee-Carson RiverWare™ models throughout the Tahoe, Truckee, and Carson River basins for short-term operations support as well as long-term planning studies. Such wide stakeholder use of the models motivates the need for development of a robust hydrologic dataset to drive said models. These datasets are important as they drive the models used in making operational, accounting, and planning analyses. These analyses lead to decisions in the Truckee Basin that impact the operations of reservoirs and basin stakeholder operational scheduling. The scheduling has impacts across the Truckee Basin which include reservoir levels, releases, flows through the basin, and impacts to users of the basin as a result.

The purpose of the data development effort documented herein is more than just developing a ~~static~~ dataset for the 2001-2021 period as has been the objective of previous data development efforts. Rather, it is to outline an approach and methodology by which the hydrologic dataset can continue to grow year-by-year and be redeveloped if there are changes in the models' water balance. The tools and processes described are designed to be repeated periodically (i.e., annually) so that the models use hydrologic data for the most recent water year.

The report begins with an overview of the basin. Then, the general water balance modeled by the RiverWare models and utilized in the data development process is described. Next, the process by which the data is developed starting with the raw data collection, review, and revision is outlined. The process to develop the raw or observed data required by the models is then detailed. Finally, the appendices describe the specifics of the 2001-2021 dataset development tools and process according to the current water balance in the model. Note that verification of the data developed was done with the water year 2000 to 2021 developed data. Data for water years 2017 through 2021 has been developed using the methods described in this document.

1.1 AUDIENCE AND BASE DATA ASSUMPTIONS

- The document is written for water management professionals who are familiar with the Truckee-Carson System
- Approved United States Geological Survey (USGS) data were used and assumed to be valid
- The United States District Court Water Master of Reno, Nevada (Water Master) data were corrected daily and assumed to be valid and true

1.2 Basin Overview

A map of the Truckee River basin upstream of the Truckee River at Farad (Farad) Gage, including the delineation of the contributing area for each subbasin, is included in Figure 1.

Figure 2 includes a graphical representation of the relative size of gains, losses, and diversions in the basin as well as the geographical area of each subbasin. Symbols represent water balance components to the Truckee River basin. Inflows (rain drops), gain/loss in reaches (rain drops), evaporation (lightning bolts), and depletions (faucets) are shown as larger or smaller depending on the relative size of the component. For instance, the inflow to Lake Tahoe (blue rain drop) is larger than that of the Boca Reservoir Inflow. Likewise, the Pyramid Lake evaporation is larger than the Prosser Creek Reservoir evaporation.

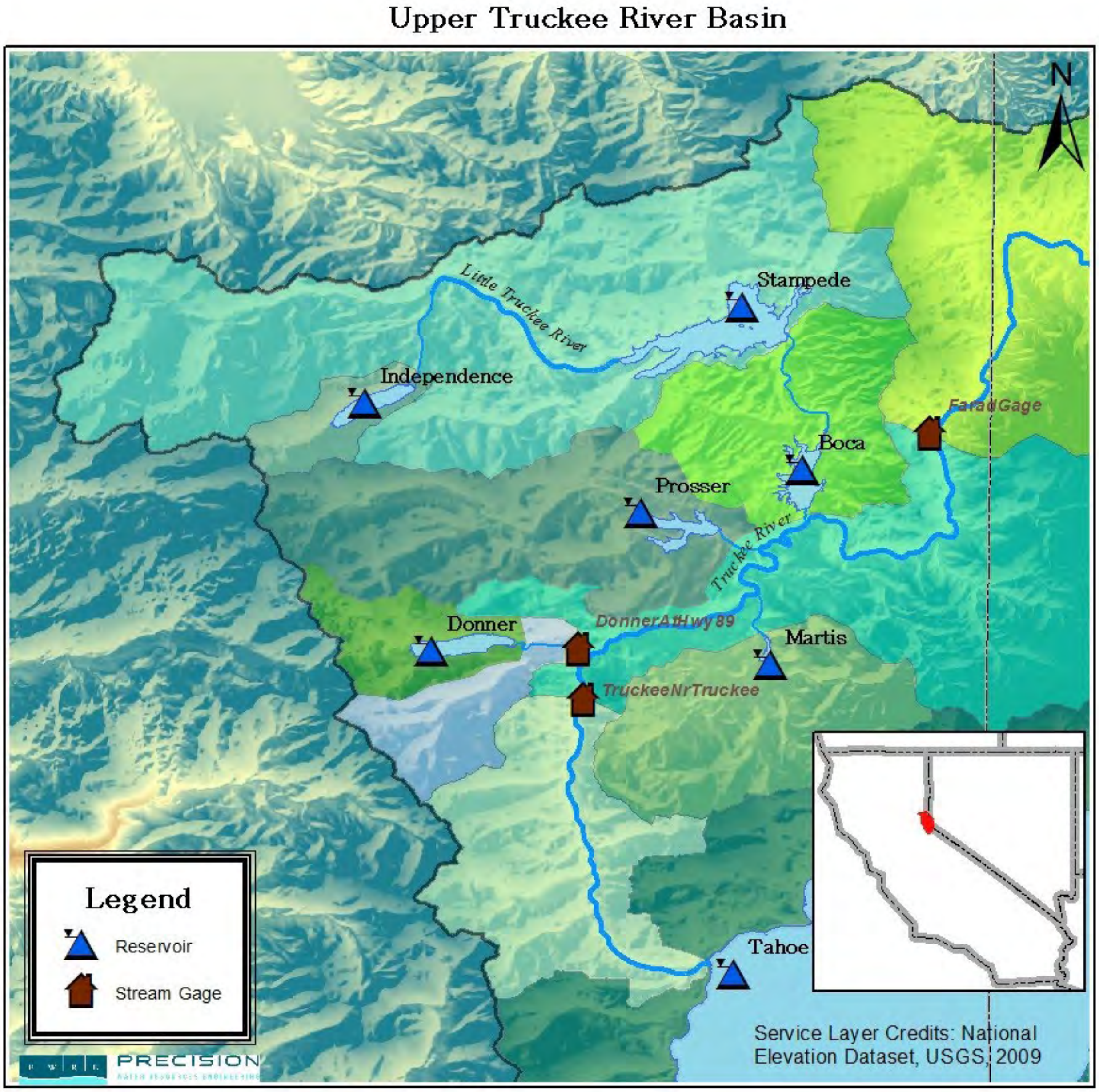


Figure 1: Map of Truckee River Basin upstream of the Farad Gage with contributing subbasins delineated.

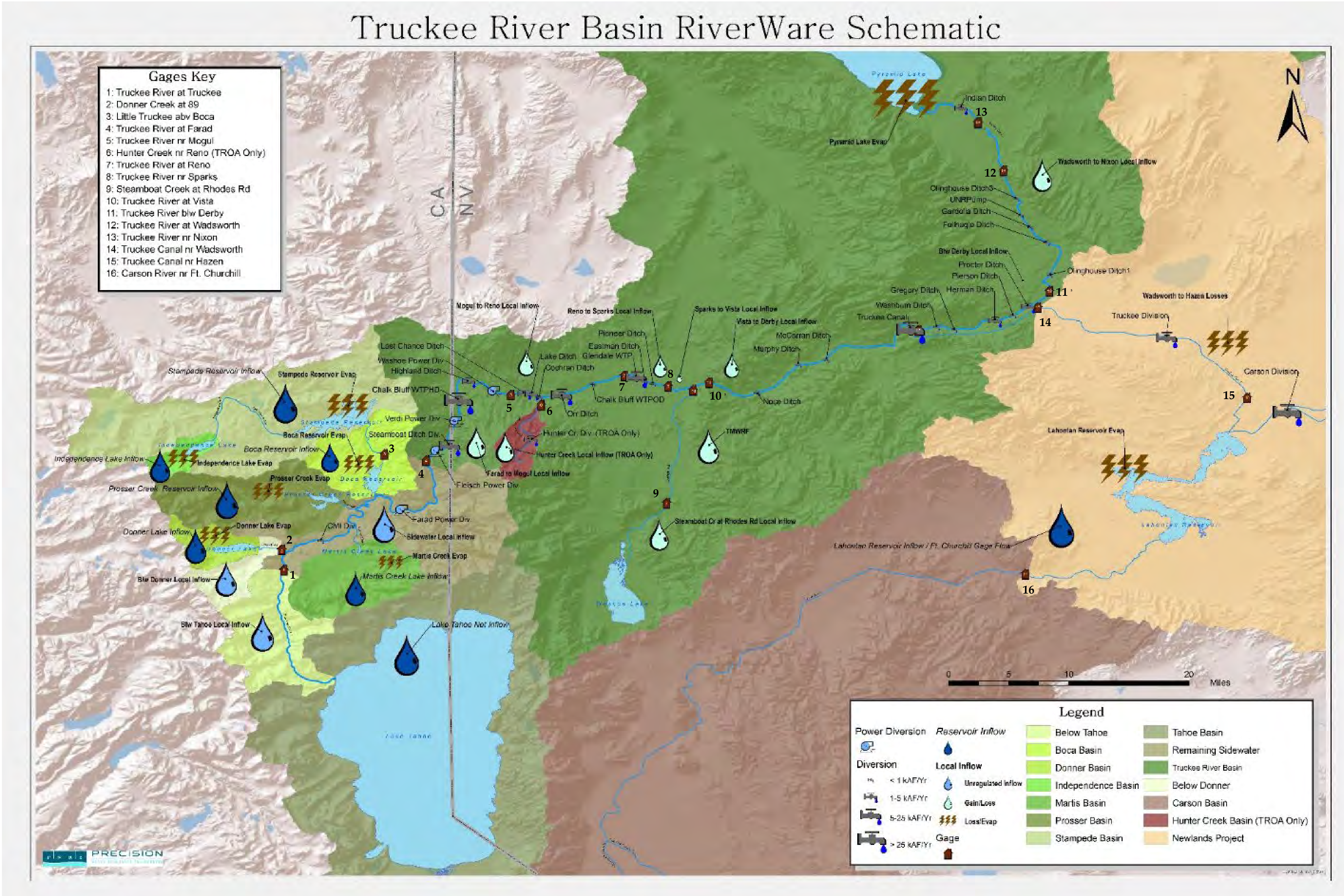


Figure 2: Truckee River Basin Map with Reservoir Inflow, Local Inflow, Diversion and Evaporation locations

1.3 Objectives

This document was developed as part of a package of files that also includes Microsoft Excel workbooks to perform the data development process. Objectives of this document are:

1. Present and describe a standard, repeatable methodology to extend the historical Truckee River basin hydrology dataset – a dataset suitable for use to drive the widely-used basin RiverWare models.
2. Outline and validate the use of this methodology in developing data for the water years 2000 through 2021.

More specifically, the purpose of this process is to extend the historical Truckee River basin inflow hydrology dataset. This dataset was developed specifically to reflect the water balance used within the Truckee River Basin Truckee River Operating Agreement (TROA) Operations and Accounting and TROA Planning RiverWare models. Methodologies developed for this data extension effort were designed to be standardized and repeatable to ensure the ongoing existence of a current, documented, and consistently developed dataset for use in the wide variety of important planning and management studies that are undertaken by the parties of the Truckee and Carson Basins.

1.4 Background

The data for water year 1901 through 2000 were developed by disaggregating monthly data from the TCDATFIL, which is the hydrology data set for the Truckee River Operations Model (TROM) (Fulwiler & Lawler, 2012) (Fulwiler & Lawler, 2010). TROM is a physically based Fortran model that utilizes meteorological, land use, and soil data to determine water depletions and accretions for the Truckee-Carson system. The effort utilized the diversion data available at the time and a water balance that was like the RiverWare model water balance.

RiverWare is a comprehensive water resources system modeling platform that was developed at the University of Colorado. The software is licensed and maintained by the Center for Advanced Decision Support for Water and Environmental Systems at the University of Colorado. In the early 2000s, RiverWare was selected by a group of Truckee Basin stakeholders including the Lahontan Basin Area Office of the Bureau of Reclamation (LBAO) and the Water Master Office. A one-year operations model and a long-term planning model were developed in RiverWare and have been increasing in use since that time. The water balance of the Truckee Basin represented in the

RiverWare model is like that of the TROM model, but not entirely the same. Using TCDATFIL can be useful, it can be improved to ensure that hydrologic data be developed consistently, both in method and water balance, to be used in the RiverWare models. Given the basin's ever-increasing dependence on the RiverWare models, it is important to develop completely consistent hydrologic data for use within the models.

The Water Master's office is responsible for measurement and management of most of the diversion data for the Truckee River downstream of Farad (below Farad). In 2016 and 2017, the Water Master completed a review and digitization process (much of these data were only available as scanned hand-written ledger reports) of their historical diversion data going back to 1984. With this raw diversion data now available, redevelopment of the below Farad local inflow data from 1984 to 2000 may be warranted as the previous local inflow data were developed by post-processing TROM model output. Computation of inflow data before October 1, 2000, was not completed as part of this effort.

2 WATER BALANCE OVERVIEW

This section describes the general assumptions of computing a water balance for both a reservoir and a river reach. Assumptions that were made for this process are discussed in the subsections. The data developed by this process are intended to be consistent with the unique water balance described in the TROA Operations and Accounting and TROA Planning RiverWare models. These models were developed for seasonal or long-term water supply operational planning under TROA by stakeholders and decisionmakers in the Truckee River Basin and calibration of statistical and physical hydrologic models. If these data are used outside of the RiverWare model platform or for a purpose other than modeling the river operations under TROA, one should verify that the water balance is consistent with the assumptions discussed in this report.

In more arid climates (such as that of the Truckee River basin), reservoirs have carry-over storage that is used to compensate for year-to-year variations in streamflow and demand (Maidment, 1993, p. 27.7). Data development results must be optimized on one primary timescale (annual, monthly, or daily) while other timesteps must be computed. As carry-over reservoirs (like Lake Tahoe and Stampede Reservoir) have sufficient storage to compensate for seasonal fluctuations in flow, the annual inflow volume is of particular importance for planning purposes.

Considering the purpose of the dataset being developed is important when deciding quality assurance (QA)/quality control (QC) methodologies to apply and which verification metrics to employ. For example, when data are developed to minimize the daily deviations (e.g., linear regression on daily data), the long-term (annual) deviations can be unacceptably large causing the cumulative error over longer planning runs to be significant (Fulwiler & Lawler, 2012). As a result, an annual timescale was used as the verification time scale for this dataset: differences in annual volumes between the developed and reference gages were prioritized over differences in daily patterning since the data will be used primarily for water supply modeling purposes.

2.1 Water Balance Overview

Computation of the observed hydrologic inflows to a system first requires designation of a closed water balance. For a generalized basin, the water balance can be specified as:

$$\Delta Storage = \sum Inflows - \sum Outflows \tag{1}$$

Equation (1) is based on the principle of conservation of mass. The terms in Equation (1) can be expanded for a reservoir as:

$$\sum Inflows = Precipitation + Surface\ water\ inflows + Groundwater\ inflows + Other\ inflows \tag{2}$$

$$\sum Outflows = Outlet\ works\ release + Spillway\ release + Diversions + Evaporation + Transpiration + Groundwater\ outflows + Seepage + Other\ outflows \tag{3}$$

Equations (2) and (3), represent an expanded form of the water balance (Equation 1) with additional terms of potential importance for a reservoir. The terms "Other inflows" and "Other outflows" were included to illustrate that this is "certainly not an exhaustive refinement" of the water balance (USGS, 2007, p. 6).

When computing a water balance, Equations (1), (2) and (3) are rearranged so that measured or estimated quantities are on one side and the aggregate quantity term(s) being computed is(are) on the other.

2.2 RiverWare Reservoir Water Balance

The following water balance equation defines the term "hydrologic inflow" (inflow to a reservoir) to be consistent with the RiverWare terminology. Equation (4) can be derived by combining Equations (1), (2), and (3) and aggregating any processes not represented on the right side of Equation (4) into the term "hydrologic inflow". The sign convention implied in Equation (4) is that hydrologic inflow will be positive when it represents an inflow to the reservoir and negative when it represents an outflow from the reservoir.

$$Hydrologic\ Inflow = \Delta Storage + Gaged\ Outflows + Evaporation + Diversion(s) - Gaged\ Inflows - Precipitation \quad (4)$$

The data source for each of the terms in Equation (4) will be quantified and discussed in more detail in Section 3, and the specific measurement devices and datasets used for each reservoir are reported in Appendices 8.1 and 8.2. Not all hydrologic processes represented in Equation (4) will be explicitly measured or calculated herein, so their contributions will be lumped into the resulting hydrologic inflow calculation. While Equation (4) represents the calculation method for hydrologic inflow, the physical definition of hydrologic inflow as a function of the terms in Equations (2) and (3) can be expressed as:

$$Hydrologic\ Inflow = Surface\ runoff + Bank\ Discharge + Ground\ water\ inflitration + Other\ inflows - Transpiration - Bank\ Storage - Seepage - Other\ outflows - Error_{Storage} - Error_{Outflow} - Error_{Evaporation} - Error_{Diversions} + Error_{Gaged\ Inflows} + Error_{Precipitation} \quad (5)$$

Given the geography of the Truckee River basin and the subbasins of each reservoir, it is expected that the dominant term of the hydrologic inflow computation is surface runoff. During the baseflow period of the summer months, the magnitude of the hydrologic inflow is likely controlled by the error in the evaporation. This is expected because surface inflows are low and the evaporation is being modeled as mean monthly evaporation rates that were developed by Desert Research Institute (Huntington & McEvoy, 2011). The mean month evaporation was developed using data from 2000 through 2009, a relatively short dataset and the variability in Complimentary Relationship Lake Evaporation (CRLE) monthly evaporation from year to year is not reported however deviations in the actual monthly evaporation from the reported 2000-2009 average would manifest as errors in the computed local inflow. In addition, the same value for R_s (solar radiation, the most sensitive CRLE input variable) was used for all reservoirs except Lahontan due to limitations in data availability (Huntington & McEvoy, p. 13) so the method does not account for variability in solar radiation in the Truckee River Reservoirs. Estimation of daily evaporation is required by the TROA (TROA, 2008). Therefore, it cannot be lumped with the other inflows, and the computed hydrologic inflow should be consistent with the current modeling assumptions.

The terms used in the water balance to evaluate Equation (4) for each reservoir and Equation (8) for each local inflow reach upstream of the Truckee River at Farad gage

(Farad) (Figure 1 and Figure 2) is described in Table 1. Further description of the data sources of each site are included in Appendices 8.1 and 8.2

*Table 1: Summary of water balance terms for each reservoir subbasin upstream of Farad (above Farad). *Lake Tahoe is the only reservoir modeled as a net inflow reservoir (no precipitation or evaporation). Evaporation for all reservoirs is modeled as the historical average month values as described by the Desert Research Institute (DRI) (Huntington & McEvoy, 2011). The values listed are the TROA Information System Site Name – Datatype Name for each site (TIS, 2021).*

Reservoir - Reach	Inflows (not including Hydrologic Inflow)	Outflows	Pool Elevation
Lake Tahoe*	N/A	Lake Tahoe - WM outflow	Lake Tahoe - WM pool elevation
Donner Lake	Donner Lake - WM precipitation	Donner Lake - WM outflow	Donner Lake - WM pool elevation
		Evaporation	
Prosser Creek Reservoir	Prosser Creek Reservoir - WM precipitation	Prosser Creek Reservoir - WM outflow	Prosser Creek Reservoir - WM pool elevation
		Evaporation	
Martis Creek Reservoir	Martis Creek Reservoir - precipitation	Martis Creek Reservoir - WM outflow	Martis Creek Reservoir - WM pool elevation
		Evaporation	
Independence Lake	Independence Lake - WM precipitation	Independence Lake - WM outflow	Independence Lake - WM pool elevation
		Evaporation	
Stampede Reservoir	Stampede Reservoir - WM precipitation	Stampede Reservoir - WM outflow	Stampede Reservoir - WM pool elevation
	Independence Lake - WM Outflow	Evaporation	
		Sierra Valley Diversion	
Boca Reservoir	Boca Reservoir - WM precipitation	Boca Reservoir - WM outflow	Boca Reservoir - WM pool elevation
	Stampede Reservoir - WM outflow	Evaporation	

For hydrologic inflow to Lahontan Reservoir, a water balance was not necessary because the USGS time series data for the Carson River at Ft. Churchill Gage is used. The losses in Lahontan Reservoir are solved for using a different method that was produced as part of a 2013 study by the Bureau of Reclamation (USBR, 2013).

2.3 River Reach Local Inflow Water Balance Overview

Computation of the water balance for a river reach can use a simplified version of Equation (1) where the $\Delta Storage$ is set to zero. Although the volume of water in a reach change slightly from day to day as the depth of the water changes, the magnitude of these changes is small relative to the total flow through the reach. The terms from Equation (2) and Equation (3) can be defined in the cases of reach local inflow and outflow as:

$$\sum Inflows = Reach\ Inflow + Gaged\ Tributaries + Return\ flow + Precipitation + Sheet\ flow + Bank\ discharge + Ground\ water\ inflitration + Other\ inflows \quad (6)$$

$$\sum Outflows = Reach\ Outflow + Diversions + Evaporation + Transpiration + Bank\ storage + Seepage + Other\ outflows \quad (7)$$

The water balance terms that are utilized by the RiverWare model using the RiverWare slot "Local Inflow" are summarized by Equation (8) below:

$$Local\ Inflow = Reach\ Outflow + \sum Diversions - Reach\ Inflow - \sum Tributaries \quad (8)$$

The physical quantities represented by the Local Inflow term can be computed by substituting Equation (6) and Equation (7) into Equation (1) and solving for Local Inflow as shown in Equation (9). Equation (9) is analogous to Equation (5) for a reservoir and can be thought of as a definition of Local Inflow. It represents the sum of the physical components contributing to the Local Inflow volume as well as measurement errors of quantities in Equation (8). Note that Equation (9) is not used for calculation, so the physical processes are not discussed here. "Other Inflows" is included to illustrate that this is not an exhaustive list of physical processes.

$$\begin{aligned} Local\ Inflow = {} & \Delta Storage - Evaporation - Transpiration - Bank\ Storage \\ & - Other\ outflows + Precipitation + Sheet\ flow + Bank\ Discharge \\ & + Groundwater\ infiltration + Other\ Inflows \\ & + \sum Errors\ in\ Measured\ Quantities \quad (9) \end{aligned}$$

Note that it would be possible to estimate terms in Equation (9) and include the estimated term from the right side of Equation (9) in the right side of the water balance in Equation (8). However, before doing so the following passage from (Loucks & van Beek, 2005, p. 264) should be considered:

"…Increasing model complexity will not always eliminate or reduce uncertainty in model output. Adding complexity is generally not a good idea when the increased complexity is based on processes whose parameters are difficult to measure, when the right equations are not known

at the scale of application, or when the amount of data for calibration is small compared to the number of parameters."

In this case, Equation (8) contains sufficient detail for accounting and planning purposes.

It is important to understand that the local inflows as defined in this report are unique to the water balance currently represented in the RiverWare models. For instance, in this effort loss or gain from groundwater is not considered separately as the current RiverWare models do not explicitly represent groundwater processes. However, if future RiverWare models explicitly represent groundwater processes, then the local inflow calculations will need to be updated accordingly. This is also true if a diversion is added, a tributary is added, or any other similar changes are made to the RiverWare model. The water balance associated with each local inflow reach above the Farad gage is summarized in Table 2, and the water balance associated with each local inflow reach downstream of the Farad gage is summarized in Table 3. The stream gages associated with these sites are summarized in Appendix 8.1 and the data collection instruments are summarized in Appendix 8.2.

It is worth noting that retired ditches (diversions) are included explicitly in the local inflow calculations even though they are not currently modeled in the RiverWare models. It is important to account for any retired ditches because this depletion from the river will not continue as it occurred in the past, and their omission from the RiverWare models is the same as including them with no diversion. Historic ditch diversions are important to include in historical data development equations because these diversions are part of the historic gage flows in the river and are therefore a part of the developed dataset.

Table 2: Definition of Water Balance for Sidewater local inflow subbasins upstream of Farad and downstream of the reservoirs which is divided into three-subbasins.

Reservoir – Reach	Inflows	Outflows
Below Donner Local Inflow	Donner Lake – WM outflow	Donner Cr at Hwy 89 – WM flow
Below Tahoe Local Inflow	Lake Tahoe – WM outflow	Truckee R nr Truckee – WM flow
Sidewater Local Inflow	Donner Creek at Hwy 89 – WM flow	Truckee R at Farad – WM flow
	Truckee R nr Truckee – WM flow	
	Martis Creek Reservoir – WM outflow	
	Prosser Creek Reservoir – WM outflow	
	Boca Reservoir – WM outflow	

*Table 3: Water balance used for local inflow below Farad computation. *Indicates retired ditches, ** North Truckee Ditch only diverted 8 AF/year for 2015 and 2016.*

Reach	Inflows		Outflows	
	Upstream Gage	**Tributaries**	**Downstream Gage**	**Diversions**
Farad To Mogul	Farad Gage		Truckee At Mogul	ChalkBluff WTPHD
				Steamboat Ditch
				Coldron Ditch*
				Highland Ditch
				Highland Plant*
				Hunter Ck Plant*
Mogul To Reno	Truckee At Mogul	Hunter Creek	Truckee At Reno	Last Chance Ditch
				Lake Ditch
				Katz Ditch*
				Cochran Ditch*
				Hunter Creek Diversion*
				Orr Ditch
				Chalk Bluff WTPOD
Reno To Sparks	Truckee At Reno		Truckee At Sparks	Idlewild Plant*
				Glendale WTP
				Sessions Ditch*
				Pioneer Ditch
				Glendale Ditch
Sparks To Vista	Truckee At Sparks	Steamboat Creek at Steamboat	Truckee At Vista	North Truckee Ditch**
		TMWRF		
Vista To Derby	Truckee At Vista		Truckee Blw Derby	Noce Ditch
				Murphy Ditch
				McCarran Ditch*
				Truckee Canal Nr Wadsworth
Blw Derby	Truckee Blw Derby		Truckee At Wadsworth	Washburn Ditch
				Gregory Ditch
				Herman Ditch
				Pierson Ditch*
				Proctor Ditch
Wadsworth To Nixon	Truckee At Wadsworth		Truckee At Nixon	Olinghouse Ditch 1
				Fellnagle Ditch
				Gardella Ditch*
				Olinghouse Ditch 3

3 METHODS

The methodologies employed to develop a complete hydrologic dataset for the RiverWare models in the Truckee-Carson basin are described in the following sections. The section is comprised of two subsections that describe the entire process including data collection, preprocessing, computation, post-processing, and review for both the regions of the basin above and below the Farad gage. Finally, a subsection describing some of the specifics of implementing this process is included.

The methodologies designed for developing the data upstream of the Farad gage are different than those used to develop data downstream of the Farad gage. There are two primary reasons for this. First, the inflows to the system upstream of Farad are dominated by seasonal snowmelt runoff and represent the majority of flows in the system; the natural inflows downstream of Farad are significantly smaller and constitute a small percentage of the total flow in the river. In the section of the river below the Farad gage, gaging uncertainty causes more significant challenges in accurately determining the quantity of daily inflow and needs to be taken into consideration more carefully.

Second, to compute reasonable inflows for Sidewater (the unregulated inflows to the system above Farad), the releases from each of the five-reservoirs (Lake Tahoe, Donner Lake, Prosser Creek Reservoir, Martis Creek Reservoir, and Boca Reservoir) that release to the Truckee River need to be routed downstream to account for travel time. The Water Master office's daily data accounts for this travel time. The daily value of the Sidewater flow is a critical parameter for Truckee River operational policy. Thus, additional effort was taken to account for the travel time of release changes in the upper basin to compute the daily unregulated inflows more accurately.

3.1 ABOVE FARAD DATA DEVELOPMENT

Figure 3 shows the workflow and steps required to develop data Above Farad. The steps are grouped into three categories: Data Collection, RiverWare Processing, and Post-Processing. Each category has a subsection in the document that is referenced in Figure 3. The headers above steps within each category reference specific subsections of the document where more detail can be found.

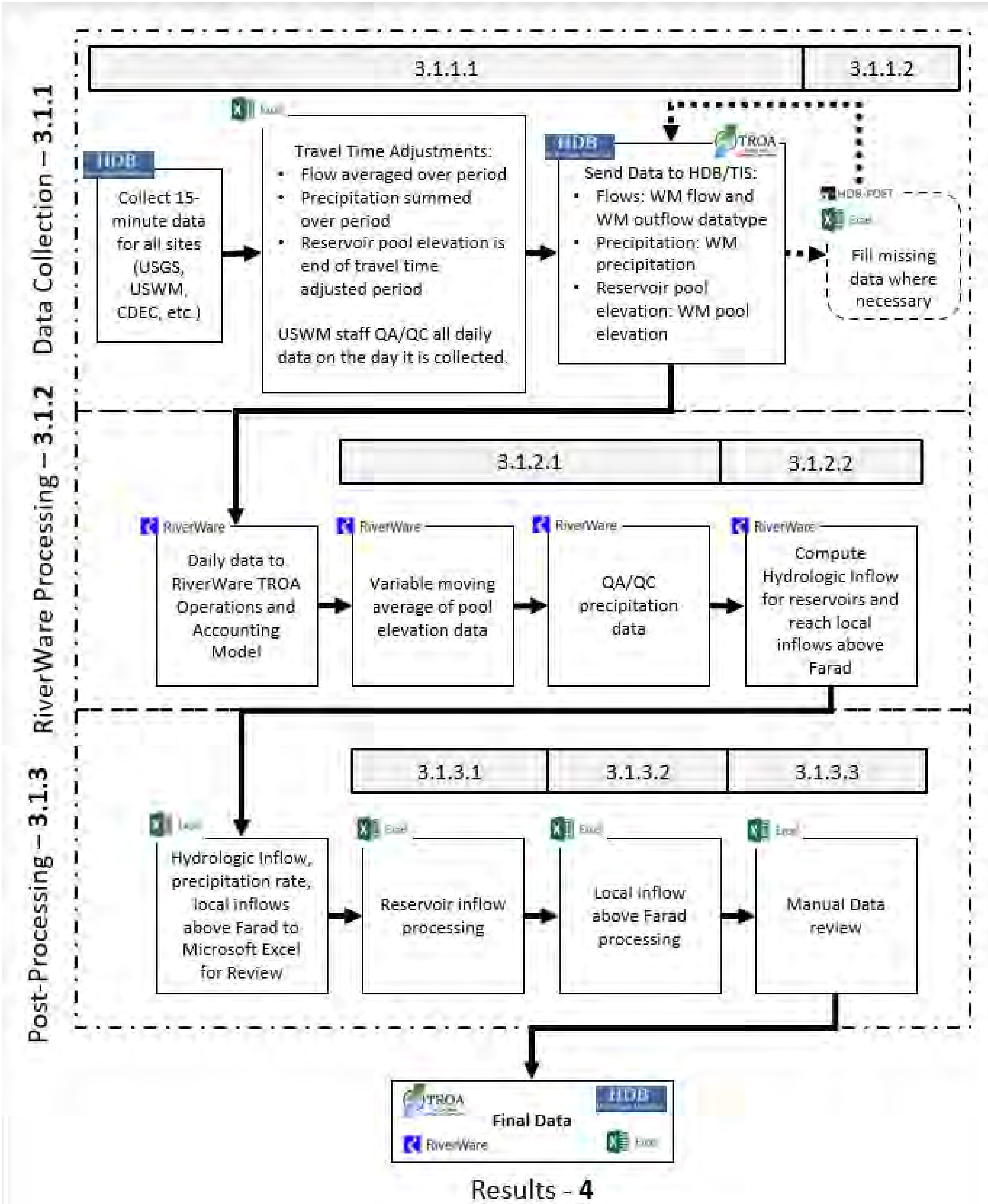


Figure 3: Flow Chart of Above Farad Data Development

3.1.1 Data Collection

Data was collected from various agencies to perform the necessary computations. A summary of the gaging stations used to complete this report are summarized in Appendix 8.1.

3.1.1.1 Data Sources

For sites above (and including) the Farad gage (reservoir elevation, reservoir release, precipitation, and stream gage flow), daily data tabulated by the Water Master and stored on the TROA Information System (TIS, 2021) were used. For sites downstream of the Farad gage, USGS approved daily data were used (where available), and TIS data were used for sites not monitored by USGS. Some of the TIS data are provided by other agencies that include Truckee Meadows Water Authority, California Data Exchange Center (CDEC), U.S. Army Corp of Engineers, and the Washoe County Conservation District. A detailed listing of the electronic source(s) for each measurement is provided in Appendix 8.1.

USGS approved data were not used for sites upstream of the Farad Gage (USGS 10346000) primarily due to the impacts of the travel time on the computations of the Sidewater local inflow components above Farad. If daily local inflows are computed using data for which daily values are computed over the same 24-hour period (e.g., midnight to midnight as employed by USGS), then erroneous daily local inflows (both gains and losses) will be computed due to a failure to consider travel time. This is especially significant when large releases have not reached the downstream gage. Regardless of the data that is used to inform this method, USGS or from TIS, the data would need to be processed further as described in subsequent sections of this document. The time adjusted TIS data was determined to be the starting data that would require the fewest changes and best data to correctly compute Sidewater local inflow above Farad.

Daily data on TIS for the reservoir releases are computed using instantaneous data corresponding 24-hour periods that are adjusted for the travel time between the gaging location and the Farad gage. Daily data on TIS are verified by the Water Master's office each day with special attention to computing inflow data and are used to complete the reservoir release and storage accounting of the system. With the verification, these daily data are of sufficient quality for use in development of historical local inflow data. Because USGS approved data are used for stream gages below the Farad Gage, any corrections made by USGS in their annual review process will be represented in the local inflows below Farad.

Precipitation measurement stations only exist for Lake Tahoe, Donner Lake, Prosser Creek Reservoir, Stampede Reservoir, Boca Reservoir, and Independence Lake. Moreover, the Prosser Creek Reservoir and Stampede Reservoir precipitation stations were added in 2016. For a detailed list of the precipitation gaging stations, see

Appendix 8.1 Data Sources. Where and when gaging data were unavailable, the precipitation over the surface of a reservoir was estimated using the average of the ratio between available point precipitation measurements and the Parameter-elevation Relationships on Independent Slopes Model (PRISM) values that were tabulated by Huntington (Huntington & McEvoy, 2011, p. Table 9). This method is in line with the recommendation of the California Department of Water Resources in their draft Handbook for Water Budget Development (Cal DWR, 2020, p. 62) where gaged data is unavailable.

A description of the physical instruments (make, model, type, etc.) used to collect the above data are included in Appendix 8.2.

3.1.1.2 Data Filling

Some stream gage sites did not have data for the entire period of record. Where data filling had to be done for a significant time period (more than two months), the USGS SREF (Streamflow Record Extension Facilitator) tool (USGS Water Resources Statistics Software, 2016) was used. USGS SREF finds the best correlation with other stream gages in the basin and uses the relationship to fill missing data. Where data for other required sites were unavailable, filling was completed using linear regressions to nearby sites, seasonal averages, or other methods. A detailed description of the sites, time periods, and the method used for data filling is discussed in Appendix 8.3.

3.1.2 RiverWare Processing

After the required data were collected, inflows above Farad were calculated using the RiverWare model. RiverWare performs data pre-processing on reservoir elevation (3.1.2.1.1) and precipitation (3.1.2.1.2) data before solving for the water balance described in Section 2.1. This pre-processing is described in the following sections.

3.1.2.1 Data Pre-Processing

The source data were reviewed to address errors and reduce gaging uncertainty (e.g., measurement error) where possible before computation of the hydrologic inflows to the system. In this context, data pre-processing is a task that consists of identifying data which do not appear to be reasonable and adjusting the data to represent a more-realistic scenario. It was a necessary step to prevent erroneous measurements, outliers, and other anomalies from influencing future calculations and decisions based on results.

There is subjectivity involved in data pre-processing that is unavoidable since objective measurements and calculations are adjusted. Several data pre-processing algorithms were developed in this study and are described in Sections 3.1.2.1.1 and 3.1.2.1.2. These algorithms attempt to minimize the subjectivity in the data review process, but several involve applying coefficients and thresholds determined qualitatively by the authors. Use of consistent coefficients and methods to develop future data will ensure that these subjective issues are addressed in a consistent way when computing future inflow data. In general, these methods identify errors in the timing and location of flows and were developed in such a way to avoid altering the annual volume. While this introduces subjectivity into the review process, the authors attempted to minimize the subjectivity, and introducing limited subjectivity into the process is preferrable to leaving obvious errors in the data unaddressed by the automated procedures in the computed dataset. The following sections explain the importance of applying corrections to certain data.

3.1.2.1.1 Reservoir Elevation Smoothing

Reservoir hydrologic inflow uncertainty is generally dominated by pool elevation measurement uncertainty as this quantity can only be measured to the nearest 0.01 feet. Even on a small reservoir such as Donner Lake, 0.01 feet equates to 7 to 9 acre-feet (AF) depending on the pool elevation. For a large reservoir such as Lake Tahoe, 0.01 feet is equal to 1,200 AF (605 cubic feet per second [cfs]-days). These volumes converted to daily flows are generally much larger than the uncertainty in the streamflow gages and therefore dominate the water balance equation used to compute the reservoir's hydrologic inflow. Therefore, the most effective way to reduce uncertainty in the calculated reservoir hydrologic inflow is to reduce the uncertainty in the pool elevation because the elevation uncertainty is the dominant source and can be prone to painting (short term oscillations in the reading) due to wind and instrumentation inaccuracies. Probability theory dictates that the uncertainty in a measurement can be reduced by averaging multiple independent measurements of the same quantity. The result is reducing the uncertainty by a factor of $1/\sqrt{Number\ of\ Measurements}$. If a variable-length moving average is applied to the pool elevation measurement, the nearby elevation measurements can be treated as independent of the local pool elevation measurement at that time if the range of the measurements is small. On the desired date, this will reduce the uncertainty in the daily computed inflows.

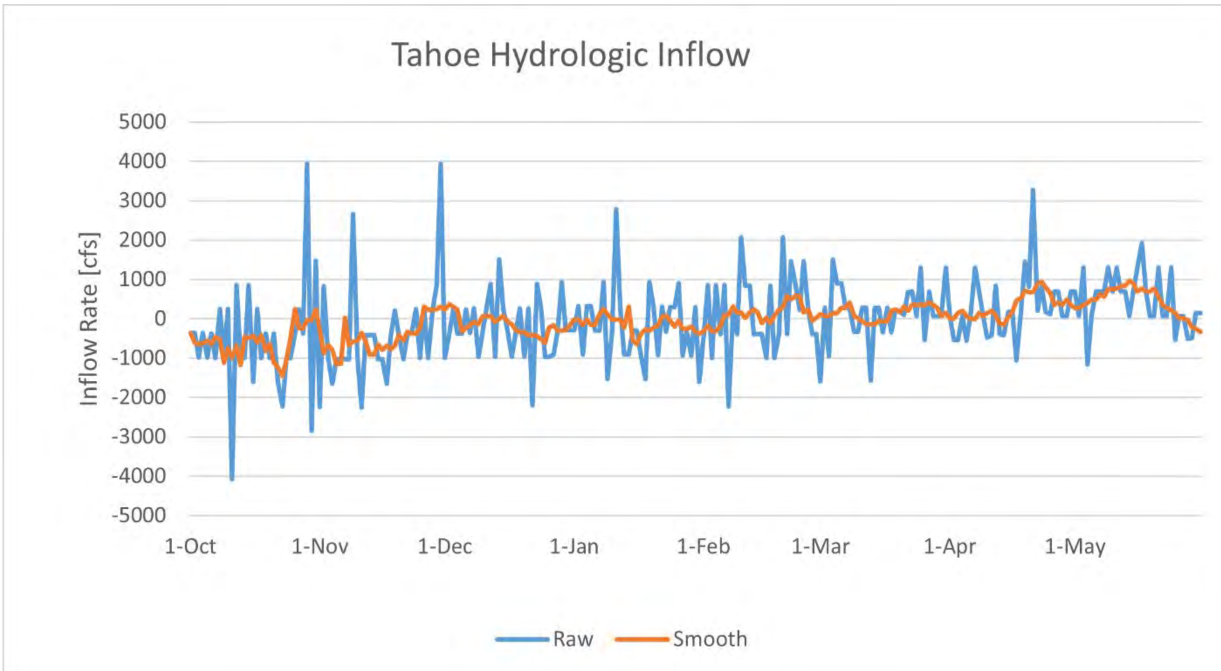
Without utilizing an elevation smoothing methodology, the computed inflow values necessarily step in increments equivalent to the volume in each .01-foot increment of storage. This method has the added benefit of being able to more accurately calculate reservoir inflows at a gradation less than the equivalent of 0.01 feet elevation. This is especially important on Lake Tahoe for which a daily step of .01 feet in measured elevation (finest step possible using current gaging technology) translates into a 600 cfs change in the computed hydrologic inflow. For example, if a decrease in elevation of 0.01 feet is measured and a hydrologic inflow equal to 0.01 feet is computed every other day, applying a moving average to the pool elevation computes a hydrologic inflow equal to 0.005 feet every day which is the more likely to represent the hydrologic inflow.

