SAN JUAN BASIN HYDROLOGY MODEL DOCUMENTATION

Prepared for the

San Juan Recovery Implementation Program

November 16, 2020

San Juan River Basin Recovery Implementation Program
U.S. Fish and Wildlife Service

U.S. Bureau of Reclamation
Western Colorado Area Office
Durango, CO

Precision Water Resources Engineering
Loveland, CO

Table of Contents

List of Tables

LIST OF FIGURES

List of Appendices

ABBREVIATIONS, ACRONYMS, AND KEY TERMS

AF/af	acre-feet (common unit of water volume)
AFY/afy	acre-feet per year
ALP	Animas-La Plata Project
baseline	Confusing term that means different things through various SJBHM and SJRIP components. Term should not be used alone, but always with more descriptive qualifiers (e.g., "SJBHM Baseline Demands", "San Juan StateMod Baseline", see Section 2.1)
CDSS	Colorado's Decision Support System
CDWR	Colorado Department of Water Resources
cfs	cubic feet per second (common unit of water flow)
Corps	U.S. Army Corps of Engineers
CWCB	Colorado Water Conservation Board
EA	Environmental Assessment
EIS	Environmental Impact Statement
ESA	Endangered Species Act
ET	evapotranspiration
Flow Recommendations	Flow criteria and hydrographs recommended in 1999 by the SJRIP Biology Committee to aid in recovery of endangered fish species
Gen 4 (and other numbers)	Refers to the fourth, and current, generation of the SJBHM. Gen 1, 2, & 3 refer to previous generations.
GIS	geographic information system
M&I	municipal and industrial
NGWSP	Navajo-Gallup Water Supply Project
NIIP	Navajo Indian Irrigation Project
NMISC	New Mexico Interstate Stream Commission
NMOSE	New Mexico Office of the State Engineer
NOAA	U.S. National Oceanographic and Atmospheric Administration
Reclamation (or USBR)	U.S. Bureau of Reclamation
RiverWare	Water resource modeling platform (see Sec. 1.2.3)
San Juan StateMod model	CDSS's StateMod model of the San Juan basin and SJBHM model component for most Colorado areas (see Sections 1.2.2, 2, & 3)
scenario	Specific configuration of a model (that can have multiple configs)
SJBHM	San Juan Basin Hydrology Model
SJC	San Juan-Chama Project
SJRIP	San Juan River Basin Recovery Implementation Program
SJRIP RiverWare model	Primary model component of the SJBHM and the mainstem of the San Juan River and NM areas (see Sections 1.2.2, 2, & 5)
SJRIP RiverWare Historical model	Version of the SJRIP RiverWare model configured to represent historical San Juan basin conditions (see Sections 2 & 4)
StateMod	Water resource modeling platform used by CDSS (see Sec. 1.2.3)
Tribal Reserved Water Rights	Refers to various water rights that have been legally reserved for tribal uses, but to this date have not been fully developed/utilized
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

1 BACKGROUND AND PURPOSE

1.1 BACKGROUND

The San Juan River basin, shown below in Figure 1-1, drains an area of almost 25,000 square miles. Of the drainage area, about 39 percent is in New Mexico, 23 percent in Colorado, 20 percent in Arizona, and 17 percent in Utah. By average flow, the San Juan River is the third largest tributary to the Colorado River. From its source on the Continental Divide in southern Colorado, it flows over 350 river miles in a general westerly direction to its confluence with Lake Powell in southern Utah.

Basin elevations vary from over 14,000 feet on the crests of mountain peaks in the San Juan range down to about 3,700 feet above sea level at the confluence with Lake Powell. Precipitation varies from more than 60 inches annually in small areas along the high peaks, to less than 10 inches in extensive parts of the basin, to less than one-tenth inch in others.

The San Juan River Basin Recovery Implementation Program (SJRIP) was established in 1992 with the goals of recovering the native fish community of the San Juan River, specifically the endangered Colorado Pikeminnow and Razorback Sucker, while allowing continued water development and management activities within the basin. To support the recovery goal, the “Flow Recommendations for the San Juan River” were prepared by the SJRIP Biology Committee and published in 1999 (Holden, 1999). Determined from data gathered and analyzed during a 7-year research period (1991 to 1997), the flow recommendations presented flow criteria and hydrographs specifically designed to aid in the recovery of the endangered fish species.

The remainder of Section 1 provides an overview of the San Juan Basin Hydrology Model (SJBHM) including its purposes and uses in supporting the SJRIP, summaries of the current model(s) and components, and a brief history of the SJBHM modeling efforts.

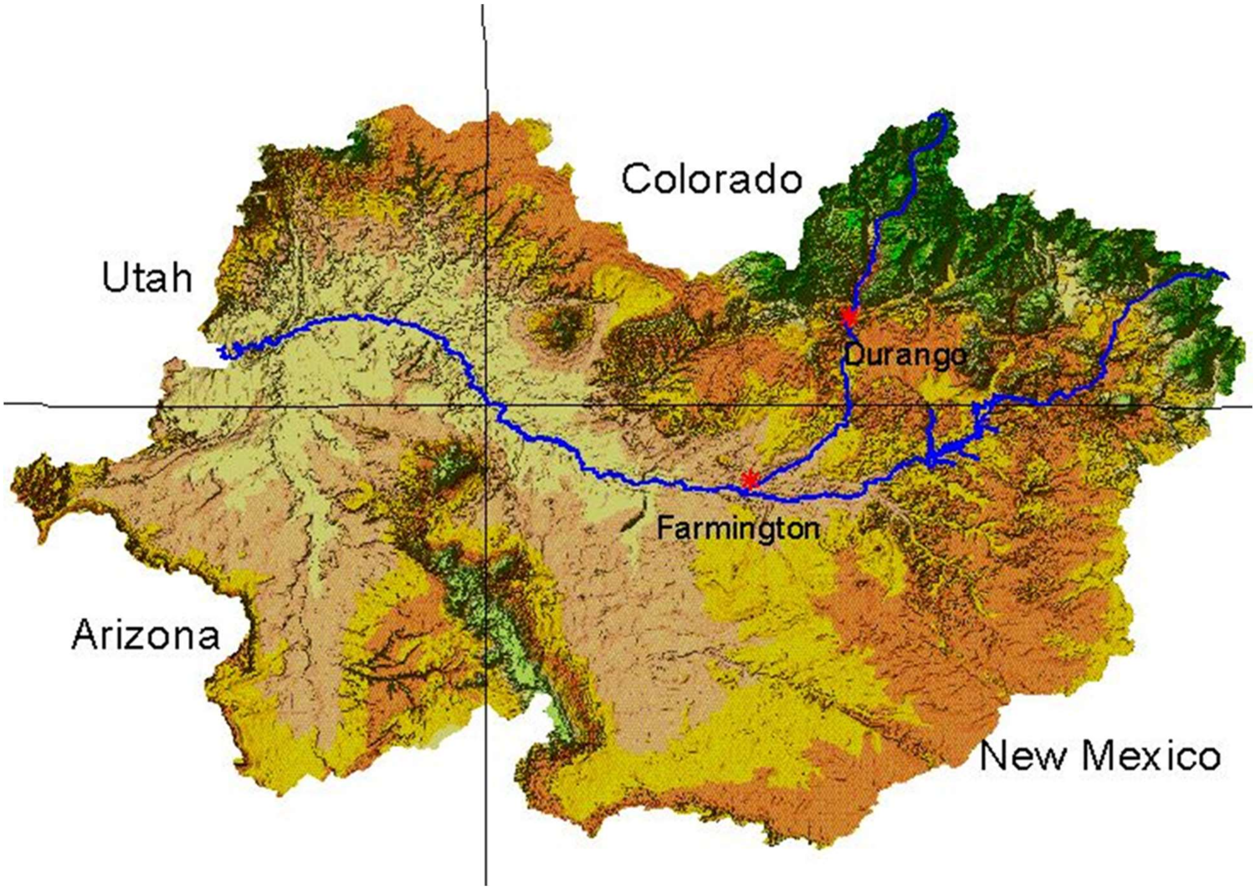


Figure 1-1: San Juan River Basin Location Map.

1.2 Overview of the San Juan Basin Hydrology Model (SJBHM)

1.2.1 Model Purpose

A hydrologic water resource system model is a computer representation of the physical processes associated with water moving through a river basin for various time periods and timesteps, including flows through river reaches, storage in reservoirs, diversions, consumptive uses, return flows from water users, other system losses (e.g., evaporation and transpiration), and other related processes. These types of models can be used for many purposes from short-term operational forecasting to long-term policy and water supply planning.

The San Juan Basin Hydrology Model (SJBHM) was designed and developed for the SJRIP to be used for long-term planning purposes such as developing and evaluating Navajo Reservoir operating rules that will support the goals of the SJRIP while continuing to provide reliable water supply to the basin's water users. The model is also used to simulate and assess the impacts of various levels of water use scenarios on streamflows and determine how well the flow recommendations can be met at certain levels of development.

The initial and continued development and application of the SJBHM and its datasets can be broadly lumped into three major efforts, which are described briefly below:

- Historical data development – Collection, development, and estimation of historical streamflows, depletions, and other necessary hydrologic data for the full model period of water years 1929 through 2013 to support computation of naturalized flows, model development, and definition of scenarios.
- Natural/naturalized flows development – Development of historical models to compute historical naturalized flows using estimated historical depletions and recorded gaged flows and reservoir operations. For the SJBHM this is accomplished in the historical configuration in both the San Juan StateMod and SJRIP RiverWare models, which are introduced in the next section.
- Water resource system model development – Development and application of water resource system models that use estimated historical naturalized flows, baseline demands, optional depletions, and operating criteria to investigate options to provide water for endangered fish habitat, for existing water use and depletions, and for additional water development.

1.2.2 Model Description

The SJBHM consists of two distinct water resource system models that are used in a coordinated manner. These two models are the ***"San Juan StateMod"*** model and the ***"SJRIP RiverWare"*** model and are referred to as such throughout this documentation. These two modeling platforms are described further below.

The primary model used for SJRIP analysis is the ***"SJRIP RiverWare"*** model, a water resource system model built with the RiverWare modeling platform, which is described further below. The SJRIP RiverWare model simulates the mainstems of the San Juan and Animas Rivers primarily in New Mexico but also includes the San Juan-Chama Project (SJC) diversions, the Animas-La Plata Project (ALP) operations on the Animas River below Durango, all of which are in Colorado, and the lower portion of the San Juan River in Utah above the Bluff gage. The SJRIP RiverWare model is a daily timestep model that simulates Navajo Reservoir and its operations, including recovery releases, flood control releases, and deliveries to both agricultural and municipal water users including the Navajo Indian Irrigation Project (NIIP) and Navajo-Gallup Water Supply Project (NGWSP). The SJRIP RiverWare model is not used for real-time operations of Navajo Reservoir or any other projects in the basin.

The State of Colorado's "***San Juan StateMod"*** model is used to support the SJRIP RiverWare model. Water use and other streamflow depletions in Colorado above the SJRIP RiverWare model's boundary inflow nodes are simulated within San Juan StateMod. This monthly timestep model provides the boundary inflows to the SJRIP RiverWare model from its principal runoff sources in Colorado, including the Los Pinos, Piedra, and upper San Juan Rivers that flow into Navajo Reservoir, and the Animas, Florida, and Mancos Rivers and McElmo Creek that join the main system below Navajo. Vallecito, Lemon, and Long Hollow reservoirs are simulated within San Juan StateMod and their representation is considered sufficient for the SJBHM purposes.

The portions of the San Juan basin that are covered by each model are shown on the map below in Figure 1-2. This map also highlights the two areas in Colorado, the ALP area on the Animas River below Durango and the SJC diversion area in the upper San Juan tributaries, that are represented within San

Juan StateMod but “remodeled” within the SJRIP RiverWare model. These areas are discussed further in Section 5.3 of the documentation. Note that the portions of the basin in Utah and Arizona are represented by inclusion in the SJRIP RiverWare model’s local inflows.

1.2.3 Modeling Platforms

As mentioned above, the primary modeling platforms used for the SJBHM are StateMod and RiverWare, which are both generalized software tools that are used to build hydrologic models of specific water resource systems. These models are supported by several datasets and data management interfaces (DMIs) that are used to move data between datasets and models.

RiverWare is a generalized hydrologic water resource system modeling platform that allows the user to develop customized models of specific river basin systems (Zagona et al., 2001). RiverWare is developed and supported by the Center for Advanced Decision Support for Water and Environmental Systems (CADSWES) at the University of Colorado. RiverWare is a physically based platform with advanced water accounting options including a water right allocation function, however accounting and water right allocation are not simulated in the SJRIP RiverWare model. In RiverWare, highly customizable “rules” are used to simulate the various criteria and procedures that are used to operate the system, such as calculating and setting reservoir releases or water user diversions. The SJRIP RiverWare model is further discussed in considerable detail throughout this documentation. Further information and documentation are available for the RiverWare software at http://www.riverware.org/.

StateMod is the surface water model component of the Colorado Water Conservation Board’s (CWCB) Colorado Decision Support System (CDSS). StateMod is a mostly generic hydrological modeling tool that can readily be configured to compute naturalized flows and to allocate natural flow to water rights following the prior appropriation doctrine used in Colorado, which is its primary strength. The CDSS uses the United States Geological Survey’s (USGS) Mixed Stations Model to fill missing periods of naturalized flows at gaged stations and to estimate flows in ungaged tributaries. Information and documentation are available for the StateMod software at http://cdss.state.co.us/.

1.2.4 Model Period and Input Hydrology

Historical hydrologic conditions (e.g., river inflows) are often used in long-term planning modeling and analysis as a basis to evaluate the potential impacts of various alternatives, such as new or modified policy, operational and management procedures, water uses, or infrastructure within a basin. This type of analysis typically utilizes historical river inflows as model inputs to drive the simulation of the system. A major assumption in these analyses is that historical hydrologic conditions are representative of probable future hydrologic conditions. The validity of this assumption depends largely on the hydrology period selected and requires that it be of sufficient length to capture a wide range of hydrologic conditions in terms of magnitudes, frequencies, cyclic climatic patterns of wet and dry years, and other factors.

The modeling period for the SJBHM is currently water years 1929 through 2013 (10/1/1928-9/30/2013). This period was chosen based upon available historical data and has been and will continue to be extended as resources and data become available. This 85-year historical period is assumed to be of sufficient length to be representative of the hydrologic regime in the San Juan basin and contains years of very wet hydrology (e.g., 1941), and very dry hydrology (e.g., 2002). It is also assumed to be sufficiently representative of the hydrology that may occur in future periods. It is noted that the period between 2013 and the present (2018) that is not currently included in the model period has contained some particularly dry years. The next model data update will bring these years into the model period.

Historical natural (and/or naturalized) flows are used as the base hydrology input to the models. From historical natural flows, different levels of water usage, reservoir operations, and other system changes can be simulated to estimate how the water resource system may react in various scenarios under the same historical hydrology. Historical natural flows are computed by taking historical observed streamflows at available gages throughout the river basin and adjusting them for human influences. These influences may include historical depletion of flows through consumptive use, imports/exports of water to other basins, and flow regulation and evaporation losses by reservoirs. Various historical data are required to estimate historical natural flows including streamflows, reservoir storages and releases, recorded and estimated diversion data, and other depletions such as evaporation. Main data sources include the United States Geological Survey (USGS), National Oceanographic and Atmospheric Administration (NOAA), Bureau of Reclamation (Reclamation), Colorado State Engineer's Office diversion records, New Mexico Interstate Stream Commission, geographic information system (GIS) coverages, and others.

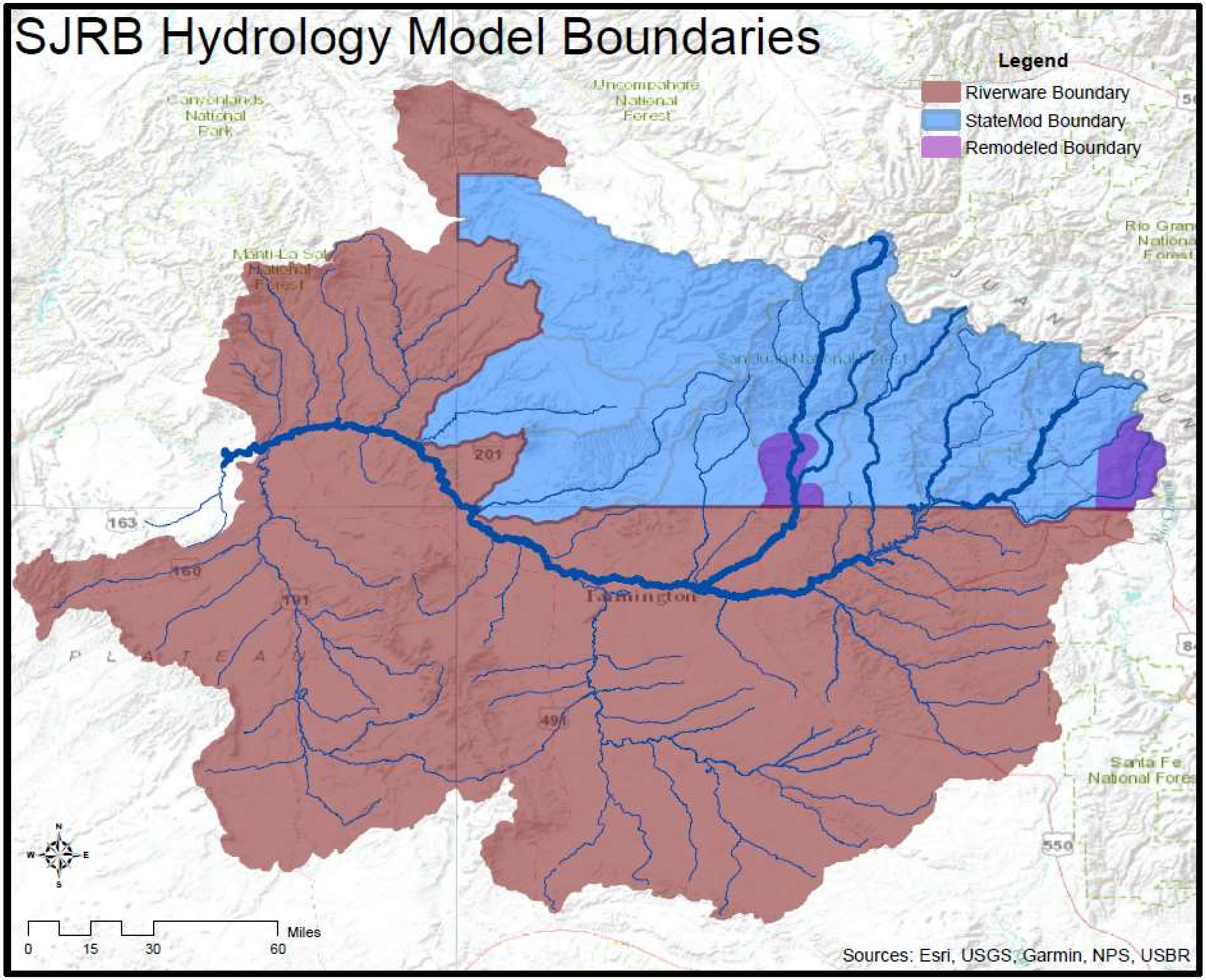


Figure 1-2: San Juan Basin Map with Approximate San Juan StateMod and SJRIP RiverWare Model Coverage Boundaries.

1.3 History of SJBHM Models and Modeling Efforts

The current version of the SJBHM is referred to as the fourth-generation (or "Gen 4") of the model.

The first-generation SJBHM RiverWare model was developed in 1997. The basic configuration was cloned from an existing model and extended to support the needs of the SJRIP. It operated the San Juan Chama (SJC) Project and Navajo Reservoir explicitly but modeled the Animas-La Plata (ALP) Project implicitly. The first-generation model was used to implement SJRIP flow recommendations and for NIIP consultation runs. In 1999, the second generation of the SJBHM implemented a more explicit simulation of the ALP project and its coordinated operations with Navajo Reservoir. The second-generation model was used for ALP Environmental Impact Statement (EIS) and Navajo EIS runs.

Both the first and second-generation were monthly timestep models which limited the model's ability to make sophisticated decisions based upon previous performance. Although internal daily computations were made at SJC, ALP and Navajo Reservoir, the overall simulation was still monthly. Consequently, the model had no way of seeing the resulting daily flow hydrographs at the San Juan at Four Corners gage and other important flow gages. The limitations of the previous models and datasets were the primary motivation for creating the third-generation (or "Gen 3") model. The depletion levels of the initial iteration of the Gen 3 model were equivalent to the Navajo EIS depletion levels. The Gen 3 model was transformed into a complex suite of models to accomplish these purposes.

Because of changes within both resources and the improving capabilities of Riverware, the Gen 3 model was consolidated from its complex suite of models into a single daily timestep model, which is now referred to as the fourth-generation, or Gen 4, model. The Gen 4 SJBHM is a river and reservoir operations model simulated on a daily timestep in RiverWare. This model is supported by natural flow data from San Juan StateMod and depletion data from an evapotranspiration model (Blaney-Criddle) and other data sources. Releases from Navajo reservoir are made in the model to simulate incorporating the flow recommendations into other reservoir operations such as water supply deliveries and flood control. The SJBHM is supported by several datasets including historical hydrologic conditions and water uses, current conditions, and planned future (or "Baseline") conditions. The Gen 4 model's Baseline configuration includes full Tribal settlement water uses for the four major tribes in the San Juan River basin.

1.4 Role of the SJBHM in ESA Section 7 Consultations

The U.S. Fish and Wildlife Service's overview on consultations states:

> *The purposes of the Endangered Species Act (ESA) are to provide a means for conserving the ecosystems upon which endangered and threatened species depend and a program for the conservation of such species. The ESA directs all federal agencies to participate in conserving these species. Specifically, section 7 (a)(1) of the ESA charges federal agencies to aid in the conservation of listed species, and section 7 (a)(2) requires the agencies, through consultation with the U.S. Fish and Wildlife Service (USFWS), to ensure their activities are not likely to jeopardize the continued existence of listed species or destroy or adversely modify their critical habitat. – U.S. Fish and Wildlife Service*

A major recovery component of the SJRIP and a requirement of the Animas-La Plata Biological Opinion is the requirement for Reclamation to provide flows for the recovery of the endangered fishes in the San Juan River through the operation of Navajo Reservoir. Flow recommendations necessary for the recovery of the two endangered fish were developed by the SJRIP (San Juan Flow Recommendations, Holden 1999) and the USFWS recognizes these as the best available scientific information concerning flows for use in Section 7 consultations. The USFWS also recognizes that the flow recommendations may change over time.

Because the USFWS is required to use the best available science to make its determinations, the USFWS will use SJBHM run(s) conducted by the action agency or Reclamation. Evaluation by the USFWS of model runs will be used to determine the level of impact, if any, of the proposed action on Reclamation's ability to meet the flow recommendations through the operation of Navajo Reservoir. However, the model runs will not be the sole criteria in determining the level of impact. The impact of a potential project to the ability to meet flow recommendations will also be associated to biological impacts to the endangered fish and their Critical Habitat.

In interpreting the results generated by the SJBHM, the USFWS will consider the assumptions used in the model, the limitations associated with the range of variability of the data used, and the level of accuracy and precision in the model results. In considering the assumptions used in the model, the USFWS and Reclamation, in consultation with the Program, will evaluate the schedule of depletions being used to ensure that they accurately reflect depletions as they are occurring in the Basin. This schedule of demands is termed the ***"SJBHM Baseline Demands"*** and are intended to represent worst case, or "full", human water use demand conditions on the San Juan River based upon Congressionally and State approved settlements, water rights, and water supply projects. The SJBHM Baseline demand scenario includes all Tribal Reserved water rights that have been confirmed by Congress. The SJBHM Baseline demand scenario is described further in Section 2 of this documentation.

The purpose and use of the SJBHM regarding ESA consultations is further described in the May 1, 2008 letter from the SJRIP Program Coordinator to the SJRIP Coordination Committee, included as Appendix A.

2 SUMMARY OF SJBHM SCENARIOS AND CONFIGURATIONS

The San Juan Basin Hydrology Model (SJBHM) consists of two distinct surface water resource system models, the SJRIP RiverWare model (Section 5) and the San Juan StateMod model (Section 3). Additionally, the SJRIP RiverWare Historical model (Section 4), a slightly modified version of the SJRIP RiverWare model, is used to simulate the historical configuration of the San Juan system. These models are each discussed in detail in this documentation in the sections indicated above. The SJRIP RiverWare and the San Juan StateMod models can be each be flexibly configured to simulate alternative scenarios as desired for various analysis by the SJRIP or other stakeholders. However, in order to appropriately simulate a desired SJBHM scenario, it is critical that the correct scenarios and configurations of each model are used. The purpose of this section is to summarize and clarify how the various scenarios and configurations of the models are used together to simulate the overall SJBHM scenarios. Additionally, Figure 2-1 at end of this section illustrates how the models and datasets within the SJBHM interact.

The overall SJBHM scenarios, and the San Juan StateMod and SJRIP RiverWare model scenarios/configurations used for each, are summarized in Table 2-1 and described in more detail below.

Table 2-1: SJBHM Scenarios and Corresponding San Juan StateMod and SJRIP RiverWare Scenarios/Configurations.

SJBHM Scenario	Utilized San Juan StateMod Model Scenarios/Configuration	Utilized SJRIP RiverWare Model Scenarios/Configuration
SJBHM Baseline Demands Scenario	San Juan StateMod Baseline with Tribal Reserved Scenario	SJRIP RiverWare model with SJBHM Baseline demands
SJBHM Current Conditions Demands Scenario	San Juan StateMod Baseline without Tribal Reserved Scenario	SJRIP RiverWare model with SJBHM Current Conditions demands
Historical Scenario	San Juan StateMod Historical Scenario	SJRIP RiverWare Historical model with historical depletions

2.1 SJBHM BASELINE DEMANDS SCENARIO

The SJBHM Baseline Demands scenario is the primary depletion demand and depletion scenario of the SJBHM. It is intended to represent the anticipated maximum (or full buildout) water user demands and planned project operations in the San Juan River basin. This includes the simulation of basin projects, such as the Animas-La Plata project, at their planned full level operations and utilization, even though they may not be operating at that level in the present day. This scenario includes all Tribal Reserved water rights that have been approved by Congress. For the purposes of the SJBHM Baseline scenario, the SJRIP and Reclamation have decided that the States are responsible for defining their respective baseline demands, which are as follows:

- Colorado has elected to use the demand scenario defined in the current “San Juan StateMod Baseline with Tribal Reserved” scenario. Note that this “StateMod Baseline” term is different from the “SJBHM Baseline” term and that the full terms are used throughout this documentation to avoid confusion. This San Juan StateMod scenario is described in Section 3.5.2. Colorado uses irrigated acreages from the most recent irrigated area assessment (2010) to generate StateMod Baseline demands for agricultural water users. For the purposes of the SJBHM, Colorado and the SJRIP assume that these demands adequately represent the anticipated maximum future conditions due to the limited future development potential. This scenario also assumes full use of all approved Tribal Reserved water rights in Colorado.

- New Mexico has elected to use their demands as presented in Section 5.6 for the SJBHM Baseline demand scenario. New Mexico uses the maximum historical irrigated acres for most agricultural water users, and the full decreed acreages for Tribal irrigation projects, to generate their SJBHM Baseline agricultural demands. This scenario also assumes full use of all approved Tribal Reserved water rights in New Mexico.

2.2 SJBHM Current Conditions Demands Scenario

The SJBHM Current Conditions Demands scenario has recently been developed to reflect current or expected near-future demand levels, or the levels that have been observed or are expected to occur during approximately the 2010-2020 period and are shown in Section 5.6. For this scenario, the “San Juan StateMod Baseline without Tribal Reserved” scenario is utilized, which contains the same “San Juan StateMod Baseline” demands used in the SBJHM Baseline demand scenario (which are generated from 2010 acreages and approximately current non-agricultural uses), however this scenario assumes no use of the future Tribal Reserved water rights in Colorado that have not yet been used. Similarly, this scenario uses current or expected near-future tribal water uses in New Mexico, which may be lower than the full settlement amounts represented in the SJBHM Baseline Demands scenario.

This scenario has been used to evaluate the performance of the SJRIP spring release hydrograph scheduling procedures in meeting the SJRIP flow recommendations under basin demand conditions more like those currently present than those represented in the SJBHM Baseline demand scenario.

2.3 Historical Scenario

The Historical scenario is used for calibration and validation for both the San Juan StateMod and SJRIP RiverWare models. Importantly, it is also used to generate the local inflows that are used in the SJRIP RiverWare model. For this scenario, the San Juan StateMod Historical configuration and scenario are utilized along with the SJRIP RiverWare Historical model configuration. These model configurations both utilize historical streamflow, depletion, and operational data to simulate the hydrology of the San Juan system as it occurred historically.

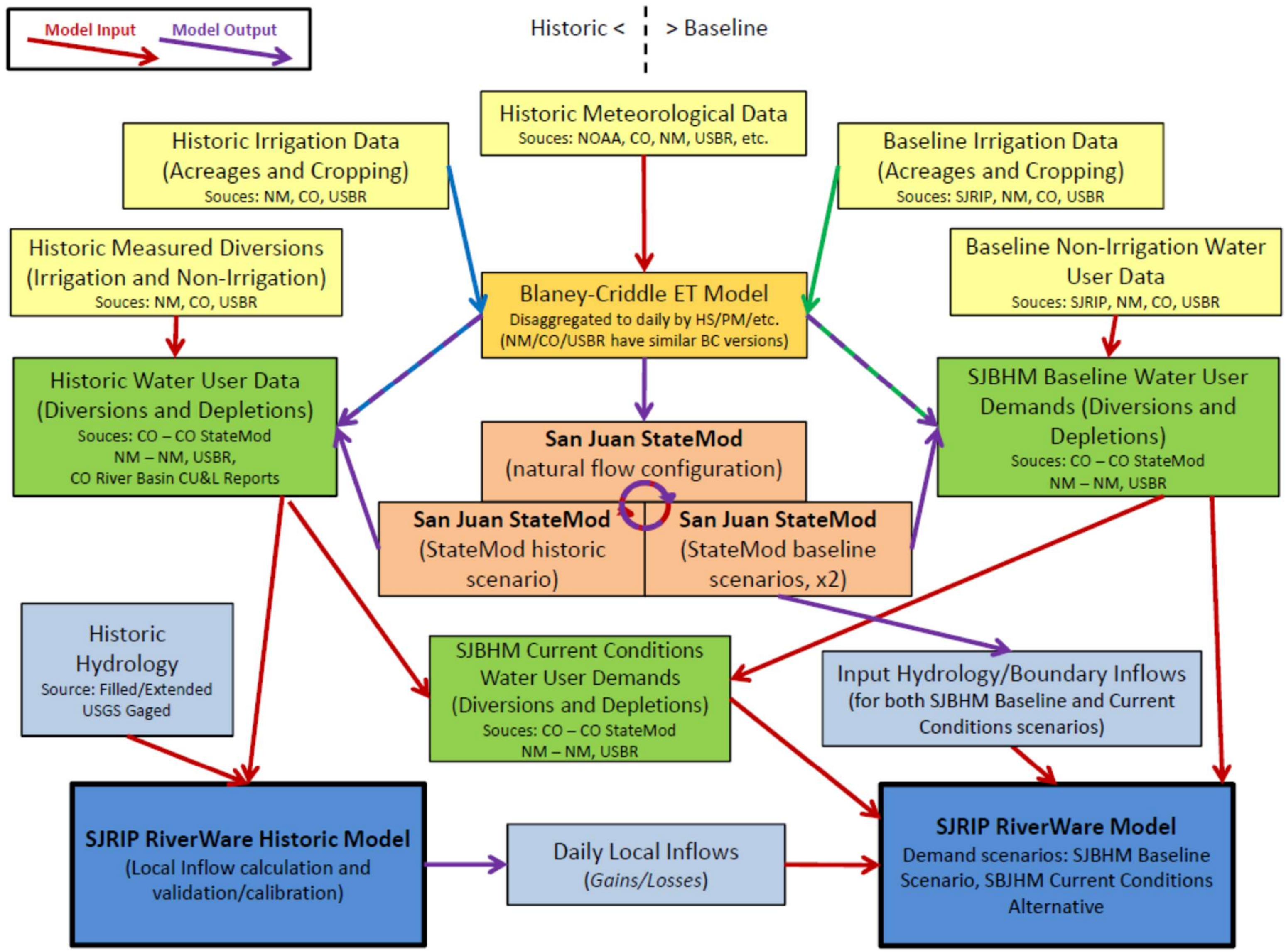


Figure 2-1: SJBHM Model and Dataset Interface Schematic.

3 San Juan StateMod

3.1 Introduction

The San Juan StateMod model is the State of Colorado's implementation of the StateMod software for the San Juan River Basin in Southwest Colorado within its Colorado Decision Support System (CDSS). StateMod is the surface water model component of the multi-model and support tool CDSS water management system developed by the Colorado Water Conservation Board (CWCB). The State of Colorado developed, maintains, and updates the base San Juan StateMod model and scenarios independent of Reclamation and the other SJRIP parties. The SJBHM uses model results from San Juan StateMod scenarios that have been selected and specifically configured for SJRIP modeling, which are described below.

The San Juan StateMod model simulates the basin's surface water system in Colorado, including river flows, reservoir storages, and various water supply and demand processes including water rights allocations, diversions, and return flows. The San Juan StateMod model also includes the Dolores River Basin because of closely tied water allocations due to the transbasin deliveries of the Dolores Project that exports Dolores River water into the McElmo Creek tributary basin of the San Juan Basin. It runs on a monthly timestep with a full model period of 1909 to 2013.

For further information regarding the San Juan StateMod model, please refer to its full documentation, included as Appendix B. Further information about the CWCB and CDSS can be found online at http://cwcb.state.co.us/ and https://www.colorado.gov/cdss. Additionally, a summary of the current San Juan StateMod model output and how it varies between the utilized San Juan StateMod scenarios is included as Appendix C.

3.2 Coordinated Usage of San Juan Statemod with SJRIP RiverWare for the SJBHM

As previously described in more detail, the SJBHM consists of two distinct water resource system models that are used in a coordinated manner to meet the needs of the San Juan River Basin Recovery Implementation Program (SJRIP). These two models are the San Juan StateMod model and the SJRIP RiverWare model.

The San Juan StateMod model is utilized within the SJBHM for simulation of the portions of the San Juan River basin within the State of Colorado. This area consists of nearly the complete headwaters of the San Juan basin above Navajo Reservoir, and the portions of the Animas, La Plata, and Mancos River and McElmo Creek basins that are within Colorado. Draining the southern part of the San Juan Mountains, this area normally provides most of the total surface water into the San Juan River. The San Juan StateMod model is used within the SJBHM to simulate the water supply and associated depletions to natural flow for the basin areas in Colorado. It also simulates the upper San Juan River and tributary basin outflows from Colorado into Navajo Reservoir and the main stem of the San Juan River in New Mexico. The San Juan StateMod model simulates reservoir operations at Vallecito, Lemon, and other reservoirs. Additionally, it simulates the La Plata Compact and Long Hollow reservoir operations. Please refer to the full San Juan StateMod model documentation (Appendix B) for more details.

The SJRIP RiverWare model receives a large amount of its required input data from San Juan StateMod model output. This data includes both inflow hydrology (e.g., simulated boundary gage river flow data) and water usage data (e.g., simulated depletions) of the basin's water users in Colorado. While previous San Juan StateMod versions included some model nodes downstream of the Colorado state line for certain rivers, the current version of the San Juan StateMod model ends at the Colorado state line for all its simulated basins in the San Juan system. Reclamation and the U.S. Fish and Wildlife Service (USFWS) have determined that San Juan StateMod's representation of the San Juan River Basin's hydrology and water uses in Colorado is sufficient for the SJRIP's hydrology modeling needs. For that reason, the SJRIP RiverWare model's representation of the San Juan River begins at the downstream boundaries of the San Juan StateMod model's network, with the two exceptions discussed in the next section.

Given that the SJRIP RiverWare model's full period runs from October 1928 to September 2013, only the corresponding San Juan StateMod output is used despite the full San Juan StateMod period being 1909 to 2013. Nonetheless, the San Juan StateMod run period is not modified and only the San Juan StateMod output for the SJRIP RiverWare model period is used. No date translation is necessary as the utilized dates are consistent between the historical period and both the San Juan StateMod and SJRIP RiverWare models. Generally, Colorado provides the necessary San Juan StateMod model output as well as the San Juan StateMod models themselves for SJBHM use. Providing the models themselves significantly aids in interfacing and data management between San Juan StateMod and the SJRIP RiverWare model and allows for investigation and review of San Juan StateMod results at a much higher level of detail than otherwise possible.

3.3 Description of Overlapping Model Areas

As mentioned above, for the most part, the simulated areas of the SJRIP RiverWare model and the San Juan StateMod model do not overlap and the SJRIP Riverware model begins at the downstream boundary of the San Juan StateMod model. There are, however, a couple necessary exceptions to this in the upper San Juan basin headwaters (in the Navajo, Little Navajo, and Blanco Rivers) and in the Animas basin.