This impact is most significant when the elevation changes slowly. When there is a sudden change in elevation, a moving average is not desirable because it will mute the sharpness of the peak hydrologic inflow. Thus, a variable-length moving average is preferred. If a variable-length moving average is applied to a daily quantity, some of the daily quantities are impacted. However, when applying the variable-length moving average to the pool elevation, computed hydrologic inflow volumes for longer periods are minimally affected because Equation (4) could be applied at any time interval (monthly, seasonal, annual, etc.).

In application, a moving average was applied to the observed pool elevation using an initialization rule in the RiverWare model. The length of the moving average was adjusted so that all the measurements included in the moving average are within a desired threshold. This is to keep variations in elevation over the averaging period small. For this analysis, a smaller threshold was applied to Lake Tahoe because it is much larger than the other reservoirs. The threshold applied for Lake Tahoe was ±0.1 feet; for all other reservoirs, nearby elevation readings within ±0.2 feet of the current elevation were averaged. These thresholds were determined by computing the value required to reduce the uncertainty in the computed inflow to less than or equal to the computed inflow (Maidment, 1993). The RiverWare initialization rule is reproduced in Appendix 8.7 (Figure 47).

Figure 4 shows the computed hydrologic inflows for Lake Tahoe and Martis Creek Lake between October and June of 2001 before and after the reservoir elevation smoothing routine was applied. The figure is an example of the importance of this routine particularly in a large reservoir such as Lake Tahoe where elevation readings that vary by the measurement tolerance of +/- 0.01 ft result in storage changes of over 1,000 AF. In the period plotted, the computed hydrologic inflow changed by an average of around 1,000 CFS each day with a maximum of 6,700 CFS before elevation smoothing. These dramatic changes in inflow do not reflect reality and illustrate how sensitive the calculation is to small changes in pool elevation. In some cases, however, this process smooths out the larger inflow events too dramatically; these instances are corrected in the manual review part of the process.

In smaller reservoirs such as Martis Creek Lake where small changes in elevation do not result in similarly dramatic changes in storage and computed hydrologic inflow, the results of the elevation smoothing routine are less pronounced. In both the cases, total inflow volume is conserved – a significant advantage of this smoothing method over other methods that may erroneously increase or decrease the annual reservoir storage volume.



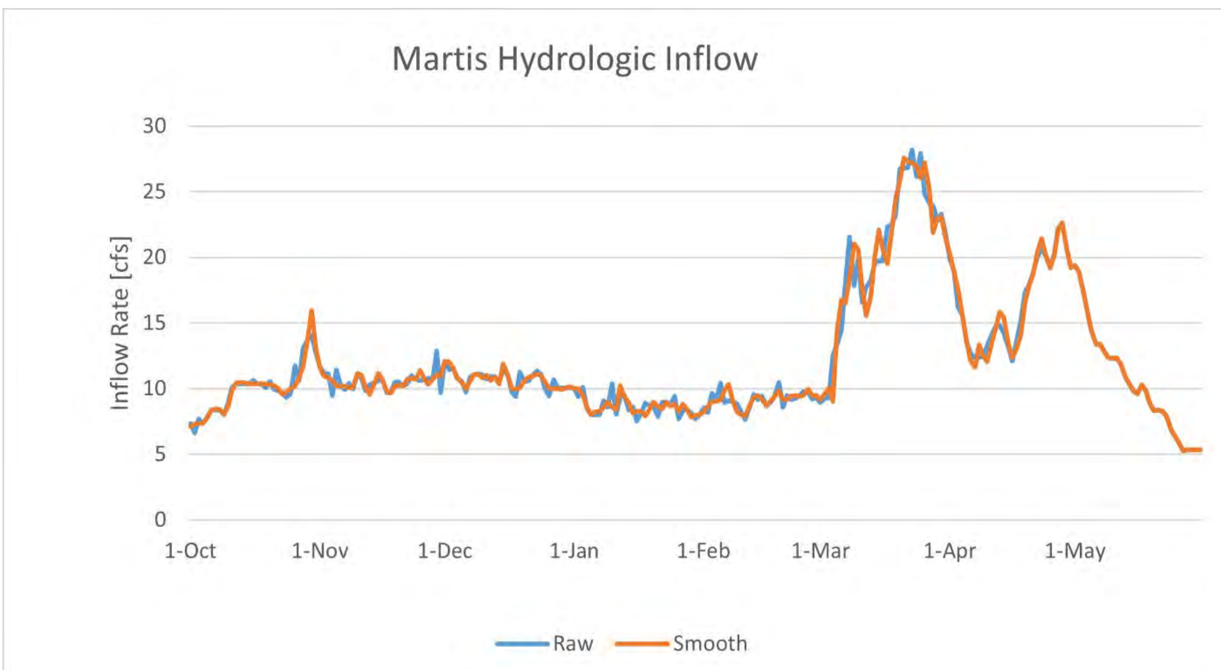


Figure 4: Computed Hydrologic Inflow for Tahoe and Martis Reservoirs between October and June 2001, before (Raw) and after (Smooth) pool elevation smoothing.

3.1.2.1.2 Reservoir Precipitation Verification

Precipitation measurements are recorded as point measurements at locations near the reservoirs. As described in Section 3.1.1.1 Data Collection, Precipitation gages for

Stampede Reservoir and Prosser Reservoir were added in March 2016, and Martis Creek Lake still lacks a precipitation gage even though the reservoir began filling in 1972. Where precipitation data is unavailable, the PRISM method tabulated in the 2011 DRI Publication was used (Huntington & McEvoy, 2011).

If the estimated precipitation over the surface of the water body is accurate, one would expect that the other inflows to the reservoir should increase on the same day as a precipitation event. Precipitation would have also likely occurred in the area surrounding the reservoir resulting in a greater surface runoff into the reservoir. When computing hydrologic inflows as described in Equation (4), precipitation volume often exceeds the computed net inflow to the reservoir resulting in a negative value for Equation (4).

This is particularly likely to occur when the inflow is low, and a large precipitation event occurs suddenly. In this case, a likely explanation is that the measured precipitation was greater than the actual average precipitation over the lake surface. However, this effect could also be explained by uncertainty in other water balance measurements (inflow, storage, outflow, etc.). For instance, the precipitation measured over Boca Reservoir on December 10, 2016, was 0.98 inches which would be 42.3 AF when applied to Boca Reservoir's entire surface (515.8 acres on that day). However, the net inflow on that day was only 34.9 AF. When instances like this occur (after making the corrections to the pool elevation discussed in Section 3.1.2.1.1), the precipitation measurement should be reduced to avoid unreasonable inflow computations.

For this analysis, daily precipitation measurements that are inappropriately large were reduced by a RiverWare Initialization rule such that the precipitation does not exceed 95% of the concurrent daily hydrologic inflow. This value is arbitrary but reasonable because on one hand it is hard to imagine a real rainstorm for which precipitation on the surface of a water body can account for more than 95% of the total net inflow to that water body. On the other hand, it was chosen to be quite close to 100% to not introduce excessive changes to the observed precipitation and acknowledge that events such as thunderstorms isolated to the lake surface are possible. This Initialization rule is reproduced in Appendix 8.7 (Figure 38). Table 4 shows the number of days that this adjustment is made for each reservoir.

Table 4 Number of Days per water year from 2016 through 2021 in which a precipitation adjustment was made.

Water Year	Boca	Donner	Independence	Lahontan	Martis	Prosser	Stampede	Tahoe
2016	0	0	0	0	0	0	16	0

2017	0	0	0	0	0	0	0	0
2018	0	0	0	0	0	0	0	0
2019	22	17	23	0	0	2	15	0
2020	27	10	10	0	0	0	12	0
2021	0	0	0	0	0	0	0	0

This discussion makes it apparent that adding precipitation introduces another term with uncertainty to the water balance. Generally, a term is only added to the water balance (included in the RiverWare model) if it is necessary for the administrative requirements on the model. For TROA, modeling the precipitation is necessary to compute the evaporation charged to storage accounts under TROA (TROA, 2008, pp. 5-26) – a relevant concern of water supply planning in the Truckee River Basin. Thus, precipitation cannot be omitted from the water balance without compromising the efficacy of the computed data. The criteria for adjusting the precipitation rate are described in Equation (10) below, and a result of applying this adjustment to the December 10, 2016 event is plotted in Figure 5.

$$Precipitation \leq (\Delta Storage + Outflows + Evaporation + Diversion(s) - Gage\ Inflows) * 95\% \quad (10)$$

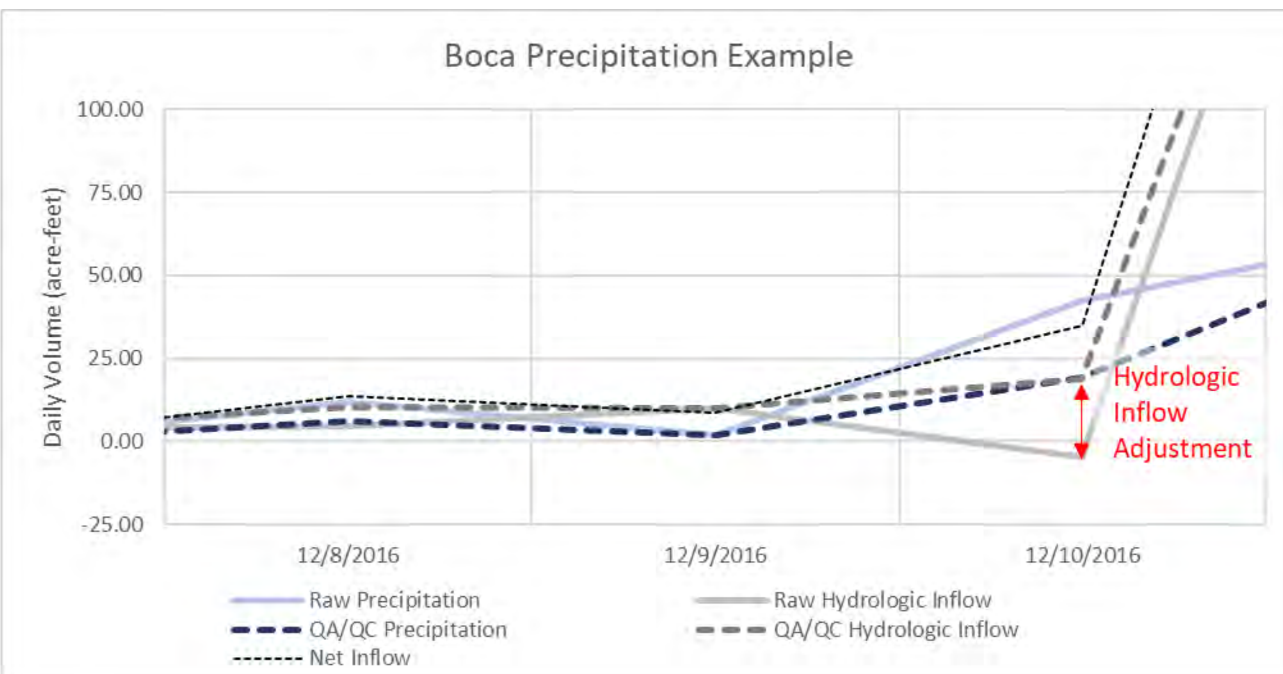


Figure 5: Boca precipitation correction

3.1.2.2 Data Computation

After data collection and pre-processing, the RiverWare model was utilized to compute the inflows to reservoirs and local inflows above the Farad gage. This allows efficient and precise interpolations between measured pool elevations and the corresponding tabulated storage and surface area, and it ensures that the computed inflow mass balance is consistent with the water balance for the model. Detailed description of the water balance solved for by RiverWare is discussed in Section 2.2, and the specific water balance for each quantity is summarized in Table 1.

The inflow quantities that are computed using the RiverWare model include:

- Lake Tahoe Net Inflow (labeled Hydrologic Inflow in the model)
- Donner Lake Hydrologic Inflow
- Martis Creek Reservoir Hydrologic Inflow
- Prosser Creek Reservoir Hydrologic Inflow
- Boca Reservoir Hydrologic Inflow
- Stampede Reservoir Hydrologic Inflow
- Independence Lake Hydrologic Inflow
- Local Inflow between Lake Tahoe and the Truckee River at Truckee gage (Below Tahoe)
- Local Inflow between Donner Lake and the Donner Creek at Highway 89 gage (Below Donner)
- Other Local inflow upstream of the Farad gage (Other Sidewater)
- Farad Natural Flow (the sum of nine previous quantities, excluding Tahoe Hydrologic Inflow)

3.1.3 Above Farad Post-Processing

Computed inflow data from RiverWare were exported to Microsoft Excel using the "Excel_DataDevelopment_Output" Data Management Interface (DMI) for post-processing through various Visual Basic for Applications (VBA) macros. These macros were designed to correct gross data errors for the reservoir hydrologic inflow and local inflow components. The computed inflow from RiverWare is referenced as the "smoothed" flow or data in this section of the document. The VBA macros that perform the post-processing are reproduced in Appendix 8.7. Those macros include:

- HydrologicInflowsSheet - Moves the hydrologic inflow data to a tab for processing.
- Hydrologic Inflows - Processes the hydrologic inflows to check for anomalies.
- SidewaterSheet - brings sidewater data to a new tab for review.

- SidewaterInflows - evaluates the sidewater Local Inflow nodes for mirroring and attempts to reallocate water between sidewater nodes.
- ReviewedData - moves processed data to a review tab in the workbook for viewing purposes.
- ManualData - moved processed data to a manual data sheet for further manual (or non-automated) processing.

After the post-processing by the VBA macros was complete, a manual data review was performed to address issues not addressed by the VBA macros.

3.1.3.1 Reservoir Inflow Automated Post-Processing

The smoothed data that was output from RiverWare (the result of Section 3.1.2.2) were observed to have irregular spike and trough combinations where an irregular daily hydrologic inflow value was followed the next day by a value of similar magnitude but opposite sign. These irregularities are suspected to be due to an incorrect elevation gage reading. Furthermore, other dramatic events were observed when a reservoir pool elevation was shifted by the agency in charge of measuring the data. These events show a negative trough or positive spike that is inconsistent with the nearby days and does not correspond to other similar events at other reservoirs or with observed precipitation events. The negative troughs are easy to identify and correct. The positive spikes are more difficult to identify and need to be distinguished between precipitation events and error spikes.

As a means of processing large scale daily data, an algorithm was developed in VBA and applied to the data. As a part of this algorithm, a bias correction is applied to preserve annual volumes of the original data. The remainder of this section discusses the methodology of this algorithm in detail. Refer to Appendix 8.7 for the text of the VBA macro that applies this methodology.

To identify and correct inappropriate spikes and troughs:

1. Iterate through daily data to identify days that are irregular. A day is flagged as irregular (i.e., a spike or a trough) if one of the following conditions exists:
    i. The hydrologic inflow values on the current day, previous day, and the next day are all positive, AND:
        a. The hydrologic inflow value on the current day is greater than 5 times the hydrologic inflow value on the previous day and the next day, OR

   b. The hydrologic inflow value on the current day is less than 0.33 times the hydrologic inflow value on the previous day and the next day.

ii. The hydrologic inflow values on the current day, previous day, and the next day are all negative, AND:
   a. The hydrologic inflow value on the current day is less than 5 times the hydrologic inflow value on the previous day and the next day, OR
   b. The hydrologic inflow value on the current day is greater than 0.33 times the hydrologic inflow value on the previous day and the next day.

iii. The hydrologic inflow on the current day is positive and the previous and next days are opposite in sign, AND there's more than 400% absolute difference between the value on the current day and the values on the previous and next days.

iv. The hydrologic inflow on the current day is negative and the previous and next days are opposite in sign, AND there's more than 33% absolute difference between the value on the current day and the values on the previous and next days.

v. The hydrologic inflow values on the current and next days are greater than 500% (absolute) than the moving average AND less than 2500% (absolute) than the moving average.

2. After the days are flagged:

   i. The hydrologic value on the current day identified in step 1 (i) through (iv) is corrected by replacing it with a moving average (past days). To conserve volume, the difference between the new value and the old value (divided by the number of days used to calculate the moving average) is subtracted from the previous days used to calculate the moving average.
      a. If there are 31 or more days before the current day in the data, the moving average is calculated based on 31 days.
      b. If there are less than 31 days before the current day in the data, the moving average is calculated based on the number of available days.

   ii. The hydrologic values on the current and next days identified in step 1 (v) are corrected by replacing them with the average of the two values. The volume is conserved by this calculation.

The values of 5 and 0.33 times, 400%, 33%, 500%, and 2500% were determined by trial-and-error based on review of the data from 2001-2021. These values captured errors in most of the data. Relaxing the values caused the correcting algorithm to miss obvious errors; constraining the values corrected data that didn't need to be corrected. Lake Tahoe was not included in the data review process for step 1 (i) through (iv) but was included in step 1 (v). Figure 6 shows an example of a step 1 (v) and step 2 (ii) correction where the smoothed data (labeled "Smooth") were corrected (labeled "Reviewed").

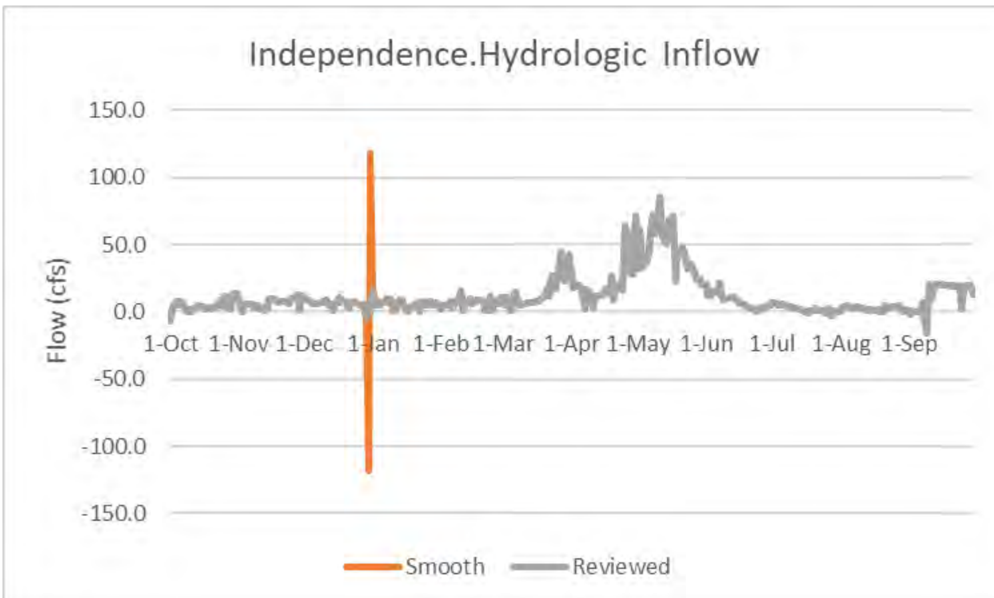


Figure 6: Example of a Large Spike and Trough on Independence Reservoir that was solved by an average of the two values.

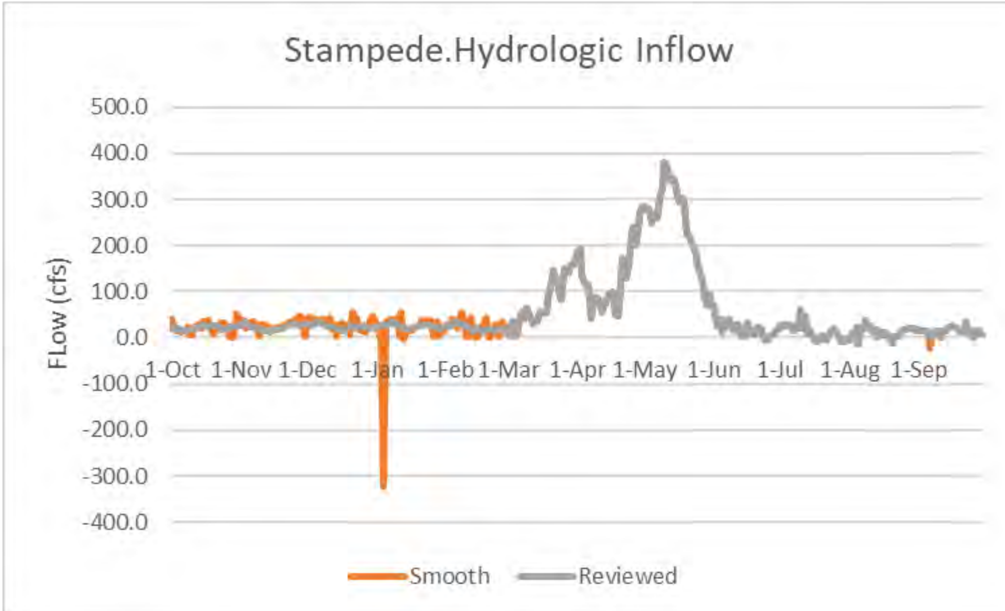


Figure 7: Example of Large Trough on Stampede Reservoir smoothed by adjusting the previous 60 days.

The elevation readings for the Truckee River Reservoirs have a maintenance schedule of 6-8 weeks(see Section 8.2: Data Collection Instruments). When these readings are made, USGS will occasionally apply corrections to the elevation causing a sudden change in elevation (either positive or negative). According to the Water Master, elevation corrections are made approximately twice a year especially when large changes in stage have occurred. USGS will apply these corrections backward based on their judgment, but the Water Master will not.

When such an adjustment occurs, it appears in the data as a conspicuous, single day, positive or negative computed inflow with a magnitude much larger than surrounding flows. An example of a positive elevation shift causing a negative inflow is shown in Figure 7. Most likely, the difference between measured and physical elevation accrued slowly as the elevation of the water body changed since the previous measurement. According to the Water Master, these shifts in inflows over approximately 6-months were too high in the case of a negative shift or too low in the case of a positive shift. Adjusting the inflows over a 6-month period did not seem reasonable, and it is possible that the difference in elevation had accrued over the previous 6-8 weeks (the USGS's typical maintenance period). As such, an adjustment period of 31 days was used because it was long enough to avoid significantly changing the inflow over the period (as shown in Figure 7) (Blanchard, 2020).

If such an event is categorized as a single day trough or spike because of a reservoir elevation shift, the algorithm compares the error with the previous 31-day average of hydrologic inflow (described above in the data flagging process steps 1 (i) – (iv)) and corrects it according to the process described in step 2 (i) above. Figure 7 shows an example where the corrected ("Reviewed") data have the large negative trough removed.

This algorithm removes the obvious errors in the hydrologic inflow data to reservoirs. A more thorough manual review then removes errors this process is not able to correct. That discussion is in Section 3.1.3.3.

3.1.3.2 Local Inflow Above Farad Automated Post-Processing

The unregulated inflow to the Truckee River above the Farad Gage is known as the Local Inflow above Farad and referred to as Sidewater in this document. The Sidewater flow components are composed of Below Tahoe, (area below the Lake Tahoe Dam and the Truckee River Nr Truckee CA (USGS 10338000, referred to as TruckeeNrTruckee in Figure 1) gage), Below Donner (area below Donner Lake Dam and the Donner Creek At Hwy 89 (USGS 10338700, referred to as DonnerAtHwy89 in Figure 1) gage), and the Sidewater Local Inflow (area below those two gages, Prosser Creek Reservoir, Boca Dam and Martis Creek Reservoir. A map of the respective subbasins is shown in Figure 2.

Using RiverWare, a series of local inflow data for each Sidewater component were computed using the input releases from the upstream reservoirs and the appropriate measured stream gage values. In the Sidewater inflow data set, there are several classes of measurement errors. One type of error is an inconsistent measurement at one or both of the middle gages (Donner Creek at Hwy 89 or Truckee River Near Truckee) which are less than two miles apart and about 16 river miles upstream of the Farad Gage (Google Earth). This type of error can produce a "mirroring" behavior among the subbasins. For example, if the middle gage(s) is(are) erroneously low, then the upstream subbasin computes a large positive inflow and the downstream computes a large negative inflow such that the magnitudes are nearly equal and opposite. A VBA macro was developed to correct these issues and is explained below. This macro is reproduced in Appendix 8.7 in Figure 52.

The macro compares the daily value for each subbasin to the running average for that subbasin. The deviations for the three subbasins on a given day are compared to identify days when one subbasin is above average while other subbasin(s) are below average or vice versa. When a discrepancy is identified, a correction is made that preserves the total Sidewater flow while maintaining similar deviations from the nearby averages at each subbasin. This process is repeated for averaging periods between 11 and 51 days between thresholds of 80 and 5 cfs. As shown in Figure 8, these corrections will cause an equal and opposite effect on the upper and lower subbasins.

The reservoir outflows that directly flow into the Truckee River and the Farad Gage measurements are not changed. Some inconsistent data may be due to inaccurate reservoir release measurements; however, programmatic identification of these errors would be more difficult to detect and correct. Further, corrections to the reservoir outflows would change the total inflow to the reservoirs which would impact the total volume stored in the reservoirs – an important operational parameter.

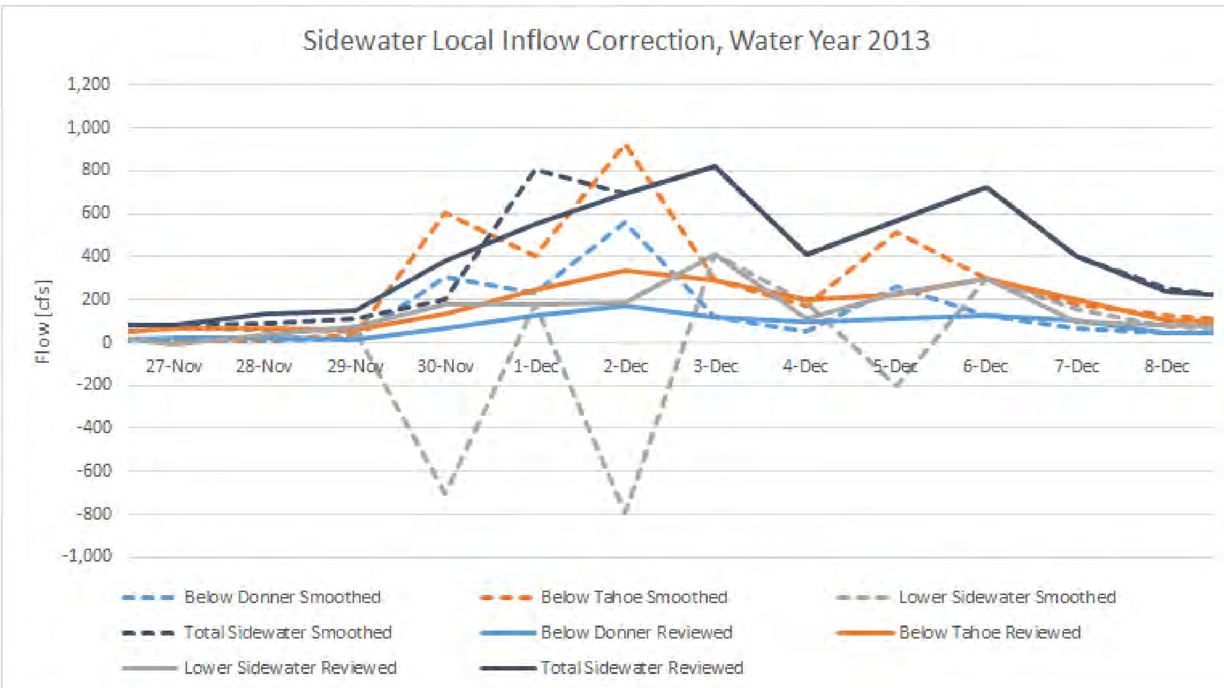


Figure 8: Sidewater Inflow Data before and after correction

These alterations remove instances from the data that differ from the known hydrologic processes in the basins of interest. In the example shown in Figure 8 from Water Year 2013, below Tahoe has a computed flow of over 900 cfs while the lower Sidewater has a reported flow of approximately -800 cfs. It is likely that neither of these values are accurate due to an error of high measurement at the middle gages (Truckee River Nr Truckee CA and Donner C At Hwy 89).

Before the algorithm was run, the data showed mirroring behavior on November 30th, December 2nd, and December 5th. A likely explanation for this is that the increase in flow had reached the Truckee River at Truckee and Donner Creek at 89 gages by the end of the period used for December 2nd but had not yet reached the Farad gage. This would cause a negative flow to be computed for the "Sidewater" basin on December 2nd which would then be compensated with an overly large flow on December 3rd after the flow reached Farad. The algorithm successfully identified and fixed this issue. It is important to note that although the algorithm corrects based on the recently observed average flow for that subbasin, it is still able to preserve seasonal trends in the data such as higher volumes at the end of November and beginning of December. All three Sidewater regions are small, adjacent, and geographically similar and should therefore exhibit very similar hydrologic responses. The corrected data maintains this consistency making it preferrable to the uncorrected data.

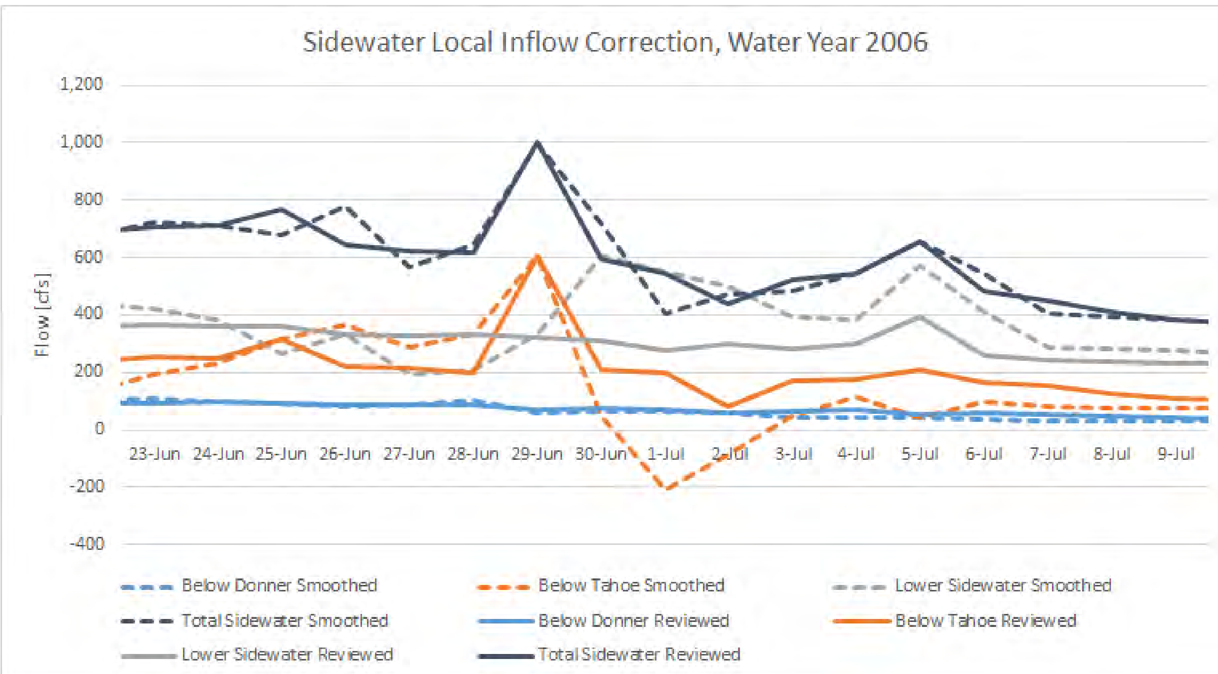


Figure 9: Sidewater Local inflow data before and after correction

Figure 9 shows another example of a similar correction made to Sidewater local inflow data. The Below Tahoe local inflow had an unusual negative trough on July 1, 2006, while Sidewater (Lower Sidewater in Figure 9) was showing a relative increase, and the below Donner reach was roughly steady. The algorithm identified this issue, increased the local inflow on the Below Tahoe reach, and decreased the values for the Sidewater reach. Total Sidewater volume is conserved over the period of adjustment.

3.1.3.3 Above Farad Manual Data Review

Once the VBA macro corrections for reservoir shifts and major gage errors were completed, a thorough manual data review was conducted for the data Above Farad. A Microsoft Excel tool was employed to visualize the data and assist in the manual verification process. The manual review was performed to correct periods of data with atypical discrepancies that were observed in the data Above Farad. Appendix 8.4 contains a table with a summary of changes by water year for the Above Farad inflow data. In this section are four figures illustrating examples of common manual changes made to data Above Farad[1].

In general, the discrepancies include exceptionally "noisy" reservoir inflow data where fluctuations to the inflow were greater than what is reasonable. Data were adjusted when negative inflows to a reservoir were observed before a large inflow event due to a storm. This error is most likely due to inconsistent timing of the gages used in the water balance. Large positive and negative spike and trough combinations not resolved by the algorithms described above were corrected, and spikes that should not have been corrected by the algorithms were restored.

Noisy computed inflow data were corrected using a moving average over a specified period, usually between 7 and 10 days, and were bias corrected to preserve the inflow volume. For irregular spikes or negative inflow, a combination of correcting daily data or using a moving average with bias corrections to preserve volume was used.

[1] For a complete list of all edits made within the manual process. The Microsoft Excel Workbooks that allow the manual process have archived changes for each location Above Farad that was edited through the process.

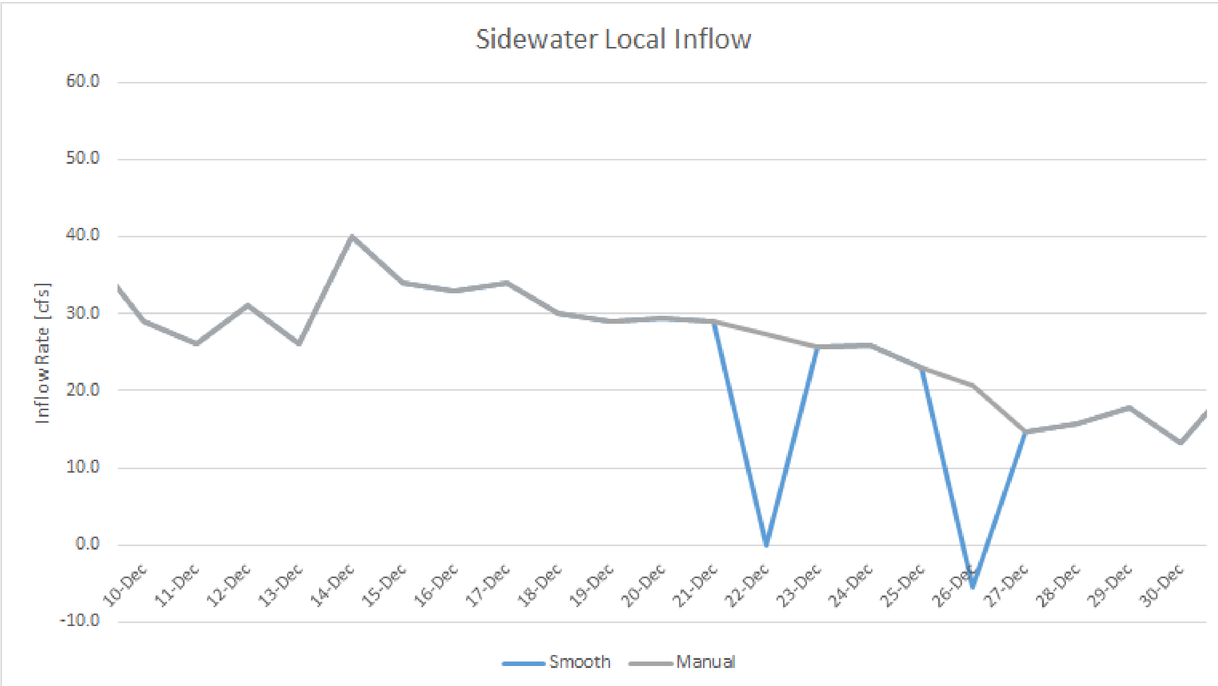


Figure 10: Manual data correction made to Other Sidewater Local Inflow, water year 2001.

Figure 10 illustrates a manual adjustment made to Sidewater local inflow in December 2000 which is one of the common corrections made during the Above Farad data review process. It is expected that the three Sidewater reaches above Farad (Below Tahoe, Below Donner, and Remaining Sidewater) would demonstrate similar hydrologic responses. Sudden spikes or troughs that are shown in one of these quantities but not the other two can likely be attributed to gaging error, and corrections can be made while maintaining the total Sidewater volume. The December 2000 example shown in Figure 10 shows two sudden, one day troughs in the data which were adjusted to match surrounding values. In this case, volume was preserved by adjusting data in the other two Sidewater reaches to maintain the total volume over that time period.

Figure 11 shows an example of another common adjustment made to Above Farad data as a part of the manual adjustment phase. A volume correcting moving average is applied to Prosser hydrologic inflow in December 2002 to address an irregular trough on December 25 inconsistent with data from the nearby reservoirs. First, a moving average was applied to the period of data containing the irregularity to smooth out the trough. Then, two sums were computed for that same period - one with the data before the moving average and the other with the averaged data. To conserve volume, each of the edited points was multiplied by the ratio of the resulting sums.

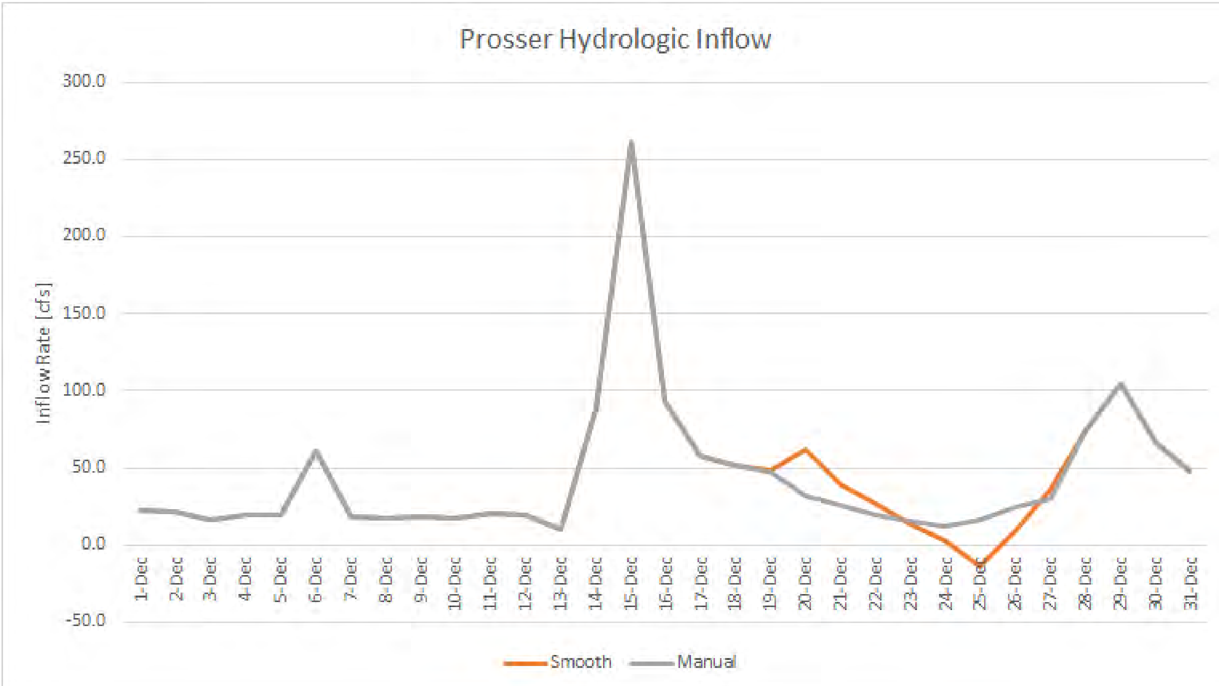


Figure 11: Manual data correction made to Prosser Hydrologic Inflow, water year 2003.

In Figure 12, another volume preserving moving average adjustment was applied during the manual data review process. In this example, Boca hydrologic inflow data were unreasonably noisy between October 2003 and February 2004. There is no reasonable hydrologic explanation for this extreme daily variability of inflow to Boca Reservoir. The moving average smoothed the data, and the same volume correction method used for Figure 11 ensured that volume was conserved over the adjusted period.

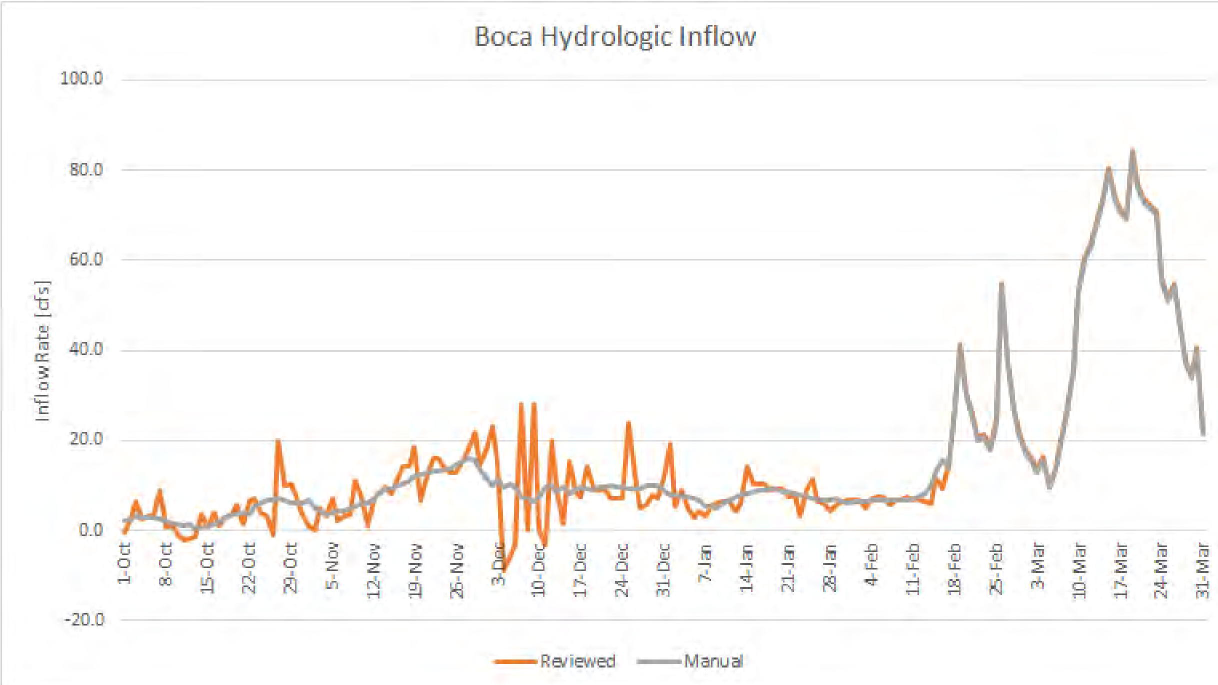


Figure 12: Manual data correction made to Boca Hydrologic Inflow, water year 2004.

Figure 13 shows an irregular trough followed by a spike in Donner hydrologic inflow identified during the manual data review. October 10, 2011, had an unusual value near zero followed by a large spike the following day inconsistent with any precipitation events. Data on October 10 and 11 were set to the average of the two irregular days removing the spike and trough while conserving volume.

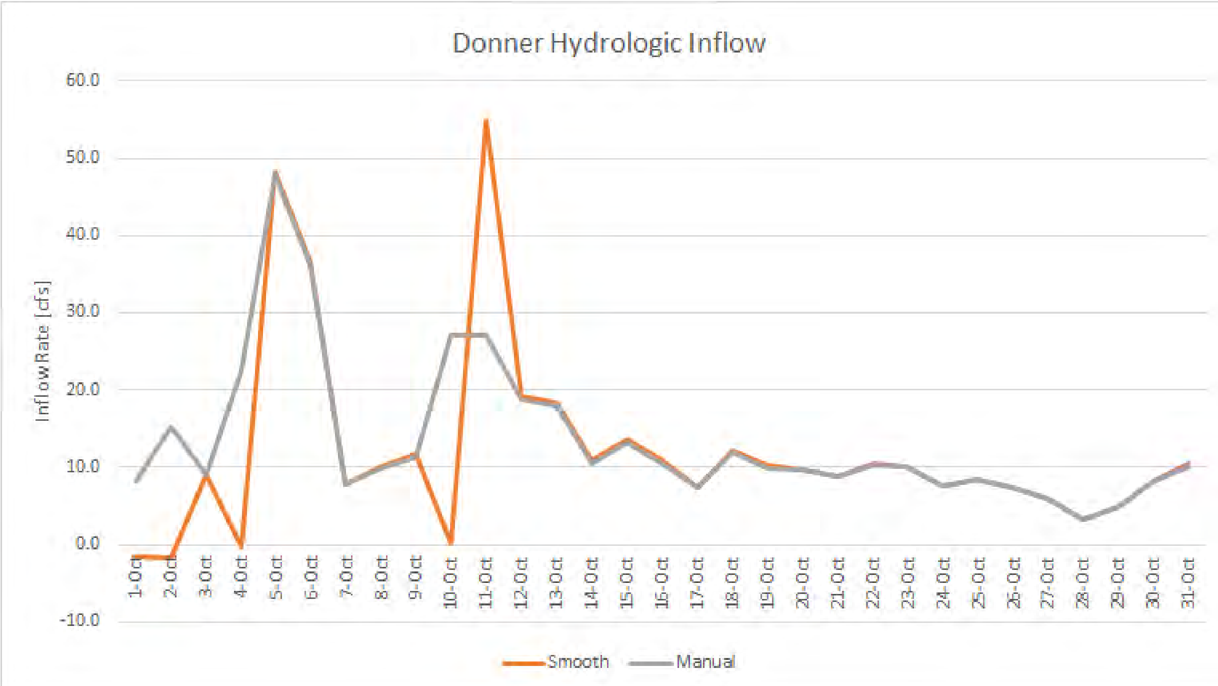


Figure 13: Manual data correction made to Donner Hydrologic Inflow, water year 2012.

3.2 Methods – Below Farad

As described in the beginning of Section 3, methodologies used to develop data upstream of the Farad gage vary significantly from the methodologies used to develop data downstream of the Farad gage. This section will describe the methods used to develop reach local inflows Below Farad.

3.2.1 Steps For Below Farad Data Development

Figure 14 describes the steps required to compute the reach local inflow data and the software used to complete each step. The steps are grouped into three categories: Data Collection, Data Computation, and Post-Processing. Each category has a subsection in the document referenced in the flow chart. The headers above each step reference specific subsections of the document.

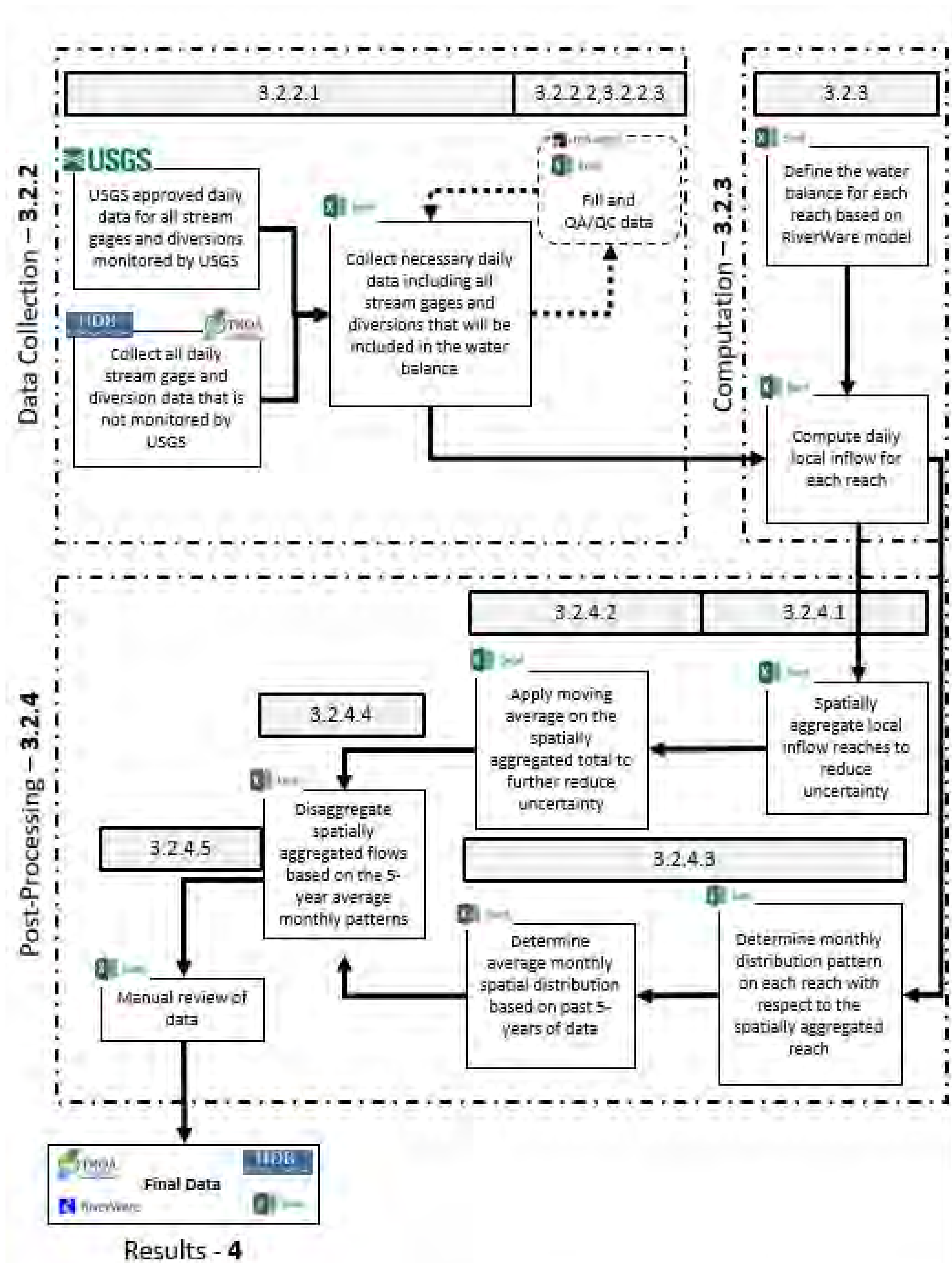


Figure 14: Flow Chart of Below Farad Data Development

3.2.2 Data Collection

Data were collected from various agencies to perform the necessary computations. A summary of the gaging stations used to complete this report are summarized in Appendix 8.1.

3.2.2.1 Data Sources

For sites downstream of the Farad gage, the USGS approved daily data were used where available, and TIS data was used for sites not monitored by USGS. Some of the TIS data are provided by other agencies including Truckee Meadows Water Authority, CDEC, U.S. Army Corp of Engineers, and the Washoe County Conservation District. A detailed discussion of the electronic source for each measurement is provided in Appendix 8.1 Data Sources. A description of the physical instruments (make, model, type, etc.) used to collect the above data are included in Appendix 8.2.

3.2.2.2 Data Filling

Some stream gage sites did not have data for the entire period of record or had missing data.

Where data filling had to be done for a significant time period (more than two months), the USGS SREF tool (USGS Water Resources Statistics Software, 2016) was used. USGS SREF finds the best correlation with other stream gages in the basin and uses the relationship to fill missing data. Where data for other required sites were unavailable, filling was completed using linear regressions to nearby sites, seasonal averages, or other methods. A detailed description of the sites, time periods, and the method used for data filling is in Appendix 8.3.

3.2.2.3 Stream Gage Verification

The only notable correction made to stream flow gage data was to Hunter Creek gage data. Each spring (late March to early May), there is a large spike in inflow on the order of 60 cfs. This is due to flushing procedures that occur when preparing the Steamboat Ditch for operations and is not hydrologically driven. Given that the source of the discrepancy is known, the stream gage data were adjusted to remove the inflow spike each year. The Steamboat Ditch diversion was also adjusted accordingly. Adjustments were made for 2004, 2005, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2015, and 2016. The adjustment for 2016 is shown in Figure 15 and is typical of the corrections made for other years.

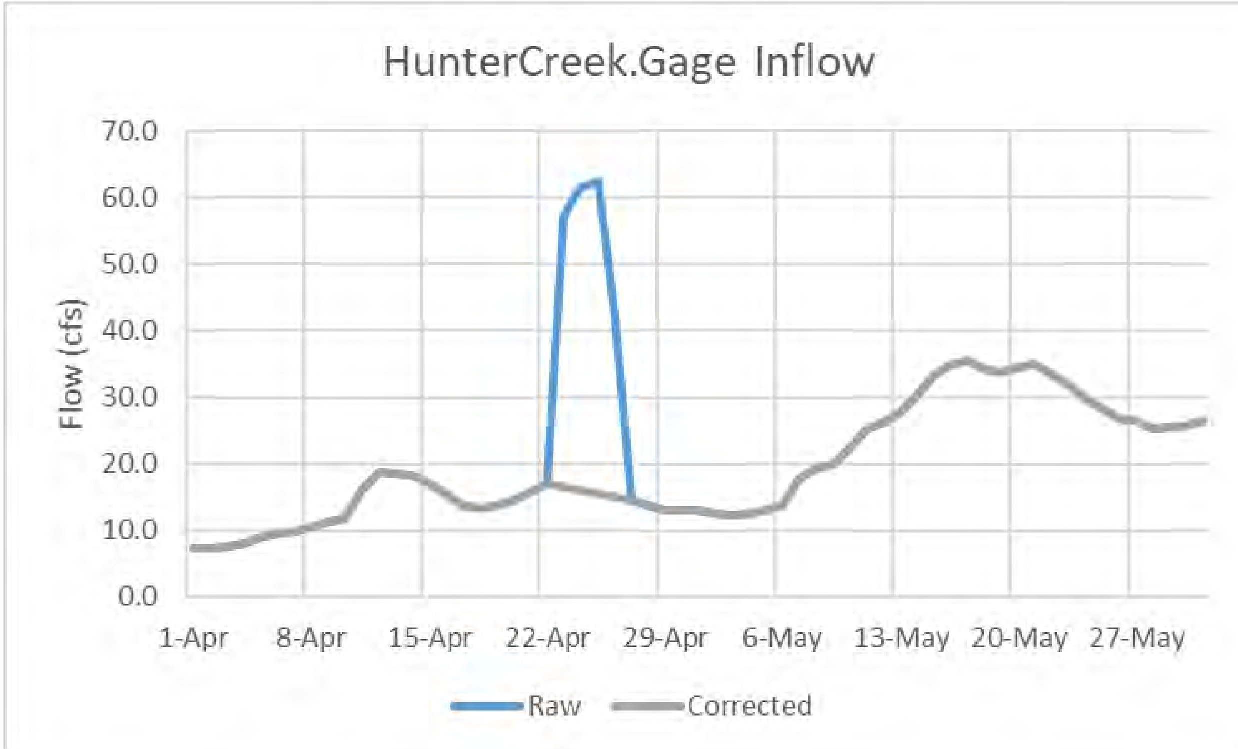


Figure 15: Hunter Creek corrected gage flow 2016, typical of corrections made in other years.

3.2.3 Below Farad Data Computation

The local inflow dataset was developed for 1984 – 2021. Year 1984 was selected as the start year because it is the earliest period of the record where the Water Master diversion data has been digitized. All agricultural ditch data were obtained from the TIS (TIS, 2021). These data were extensively reviewed by Water Master staff and Precision Water Resources Engineering and corrected for erroneous readings arising from standing water or incorrect measurements. Some ditches had incomplete data. The gaps in the data were filled using interpolation, past trends, or a distribution of monthly volumes after discussing with the Water Master staff. The techniques used to review and correct the developed datasets are discussed in Section 3.2.4.

A unique water balance was developed between every pair of successive stream gages on the Truckee River from the Farad gage downstream to the Truckee River at Nixon gage. The historical gain or loss occurring between the two gages was computed using the local inflow water balance equation. The general water balance equation specified in Equation (8) was solved daily for every adjacent pair of stream gages. The equation is repeated here for convenience.

$$Local\ Inflow = Reach\ Outflow + \sum Diversions - Reach\ Inflow - \sum Tributaries \quad (8)$$

Between Farad and Pyramid Lake are eight stream gages (excluding the Truckee River at Glendale gage which was added to the system in 2014) on the mainstem of the Truckee River that are modeled. Thus, there are seven unique local inflow water balance equations. The details of these water balances with the stream gages, diversions, and tributaries can be found in Table 3. Retired ditches are included in the water balance even though they are not currently modeled as explained at the end of Section 0.

For the local inflow computation, return flows are not considered separately from local inflows even though the magnitude could be estimated as a fraction of the diversion. Even if the return flow magnitude is approximated, the timing and location is uncertain. Therefore, including this in the computation will add to the overall uncertainty. Instead, excluding return flows in the water balance lumps them into the calculated local inflow term therefore including them in the local inflow dataset. The drawbacks of this are that return flows from retired ditches are part of the local inflows, and future diversions significantly different from historical diversions could still show a return flow pattern similar to historic patterns. However, without the ability to adequately determine the magnitude, location, and timing of return flows from diversions, the added uncertainty does not justify including them explicitly in the calculations.

Some ditches divert excess water due to imprecise diverting mechanisms, infrequent diversion management, etc. which results in all or a portion of the diverted water returning to the river unconsumed. This spill back, return, of water is usually ungaged. Where data is available, they are incomplete and available for only a few years. Therefore, spill data are not considered on any ditch for the local inflow calculations as the spill might return to the river at a different time or place. As a result, spills are also lumped into the local inflow calculation. The exception to this is Washburn ditch as only net data (diversion head – spill) are available for the majority of years. For consistency, net diversions are used for all years.

3.2.4 Below Farad Post-Processing

As mentioned above, the mainstem of the Truckee River from Farad to Nixon contains eight modeled stream gages used for this analysis. Intuition dictates utilizing each of the intermediate stream gages to divide the basin into subbasins then calculating the local inflow for each thereby capturing the spatial variability of inflows along the Farad to Nixon reach. In practice, however, the computed local inflows to each reach are quite small in comparison to the total flow in the river. As a result, the raw local inflows computed for each sub-reach by the water balance equation show erratic and unreasonable behavior.

In many cases, the computed local inflow for one sub-reach is significantly negative while significantly positive in a neighboring sub-reach such that the absolute value of the local inflow in one or more sub-reaches is orders-of-magnitude greater than the computed inflow for the whole Farad to Nixon reach. This does not represent the actual hydrologic behavior of these sub-reaches. Thus, data that exhibits these characteristics would not be usable for other studies and efforts using the RiverWare Operations and Planning Models.

The most likely explanation for this unsuitable data lies not in the formulation of the water balance equation but in the observed data itself. Local inflows contain excessive uncertainty that is an inextricable byproduct of the equation from which they are computed with this simple water balance approach. Appendix 8.6 details a thorough analysis performed to substantiate this important conclusion; it led to the following strategy for developing reasonable and useful local inflows through the Truckee Meadows (the region between the Truckee River at Mogul and the Truckee River at Vista gages).

Generally, the most straightforward way to reduce uncertainty in a computed hydrologic quantity is to aggregate temporally and/or spatially. Aggregation increases the magnitude of the computed quantity and will inherently reduce uncertainty (Maidment, 1993, p. 20.3). This is discussed in greater detail in Appendix 8.6. The specifics of the spatial and temporal aggregation techniques employed are outlined in the following sections.

Considering the significant challenges posed by the uncertainty inherent in computing local inflows in Below Farad, the procedure for determining the local inflows in Below Farad is more involved than that for the Above Farad. The following strategy is employed to develop reasonable and useful inflows for the reaches Below Farad:

1. Compute the raw daily local inflow for each sub-reach in the Below Farad basin (Farad to Nixon reaches) using the observed daily data for each.

2. Compute the raw daily local inflow for the entire Below Farad (Farad gage to the Truckee River at Nixon gage) reach by summing the sub-reach local inflows calculated in step 1.
3. Apply a seven-day moving average to the computed raw daily local inflows from step 2.
4. Using the raw daily local inflows for each sub-reach from step 1, calculate the monthly percentage of the total local inflow (from step 2) that comes into each sub-reach.
5. Determine the monthly average of the percentage of total local inflow for each sub-reach of the previous five years.
6. Determine the daily local inflow to each sub-reach by taking the daily local inflow for the Below Farad basin from Step 3 and multiplying it by the appropriate percentage determined in Step 5 for that sub-reach.

Details for each of these steps are presented in the following sections.

3.2.4.1 Spatial Aggregation

The seven local inflows developed on a daily timestep are added together to generate a daily total local inflow timeseries for the whole lower Truckee River (Below Farad). Spatially aggregating all the sub-reaches into one reach – Farad to Nixon – results in reducing the uncertainty in the resulting local inflow and reducing unwanted spike to trough fluctuations in the local inflows computed from one reach to the next. Uncertainty is reduced by spatial aggregation because the six intermediate stream gage measurements and their associated uncertainties between Farad and Nixon (Mogul to Wadsworth) are effectively removed from the equation by calculating the aggregate local inflow.

One common error addressed by this aggregation is a spike followed by a trough (or vice-versa) in a sub-reach's computed inflow. This error is encountered and addressed in the Above Farad reservoir inflow computation post-processing process described in section 3.1.3.1. The same process is applied here to the aggregate local inflow results. It is implemented by the "removeSpikesBelowFarad" VBA macro. This macro is reproduced in Appendix 8.7 (Figure 55).

Further review of the computed inflows for the sub-reaches shows another common error addressed by spatial aggregation. Often, the computed local inflows for one sub-reach show a significant loss with a similar magnitude gain in the next downstream sub-reach, or vice-versa, that does not follow an annual pattern or have any obvious hydrologic reason. An example is shown in Figure 20. The most likely explanation is that the measured flow on the gage at the boundary of these two sub-reaches is in-error but within its published uncertainty.

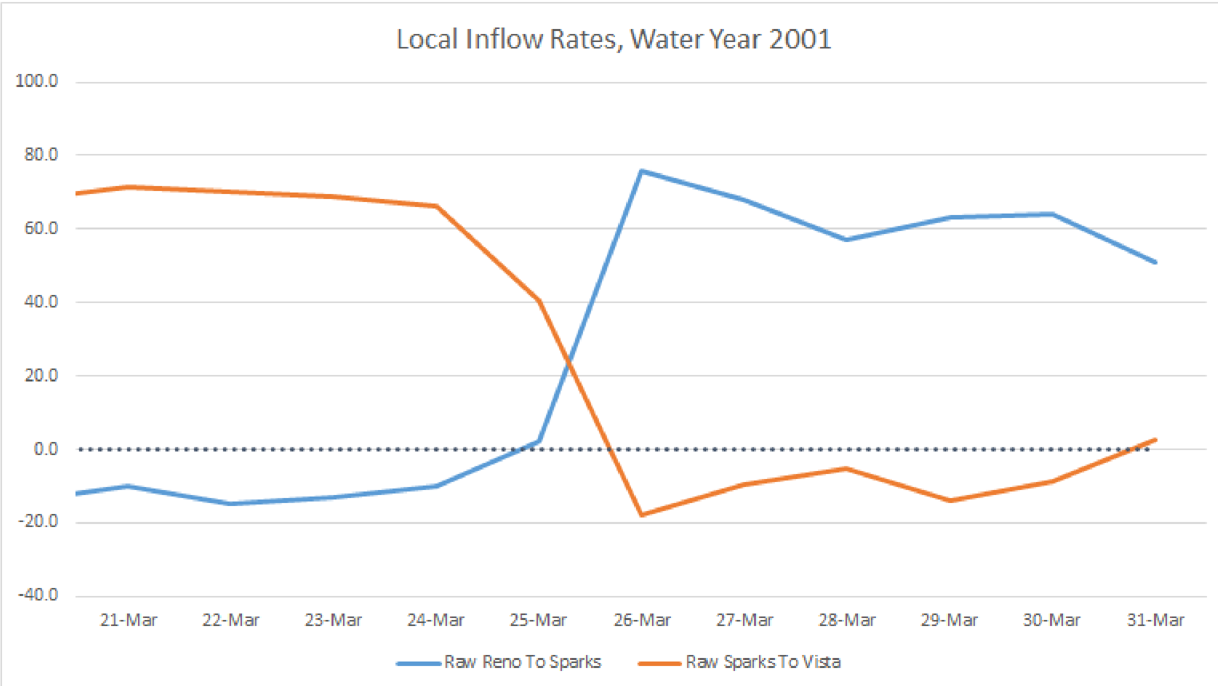


Figure 16: Neighboring reaches showing mirrored gains and losses due to bad gage reading.

Figure 16 shows the computed local inflow on two neighboring reaches (Reno to Sparks and Sparks to Vista). Prior to March 25, Sparks to Vista has a measurement of ~70 cfs while Reno to Sparks shows a measurement of ~-15 cfs. On March 26, the computed inflows switch with the total volume between the two reaches being equivalent. This mirroring effect happens predominantly because the gains (or losses) in the reach are small in comparison to the total flow in the reach, and there was a correction (presumably) applied by USGS on March 25 to the Sparks gage causing the computed inflows to reverse. When this effect occurs on all seven reaches frequently through the dataset, it is not feasible to determine which stream gages are reporting high and which are reporting low and make any meaningful corrections for these errors. These effects are discussed in Maidment's Handbook of Hydrology as summarized in Appendix 8.6 (Maidment, 1993).

Spatial aggregation of the Below Farad sub-reaches removes this effect for all intermediate gages and produces a timeseries of aggregate local inflow that is more reliable.

3.2.4.2 Temporal Aggregation of Raw Daily Spatially Aggregated Local Inflows

Once the spatially aggregated local inflows have been computed, a temporal aggregation is performed. To further reduce uncertainty, a moving average of ±3 days (7 days total) is applied to the spatially aggregated local inflow data. This operation is volume-conserving.

In addition to reducing uncertainty, this temporal aggregation also resolves issues that arise from travel time. The base gage data uses the same averaging period (all USGS approved daily data is averaged from midnight to midnight). When a change in flow at an upstream gage has not arrived at the downstream gage in a particular 24-hour period, an erroneous gain or loss (negative for an increase and positive for a decrease) will be computed followed by an equal and opposite error in the computed inflow the next day. As shown in Figure 17, if this is not corrected the data will show an inappropriately low computed inflow one day with a compensating (also inappropriate) high local inflow on the following day. These computed inflows do not represent an actual hydrologic response in the sub-reach. They only represent that the real-world travel time is not taken into consideration when using the same averaging periods for the daily flow data. Applying this moving average to the raw spatially aggregated local inflows substantially reduces errors of this type in addition to reducing the uncertainty in these values that arise from random error.

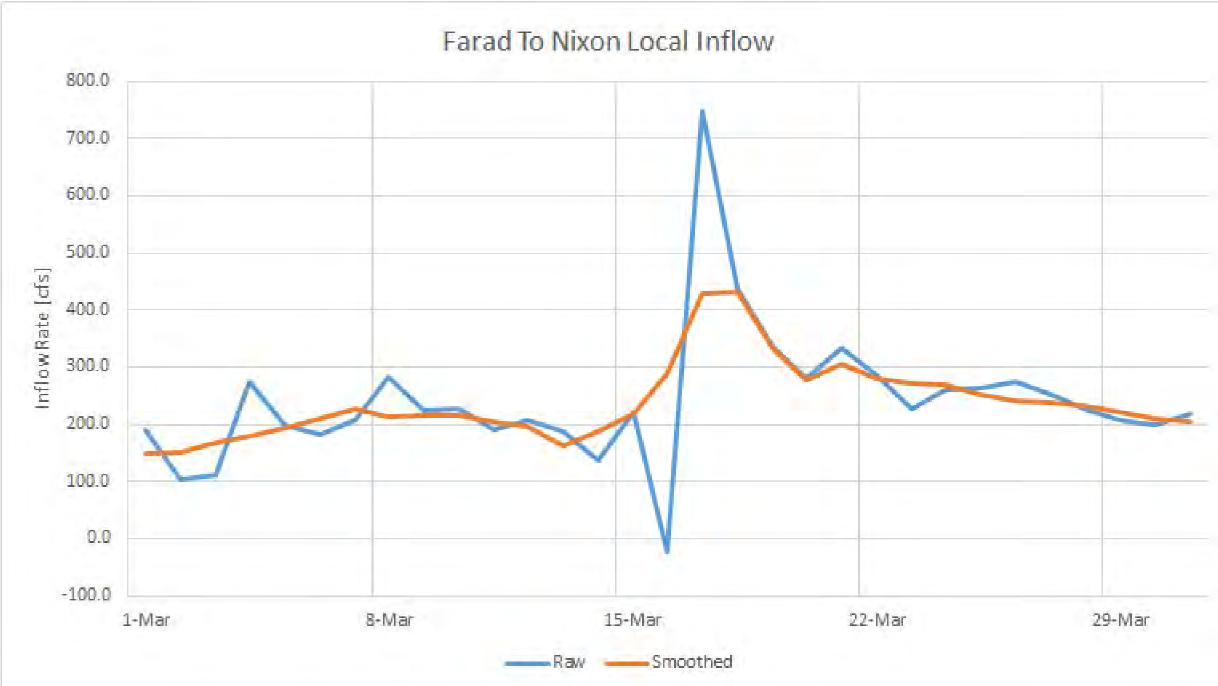


Figure 17: Application of 7 day moving average to spatially aggregated local inflow data, March 2011

3.2.4.3 Temporal Aggregation of Reach Ratios

After determining the aggregate local inflow in the lower Truckee Basin, spatially aggregating all the reaches, and temporally aggregating with a 7-day moving average, the inflows need to be distributed appropriately to the seven sub-reaches. Rather than attempting to calculate each local inflow timeseries directly and independently, the historical patterns of local inflow distribution from the total Below Farad to the sub-reaches are characterized and used to distribute the aggregate inflow to the sub-reaches.

The portion of the total local inflow in each of the sub-reaches varies both spatially among the seven sub-reaches and temporally throughout the year. These patterns are only apparent in historical data when viewed over long time periods. Daily distribution data among the sub-reaches is noisy and erratic, making meaningful determinations of daily distribution allocation a fruitless pursuit. However, when the distribution data is aggregated over a longer period, meaningful patterns emerge. To identify these patterns, the monthly average local inflow portion for each sub-reach was computed from the raw computed inflows for the entire period. Next, the monthly ratio of the total Farad to Nixon inflow from each reach was computed.

To identify any monthly patterning present in these data, a long-term temporal average of monthly ratios was calculated for each month and reach. Determining the appropriate period over which to average these data required uncertainty analysis. Details of this analysis are included in Appendix 8.6. The uncertainty analysis determined the previous five years was the appropriate averaging period. Assuming the historical USGS schedule of manual measurements occurred approximately every 15 to 30 days, this ensures at least five measurements per month of the year over the five-year averaging period.[2]

Several steps were taken to address irregularities in the monthly reach ratio data. The QA/QC processes used on the local inflow data are summarized in the following steps. The computation in each step is completed based on the result of the previous step.

1. Compute the monthly average local inflow for each sub-reach using stream gage data.
2. Compute the total Farad to Nixon local inflow by spatially aggregating the sub-reach data.
3. Compute the ratio of the total reach inflow that occurred in each reach for each month.
4. Combine the ratios from the Vista to Derby and Blw Derby reaches to correct the Truckee Canal spillback which is ungaged and causes the computed Vista To Derby inflow to be negative with a compensating positive Blw Derby (see Figure 18 for example; these will be disaggregated later in Step 8). This step combines the ratios of Vista to Derby and Blw Derby based on observed flow data, then those ratios will be disaggregated based on drainage area later to account for the Truckee Canal spillback.
5. Remove all negative ratios for each month.
6. Scale the monthly ratios so the annual sum is 1.
7. Disaggregate the Reno To Sparks reach ratios into Reno to Glendale and Glendale to Sparks based on reach lengths approximated using Google Earth (Google Earth).
8. Disaggregate the Vista to Wadsworth reach ratios (step 4) into Vista to Derby and Blw Derby (Derby to Wadsworth) based on drainage area.

[2] In 2016 the USGS manual measurement frequency for most stream gages in the Truckee River Basin was increased to twice per month to better support implementation of TROA. The additional measurement frequency should improve the accuracy of computed inflows in the Truckee River Basin in the future.

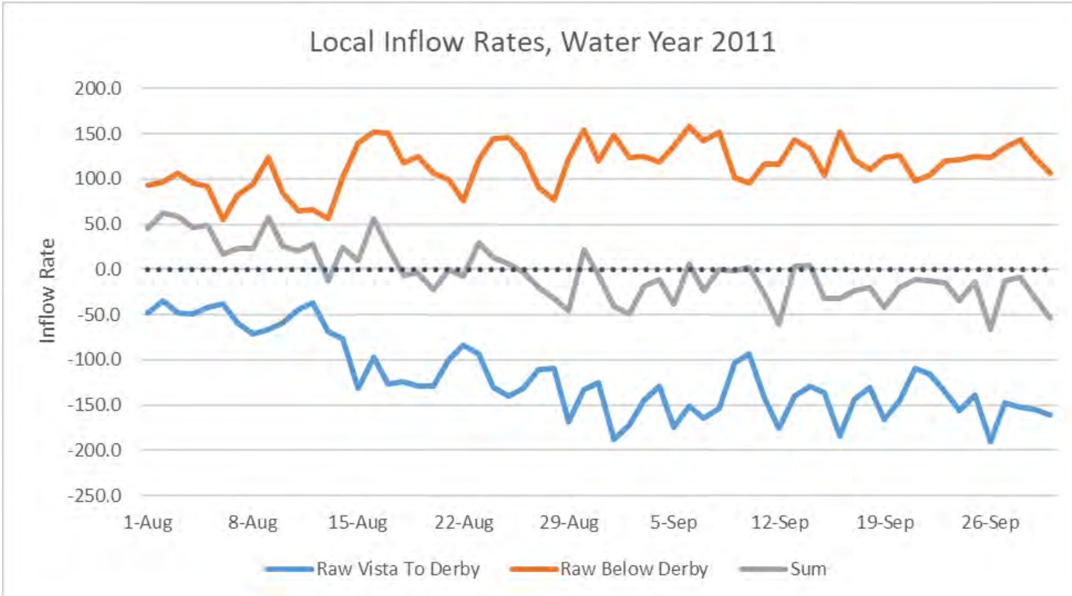


Figure 18: Raw local inflow data for the reaches directly above and below Derby Dam, influenced by Truckee Canal diversion and spill.

Note that the Truckee River at Glendale Avenue near Sparks (USGS 10348036) gage was not used in this study because of a limited period of record (2001-2016). However, a future analysis can use Glendale gage data to solve the water balance similar to other intermediate gages between Farad and Nixon. Alternatively, it could be reserved for verification.

3.2.4.4 Spatial Disaggregation

Once the monthly distribution ratios have been determined for each of the sub-reaches in Below Farad, daily local inflows for each sub-reach can be computed. The local inflows for each sub-reach are computed by taking the aggregate local inflow for the Below Farad portion of the Truckee River and multiplying it by the appropriate distribution ratio based on month and sub-reach.

Note that the local inflows are not restricted to positive values. It is not uncommon for the ungaged contributions to Below Farad to result in a net loss especially under dry conditions. When the total Farad to Nixon local inflow is negative, a positive ratio applied to the negative local inflow will result in a negative reach local inflow.

3.2.4.5 Below Farad Data Review

Once the Below Farad data was developed, a manual review of the data was conducted to ensure no additional irregularities or anomalies exist in the data. The review focused on the computed Farad to Nixon local inflow which was spatially disaggregated to the seven reaches using the methodologies described in Section 3.2.4.4. The review identified data not following anticipated hydrologic behavior within the basin. When necessary, corrections were implemented on identified issues. The volume was preserved for all corrections using bias correction or averaging. The verification for the Nixon gage discussed in Section 5.2.1.4 confirms the volume was preserved. The following discussion describes common manual corrections Below Farad.

3.2.4.5.1 High Flow Event Muting and Timing

The most common issue was the smoothing algorithm muting out the high flow events due to over-smoothing. The smoothing algorithm uses a 7-day running average that works well in low flow periods but is problematic with higher flows. These issues were manually corrected using the raw computed inflows. Other corrections for high flow events included lowering smoothed data before a storm to the original base flow and increasing the high inflows that represent a high pulse to preserve the volume.

3.2.4.5.2 Inconsistent Inflows Above and Below Farad

Another issue included erroneous negative flows when the Above Farad data had large positive values. Certain negative values were justified, but those that were not justified were adjusted using a method to smooth the data with a bias fixing algorithm to preserve the volume. This method uses a minimal difference from recently observed mean to make corrections. These corrections could lead to altering the total inflow Above Farad and likely contributed to the difference in verification volume discussed in Section 5.1.

3.2.4.5.3 Examples of Changes When Implementing the Manual Review Process

A full list of changes per water year is included in Appendix 8.5, and two examples of typical changes made during the manual review process are described below.

Figure 19 shows a large trough and spike in Farad to Nixon local inflow data in September 2004. These irregularities are most likely due to bad gage data or not accounting for travel time after flow changes and were smoothed using a longer moving average. The result of the smoothing algorithms resulted in a flow that removes the trough spike nature in September 2004.

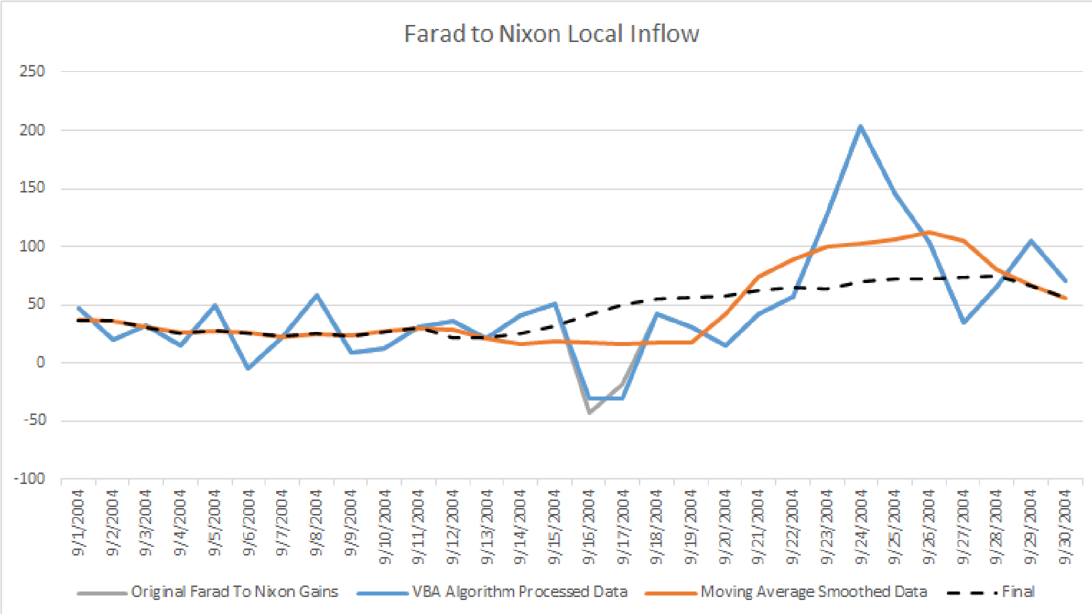


Figure 19: Manual correction made to Farad to Nixon local inflow data (cfs), water year 2004.

Figure 20 shows another manual correction made on Farad to Nixon local inflow data. A high flow event on February 10, 2015, was incorrectly muted by the smoothing algorithm. The high flow was restored by the manual review process. This is an example of the manual correction described in Section 3.2.4.5.1 - the most common type of manual correction made to Below Farad data.

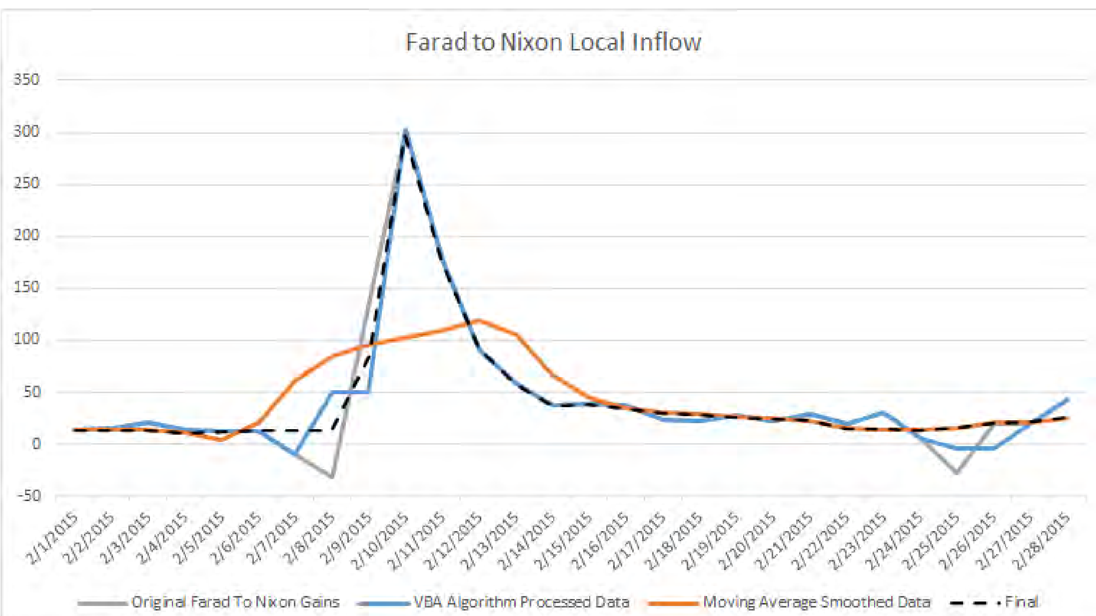


Figure 20: Manual correction made to Farad to Nixon local inflow data (cfs), water year 2015.