In the upper San Juan basin headwaters, it has been determined that the San Juan StateMod representation of the Azotea Tunnel diversions to the San Juan-Chama project (SJC) is not detailed enough for the needs of the SJBHM. This is because the monthly timestep of the San Juan StateMod model is not able to simulate the daily minimum flow bypass requirements of each of the three river diversion structures that can be important in determining the overall SJC diversions. As a result, the San Juan StateMod results for the Upper San Juan headwaters above the Carracas gage are adjusted to reflect simulated daily timestep SJC diversions within the SJRIP RiverWare model. The net effects of the SJC re-simulation are applied by adjusting the San Juan StateMod output of the San Juan River at Carracas. This process is further explained in the Section 5.3.2 of this documentation.

In the Animas River basin, the San Juan StateMod model does not simulate the operations of the Animas-La Plata (ALP) project on the Animas River near Durango, including the off-stream pumping from the Animas River to Lake Nighthorse, the reservoir created by Ridges Basin Dam. In the real-world, limited ALP operations have begun, including an initial fill of the reservoir in 2011, and thus the ALP project is anticipated to play an important part in the San Juan basin hydrology. Because of this, the ALP project and Lake Nighthorse are simulated in more detail in the SJRIP RiverWare model which necessitates that its representation of the Animas River begins close to 20 miles upstream of the state line at the USGS Animas at Durango streamflow gage. This overlapping model area contains several San Juan StateMod nodes representing water user diversions, return flows, and tributary inflows. To account for this overlapping area, the SJRIP RiverWare model re-simulates the Animas River and its water users between the Durango gage and the CO-NM state line to represent the operations of the ALP. The Colorado water users in this reach that are independent from ALP operations are configured to remain consistent with their results from San Juan StateMod. This process is further explained in the Section 5.3.3 of this documentation.

3.4 San Juan StateMod Model Version and Minor Modifications

The San Juan StateMod model currently being used is slightly modified from version 15.00.01 and has a last revision date of 10/28/2015. The model was provided by Colorado through their contractor, Wilson Water Group. Between 2016 and 2017, Reclamation's contractor, Precision Water Resources Engineering, worked with Wilson Water Group to review and update the boundaries between the San Juan StateMod model and the SJRIP RiverWare model. Based on this 2016 model boundary review, the SJRIP RiverWare model's representation of the overlapping portion of the Animas River basin in Colorado was updated to account for changes that had occurred in San Juan StateMod since the last time that the boundary was reviewed.

In addition, based on the 2016 model boundary review, a few minor modifications were made to the original San Juan StateMod model to allow it to be appropriately used with the SJRIP RiverWare model. In San Juan StateMod, all the return flows from diversions within Colorado that return to the San Juan River in New Mexico are lumped into a single model node as there is no need to separate them further. For the purposes of the SJRIP RiverWare model, however, it was necessary that the return flows be further subdivided so that they could be applied at the proper locations. Thus, the single node (called SJ_Return), that received all these return flows was divided into 3 nodes (called Arch_Return, 4C_Return, and Bluff_Return), and return flows that were accruing to the single node were moved to the most appropriate node based on their actual return location to the San Juan River within New Mexico. The Arch_Return node receives any return flows that accrue above or into Navajo Reservoir, and 4C_Return received those accruing above the San Juan at Four Corners gage, and the Bluff_Return received those accruing between the Four Corners and the San Juan near Bluff gage. These changes do not alter any of the total quantities calculated by San Juan StateMod, they only provide a more detailed breakdown of the return flow locations. These nodes are noted in the SJBHM San Juan StateMod network schematic included as Appendix D.

3.5 San Juan StateMod Model Scenarios

3.5.1 San Juan StateMod Historical Scenario

The San Juan StateMod Historical Scenario is used to provide much of the input data to the SJRIP RiverWare model's historical configuration which is used to calculate the local inflows used in the other SJRIP RiverWare model configurations. In short, the StateMod Historical Scenario represents the historical flow of water though the system. To achieve this, San Juan StateMod back-calculates the historical natural flows and various other gain/loss terms by accounting for the historical diversions, depletions, and operations of the system. Reservoirs are not represented until they existed historically, after which the reservoir outflows are forced to historical values. The natural flows and other gain/loss terms are subsequently used to drive other scenarios. The StateMod Historical scenario is also used during the calibration process to confirm that the San Juan StateMod model appropriately represents basin demands and operations.

3.5.2 San Juan StateMod Baseline Scenario

The San Juan StateMod Baseline Scenario simulates the San Juan basin's water resources under the historical hydrology (the natural flows from the Historical Scenario) but as if the system's currently existing operational procedures, policy, infrastructure (including reservoirs), projects, and demand levels were in place throughout the full model period. The purpose of the StateMod Baseline scenario is to provide a representation of system conditions that can then be compared to various "what if" alternatives that represent various changes to the system. For agricultural water users, the StateMod Baseline demands represent the diversion demands required to fully meet the crop irrigation requirement for the "current" acreages and crop mixes as determined from the 2010 irrigated acreage assessments. Municipal and Industrial demands are set according to recent averages or values to reflect current usage levels. For the purposes of the SJBHM, Colorado and the SJRIP assume that these demands adequately represent the anticipated maximum future conditions due to the limited future development potential. For more information please see the San Juan StateMod model documentation (Appendix B).

There are two versions of the San Juan StateMod Baseline scenario that are used within the SJBHM for varying purposes:

3.5.2.1 San Juan StateMod Baseline with Tribal Reserved Scenario

In the Baseline with Tribal Reserved Scenario, future water uses under Tribal Reserved Water Rights are included for both the Southern Ute Indian Tribe (SUIT) and the Ute Mountain Ute Tribe (UMU). The future reserved demands represent the allowable water uses under various settlements that have not yet been used within the basin. This is the San Juan StateMod scenario used in conjunction with the SJRIP RiverWare model for the SJBHM's Baseline demand scenario.

3.5.2.2 San Juan StateMod Baseline without Tribal Reserved Scenario

In the Baseline without Tribal Reserved Scenario, the future Tribal Reserved Water Right demands are turned off in the model, and thus only the currently used demand levels are represented. This scenario is only used for limited and specific purposes within the SJBHM, such as with the SJRIP RiverWare model's "Current Conditions Demands" runs.

3.6 San Juan StateMod-to-SJRIP RiverWare Workbooks and TSTool Scripts

Three (3) Excel workbooks receive and hold the required San Juan StateMod model run output, one for each utilized San Juan StateMod scenario. These workbooks are populated with San Juan StateMod results which can then be easily input to SJRIP RiverWare using Data Management Interfaces (DMIs). Additionally, these workbooks hold the depletion reporting data from San Juan StateMod for the basin areas in Colorado that are not directly used in the SJRIP RiverWare model. TSTool, the time-series data management utility in CDSS, is used to collect the required San Juan StateMod output data from the raw, binary format San Juan StateMod output. A set of TSTool scripts is used to collect the results, perform appropriate aggregations, and output the necessary San Juan StateMod results to the Excel workbooks. There are 21 TSTool scripts, 7 for each San Juan StateMod scenario, that correspond to a standard 7 worksheets within the 3 main Excel workbooks. The TSTool scripts are organized generally by San Juan tributary subbasin: Upper San Juan (headwaters above Carracas), Piedra, Pine, Animas (which contains the Florida), La Plata, Mancos, and McElmo. Each script outputs the San Juan StateMod monthly flows, aggregates and outputs the subbasins' total depletions by reporting groups, and outputs other required data for the SJRIP RiverWare model and SJBHM reporting. Both the workbooks and the TSTool scripts contain many helpful internal descriptions and comments. The output parameters are the same for each of the 3 San Juan StateMod scenarios described above. A description of the data output from San Juan StateMod is shown below.

3.7 SJRIP RiverWare Model Inputs from San Juan StateMod

The following San Juan StateMod output data is used directly as input data for the SJRIP RiverWare model. As noted below, in some cases a slightly different San Juan StateMod node than the main flow gage node is used to account for flow effects downstream of the actual gage location. The San Juan StateMod parameter names are shown below in Table 3-1.

3.7.1 Hydrology (Main River/Gage Inflows)

These main flow locations represent the main inflow data used to drive the SJRIP RiverWare model.

Above Navajo Reservoir:

- San Juan River near Carracas, CO (USGS 09346400)
- Piedra River near Arboles, CO (USGS 09349800)
  - Adjusted to mouth due to a diversion below gage.
- Rock Gulch at mouth (ungaged but modeled in San Juan StateMod)
- Los Pinos (Pine) River at La Boca, CO (USGS 09354500)
- Spring Creek at La Boca, CO (USGS 09355000)

Below Navajo Reservoir:

- Animas River at Durango, CO (USGS 09361500)
  - Adjusted to include flow from Lightner Creek (ungaged but modeled in San Juan StateMod) that enters the Animas River shortly below the Durango gage.
- Florida River at Bondad, CO (USGS 09363200)

    - Adjusted to confluence with Animas due to a diversion below gage.
- La Plata River at Colorado-New Mexico State Line (USGS 09366500)
    - Adjusted to include return flows downstream of gage.
- Mancos River near Towaoc, CO (USGS 09371000)
    - Adjusted to mouth for a diversion below gage.
- McElmo Creek near Colorado-Utah State Line (USGS 09372000)
    - Adjusted to include flow from Yellow Jacket Creek (ungaged but modeled in San Juan StateMod) that enters McElmo Creek shortly below gage.

3.7.2 Other Hydrology/Gage Flows

These three flow locations for tributaries in the Upper San Juan basin represent the river flows at the three San Juan-Chama Project diversion locations. The San Juan StateMod model output is used for the reoperation of the SJC diversion within the SJRIP RiverWare model.

- Navajo River at Tunnel Diversion
- Little Navajo River at Tunnel Diversion
- Blanco River at Tunnel Diversion

3.7.3 San Juan StateMod Diversions ("Supply" in StateMod)

This group contains the San Juan StateMod San Juan-Chama Project (SJC) export diversion and also the 6 diversion nodes (4 on the Animas, 2 on the La Plata) that are represented within both SJRIP RiverWare and San Juan StateMod. The 4 Animas diversions, which are fully within Colorado, must be re-simulated in SJRIP RiverWare due to the upstream ALP operations, however their diversions are forced to those calculated by San Juan StateMod rather than being dynamically simulated in SJRIP RiverWare. The 2 La Plata diversions divert from the river within Colorado to irrigated lands within New Mexico, and thus their depletion demands are represented dynamically within SJRIP RiverWare with the ETAC method. For these, SJRIP RiverWare forces the total diversion to be that calculated by San Juan StateMod, and the respective return flows are then calculated by the San Juan StateMod diversion minus the SJRIP RiverWare depletion, allowing for the overall water balance to be maintained.

- San Juan-Chama Project (Azotea Tunnel) Total Diversion
- East Mesa Ditch Total Diversion (SID 3001094, Animas River above Florida)
- Animas Ditch Total Diversion (SID 3001023, Animas River above Florida)
- Animas River Southern Ute Indian Tribe (SUIT) Future Reserved Demands Total Diversion (SID 30_SUIT, Animas River below Florida)
- Animas River StateMod Aggregate Diversion Site (ADS, lumped minor diversions) Total Diversion (SID 30_ADS010)
- Pioneer Ditch Total Diversion (SID 3304640, La Plata River)
- Enterprise Ditch Total Diversion (SID 3304639, La Plata River)

3.7.4 San Juan StateMod Return Flows

The following San Juan StateMod return flows are used within the SJRIP RiverWare model. These represent aggregated return flows from San Juan StateMod diversions that bypass and thus are not captured within the main inflow nodes and return flows from upstream diversions that accrue to the San Juan StateMod nodes on the Animas River in the overlapping model zone.

Aggregated Return Flows that Bypass Main Inflow Nodes:

- Aggregated Return Flows above Navajo Reservoir (“Arch_Return”)
- Aggregated Return Flows above San Juan River at Four Corners (“4C_Return”)
- Aggregated Return Flows above San Juan River near Bluff (“Bluff_Return”)

Animas River Overlapping Model Node Return Flows:

- Return Flows above East Mesa Ditch (SID 3001094, on Animas River above Florida)
- Return Flows above Animas Ditch (SID 3001023, on Animas River above Florida)
- Return Flows to San Juan StateMod Node 30_ADS010 (on Animas River below Florida)
- Return Flows to San Juan StateMod Node 30_ARS005 (on Animas River below Florida)

3.7.5 Other San Juan StateMod Output Used for Reporting Only (not directly within SJRIP RiverWare)

The following data is San Juan StateMod output that is utilized for SJBHM depletion reporting purposes. This data, however, is not used directly within the SJRIP RiverWare model. Even without being directly utilized, the river depletion effects of this data are present within the San Juan StateMod hydrology flows used for the SJRIP RiverWare model inflows. A complete breakdown of the San Juan StateMod nodes aggregated into each listed parameter is provided in Appendix E.

- Upper San Juan River Basin above Navajo Reservoir
    - Aggregated Basin Total Diversion Depletion
    - Aggregated Basin Total Reservoir Evaporation
    - Basin Total Future Tribal Reserved (Southern Ute Indian Tribe, SUIT) Depletion
- Piedra River Basin above Navajo Reservoir
    - Aggregated Basin Total Diversion Depletion
    - Aggregated Basin Total Reservoir Evaporation
    - Basin Total Future Tribal Reserved (SUIT) Depletion
- Los Pinos River Basin above Navajo Reservoir
    - Aggregated Basin Total Diversion Depletion
    - Aggregated Basin Total Reservoir Evaporation
    - Basin Total Future Tribal Reserved (SUIT) Depletion
- Animas River Basin above Durango
    - Aggregated Basin Total Diversion Depletion
    - Aggregated Basin Total Reservoir Evaporation
    - Basin Total Future Tribal Reserved (SUIT) Depletion
- Florida River Basin above confluence with Animas
    - Aggregated Basin Total Diversion Depletion
    - Aggregated Basin Total Reservoir Evaporation
- La Plata River Basin above State Line
    - Aggregated Basin Total Diversion Depletion
    - Aggregated Total Reservoir Evaporation

- Basin Total Future Tribal Reserved (SUIT) Depletion
- Mancos River Basin above State Line
  - Aggregated Basin Total Diversion Depletion
  - Aggregated Total Reservoir Evaporation
  - Basin Total Future Tribal Reserved (Ute Mountain Ute Tribe, UMU) Depletion
- McElmo Creek Basin above State Line
  - Aggregated Basin Total Diversion Depletion
  - Aggregated Total Reservoir Evaporation
  - Basin Total Future Tribal Reserved (UMU) Depletion
  - Basin Total Imports from Dolores Basin

3.8 How the San Juan StateMod Data is Used Within the SJRIP RiverWare Model

In the SJRIP RiverWare model, a DMI pulls the required San Juan StateMod output from the appropriate Excel workbook. The data is brought into SJRIP RiverWare in its original monthly volume format and is placed in monthly Series Slots on a Data Object. Both the DMI and the Data Object are named "StateModHistoricMonthlyInputs" and "StateModBaselineMonthlyInputs" in the SJRIP RiverWare models respectively. At the beginning of a SJRIP RiverWare model run, initialization rules disaggregate the San Juan StateMod monthly volumes to daily flows and set them to the appropriate slots on the simulation objects. For the 10 main inflow nodes, the monthly volumes are disaggregated using monthly-to-daily patterns calculated by appropriate historical flow gage records. For the other San Juan StateMod inputs, the monthly volumes are evenly distributed to daily flows.

Within a SJRIP RiverWare Historical model run, the San Juan StateMod values are simply set as inputs as the historical simulation is essentially just a basic mass-balance solution used to calculate the historical local inflows.

Within a SJRIP RiverWare model run, the San Juan StateMod values are also initially set as inputs. However, because the system is simulated in a dynamic way, various RiverWare rules are used to make certain adjustments or do other things with the San Juan StateMod data. As mentioned above, the baseline SJRIP RiverWare model uses rules to re-simulate San Juan StateMod's SJC diversion. This process is described in detail in Section 5.3.2 of this documentation. In short, the difference between the San Juan StateMod solution and the reoperated SJRIP RiverWare solution for the SJC diversions are used to apply appropriate adjustments to the main inflow of the San Juan River at Carracas. For example, if in a given month the San Juan StateMod SJC volume is 1000 AF higher than the reoperated SJRIP RiverWare SJC volume, that 1000 AF is added to the original San Juan StateMod San Juan River at Carracas inflow for that month to account for the lower SJC diversion leaving more flow in the San Juan basin.

RiverWare rules are also used within a SJRIP RiverWare model run to ensure that the simulated diversions of the Animas River water users are equal to those simulated in San Juan StateMod, which ensures that simulated ALP project operations do not affect these water users. Additionally, the San Juan StateMod "Total Supply" solutions for Enterprise and Pioneer ditches on the La Plata River are used to pattern those ditches demands from monthly to daily timesteps.

Table 3-1: San Juan StateMod Model Data Used Directly in the SJRIP RiverWare Model

Input Name	San Juan StateMod Parameter Code
Hydrology	
Navajo River at Tunnel	7704635.River_Inflow
Little Navajo River at Tunnel	7704636.River_Inflow
Blanco River at Tunnel	2904667.River_Inflow
San Juan River near Carracas	09346400.River_Outflow
Piedra River near Arboles	7801910_Dwn.River_Outflow
Rock Gulch at mouth	4600503.River_Outflow
Los Pinos River at La Boca	09354500.River_Outflow
Spring Creek at La Boca	09355000.River_Outflow
Animas River at Durango	3001691.River_Outflow
Florida River at Bondad	3001904_Dwn.River_Outflow
La Plata River at State Line	LP_Return.River_Outflow
Mancos River near Towaoc	34_AMS001. River_Outflow
McElmo Creek near State Line	09372000.River_Outflow + 3200590.River_Outflow
Diversions (Supplies)	
San Juan-Chama Diversion	7799999.Consumptive_Use
East Mesa Ditch Total Diversion	3001094.Total_Supply
Animas Ditch Total Diversion	3001023.Total_Supply
SUIT Future Tribal Reserved Total Diversion	30_SUIT.Total_Supply
Animas River Agg. Div. Site Total Diversion	30_ADS010.Total_Supply
Enterprise Ditch Total Diversion	3304639.Total_Supply
Pioneer Ditch Total Diversion	3304640.Total_Supply
Return Flows (RFs)	
Aggregated RFs above Navajo Res	Arch_Return.Return_Flow
Aggregated RFs above San Juan @ 4C	4C_Return.Return_Flow
Aggregated RFs above San Juan near Bluff	Bluff_Return.Return_Flow
Return Flows above East Mesa Ditch	3001094.Return_Flow
Return Flows above Animas Ditch	3001023.Return_Flow
Return Flows above StateMod Agg. Div. Site	30_ADS010.Return_Flow
Return Flows above StateMod Agg. Res. Site	30_ARS005.Return_Flow

4 SJRIP RiverWare Historical Model

4.1 Introduction and Purpose

The SJRIP RiverWare Historical model is a component of the San Juan Basin Hydrology Model (SJBHM). The SJRIP RiverWare Historical model is a version of the SJRIP RiverWare model that has been modified to represent the historical hydrology and water uses of the San Juan River's water resource system. The primary purpose of the SJRIP RiverWare Historical model is to calculate the system's daily timestep local inflows, which are required inputs to the SJRIP RiverWare model. Broadly, the SJRIP RiverWare Historical model calculates the local inflows by utilizing the historical dataset to produce a simulation of the historical basin conditions where the only unknown variables are the local flows in each of the model's defined local inflow calculation reaches. The model then calculates the local inflows by solving the mass-balance for each reach, based on historical gage flows and the effects of historical water user diversions and return flows, reservoir operations, and other system operations. There are 10 defined local inflow reaches used by the SJRIP RiverWare Historical and SJRIP RiverWare models, which are described below in Section 4.4. The historical datasets are also described in detail.