4 DATA DEVELOPMENT RESULTS

The dataset produced by the data development effort has the following daily quantities, all from 10/1/2000 – 12/31/2016 (Water Years 2001-2016):

*Table 5: Summary of the datasets developed in this effort, all ranging from Oct. 1, 2000 – Dec. 31, 2016 (Water Years 2001 – 2016) *Tahoe's Hydrologic Inflow is a net inflow, meaning that it includes precipitation and evaporation*

	Precipitation Rate	Hydrologic Inflow	Local Inflow	Other Stream Gage Flows
Above Farad				
Boca	✓	✓		
Donner	✓	✓		
Independence	✓	✓		
Martis	✓	✓		
Prosser	✓	✓		
Stampede	✓	✓		
Tahoe*	✓	✓		
Below Donner			✓	
Below Tahoe			✓	
Sidewater			✓	
Farad Natural Flow		✓		
Below Farad				
Farad to Mogul			✓	
Mogul to Reno			✓	
Reno to Glendale			✓	
Glendale to Sparks			✓	
Sparks to Vista			✓	
Vista to Derby			✓	
Below Derby			✓	
Wadsworth To Nixon			✓	
Hunter Creek				✓
Steamboat Creek at Steamboat				✓
Carson River at Ft Churchill				✓

Of note in the datasets: The hydrologic and local inflows were computed using the water balances described throughout this paper (Sections 2 and 3), and then reviewed and edited using the techniques described in Sections 3.1.3 and 3.2.4. Other datasets (e.g., the "Other Stream Gage Flows") are reports of USGS approved data with minimal data development involved. The only correction applied to "Other Stream Gage Flows" was to Hunter Creek that addressed a known flushing event. These datasets are listed here and described in the Data Development Results section because they are included in the final, all-encompassing dataset. The Farad Natural Flow is calculated as a sum of the hydrologic inflows on the Above Farad Reservoirs (excluding Tahoe) and the three Sidewater local inflow components. While just an aggregation of other calculated quantities, the Farad Natural Flow is an important and often discussed parameter, so it is included in the list of developed data. Lastly, the Tahoe hydrologic inflow is a net inflow meaning evaporation and precipitation, tributary runoff, and bank storage are lumped into the hydrologic inflow term. This is due to the complexity of approximating evaporation on Lake Tahoe and follows longstanding historic practice.

The ensuing sections will summarize the results of the data development effort and compare it to historic datasets using tables and figures to provide quantification of these data.

4.1.1 Summary Tables and Figures

Table 6 and Table 7 show the maximum, median, and average annual and April through July inflow volumes computed for each reservoir as well as Farad Natural Flow and total Sidewater volumes. The maximum annual hydrologic inflow volumes occurred in 2011 for five of the seven reservoirs. All seven had their maximum April through July hydrologic volumes occur in 2011. The minimum years show more variety with four different years appearing in the "Minimum Water Year" column across the two computed volumes. The maximum April through July Farad natural flow volume is 12.6 times greater than the minimum value whereas the maximum annual volume is 5.8 times greater than the minimum. Each of the average volumes, annual and April through July, are greater than the medians due to high flow years like 2011 and 2006 skewing the distribution.

Table 6: Maximum, minimum, median, and average annual computed hydrologic inflow volume for each reservoir

Above Farad Annual Inflow Volumes, Water Years 2001-2016						
	Maximum Water Year	**Maximum [AF]**	**Minimum Water Year**	**Minimum [AF]**	**Median [AF]**	**Average [AF]**
Boca	2011	28,938	2001	1,611	5,205	7,634
Donner	2011	48,002	2001	9,458	20,863	23,604
Independence	2011	28,012	2014	6,940	12,603	14,150
Martis	2006	38,168	2015	4,530	9,776	13,123
Prosser	2011	110,091	2015	19,727	42,349	49,323
Stampede	2006	197,589	2014	29,453	73,509	84,669
Tahoe	2011	582,271	2001	-173,370	-31,076	48,367
Total Sidewater	2006	354,211	2015	59,451	115,283	143,225
Farad Natural Flow	2006	798,363	2015	138,143	278,898	335,727

Table 7: Maximum, minimum, median, and average computed April – July hydrologic inflow volume for each reservoir

Above Farad April - July Inflow Volumes, Water Years 2001-2016						
	Maximum Water Year	**Maximum [AF]**	**Minimum Water Year**	**Minimum [AF]**	**Median [AF]**	**Average [AF]**
Boca	2011	19,589	2002	-809	863	2,913
Donner	2011	34,107	2015	2,489	12,950	13,938
Independence	2011	20,453	2015	2,400	8,864	9,534
Martis	2011	22,443	2014	1,258	4,162	6,346
Prosser	2011	83,752	2015	7,072	29,144	32,799
Stampede	2011	160,017	2015	10,619	51,934	58,734
Tahoe	2011	355,767	2001	-18,151	55,831	95,633
Total Sidewater	2011	231,702	2015	21,113	73,262	92,311
Farad Natural Flow	2011	572,062	2015	45,341	177,100	216,574

Figure 21 and Figure 22 display each year's annual and April through July hydrologic inflow volumes for the six reservoirs, excluding Tahoe, between water years 2001 and 2016. The years 2006 and 2011 are the wettest years of the period with very similar total annual volumes. When looking specifically at April through July volume, 2011 is the wettest year of the 16-year study range with a total April through July volume about 1.3 times greater than 2006. Of the sixteen years studied, 13 of them produced less than half of the April through July volume seen in 2011. Of the six reservoirs plotted, Stampede consistently has the largest hydrologic inflow volumes.

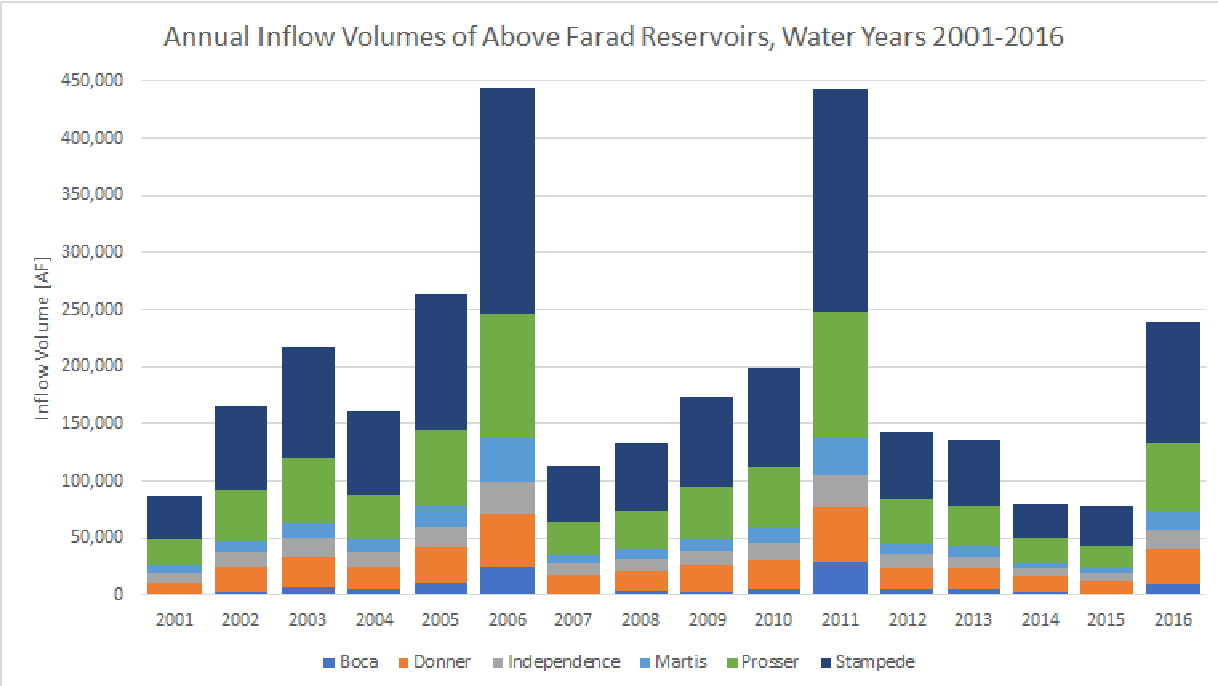


Figure 21: Computed annual hydrologic inflow volume for each reservoir, water years 2001 – 2016.

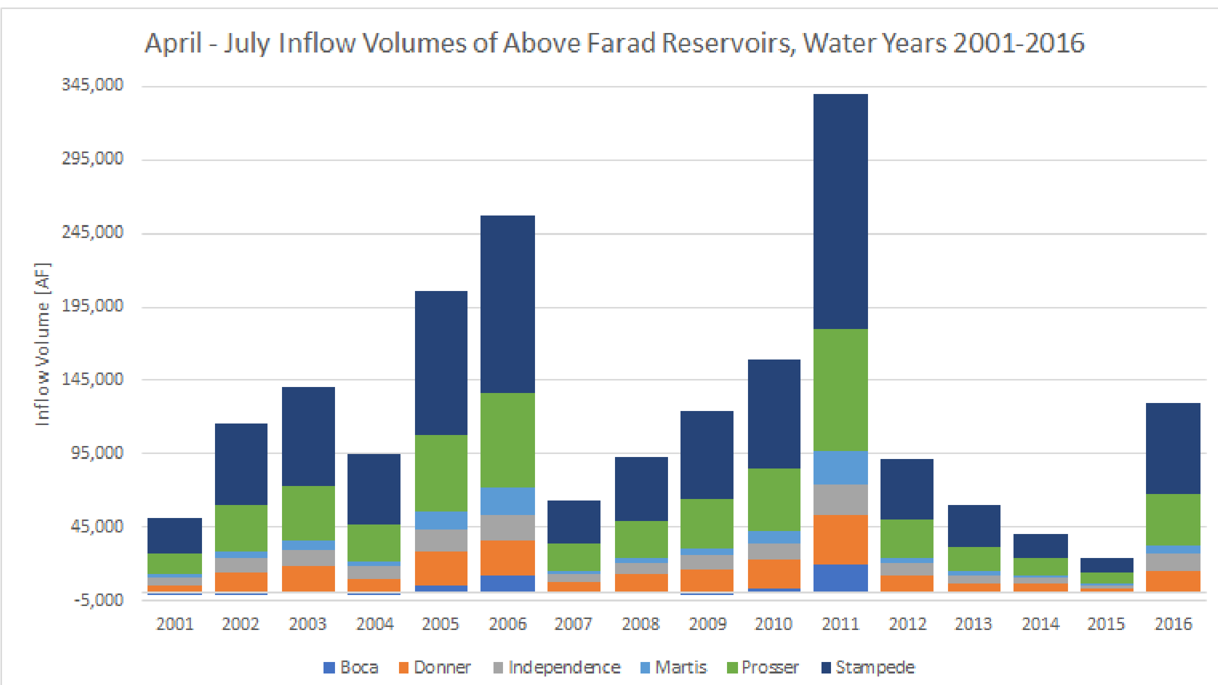
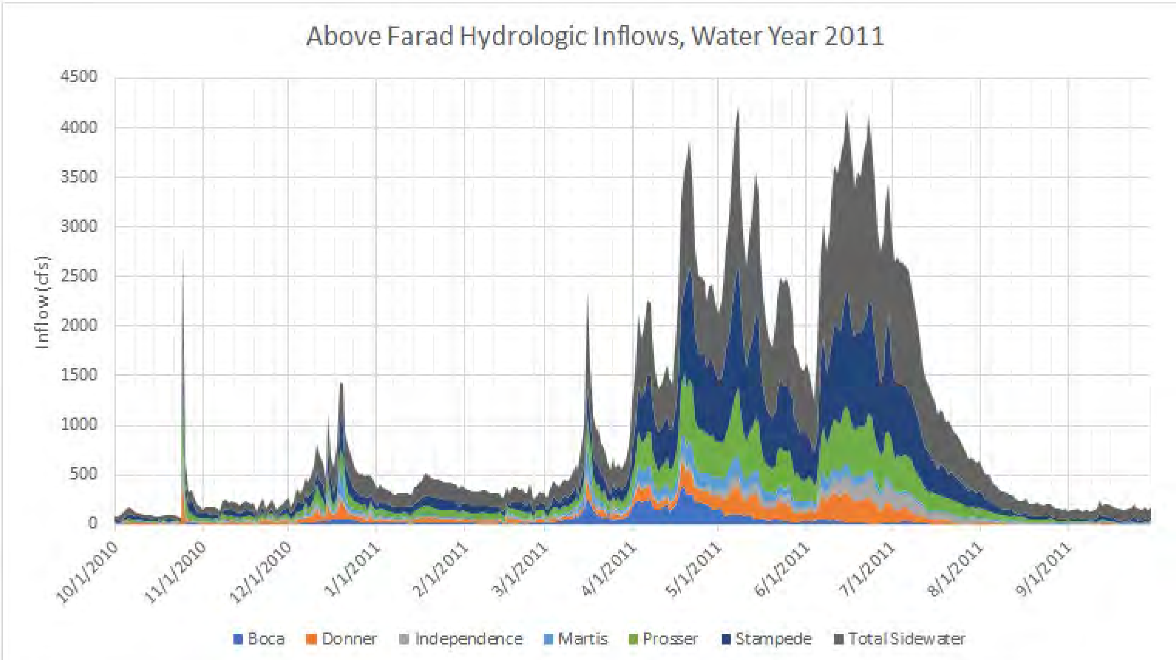


Figure 22: Computed hydrologic inflow April – July volume for each reservoir, water years 2001 – 2016.



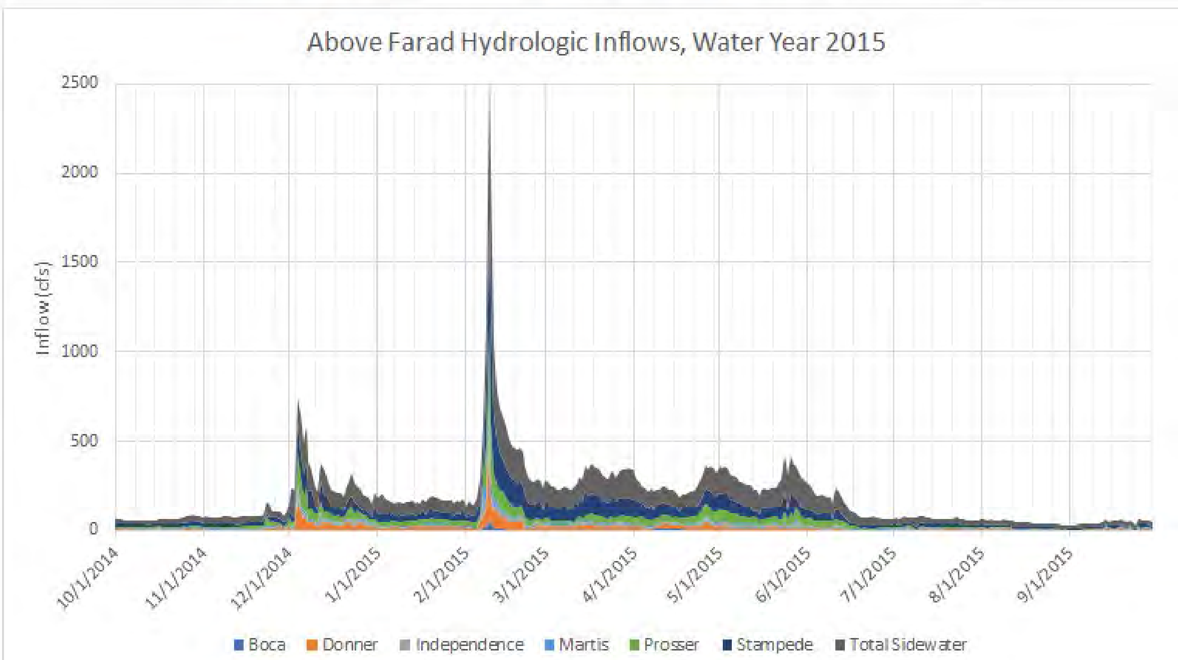


Figure 23: Above Farad Hydrologic Inflows for water years 2011 (wet) and 2015 (dry)

Figure 23 shows the Farad natural flow delineated by drainage basin for the six reservoirs, excluding Tahoe, for a wet year (2011) and a dry year (2015). The difference between the two years is large. In water year 2015, the Farad natural flow exceeds 500 cfs for two short periods - once briefly in December 2014 and again in February 2015. In water year 2011, however, the Farad natural flow is consistently well above 500 cfs between March and August as well as a few other short periods earlier in the year. In 2011, the Farad natural flow peaked at over 3000 cfs six separate times during the runoff between April 1st and the end of July.

Figure 24 and Figure 25 display the annual and April through July volumes for Tahoe net inflow, Farad natural flow, and Carson River near Ft. Churchill gaged flow for water years 2001-2016. The volumes on all three basins follow similar trends. As described in Section 2.2, Tahoe is modeled as a net inflow reservoir meaning that evaporation and precipitation are included in the computed inflow value rather than being modeled explicitly. This explains why Tahoe's annual net inflow can be negative - if evaporation exceeds the total amount of hydrologic input into the lake.

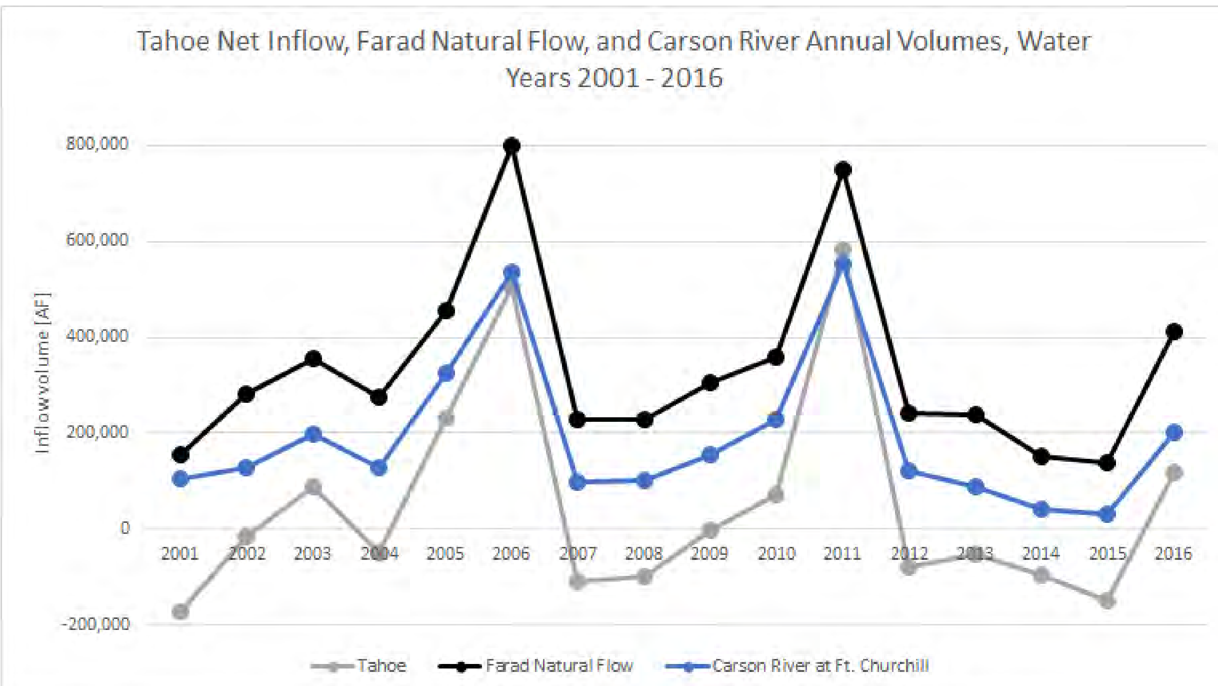


Figure 24: Tahoe Net Inflow, Farad Natural Flow, and Carson River at Ft. Churchill annual volumes, water years 2001 – 2016

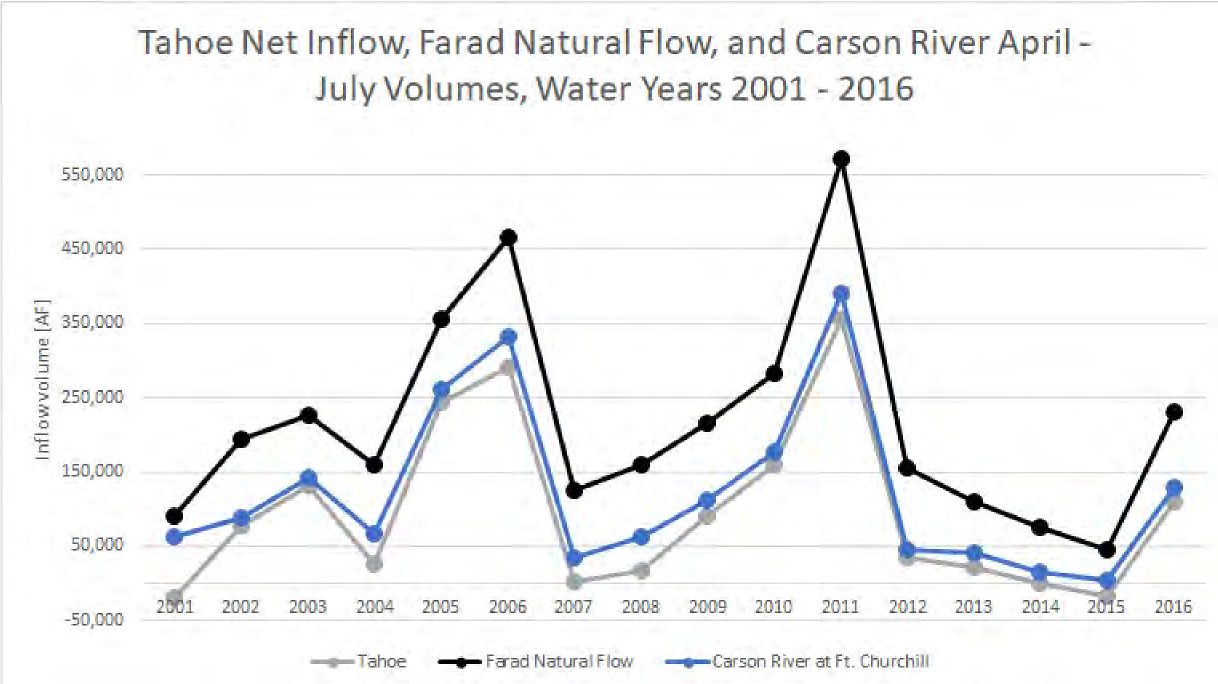


Figure 25: Tahoe Net Inflow, Farad Natural Flow, and Carson River at Ft. Churchill April – July volumes, water years 2001 – 2016

Figure 26 shows the annual computed precipitation volumes for each reservoir, excluding Tahoe, between 2001 and 2016. The reservoirs follow similar, but not identical, trends. For instance, in 2002 Donner recorded a slight decrease in precipitation compared to 2001 while the other reservoirs all recorded slightly higher precipitation volumes in 2002 compared to 2001.

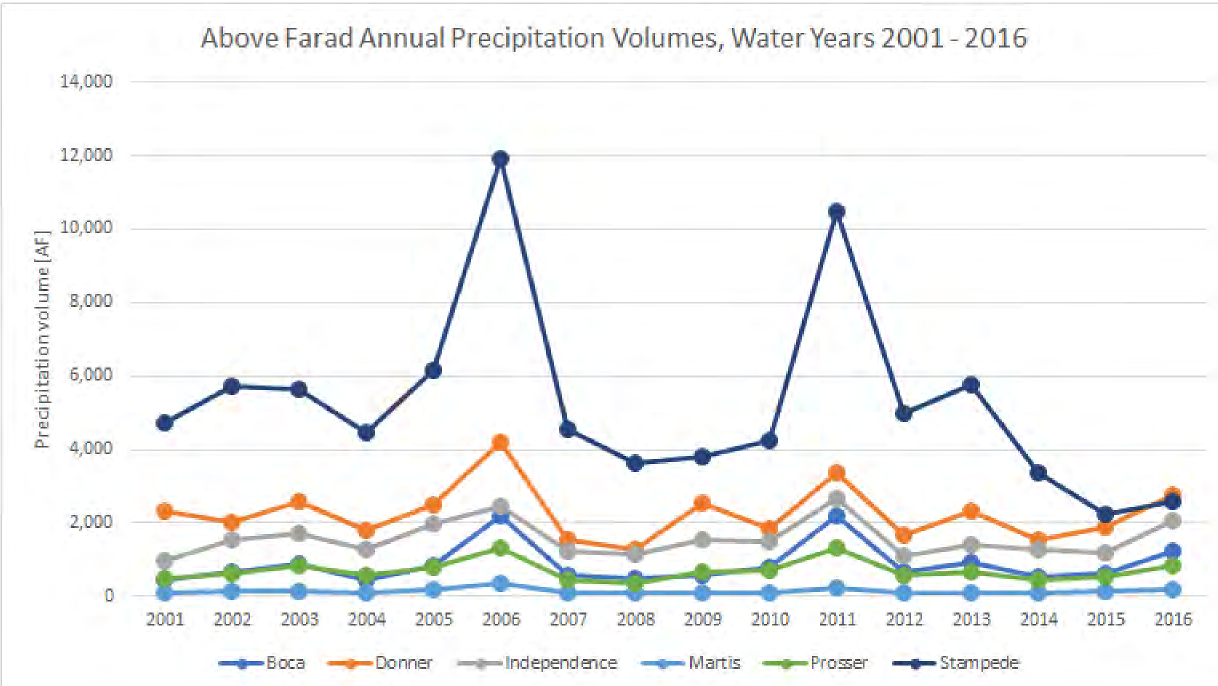


Figure 26: Annual computed volume of precipitation on water surface for above Farad reservoirs (excluding Tahoe), water years 2001 – 2016.

Table 8 and Figure 27 display statistics for the computed local inflow volumes for each of the eight reaches below Farad. The Sparks to Vista reach consistently receives the highest local inflow of all the reaches. The below Farad to Mogul data shows 2011 is the wettest year of the study period as do the above Farad data. Interestingly, however, 2006 does not stand out as a wet year when looking at below Farad local inflow data.

Table 8: Maximum, minimum, median, and average annual computed local inflow volume for each reach

	Below Farad Annual Local Inflow Volumes, Water Years 2001-2016					
	Maximum Water Year	**Maximum [AF]**	**Minimum Water Year**	**Minimum [AF]**	**Median [AF]**	**Average [AF]**
Farad to Mogul	2011	18,057	2009	773	6,029	6,998
Mogul to Reno	2011	8,903	2007	-135	3,161	3,469
Reno to Glendale	2003	1,282	2009	-82	343	517
Glendale to Sparks	2003	2,402	2009	-154	643	968
Sparks to Vista	2011	36,276	2007	5,156	13,840	16,470
Vista To Derby	2011	3,366	2014	363	1,129	1,355
Below Derby	2011	3,470	2014	374	1,164	1,397
Wadsworth to Nixon	2003	7,425	2014	1,094	3,359	3,870

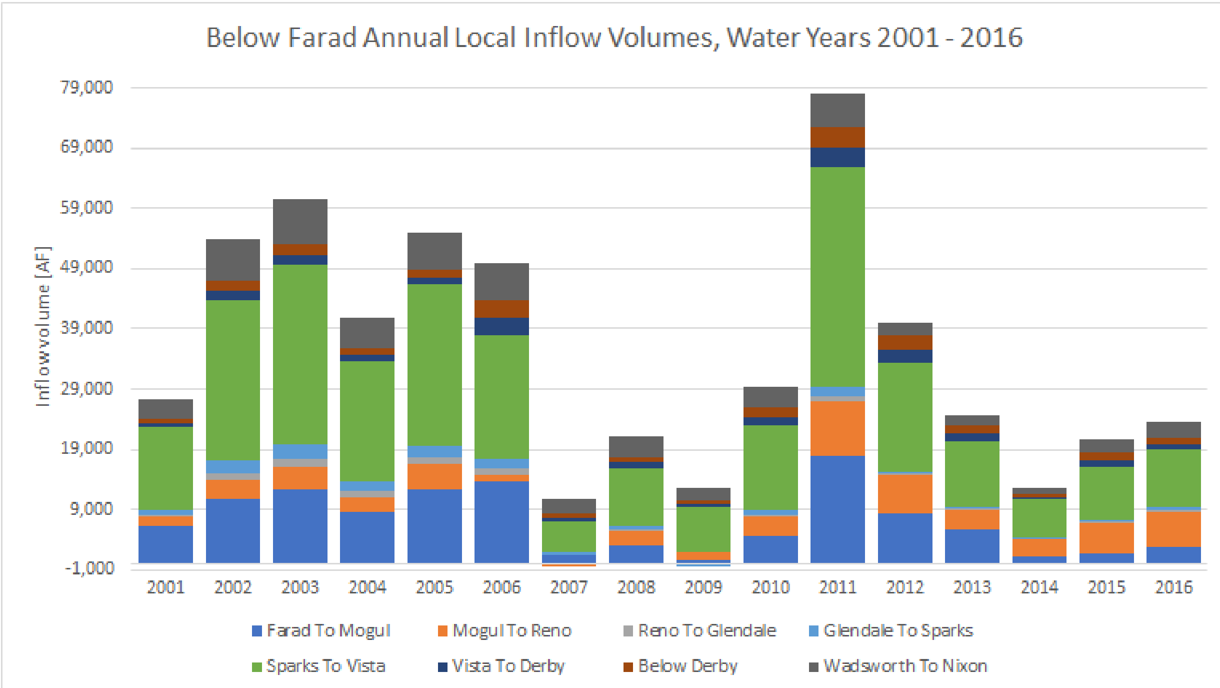


Figure 27: Computed annual local inflow volume for each reach, water years 2001 – 2016.

Figure 28 plots the daily computed local inflow rates for each reach below Farad in a wet year (2011) and dry year (2015). There are times in both years where all reaches show negative local inflow values. One potential explanation for this is considering the "storage" of water within a river reach during a stage increase of water in the river due to operational releases. Storage is left out of the reach water balance. When stage is increased in the river, the increase in storage in the reach is computed as a loss in the reach, followed by a gain when the river stage recedes. This can result in negative and positive local inflow values that look irregular. Groundwater aquifer interactions with the Truckee River are also a factor in the Truckee Meadows water balance.

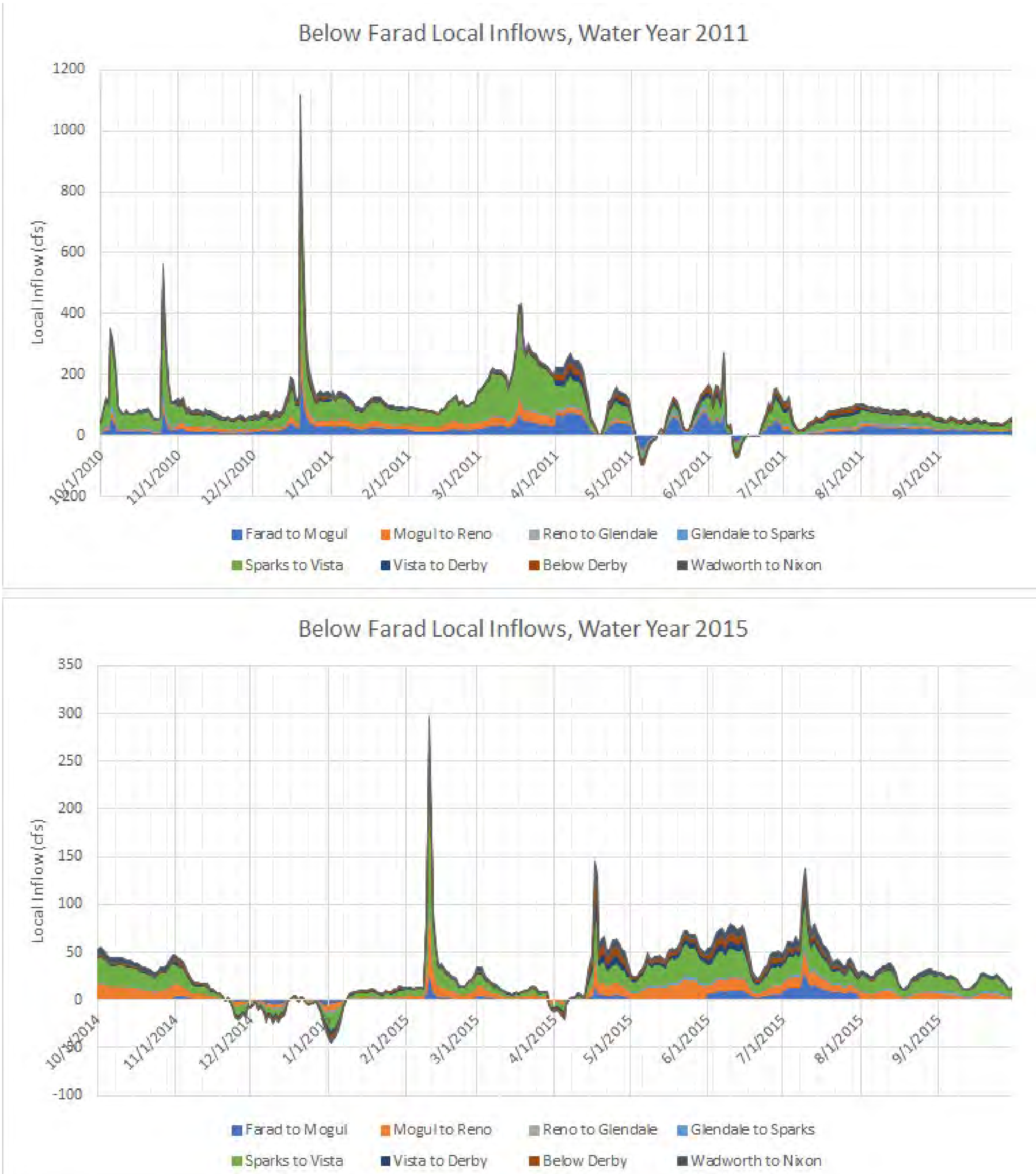


Figure 28: Comparison of below Farad local inflows in water year 2011 (wet) and 2015 (dry)

Table 9 contains summary statistics for two gaged tributaries to the Truckee as well as the Carson River at Ft. Churchill. Of note is the skew on the Carson River data. The average annual volume at Ft. Churchill is significantly higher than the median. This can be explained by the many diversions upstream of the Ft. Churchill gage. A large portion of the river is diverted in a dry year whereas the diversions are a smaller percentage of the total inflow in a wet year. In 2011, the Ft. Churchill gage saw almost 19 times as much volume as in 2015, confirming that the average will be highly skewed by high flow years.

Table 9: Maximum, minimum, median, and average annual volumes for key stream gages, water years 2001 – 2016

	Stream Gage Annual Volumes, Water Years 2001-2016					
	Maximum Water Year	**Maximum [AF]**	**Minimum Water Year**	**Minimum [AF]**	**Median [AF]**	**Average [AF]**
Hunter Creek	2006	12,142	2014	2,814	4,231	5,360
Steamboat Creek at Steamboat	2006	16,837	2015	840	2,958	4,404
Carson River at Ft Churchill	2011	551,301	2015	29,631	128,443	189,893

4.1.2 Historical Comparisons

A comparison of the 2001-2016 data relative to the 1901-2000 dataset (which was not computed using the methodologies presented herein) conveys that the 2001-2016 period was generally much drier than the 1901-2000 period. Comparing the April through July natural flow volume at Farad, the average for 1901-2000 is 274 KAF, but the average for 2001-2016 is 21% less at 217 KAF. The Ft Churchill and Lake Tahoe average inflows reduced by a more significant margin at 32% and 26%, respectively. This period also includes the driest April through July volume on record for all three river basins that occurred in water year 2015. Water year 2015 is the fifth driest water year on record due to few winter and spring rainstorms (see Figure 23). Further data is included in Table 10, Table 11, and Table 12.

Table 10: Comparison of Farad inflow volumes for the 1901-2000 period to the new dataset for 2001-2016.

	April through July Volume (KAF)			Water Year Volume (KAF)		
	1901-2000	**2001-2016**	**Change**	**1901-2000**	**2001-2016**	**Change**
Maximum	713.3	572.1	-141.3	936.1	798.4	-137.7
Average	273.7	216.5	-57.3	413.2	335.4	-77.8
Median	251.7	177.1	-74.6	384.8	278.9	-105.9
Minimum	49.4	43.9	-5.5	92.6	133.3	40.7

Table 11: Comparison of Carson River at Ft. Churchill (Lahontan) inflow volumes for the 1901-2000 period to the new dataset for the 2001-2016.

	April through July Volume (KAF)			Water Year Volume (KAF)		
	1901-2000	2001-2016	Change	1901-2000	2001-2016	Change
Maximum	570.4	389.6	-180.8	804.6	551.3	-253.3
Average	190.2	123.2	-67.0	297.2	189.9	-107.4
Median	182.3	78.3	-104.0	264.4	128.4	-136.0
Minimum	5.3	3.9	-1.4	26.3	29.6	3.3

Table 12: Comparison of Lake Tahoe net inflow depths for the 1901-2000 period to the new dataset for the 2001-2016.

	April 1 to High GCR (feet)			Low to High GCR (feet)		
	1901-2000	2001-2016	Change	1901-2000	2001-2016	Change
Maximum	4.0	3.0	-1.0	7.3	5.8	-1.6
Average	1.5	1.0	-0.5	2.9	2.1	-0.8
Median	1.4	0.7	-0.6	2.6	1.7	-1.0
Minimum	0.2	0.2	0.0	0.2	0.5	0.3

The drought of 2012-2016 is of historic significance. The average water year volume for 2013-2015 is 175 KAF - the driest three-year average on record. Similarly, the average from 2012-2015 is only 191.8 KAF - the driest four-year average on record. In fact, 2012-2015 is only the second time in the period of record where four consecutive years have an April through July volume less than 200 KAF; the previous occurrence was 1928-1931. Three consecutive years with Farad April through July volumes less than 200 KAF has occurred six times since 1901 - on average once every 19 years.

Overall, the period from 2001 through 2016 ranks 90 out of 100 in terms of average water year volume at Farad. The 2001 through 2016 period includes two water years that were larger than 30% exceedance: water year 2006 and water year 2011. The total Farad natural flow that occurred in these two water years was 1,547 KAF which accounts for 29% of the natural flow over the 16-year period. Given that these years split the otherwise very dry 16-year period roughly into thirds, the water stored in 2006 and 2011 refilled much of the water supply that was used in the following years.

Another important characteristic of the annual volume is the percentage which occurs between April through July. All the Truckee River basin reservoirs have restrictions (though Lake Tahoe and Lahontan do not have formal restrictions) to reserve a portion of their storage for the summer months to protect from flooding in the winter months. With these flood storage restrictions, it is important that there is sufficient runoff remaining in the April through July period to fill the flood space in the reservoirs. As shown in Table 13, the average of these ratios has changed for the three basins decreasing 1.7% for the Truckee River Basin above Farad, increasing 0.9% for the Carson River at Ft. Churchill (Lahontan), and decreasing 3.4% for Lake Tahoe. The average change among the three basins is a decrease of 1.4%. Given that the magnitude of the change is small, the direction of the change is inconsistent among the basins, and the value of the change varies greatly from year to year (the 1901-2016 standard of deviation is 11.8%), it does not appear that a significant trend either up or down is occurring.

Table 13: Percent of Water Year volume occurring between April and July

	Percent of Average Water Year Volume Occurring April-July		
	1901-2000	**2001-2016**	**Change**
Farad	66.3%	64.5%	-1.7%
Lahontan	64.0%	64.9%	0.9%
Tahoe	53.2%	49.8%	-3.4%

The new period of record (1901-2016) annual and April through July statistics are summarized in below in Table 14.

Table 14: Summary of updated period of record (WY1901-2016) annual and water year statistics for Farad, Tahoe (shown in terms of Gates Closed Rise), and Lahontan inflows.

	Farad (KAF)		Lahontan (KAF)		Tahoe Rise (ft)	
	April-July	**Water Year**	**April-July**	**Water Year**	**April to High**	**Low to High**
Maximum	713.3	936.1	570.4	804.6	4.02	7.34
Average	265.8	402.4	181.0	282.4	1.46	2.76
Median	230.3	364.9	167.1	249.9	1.28	2.42
Minimum	43.9	92.6	3.9	26.3	0.17	0.21

5 VERIFICATION

The computed hydrologic and local inflows are results of a mass balance using measured quantities and therefore should not be validated using a traditional model validation technique. However, methods can be developed to verify no calculation errors have been made. In general, this involves confirming volume has been conserved. As described in Section 2, volume conservation is critical for maintaining the long-term water balance and preserving the accuracy of longer planning runs. The following sections describe the different verification methods applied to Above and Below Farad data.

5.1 Above Farad Verification

For the Above Farad reservoir system, a single mass balance calculation covering the entire study period, water years 2001 – 2016, was performed to confirm that the total volume was conserved. A 16-year net inflow was calculated for the system two different ways: first by using reservoir storage and stream gage measurements and then by using computed hydrologic inflows, precipitation, and evaporation amounts. Equation (1) can be rearranged as the following when all the reservoirs above Farad are considered as a single system:

$$\sum(Hydrologic\ Inflow + Precipitation - Evaporation) - Sierra\ Valley\ Diversion = \sum \Delta Storage + 16\ Year\ Farad\ Volume \quad (11)$$

The left side of Equation (11) is referred to as the "*Computed Net Inflow*," and the right side as the "*Measured Net Inflow*." In theory, the two Net Inflows should match perfectly since Farad gage and reservoir storage data were used to compute Hydrologic Inflow, Precipitation, and Evaporation. Consequently, this calculation amounts to a verification that no major mistakes were made during the computation and data review process. The results of the calculation are shown in Table 15 below.