In addition to calculating the local inflows, the SJRIP RiverWare Historical model can also be used to verify and validate various historical data and identify errors and issues within these datasets. It can also be used to verify and validate various modeling methods and procedures (or develop and test new methods), such as return flow estimation techniques, by analyzing a method's ability to reproduce historical conditions while generating reasonable and expected local inflows. The SJRIP RiverWare Historical model validation process and local inflow calculation results are presented and discussed in Appendix F of this documentation.

In the context of the SJBHM, the local inflows refer to a reach's net flow gains or losses that are not otherwise represented in the model. Ideally, the majority of the magnitude of the local inflows will consist of actual inflows of water to the river system such as unmodeled tributary inflows and direct river bank runoff. In application, however, there are various processes that can't feasibly be simulated explicitly for various reasons such as a lack of adequate data and/or appropriate methods, or that aren't simulated due to a desire for model simplicity. Examples of these processes include reach flow losses due to surface evaporation and evapotranspiration of riparian vegetation, flow gains or losses due to seepage both to or from groundwater and not otherwise simulated, and unmodeled minor water user diversions and/or return flows. As they are not explicitly simulated within the models, these processes are implicitly represented by being lumped into the local inflows. Since the SJBHM's local inflows are calculated in the SJRIP RiverWare Historical model using historical data and system conditions, these gains and losses are assumed to be the same in the SJRIP RiverWare model as they were historically. Put another way, it is assumed that the various historical net flow gain/loss effects implicitly included in the local inflows are representative of those that would occur within the system under baseline conditions if historical hydrology conditions were to reoccur.

Additionally, since the SJRIP RiverWare Historical model calculates the local inflows with a mass-balance approach, they serve as a "catchall" term and will contain the effects of various uncertainties such as data error (e.g., streamflow gage error), flow travel times, and incorrect estimations of historical diversion, depletion, and return flow values (or the location of the historical diversions and return flows) of the basins water users. When internal to the system, many of these types of effects can cause "offsetting" local inflow values that can be corrected using appropriate post-processing techniques. For example, an errantly high flow value at the San Juan at Shiprock gage can cause a high positive local inflow value for the reach above the gage alongside a corresponding and opposite negative local inflow value in the reach below the gage. These types of issues are corrected for in the SJRIP RiverWare Historical model by applying both spatial and temporal smoothing and redistribution techniques at the end of the model run. The post-processing techniques utilized are described in more detail later in this section.

4.2 General SJRIP RiverWare Historical Model Simulation Procedure

The model period of the SJRIP RiverWare Historical model is identical to that of the SJRIP RiverWare model and runs from 10/1/1928 to 9/30/2013 on a daily timestep. Although the SJRIP RiverWare Historical model is run in RiverWare's "Rulebased Simulation" mode, the model does not use rules to make operational decisions (such as determining reservoir release schedules) as is done in the full SJRIP RiverWare model. Additionally, there is no need for the "Run Cycles" used in the full SJRIP RiverWare model. The limited SJRIP RiverWare Historical model rules are only used to set specific slots to historical values and to make post-processing calculations at the end of the model run. Thus, the simulation completed in the SJRIP RiverWare Historical model is functionally equivalent to RiverWare's basic "Simulation" mode. This means that all necessary information is provided as inputs to the model network and the model solves the remaining unknown network parameters by utilizing RiverWare's object methods and dispatching procedures. Essentially, historical data is used to define all inflows and outflows from each local inflow reach with the sole exception of the local inflow values. During a run, the model then calculates the historical local inflows by solving the mass-balance of each reach.

To achieve this, all input data is set to the model objects at the beginning of a model run by initialization rules. The historical boundary inflows (i.e., San Juan StateMod historical model output) and flow gage data are set as inputs on the appropriate model nodes, the historical Navajo Reservoir data is set to the Navajo Reservoir object, and the historical water user diversion and depletion data is set to the water user objects. Additionally, the various other necessary historical data is set in throughout the model network, including several additional inflows representing return flows from Colorado water users simulated by San Juan StateMod, Navajo Indian Irrigation Project (NIIP) return flows, and the "Ridges Basin Net Depletion" node used to represent the limited operations of the Animas-La Plata (ALP) Project during the model period.

SJRIP RiverWare Historical model runs are conducted on a day by day, chronological order basis in the same way as a SJRIP RiverWare model run. On each timestep, the model objects dispatch and utilize the input data to calculate the day's local inflow in each of the 10 local inflow reaches. The calculated water user return flows based on the input historical diversion and depletion are routed into the future and split between their return locations (if applicable) using the water user object methods and set to the appropriate model slots and timesteps providing the necessary additional data for the model to solve the next timestep. Unlike the SJRIP RiverWare model, which contains multiple "run cycles" and runs through the full model period several times, the SJRIP RiverWare Historical model does not contain run cycles and thus only needs to run through the model period once to generate its final results.

4.3 Similarities and Differences Between the SJRIP RiverWare Historical and SJRIP RiverWare Models

With only a few specific exceptions, the SJRIP RiverWare Historical model's system network is the same as that of the SJRIP RiverWare model. This means that the models objects (or nodes) and links are almost identical between the models. Only a few minor differences are necessary to appropriately represent the historical system and are described below. These differences are either necessary to represent distinct physical changes that have occurred between the historical system and the current system, or to allow for an appropriately simplified representation of the historical network.

Along with a nearly identical model network, corresponding objects in both models use the same "object methods" to simulate specific processes relating to the objects. The most notable example of these object methods are the methods used to spatially divide (or "split") a water user's return flows between return locations and to temporally lag and attenuate (or "route") the return flow generated on a given day through a future period. For each corresponding water user, the same return flow methods are used in both the SJRIP RiverWare Historical and SJRIP RiverWare models. An additional example of the same object method being used in both models is the method and rates used to simulate evaporation on Navajo Reservoir. Just like using the same system network, using consistent object methods helps to ensure that the local inflows calculated within the SJRIP RiverWare Historical model are directly applicable to the SJRIP RiverWare model.

The SJRIP RiverWare Historical model contains the following differences from the SJRIP RiverWare model:

Navajo Reservoir – Navajo Reservoir did not exist throughout the entire model period, but rather was constructed during the period and began storing water in 1962. Nevertheless, the SJRIP RiverWare Historical model network contains the Navajo Reservoir object and the object is simply forced to act as a passthrough reach object with no effect on river flows during the historical period before it existed. This is discussed in more detail in the section below describing the historical Navajo Reservoir dataset.

Animas-La Plata Project – The Animas-La Plata Project was built in the later part of the model period and only limited operations were conducted in the last few years of the model period. Due to the limited operations, the effects of ALP operations on flows in the Animas River can be represented in a simplified fashion within the SJRIP RiverWare Historical model. Thus, the Ridges Basin Reservoir object and the various ALP water users that are present in the SJRIP RiverWare model are not included in the SJRIP RiverWare Historical model and are instead replaced by the "RidgesBasinNetDepletion" reach object, which is used to account for the ALP's net flow effects. This is discussed in more detail in the section below describing the historical ALP dataset.

SJRIP RiverWare Historical Model Only Water User, "AboveArchuleta" – This water user represents an irrigated agricultural area that was largely inundated by Navajo Reservoir. Based on historical data provided by the New Mexico State Engineer, in the period from 1929-1956, the irrigated area was a constant 175 acres. In 1957 the area increased to its maximum of 205 irrigated acres before decreasing to 50 acres during 1958-1962, and then 20 acres from 1963-1976. Beginning in 1977, the area decreased approximately linearly to 0 acres in 1994 and has not had any irrigated area since that year. For the purposes of the historical model, it is assumed that this water user diverted at a node directly downstream of Navajo Reservoir and directly above the Archuleta gage. As it no longer exists, this water user is not present in the SJRIP RiverWare model.

SJRIP RiverWare Historical Model Only Water User, "CudeiHistoric" – This water user is used to account for the fact that the diversion location of the Cudei Canal changed during the model period. Through 2002, the Cudei Canal diversions were made through their own diversion structure from the San Juan River upstream of the Mancos River. That diversion structure was removed following the 2002 irrigation season and beginning in 2003, Cudei received its deliveries through the Hogback canal. Thus, in addition to the "CudeiCanal" water user representing their present diversion location at the Hogback diversion, a "CudeiHistoric" water user is included only in the SJRIP RiverWare Historical model at the approximate river location of their old diversion structure. During the SJRIP RiverWare Historical model simulation, all historical Cudei Canal diversions through 2002 are placed on the "CudeiHistoric" water user, and all historical diversions from 2003 on are placed on the "CudeiCanal" water user. It should be noted that only the diversion location was changed, and not the irrigated area, and thus the return flow methods and locations of both water user objects are the same.

NIIP Return Flow Reaches – The SJRIP RiverWare Historical model uses 3 RiverWare reach objects ("NIIPGallegosReturns", "NIIPAmarilloReturns", and "NIIPChacoReturns") to apply the measured historical surface return flow data from the NIIP irrigated lands that return to the San Juan River at those three locations. These three objects do not exist in the full SJRIP RiverWare model because in that model the NIIP return flows do not use historical data but are simulated dynamically and are directly linked through the NIIP water user and groundwater objects, as described in 5.3.5. Please note, however, that the locations where the NIIP return flows return to the San Juan River are the same between the models.

Some remaining minor network differences between the SJRIP RiverWare Historical model and the SJRIP RiverWare model include:

- The 5 "bypass" diversion objects (BYP_Archuleta, BYP_Farmington, BYP_Shiprock, BYP_FourCorners, and BYP_Bluff) that exist only for specific calculation purposes in the SJRIP RiverWare are not necessary in the SJRIP RiverWare Historical model.
- The NIIP Groundwater objects used in the SJRIP RiverWare model are not present in the SJRIP RiverWare Historical model because observed historical NIIP return flows are used and are assumed to contain both the historical surface water return flows as well as any GW return flows that may have been present as the project has been developing.
- As it did not exist during the SJRIP RiverWare Historical model period, the Navajo-Gallup Water Supply Project's San Juan River diversion structure object is not present in the SJRIP RiverWare Historical model. In the SJRIP RiverWare model, this diversion is simulated with the "NavajoGallupBalance" water user object.
- The 4 SJRIP RiverWare model "unspecified" demand water users are not included in the SJRIP RiverWare Historical model as they do not represent actual water users with historical water uses.
- The SJRIP RiverWare model's "SM Animas SUIT Reserved" water user is not included in the SJRIP RiverWare Historical model as this water user represents future SUIT reserved water uses that did not occur historically.

- The “SupplementalWater” reach used in the SJRIP RiverWare model is not included in the SJRIP RiverWare Historical model because it serves a specific purpose and is not needed.

4.4 Local Inflow Reaches

The SJRIP RiverWare Historical model calculates daily-timestep timeseries of local inflows for 10 local inflow reaches, which are listed initially below. The local inflow names generally correspond to the reach’s downstream flow gage. Subsequently, the mass-balance components of each of the local inflow reaches are shown. Streamflow gages and water user names are further defined later in the documentation.

- San Juan above Navajo Reservoir
- San Juan near Archuleta
- San Juan at Farmington
- San Juan at Shiprock
- San Juan at Four Corners
- San Juan near Bluff
- Animas above Florida
- Animas near Cedar Hill
- Animas at Farmington
- La Plata River

4.4.1 San Juan above Navajo Reservoir Local Inflow Reach

This local inflow reach is used to calculate local inflows that accrue to the San Juan River above Navajo Reservoir below the several upstream tributary gages or directly into Navajo Reservoir. The mass balance components of this local inflow reach are shown in Table 4-1 below.

Table 4-1: Local Inflow Reach Components – San Juan above Navajo Reservoir

Local Inflow Reach Components - San Juan above Navajo Reservoir	
Primary Inflow Node(s)	San Juan River near Carracas, Piedra River near Arboles, Rock Gulch at mouth, Los Pinos River at La Boca, Spring Creek at La Boca
Tributary Inflows to Reach	none
Water User Diversions from Reach	JicarillaNonIr, JicarillaIrr, USNavajoNonIr, USNavajoIrr
Water User Return Flows to Reach[1]	JicarillaNonIr, JicarillaIrr, USNavajoNonIr, USNavajoIrr
Other Components	StateMod Return Flows above Navajo[2]
Primary Outflow Node	*Pre-Navajo Period:* San Juan River near Archuleta *Navajo Reservoir Period:* Model Calculated Navajo Reservoir Inflow
1: Return flow split percentages shown in parenthesis are the total portion of the water user’s return flow that returns within the reach, although it may return to multiple locations within that reach. If not specified, they are 100%. 2: Lumped return flows from upstream San Juan StateMod water users that return to this reach.	

4.4.2 San Juan near Archuleta Local Inflow Reach

This local inflow reach is used to calculate local inflows that accrue to the San Juan River between Navajo Reservoir and the Archuleta gage, which is only ~7 miles downstream of the reservoir. As Navajo Reservoir did not exist prior to 1962, the local inflows before that time are assumed to be 0. Due to the proximity of the Archuleta gage to the reservoir and the very small intervening drainage area, the calculated local inflows once Navajo Dam exists essentially amount only to flow estimation differences between the measured Navajo Reservoir outflow and the flow measured by the Archuleta gage. For these reasons, the local inflows calculated by the SJRIP RiverWare Historical model for this reach are lumped into the San Juan at Farmington reach local inflows during post-processing, and thus the final San Juan near Archuleta local inflows provided to the SJRIP RiverWare model are assumed to be 0 for the full model period. The mass balance components of this local inflow reach are shown in Table 4-2 below.

Table 4-2: Local Inflow Reach Components – San Juan near Archuleta

Local Inflow Reach Components - San Juan near Archuleta	
Primary Inflow Node(s)	*Pre-Navajo Period:* San Juan River near Archuleta (adjusted upstream)[2] *Navajo Reservoir Period:* Navajo Reservoir Outflow
Tributary Inflows to Reach	none
Water User Diversions from Reach	AboveArchuleta
Water User Return Flows to Reach[1]	AboveArchuleta
Other Components	none
Primary Outflow Node	San Juan River near Archuleta
1: Return flow split percentages shown in parenthesis are the total portion of the water user's return flow that returns within the reach, although it may return to multiple locations within that reach. If not specified, they are 100%. 2: For the pre-Navajo period, the Archuleta gage flow is adjusted upstream to right above the "AboveArchuleta" water user's diversion, resulting in 0 calculated local inflow for the whole pre-Navajo period.	

4.4.3 San Juan at Farmington Local Inflow Reach

This local inflow reach is used to calculate local inflows that accrue to the San Juan River between the Archuleta gage and the Farmington gage. This also includes local inflows to the Animas River below the Animas at Farmington gage. The mass balance components of this local inflow reach are shown in Table 4-3 below.

Table 4-3: Local Inflow Reach Components – San Juan at Farmington

Local Inflow Reach Components - San Juan at Farmington	
Primary Inflow Node(s)	San Juan River near Archuleta
Tributary Inflows to Reach	Animas River at Farmington
Water User Diversions from Reach	ArchuletaDitch, CitizenDitch, TurleyDitch, Hammond, DEP_NMU3NonIr, BloomfieldMI, FarmersMutual (on Animas below Farmington gage)
Water User Return Flows to Reach[1]	ArchuletaDitch, CitizenDitch, TurleyDitch, Hammond, DEP_NMU3NonIr, BloomfieldMI *Returns from Animas above Farmington gage WU's:* FarmingtonMI (90%), EchoDitch (85%), DEP_NMU2NonIr
Other Components	NIIPGallegosReturns (NIIP surface return flows)
Primary Outflow Node	San Juan River at Farmington
1: Return flow split percentages shown in parenthesis are the total portion of the water user's return flow that returns within the reach, although it may return to multiple locations within that reach. If not specified, they are 100%.	

4.4.4 San Juan at Shiprock Local Inflow Reach

This local inflow reach is used to calculate local inflows that accrue to the San Juan River between the Farmington gage and the Shiprock gage. This also includes local inflows to the La Plata River below the La Plata near Farmington gage. The mass balance components of this local inflow reach are shown in Table 4-4 below.

Table 4-4: Local Inflow Reach Components – San Juan at Shiprock

Local Inflow Reach Components - San Juan at Shiprock	
Primary Inflow Node(s)	San Juan River at Farmington
Tributary Inflows to Reach	La Plata River near Farmington
Water User Diversions from Reach	FruitlandAndCambridge, SJGeneratingStation, JewettValley, DEP_NMU6NonIr, FourCornersPP, Hogback, CudeiCanal[2], DEP_NMU5NonIr, ShiprockMI
Water User Return Flows to Reach[1]	FruitlandAndCambridge, SJGeneratingStation, JewettValley, DEP_NMU6NonIr, FourCornersPP, Hogback (35%) *Returns from Animas WU's:* FarmingtonMI (10%), FarmingtonGlade, FarmersMutual
Other Components	NIIPAmarilloReturns and NIIPChacoReturns (NIIP surface return flows)
Primary Outflow Node	San Juan River at Shiprock
1: Return flow split percentages shown in parenthesis are the total portion of the water user's return flow that returns within the reach, although it may return to multiple locations within that reach. If not specified, they are 100%. 2: This is the current location of Cudei's diversions (through Hogback Canal), used in 2003 and after.	

4.4.5 San Juan at Four Corners Local Inflow Reach

This local inflow reach is used to calculate local inflows that accrue to the San Juan River between the Shiprock gage and the Four Corners gage. This also includes local inflows to the Mancos River below the downstream-most San Juan StateMod node. The mass balance components of this local inflow reach are shown in Table 4-5 below.