Table 15: Results of the Above Farad 16-year mass balance verification calculation

	USGS	WM
Measured Net Inflow [AF]	5,832,608	5,874,440
Computed Net Inflow [AF]	5,871,675	
% Error	0.67%	0.05%

The first thing to note is the difference in 16-Year volume at Farad when comparing Water Master data vs. USGS data. As discussed in Section 3.1, Water Master data were used in the Above Farad data development primarily to efficiently allow for travel time adjustments. A drawback to this is that the Water Master stream gage data do not get the same retroactive shifts that the USGS periodically applies to their data. Over 16 years, this amounted to a difference of approximately 42,000 AF, or 0.6%, between the two entities. As expected, the *Computed Net Inflow* more closely matches the *Measured Net Inflow* when using the Water Master Farad gage data rather than the USGS data since the Water Master's data were used for the data development study. The *Computed* and *Measured Net Inflows* agree within 0.05% (2,800 AF) confirming that volume is conserved in the computed Hydrologic Inflows, Evaporation and Precipitation volumes over the course of the 16-year study.

5.2 Below Farad Verification

A different technique was used to verify the Local Inflow data developed for reaches below Farad again with an emphasis on conservation of volume. As described in Section 3.2.4.1, the total Local Inflow for the Farad to Nixon reach was first calculated essentially ignoring intermediate stream gages to reduce uncertainty. This total Local Inflow was then spatially disaggregated into components using the method discussed in Section 3.2.4.4. The final computed Local Inflow components represent eight reaches along the Truckee River between Farad and Nixon. The verification method for these data should address total conservation of volume between Farad and Nixon as well as the accuracy of the disaggregation method. Meeting these goals will ensure water is not being harvested or lost through the method and confidence and completeness to the method will be ensured. To meet these goals, Equation (8) (the equation for Local Inflow) was rearranged and written as shown in Equation (12).

This equation was used in the simulation of daily flows at four different gages, including the Truckee River at Nixon gage, and the results of the simulation were compared to accepted USGS stream gage data.

$$\begin{aligned} &Simulated\ Gage\ Flow \\ &= Farad\ Gage\ Flow + \sum Local\ Inflows_{Farad\ to\ Gage} \\ &+ \sum Tributaries_{Farad\ to\ Gage} - \sum Diversions_{Farad\ to\ Gage} \end{aligned} \quad (12)$$

Four gages were chosen to test this verification: Truckee River gages at Glendale (above the Sparks Gage), Tracy (between Vista and Derby), Wadsworth (downstream of the Derby Dam), and Nixon. Of the four, Tracy and Glendale were not used at all in the inflow computations and are therefore completely independent from the data development method. As a result, they are the "truest" test of the method. Wadsworth was only used to determine the ratio of the Farad to Nixon Inflow occurring in each reach. Therefore, the pattern of the flow should match closely, but the magnitude of flow from these gages is an independent test of the method. The Nixon gage was used directly to compute the Farad to Nixon inflow, so the simulated flow should match closely in magnitude and timing. Table 16 lists all the local inflow components, tributaries, and diversions used to evaluate Equation 12 for each of the four test gages. Note that the Tracy gage lies between the Vista and Derby gages, so only a portion of the Vista to Derby Local Inflow was used in the simulation of the Tracy gage flow. The portion was determined using a ratio of gage drainage areas published by USGS.

*Table 16: Local Inflow Components, Tributaries, and Diversions used to evaluate Equation 14 for each of the four test gages. *The Tracy gage lies between the Vista and Derby gages, so only a portion of the Vista to Derby Local Inflow was used in the simulation of the Tracy gage flow*

Below Farad Verification Mass Balance				
	Glendale	Tracy	Wadsworth	Nixon
Local Inflows				
Farad To Mogul	✓	✓	✓	✓
Mogul To Reno	✓	✓	✓	✓
Reno To Glendale	✓	✓	✓	✓
Glendale To Sparks		✓	✓	✓
Sparks To Vista		✓	✓	✓
Vista To Derby		✓*	✓	✓
Below Derby			✓	✓
Wadsworth To Nixon				✓
Tributaries				
Hunter Creek	✓	✓	✓	✓
Steamboat Creek		✓	✓	✓
TMWRF		✓	✓	✓
Diversions				
Steamboat Ditch	✓	✓	✓	✓
Chalk Bluff WTPHD	✓	✓	✓	✓
Highland Ditch	✓	✓	✓	✓
Last Chance Ditch	✓	✓	✓	✓
Lake Ditch	✓	✓	✓	✓
Orr Ditch	✓	✓	✓	✓
Chalk Bluff WTPOD	✓	✓	✓	✓
Glendale WTP	✓	✓	✓	✓
Pioneer Ditch		✓	✓	✓
North Truckee Ditch		✓	✓	✓
Noce Ditch		✓	✓	✓
Murphy Ditch		✓	✓	✓
McCarran Ditch		✓	✓	✓
Truckee Canal Diversion			✓	✓
Washburn Ditch			✓	✓
Gregory Ditch			✓	✓
Herman Ditch			✓	✓
Proctor Ditch			✓	✓
Olinghouse Ditch 1				✓
Fellnagle Ditch				✓
Gardella Ditch				✓
Olinghouse Ditch 3				✓

For the three test gages above Nixon, the accuracy of the disaggregation method can be evaluated using a metric called the Nash-Sutcliffe Efficiency ("NSE"). The NSE evaluates the fit of simulated data points to observed data points and is recommended by the American Society of Civil Engineers (ASCE) (Moriasi, et al., 2007) as a reliable function for evaluating the overall fit of a hydrograph. Equation (13) displays the NSE formula, and Table 17 shows an NSE performance grading criteria proposed by (Moriasi, et al., 2007).

$$NSE = 1 - \frac{\sum_{t=1}^{T}(Q_{sim}^{t} - Q_{obs}^{t})^2}{\sum_{t=1}^{T}(Q_{obs}^{t} - \bar{Q}_{obs})^2} \quad (13)$$

Table 17: Nash-Sutcliffe Efficiency Performance Criteria

Performance Rating	NSE
Very Good	0.75 - 1.00
Good	0.65 - 0.75
Satisfactory	0.50 - 0.65
Unsatisfactory	< 0.50

Where:

$Q_{sim}^{t} = simulated\ flow\ at\ time\ t$

$Q_{obs}^{t} = observed\ flow\ at\ time\ t$

$\bar{Q}_{obs} = Average\ of\ the\ Oberved\ data$

The NSE was calculated for each of the test gages, including Nixon, with results summarized in Table 18.

Table 18: Computed Nash-Sutcliffe Efficiency for simulated flows at each of the test gages

Gage	Nash-Sutcliffe Efficiency
Glendale	0.93
Tracy	0.98
Wadsworth	0.96
Nixon	0.94

Table 18 shows that the gage flows perform well above the "Very Good" minimum threshold (Table 17). These results, combined with the results in Figure 32 showing near perfect conservation of volume between Farad and Nixon, increases confidence in the computed Below Farad Local Inflow datasets.

The results are shown for each gage below with the measured and simulated flows plotted daily for the full range of the study period except for the Glendale gage which was installed in 2014. The gray line above the flow curves is plotted on a secondary vertical axis and displays the cumulative % volume error between the measured and simulated flows.

5.2.1.1 Truckee River at Glendale Verification

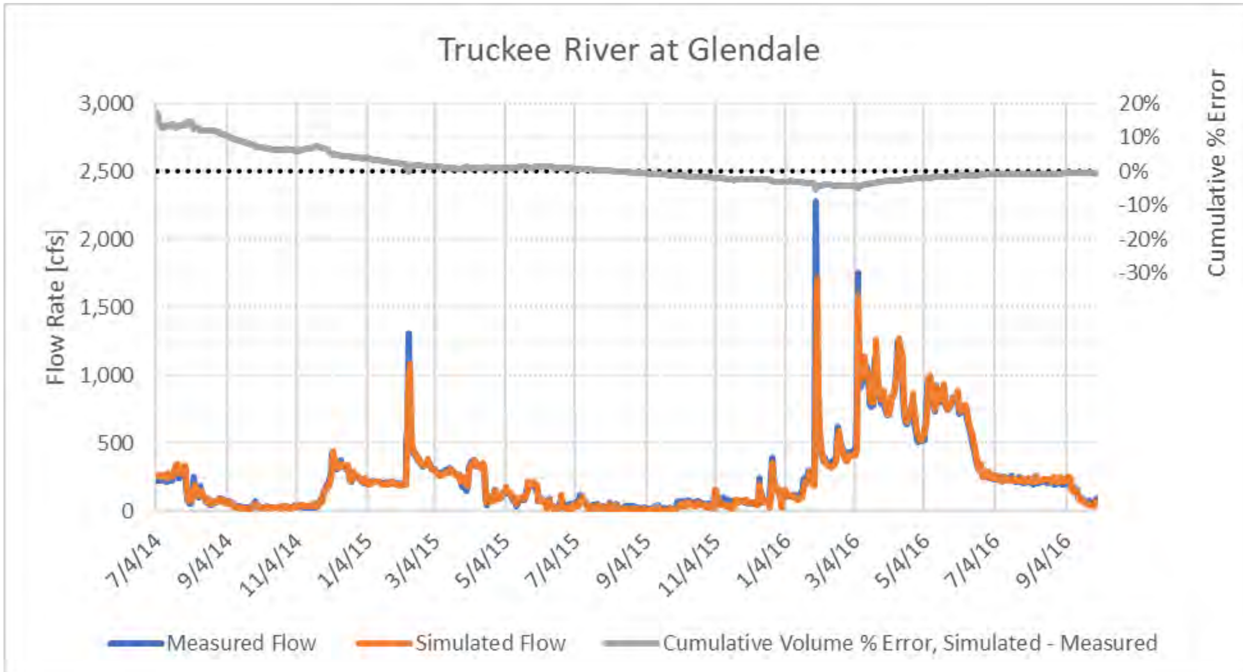


Figure 29: Results of the below Farad flow simulation verification method at Glendale

Figure 29 shows the results of the below Farad verification method for the Glendale gage which was installed in July of 2014. The Glendale gage was not used for this study because it was installed in the middle of the study period (though it is used in the modeling). This means it is an independent measurement to verify the overlapping period of the simulated and Glendale gage datasets. By the end of water year 2016, the simulated flow at Glendale produced a total volume 0.7% less than the Glendale gage. The method underestimated events over 1,000 cfs by an average of 1.4%. However, these events represent only 2% of the days in the short and dry dataset that is available, and the Glendale gage was new at the time of these events. Thus, the reported flows may not be reliable as there would have been limited manual measurements to create a rating curve. The simulated flow also often produces peak flows one day later than the date of peak flows measured by the gage; this may be caused by the travel time from the Glendale to the Nixon gage which was used to compute the daily local inflows. The simulated Glendale flow was within 5% of the gage flow on 30% of days. USGS estimates the accuracy of the gage at 5% (Table 38), so the gaged flow should be within 5% of the true flow 68% of the time (+/- one standard of deviation). Therefore, the differences between the simulated flow and the gage flow are partially explained by gaging uncertainty in the Glendale gage. These additional inputs will necessarily introduce more uncertainty to the calculated values because the computation of inflow requires use of multiple gages. The simulated flow is within 19% of the Glendale gage flow 68% of the time - an empirical estimate of the uncertainty in the simulated flow. With an NSE of 0.93 (Table 18), the Glendale gage was the worst fit of the four gages but still scored much higher than the minimum threshold for “Very Good” performance specified in Table 17.

5.2.1.2 Truckee River at Tracy Verification

Figure 30 shows the results of the flow simulation method at the Tracy gage. The Tracy Gage is not used in the modeling or the data development process making it an independent measurement ideal for verification purposes. Also, unlike the Glendale gage the period of record of the Tracy gage encompasses the entire study period. Interestingly, the simulated flow at Tracy is within 5% of the gaged flow on 50% of days which is significantly better than Glendale and approaches the bounds expected from the gaging uncertainty of the Tracy gage. Like Glendale, the simulated flow at Tracy underestimated some of the high flow events underpredicting flows between 1,000 and 2,500 cfs by 2.2% and flows over 2500 cfs by 17.3% on average. However, these flows represent only 1.3% of the dataset. At the end of the verification period, the cumulative simulated Tracy volume was 1.0% less than the measured volume. Despite being completely independent of the study computation, the simulated flow had an NSE score of 0.98 when compared to the Tracy Gage. This makes it the best fit of the four gages and much higher than the minimum threshold for "Very Good" performance specified in Table 17.

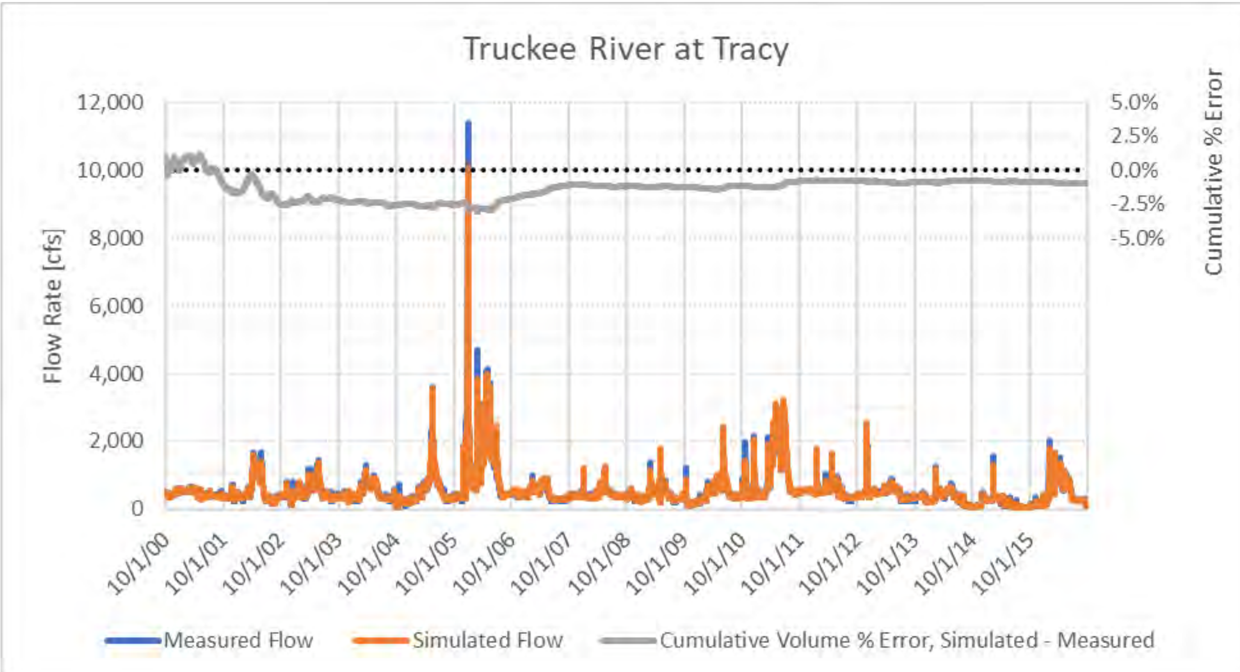


Figure 30: Results of the below Farad flow simulation verification method at Tracy

5.2.1.3 Truckee River at Wadsworth Verification

Figure 31 displays the results of the verification method used at the Wadsworth gage. The Wadsworth gage was used to determine the monthly proportion of the Farad to Nixon flow occurring upstream of the Wadsworth gage (see Section 3.2.4.4). However, it was not used to determine the magnitude of the Farad to Nixon local inflow. This is important because, unlike Tracy and Glendale, the observed Wadsworth gage flows are used in the simulation of the same gage flows (though not directly). For the Wadsworth gage, the flows under 500 cfs (84% of the record) were overestimated by 6.1% on average while the flows over 500 cfs (16% of the record) were underestimated by 4.2% on average. The largest measured flow at Wadsworth was 10,000 cfs on 1/1/2006. The simulated flow estimated that value to be 10,096 cfs - well within the 5% gaging error estimate (Table 43). In the simulation, though, the event occurred one day earlier. This is different than the Glendale gage where peak flows in the simulation tended to occur one day after they were measured. Peak flow timing errors are most likely due to travel time difficulties discussed in Section 3.2.4.2. Similar to Glendale, simulated flows were within 5% of the gage flows on 32% of days - about half of the 68% of days that would be expected from a gage with 5% uncertainty. Over the study period, the simulated volume was 1.8% less than the measured volume. Figure 31 shows that this difference accumulated mostly in water years 2001, 2006, and 2011. The simulated flow had an NSE score of 0.96 when compared to the Wadsworth Gage making it the second best fit of the four gages and much higher than the minimum threshold for "Very Good" performance specified in Table 17.

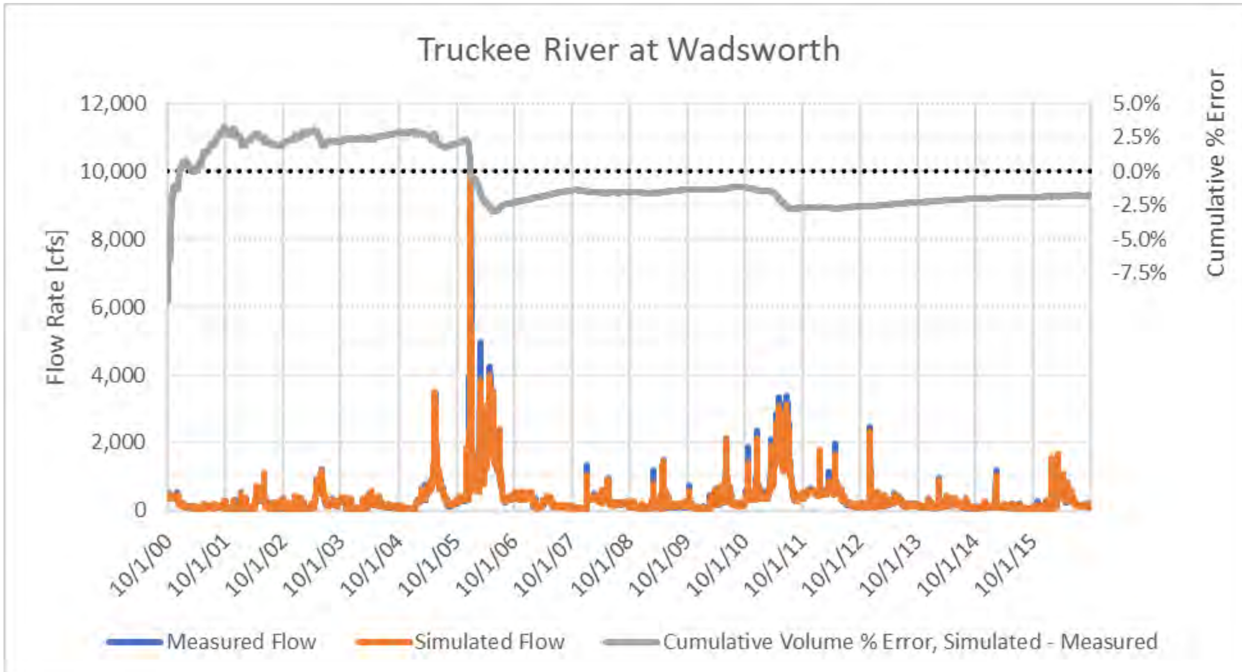


Figure 31: Results of the below Farad flow simulation verification method at Wadsworth

5.2.1.4 Truckee River at Nixon Verification

Figure 32 shows the results of the total volume verification method used for the below Farad reaches. The Nixon gage was directly used to compute the Farad to Nixon local inflow so the simulated volume of Nixon would be expected to match the gaged volume very closely. Review of the cumulative volume percent error shows that the simulated flow is never more than 1.1% over or 0.4% less than the gaged flow after the first month of the dataset. The simulated cumulative volume is 0.02% (800 AF) more than the gaged flow confirming that volume was conserved in the computation methods. Like the other gages, there is disagreement at a daily scale. The simulated flows at Nixon are within 5% of the gaged flows on 44% of the days which is about two-thirds of the 68% deviation that would be expected from a stream gage with 5% error. The simulated flow had an NSE score of 0.94 when compared to the Nixon Gage making it the third best fit of the four gages and much higher than the minimum threshold for "Very Good" performance specified in Table 17.

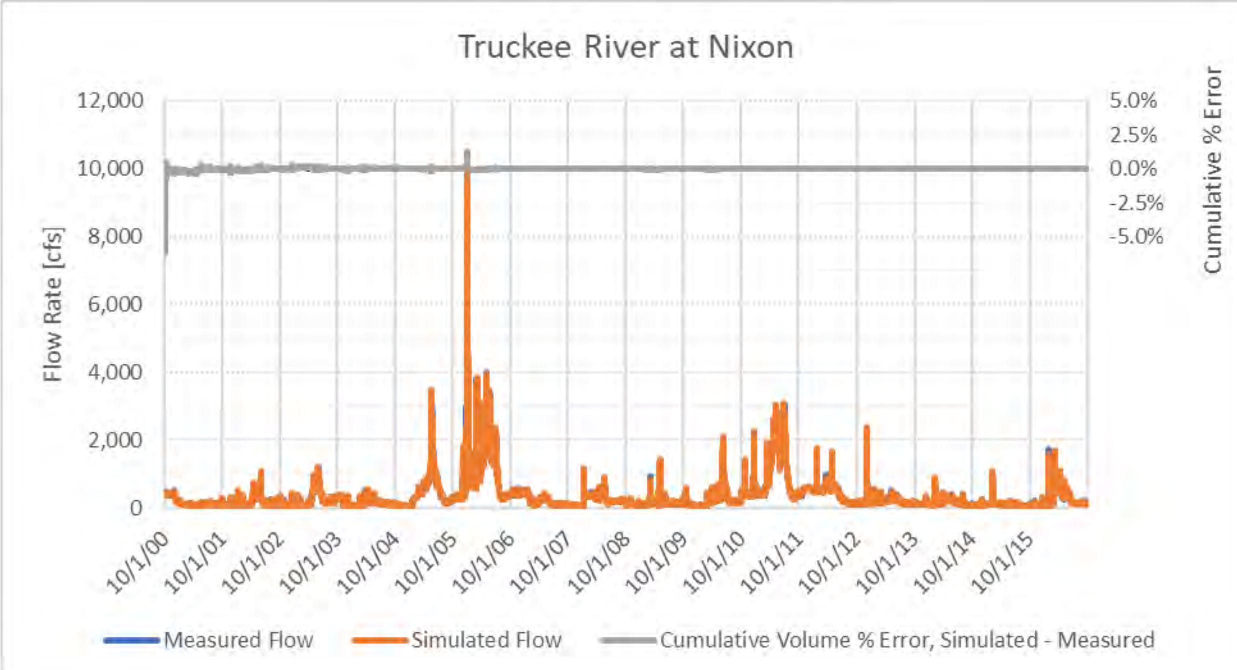


Figure 32: Results of the below Farad flow simulation verification method at Nixon

6 Conclusion and Future Analysis

This report establishes a process to compute the hydrologic inflows to the Truckee-Carson River basins that are needed to run the associated RiverWare models. These computed inflows are specific to the water balance assumed in the RiverWare models and were developed to allow for regular extension of the dataset in years to come.

Inclusion of water year 2001-2021 data into the dataset used for planning and operational studies will greatly improve the credibility of the previous dataset in relation to drought planning due to the inclusion of the 2012-2015 drought.

As shown in Section 5.1, the Farad Natural Flow computed for the study period agreed with the independent computation of the net inflow over the study period by 0.05% (when comparing to the Water Master Flow data at Farad), and the USGS Approved volume at Farad differs from the Water Master Flow data by 0.67%. Thus, the method accurately computes the volume of inflows upstream of the Farad Gage and will be sufficient for use in model planning and operational studies.

In Section 5.2, the methods for computing inflows downstream of Farad were shown to reproduce the independently observed stream flow at the Glendale and Tracy Gages with NSE scores of 0.93 and 0.98, respectively. These simulated flows match the Tracy gage more closely than what would be expected from random gaging error. For the Nixon gage, the simulated flows matched the study period volume to within 0.02% (800 AF over 16 years). These comparisons show that the method for computation of inflows to the basin presented herein conserve volume and are appropriate for use in water resource planning studies and operational forecasting.

For future water year data, the data from a completed TROA Operations and Accounting model can be processed and reviewed, then added to data of record. This process is designed to make the most current observed hydrology from a water year available for analysis in the next water year in an efficient and consistent manner.

7 References

Blanchard, C. (2020, 8 14). U.S. District Court Water Master. (C. Erkman, Interviewer)

Cal DWR. (2020). Handbook For Water Budget Development.

Fulwiler, & Lawler. (2010). TCDATFIL Disaggregation to Daily Data.

Fulwiler, J., & Lawler, C. (2012). *Truckee Meadows Local Inflow Dataset.* San Rafael, California: N/A.

Google Earth. (n.d.). 2020 Google. Retrieved 8 14, 2020, from https://earth.google.com/

Huntington, J. L., & McEvoy, D. (2011). *Climatological Estimates of Open Water Evaporation from Selected Truckee and Carson River Basin Water Bodies, California and Nevada.* Desert Research Institute, Hydrologic Sciences. Reno, NV: Desert Research Institute.

Loucks, D. P., & van Beek, E. (2005). *Water Resources Systems Planning and Management.* Paris: United Nations Educational, Scientific and Cultural Organization.

Maidment, D. R. (1993). *Handbook of Hydrology.* New York: McGraw-Hill, Inc.

Michael R. Lindeburg, P. (2015). *Civil Engineering Reference Manual for the PE Exam* (15 ed.). Belmont, CA: PPI.

Moriasi, D., Arnold, J., Van Liew, M., Bingner, R., Harmel, R., & Veith, T. (2007). *Model evaluation guidelines for systematic quantification of accuracy in watershed simulations.* Transactions of the ASABE, 50, 885.

R. D. Harmel, R. J. (2006, May). Cumulative Uncertainty in Measured Streamflow and Water Quality Data for Small Watersheds. *Research Gate*, pp. 689-701.

Slade, R. M. (2004). General methods, information, and sources for collecting and analyzing water-resources data.

Testimony of Jeffrey D. Rieker, Water Right Application 31487, 31488; Change Petition 5169, 9247, 15673, 18006 (State Water Resource Control Board 6 29, 2010).

TIS. (2021, 12 7). Retrieved from TROA Information System: http://www.troa.net/tis/

TMWA. (2016, November 21). Retrieved from Truckee Meadows Water Authority: https://tmwa.com/

TRA. (1935). *Truckee River Agreement*. Retrieved from http://www.troa.net/documents/TRA_1935/

TROA. (2008, September 6). *Truckee River Operating Agreement*. Retrieved from http://www.troa.net/documents/TROA_Sep2008/troa_final_09-08_full.pdf

USBR, T. S. (2013). *Updated Lahontan Reservoir Loss Modeling Review and Analysis.*

USGS. (2007). Water Budgets: Foundations for Effective Water-Resources and Environmental Management.

USGS. (2022, August 11). Retrieved from USGS Surface-Water Annual Statistis for Nevada Truckee River at Farad CA: https://waterdata.usgs.gov/nv/nwis/annual/?referred_module=sw&site_no=10346000&por_10346000_7685=2207425,00060,7685,1909,2022&start_dt=2000&end_dt=2020&year_type=W&format=html_table&date_format=YYYY-MM-DD&rdb_compression=fi

USGS. (2022, August 11). Retrieved from USGS Surface-Water Annual Statistis for Nevada Truckee River at Nixon NV: https://waterdata.usgs.gov/nv/nwis/annual/?referred_module=sw&site_no=10351700&por_10351700_103007=172991,00060,103007,1958,2022&start_dt=2000&end_dt=2020&year_type=W&format=html_table&date_format=YYYY-MM-DD&rdb_compression

USGS Water Resources Statistics Software. (2016). Retrieved from USGS: https://water.usgs.gov/software/lists/statistics

8 APPENDICES

8.1 DATA SOURCES

Table 19: Reservoir precipitation gaging stations, period of record, agency, and method.

Reservoir	Agency	Agency ID	Collection Method	TIS Daily SDI	Daily Aggregation Method	Start of Record	Notes
Boca	NWS / USWM		Manual	150351	Travel Time Adjusted	Dec 1, 1936	
Tahoe	NWS / USWM		Manual	150313	Travel Time Adjusted	Jan 1, 1931	
Donner	USGS		Heated tipping bucket	150309	Travel Time Adjusted	Sep 19, 1997	15-minute data aggregated to daily based on TTA daily period
Independence	NRCS SNOTEL	Independence Camp, 539	100" Transducer – Druck	16024	Travel Time Adjusted	Oct 1, 1978	15-minute data aggregated to daily based on TTA daily period
Stampede	USGS	10344300	Heated tipping bucket	160000	Travel Time Adjusted	Mar 2, 2016	
Prosser	USGS	10340300	Heated tipping bucket	159998	Travel Time Adjusted	Mar 2, 2016	
Martis						N/A	PRISM used to estimate precipitation based on measurements from other reservoirs.

Table 20: Reservoir pool elevation gaging stations, period of record, agency, and method

Reservoir	Agency	Agency ID	TIS Daily SDI	Daily Aggregation Method	Start of Record	Notes
Boca	USGS	10344490	154008	End of travel time adjusted period	Oct 31, 1939	
Tahoe	USGS	10337000	154003	End of travel time adjusted period	Apr 30, 1900	Values are in feet above Lake Tahoe datum 6220’
Donner	USGS	10338400	155852	End of travel time adjusted period	Jan 5, 1989	
Independence	USGS	10342900	155853	End of travel time adjusted period	Nov 10, 1988	
Stampede	USGS	10344300	154009	End of travel time adjusted period	Aug 9, 1970	
Prosser	USGS	10340300	154012	End of travel time adjusted period	Jan 1, 1964	
Martis	CDEC		155854	End of travel time adjusted period	Jan 15, 2000	

Table 21: Reservoir release gaging stations, methods, and period of record

Reservoir	Agency	Agency ID	Collection Method	TIS Daily SDI	Daily Aggregation Method	Start of Record	Notes
Boca	USWM	N/A	Manual reading from acoustic meter on penstock	154007	Average of 24 hours before end of travel time adjusted period	Jan 1, 2000	Computed from release changes, the USGS gage 10344500 is used as a backup
Tahoe	USGS	10337500		154004	Average of 24 hours before end of travel time adjusted period	July 1, 1895	
Donner	USGS	10338500		154015	Average of 24 hours before end of travel time adjusted period	Jan 1, 1929	
Independence	USGS	10343000		154019	Average of 24 hours before end of travel time adjusted period	Oct 21, 1909	
Stampede	USWM	N/A	Manual reading from acoustic meter on penstock	154010	Average of 24 hours before end of travel time adjusted period	Jan 1, 2000	Computed from release changes, the USGS gage 10344400 is used as a backup
Prosser	USWM	N/A		154013	Average of 24 hours before end of travel time adjusted period	Jan 1, 2000	Computed from release changes

Martis	CDEC	N/A	154021	Average of 24 hours before end of travel time adjusted period	Jan 1, 1958	

Table 22: Stream gaging stations, period of record and methods

Stream Gage	Agency	Agency ID	TIS Daily SDI	Daily Aggregation Method	Start of Record	Notes
TRUCKEE R NR TRUCKEE CA	USGS	10338000	159950	Average of 24 hours before end of travel time adjusted period	Dec 1, 1944	Before Oct 1, 2014, the USGS gage was used
DONNER C AT HWY 89 NR TRUCKEE CA	USGS	10338700	159981	Average of 24 hours before end of travel time adjusted period	Dec 1, 1944	Before Oct 1, 2014, the USGS gage was used
TRUCKEE R A FARAD CA	USGS	10346000	154027	Average of 24 hours before end of travel time adjusted period	Jan 1, 1909	Before Jan 1, 2000, the USGS gage was used
TRUCKEE RV NR MOGUL, NV	USGS	10347460	N/A	USGS Approved Daily Data	Feb 19, 1993	
HUNTER CK NR RENO, NV	USGS	10347600	N/A	USGS Approved Daily Data	Oct 1, 1961	
TRUCKEE RV AT RENO, NV	USGS	10348000	N/A	USGS Approved Daily Data	Oct 1, 1906	
TRUCKEE RV AT GLENDALE AVE NR SPARKS, NV	USGS	10348036	N/A	USGS Approved Daily Data	Jul 4, 2014	
TRUCKEE RV NR SPARKS, NV	USGS	10348200	N/A	USGS Approved Daily Data	Apr 20, 1977	
STEAMBOAT CK AT STEAMBOAT, NV	USGS	10349300	N/A	USGS Approved Daily Data	Oct 1, 1961	

STEAMBOAT CK AT CLEANWATER WAY NR RENO, NV	USGS	10349980	N/A	USGS Approved Daily Data	Jul 29, 1976	
TRUCKEE RV AT VISTA, NV	USGS	10350000	N/A	USGS Approved Daily Data	August 18, 1899	
TRUCKEE CANAL NR WADSWORTH, NV	USGS	10351300	N/A	USGS Approved Daily Data	Oct 1, 1966	This is a USGS gage that measures the diversion into the canal after the Gilpen spill.
TRUCKEE RV BLW DERBY DAM NR WADSWORTH, NV	USGS	10351600	N/A	USGS Approved Daily Data	Jan 1, 2018	
TRUCKEE RV AT WADSWORTH, NV	USGS	10351650	N/A	USGS Approved Daily Data	May 1, 1965	
TRUCKEE RV NR NIXON, NV	USGS	10351700	N/A	USGS Approved Daily Data	Oct 1, 1957	

Table 23: Diversion gaging agency, methods, period of record

Diversion Name	Agency	TIS Daily SDI	Daily Aggregation Method	Start of Record	Notes
ChalkBluffWTPHD	TMWA	150574		Mar 21, 1994	
ChalkBluffWTPOD	TMWA	150574		Apr 1, 1998	
Cochran Ditch	USWM	150518		Apr 16, 1984	
Coldron Ditch	USWM	150507		Apr 16, 1984	
Fellnagle Ditch		156198		Apr 15, 2008	
Gardella Ditch		150544		Apr 23, 1984	
Glendale Ditch		155910		Apr 17, 1985	
GlendaleWTP	TMWA	150576		Feb 8, 1984	
Gregory Ditch		150534		Apr 17, 1984	
Herman Ditch		156251		Apr 17, 1984	
Highland Ditch	TMWA	150509		Jan 1, 1984	
Highland Plant	TMWA			Jan 1, 1984	
Hunter Creek Diversion	TMWA			Jan 1, 1984	
Idlewild Plant	TMWA			Feb 8, 1984	
Katz Ditch	USWM	155914		Apr 16, 1984	
Lake Ditch	USWM	156241		Apr 16, 1984	
Last Chance Ditch	USWM	156246		Apr 16, 1984	
McCarran Ditch	USWM	150528		Apr 17, 1984	
Murphy Ditch	USWM	150526		Apr 17, 1984	
Noce Ditch	USWM	155916		Apr 17, 1984	
North Truckee Ditch	USWM	150524		Apr 23, 1984	
Olinghouse Ditch1	USWM	156261		Apr 15, 1984	
Olinghouse Ditch3	USWM	156265		Apr 15, 1984	
Orr Ditch	USWM	156256		Apr 16, 1984	
Pierson Ditch	USWM	150538		Apr 17, 1984	
Pioneer Ditch	USWM	156269		Apr 21, 1984	
PLPT_MI					
Proctor Ditch	USWM	150600		Apr 12, 1984	
Sessions Ditch	USWM	155918		May 7, 1984	
Steamboat Ditch	USWM	156065		Apr 16, 1984	
Steamboat To Hunter Ck Plant	TMWA				

Truckee Canal Nr Wadsworth, NV	USGS	N/A	USGS Approved Daily Data	Oct 1, 1966	This is a USGS gage that measures the diversion into the canal after the Gilpen spill.
Washburn Ditch	USWM	150512		Apr 23, 1984	

8.2 DATA COLLECTION INSTRUMENTS

Information showed in this appendix was provided by the agency responsible for maintenance of the gaging system (USGS or USWM) and is current as of September 2017.