Table 4-5: Local Inflow Reach Components – San Juan at Four Corners

Local Inflow Reach Components - San Juan at Four Corners	
Primary Inflow Node(s)	San Juan River at Shiprock
Tributary Inflows to Reach	Mancos River
Water User Diversions from Reach	DEP_NMU7NonIr, CudeiHistoric[2]
Water User Return Flows to Reach[1]	Hogback (65%), ShiprockMI, CudeiCanal/CudeiHistoric, DEP_NMU7NonIr
Other Components	StateMod Return Flows above Four Corners[3]
Primary Outflow Node	San Juan River at Four Corners
1: Return flow split percentages shown in parenthesis are the total portion of the water user's return flow that returns within the reach, although it may return to multiple locations within that reach. If not specified, they are 100%. 2: This is the historical location of Cudei ditch's diversion, used in 2002 and before. 3: Lumped return flows from upstream San Juan StateMod water users that return to this reach.	

4.4.6 San Juan near Bluff Local Inflow Reach

This local inflow reach is used to calculate local inflows that accrue to the San Juan River between the Four Corners gage and the Bluff gage. This also includes local inflows to McElmo Creek below the downstream-most San Juan StateMod node. The mass balance components of this local inflow reach are shown in Table 4-6 below.

Table 4-6: Local Inflow Reach Components – San Juan near Bluff

Local Inflow Reach Components - San Juan near Bluff	
Primary Inflow Node(s)	San Juan River at Four Corners
Tributary Inflows to Reach	McElmo Creek
Water User Diversions from Reach	UtahIrr
Water User Return Flows to Reach[1]	UtahIrr
Other Components	StateMod Return Flows above Bluff[2]
Primary Outflow Node	San Juan River near Bluff
1: Return flow split percentages shown in parenthesis are the total portion of the water user's return flow that returns within the reach, although it may return to multiple locations within that reach. If not specified, they are 100%. 2: Lumped return flows from upstream San Juan StateMod water users that return to this reach.	

4.4.7 Animas above Florida Local Inflow Reach

This local inflow reach is used to calculate local inflows that accrue to the Animas River between the Animas River below Lightner Creek and the mouth of the Florida River. Initially, the model calculates the local inflows for a longer reach from the boundary inflow node of the Animas River below Lightner Creek to the Animas River at Cedar Hill gage. These calculated local inflows are then distributed to the "Animas above Florida" and "Animas near Cedar Hill" local inflow reaches by simple percentages of 82% and 18% respectively. This procedure is used to move the inflow location of the majority of these local inflows upstream from the Cedar Hill gage in the model so that they may be accessible to water users. The mass balance components of this local inflow reach are shown in Table 4-7 below.

Table 4-7: Local Inflow Reach Components – Animas above Florida

Local Inflow Reach Components – Animas above Florida	
Primary Inflow Node(s)	Animas River below Lightner Creek[2]
Tributary Inflows to Reach	none
Water User Diversions from Reach	SM East Mesa Ditch, SM Animas Ditch
Water User Return Flows to Reach[1]	none[3]
Other Components	StateMod Return Flows to 3001094[4], StateMod Return Flows to 3001023[4]
Primary Outflow Node	Animas River at confluence with Florida River
1: Return flow split percentages shown in parenthesis are the total portion of the water user's return flow that returns within the reach, although it may return to multiple locations within that reach. If not specified, they are 100%. 2: Boundary inflow from San Juan StateMod is the location below Lightner Creek downstream of the Durango gage. 3: Reach contains no return flows simulated by SJRIP RiverWare. 4: Lumped San Juan StateMod return flows to nodes in the "overlapping model area" from upstream StateMod water users, including any return flows from San Juan StateMod water users that are represented within SJRIP RiverWare (RW doesn't model the return flows from these water user objects and instead uses the San Juan StateMod results).	

4.4.8 Animas near Cedar Hill Local Inflow Reach

This local inflow reach is used to calculate local inflows that accrue to the Animas River between the Animas at the mouth of the Florida River and the Cedar Hill gage. Initially, the model calculates the local inflows for a longer reach from the boundary inflow node of the Animas River below Lightner Creek to the Animas River at Cedar Hill gage. These calculated local inflows are then distributed to the "Animas above Florida" and Animas near Cedar Hill" local inflow reaches by simple percentages of 82% and 18% respectively. This procedure is used to move the inflow location of the majority of these local inflows upstream from the Cedar Hill gage in the model so that they may be accessible to water users. The mass balance components of this local inflow reach are shown in Table 4-8 below.

Table 4-8: Local Inflow Reach Components – Animas near Cedar Hill

Local Inflow Reach Components – Animas near Cedar Hill	
Primary Inflow Node(s)	Animas River at confluence with Florida River
Tributary Inflows to Reach	Florida River at mouth
Water User Diversions from Reach	SM Aggregate Diversion
Water User Return Flows to Reach[1]	none[2]
Other Components	StateMod Return Flows to 30_ADS010[3], StateMod Return Flows to 30_ARS005[3]
Primary Outflow Node	Animas River near Cedar Hill
1: Return flow split percentages shown in parenthesis are the total portion of the water user's return flow that returns within the reach, although it may return to multiple locations within that reach. If not specified, they are 100%. 2: Reach contains no return flows simulated by SJRIP RiverWare. 3: Lumped San Juan StateMod return flows to nodes in the "overlapping model area" from upstream San Juan StateMod water users, including any return flows from San Juan StateMod water users that are represented within SJRIP RiverWare (RW doesn't model the return flows from these water user objects and instead uses the San Juan StateMod results).	

4.4.9 Animas at Farmington Local Inflow Reach

This local inflow reach is used to calculate local inflows that accrue to the Animas River between the Cedar Hill gage and the Animas at Farmington gage. The mass balance components of this local inflow reach are shown in Table 4-9 below.

Table 4-9: Local Inflow Reach Components – Animas at Farmington

Local Inflow Reach Components – Animas at Farmington	
Primary Inflow Node(s)	Animas River near Cedar Hill
Tributary Inflows to Reach	none
Water User Diversions from Reach	TwinRocks, Ralston, NMAnimasIrr, AztecMI, FarmingtonMI, DEP_NMU2NonIr, FarmingtonGlade, EchoDitch
Water User Return Flows to Reach[1]	TwinRocks, Ralston, NMAnimasIrr, AztecMI, EchoDitch (15%)
Other Components	none
Primary Outflow Node	Animas River at Farmington
1: Return flow split percentages shown in parenthesis are the total portion of the water user's return flow that returns within the reach, although it may return to multiple locations within that reach. If not specified, they are 100%.	

4.4.10 La Plata River Local Inflow Reach

This local inflow reach is used to calculate local inflows that accrue to the La Plata River between the Colorado-New Mexico state line and the La Plata River near Farmington gage. The mass balance components of this local inflow reach are shown in Table 4-10 below.

Table 4-10: Local Inflow Reach Components – La Plata River

Local Inflow Reach Components – La Plata	
Primary Inflow Node(s)	La Plata River at State Line
Tributary Inflows to Reach	none
Water User Diversions from Reach	LaPlataNonIr, LowerLaPlataIrr
Water User Return Flows to Reach[1]	Pioneer[2], Enterprise[2], LaPlataNonIr, LowerLaPlataIrr
Other Components	none
Primary Outflow Node	La Plata River near Farmington
1: Return flow split percentages shown in parenthesis are the total portion of the water user's return flow that returns within the reach, although it may return to multiple locations within that reach. If not specified, they are 100%. 2: SJRIP RiverWare simulates historical return flows from Pioneer and Enterprise from San Juan StateMod diversions and NMOSE depletions.	

4.5 Local Inflow Post-Processing Procedures

During a SJRIP RiverWare Historical model run, the SJRIP RiverWare Historical model calculates raw daily timestep local inflows using a mass-balance approach based on known or estimated historical data for the components in each defined local inflow reach, with the local inflow term being the only unknown. For this reason, the local inflow terms serve as "catchalls" and will contain the effects of various data and model uncertainties including data errors such as streamflow gage errors, uncertainty associated with filled/extended historical gage flows, flow travel times, and incorrect estimations of the basin water users' historical diversions, depletions, and return flows, as well as the locations of the historical diversions and return flows. Due to both the quantity and quality of the historical data available, these types of issues can present significant uncertainties, however, the historical data used has undergone substantial QA/QC and is considered the best available.

When these types of issues are internal to the system, they often cause "offsetting" local inflow values that can be corrected using appropriate post-processing techniques. For example, an errantly high flow value at the San Juan at Shiprock gage can cause a high positive local inflow value for the reach above the gage alongside a corresponding and opposite negative local inflow value in the reach below the gage. When uncorrected, these types of issues can cause significant issues in the simulation and results of the SJRIP RiverWare model runs. For example, errantly high day-to-day variability in local inflows can cause simulated Navajo Reservoir releases with similarly high day-to-day variability, but that are unrealistic when compared to observed typical Navajo Reservoir releases.

Issues and uncertainties associated with the calculated local inflows are accounted for in the SJRIP RiverWare Historical model by applying both spatial and temporal smoothing and redistribution techniques to the calculated raw local inflows at the end of the SJRIP RiverWare Historical model run. It is important to note that these methods always conserve mass, which means that the overall calculated local inflow volumes to the system are maintained and that no water is made or lost during the post-processing. The methods were developed with the overall objective of minimizing the amount of post-processing necessary while creating a set of daily timestep local inflows that reasonably approximate the timing and magnitudes of actual gains and losses to the San Juan system. An example of raw and final post-processed daily calculated local inflows is shown below in Figure 4-1. Additionally, the resulting calculated local inflows, including average annual patterns by node, are discussed in Appendix F to this documentation.

The local inflow post-processing procedure applied by the SJRIP RiverWare Historical model is as follows. These steps are applied in order and each subsequent step uses the adjusted values calculated by the previous steps.

1. Raw daily timestep local inflows at each local inflow node are calculated by a direct reach mass-balance approach.
2. A three (3) day running average is applied to each daily local inflow timeseries.
3. San Juan near Archuleta local inflows are combined with San Juan at Farmington local inflows as discussed above in Section 4.4.2.
4. If either San Juan at Shiprock or San Juan at Four Corners daily local inflows are negative, their daily average is applied to both nodes.
5. If San Juan at Farmington daily local inflow is positive and San Juan at Shiprock is negative, their daily average is applied to both nodes.
6. If San Juan at Farmington daily local inflow is positive and San Juan at Four Corners is negative, their daily average is applied to both nodes.
7. If San Juan at Bluff daily local inflow is positive and San Juan at Four Corners is negative, their daily average is applied to both nodes.
8. If San Juan at Bluff daily local inflow is positive and San Juan at Shiprock is negative, their daily average is applied to both nodes.
9. For each local inflow node, monthly averages are calculated for each month of the full period, and if a monthly average is negative, each daily value for that month is set to the monthly average value. If the monthly average is positive, the values are left unchanged, including any negative daily flows within that month.
10. A final 15-day running average is applied to all local inflow nodes for the full period.

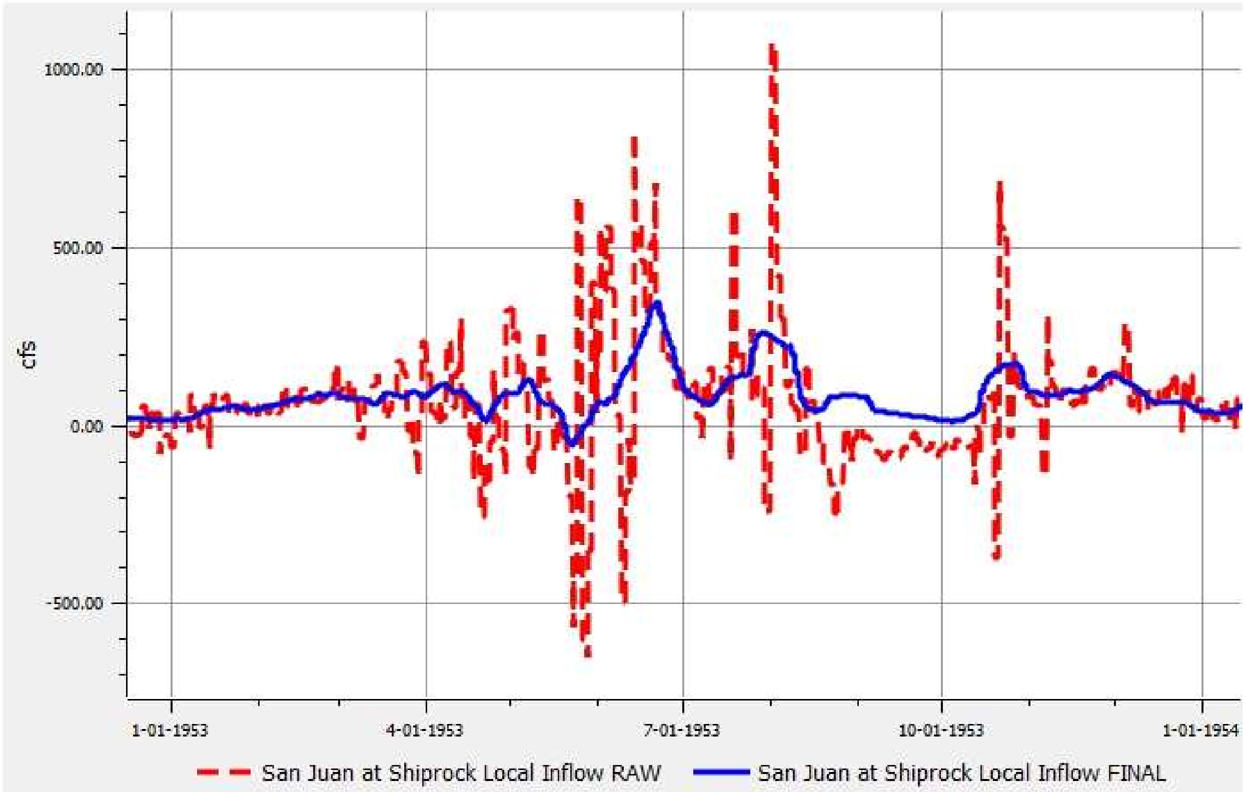


Figure 4-1: Example of Post-Processing Effects on Calculated Local Inflows

4.6 Historical Datasets and Use Within the SJRIP RiverWare Historical Model

4.6.1 San Juan StateMod Historical Model Data

Various data from the San Juan StateMod historical model output is utilized within the SJRIP RiverWare Historical model. The specific data used and mentioned generally below is discussed in more detail in the San Juan StateMod section of the SJBHM documentation.

Output from the San Juan StateMod historical Scenario is used to provide the historical boundary inflows to the SJRIP RiverWare Historical model in the same way and to the same nodes that it is for the SJRIP RiverWare model. The San Juan StateMod historical monthly flow volumes are disaggregated to daily flows using ratios calculated from the historical daily streamflow dataset (discussed next). San Juan StateMod's historical data and results are used for all the system's water users in Colorado and their uses and effects are reflected in the boundary inflows. Within the SJRIP RiverWare model, San Juan StateMod simulated historical diversions are applied for the 3 Colorado water users ("SM East Mesa Ditch", "SM Animas Ditch", and "SM Aggregate Diversion") that exist in the "overlapping model area" on the Animas River. Similarly, the San Juan StateMod calculated historical return flows from upstream San Juan StateMod water users to various nodes within the boundaries of the SJRIP RiverWare Historical model are also applied. Both the San Juan StateMod diversions and return flows are applied on a simple monthly average flow basis.

The historical data for the Enterprise and Pioneer water users on the La Plata River present a special case that requires additional adjustments because the historical diversion data comes from the San Juan StateMod historical output, but the historical depletion data is provided by New Mexico. This occurs because these water users divert in Colorado to irrigated lands in New Mexico. To account for this disparity, the monthly historical depletions from New Mexico are "repatterned" to correspond to the monthly historical diversions from San Juan StateMod. This enables the SJRIP RiverWare Historical model to appropriately simulate the historical return flows from these water users.

4.6.2 Streamflow Data

Available historical streamflow data was obtained for streamflow gages throughout the San Juan River system from USGS. The 18 most relevant gages to the SJRIP RiverWare model and their periods of record are shown in Table 4-11 below. Of these 18 gages, only 3 have complete daily flow records for the entire, 85-year model period (10/1/1928-9/30/2013): Animas River at Durango, La Plata River at Colorado-New Mexico State Line, and San Juan River near Bluff (the Bluff gage is missing data only for October 1928, the first month of the model period). Additionally, both the Animas River and San Juan River at Farmington gages are missing only the first 2 years of the period. Unfortunately, many important flow gages throughout the system do not have data for large portions of the model period. This is often because the gages were not installed until later dates. For example, the records for the San Juan River at Archuleta gage and the several gages on the various tributaries that make up Navajo Reservoir's inflow, don't begin until the 1950s/60s.

The limited historical daily flow data at important streamflow gages presents a significant source of uncertainty to various aspects of the SJBHM. The issues relating to missing data and the use of filled and extended data (discussed next) cause less overall uncertainty for "internal" gages (i.e., those not at the model's upstream or downstream boundaries) than for boundary gages, as uncertainty at internal gages will only affect the distribution of the calculated local inflows rather than the overall volumes.

Due to the limited periods of record of many important gages, extensive data filling and extending was required for many of the system's streamflow gages as complete streamflow data records are required for many gages for the entire model period. The USGS Streamflow Record Extension Facilitator (SREF) application was used for this purpose. SREF allows for efficient filling and extension of missing streamflow gage data using various regression techniques based on hydrologically similar analog (or "index") stations. The SREF program also facilitates the selection of suitable index stations based on the correlation of overlapping data periods. The SREF program was used to generate complete daily flow records for each of the gages in Table 4-11 with incomplete data. It should be noted that index gages were selected from the complete set of available gages and not only those shown in the table. Furthermore, care was taken during this process to select appropriate index gages and time periods that did not contain major physical changes or differences from the site being filled, such as the presence or construction of significant upstream reservoirs.

Historical streamflow gage data is used in two distinct ways in the SJRIP RiverWare Historical model.

- At the boundary inflow nodes, monthly San Juan StateMod historical model flows are used instead of the developed daily historical flows. These monthly flows are, however, patterned to daily flows by the patterns of the developed daily flows. Monthly San Juan StateMod historical

flows are used because the periods of missing historical gage flows are estimated by the StateMod historical model with different methods such as mass-balance calculations or more advanced filling and extending procedures and thus it is assumed that the San Juan StateMod methods will produce better estimates of historical flows than the SREF methods. Actual historical daily gage flow data is used within San Juan StateMod on an aggregated monthly flow basis wherever it exists. The boundary inflow nodes using San Juan StateMod's historical monthly flows patterned to daily flows are:
    - San Juan River near Carracas
    - Piedra River near Arboles
    - Rock Gulch at mouth
    - Los Pinos River at La Boca
    - Spring Creek at La Boca
    - Animas River below Lightner Creek
    - Florida River at mouth
    - La Plata River at Stateline
    - Mancos River at mouth
    - McElmo Creek at mouth
- For the SJRIP RiverWare model's "internal" streamflow gage nodes, as well as for the downstream-most model node, the developed historical daily flow data records are used directly as inputs. This forces the simulated flows at these locations to historical values and enables the model to solve for the system's local inflows. Developed historical daily flows are used at the following SJRIP RiverWare Historical model nodes:
    - San Juan River near Archuleta
    - San Juan River at Farmington
    - San Juan River at Shiprock
    - San Juan River at Four Corners
    - San Juan River near Bluff
    - Animas River near Cedar Hill
    - Animas River at Farmington
    - La Plata River near Farmington

Table 4-11: Major Streamflow Gages within Model Extent and Historical Periods of Record.

USGS Gage ID	Gage Name	Period of Record[1]
09346400	San Juan River near Carracas, CO	11/1/1961 – Present
09349800	Piedra River near Arboles, CO	9/1/1962 – Present
09354500	Los Pinos River at La Boca, CO	1/1/1951 – Present
09355000	Spring Creek at La Boca, CO	1/1/1951 – 9/30/2011
09355500	San Juan River near Archuleta, NM	12/01/1954 – Present
09361500	**Animas River at Durango, CO**	10/1/1928 – Present
09362000	Lightner Creek near Durango, CO	10/1/1928 – 9/30/1949
09363200	Florida River at Bondad, CO	10/1/1956 – 9/30/1983
09363500	Animas River near Cedar Hill, NM	11/1/1933 – Present
09364500	Animas River at Farmington, NM	10/1/1930 – Present
09365000	San Juan River at Farmington, NM	10/1/1930 – Present
09366500	**La Plata River at CO-NM State Line**	10/1/1928 – Present
09367500	La Plata River near Farmington, NM	3/1/1938 – Present[2]
09368000	San Juan River at Shiprock, NM	10/1/1934 – Present
09371000	Mancos River near Towaoc, CO	10/1/1928 – Present[3]
09371010	San Juan River at Four Corners, CO	10/1/1977 – Present
09372000	McElmo Creek near CO-UT State Line	3/1/1951 – Present
09379500	**San Juan River near Bluff, UT**	11/1/1928 - Present

Bold gages are those with ~full periods of record through the model period.
1: Periods of record reported in this table begin at the start of the model period (10/1/1928). Some gages have records that extend before 10/1/1928.
2: Missing 10/1/2003 – 6/7/2005.
3: Missing 10/1/1943 – 3/31/1951.

4.6.3 New Mexico Agricultural Water Users

Historical data for the system's New Mexico agricultural water users (or "irrigated areas") in New Mexico was provided by the New Mexico Office of the State Engineer (NMOSE). Table 4-12 shows these irrigated areas and the corresponding SJRIP RiverWare water users. As noted in the table, a few minor differences exist between the NMOSE defined irrigated areas and the SJRIP RiverWare model water users and are accounted for by appropriately combining or splitting the provided data to match the SJRIP RiverWare water users.

The provided data includes the historical annual irrigated acreages for each year from 1929-2014, the breakdown of irrigation methods (flood vs. sprinkler vs. drip irrigation) and estimated historical monthly total depletions. The historical total monthly depletions are broken down to incidental depletions and crop irrigation requirement (CIR) depletions estimated by the NMOSE's Blaney-Criddle ET model. These historical depletions are also dependent on the historical crop mixes of the irrigated lands.

Based on the provided historical irrigation method breakdowns, the historical annual efficiencies are estimated for each of these water users. These efficiencies are then applied to the monthly depletion volumes to calculate corresponding monthly historical diversion volumes. These calculations are completed outside of the SJRIP RiverWare Historical model and the monthly historical diversion and depletion volumes are then imported into the model.

Within the SJRIP RiverWare Historical model, at the beginning of the model run, these monthly volumes are disaggregated to daily diversion and depletion flows using a custom monthly to daily disaggregation technique that produces smoothed daily series without steps between months while maintaining the original monthly volumes. Example results of this technique are illustrated below in Figure 4-2.

Table 4-12: NMOSE Provided New Mexico Irrigated Areas and Corresponding SJRIP RiverWare Water Users.

New Mexico Irrigated Area[1]	**SJRIP RiverWare Water User**	**Notes**
Pine River Area	USNavajoIrr	
Dulce Area	JicarillaIrr	
Animas above Animas R. at Farmington Gage	NMAnimasIrr	This single area for which data is provided by NM is represented by the 3 distinct RW water users. The provided historical depletions are split by historical acreage percentages between the 3 areas.[3]
	Ralston	
	TwinRocks	
Above Archuleta	AboveArchuleta	This water user is only present in the SJRIP RiverWare Historical model as the last year of irrigation was 1993.
Citizens Ditch	CitizenDitch	
Archuleta Ditch	ArchuletaDitch	
Turley Ditch	TurleyDitch	
Hammond Area	Hammond	
Echo Area	EchoDitch	
Upper La Plata River Area[2]	Enterprise	This single area for which data is provided by NM is represented by the 2 distinct RW water users. The provided historical depletions are split by historical acreage percentages between the 2 areas.[3]
	Pioneer	
La Plata River Area[2]	LowerLaPlataIrr	
Farmington Glade	FarmingtonGlade	
Farmers Mutual Ditch	FarmersMutual	
Jewett Valley	JewettValley	
Fruitland	FruitlandAndCambridge	These two areas are combined to a single water user in RW.
Cambridge		
Hogback East	Hogback	These two areas are combined to a single water user in RW.
Hogback West		
Cudei	CudeiCanal	Cudei's changed diversion location (beginning in 2003) is represented in the SJRIP RiverWare Historical model.

1: New Mexico irrigated areas as defined by the NMOSE.
2: Historical depletions of the La Plata River irrigated areas are reduced ("shorted") based on monthly La Plata River flows by the NMOSE. Provided historical depletions for all other areas assume full supply.
3: Further breakdown of historical acreages between water users was available in old SJBHM datasets.
Additionally, for the purposes of the SJBHM, the Chaco River, Whiskey Creek, and Red Wash irrigated areas are considered off-stream water users and are not explicitly represented in the SJRIP RiverWare models. Thus, the historical net effects of these irrigated areas on San Juan River flows are implicitly included within the calculated local inflows and are assumed to be the same in the SJRIP RiverWare model as they were historically.

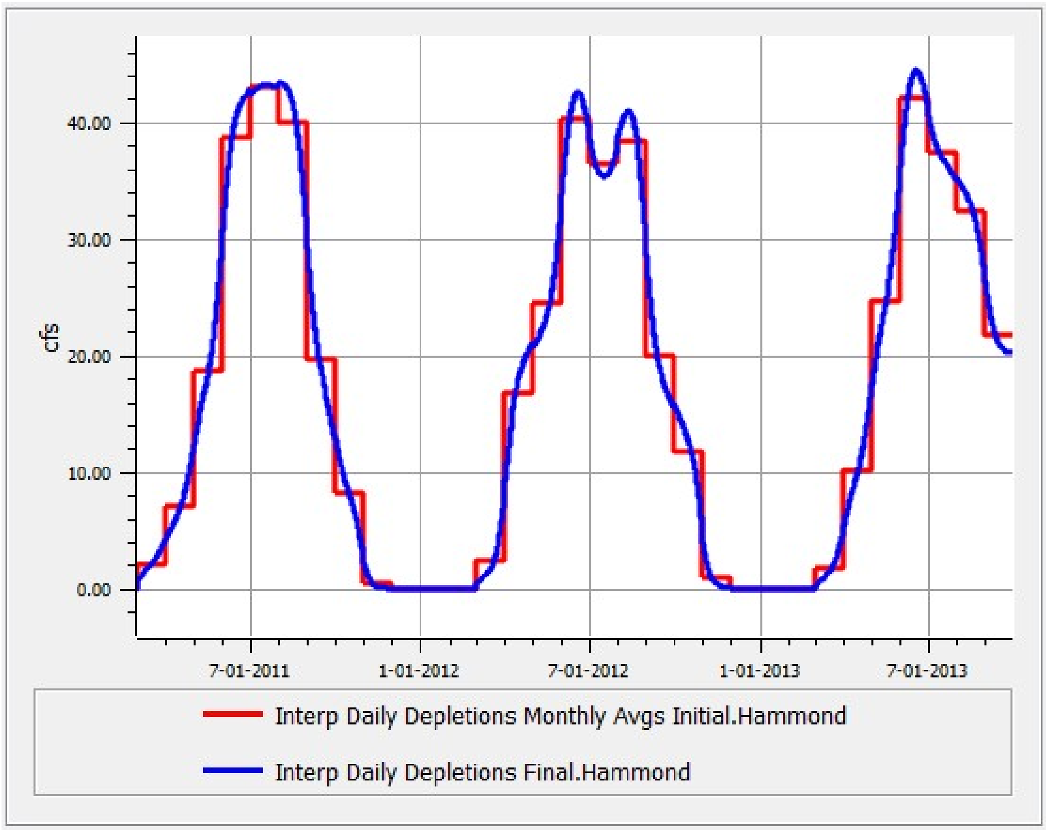


Figure 4-2: Illustration of Monthly to Daily Disaggregation Technique Used for New Mexico Agricultural Water Users.

4.6.4 New Mexico Non-Agricultural Water Users

The SJRIP RiverWare Historical model's non-agricultural water users in New Mexico are shown in Table 4-13.

Historical data for the system's New Mexico non-agricultural water users relies on several data sources, but primarily the Colorado River Basin's Consumptive Uses and Losses (CU&L) reports and supporting data. These reports are produced by Reclamation every 5 years and are available from the Reclamation Upper Colorado Region website under Environmental Documents, Plans and Reports (https://www.usbr.gov/uc/envdocs/plans.html). CU&L data is reported as annual volumes and summarized to 8 reporting categories: Fish and Wildlife, Livestock, Stockpond, Mining, Power, Urban and Rural, Municipal, and Small Reservoir Evaporation.

CU&L data is utilized for all New Mexico non-irrigation water users with the exception of the two power plants, the San Juan Generating Station and the Four Corners Power Plant. Historical power plant data was provided by the NMISC and the power companies and was backed out of the CU&L data to prevent double counting. The categorized New Mexico CU&L depletions are distributed between 8 hydrologic "units" for the purposes of the SJBHM using spatial distribution factors developed during Gen 2 and Gen 3 SJBHM development. Similarly, developed temporal distribution factors are used to disaggregate the annual CU&L data to monthly timesteps.

Because CU&L data is only available back to 1981, the distributed CU&L data was extended back in time through water year 1929 to cover the full model period. All CU&L categories aside from M&I and power were assumed to be the same as 1981 levels. 1929-1980 M&I uses were prorated based on historical populations.

The NM CU&L units used within the SJBHM are described briefly below. These units were defined in early SJBHM development (Gen 2 or prior).

- NM Unit 1 (“USNavajoNonIr”): This unit represents the area of the San Juan basin within New Mexico above Navajo Reservoir. It is now called USNavajoNonIr in the SJRIP RiverWare models. The CU&L data are adjusted for the JicarillaNonIr depletions that are within this area but represented separately within the model.
- NM Unit 2: This unit represents the area of the Animas basin within New Mexico above the confluence with the San Juan River. The cities of Aztec and Farmington are within this unit and are separated out of the CU&L data so they can be represented individually.
- NM Unit 3: This unit represents the area of the San Juan basin along the mainstem San Juan River within New Mexico between Navajo Reservoir and the Farmington gage. The city of Bloomfield is within this unit and is separated out of the CU&L data so it can be represented individually.
- NM Unit 4 (“LaPlataNonIr”): This unit represents the area of the La Plata basin within New Mexico above the confluence with the San Juan. It is now called LaPlataNonIr in the SJRIP RiverWare models.
- NM Unit 5: This unit is considered an offstream depletion, see next paragraph.
- NM Unit 6: This unit represents the area of the San Juan basin along the mainstem San Juan River within New Mexico between the Farmington and Shiprock gages. The city of Shiprock is within this unit and is separated out of the CU&L data so it can be represented individually.
- NM Unit 7: This unit represents the area of the San Juan basin along the mainstem San Juan River within New Mexico between the Shiprock and Four Corners gages.
- NM Unit 8: This unit is considered an offstream depletion, see next paragraph.

NM depletion unit 5 (Chaco Wash area) and unit 8 (Whiskey Creek area) are currently considered offstream depletions, which are depletions that occur within an ungaged or otherwise not explicitly simulated stream reach. These depletions are incorporated into the SJBHM implicitly within the calculated local inflows, i.e., they are not accounted for explicitly in the SJRIP RiverWare Historical model and thus their net depletion effects are present within the calculated local inflows used in the SJRIP RiverWare model, where they are also not accounted for explicitly. This same process used to incorporate other offstream depletions within the SJBHM.

These historical data sources and processes are consistent with those used in Gen 2 and Gen 3 of the SJBHM however they have not been explicitly reviewed during Gen 4 model and data development and updates. It is recommended that these sources and processes be thoroughly reviewed as resources are available to ensure that the best available data is being used.

Table 4-13: SJRIP RiverWare Historical Model New Mexico M&I and Non-Agricultural Water Users and Data Sources.

Water User	Historical Data Sources	Notes
JicarillaNonIr	Provided by Jicarilla	Historical depletions began in 1992.
USNavajoNonIr	CU&L	Equivalent to NMU1.
DEP_NMU3NonIr	CU&L	
BloomfieldMI	CU&L	Separated out of NMU3.
AztecMI	CU&L	Separated out of NMU2.
FarmingtonMI	CU&L	Separated out of NMU2.
DEP_NMU2NonIr	CU&L	
LaPlataNonIr	CU&L	Equivalent to NMU4.
SJGeneratingStation	Provided by NMISC and power plants	
DEP_NMU6NonIr	CU&L	
FourCornersPP	Provided by NMISC and power plants	
ShiprockMI	CU&L	Separated out of NMU6.
DEP_NMU7NonIr	CU&L	
UtahIrr[1]	CU&L	
1: The Utah irrigation node is simulated with the same basic procedures and is included in this category for convenience. These depletions are located on the San Juan River in Utah between the Four Corners gage and the Bluff gage.		

4.6.5 Navajo Indian Irrigation Project (NIIP)

NIIP operations began in 1976 and have increased steadily as the project has been built and more irrigated acreage has been brought online. The maximum irrigated acres during the model period was in the last year, 2013, at 71,444 acres. The full NIIP planned buildout of 110,630 acres is expected to occur by 2040.

There are two sources of NIIP data used in the SJRIP RiverWare Historical model. Daily historical NIIP diversions from Navajo Reservoir were obtained from Reclamation and are used in the SJRIP RiverWare Historical model as part of the Navajo Reservoir dataset. Additionally, monthly historical NIIP data was provided by the Navajo Nation through Keller-Bliesner Engineering for the period of 1976-2015. When aggregated, the Reclamation provided daily NIIP diversion values agree well with the monthly diversion values. The only NIIP monthly data from this source used within the SJRIP RiverWare Historical model are the monthly return flows at the three return locations of Gallegos, Ojo Amarillo, and Chaco. These return flows are applied in the SJRIP RiverWare Historical model as simple monthly averages.

4.6.6 Navajo Reservoir

Historical Navajo Reservoir data was provided by Reclamation. Data for Navajo Reservoir begins following its construction when it began filling in the beginning of July 1962 and the first day of outflow data is July 2, 1962. Thus, within the SJRIP RiverWare Historical model's simulation, there are two distinct periods regarding the representation of Navajo Reservoir.

- ***"Pre-Navajo Reservoir Period"***: 10/1/1928 – 7/1/1962
- ***"Navajo Reservoir Period"***: 7/2/1962 – 9/30/2013

During the ***"Pre-Navajo Reservoir Period"***, the reservoir is assumed to be empty with zero storage, surface area, and reservoir evaporation prior to this date. This is by setting the Navajo Reservoir Pool Elevation to 5774 ft on all prior dates which represents the zero storage and surface area values of both the Elevation-Volume and Elevation-Surface Area tables. During this pre-reservoir period (10/1/1928 - 7/1/1962) the outflow of the Navajo Reservoir object is calculated during the model run by adjusting the flow at the San Juan River near Archuleta gage upstream to a river location directly above the "Above Archuleta" water user by accounting for that water user's historical diversion and return flow. During this period the Navajo Reservoir object's inflow and outflow are both assumed to be equal to this flow and thus the model object simply acts as simple reach with no reservoir effects representing the historical river flow directly above this water user.

In the ***"Navajo Reservoir Period"***, once the reservoir existed historically, the historical data for Navajo Reservoir is utilized by the model to drive the reservoir's simulation to historical conditions. To achieve this, the daily pool elevations, reservoir outflows, and NIIP diversions are set to their historical values and the model calculates the remaining reservoir parameters during the model run. The historical pool elevation data is used to eliminate potential issues in the historical storage data due to changing elevation-volume curves. From the historical daily pool elevations, the model calculates the corresponding daily storages, surface areas, evaporation, and the historical total reservoir inflows. Navajo Reservoir's physical characteristics, i.e., the elevation-volume, elevation-surface area, and evaporation rate tables, are the same between the SJRIP RiverWare Historical and SJRIP RiverWare models. The model's simulation of historical Navajo Reservoir conditions can be validated by comparing the model calculated inflows to the historical inflows from the Reclamation data. Figure 4-3 shows the excellent agreement between the SJRIP RiverWare Historical model calculated monthly reservoir inflow volumes and the monthly inflow volumes from the historical Reclamation data, as evidenced by a slope of 0.9996 and an R^2 of 0.9999.

The historical Navajo Reservoir dataset is housed in the "HistoricReclamationData.xlsx" workbook. Within the SJRIP RiverWare Historical model, the data is contained in daily series slots in the "DailyFilledHistoricStreamflows" object.

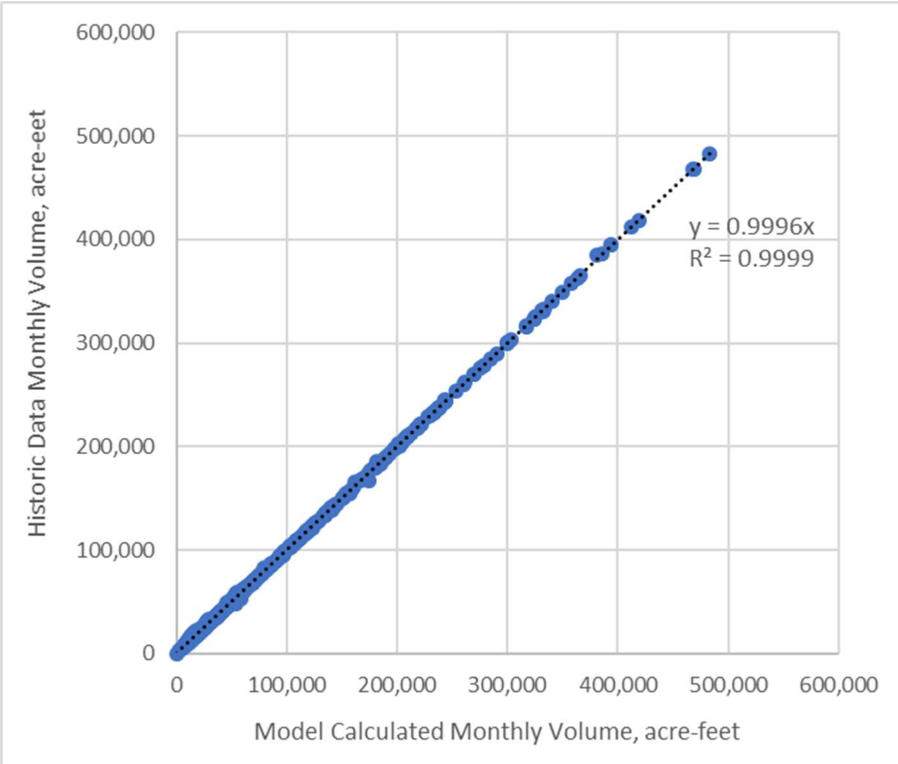


Figure 4-3: Comparison of Historical Navajo Reservoir Monthly Inflow Volumes, Modeled vs. Calculated.