Table 24: USGS site 10337000 Lake Tahoe

Meas Equip		Recording Equip	
Type/Method	Float	Type/Method	data logger
Make	Handar encoder	Make	Design Analysis
Model	436A	Model	H500XL
Serial #	unknown	Serial #	1871
Date of installation	unknown	Units of measurement	feet
Last calibrated	2/14/2017	Frequency of recording	every 15 minutes
Est accuracy of meas	0.05%		
Description of method	data logger		
Maintenance schedule	every 6-8 weeks or as needed		
USGS Site	https://waterdata.usgs.gov/nwis/uv?10337000		

Table 25: USGS site 10337500 Truckee R at Tahoe City

Meas Equip		Recording Equip	
Type/Method	Transducer	Type/Method	data logger
Make	Design Analysis	Make	Design Analysis
Model	H350XL	Model	H350XL
Serial #	4546	Serial #	4546
Date of installation	unknown	Units of measurement	feet
Last calibrated	3/10/2017	Frequency of recording	every 15 minutes
Est accuracy of meas	0.05%		
Description of method	data logger		

Maintenance schedule	every 2-4 weeks or as needed		
Site	https://waterdata.usgs.gov/nwis/uv?10337500		

Table 26: USGS site 10338400 Donner Lk nr Truckee

Meas Equip		Recording Equip	
Type/Method	Transducer	Type/Method	data logger
Make	Design Analysis	Make	Design Analysis
Model	H350XL	Model	H350XL
Serial #	1565	Serial #	1565
Date of installation	unknown	Units of measurement	feet
Last calibrated	3/17/2017	Frequency of recording	every 15 minutes
Est accuracy of meas	0.05%		
Description of method	data logger		
Maintenance schedule	every 6-8 weeks or as needed		
USGS Site	https://waterdata.usgs.gov/nwis/uv?10338400		

Table 27: USGS Site 10338500 Donner Cr at Donner Lk

Meas Equip		Recording Equip	
Type/Method	Transducer	Type/Method	data logger
Make	Design Analysis	Make	Design Analysis
Model	H350XL	Model	H350XL
Serial #	1410	Serial #	1410
Date of installation	unknown	Units of measurement	feet
Last calibrated	3/8/2017	Frequency of recording	every 15 minutes
Est accuracy of meas	0.05%		
Description of method	data logger		
Maintenance schedule	every 6-8 weeks or as needed		
USGS Site	https://waterdata.usgs.gov/nwis/uv?10338500		

Table 28: USGS site 10340300 Prosser Cr Reservoir nr Truckee

Meas Equip		Recording Equip	
Type/Method	Transducer	Type/Method	data logger
Make	Design Analysis	Make	Design Analysis
Model	H350XL	Model	H350XL
Serial #	1807	Serial #	1807
Date of installation	unknown	Units of measurement	feet
Last calibrated	3/17/2017	Frequency of recording	every 15 minutes
Est accuracy of meas	0.05%		
Description of method	data logger		
Maintenance schedule	every 6-8 weeks or as needed		
USGS Site	https://waterdata.usgs.gov/nwis/uv?10340300		

Table 29: USGS Site 10340500 Prosser Cr blw Prosser Cr Res

Meas Equip		Recording Equip	
Type/Method	Transducer	Type/Method	data logger
Make	Design Analysis	Make	Design Analysis
Model	H350XL	Model	H350XL
Serial #	3868	Serial #	3868
Date of installation	unknown	Units of measurement	feet
Last calibrated	3/22/2017	Frequency of recording	every 15 minutes
Est accuracy of meas	0.05%		
Description of method	data logger		
Maintenance schedule	every 6-8 weeks or as needed		
USGS Site	https://waterdata.usgs.gov/nwis/uv?10340500		

Table 30: USGS site 10342900 Independence Lk nr Truckee

Meas Equip		Recording Equip	
Type/Method	Transducer	Type/Method	data logger
Make	Design Analysis	Make	Design Analysis
Model	H350XL	Model	H350XL
Serial #	4542	Serial #	4542
Date of installation	unknown	Units of measurement	feet
Last calibrated	2/15/2017	Frequency of recording	every 15 minutes
Est accuracy of meas	0.05%		
Description of method	data logger		
Maintenance schedule	every 6-8 weeks or as needed		
USGS Site	https://waterdata.usgs.gov/nwis/uv?10342900		

Table 31: USGS site 10343000 Independence Cr blw Independence Lk

Meas Equip		Recording Equip	
Type/Method	Transducer	Type/Method	data logger
Make	Design Analysis	Make	Design Analysis
Model	H350XL	Model	H350XL
Serial #	1514	Serial #	1514
Date of installation	unknown	Units of measurement	feet
Last calibrated	2/15/2017	Frequency of recording	every 15 minutes
Est accuracy of meas	0.05%		
Description of method	data logger		
Maintenance schedule	every 6-8 weeks or as needed		
USGS Site	https://waterdata.usgs.gov/nwis/uv?10343000		

Table 32: USGS site 10344300 Stampede Reservoir nr Truckee

Meas Equip		Recording Equip	
Type/Method	Transducer	Type/Method	data logger
Make	KPSI	Make	Design Analysis
Model	500	Model	H522
Serial #	unknown	Serial #	4114
Date of installation	unknown	Units of measurement	feet
Last calibrated	3/2/2017	Frequency of recording	every 15 minutes
Est accuracy of meas	0.05%		
Description of method	data logger		
Maintenance schedule	every 6-8 weeks or as needed		
USGS Site	https://waterdata.usgs.gov/nwis/uv?10344300		

Table 33: USGS site 10344490 Boca Reservoir nr Truckee

Meas Equip		Recording Equip	
Type/Method	Transducer	Type/Method	data logger
Make	KPSI	Make	Design Analysis
Model	500	Model	H522
Serial #	1020	Serial #	1367
Date of installation	unknown	Units of measurement	feet
Last calibrated	3/21/2017	Frequency of recording	every 15 minutes
Est accuracy of meas	0.05%		
Description of method	data logger		
Maintenance schedule	every 6-8 weeks or as needed		
USGS Site	https://waterdata.usgs.gov/nwis/uv?10344490		

Table 34: USGS site 10344400 Little Truckee R abv Boca Reservoir

Meas Equip		Recording Equip	
Type/Method	Transducer	Type/Method	data logger
Make	Design Analysis	Make	Design Analysis
Model	H350XL	Model	H350XL
Serial #	1568	Serial #	1568
Date of installation	unknown	Units of measurement	feet
Last calibrated	3/21/2017	Frequency of recording	every 15 minutes
Est accuracy of meas	0.05%		
Description of method	data logger		
Maintenance schedule	every 6-8 weeks or as needed		
USGS Site	https://waterdata.usgs.gov/nwis/uv?10344400		

Table 35: USGS site 10344500 Little Truckee R blw Boca Reservoir

Meas Equip		Recording Equip	
Type/Method	Transducer	Type/Method	data logger
Make	Design Analysis	Make	Design Analysis
Model	H350XL	Model	H350XL
Serial #	unknown	Serial #	unknown
Date of installation	unknown	Units of measurement	feet
Last calibrated	3/20/2017	Frequency of recording	every 15 minutes
Est accuracy of meas	0.05%		
Description of method	data logger		
Maintenance schedule	every 6-8 weeks or as needed		
USGS Site	https://waterdata.usgs.gov/nwis/uv?10344500		

Table 36: USGS Site 10347460 Truckee River Near Mogul

Meas Equip		Recording Equip	
Type/Method	Radar, Transducer, Tipping Bucket Rain Gage	Type/Method	data logger
Make	Design Analysis	Make	Design Analysis
Model	H3613i, H350XL, 4264	Model	H-2221
Serial #		Serial #	
Date of installation	Gage installed and record began on Feb 18, 1993. Discontinued Oct 3, 1995. Re-established Sep 27, 1996.	Units of measurement	feet
Last calibrated	see last measurement on web page	Frequency of recording	every 15 minutes
Est accuracy of meas	0.05%		
Description of method	data logger		
Maintenance schedule	every 6 weeks or as needed		
Site	https://waterdata.usgs.gov/nwis/uv?10347460		

Table 37: USGS Gage 10348000 Truckee River at Reno

Meas Equip		Recording Equip	
Type/Method	Transducer	Type/Method	data logger
Make	Design Analysis	Make	Design Analysis
Model	H350XL	Model	H350XL
Serial #		Serial #	
Date of installation	Station established Jul 1, 1906 by U.S. Reclamation Service. Jul 1906 to Sep 1946, staff gages at sites 1/2 to 1 mile upstream at different datums. Records for Oct 1919 to Dec 1946, partly furnished by Federal Court Water Master in cooperation with U.S. Reclamation Service. Gage established at present location in Oct 1998 and operated concurrently with the gage at the previous location approximately 2,700 feet downstream until Jul 30, 1999, at which time the downstream gage was discontinued. Re-established:Jan 1, 1947 by U.S.G.S. in	Units of measurement	feet

	cooperation with U.S. Corps of Engineers.		
Last calibrated	see last measurement on web page	Frequency of recording	every 15 minutes
Est accuracy of meas	0.05%		
Description of method	data logger		
Maintenance schedule	every 6 weeks or as needed		
Site	https://waterdata.usgs.gov/nwis/uv?10348000		

Table 38: USGS Gage 10348036 Truckee River at Glendale Avenue Near Sparks

Meas Equip		Recording Equip	
Type/Method	Transducer	Type/Method	data logger
Make	Sutron	Make	Sutron
Model	Accububble	Model	Satlink 2
Serial #		Serial #	
Date of installation	Gage established July 2014.	Units of measurement	feet
Last calibrated	see last measurement on web page	Frequency of recording	every 15 minutes
Est accuracy of meas	0.05%		
Description of method	data logger		
Maintenance schedule	every 6 weeks or as needed		
Site	https://waterdata.usgs.gov/nwis/uv?10348036		

Table 39: USGS Gage 10348200 Truckee River Near Sparks

Meas Equip		Recording Equip	
Type/Method	Transducer	Type/Method	data logger
Make	Sutron	Make	Sutron
Model	Accububble	Model	Satlink 2
Date of installation	Gage installed and record began on Apr 20, 1977.	Units of measurement	feet
		Frequency of recording	every 15 minutes
Last calibrated	see last measurement on web page		
Est accuracy of meas	0.05%		
Description of method	data logger		
Maintenance schedule	every 6 weeks or as needed		
Site	https://waterdata.usgs.gov/nwis/uv?10348200		

Table 40: USGS Gage 10350000 Truckee River At Vista

Meas Equip		Recording Equip	
Type/Method	Transducer	Type/Method	data logger
Make	Design Analysis	Make	Design Analysis
Model	H350XL	Model	H-2221
Date of installation	Gage installed Aug 25, 1993 to replace the previous gage located at a site 1.2 miles downstream, which was discontinued Oct 19, 1994 due to continuing severe control problems. The locations are referenced to the SP RR bridge located at River Mile 52.36, which is 1.15 miles downstream of the confluence with Steamboat Creek. Aug 18, 1899, station established at site 700 feet upstream at different datum (Published as "near Vista"). Staff gage moved or washed out several times but always replaced in same general locations. Referenced to bolt in R.R. bridge abutment from May to Dec 1907. Discontinued Jan 1, 1908. Mar 21, 1908 to Apr 30, 1909, staff gage at site 200 feet upstream at different datum. Gage heights only, unpublished. The Federal Water Master operated a gage located 150 feet upstream of RR bridge from Jan 1932 to Oct 3, 1958. Daily flows are available from the FWM records during this period. On Oct 3, 1958, the station was reestablished by the USGS at site 150 feet upstream of bridge at datum 5.59 feet higher (4374.22 feet, the same datum as the FWM), with water-stage recorder installed in old wooden gage house, which had been used by the Federal Court Water Master, Reno, Nevada. The Water Master's cableway was also used. Aug 17, 1959, gage and cableway were dismantled to allow work on channel improvement project by the U.S. Corps of Engineers. A temporary staff gage was set under R.R. bridge about 1.2 miles downstream at different unknown datum, read daily by	Units of measurement	feet

	Federal Court Water Master. A new recorder well and cableway were installed at site 800 feet downstream of the RR bridge on Dec 10, 1959 at a datum of 4368.59 feet. Record was collected at this site from Dec 10, 1959 to Sep 30, 1993. On Oct 1, 1993 the gage was relocated at a site 1.0 stream-channel miles upstream of the railroad bridge near the sewage treatment plant at a datum 0.99 feet lower than the prior operated site. The elevation of the "0" gage datum at the current gaging site is 4367.60 feet above sea level.		
Last calibrated	see last measurement on web page	Frequency of recording	every 15 minutes
Est accuracy of meas	0.05%		
Description of method	data logger		
Maintenance schedule	every 6 weeks or as needed		
Site	https://waterdata.usgs.gov/nwis/uv?10350000		

Table 41: USGS Gage 10350340 Truckee River Near Tracy

10350340 TRUCKEE RV NR TRACY			
Meas Equip		Recording Equip	
Type/Method	Transducer	Type/Method	data logger
Make	Sutron	Make	Sutron
Model	Accububble	Model	Satlink 2
Serial #			
Date of installation	Gage installed Jun 23, 1997 and operated by USGS. Replaced gage (10350400) Truckee River below Tracy, operated 1.5 mi downsteam and destroyed in Jan 1997 flood. A 5.00 feet datum change was added to all reference marks on Oct 1, 1997.	Units of measurement	feet
Last calibrated	see last measurement on web page	Frequency of recording	every 15 minutes
Est accuracy of meas	0.05%		
Description of method	data logger		
Maintenance schedule	every 6 weeks or as needed		
Site	https://waterdata.usgs.gov/nwis/uv?10350340		

Table 42: USGS Gage 10351600 Truckee River Below Derby Dam Near Wadsworth

Meas Equip		Recording Equip	
Type/Method	Transducer	Type/Method	data logger
Make	Design Analysis	Make	Sutron
Model	H355	Model	Satlink 2
Serial #		Serial #	
Date of installation	Gage established Sep 30, 1958 by USGS	Units of measurement	feet
Last calibrated	see last measurement on web page	Frequency of recording	every 15 minutes
Est accuracy of meas	0.05%		
Description of method	data logger		
Maintenance schedule	every 2 weeks or as needed		
Site	https://waterdata.usgs.gov/nwis/uv?10351600		

Table 43: USGS Gage 1031650 Truckee River Near Wadsworth

Meas Equip		Recording Equip	
Type/Method	Transducer	Type/Method	data logger
Make	Sutron	Make	Sutron
Model	Accububble	Model	Satlink 2
Serial #		Serial #	
Date of installation	Gage established Mar 9, 1965 to Sep 30, 1986 at site on right bank 0.5 mi downstream from present site by USGS. Gage re-established on Jul 30, 1993 at different datum. Some records were collected 1902-05 and published as Truckee River near Wadsworth and at "Pyramid Lake Indian Agency, near Wadsworth" in 1903. See 1950 compilation report, WSP1 1314. These records were collected at a site 18 mi north of Wadsworth and therefore are not comparable to the present site. The ADCP bank operated cableway was installed at the old gage pool mentioned above .5 mile downstream of the present site. The ADCP cableway was destroyed during the Jan 2017 flood event and has not been rebuilt as of Aug 2017.	Units of measurement	feet
Last calibrated	see last measurement on web page	Frequency of recording	every 15 minutes
Est accuracy of meas	0.05%		
Description of method	data logger		
Maintenance schedule	every 6 weeks or as needed		
Site	https://waterdata.usgs.gov/nwis/uv?10351650		

Table 44: USGS Gage 10351700 Truckee River Near Nixon

Meas Equip		Recording Equip	
Type/Method	Transducer	Type/Method	data logger
Make	Sutron	Make	Sutron
Model	Accububble	Model	Satlink 2
Serial #		Serial #	
Date of installation	Gage established Sep 26, 1957 by USGS	Units of measurement	feet
Last calibrated	see last measurement on web page	Frequency of recording	every 15 minutes
Est accuracy of meas	0.05%		
Description of method	data logger		
Maintenance schedule	every 6 weeks or as needed		
Site	https://waterdata.usgs.gov/nwis/uv?10351700		

Table 45: USGS Gage 10351300 Truckee Canal Near Wadsworth

Meas Equip		Recording Equip	
Type/Method	Index-velocity	Type/Method	data logger
Make	SonTek and SonTek	Make	Sutron
Model	ADV and IQPlus	Model	Satlink 2
Serial #		Serial #	
Date of installation	Gage established Sep 26, 1957 by USGS	Units of measurement	feet
Last calibrated	see last measurement on web page	Frequency of recording	every 15 minutes
Est accuracy of meas	0.05%		
Description of method	data logger		
Maintenance schedule	every 2 weeks or as needed		
Site	https://waterdata.usgs.gov/nwis/uv?10351300		

Table 46: USGS Gage 10351400 Truckee Canal Near Hazen

Meas Equip		Recording Equip	
Type/Method	encoder	Type/Method	data logger
Make	Handar	Make	Sutron
Model	436b	Model	Satlink 2
Serial #		Serial #	
Date of installation	Base gage was established and operated by the U.S. Bureau of Reclamation from Oct 1, 1966 to Nov 1966, when operation was taken over by the USGS. First auxiliary slope gage was established by USGS Jun 29, 1967, and discontinued Mar 17, 1973. Second Auxiliary gage established immediately above KX-Lateral head gate and operated until Sep 30, 1980. Both gage sites discontinued Sep 30, 1980 and site moved 0.1 mi downstream from Auxiliary Gage site after new control gate for Bango Check was built.	Units of measurement	feet
Last calibrated	see last measurement on web page	Frequency of recording	every 15 minutes
Est accuracy of meas	0.05%		
Description of method	data logger		
Maintenance schedule	every 6 weeks or as needed		
Site	https://waterdata.usgs.gov/nwis/uv?10351400		

8.3 DATA FILLING

Table 47: Detail of gaps in site records used for development of inflow data and the methods used to fill the data.

Site	Start	End	Comment
Cochran Ditch	1998	2000	Interpolated sporadic data where necessary.
	2001	2016	Minimal use of the order of 122 AF, for which data is not available. Assumed 0 diversions.
Coldron Ditch	1984	2016	Interpolated sporadic data where necessary.
Fellnagle Ditch	1984	2007	No data available prior to 2008. For 1984 – 2007, volume of monthly diversion from 2008 is taken and assumed a constant monthly rate.
	2008	2016	Interpolated sporadic data where necessary.
Gardella Ditch	1984	2009	Interpolated sporadic data where necessary.
Glendale Ditch	1985	1988	Interpolated sporadic data where necessary.
Glendale Plant	1984	1993	Monthly data disaggregated to daily constant value
Gregory Ditch	1984	2016	Interpolated sporadic data where necessary.
Highland Plant	1984	1993	Monthly data disaggregated to daily constant value
Hunter Creek	1984	1999	Linear regression to Truckee at Reno.
	2000	2002	Data gap from USGS, filled with the multiple linear regression used in the model. This regression equation is (4.019 + 0.111 * Independence hydrologic inflow + 0.007 * Carson R at Fort Churchill (@t+1)).
Herman	1984	2016	Interpolated sporadic data where necessary.
Idlewild Plant	1984	1993	Monthly data disaggregated to daily constant value
Indian Ditch	1984	2016	Interpolated sporadic data where necessary.
Katz Ditch	1984	1986	Interpolated sporadic data where necessary.
Lake Ditch	1984	2016	Interpolated sporadic data where necessary.
Last Chance Ditch	1984	2016	Interpolated sporadic data where necessary.
McCarran Ditch	1984	2005	Interpolated sporadic data where necessary.
	2006	20016	Limited agriculture. The Nature Conservancy (TNC) rehab project had limited diversion, but since the volume was less than 50 AF was neglected
Murphy Ditch	1/1/1984	12/31/1984	Interpolated sporadic data where necessary.
Noce Ditch	1984	1989	Interpolated sporadic data where necessary.
	2013	2015	Granite Construction monthly data is available. But ignored since the annual volumes were less than 100 AF
North Truckee Ditch	1984	2010	Interpolated sporadic data where necessary.

Olinghouse 1&3	1984	2007	No data available – estimated based on power consumption (Kw Hrs) based on monthly volumes on TIS
	2008	2016	Interpolated sporadic data where necessary.
Orr Ditch	1984	2016	Interpolated sporadic data where necessary.
Pierson Ditch	1984	2000	Interpolated sporadic data where necessary.
Pioneer Ditch	1984	2016	Interpolated sporadic data where necessary.
Proctor Ditch	1984	2016	Interpolated sporadic data where necessary.
Sessions	1984	1988	Interpolated sporadic data where necessary.
Steamboat Ck at Steamboat	4/1/1994, 6/14/1994, 9/2/2004	4/2/1984, 6/27/1984, 9/4/2004	Filled using USGS SREF tool linked to Truckee Rv at Vista
Steamboat Ditch	1984	2016	Interpolated sporadic data where necessary.
	2000	2016	If a flush from Steamboat Ditch was identified in Hunter Creek, the same amount of diversion is removed from both sites. This was done for a couple of days annually.
SteamboatToHunterCkPlant	1984	1993	Monthly data disaggregated to daily constant value
Truckee Canal Nr Wadsworth	12/8/2013	12/9/2013	USGS data indicates it as 'estimated' data and reports 0. However, based on TIS instantaneous data and review of the local inflow data it was apparent that non-zero diversion occurred for some of the days. Data was filled based on the TIS instantaneous data
Truckee Rv at Mogul	10/1/1995	9/30/1996	Filled using USGS SREF tool linked to Truckee Rv at Reno
Truckee Rv at Wadsworth	9/30/1980	8/31/1993	Filled using USGS SREF tool linked to Truckee Rv at Nixon
Truckee Rv Nr Sparks	8/13/1992, 8/6/1994	10/26/1992, 11/3/1994	Filled using USGS SREF tool linked to Truckee Rv at Reno
TMWRF	1/1/1984	9/30/1984	Constant monthly rate, based on monthly volume from 1985.
Wasburn Ditch	1984	2016	Interpolated sporadic data where necessary.
Reuse	2000	2010	Consider using Tammi's regression, which uses the daily demand. May be able to get some data from Andy Hummel.
SierraValley	7/1/2012	7/31/2012	Filled with data from WM Accounting spreadsheet
SierraValley	3/25/2013	3/31/2013	Filled with 0. Assumed that the diversion started on April 1.

8.4 MANUAL EDITS TO ABOVE FARAD DATA

Table 48: Manual adjustments to data above Farad

WY 2001			
Reservoir/Location	**Period**	**Issue**	**Solution**
All Reservoirs	Oct – Mar	Exceptionally Noisy Data	9-Day Moving Average with a bias Correction
Sidewater	22-Dec-00	Sudden one day drop	Adjusted to match other values surrounding that are not fluctuating and are fairly constant, preserved the volume
WY 2003			
Reservoir/Location	**Period**	**Issue**	**Solution**
Prosser	Dec 20 – 27, 2002	Irregular negative inflow trough	Used a volume correcting moving average to increase the Prosser inflow
WY 2004			
Reservoir/Location	**Period**	**Issue**	**Solution**
Boca, Independence, Stampede, Donner	Oct – Feb	Exceptionally Noisy Data	Performed a volume preserving moving average smoothing algorithm on non-precipitation days
WY 2005			
Reservoir/Location	**Period**	**Issue**	**Solution**
Sidewater	May 18- 19	Exceptionally high Sidewater	Adjusted the day to merge water over two days to shift the flow from one day into two days to match other gages in the Above Farad region.
WY 2006			
Reservoir/Location	**Period**	**Issue**	**Solution**
Sidewater	31-Dec	Sidewater distribution greatly reduced before a storm.	Adjusted the distribution of flows across the Sidewater nodes that maintains the daily raw total of inflow and matches the volume for the period.
WY 2007			
Reservoir/Location	**Period**	**Issue**	**Solution**
Stampede	Oct – Mar	Noisy Data	Performed a volume preserving moving average smoothing algorithm on non-precipitation days
WY 2009			
Reservoir/Location	**Period**	**Issue**	**Solution**

Blw Donner and Blw Tahoe	Oct 1 – 13, 2008	Negative values on many days in this period when total Sidewater is positive	Used the previous Sidewater ratios to redistribute the Sidewater contribution to Blw Donner and Blw Tahoe inflows.
Stampede	Oct – Mar	Noisy Inflow data	Performed a volume preserving moving average smoothing algorithm on non-precipitation days
Stampede	July – Sep	Noisy Inflow data	Performed a volume preserving moving average smoothing algorithm on non-precipitation days
Independence	July – Sep	Noisy Inflow data	Performed a volume preserving moving average smoothing algorithm on non-precipitation days
WY 2010			
Reservoir/Location	**Period**	**Issue**	**Solution**
Stampede	Oct – Mar	Noisy Inflow data	Performed a volume preserving moving average smoothing algorithm on non-precipitation days
Stampede	July – Sep	Noisy Inflow data	Performed a volume preserving moving average smoothing algorithm on non-precipitation days
Prosser	Feb and Mar	Large Positive and Negative Shifts	Adjusted to smooth the shifts to preserve the volume to not show dramatic day to day changes
Sidewater	17-Oct	Total Sidewater goes negative after a storm due to travel time.	Adjusted the values from October 16 – 19 to accommodate the storm and not show a large negative shift that wouldn't be realistic.
WY 2011			
Reservoir/Location	**Period**	**Issue**	**Solution**
Stampede	Oct – Feb	Noisy Inflow data	Performed a volume preserving moving average smoothing algorithm on non-precipitation days
Blw Tahoe	Sep 3 – 11, 2011	Inflow values goes negative while the Total Sidewater is positive	Adjusted the Blw Tahoe values to be consistent with ratios observed prior to the negative values.
WY 2012			
Reservoir/Location	**Period**	**Issue**	**Solution**
Donner	10-Oct	Spike not consistent with precipitation	Removed by averaging two days to preserve volume
Donner	June 4 – 5	Spike/Trough combination	Removed by averaging two days to preserve volume

Stampede	June 18 – 19	Spike/Trough combination	Removed by averaging two days to preserve volume
Independence	Oct – Dec	Noisy Inflow data	Performed a volume preserving moving average smoothing algorithm on non-precipitation days
Sidewater	Dec – Jan	Noisy Inflow data	Performed a volume preserving moving average smoothing algorithm on non-precipitation days
WY 2013			
Reservoir/Location	**Period**	**Issue**	**Solution**
Independence	May 28 – 29	Trough/Spike combination	Removed by averaging two days to preserve volume
Sidewater	Jan 4, July – Nov	Negative local inflows that contribute to Total Sidewater when Total Sidewater is positive	Adjusted ratios to match prior observed for each component of Sidewater, preserved the volume.
WY 2014			
Reservoir/Location	**Period**	**Issue**	**Solution**
Sidewater	July – Sep	Negative local inflows that contribute to Total Sidewater when Total Sidewater is positive	Use the previous positive day ratio to adjust negative inflow days for components of Sidewater.
WY 2015			
Reservoir/Location	**Period**	**Issue**	**Solution**
Sidewater	10/1-16, 7/24-8/7, 9/10-10/31	Negative local inflow one or more component	Revised subbasin totals with recently observed positive ratios between basins without altering the total sidewater
Donner	10/18, 11/13, 11/20, 12/11, 4/19-26, 5/5-23, 6/7-18	Periodic negative inflows from noise	Replaced negatives with reasonable value from nearby dates, and bias corrected revised volume to ensure the same total volume was preserved.
Independence	10/19-1/9, 2/4-5, 4/24-25, 6/20-7/3, 9/24-29	Periodic negative inflows from noise	Replaced negatives with reasonable value from nearby dates, and bias corrected revised volume to ensure the same total volume was preserved.

Stampede	10/15-12/14, 2/5-10, 4/22-27, 6/30-9/25	Periodic negative inflows from noise	Replaced negatives with reasonable value from nearby dates, and bias corrected revised volume to ensure the same total volume was preserved.
Boca	All year	Generally, very noisy with some periodic negative numbers	Used a 10-day running average (excluding high flows 2/7-11) and replaced negatives with reasonable value from nearby dates. Applied a bias correction to the revised volume to ensure the that the total volume was preserved.
Tahoe	11/30-12/13, 4/19-28	Smoothing algorithm removed peak flow	Set peak flow to reasonable values based on Raw data and bias corrected revised volume to ensure the same total volume was preserved.
Prosser	6/10-7/31	Periodic negative inflows from noise	Replaced negatives with reasonable value from nearby dates, and bias corrected revised volume to ensure the same total volume was preserved.
Sidewater	9/24-29	Data showed increase flowed by decrease not observed in other basins	Smoothed out variation
WY 2016			
Reservoir/Location	**Period**	**Issue**	**Solution**
Prosser	Nov 1-4, Dec 11-12	Spike/Trough combination	Removed by averaging two days to preserve volume
Stampede	Dec 14-15, 23-24	Spike/Trough combination	Removed by averaging two days to preserve volume
Stampede	Nov 1-8	Smoothing algorithm removed peak flow	Set peak flow to reasonable values based on Raw data and bias corrected revised volume to ensure the same total volume was preserved.
Martis	Oct 31- Nov 4	Spike/Trough combination	Removed by averaging two days to preserve volume
Sidewater	Aug – Sep	Negative local inflows that contribute to Total Sidewater when Total Sidewater is positive	Use the previous positive day ratio to adjust negative inflow days for components of Sidewater.

WY 2017			
Reservoir/Location	**Period**	**Issue**	**Solution**
Tahoe	Nov 19 – 21	Spike/Trough combination	Removed by averaging three days to preserve volume
Sidewater	11-Dec	Sidewater showing too high	Sidewater reduced

8.5 MANUAL EDITS TO BELOW FARAD DATA

Table 49: Manual adjustments to data downstream of Farad

WY 2001			
Reservoir/Location	**Period**	**Issue**	**Solution**
Farad To Nixon	May	High flow needed to be preserved	Edited the smoothed data to preserve a high flow event that occurred but was removed by the smoothing algorithm.
WY 2002			
Reservoir/Location	**Period**	**Issue**	**Solution**
Farad To Nixon	November	High flow needed to be preserved	Edited the smoothed data to preserve a high flow event that occurred but was removed by the smoothing algorithm.
Farad to Nixon	March	Averaging raises flows before a storm too much	Adjusted the flow values before the storm and preserved the storm that was muted from the smoothing algorithm.
Farad To Nixon	April	Averaging raises flows before a storm too much	Adjusted the flow values to be lower than the averaged smoothed values and preserve the timing of the higher flows that are muted with the smoothing algorithm.
Farad To Nixon	May	High flow needed to be preserved	Adjusted the flow values to preserve the peak flow of a high event and preserve the volume by adjusting he flows around the storm to be lower than the smoothed, but equal with other base flow values before and after the period.
WY 2003			
Reservoir/Location	**Period**	**Issue**	**Solution**
Farad To Nixon	November	High flow needed to be preserved	Edited the smoothed data to preserve a high flow event that occurred but was removed by the smoothing algorithm.
Farad To Nixon	December	Large Negative and Positive Smoothed Values that are a result of bad Gage Data	Used a minimal difference from mean correctio method to smooth the data.
Farad To Nixon	December	High flow needed to be preserved	Edited the smoothed data to preserve a high flow event that occurred but was removed by the smoothing algorithm.
Farad To Nixon	March	High flow needed to be preserved	Edited the smoothed data to preserve a high flow event that occurred but was removed by the smoothing algorithm.

Farad To Nixon	Aug	High flow needed to be preserved	Edited the smoothed data to preserve a high flow event that occurred but was removed by the smoothing algorithm.
WY 2004			
Reservoir/Location	**Period**	**Issue**	**Solution**
Farad To Nixon	December	High flow needed to be preserved	Edited the smoothed data to preserve a high flow event that occurred but was removed by the smoothing algorithm.
Farad To Nixon	February	High flows needed to be preserved	Righted the high flow corrections by editing the smoothed data to preserve the high events and smoothed the other events using a minimal difference from mean correction algorithm.
Farad To Nixon	March	Large Negative and Positive Smoothed Values that do not correspond to upper basin flow data	Used a trend to smooth out the data so that it matches the flows coming out of the Upper Basin.
Farad To Nixon	April	High flow needed to be preserved	Edited the smoothed data to preserve a high flow event that occurred but was removed by the smoothing algorithm.
Farad To Nixon	September	Large Negative and Positive Smoothed Values that are a result of bad Gage Data	Corrected with a longer moving average to smooth out the data further than already smoothed.
WY 2005			
Reservoir/Location	**Period**	**Issue**	**Solution**
Farad To Nixon	February	High flow needed to be preserved	Edited the smoothed data to preserve a high flow event that occurred but was removed by the smoothing algorithm.
WY 2006			
Reservoir/Location	**Period**	**Issue**	**Solution**
Farad To Nixon	December	High flow needed to be preserved	Edited the smoothed data to preserve a high flow event that occurred but was removed by the smoothing algorithm. Also edited the data to more closely match the high spike in flows from the Upper Basin.
Farad To Nixon	April	High flow needed to be preserved	Edited the smoothed data to preserve a high flow event that occurred but was removed by the smoothing algorithm.
WY 2007			
Reservoir/Location	**Period**	**Issue**	**Solution**

Farad To Nixon	November	False negative troughs and spikes in the Smoothed Data	Apply an additional moving average to smooth the data and preserve the volume.
Farad To Nixon	February	High flow needed to be preserved	Edited the smoothed data to preserve a high flow event that occurred but was removed by the smoothing algorithm.
WY 2008			
Reservoir/Location	**Period**	**Issue**	**Solution**
Farad To Nixon	December	High flow needed to be preserved	Edited the smoothed data to preserve a high flow event that occurred but was removed by the smoothing algorithm.
Farad To Nixon	January	High flow needed to be preserved	Edited the smoothed data to preserve a high flow event that occurred but was removed by the smoothing algorithm.
WY 2009			
Reservoir/Location	**Period**	**Issue**	**Solution**
Farad To Nixon	October	High flow needed to be preserved	Edited the smoothed data to preserve a high flow event that occurred but was removed by the smoothing algorithm.
Farad To Nixon	February/March	High flows needed to be preserved and additional smoothing is needed	Edited the smoothed data to preserve a high flow event that occurred but was removed by the smoothing algorithm. Applied an additional moving average to smooth the non-spike data and remove unlikely negative troughs.
Farad To Nixon	April	High flow needed to be preserved	Edited the smoothed data to preserve a high flow event that occurred but was removed by the smoothing algorithm.
Farad To Nixon	May	Significant loss blw Farad during increase above Farad	Corrected the two most extreme negative values, this correction was applied twice, once for May 1 – 2, and then again for May 5. These corrections smoothed the data to not have large troughs.
Farad To Nixon	September	Additional smoothing was needed.	Apply an additional moving average to smooth the data and preserve the volume.
WY 2010			
Reservoir/Location	**Period**	**Issue**	**Solution**
Farad To Nixon	October	High flow needed to be preserved	Edited the smoothed data to preserve a high flow event that occurred but was removed by the smoothing algorithm.
Farad To Nixon	January	High flow needed to be preserved	Edited the smoothed data to preserve a high flow event that occurred but was removed by the smoothing algorithm.

Farad To Nixon	February	High flow needed to be preserved	Edited the smoothed data to preserve a high flow event that occurred but was removed by the smoothing algorithm. Had to apply a higher bias correction here to preserve the volume than usual.
Farad To Nixon	April – May	High flow needed to be preserved	Edited the smoothed data to preserve a high flow event that occurred but was removed by the smoothing algorithm.
Farad To Nixon	June	High flow needed to be preserved	Edited the smoothed data to preserve a high flow event that occurred but was removed by the smoothing algorithm.
Farad To Nixon	September	High flow needed to be preserved	Edited the smoothed data to preserve a high flow event that occurred but was removed by the smoothing algorithm.
WY 2011			
Reservoir/Location	**Period**	**Issue**	**Solution**
Farad To Nixon	October – Early	High flow needed to be preserved	Edited the smoothed data to preserve a high flow event that occurred but was removed by the smoothing algorithm.
Farad To Nixon	October – Late	High flow needed to be preserved	Edited the smoothed data to preserve a high flow event that occurred but was removed by the smoothing algorithm.
Farad To Nixon	December	High flow needed to be preserved	Edited the smoothed data to preserve a high flow event that occurred but was removed by the smoothing algorithm.
Farad To Nixon	March	High flow needed to be preserved	Edited the smoothed data to preserve a high flow event that occurred but was removed by the smoothing algorithm.
Farad To Nixon	June	High flow needed to be preserved	Edited the smoothed data to preserve a high flow event that occurred but was removed by the smoothing algorithm.
Farad To Nixon	July	High flow needed to be preserved	Edited the smoothed data to preserve a high flow event that occurred but was removed by the smoothing algorithm.
WY 2012			
Reservoir/Location	**Period**	**Issue**	**Solution**
Farad To Nixon	January	High flow needed to be preserved	Edited the smoothed data to preserve a high flow event that occurred but was removed by the smoothing algorithm.
Farad To Nixon	March	High flow needed to be preserved	Edited the smoothed data to preserve a high flow event that occurred but was removed by the smoothing algorithm.
Farad To Nixon	April	High flow needed to be preserved	Edited the smoothed data to preserve a high flow event that occurred but was removed by the smoothing algorithm.
WY 2013			
Reservoir/Location	**Period**	**Issue**	**Solution**

Farad To Nixon	December	High flow needed to be preserved	Edited the smoothed data to preserve a high flow event that occurred but was removed by the smoothing algorithm.
WY 2014			
Reservoir/Location	**Period**	**Issue**	**Solution**
Farad To Nixon	December	Low Flow needed to be preserved	Edited the smoothed data to preserve a low flow event that occurred but was removed by the smoothing algorithm.
Farad To Nixon	February	High flow needed to be preserved	Edited the smoothed data to preserve a high flow event that occurred but was removed by the smoothing algorithm.
Farad To Nixon	July	High flow needed to be preserved	Edited the smoothed data to preserve a high flow event that occurred but was removed by the smoothing algorithm.
Farad To Nixon	August	High flow needed to be preserved	Edited the smoothed data to preserve a high flow event that occurred but was removed by the smoothing algorithm.
WY 2015			
Reservoir/Location	**Period**	**Issue**	**Solution**
Farad To Nixon	February	High flow needed to be preserved	Edited the smoothed data to preserve a high flow event that occurred but was removed by the smoothing algorithm.
Farad To Nixon	April	High flow needed to be preserved	Edited the smoothed data to preserve a high flow event that occurred but was removed by the smoothing algorithm.
Farad To Nixon	July	High flow needed to be preserved	Edited the smoothed data to preserve a high flow event that occurred but was removed by the smoothing algorithm.
WY 2016			
Reservoir/Location	**Period**	**Issue**	**Solution**
Farad To Nixon	January	High flow needed to be preserved	Edited the smoothed data to preserve a high flow event that occurred but was removed by the smoothing algorithm.
Farad To Nixon	March	High flow needed to be preserved	Edited the smoothed data to preserve a high flow event that occurred but was removed by the smoothing algorithm.
Farad To Nixon	April	High flow needed to be preserved	Edited the smoothed data to preserve a high flow event that occurred but was removed by the smoothing algorithm.
Farad To Nixon	May	High flow needed to be preserved	Edited the smoothed data to preserve a high flow event that occurred but was removed by the smoothing algorithm.

8.6 UNCERTAINTY ANALYSIS OF BELOW FARAD LOCAL INFLOW COMPUTATIONS

Characterization of the gains and losses in the Truckee River from the Farad gage down to the last gage on the Truckee River at Nixon has historically been a great challenge for water managers in the basin. Many efforts have been undertaken to develop a reasonable and useful historical dataset for these values, and many other efforts have been undertaken to try to understand the hydrologic and anthropogenic dynamics that determine the gains and losses in this section of the river in hopes of developing methodologies to simulate the gains and losses for purely hypothetical model runs. Describing and assessing these efforts is outside of the scope of this document. However, it is clear in performing the data development effort described in this document that the essence of the challenge for developing reasonable and useful gains and losses, commonly referred to as "local inflows" is rooted in the high level of uncertainty that is inherently part of the computation of these numbers. This fact must be recognized and addressed in any successful effort to develop a reasonable and useful dataset of local inflows in the below-Farad basin.

8.6.1 Uncertainty Cause and Discussion

The challenge begins with noting that the local inflows in this section of the basin are much smaller than the flows that come into the basin at Farad. The water year 2000 to 2020 median annual flow volume at the Farad Gage is 575 kaf (USGS, 2022), while the median annual local inflow volume is 30 kaf (USGS, 2022). The computation of the local inflow in any subreach of the basin is performed by a water balance that includes the upstream gage flow, the downstream gage flow and any gaged diversions, return flows, or tributaries in between. The gage flows are the dominant elements of the water balance no matter which sub-reach is considered.

The uncertainty challenge is best illustrated with an example of error propagation through a water balance equation in a simplified hypothetical sub-reach of the Truckee from "Upstream Gage" to "Downstream Gage". Assume that in this simple example, there are no diversions or tributaries between the two gages. Assume further that on a given day the flow measurement at Upstream Gage is 500 cfs, the flow measurement at Downstream Gage is 550 cfs. Both of these measurements are uncertain and for the purpose of this simple example, both gages will be assumed to have an uncertainty in measurement of +/- 10%. This simple example is illustrated by the schematic in Figure 33

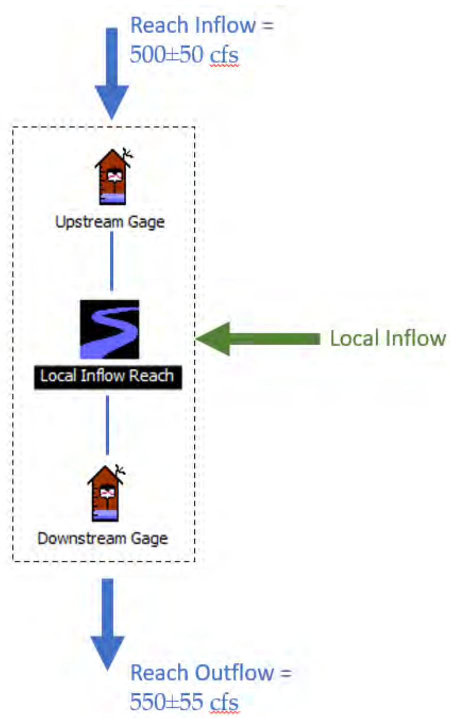


Figure 33 Simple reach schematic demonstrating the inherent uncertainty propagation challenges when local inflow to a reach is much smaller than the flows through the reach.

Taking equation 4 and only keeping the non-zero terms, the water balance for this simple example reduces to:

$$Local\ Inflow = Gaged\ Outflow - Gaged\ Inflow$$

Solving for the Local Inflow with the example numbers results in a value of 50 cfs. But the uncertainty in measurements must be taken into consideration. The equation for the propagation of uncertainty in this simple water balance addition is:

$$\mu_{Local\ Inflow} = \sqrt{\mu_{Outflow}^2 + \mu_{Inflow}^2}$$

Where μ is the uncertainty in each term in the equation. The uncertainty in the computed local inflow value in this example evaluates to 74 cfs. Thus, the local inflow computation results in a value of 50±74 cfs. The uncertainty in the local inflow value is greater than the value itself. While it is theoretically possible that the local inflow in this reach is less than zero, this result is essentially meaningless. Because of the level of uncertainty in the measured values, the magnitude of the local inflow that day is largely unknowable. Said another way, the local inflow that is being computed is of roughly the same magnitude as the uncertainty of the gage measurements. This makes the method of directly calculating daily values for the local inflows along the Truckee River below Farad inherently unreliable. The raw computations in this data development effort exemplified this problem.

Discussions of this issue in academic literature are available. Two particularly succinct and applicable ones will be highlighted. David Maidment (Maidment, 1993) in his seminal work, "Handbook of Hydrology" states that "It is critical in the design of catchment experiments, particularly those concerned with the water balance, that the experiment error attached to the effect being studied is not larger than the effect itself." When local inflows are computed by a water balance on a daily basis, this is exactly what occurs. Therefore, methodologies should be applied to either increase the value being examined or decrease the uncertainty in the value. If a quantity is averaged in time and/or space the uncertainty is reduced by the square-root of the number of observations that were averaged (Maidment, 1993, pp. 17.7, 20.3). The reduction in uncertainty by increasing the duration used for the calculation is shown in Figure 3 (Maidment, 1993). Spatial aggregation has a similar effect where the intermittent gages (and their uncertainty) that define the water balance are no longer part of the water balance equation, but computed inflow is larger because of the larger drainage area.

Figure 34 Plot that shows the reduction in random uncertainty compared to the one-day uncertainty if the same average value were computed over lengthening time periods. Uncertainty decreases with the duration (N) of the experiment by 1/√N. (Maidment, 1993, p. 13.11)

It might be intuitive to think that adding (or including) additional measurements (gages) along the river would help reduce the uncertainty in the calculated local inflow. In fact, additional gages along the river actually increase the level of uncertainty in the computed local inflows. This effect is explained well by Loucks & van Beek in "Water Resources Systems Planning and Management":

> *Uncertainty in model output can also result from errors in the model structure compared to the real system, and approximations made by numerical methods employed in the simulation. No matter how good our parameter value estimates, our models are not perfect and there is a residual model error. Increasing model complexity in order to more closely represent the complexity of the real system may not only add to the cost of data collection, but may also introduce even more parameters, and thus even more potential sources of error in model output. It is not an easy task to judge the appropriate level of model complexity and to estimate the resulting levels of uncertainty associated with various assumptions regarding model structure and solution methods.* (Loucks & van Beek, 2005, p. 260)

As discussed in Loucks & van Beek (Loucks & van Beek, 2005), differences between the model structure and the real system may cause uncertainty in model output and adding complexity to the model to address these presumed processes can add sources of error.

8.6.2 High Levels of Uncertainty in Computed Below-Farad Local Inflows

Based on this discussion of uncertainty and the simple example presented, it is not surprising that the local inflows computed for the sub-reaches show unreasonable behavior. Figure 35 compares the monthly inflow computed for each sub-reach to the total monthly inflow computed for the entire Farad-Derby Reach. As a reference the above-Farad natural flow is compared to one of its subbasins: Remaining Sidewater. When comparing the monthly average data for Remaining Sidewater to its subbasin an R^2 of 0.98 is observed which sets a baseline of how well a subbasin's monthly average flows would compare to the larger basin's monthly average flow.

Comparing the individual reaches downstream of Farad to the total Farad to Nixon monthly average inflows results in much less consistent relationships. None of the reaches between Farad and Nixon have a consistent relationship to the Farad to Nixon inflow with the best sub-reach having and R^2 of 0.22 and five of seven reaches having R^2 less than 0.10. It is of note that Figure 35 only includes monthly average inflows computed for each reach, thus understating the variability in the daily relationships. These figures support the theoretical conclusion from probability theory that the uncertainty in the measurements of each reach local inflow exceeds the magnitude of computed inflow.