4.6.7 Animas-La Plata Project

Historical data for the Animas-La Plata Project (ALP) and Ridges Basin Reservoir was provided by Reclamation. Full ALP operations did not occur during the model period, however initial ALP pumping from the Animas River through the Durango Pumping Plant to fill Ridges Basin Reservoir began in 2009 and continued in an on and off fashion through 2011 when the reservoir first neared full capacity. Additionally, except for a few days of releases in 2012, there were no significant releases to the Animas River or other diversions from Ridges Basin Reservoir made during the model period. These initial operations are shown below in Figure 4-4.

Due to the limited ALP operations during the model period and to help simplify the representation, Ridges Basin Reservoir and the ALP project components are not explicitly represented within the SJRIP RiverWare Historical model. Instead, the historical ALP data is used to calculate a daily timeseries of the historical net effect of the ALP operations on the flow in the Animas River. This net effect is called the "Ridges Basin Net Depletion" in the SJRIP RiverWare Historical model. These calculations are done outside of the SJRIP RiverWare model and the final daily timeseries is imported into the model. During a model run, the Ridges Basin Net Depletion is simply applied as an input on the "RidgesBasinNetDepletion" reach object directly downstream of the Animas River below Lightner Creek boundary inflow node. This net effect adjusts the model's Animas River flow to account for the historical ALP pumping and Ridges Basin Reservoir operations. Including the historical ALP operations in the SJRIP RiverWare Historical model's simulation ensures that the historical effects are not implicitly contained within the calculated local inflows, and thus enables the subsequent simulation of ALP Project operations in the SJRIP RiverWare model.

The daily Ridges Basin Net Depletion calculations and the historical ALP data are contained in the “ALPHistoricData.xlsx” workbook. Within the SJRIP RiverWare Historical model, the Ridges Basin Net Depletion timeseries is imported to the “Historical Model Data.RidgesBasinNetDepletion” slot and set to the “RidgesBasinNetDepletion.Local Inflow” reach object and slot by an Initialization Rule at the beginning of the model run.

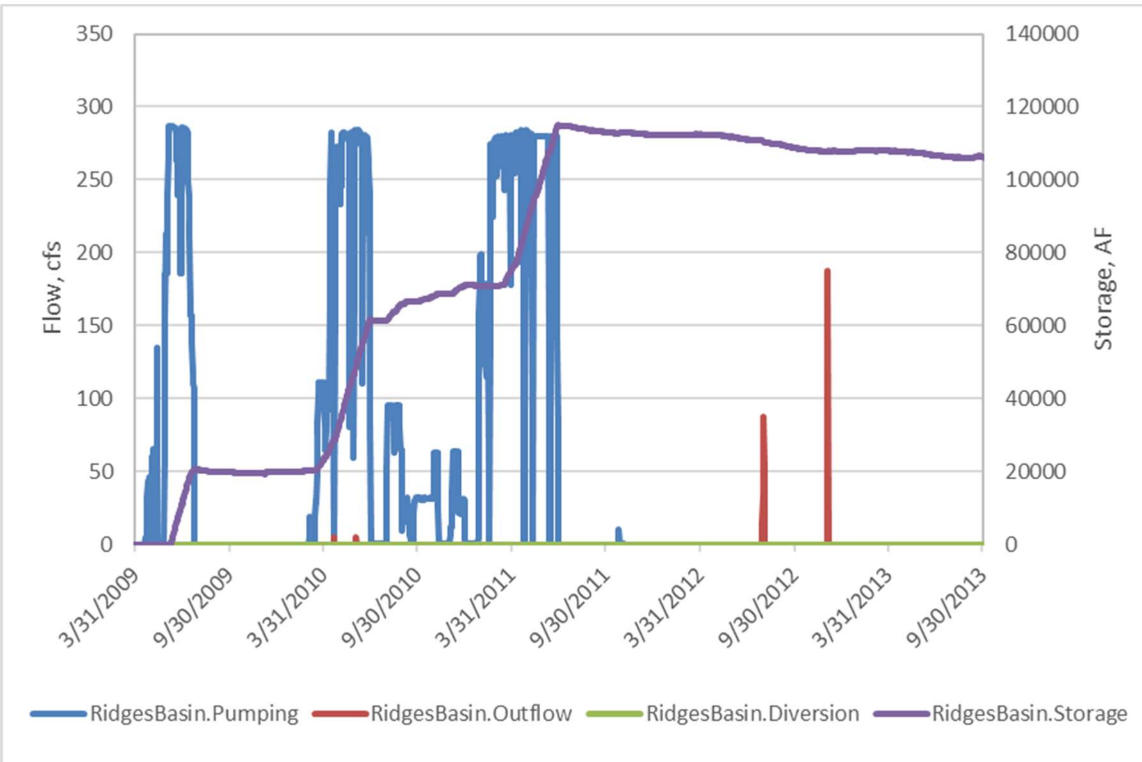


Figure 4-4: Historical Ridges Basin Reservoir Operations during the Model Period.

4.7 SJRIP RiverWare Historical Model Data Management Interfaces (DMIs)

4.7.1 Input DMIs

The SJRIP RiverWare Historical model contains 6 input DMIs that are used to pull the necessary historical data from several Excel workbooks into the model.

- ***DailyFilledHistoricFlows*** – This input DMI pulls the filled and extended historical streamflow gage data from the “SanJuanFilledHistoricData.xlsx” workbook into the “DailyFilledHistoricStreamflows” data object. This DMI also includes the historical Navajo reservoir and NIIP diversion data. This data is on a daily timestep.

- ***NIIPHistoricReturns*** – This input DMI pulls the historical NIIP return flow data from the "NIIPHistoricReturnFlows.xlsx" workbook into the "NIIPMonthlyReturns" data object for the 3 NIIP return flow nodes. This data is on a monthly timestep.
- ***NMMonthlyDepletionRequests*** – This input DMI pulls the historical New Mexico depletion request data from the "AZNMUTHistoricDepletionDataMONTHLY.xlsx" workbook into the "MonthlyHistoricDepletions" data object. This data is on a monthly timestep.
- ***NMMonthlyDiversionRequests*** – This input DMI pulls the historical New Mexico diversion request data from the "AZNMUTHistoricDepletionDataMONTHLY.xlsx" workbook into the "MonthlyHistoricDiversions" data object. This data is on a monthly timestep.
- ***RidgesBasinNetDepletion*** – This input DMI pulls the historical Animas-La Plata Project net depletion data from the "ALPHistoricData.xlsx" workbook into the "Historical Model Data" data object. This data is on a daily timestep.
- ***StateModHistoricMonthlyInputs*** – This input DMI pulls the required San Juan StateMod historical scenario model output from the "SanJuan_Historic_StateMod.xlsx" workbook into the "StateModHistoricMonthlyInputs" data object. This data is on a monthly timestep.

4.7.2 Output DMIs

The SJRIP RiverWare Historical model contains only one output DMI.

- ***DailyModelLocalInflows*** – This DMI outputs the 10 timeseries of calculated, post-processed daily timestep local inflows to the "SJRHBM_LocalInflows.xlsx" workbook. From there, they can be read into the SJRIP RiverWare model via an input DMI.

5 SJRIP RiverWare Model

5.1 Introduction

The SJRIP RiverWare model is the primary component of the San Juan Basin Hydrology Model (SJBHM). The SJRIP RiverWare model simulates the mainstems of the San Juan and Animas Rivers primarily in New Mexico but also includes the Animas River below Durango in Colorado and the lower portion of the San Juan River in Utah above the Bluff gage. It also simulates short portions of the several Navajo Reservoir inflow tributaries between the downstream most gages and the reservoir, as well as the La Plata River from the Colorado-New Mexico state line to the San Juan River. The daily timestep model simulates the operations of Navajo Reservoir, including recovery program releases, flood control releases, and deliveries to both agricultural and municipal water users including the Navajo Indian Irrigation Project (NIIP) and Navajo-Gallup Water Supply Project (NGWSP). The model also simulates Animas-La Plata Project (ALP) operations on the Animas River.

As summarized in Section 2 of this documentation, the SJRIP RiverWare model has several different configurations as part of the SJBHM. It can simulate the system under alternative operational scenarios, discussed below in Section 5.5, as well as different water user demand scenarios, discussed in 5.6. Within a given model scenario, the basin's infrastructure, policy, and operations are assumed to exist in a static sense throughout the full model run. The current version of the SJRIP RiverWare model is referred to as the fourth-generation (or Gen 4) model. The version history has been discussed previously.

5.2 Model Run Period and Input Hydrology

The SJRIP RiverWare model is run on a daily timestep with a period of 10/1/1928 to 9/30/2013. The input hydrology (or system inflows) used by the model comes from the State of Colorado's San Juan StateMod model and the SJRIP RiverWare Historical model, which are each described in detail in previous sections.

The SJRIP RiverWare model's boundary inflows come from the San Juan StateMod model and represent the streamflow that enters the mainstem system simulated by the SJRIP RiverWare model at 10 primary inflow locations, which are shown below in Table 5-1 with basic descriptions. These nodes are discussed further in Section 3.7.1 of this documentation. The boundary inflows are depleted and regulated flows (in contrast to natural flows), and reflect the water uses and effects of reservoirs and other system operations above the inflow location, as simulated by San Juan StateMod. The boundary inflow data utilized for a given SJRIP RiverWare model run can vary and comes from the appropriate, corresponding San Juan StateMod scenario configuration. There are currently two main boundary inflow datasets used to drive the SJRIP RiverWare model, the "Baseline with Tribal Reserved Scenario", which is used for the "baseline" demand scenario, and the "Baseline without Tribal Reserved Scenario", which is used for the "current conditions" demand scenario. As San Juan StateMod is run on a monthly timestep, the monthly boundary inflow volumes are disaggregated to daily flows using monthly-to-daily patterns developed from appropriate historical flow gage records.

The SJRIP RiverWare model's local inflows come from the SJRIP RiverWare Historical model configuration and represent the net flow gains and losses that accrue to the river system that are not contained in the boundary inflows or otherwise represented explicitly in the model. There are 10 local inflow nodes in the model, which are presented in Section 4.4. There is a single local inflow dataset calculated within the SJRIP RiverWare Historical model that is used for all model scenarios.

Table 5-1: SJRIP RiverWare Model Input Hydrology Nodes

Boundary Inflow Nodes	**Description**
San Juan near Carracas	Mainstem flow of the San Juan River into Navajo Reservoir
Piedra River at mouth	Flow from the Piedra River into Navajo Reservoir
Rock Gulch at mouth	Flow from Rock Gulch into Navajo Reservoir
Los Pinos River at La Boca	Flow from the Los Pinos River into Navajo Reservoir
Spring Creek at La Boca	Flow from Spring Creek into Navajo Reservoir
Animas River at Durango	Mainstem flow of the Animas River at Durango
Florida River at mouth	Flow from the Florida River at its confluence with the Animas
La Plata River at state line	Flow of the La Plata River at the CO-NM state line
Mancos River at mouth	Flow of the Mancos River at its confluence with the San Juan
McElmo Creek at mouth	Flow of McElmo Creek at its confluence with the San Juan
Local Inflow Nodes	**Description**
San Juan above Navajo Res	Accruals to Navajo Reservoir below the 5 upstream boundary inflows
San Juan near Archuleta	Accruals to the San Juan River (SJR) between Navajo Reservoir and the Archuleta gage
San Juan at Farmington	Accruals to the SJR between the Archuleta and Farmington gage
San Juan at Shiprock	Accruals to the SJR between the SJ Farmington and Shiprock gage
San Juan at Four Corners	Accruals to the SJR between the Shiprock gage and Four Corners gage
San Juan near Bluff	Accruals to the SJR between the Four Corners gage and Bluff gage
Animas above Florida	Accruals to the Animas between the Durango gage and Florida River
Animas near Cedar Hill	Accruals to the Animas between the Florida and the Cedar Hill gage
Animas at Farmington	Accruals to the Animas between the Cedar Hill gage and the Animas at Farmington gage
La Plata River	Accruals to the La Plata River between the state line and the confluence with the SJR

5.3 Simulated Reservoir and Project Operations

5.3.1 Simulation of Operations with RiverWare Run Cycles

A recent enhancement to the SJRIP RiverWare model was the addition of "Run Cycles" to facilitate efficient and accurate simulation of Navajo Reservoir and other system operations. Run cycles are used to loop through the complete model period's timesteps multiple times, which allows for the results of previous cycles to be seen and utilized by the model's rules in subsequent cycles to simulate additional operations that can then be layered on to the results of the previous cycles.

Operational rules can be constrained to execute only in certain cycles or in all cycles, depending on their purpose. The SJRIP RiverWare model currently utilizes 4 run cycles, which are organized as follows:

- ***Run Cycle 1:*** The first run cycle is used only to re-operate the San Juan-Chama Project (SJC) diversions and to apply the net adjustments to the appropriate San Juan StateMod boundary inflows.
- ***Run Cycle 2:*** The second run cycle is used to simulate base system operations, including Animas-La Plata Project (ALP) operations and initial Navajo Reservoir operations including calculating and setting the base reservoir releases required to meet the mainstem water user demands and SJRIP target baseflows.
- ***Run Cycle 3:*** The third run cycle is used to simulate the SJRIP spring releases and layer them on to the base Navajo Reservoir operations set in Run Cycle 2. Additionally, it calculates flood control requirements and makes additional flood control releases if necessary.
- ***Run Cycle 4:*** The fourth and final run cycle is used to simulate the reductions of water user diversions following shortage sharing procedures in years that a water supply shortage exists.

The simulated system operations are described below in the general order that they occur.

5.3.2 San Juan-Chama Project Reoperation

The San Juan-Chama Project (SJC) is a Reclamation transbasin diversion project consisting of a series of river diversion structures and tunnels used to export water from the upper San Juan River basin in Colorado under the continental divide to the headwaters of the Rio Chama in the Rio Grande basin in New Mexico. Water is diverted from three upper San Juan basin tributaries, the Rio Blanco, Little Navajo, and Navajo Rivers, and conveyed through a series of tunnels, the last and primary of which is the Azotea Tunnel, to Willow Creek upstream of Heron Dam.

The SJC diversions are in the upper San Juan basin within the San Juan StateMod model's extent, well upstream of the SJRIP RiverWare model's boundary. Thus, SJC diversions are simulated in San Juan StateMod and the associated flow depletions are reflected within the San Juan StateMod boundary inflows. However, the San Juan StateMod's monthly representation of SJC exports has been determined to be insufficient for SJBHM purposes because the diversion capacities and minimum bypass criteria cannot be sufficiently simulated at a monthly timestep due to the highly variable daily flows of the diverting tributaries. For this reason, the SJC diversions are reoperated within the SJRIP RiverWare model, and the resulting net differences in SJC diversions are used to adjust the San Juan StateMod boundary inflows appropriately. For example, if the total monthly volume of simulated SJC exports was lower in San Juan StateMod than is simulated by the SJRIP RiverWare model at a daily timestep, the difference is subtracted from that month's San Juan StateMod boundary inflows reflecting the net increase in depletion to the San Juan basin flows.

Simulation of the SJC exports is done in the SJRIP RiverWare model in a small network of objects detached from the main model network, shown below in Figure 5-1, and includes the three tributaries and respective diversion structures and tunnels, the Azotea Tunnel, and the 401,000 acre-foot capacity Heron Reservoir in the Rio Grande basin. The simulation of the SJC exports is completed prior to any simulation of Navajo Reservoir and the main network so that the necessary adjustments to the San Juan

StateMod boundary inflows can be made. This process is completed in the SJRIP RiverWare model's Run Cycle 1.

During simulation, daily flows in each tributary at the diversion structures are set as the monthly output flows from the appropriate San Juan StateMod scenario and disaggregated to daily flows using historical monthly-to-daily patterns. Next, each of the three diversions are limited by their minimum bypass requirements, diversion capacity, and tunnels capacities. The annual and 10-year SJC diversion volume limits are also applied. These various limits are shown below in Table 5-2 and the monthly minimum bypass flows are shown in Table 5-3. Additionally, basic operations of Heron Reservoir are simulated so that potential curtailments of SJC imports can be simulated in the case that Heron reaches its maximum elevation. This includes evaporation and supplemental deliveries of storage to water users, which are assumed to be made following the average monthly demand schedule shown in Table 5-4. Natural inflow to Heron is not simulated as they are bypassed through the reservoir and SJC imports represent the only inflows to storage.

Additionally, the model also has options to either use the raw San Juan StateMod SJC diversions or those from the NMISC Yield Study (extended to the full model period). A comparison of the annual SJC export volumes for these three options is shown below in Table 5-5 and Figure 5-2. It should be noted that, the specific San Juan StateMod scenario used (see Section 3.5.2) differs between the SJBHM Baseline and the SJBHM Current Conditions demand scenarios, which causes the San Juan StateMod and SJRIP RiverWare SJC numbers to vary slightly between model scenarios.