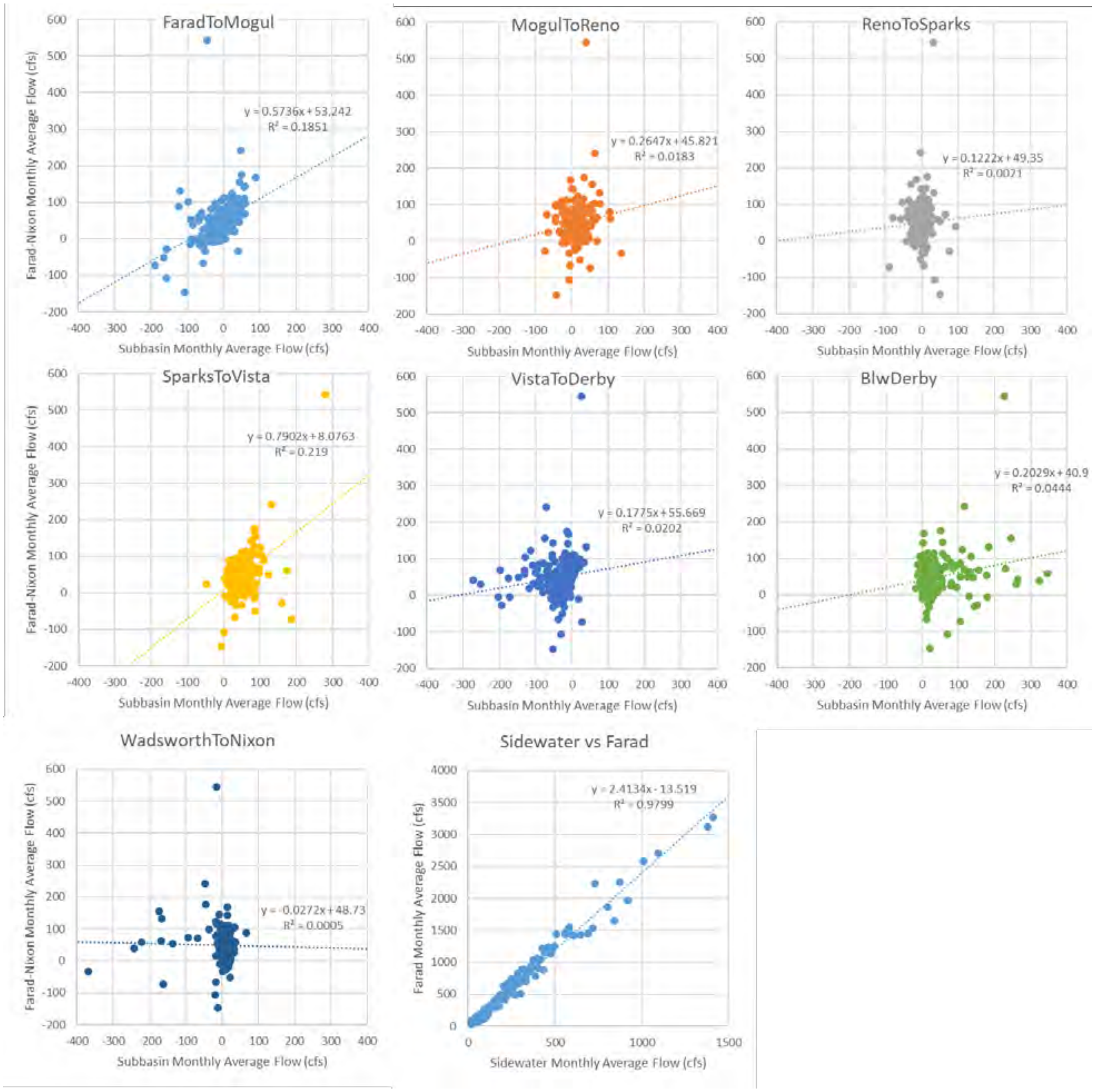


Figure 35: The raw monthly average inflows for each reach compared to monthly average Farad to Nixon inflows (Oct 2000-Dec 2016). A similar monthly comparison between the Sidewater local inflow to the inflow above Farad is included for illustrative purposes.

Figure 36 is another way to visualize the inconsistency between the computed local inflow for a given sub-reach and the total Farad to Nixon local inflow. This shows the ratios of computed local inflow in the Farad to Mogul reach to total Farad to Nixon local inflow for each month in the study period. Hydrologically speaking one would not expect the computed inflow in one sub-reach to exceed the magnitude of the inflow computed for Farad to Nixon. In Figure 36, a value of 100% means that the computed monthly volume for the sub-reach is equal to the monthly volume for Farad to Nixon (so the other sub-reaches have a net zero inflow), a value less than 0% denotes that the sub-reach has a negative monthly inflow while Farad to Nixon has a positive monthly inflow (or vice-versa). Several months have more than 50% of their ratios below zero, and many of the months have large outliers (which is caused by very small inflows for Farad to Nixon in many cases). Farad to Mogul is shown as an example, but all reaches have a similar lack of consistency.

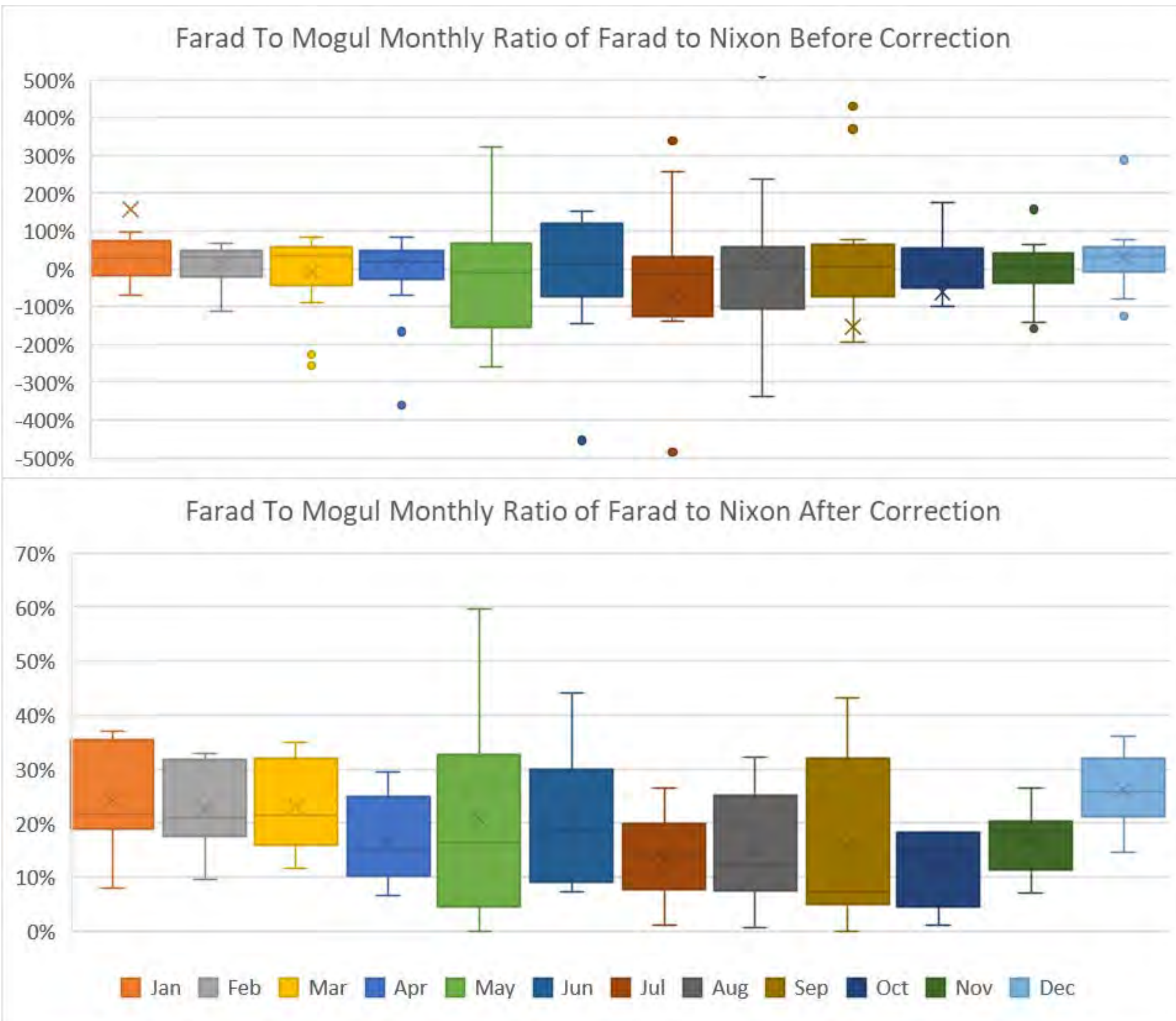


Figure 36: Box and whisker plot showing the range of monthly ratios of Farad to Mogul computed local inflow to total Farad to Nixon local inflow, before (above) and after (below) correction. Each ratio is of monthly average computed local inflow in the Farad to Mogul reach to the total Farad to Nixon local inflow for each month of the length of analysis.

As shown and discussed above, the computed sub-reach local inflow below Farad dataset shows that the computed local inflows in the eight sub-reaches are impacted more by gaging and gage error than by the mass balance components (return flow, surface flow, groundwater flows, changing land use, etc). This is evident by looking at the monthly ratios that are developed to disaggregate the total Farad to Nixon local flow (Figure 35 and Figure 36). If the local inflows were dominated by hydrology or natural process, you would expect to have a seasonal trend or a consistent pattern, which is not the case, as can be seen from Figure 35 and Figure 36. It is likely that these computed numbers are dominated by the uncertainty in the measurements.

8.6.3 Monthly Local Inflow Ratio Development Period

In Section 3.2.4.3 the process by which a set of monthly ratios for each sub-reach is determined. The monthly ratio of the sub-reach local inflow to the entire below-Farad local inflow is used to disaggregate the aggregate local inflow to the sub-reaches.

As shown in Figure 34, increasing the averaging period does decrease uncertainty, but there is a diminishing effect on reducing the uncertainty from random errors. Increasing the averaging period from 2 years to 5 years reduces the uncertainty from 3.7% to 2.3%, while increasing the period from 5 to 10 years only reduces the uncertainty from 2.3% to 1.7%. Weighing the diminishing returns of increasing the averaging period, the increasing data requirements of a longer period, and a desire to show impacts of recent change in land or other projects that may have impacted the ratio of flow occurring in each sub-reach a 5-year averaging period was selected. It is also worth noting that increasing the average duration will not reduce the uncertainty from non-random sources (Maidment, 1993)

8.6.4 Conclusion

The discussion and analysis presented in this appendix provide justification for the method that was employed to develop the local inflow data for the below-Farad reach. The method developed for this purpose and described in Section 3.2.4 recognizes the significant, inherent uncertainty present in the raw daily water balance computed local inflows and utilizes aggregation techniques to reduce uncertainty and develop a reasonable and useful set of local inflows in the lower Truckee River basin for use in the RiverWare models used in determining planning and operations in the basin. Future studies reexamining the local inflows below Farad should be undertaken as more data is available for those studies.

8.7 User Guide for Data Development Tools

Data Development in the Truckee Basin is broken into two main methodologies: Above Farad Inflow Data Development and Below Farad Inflow Data Development. As a result, development for Above Farad and Below Farad locations require a different set of tools, respectively. These tools are available, upon request, from LBAO, and this section of the report seeks to outline how to use these tools.

The tools are contained within a development package that contains the following structure:

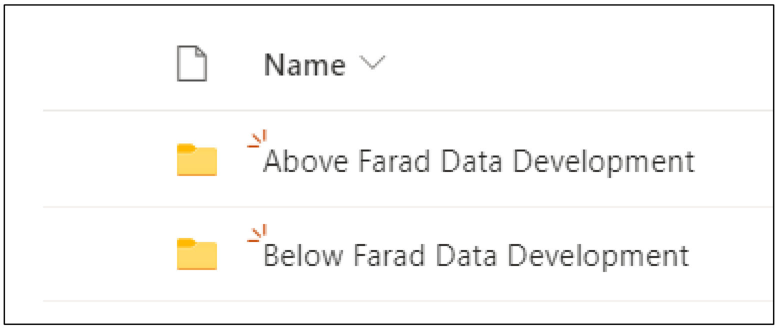


Figure 37: Data Development folder structure.

The following subsections outline how the tools available in these folders are used to develop the data. In general, the following tasks are required to Daily Hydrology for the TROA Operations and Accounting Model.

1. Develop Unprocessed Inflow Data for Above Farad inflow locations
2. Manually Review Above Farad Inflow Data Produced in Step (1)
3. Develop and Review the Below Farad Local inflows

8.7.1 Step 1: Develop Unprocessed Inflow Data for Above Farad Inflow Locations

The AboveFaradDataDevelopment.xlsx Spreadsheet allows for an easy way to use a Truckee River RiverWare model to calculate hydrologic inflow data for the Above Farad Inflow locations needed to develop Truckee River data. This section of the document will show you how to use this spreadsheet. Note, these instructions will reference the "Main Folder" of the AboveFaradDataDevelopment.xlsx Spreadsheet. The "Main Folder," also named "Above Farad Data Development," references the development folder with the following structure:

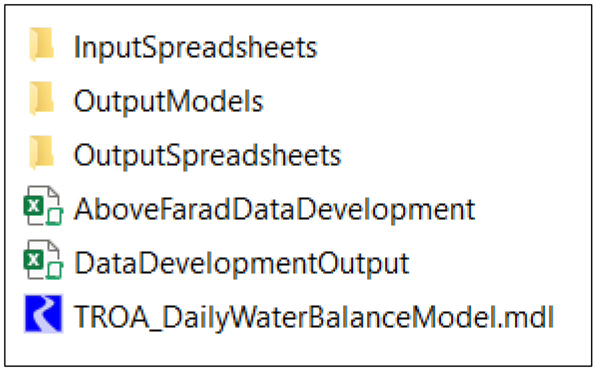


Figure 38: File Structure of the "Above Farad Data Development" folder.

The RiverWare model in this folder models the Above Farad locations in the Truckee River, and it takes as input Pool Elevations, Reservoir Outflows, and Gage flows. It will compute local inflows given these values. The following steps outline how to run this model to compute the Above Farad Local Inflows:

A. The necessary inputs need to be compiled and provided to the model. Within the "InputSpreadsheets" file of the "Main Folder", you will see an "AboveFaradInputData.xlsx" workbook. Each slot within this workbook needs to be provided with daily data. This data needs to span the timeframe of the September 30^{th} prior to the water year that data is being developed for through December 31^{st} of at least 15 months after the start date data is being developed for. Note, data must be at least 15 months long, but additional water years can be added. Be sure to save and close the workbook before proceeding to Step (B).
B. Once step (A) is complete, navigate back to the "Main Folder" of the package, and open the "AboveFaradDataDevelopment.xlsm" workbook.

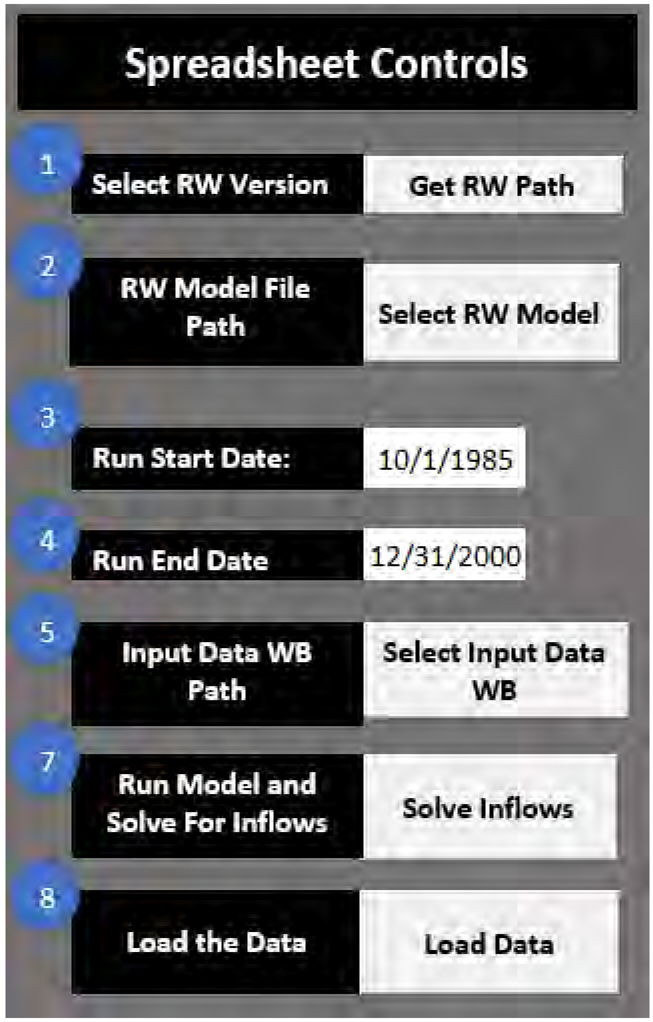


Figure 39: User Inputs for the "AboveFaradDataDevelopment.xlsm" workbook.

C. On the "ControlSheet" of this workbook, click the "Get RW Path" button. Use the file browser that appears to select the appropriate path to your RiverWare Executable. If the model has not been saved in a while, save the model in a more recent version of RiverWare prior to completing this step.
D. Next, click the "Select RW Model" button. A file browser will appear and the "TROA_DailyWaterBalanceModel.mdl" file located in the main branch of the package should be selected.
E. Next, select the start and end dates of the model run. Be sure that whatever date selection is made has corresponding input data provided for (see step (A)). NOTE – data must be provided for the initialization timestep, that is 1 day prior to the Run Start Date (September 30, 1990 for the dates in figure above).

F. Select the input data workbook, which is in the “InputSpreadsheets” subfolder of the “Main Folder”.
G. Press the “Solve Inflows” button in the workbook. This will initiate two RiverWare runs within a single terminal window. One will use raw data to calculate hydrologic inflows, and the other will use smoothed data to calculate hydrologic inflows. The runs should take less than 30 seconds to run.
H. Once the runs have finished, select the “Load Data” button. This will load RiverWare output data into the RiverWareOutput_Raw and RiverWareOutput sheets of the “AboveFaradDataDevelopment.xlsm” workbook.
I. Copy and paste these sheets into the sheets with the same names in the Data Development workbook “DataDevelopmentOutput.xlsm” and proceed to the next step.

8.7.2 Manually Review Above Farad Inflow Data Produced in Step (1)

Once the data that has been compiled has been entered into the “DataDevelopmentOutput.xlsm” workbook, a detailed review of the data is required. The blue sheets in the “DataDevelopmentOutput.xlsm” workbook contain a progression of the data as sequential steps are completed. On these sheets the darker colored columns contain computed data that will not be used - only the blue and green columns need to be reviewed. A summary of the process completed on each sheet is below:

- **RiverWareOutput_Raw:** Inflow data computed by the RiverWare model using observed data. This data has no alterations on it.
- **RiverWareOutput:** Inflow data computed after the RiverWare Pool Elevation smoothing and observed precipitation QA/QC is completed.
- **ReviewedData:** Inflow data after the VBA processing of the "RiverWareOutput" data is completed.
- **ManualData:** Final inflow data after manual adjustments are made to the "ReviewedData"

Note, conditional formatting on each sheet shows data that were altered in each step, comparing values in the current sheet to those of the previous step.

<u>The following steps describe how to utilize this workbook to review the data:</u>

A. Verify on the “WY Plot” tab that the Carson at Ft. Churchill, Hunter Creek, and Steamboat Creek plots look correct. The Carson at Ft Churchill data is input to equal the USGS approved data from the "CarsonUSGS" sheet.

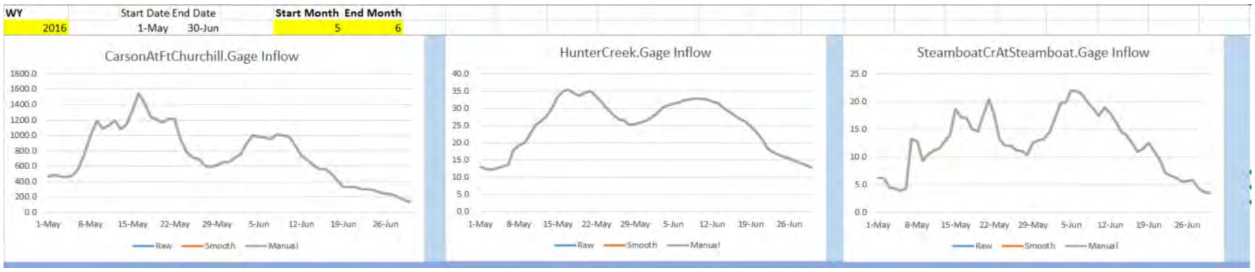
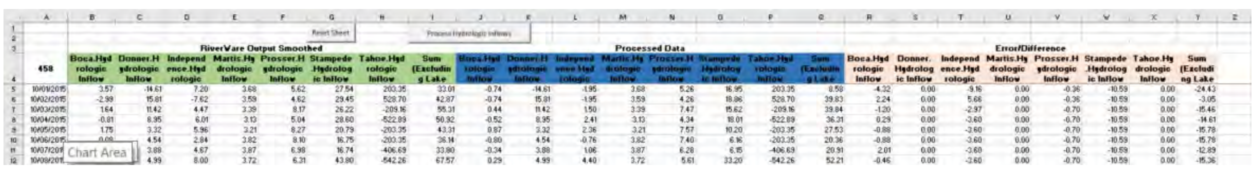


Figure 40 WY Plot Tab with Carson at Ft. Churchill, Hunter Creek, and Steamboat Creek plots

B. Go to "Processed Hydrologic Inflows" worksheet. Clicking on the **Reset Sheet** button brings in data from the “RiverWareOutput” worksheet or overwrite the existing data if they are already present. Columns B through I will have the smoothed data from the “RiverWareOutput” sheet. Initially, columns J through Q will also contain the same data. Clicking on the **Process Hydrologic Inflows** button will run the associated macro to process the hydrologic inflows and update columns J through Q. Columns R through Y will then contain the differences between the “RiverWareOutput” data and the processed data. The total sum difference between the “RiverWareOutput” data and the processed data should be zero.



458	RiverWare Output Smoothed: Boca.Hyd rologic Inflow	Donner.H ydrologic Inflow	Independ ence.Hyd rologic	Martis.Hy drologic Inflow	Prosser.H ydrologic Inflow	Stampede .Hydrolog ic Inflow	Tahoe.Hyd rologic Inflow	Sum (Excludin g Lake	Processed Data: Boca.Hyd rologic Inflow	Donner.H ydrologic Inflow	Independ ence.Hyd rologic	Martis.Hy drologic Inflow	Prosser.H ydrologic Inflow	Stampede Hydrolog ic Inflow	Tahoe.Hyd rologic Inflow	Sum (Excludin g Lake
10/01/2015	3.57	-14.61	7.20	3.68	5.62	27.54	203.35	33.01	-0.74	-14.61	-1.95	3.68	5.26	16.95	203.35	8.58
10/02/2015	-2.98	15.81	-7.62	3.59	4.62	29.45	528.70	42.87	-0.74	15.81	-1.95	3.59	4.26	18.86	528.70	39.83
10/03/2015	1.64	11.42	4.47	3.39	8.17	26.22	-209.16	55.31	0.44	11.42	1.50	3.39	7.47	15.62	-209.16	39.84
10/04/2015	-0.81	8.95	6.01	3.13	5.04	28.60	-522.89	50.92	-0.52	8.95	2.41	3.13	4.34	18.01	-522.89	36.31
10/05/2015	1.75	3.32	5.96	3.21	8.27	20.79	-203.35	43.31	0.87	3.32	2.36	3.21	7.57	10.20	-203.35	27.53
10/06/2015	[illegible]	4.54	2.84	3.82	8.10	16.75	-203.35	36.14	-0.80	4.54	-0.76	3.82	7.40	6.16	-203.35	20.36
10/07/201	[illegible]	3.88	4.67	3.87	6.98	16.74	-406.69	33.80	-0.34	3.88	1.06	3.87	6.28	6.15	-406.69	20.91
10/08/201	[illegible]	4.99	8.00	3.72	6.31	43.80	-542.26	67.57	0.29	4.99	4.40	3.72	5.61	33.20	-542.26	52.21

458	Error/Difference: Boca.Hyd rologic Inflow	Donner. Hydrolog ic Inflow	Independ ence.Hyd rologic	Martis.Hy drologic Inflow	Prosser.H ydrologic Inflow	Stampede .Hydrolog ic Inflow	Tahoe.Hy drologic Inflow	Sum (Excludi ng Lake
10/01/2015	-4.32	0.00	-9.16	0.00	-0.36	-10.59	0.00	-24.43
10/02/2015	2.24	0.00	5.66	0.00	-0.36	-10.59	0.00	-3.05
10/03/2015	-1.20	0.00	-2.97	0.00	-0.70	-10.59	0.00	-15.46
10/04/2015	0.29	0.00	-3.60	0.00	-0.70	-10.59	0.00	-14.61
10/05/2015	-0.88	0.00	-3.60	0.00	-0.70	-10.59	0.00	-15.78
10/06/2015	-0.88	0.00	-3.60	0.00	-0.70	-10.59	0.00	-15.78
10/07/201	2.01	0.00	-3.60	0.00	-0.70	-10.59	0.00	-12.89
10/08/201	-0.46	0.00	-3.60	0.00	-0.70	-10.59	0.00	-15.36

Figure 41: Processed Hydrologic Inflows with columns R through Y containing the differences

C. Go to "Processed Sidewater" worksheet. This sheet is designed on the same patterns as the previous one. Clicking on the **Reset Sheet** button will bring in data from the “RiverWareOutput” worksheet or overwrite the existing data. Columns B through E will have the smoothed data from the “RiverWareOutput” sheet. Initially, columns F through I will also contain the same data. Clicking on the **Process Sidewater** button would run the associated macro to process the sidewater inflows and update columns F through I. Columns J through M will then contain the differences between the “RiverWareOutput” data and the processed data. The total sum difference between the “RiverWareOutput” data and the processed data should be zero.

458	RiverWare Output Smoothed				Processed/Redistributed				Error/Difference			
	BlwDonner.Local Inflow	BlwTahoe.Local Inflow	SidewaterLocalInflow.Local Inflow	Total Sidewater	BlwDonner.Local Inflow	BlwTahoe.Local Inflow	SidewaterLocalInflow.Local Inflow	Total Sidewater	BlwDonner.Local Inflow	BlwTahoe.Local Inflow	SidewaterLocalInflow.Local Inflow	Total Sidewater
10/31/2015	1.70	14.00	15.20	30.90	1.70	14.00	15.20	30.90	0	0	0	0
11/01/2015	1.60	14.60	14.00	30.20	1.60	14.60	14.00	30.20	0	0	0	0
11/02/2015	1.60	14.80	18.90	35.30	1.60	14.80	18.90	35.30	0	0	0	0
11/03/2015	7.00	45.60	28.30	80.90	7.00	45.60	28.30	80.90	0	0	0	0
11/04/2015	2.90	45.60	7.60	56.10	2.90	22.74	30.46	56.10	0	-22.86375	22.86375	7.10543E-15
11/05/2015	1.40	31.20	9.80	42.40	1.40	17.26	23.74	42.40	0	-13.94375	13.94375	-7.10543E-15

Figure 42: Processed sidewater with columns J through M containing the differences

D. Go to "ReviewedData" worksheet. Clicking on the **Bring in Reviewed Data** button would bring in the processed data from "Processed Hydrologic Inflows" and "Processed Sidewater" sheets. Other data columns that were not processed such as Carson, Hunter Creek, Steamboat Cr at Steamboat, and precipitation rates would be copied from the "RiverWareOutput" sheet.

458	CarsonAtFtChurchill.Gage Inflow	HunterCreek.Gage Inflow	SteamboatCrAtSteamboat.Gage Inflow	BlwDonner.Local Inflow	BlwTahoe.Local Inflow	SidewaterLocalInflow.Local Inflow	Boca.Precipitation Rate	Donner.Precipitation Rate	Independence.Precipitation Rate	Martis.Precipitation Rate	Prosser.Precipitation Rate
10/01/2015	0.00	3.80	0.00	-1.30	4.50	24.70	0.34	1.02	0.00	0.39	0.39
10/02/2015	0.00	4.50	0.00	-0.50	7.00	34.70	0.46	0.00	0.56	0.52	0.52
10/03/2015	0.00	4.50	0.00	-0.10	11.60	23.90	0.00	0.04	0.00	0.00	0.00
10/04/2015	0.00	4.00	0.00	0.80	9.10	23.80	0.20	0.00	0.00	0.23	0.23
10/05/2015	0.00	4.50	0.00	0.90	8.60	23.80	0.00	0.00	0.00	0.00	0.00

458	Stampede.Precipitation Rate	Tahoe.Precipitation Rate	Boca.Hydrologic Inflow	Donner.Hydrologic Inflow	Independence.Hydrologic Inflow	Martis.Hydrologic Inflow	Prosser.Hydrologic Inflow	Stampede.Hydrologic Inflow	Tahoe.Hydrologic Inflow	ForecastData.Farad	Total Sidewater
10/01/2015	0.00	0.00	-0.74	-14.61	-1.95	3.68	5.26	16.95	203.35	36.48	27.9
10/02/2015	0.00	0.00	-0.74	15.81	-1.95	3.59	4.26	18.86	528.70	81.08	41.3
10/03/2015	0.00	0.00	0.44	11.42	1.50	3.39	7.47	15.62	-209.16	75.24	35.4
10/04/2015	0.00	0.00	-0.52	8.95	2.41	3.13	4.34	18.01	-522.89	70.01	33.7
10/05/2015	0.00	0.00	0.87	3.32	2.36	3.21	7.57	10.20	-208.35	60.83	33.3

Figure 43: Reviewed data

E. Use the "WY Plot" sheet to verify the data for the Reservoir Local Inflows and adjust the "ManualData" sheet as necessary. Whenever an adjustment is made it should be done in a way to ensure that volume is preserved. The sort of adjustments that are made is subjective and many of the issues can be observed by comparing inflows between sub-basins to verify if inflow spikes, troughs or odd shapes seem consistent between the various subbasins in the upper basin. Cells in Row 2, highlighted in yellow, allow a user to view specific water years and months within water years to analyze specific periods of time.

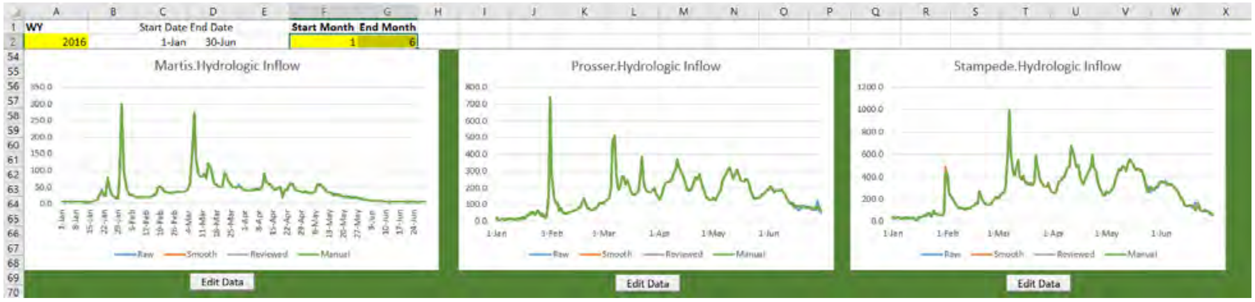


Figure 44: Cells highlighted in row two can be used to adjust the period

Edits can be made to the "Manual Data" sheet by clicking on the **Edit Data** and **Edit Local Inflows** buttons. The macro will provide a window with a list of options to apply manual edits.

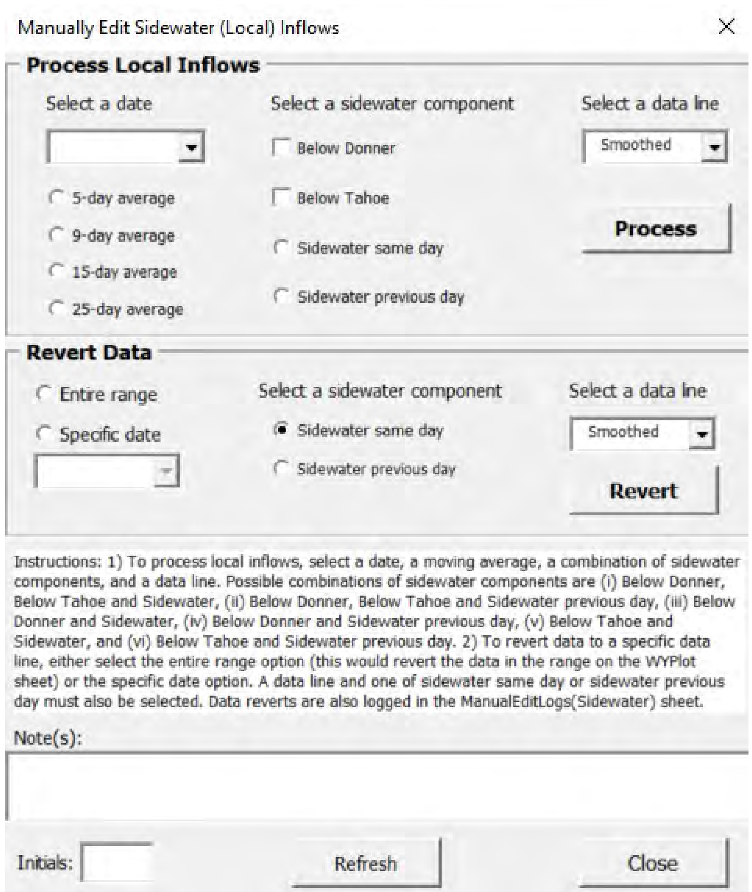


Figure 45: Macro Menu for sidewater edits

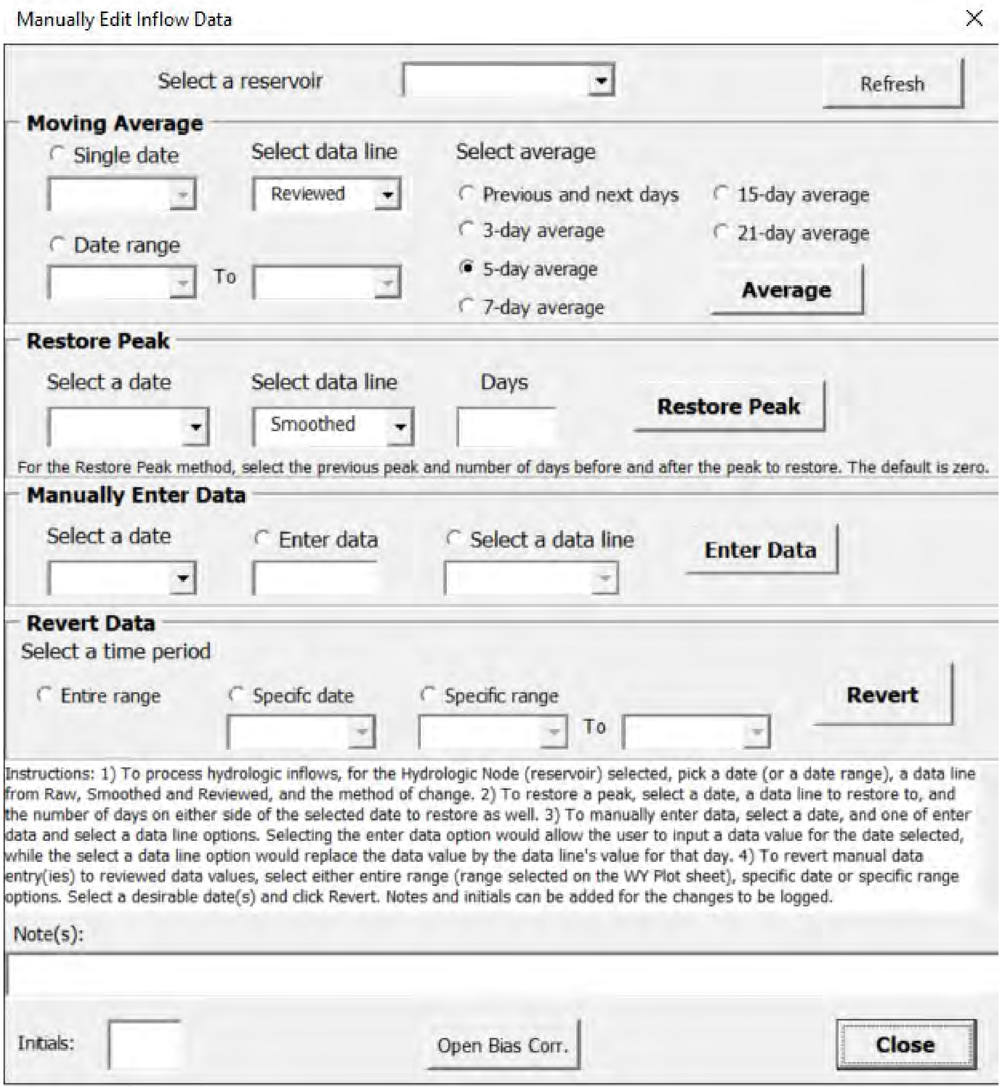


Figure 46: Manually Edit Inflow Data.

F. Manual adjustments will be recorded on the "ManualData" sheet. On this sheet, the manually edited data will be shown. Clicking on the **Reset ManualData Sheet** will bring in processed data from the "ReviewedData" sheet in columns AA to AW and BA to BW, smoothed data from the "RiverWareOutput" sheet in columns CA to CW, and raw data from the "RiverWareOutput_Raw" sheet in columns DA to DW.

This sheet is set up to have final "Manual Data" to be used in "WY Plot" sheet in columns A to Y. The data in these columns are referenced from columns AA to AW. Columns AA to AW contain data where actual manual calculations have been performed. Columns AA to AW refer to either columns BA to BW, CA to CW, or DA to DW to perform calculations. Once the calculations have been performed on columns AA to AW using BA to BW, CA to CW, and DA to DW, and the values referenced to columns A to W, columns EA to EW are added to or subtracted from the corresponding A to W columns for bias correction to conserve total volume. The columns are symmetrical meaning, for instance, column O, AO, BO, CO, DO and EO would all have Boca Hydrologic Inflow.

G. Use the "WY Plot" sheet to verify the data for reservoir and local inflows making edits to the "ManualData" sheet via user forms as necessary.
   a. Editing Local Inflows - Clicking on the **Edit Local Inflows** button below the three local inflow graphs will pop out a user form to edit local inflows. The user must select a date for which to edit data, one of 4 types of moving averages, at least one of the upper local inflows and one of the same or the previous day for the lower sidewater, and a data line (from raw, smoothed, and reviewed) to process local inflows. The user can write notes and their initials, which will be logged in the sheet "ManualEditLogs(Sidewater)", along with any changes being made, each time the user hits **Process**. Any change to local inflows will automatically preserve volume.

      The data can also be reverted to either raw, smoothed, or reviewed versions for a specific day or for the entire range selected in the “WY Plot” sheet. The revert data section of the user form is self-explanatory. Logs for reverting the data are also saved in the "ManualEditLogs(Sidewater)" sheet, along with any notes and initials of the user.

      The dropdown lists show old dates when the range in the WY Plot sheet is changed; however, the user form allows the user to manually enter a date and make changes for a date that is out of the range provided that the data are available for that day. The Refresh button resets the dates in the two dropdown lists according to the range selected in the WY Plot sheet.
   b. Clicking on the **Edit Data** button below the 7 hydrologic inflows graphs will pop out a user form to edit hydrologic inflows. There are four sections related to editing hydrologic inflows. The user must select a reservoir before moving to any section and making any changes. Unlike the local inflows, the hydrologic inflow user form does NOT conserve volume and the user must make use of the bias correction user form by clicking the **Open Bias Corr** button at the end of the hydrologic inflows user form to conserve volume. The bias correction user form will be described in a later section.

Moving Average: The user has the option to apply a moving average on a single day or multiple days by selecting the single date or date range option. Previous and next days, 3-day, 5-day, 7-day, 15-day and 21-day averages can be applied on either Raw, Smoothed or Reviewed data by selecting the desired options. Any changes made to data will be logged in the "ManualEditLogs" sheet along with any notes and initials of the user each time the user hits the Average button.

Restore Peak: The user must select a date and data line. The number of days input are the days on each side the selected date to be restored as well. For instance, for 10/5/2020, Raw data line and 1 day, manual data on 10/4/2020, 10/5/2020 and 10/6/2020 will be changed to raw data on these dates. If 0 is input in the Days field, only 10/5/2020 will be changed, for instance. If the Days field is left blank, it would be considered as 0 days. Any changes made to data will be logged in the "ManualEditLogs" sheet along with any notes and initials of the user each time the user hits the Average button.

Manually Enter Data: This section allows the user to either manually enter a data value or a data line's value for a specific day. Any changes made to data will be logged in the "ManualEditLogs" sheet along with any notes and initials of the user each time the user hits the Average button.

Revert Data: This section allows the user to revert manual data to reviewed data either for the entire range in the WY Plot sheet, a specific date or a specific date range. Any logs present in the "ManualEditLogs" for the date(s) for which the data is reverted will be deleted.

The dropdown lists show old dates when the range in the "WY Plot" sheet is changed; however, the user form allows to manually enter a date and make changes for a date that is out of the range, provided that the data are available for that day. The Refresh button resets the dates in the dropdown lists according to the range selected in the WY Plot sheet.

c. **Bias Correction:** In the "AnnualAnalysis" sheet, the difference in volumes for manual and smoothed data for different hydrologic inflows for specific years can be observed. The difference must be zero for each hydrologic inflow component indicating volume conservation. However, when the hydrologic inflows had been edited, the differences would have become non-zero. To conserve volume, the user must make use of the bias correction user form. Clicking the Open Bias Corr. button at the bottom of the hydrologic inflows' user form will open the bias correction user form. The user must select a reservoir before continuing.

i. Bias Correction: The user has the option to either apply bias correction to the entire range selected in the "WY Plot" sheet or a specific date or a specific range. The user must enter a value and select either Increase or Decrease to either add to or subtract from the selected date(s) the value entered divided by the number of days. For instance, for Boca, a value of 31 for October 2020 with Increase selected, would add 1 (31 divided by the number of days in October, 31/31 = 1) to each day's hydrologic inflow to Boca in October 2020. In the "ManualData" sheet, column EO would contain 1 from October 1 to October 30 which would be added to column O from October 1 to October 30. The changes would be logged in the "ManualEditLogs(BiasCorrection)" along with any notes and initials of the user.
ii. Undo Bias Correction: The user has the option to undo previously done bias correction for the entire range on the WY Plot, a specific date or a specific range. This would delete the values in the related columns from EA to EW (only where the undoing was done), restore columns A to W to reference columns AA to AW only without adding or subtracting columns EA to EW, and delete related logs in the "ManualEditLogs("BiasCorrection)" sheet.

H. Once the process is done, the data should be verified by a second person and then that data should be archived in a place that is usable by models.
I. This process computes the unregulated inflow data for all subbasins upstream of the Truckee River at Farad Gage and included review of the USGS Carson River at Ft Churchill data. The local inflows to the Truckee River between Farad and Pyramid Lake are computed using the " Truckee Local Inflow Calc_v12.xlsm" spreadsheet.
J. Precautions for Above Farad Data Development
   a. The macros in the "Processed Hydrologic Inflows" and "Processed Sidewater" sheets depend on the number of rows filled. Therefore, do not manually enter any values in the "Processed Hydrologic Inflows", "Processed Sidewater", "ReviewedData", and "ManualData" sheets.
   b. If you want to delete data in any of the above mentioned sheets because the newer data to be reviewed have fewer days, delete the entire rows at the end

or use the Clear All option from the Clear dropdown in Excel instead of just deleting the data entries. Excel sometimes considers the rows non-empty when only the data entries are cleared.

K. Tips for Above Farad Data Development:
   a. When doing bias correction, add to or subtract from April through July first (according to values in the "AnnualAnalysis" sheet). Then use October through March and August to September for the remaining correction. This would allow for little changes spread over the entire year instead of bigger fluctuations. If the value to be bias corrected is small, fewer months can be selected.
   b. Review data from water year to water year. For instance, if data are available from 10/1/2018 to 12/31/2020, use data from 10/1/2018 to 9/30/2020. Otherwise, when the remaining data for WY 2021 would become available and the entire WY 2021 would be reviewed, the values from 10/1/2020 to 12/31/2020 would complicate data review and might not conserve volume as expected. If still data till 12/31/2020 are used, start the next data review from 1/1/2021 instead of 10/1/2020.

L. Manual Review Tips
   a. Only manually edit the WY even though the first three months of the next water year exist.
   b. Restore real inflow events that were incorrectly altered by the macros.
   c. If there's a small inconsistent spike or a trough followed by almost the same value as the day before the spike/trough, then average the previous and next days' values to get the current day's value.
   d. In the case of noisy data, 7-day moving average (3 days before and 3 days after) should be applied. If implementing the moving average changes the total volume, the values should be multiplied by a scaling factor to conserve the total volume. The scaling factor can change between values as.
   e. Usually there are small troughs before big inflow events. In that case, the moving average would greatly increase the value of the trough significantly changing the volume. Try to reduce the increased value by multiplying it with a scaling factor or take a 3-day moving average (especially if the value after the trough is not so big) or replace that value with the average of the previous and the next day. Similarly, big inflow events can cause spikes in days before or after the inflow events. Same strategy should be applied in this case too.

f. If the processed (reviewed) data has incorrectly increased or decreased the values, i.e., changed inconsistent spikes to troughs or vice versa, use smoothed (RiverWareOutput) for moving averages within those segments.
g. If there are two inflow events nearby, use 3- or 5-day moving average as suitable.
h. If there are inconsistencies/irregularities at the start of the data and not enough data points to take a 7-day moving average, first two or three values can be averaged as suitable, replacing the original values.

Once the process is done, the data should be verified by a second person and then that data should be archived in a place that is usable by models.

8.7.3 Instructions for Reviewing the Below Farad Data

The local inflows to the Truckee River between Farad and Pyramid Lake are computed using the "Truckee Local Inflow Calc_v12.xlsm" spreadsheet found in the "Below Farad Data Development" folder. The following steps detail how to use this workbook too compute the inflows.

A. Verify that the data between 1986 and 2000 is correct in the AllData tab.
    a. Gage data – you can use the "USGSDataQuery.xlsm" workbook to get USGS Data and verify.
    b. Ditch Data as possible, may need to check in with Dave Wathen with the Water Master's Office.
B. Build the water balance
    a. Gages and inflows are likely the same
    b. Include all diversions if they were at one time on during the 1986 to 2000 period
C. Press the "Populate Data" button to build all reach sheets and compute the local inflow data.
    a. The Populate Data Macro does 3 major tasks.
        i. Set the dates in all necessary sheets matching the Start and End Date user input and clear all preexisting data.
        ii. Based on the number of local inflow reaches user input (L2), and based on the names of the reaches entered (B4 through P4 and B21 through N21) sheets will be added or deleted and renamed.

iii. Based on the outflow and inflow entries (e.g., B8 through B15 and B16 through B20) data will be pulled from "AllData" sheet and pasted in the relevant sheets.

D. Press the "Calculate" button and do a first review of smoothing the Farad to Nixon local inflow.
    a. **Calculate** - For saving file size and computation time on the spreadsheet the formulae required for calculating water balance, etc., is present only on the first row. The macro Calculate will propagate the formulae to all the rows and paste it as values. It will also update the data on the 'DataToRW' sheet. So, every time new data is introduced to the workbook the **Calculate** macro has to be run to update all Calculations. The button **Calculate** is also available on all sheets requiring data so that it can be executed from any sheet as required.

E. Manually review the data on the "QAQC" tab.

F. Ask Questions to PWRE when they come up.

8.8 RIVERWARE RULES AND VBA CODE

Screenshots of RPL rules and VBA macros that are described in the document are included below.

8.8.1 RiverWare Initialization Rules

```
FOR ( OBJECT res IN ListSubbasin ( "Reservoir" ) - { Pyramid } ) DO
  WITH ( NUMERIC threshold
         = IF ( res == Tahoe ) THEN
             0.10000000 "ft"
           ELSE
             0.20000000 "ft"
           END IF ) DO
    FOR ( DATETIME day IN RunStartDate () TO BuildAccountingEndDateDMI () ) DO
      res . "Pool Elevation" [ day ]
        = WITH LIST day9 = GetSlotVals ( res . "Pool Elevation" ,
                                         DateMax ( day - 4.00000000 "day" ,
                                                   RunStartDate () - 1.00000000 "day" ) ,
                                         DateMin ( day + 4.00000000 "day" ,
                                                   BuildAccountingEndDateDMI () ) ) DO
            IF ( MaxItem ( day9 ) - MinItem ( day9 ) < threshold AND ( LENGTH day9 ) == 9.00000000 ) THEN
              FOR ( NUMERIC val IN day9 ) AVE
                val
              END FOR
            ELSE
              WITH LIST day7 = GetSlotVals ( res . "Pool Elevation" ,
                                             DateMax ( day - 3.00000000 "day" ,
                                                       RunStartDate () - 1.00000000 "day" ) ,
                                             DateMin ( day + 3.00000000 "day" ,
                                                       BuildAccountingEndDateDMI () ) ) DO
                IF ( MaxItem ( day7 ) - MinItem ( day7 ) < threshold AND ( LENGTH day7 ) == 7.00000000 ) THEN
                  FOR ( NUMERIC val IN day7 ) AVE
                    val
                  END FOR
                ELSE
                  WITH LIST day5 = GetSlotVals ( res . "Pool Elevation" ,
                                                 DateMax ( day - 2.00000000 "day" ,
                                                           RunStartDate () - 1.00000000 "day" ) ,
                                                 DateMin ( day + 2.00000000 "day" ,
                                                           BuildAccountingEndDateDMI () ) ) DO
                    IF ( MaxItem ( day5 ) - MinItem ( day5 ) < threshold AND ( LENGTH day5 ) == 5.00000000 ) THEN
                      FOR ( NUMERIC val IN day5 ) AVE
                        val
                      END FOR
                    ELSE
                      WITH LIST day3 = GetSlotVals ( res . "Pool Elevation" ,
                                                     DateMax ( day - 1.00000000 "day" ,
                                                               RunStartDate () - 1.00000000 "day" ) ,
                                                     DateMin ( day + 1.00000000 "day" ,
                                                               BuildAccountingEndDateDMI () ) ) DO
                        IF ( MaxItem ( day3 ) - MinItem ( day3 ) < threshold AND ( LENGTH day3 ) == 3.00000000 ) THEN
                          FOR ( NUMERIC val IN day3 ) AVE
                            val
                          END FOR
                        ELSE
                          res . "Pool Elevation" [ day ]
                        END IF
                      END WITH
                    END IF
                  END WITH
                END IF
              END WITH
            END IF
          END WITH
    END FOR
  END WITH
END FOR
```

Figure 47: Smooth Observed PE" Initialization Rule used to perform moving average on input pool elevation readings.

```
FOR ( OBJECT res IN ListSubbasin ( "FR Reservoirs" ) ) DO
    WITH ( NUMERIC precipRatio
            = 0.95000000 ) DO
        FOR ( DATETIME day IN RunStartDate () TO BuildAccountingEndDateDMI () ) DO
            IF ( NaNToZero ( res . "Precipitation Rate" [ day ] ) > 0.00000000 "in/day" ) THEN
                WITH ( NUMERIC netInflow
                        = CalculateNetInflow ( res ,
                                               day ) ) DO
                    WITH ( NUMERIC area
                            = ElevationToArea ( res ,
                                                res . "Pool Elevation" [ day ] ) ) DO
                        IF ( netInflow / area + res . "Evaporation Rate Periodic" [ day ] < res . "Precipitation Rate" [ day ] ) THEN
                            res . "Precipitation Rate" [ day ]
                                = Max ( Min ( ( netInflow / area + res . "Evaporation Rate Periodic" [ day ] ) * precipRatio ,
                                              res . "Precipitation Rate" [ day ] ) ,
                                        0.00000000 "in/day" )
                        END IF
                    END WITH
                END WITH
            END IF
            IF ( IsNaN ( res . "Precipitation Rate" [ day ] ) ) THEN
                res . "Precipitation Rate" [ day ]
                    = 0.00000000 "in/day"
            END IF
        END FOR
    END WITH
END FOR
```

Figure 48: "Smooth Precip" Initialization Rule used to reduce precipitation events that exceed that day's calculated inflow to 95% of the calculated inflow

8.8.2 VBA Macros

The text of the VBA Macros referenced in the main body of the document are reproduced below.

```
Sub HydrologicInflowsSheet()   'Subroutine to bring smoothed hydrologic inflows to a new sheet to
process (review) them.

Application.Calculation = xlCalculationManual
Application.ScreenUpdating = False

Dim n As Integer    'daily data counter
Dim res_sheet As Worksheet   'variable declaration for the new Processed Hydrologic Inflows worksheet
Dim riverwareoutput As Worksheet    'variable declaration for the existing RiverWareOutput worksheet

Set res_sheet = ThisWorkbook.Worksheets("Processed Hydrologic Inflows")   'storing Processed
Hydrologic Inflows in the variable
Set riverwareoutput = ThisWorkbook.Worksheets("RiverWareOutput")    'storing RiverWareOutput in the
variable

res_sheet.Select    'clearing existing contents of cells before bringing in data.
Range("A5:Y5").Select
Range(Selection, Selection.End(xlDown)).Select
Selection.clearcontents

riverwareoutput.Select   'bringing in smoothed data (RiverWareOutput) to Processed Hydrologic Inflows
Range("A5").Select
Range(Selection, Selection.End(xlDown)).Copy
res_sheet.Range("A5").PasteSpecial xlPasteValues
riverwareoutput.Select
Range("O5:U5").Select
Range(Selection, Selection.End(xlDown)).Copy
res_sheet.Range("B5").PasteSpecial xlPasteValues    'bringing in smoothed data for reference
res_sheet.Range("J5").PasteSpecial xlPasteValues    'bringing in smoothed data that would be processed

res_sheet.Select
n = ActiveSheet.UsedRange.Rows.Count - 2    'counting the number of days for daily data
Cells(4, 1) = n   'printing the number of days for daily data

For i = 5 To n + 4   'printing the sum of hydrologic inflows excluding Lake Tahoe
  Cells(i, 9) = Cells(i, 2) + Cells(i, 3) + Cells(i, 4) + Cells(i, 5) + Cells(i, 6) + Cells(i, 7)
  Cells(i, 17) = Cells(i, 9)
Next i
Range("A5").Select
Range(Selection, Selection.End(xlDown)).NumberFormat = "mm/dd/yyyy"

Application.ScreenUpdating = True
Application.Calculation = xlCalculationAutomatic

End Sub
```

Figure 49 Hydrologic Inflow Sheet VBA Macro

```
Sub HydrologicInflows()   'Subroutine to process hydrologic inflows

Application.Calculation = xlCalculationManual
Application.ScreenUpdating = False

Dim n As Integer    'daily data counter
Dim no_of_days As Integer    'number of days used to calculate moving average
Dim no_of_daysChange As Integer 'number of days used to change previous values
Dim moving_sum As Double, moving_avg As Double, new_val As Double, sum As Double
Dim DiffBtwDays As Double    'difference in flow values between days
Dim RatioDiffToYest As Double, RatioDiffToTom As Double

Worksheets("Processed Hydrologic Inflows").Activate

n = ActiveSheet.UsedRange.Rows.Count - 2    'to count the number of days; -2 because there are 2 extra
rows with filled data
moving_sum = 0

For i = 5 To n + 4   'iterates through daily data

 For j = 10 To 16   'iterates through columns

  If i = 5 Or Cells(i - 1, j) = 0 Or Cells(i + 1, j) = 0 Then   'values of the following three variables based on
conditions
   DiffBtwDays = 0
   RatioDiffToYest = 0
   RatioDiffToTom = 0
  Else
   DiffBtwDays = Cells(i - 1, j) - Cells(i, j)
   RatioDiffToYest = DiffBtwDays / Cells(i - 1, j)
   RatioDiffToTom = (Cells(i + 1, j) - Cells(i, j)) / Cells(i + 1, j)
  End If

  If i = 5 Then    'to calculate moving average if there is only 1 day's data
   moving_avg = Cells(i, j)
  End If

  moving_sum = 0   'to zero the moving sum before new calculation

  If 5 < i And i < 35 Then    'to calculate moving average if days are fewer than 30
   For m = 5 To i
    moving_sum = moving_sum + Cells(m, j)
   Next m
   no_of_days = i - 4
   moving_avg = moving_sum / no_of_days
  End If

  If i > 34 Then   'to calculate thirty one-day moving average
```

```
    For m = i - 30 To i
      moving_sum = moving_sum + Cells(m, j)
    Next m
    no_of_days = 31
    moving_avg = moving_sum / no_of_days
  End If

  If no_of_days = 1 Then
    no_of_daysChange = no_of_days
  Else
    no_of_daysChange = no_of_days - 1
  End If


  If i > 5 Then    'for more than 1 day

    If j < 16 Then    'to remove Lake Tahoe from single day spikes and troughs checks

      If Cells(i - 1, j) > 0 And Cells(i, j) > 0 And Cells(i + 1, j) > 0 Then   'if the previous, current and next
days' values are all positive
        If (Cells(i, j) > 5 * Cells(i - 1, j) And Cells(i, j) > 5 * Cells(i + 1, j)) Or (Cells(i, j) < 0.33 * Cells(i - 1, j) And
Cells(i, j) < 0.33 * Cells(i + 1, j)) Then
          old_val = Cells(i, j)
          Cells(i, j) = moving_avg
          diff_new_old = Cells(i, j) - old_val
          If i < 35 Then
            For m = 5 To i - 1
              Cells(m, j) = Cells(m, j) - diff_new_old / no_of_daysChange
            Next m
          End If
          If i > 34 Then
            For m = i - 30 To i - 1
              Cells(m, j) = Cells(m, j) - diff_new_old / no_of_daysChange
            Next m
          End If
        End If
      End If

      If Cells(i - 1, j) < 0 And Cells(i, j) < 0 And Cells(i + 1, j) < 0 Then   'if the previous, current and next
days' values are all negative
        If (Cells(i, j) < 5 * Cells(i - 1, j) And Cells(i, j) < 5 * Cells(i + 1, j)) Or (Cells(i, j) > 0.33 * Cells(i - 1, j) And
Cells(i, j) > 0.33 * Cells(i + 1, j)) Then
          old_val = Cells(i, j)
          Cells(i, j) = moving_avg
          diff_new_old = Cells(i, j) - old_val
          If i < 35 Then
            For m = 5 To i - 1
              Cells(m, j) = Cells(m, j) - diff_new_old / no_of_daysChange
```

```
          Next m
        End If
        If i > 34 Then
          For m = i - 30 To i - 1
            Cells(m, j) = Cells(m, j) - diff_new_old / no_of_daysChange
          Next m
        End If
      End If
    End If

    If (Cells(i - 1, j) < 0 And Cells(i, j) > 0 And Cells(i + 1, j) > 0) Or _
    (Cells(i - 1, j) < 0 And Cells(i, j) > 0 And Cells(i + 1, j) < 0) Or _
    (Cells(i - 1, j) > 0 And Cells(i, j) > 0 And Cells(i + 1, j) < 0) Then   'if the previous, current and next
days' values are positive and/or negative in different combinations
      If Abs(RatioDiffToYest) > 4 And Abs(RatioDiffToTom) > 4 Then
        old_val = Cells(i, j)
        Cells(i, j) = moving_avg
        diff_new_old = Cells(i, j) - old_val
        If i < 35 Then
          For m = 5 To i - 1
            Cells(m, j) = Cells(m, j) - diff_new_old / no_of_daysChange
          Next m
        End If
        If i > 34 Then
          For m = i - 30 To i - 1
            Cells(m, j) = Cells(m, j) - diff_new_old / no_of_daysChange
          Next m
        End If
      End If
    End If

    If (Cells(i - 1, j) < 0 And Cells(i, j) < 0 And Cells(i + 1, j) > 0) Or _
    (Cells(i - 1, j) > 0 And Cells(i, j) < 0 And Cells(i + 1, j) > 0) Or _
    (Cells(i - 1, j) > 0 And Cells(i, j) < 0 And Cells(i + 1, j) < 0) Then   'if the previous, current and next
days' values are positive and/or negative in different combinations
      If Abs(RatioDiffToYest) > 0.33 And Abs(RatioDiffToTom) > 0.33 Then
        old_val = Cells(i, j)
        Cells(i, j) = moving_avg
        diff_new_old = Cells(i, j) - old_val
        If i < 35 Then
          For m = 5 To i - 1
            Cells(m, j) = Cells(m, j) - diff_new_old / no_of_daysChange
          Next m
        End If
        If i > 34 Then
          For m = i - 30 To i - 1
            Cells(m, j) = Cells(m, j) - diff_new_old / no_of_daysChange
          Next m
```

```
        End If
      End If
    End If

  End If

  If Abs((moving_avg - Cells(i, j)) / moving_avg) > 5 And Abs((moving_avg - Cells(i + 1, j)) /
moving_avg) > 5 _
  And Abs((moving_avg - Cells(i, j)) / moving_avg) < 25 And Abs((moving_avg - Cells(i + 1, j)) /
moving_avg) < 25 Then    'if the current and next days' values are greater than 5 times and less than 25
times than the moving average
    new_val = (Cells(i, j) + Cells(i + 1, j)) / 2
    Cells(i, j) = new_val
    Cells(i + 1, j) = new_val
  End If

 End If
 Next j
Next i

For i = 5 To n + 4   'printing the new sum of hydrologic inflows (excluding Lake Tahoe) and differences
between smoothed and processed (reviewed) inflows
 Cells(i, 17) = Cells(i, 10) + Cells(i, 11) + Cells(i, 12) + Cells(i, 13) + Cells(i, 14) + Cells(i, 15)
 Cells(i, 18) = Cells(i, 10) - Cells(i, 2)
 Cells(i, 19) = Cells(i, 11) - Cells(i, 3)
 Cells(i, 20) = Cells(i, 12) - Cells(i, 4)
 Cells(i, 21) = Cells(i, 13) - Cells(i, 5)
 Cells(i, 22) = Cells(i, 14) - Cells(i, 6)
 Cells(i, 23) = Cells(i, 15) - Cells(i, 7)
 Cells(i, 24) = Cells(i, 16) - Cells(i, 8)
 Cells(i, 25) = Cells(i, 17) - Cells(i, 9)
Next i

Application.ScreenUpdating = True
Application.Calculation = xlCalculationAutomatic
End Sub
```

Figure 50 Hydrologic Inflows VBA Code

```
Sub SidewaterSheet()    'Subroutine to bring smoothed sidewater inflows to a new sheet to process
(review) them

Application.Calculation = xlCalculationManual
Application.ScreenUpdating = False

Dim n As Integer    'daily data counter
Dim red_sheet As Worksheet   'variable declaration for the new Processed Sidewater worksheet
Dim riverwareoutput As Worksheet    'variable declaration for existing RiverWareOutput worksheet

Set red_sheet = ThisWorkbook.Worksheets("Processed Sidewater")   'storing Processed Sidewater in the
variable
Set riverwareoutput = ThisWorkbook.Worksheets("RiverWareOutput")    'storing RiverWareOutput in the
variable

red_sheet.Select    'clearing existing contents of cells before bringing in data
Range("A5:M5").Select
Range(Selection, Selection.End(xlDown)).Select
Selection.clearcontents

riverwareoutput.Select   'bringing in smoothed data (RiverWareOutput) to Processed Sidewater
Range("A5").Select
Range(Selection, Selection.End(xlDown)).Copy
red_sheet.Range("A5").PasteSpecial xlPasteValues
riverwareoutput.Select
Range("E5:G5").Select
Range(Selection, Selection.End(xlDown)).Copy
red_sheet.Range("B5").PasteSpecial xlPasteValues
red_sheet.Range("F5").PasteSpecial xlPasteValues
red_sheet.Select
n = ActiveSheet.UsedRange.Rows.Count - 2    'counting the number of days for daily data
Cells(4, 1) = n   'printing the number of days for daily data
For i = 5 To n + 4   'summing the daily sidewater inflows
  Cells(i, 5) = Cells(i, 2) + Cells(i, 3) + Cells(i, 4)
  Cells(i, 9) = Cells(i, 5)
Next i

Range("A5").Select
Range(Selection, Selection.End(xlDown)).NumberFormat = "mm/dd/yyyy"
Range("A5:M5").Select
Range(Selection, Selection.End(xlDown)).Interior.ColorIndex = 0
```

```
Application.ScreenUpdating = True
Application.Calculation = xlCalculationAutomatic
End Sub
```

Figure 51 SidewaterSheet VBA Macro

Sub SidewaterInflows() – macro to edit the sidewater inflows for errors specified within the macro.

```
Application.Calculation = xlCalculationManual
Application.ScreenUpdating = False

Dim n As Integer    'daily data counter
Dim C1 As Integer    'first column (Below Donner) of smoothed data
Dim C2 As Integer    'second column (Below Tahoe) of smoothed data
Dim C3 As Integer    'third column (Sidewater).
Dim t1 As Integer    'first column of processed (reviewed) data
Dim t2 As Integer    'second column of processed (reviewed) data
Dim t3 As Integer    'third column of processed (reviewed) data
Dim start As Integer  'first row to be processed
Dim finish As Integer  'last row to be processed
Dim av1 As Double    'moving average for C1
Dim av2 As Double    'moving average for C2
Dim av3 As Double    'moving average C3
Dim pav3 As Double   'moving average corrected for time delay C3
Dim sumDiff As Double  'difference between processed and smoothed sums
Dim diff1 As Double   'difference between daily measurement and moving average for Below Donner
Dim diff2 As Double   'difference between daily measurement and moving average for Below Tahoe
Dim diff3 As Double   'difference between daily measurement and moving average for Sidewater
Dim pdiff3 As Double  'difference between time delay moving average and daily measurement for
Sidewater
Dim numav As Integer  'number of neighbors on each side to be averaged
Dim thresh As Double  'threshold for difference from moving average to be corrected

C1 = 2
C2 = 3
C3 = 4
t1 = 6
t2 = 7
t3 = 8

Sheets("Processed Sidewater").Select

n = ActiveSheet.UsedRange.Rows.Count - 2    'counting the number of days for daily data
start = 35
finish = n + 4

For x = 1 To 5   'This loops through five "settings" of sensitivity. It first targets the most abrupt errors, then
moves to the more gradual errors.
  numav = 5 * x
  thresh = 160 / (2 ^ x)   'between 80 and 5 cfs
```

```
 For i = start To finish   'loops through entire set of rows and makes corrections

   av1 = 0
   av2 = 0
   av3 = 0
   pav3 = 0

   For m = 1 To numav
     av1 = av1 + Cells(i + m, C1) + Cells(i - m, C1)
     av2 = av2 + Cells(i + m, C2) + Cells(i - m, C2)
     av3 = av3 + Cells(i + m, C3) + Cells(i - m, C3)
     pav3 = pav3 + Cells(i - 1 + m, C3) + Cells(i - 1 - m, C3)
   Next m

   av1 = av1 / (2 * numav)
   av2 = av2 / (2 * numav)
   av3 = av3 / (2 * numav)
   pav3 = pav3 / (2 * numav)

   diff1 = Cells(i, t1) - av1
   diff2 = Cells(i, t2) - av2
   diff3 = Cells(i, t3) - av3
   pdiff3 = Cells(i - 1, t3) - av3

   If Abs(diff1) > thresh And Abs(diff2) > thresh Then 'check to see if both upper sidewaters are mirroring

     If (Abs(diff3) > thresh And diff1 * diff3 < 0 And diff2 * diff3 < 0) Then  'if the same day of the
downstream sidewater is mirroring
       Cells(i, t1) = Cells(i, t1) + (diff3 / Abs(diff3)) * (Abs(diff1 * diff3 / (diff2 + diff1)) + Abs(diff1)) / 2    'New
values are computed by adding the corresponding percentage of total divergence to each sidewater'
       Cells(i, t2) = Cells(i, t2) + (diff3 / Abs(diff3)) * (Abs(diff2 * diff3 / (diff2 + diff1)) + Abs(diff2)) / 2
       Cells(i, t3) = Cells(i, t3) + (diff1 / Abs(diff1)) * ((Abs(diff1 * diff3 / (diff2 + diff1)) + Abs(diff1)) / 2 +
(Abs(diff2 * diff3 / (diff2 + diff1)) + Abs(diff2)) / 2)
       Cells(i, 12).Interior.Color = RGB(0, 0, 255)

     ElseIf (Abs(pdiff3) > thresh And diff1 * pdiff3 < 0 And diff2 * pdiff3 < 0) Then  'if the previous day is
mirroring
       Cells(i, t1) = Cells(i, t1) + (pdiff3 / Abs(pdiff3)) * (Abs(diff1 * pdiff3 / (diff2 + diff1)) + Abs(diff1)) / 2
       Cells(i, t2) = Cells(i, t2) + (pdiff3 / Abs(pdiff3)) * (Abs(diff2 * pdiff3 / (diff2 + diff1)) + Abs(diff2)) / 2
       Cells(i - 1, t3) = Cells(i - 1, t3) + (diff1 / Abs(diff1)) * ((Abs(diff1 * pdiff3 / (diff2 + diff1)) + Abs(diff1)) /
2 + (Abs(diff2 * pdiff3 / (diff2 + diff1)) + Abs(diff2)) / 2)
       Cells(i - 1, 12).Interior.Color = RGB(0, 0, 255)
```

```
    End If

   ElseIf (Abs(diff1) > thresh And ((Abs(diff3) > thresh And diff1 * diff3 < 0) Or (Abs(pdiff3) > thresh And
diff1 * pdiff3 < 0))) Then  'if only the first of the upper sidewaters is mirroring

    If (Abs(diff3) > thresh And diff1 * diff3 < 0) Then   'if the same day is mirroring
     Cells(i, t1) = Cells(i, t1) + (diff3 / Abs(diff3)) * (Abs(diff1) + Abs(diff3)) / 2
     Cells(i, t3) = Cells(i, t3) + (diff1 / Abs(diff1)) * (Abs(diff1) + Abs(diff3)) / 2
     Cells(i, 12).Interior.Color = RGB(0, 255, 0)

    ElseIf (Abs(pdiff3) > thresh And diff1 * pdiff3 < 0) Then    'if the previous day is mirroring
     Cells(i, t1) = Cells(i, t1) + (pdiff3 / Abs(pdiff3)) * (Abs(diff1) + Abs(pdiff3)) / 2
     Cells(i - 1, t3) = Cells(i - 1, t3) + (diff1 / Abs(diff1)) * (Abs(diff1) + Abs(pdiff3)) / 2
     Cells(i - 1, 12).Interior.Color = RGB(0, 255, 0)

    End If

   ElseIf (Abs(diff2) > thresh And ((Abs(diff3) > thresh And diff2 * diff3 < 0) Or (Abs(pdiff3) > thresh And
diff2 * pdiff3 < 0))) Then  'if only the second upper sidewater is mirroring

    If (Abs(diff3) > thresh And diff2 * diff3 < 0) Then   'if the same day is mirroring
     Cells(i, t2) = Cells(i, t2) + (diff3 / Abs(diff3)) * (Abs(diff2) + Abs(diff3)) / 2
     Cells(i, t3) = Cells(i, t3) + (diff2 / Abs(diff2)) * (Abs(diff2) + Abs(diff3)) / 2
     Cells(i, 12).Interior.Color = RGB(255, 0, 0)

    ElseIf (Abs(pdiff3) > thresh And diff2 * pdiff3 < 0) Then    'if the previous day is mirroring
     Cells(i, t2) = Cells(i, t2) + (pdiff3 / Abs(pdiff3)) * (Abs(diff2) + Abs(pdiff3)) / 2
     Cells(i - 1, t3) = Cells(i - 1, t3) + (diff2 / Abs(diff2)) * (Abs(diff2) + Abs(pdiff3)) / 2
     Cells(i - 1, 12).Interior.Color = RGB(255, 0, 0)

    End If

   End If

  Next i

Next x


For i = 5 To n + 4   'printing the new sum of sidewater inflows and differences between smoothed and
processed (reviewed) sidewater inflows
  Cells(i, 9) = Cells(i, 6) + Cells(i, 7) + Cells(i, 8)
  Cells(i, 10) = Cells(i, 6) - Cells(i, 2)
  Cells(i, 11) = Cells(i, 7) - Cells(i, 3)
```

```
  Cells(i, 12) = Cells(i, 8) - Cells(i, 4)
  Cells(i, 13) = Cells(i, 9) - Cells(i, 5)
Next i

Application.ScreenUpdating = True
Application.Calculation = xlCalculationAutomatic

End Sub
```

Figure 52 SidewaterInflows VBA Macro

```
Sub ReviewedData()   'subroutine to bring processed data from Processed Hydrologic Inflows and
Processed Sidewater worksheets to the ReviewedData worksheet

Application.Calculation = xlCalculationManual
Application.ScreenUpdating = False

Dim res_sheet As Worksheet
Dim red_sheet As Worksheet
Dim rev_sheet As Worksheet
Dim man_sheet As Worksheet
Dim riverwareoutput As Worksheet

Set res_sheet = ThisWorkbook.Worksheets("Processed Hydrologic Inflows")
Set red_sheet = ThisWorkbook.Worksheets("Processed Sidewater")
Set rev_sheet = ThisWorkbook.Worksheets("ReviewedData")
Set man_sheet = ThisWorkbook.Worksheets("ManualData")
Set riverwareoutput = ThisWorkbook.Worksheets("RiverWareOutput")

rev_sheet.Select
Range("A5:W5").Select
Range(Selection, Selection.End(xlDown)).Select
Selection.clearcontents

res_sheet.Range("A:A").Copy Destination:=rev_sheet.Range("A1")
res_sheet.Select
Range("J5:P5").Select
Range(Selection, Selection.End(xlDown)).Copy
rev_sheet.Range("O5").PasteSpecial xlPasteValues

red_sheet.Select
Range("F5:H5").Select
Range(Selection, Selection.End(xlDown)).Copy
rev_sheet.Range("E5").PasteSpecial xlPasteValues

red_sheet.Select
Range("I5").Select
Range(Selection, Selection.End(xlDown)).Copy
rev_sheet.Range("W5").PasteSpecial xlPasteValues

riverwareoutput.Select
Range("B5:D5").Select
Range(Selection, Selection.End(xlDown)).Copy
rev_sheet.Range("B5").PasteSpecial xlPasteValues
```

```
riverwareoutput.Select
Range("H5:N5").Select
Range(Selection, Selection.End(xlDown)).Copy
rev_sheet.Range("H5").PasteSpecial xlPasteValues

rev_sheet.Select
n = Cells(4, 1)
For i = 5 To n + 4
  Cells(i, 22) = Cells(i, 5) + Cells(i, 6) + Cells(i, 7) + Cells(i, 15) + Cells(i, 16) + Cells(i, 17) + Cells(i, 18) +
Cells(i, 19) + Cells(i, 20)
Next i
Range("A5").Select
Range(Selection, Selection.End(xlDown)).NumberFormat = "mm/dd/yyyy"

Application.ScreenUpdating = True
Application.Calculation = xlCalculationAutomatic

End Sub
```

Figure 53 ReviewedData VBA Macro

```
Sub ManualData()    'subroutine to bring processed (reviewed) data to the ManualData worksheet to
manually review the data

Application.Calculation = xlCalculationManual
Application.ScreenUpdating = False

Dim raw_sheet As Worksheet
Dim rev_sheet As Worksheet
Dim man_sheet As Worksheet
Dim riverwareoutput As Worksheet

Set raw_sheet = ThisWorkbook.Worksheets("RiverWareOutput_Raw")
Set rev_sheet = ThisWorkbook.Worksheets("ReviewedData")
Set man_sheet = ThisWorkbook.Worksheets("ManualData")
Set riverwareoutput = ThisWorkbook.Worksheets("RiverWareOutput")

man_sheet.Select
Range("AA5:EW5").Select
Range(Selection, Selection.End(xlDown)).Select
Selection.clearcontents

rev_sheet.Select    'to bring reviewed data into manual datasheet for reference
Range("A5:W5").Select
Range(Selection, Selection.End(xlDown)).Copy
man_sheet.Range("BA5").PasteSpecial xlPasteValues

rev_sheet.Select    'to bring reviewed data into manual datasheet to perform calculations on
Range("A5:U5").Select
Range(Selection, Selection.End(xlDown)).Copy
man_sheet.Range("AA5").PasteSpecial xlPasteValues

riverwareoutput.Select    'to bring smoothed data into manual datasheet to perform calculations on if
needed
Range("A5:W5").Select
Range(Selection, Selection.End(xlDown)).Copy
man_sheet.Range("CA5").PasteSpecial xlPasteValues

raw_sheet.Select    'to bring raw data into manual datasheet to perform calculations on if needed
Range("A5:W5").Select
Range(Selection, Selection.End(xlDown)).Copy
man_sheet.Range("DA5").PasteSpecial xlPasteValues

raw_sheet.Select    'to bring dates into manual datasheet to perform bias correction
Range("A5").Select
```

```
Range(Selection, Selection.End(xlDown)).Copy
man_sheet.Range("EA5").PasteSpecial xlPasteValues

ThisWorkbook.Worksheets("ManualEditLogs").Select
Range("A2:G2").Select
Range(Selection, Selection.End(xlDown)).Select
Selection.Clear

ThisWorkbook.Worksheets("ManualEditLogs(Sidewater)").Select
Range("A2:G2").Select
Range(Selection, Selection.End(xlDown)).Select
Selection.Clear

ThisWorkbook.Worksheets("ManualEditLogs(BiasCorrection)").Select
Range("A2:G2").Select
Range(Selection, Selection.End(xlDown)).Select
Selection.Clear

man_sheet.Activate
Range("A5").Select
Range(Selection, Selection.End(xlDown)).NumberFormat = "mm/dd/yyyy"
Range("AA5").Select
Range(Selection, Selection.End(xlDown)).NumberFormat = "mm/dd/yyyy"
Range("BA5").Select
Range(Selection, Selection.End(xlDown)).NumberFormat = "mm/dd/yyyy"
Range("CA5").Select
Range(Selection, Selection.End(xlDown)).NumberFormat = "mm/dd/yyyy"
Range("DA5").Select
Range(Selection, Selection.End(xlDown)).NumberFormat = "mm/dd/yyyy"

Application.ScreenUpdating = True
Application.Calculation = xlCalculationAutomatic

End Sub
```

Figure 54 ManualData VBA Macro

```
Sub removeSpikesBlwFarad()
 Dim col As Integer, row As Integer, j As Integer, m As Integer
 Dim NumDys As Integer, l As Integer
 Dim OrigVal As Double, PrevAvg As Double, DiffBtwDays As Double, RatioDiffToYest As Double
 Dim RatioDiffToTom As Double, RatioDiffToAvg As Double, newval As Double
 Dim ChngVal As Double, t As Double

 Application.ScreenUpdating = False
 Application.Calculation = xlCalculationManual
 col = 3
 Sheets("QAQC").Select

 Range("D4:D100000").Select
 Selection.ClearContents

 For col = 3 To 3
    For row = 4 To 5573 'ActiveSheet.UsedRange.Rows.Count
     If row = 1692 Then
     l = 0
     End If
     'Cells(row, col).Select
     If Cells(row, col + 1) = "" Then
      OrigVal = Cells(row, col)
     Else
      OrigVal = Cells(row, col + 1)
     End If
      'To Identify the double spike, where a large postive and negative value lead or follow the previous
day of negative or positive of the opposite sign
      If row > 34 Then 'Take the Avereage of the previous period. If the date is such that five days (days 5
to 9) are not available, take a different average
       t = 0    ' 5 days is arbitrary and could be turned into a function based on another factor.
       For j = row - 30 To row - 1
        t = t + Cells(j, col)
       Next j
       PrevAvg = t / 30 ' This would need to be adjusted if it is not five days

      ElseIf row > 4 Then
       t = 0
       For m = 4 To row - 1
        t = t + Cells(m, col)
       Next m
       PrevAvg = t / (row - 2)
      ElseIf row = 4 Then
       PrevAvg = OrigVal
      End If
```

```
        If row = 4 Or Cells(row - 1, col) = 0 Or Cells(row + 1, col) = 0 Then
         DiffBtwDays = 0
         RatioDiffToYest = 0
         RatioDiffToTom = 0
         RatioDiffToAvg = 0
        Else
         DiffBtwDays = Cells(row - 1, col) - OrigVal
         RatioDiffToYest = DiffBtwDays / Cells(row - 1, col)
         RatioDiffToTom = (Cells(row + 1, col) - OrigVal) / Cells(row + 1, col)
         RatioDiffToAvg = OrigVal / PrevAvg
        End If

        'Check to see if the value is abnormal
        If (Abs(OrigVal) > Abs(PrevAvg) * 10 And Abs(OrigVal) > 10) And Abs(RatioDiffToYest) > 0.667 Or
RatioDiffToAvg < 0.25 And Abs(RatioDiffToYest) > 0.667 And Abs(RatioDiffToTom) > 0.667 And row > 25
And Abs(OrigVal) > 18 Then '10 is an arbitrary number and could be formed into a function
         'Check to see if there is a double spike, if there is, average the values. Need to check if the values
are opposite signs and the values are much
         'greater than the average of the previous values.
         If (Cells(row + 1, col) + OrigVal) / 2 < PrevAvg * 1.7 _
           Or Cells(row + 1, col) < 0 And OrigVal > 0 And Abs(Cells(row + 1, col)) > PrevAvg * 10 _
           Or Cells(row + 1, col) > 0 And OrigVal < 0 And Abs(Cells(row + 1, col)) > PrevAvg * 10 Then
          newval = (Cells(row + 1, col) + OrigVal) / 2
          Cells(row, col + 1) = newval
          Cells(row + 1, col + 1) = newval
         End If
        End If
    Next row
  Next
  Application.Calculation = xlCalculationAutomatic

End Sub
```

Figure 55 "removeSpikesBlwFarad" macro to adjust spikes and troughs in computed local inflow.