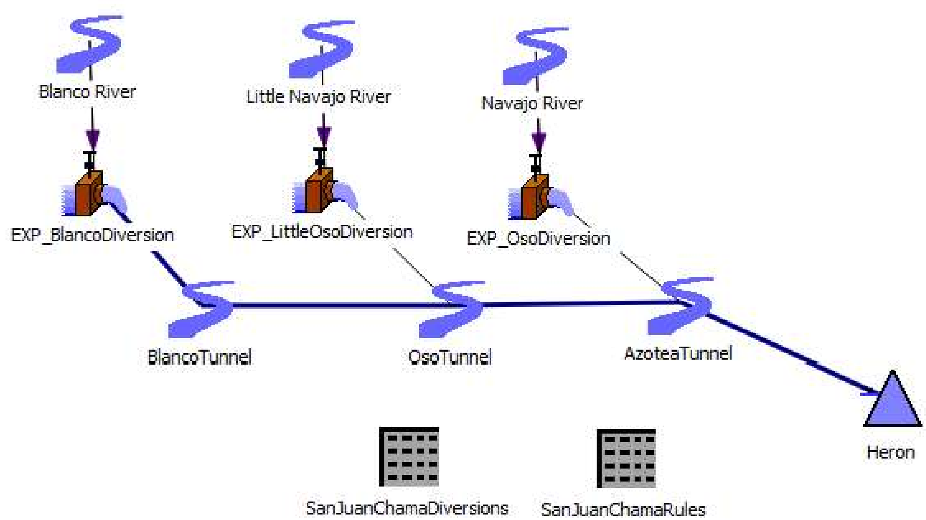


Figure 5-1: Representation of the San Juan-Chama Project in SJRIP RiverWare used for Adjustment of San Juan StateMod Results

Table 5-2: San Juan-Chama Diversion Structure Capacities and Other Limiting Criteria

Criteria	Limit
Blanco Diversion Capacity	520 cfs
Little Oso Diversion Capacity	150 cfs
Oso Tunnel Capacity	550 cfs
Oso Diversion Capacity	650 cfs
Azotea Tunnel Capacity	1050 cfs
Max Annual SJC Diversion Volume	270,000 ac-ft
Max 10-year SJC Diversion Volume	1,350,000 ac-ft
Heron Reservoir Max Elevation	7,186.1 ft

Table 5-3: San Juan-Chama Diversion Structure Minimum Bypass Flows

SanJuanChamaRules.BypassFlows

File Edit Row Column View Adjust

BypassFlows

Value:

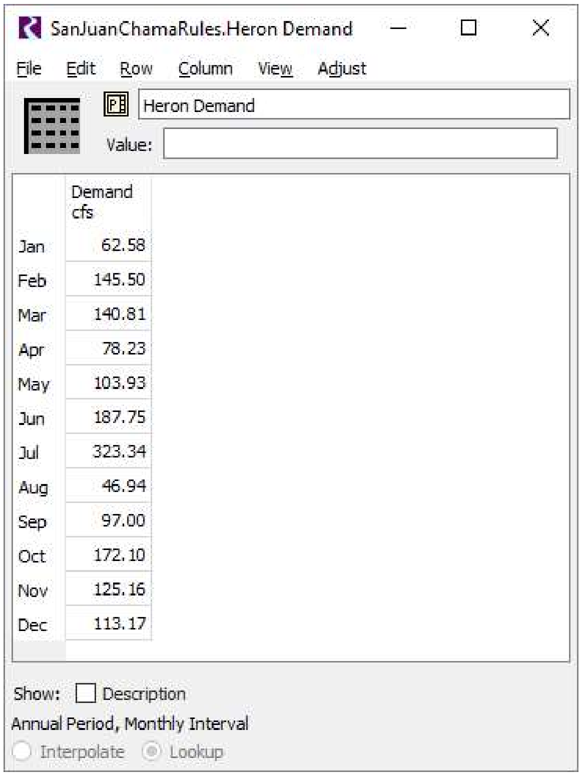
	Blanco cfs	LittleOso cfs	Oso cfs
Jan	15.00	4.00	30.00
Feb	15.00	4.00	34.00
Mar	20.00	4.00	37.00
Apr	20.00	4.00	37.00
May	40.00	27.00	88.00
Jun	20.00	27.00	55.00
Jul	20.00	27.00	55.00
Aug	20.00	27.00	55.00
Sep	20.00	27.00	55.00
Oct	20.00	4.00	37.00
Nov	20.00	4.00	37.00
Dec	15.00	4.00	37.00

Show: **Description**

Annual Period, Monthly Interval

Interpolate Lookup

Table 5-4: Heron Reservoir Monthly Demands



	Demand cfs
Jan	62.58
Feb	145.50
Mar	140.81
Apr	78.23
May	103.93
Jun	187.75
Jul	323.34
Aug	46.94
Sep	97.00
Oct	172.10
Nov	125.16
Dec	113.17

Table 5-5: Comparison of Annual San Juan-Chama Export Volumes, NMISC vs. San Juan StateMod vs. SJRIP RiverWare.

	NMISC Yield Study[1]	**San Juan StateMod**	**SJRIP RiverWare**
Average Annual Volume, ac-ft	104,379	91,094	105,243
Minimum Annual Volume, ac-ft	7,449	3,235	7,346
Maximum Annual Volume[2], ac-ft	210,481	191,641	233,454
Minimum 10-Year Volume, ac-ft	854,540	731,900	851,365
Maximum 10-Year Volume, ac-ft	1,348,206	1,262,300	1,350,000

1: Original NMISC Yield Study data is 10/1935-9/2005 and has been extended to the full model period of 10/1928-9/2013.
2: These are the maximum simulated annual diversion volumes, not the maximum allowable annual volume limit.

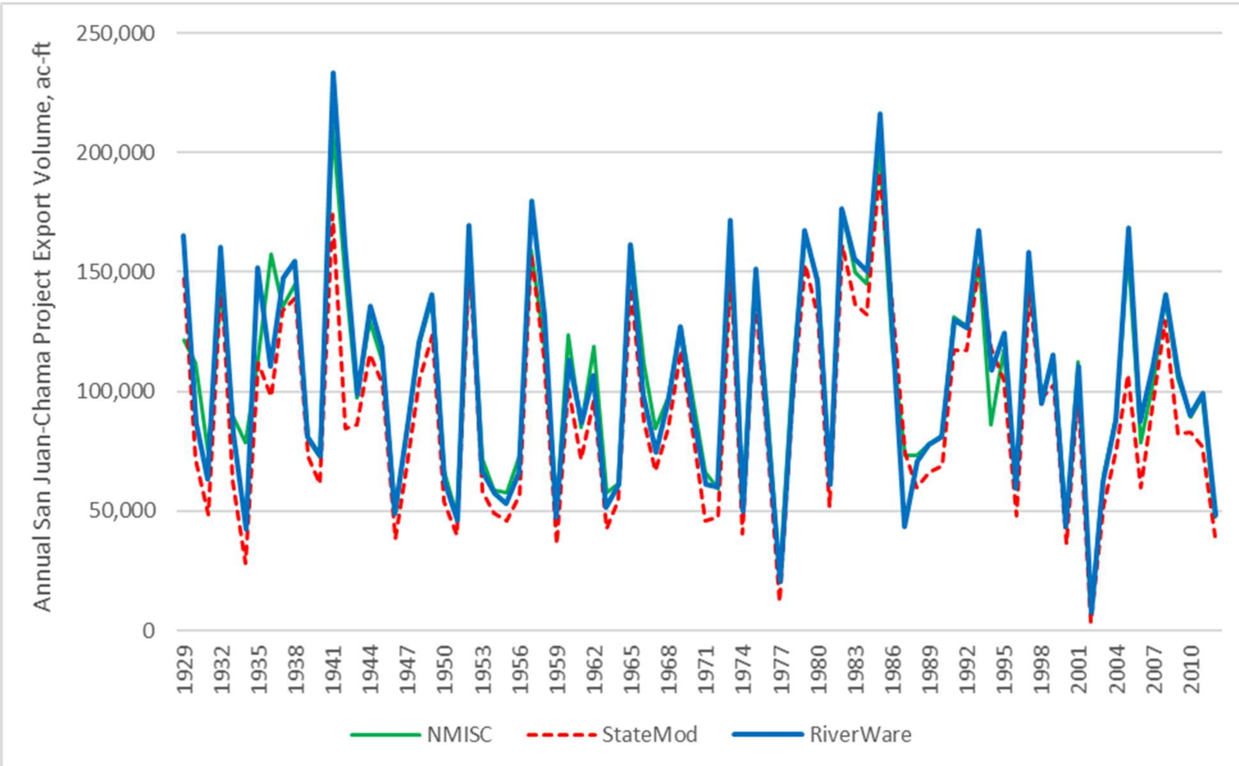


Figure 5-2: Annual San Juan-Chama Project Export Volumes, NMISC vs. San Juan StateMod vs. SJRIP RiverWare.

5.3.3 Animas-La Plata Project and Ridges Basin Reservoir Operations

The Animas-La Plata Project (ALP) is a water supply project on the Animas River. It consists of a pumping plant from the Animas River near Durango to the off-stream Ridges Basin Reservoir, and associated facilities. Basic ALP and Ridges Basin Reservoir operations and demands are simulated in the SJRIP RiverWare model. This simulation is completed within model Run Cycle 2 so that the Animas River flows are solved completely by the model and can be used for the Navajo Reservoir SJRIP operations that are simulated in Run Cycle 3. The basic ALP operating parameters are shown below in Table 5-6 and the minimum Animas River bypass flows at the ALP pumping plant are shown in Table 5-7.

The ALP project and Ridges Basin operations are simulated as follows:

1. Calculate the maximum available for pumping subject to the minimum bypass requirements and limitations of not impacting the San Juan StateMod simulated diversions to the Colorado water users on the Animas River between the pumping plant and New Mexico, and those of the NM direct flow water users on the Animas River.
2. Set pumping to Durango M&I to the minimum of the daily demand, capacity, or maximum available for pumping.
3. Set pumping to Ridges Basin Reservoir subject to the remaining flow available for pumping, the minimum and maximum pumping rates, and Ridges Basin maximum storage.

4. Set diversions and releases from Ridges Basin Reservoir to meet ALP demands not met by direct flow supply.

Table 5-6: Basic Animas-La Plata Project and Ridges Basin Reservoir Operating Parameters

Parameter	Value
Minimum pumping rate to Ridges Basin	15 cfs
Maximum pumping rate to Ridges Basin	280 cfs
Maximum pumping rate to Durango M&I	12 cfs
Ridges Basin Minimum Storage	500 ac-ft
Ridges Basin Maximum Storage	120,000 ac-ft

Table 5-7: Minimum Bypass at the ALP Pumping Plant

ALPData.MinBypass

File Edit Row Column View Adjust

MinBypass

Value:

	January cfs	February cfs	March cfs	April cfs	May cfs	June cfs	July cfs	August cfs	September cfs	October cfs	November cfs	December cfs
0: MinBypass	125.00	125.00	125.00	225.00	225.00	225.00	225.00	225.00	225.00	160.00	160.00	125.00

Show: Description

5.3.4 Navajo Reservoir Operations

Navajo Reservoir is operated primarily to provide water supply to downstream water users and to facilitate meeting the SJRIP flow recommendations. The basin’s largest water user, the Navajo Indian Irrigation Project (NIIP), diverts directly from the reservoir through a dedicated outlet. Navajo Reservoir’s basic operating parameters are shown below in Table 5-8.

Table 5-8: Basic Navajo Reservoir Operating Parameters

Parameter	Value
Minimum pool elevation	5,990 ft
Minimum release	250 cfs
Maximum release (outlet capacity)	5,000 cfs
Maximum operational elevation (unregulated spillway elevation)	6,085 ft

5.3.4.1 Water Supply and Target Baseflow Operations

Navajo Reservoir operations are simulated in several phases by the SJRIP RiverWare model using the run cycles previously outlined. The base reservoir operations, which consist of NIIP diversions and river releases to meet water user demands and target baseflows are simulated in Run Cycle 2.

To accomplish this, the target baseflows at the four mainstem San Juan River gages (Farmington, Shiprock, Four Corners, and Bluff) are first calculated using the “three-gage rule”, which uses the minimum of the 7-day running average of the three upstream gages or the three downstream gages. These flow targets are then applied to the simulation objects and the “NetSubbasinDiversionRequirement” RiverWare function is called by a rule to calculate the Navajo Reservoir release required to fully meet the daily diversion demands of all mainstem water users as well as the target baseflows at the gages. This powerful function calls on RiverWare to iterate internally to calculate the required release by allowing the water user objects to solve their diversions and return flows based on the various simulation methods, diversion and depletion requests, and return flow calculation methods, while also taking into account the gains and losses from tributaries and local inflows along the full mainstem San Juan River model nodes.

This calculated required release is then set as that day’s outflow from Navajo Reservoir and the model moves on to the next timestep. In Run Cycle 2, these are the only Navajo Reservoir outflows simulated, and thus the reservoir is allowed to fill and spill as needed over the unregulated spillway. However, this is a temporary solution used only to calculate the total volumes of releases needed to meet the water user demands and target baseflows for use in the SJRIP Spring Peak Release Available Water calculations.

5.3.4.2 SJRIP Spring Release Hydrographs

The SJRIP Spring Release hydrographs are calculated and set in Run Cycle 3 according to the SJRIP release scenario being simulated, which are described later. On March 1 of each year during this cycle, the total available water is calculated based on the specific criteria for the given scenario using the volume of base releases necessary to meet the mainstem water user demands and target baseflows, and a SJRIP release hydrograph is calculated or selected. Increased summer target baseflows and SJRIP fall releases may also be set if determined to be applicable. This schedule is then superimposed on top of the base Navajo Reservoir releases that were set in Run Cycle 2 and the reservoir resolves based on the increased release schedule.

5.3.4.3 Flood Control Operations

Operations to enforce the U.S. Army Corps of Engineers (Corps) Navajo Reservoir flood control diagram (2011) are also simulated within the model during Run Cycle 3. The operational requirements defined by the Corps in the diagram limits the maximum allowable storage level of Navajo Reservoir between January 1 and July 15 of each year based on the most probable (50% exceedance probability) modified unregulated inflow forecast to the reservoir between the given date and July 15. The modified unregulated forecast means that the forecasted inflow has been adjusted for estimated San Juan-Chama exports and change in storage in Vallecito Reservoir.

If the reservoir requires additional flood control releases above the SJRIP spring peak release schedule set in the previous step to observe the required flood control storage level determined from the flood control diagram, they are made.

The results of the simulation process of updating the Navajo Reservoir releases with the SJRIP spring peak release schedule and flood control releases and the resulting decrease in simulated Navajo Reservoir storages is illustrated below in Figure 5-3.

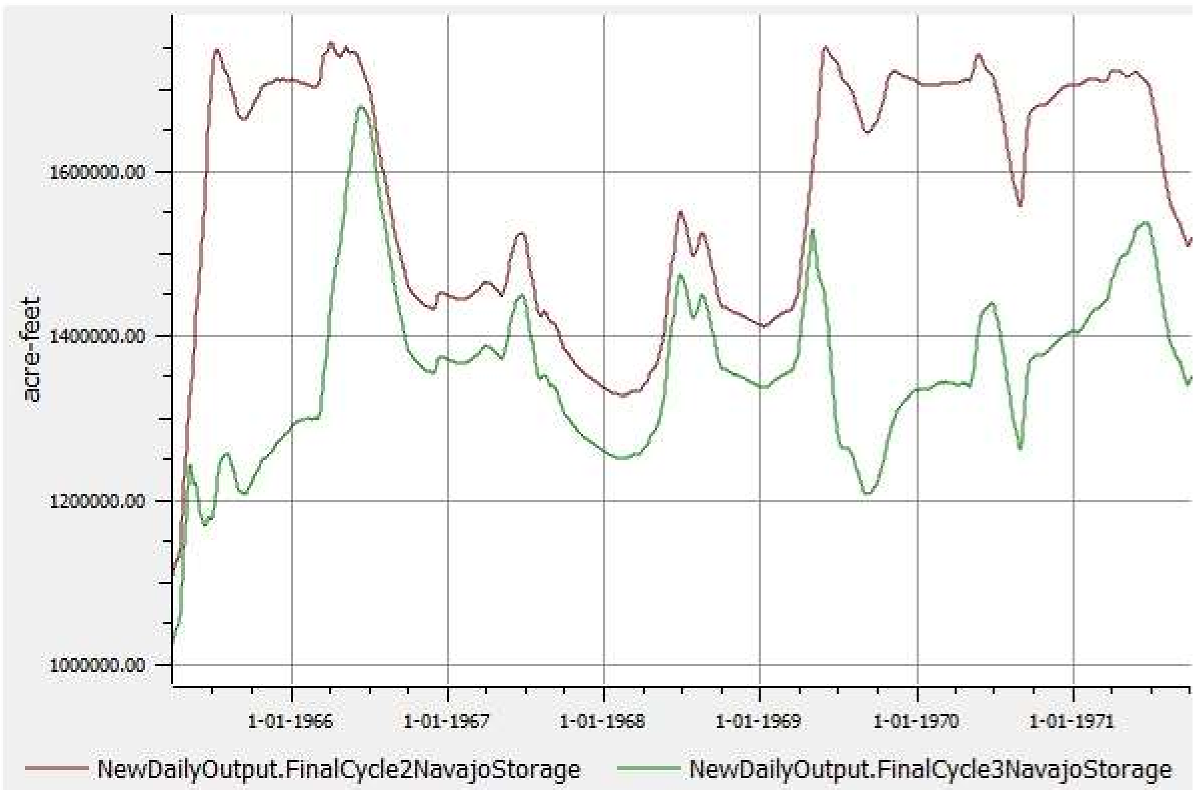


Figure 5-3: Simulated Navajo Reservoir Storage, Run Cycle 2 vs. Run Cycle 3.

5.3.4.4 Simulation of Shortage Sharing

Shortages occur when there is insufficient water supply to fully meet the needs of all mainstem water users while maintaining a Navajo Reservoir pool elevation above the minimum of 5,990 ft. In real operations, shortages are forecasted in advance based on the current storage, forecasted inflow, and anticipated releases, and estimated evaporation losses. If a shortage is determined to be likely to occur, an estimated shortage percentage is calculated and the water supply to the shortage sharing parties is reduced accordingly and reservoir releases are reduced to preserve storage volume.

The shortage sharing process is simulated within the SJRIP RiverWare model with Run Cycle 4, the final run cycle. Within the Run Cycle 3 solution, shortage conditions are forced not to occur even at full water user demand and reservoir release values by the addition of “supplemental water” to force Navajo to remain at the minimum pool elevation of 5,990 ft. In Run Cycle 4, the model runs through all the timesteps without adjusting the Run Cycle 3 solution unless it finds a year that a shortage condition exists. If this occurs, the shortage percentage of the given year is applied, and the demands of the appropriate water users and reservoir releases are reduced accordingly and the supplemental water that was added in Run Cycle 3 is removed. It is assumed that these reductions begin on March 1st of the shortage year. Currently, the determination of the shortage sharing percentage for simulated shortage years is a manual, iterative process to find the percentage that causes the simulated Navajo Reservoir storage coming out of the shortage period to be exactly equal to that of the Run Cycle 3 solution. An automated procedure to calculate the shortage percentage determination is currently being developed to eliminate the current manual process.

The shortage sharing procedures currently simulated by the SJRIP RiverWare model reflect the procedures as defined by the 2017-2020 shortage sharing agreement, which is included as Appendix H to this documentation.

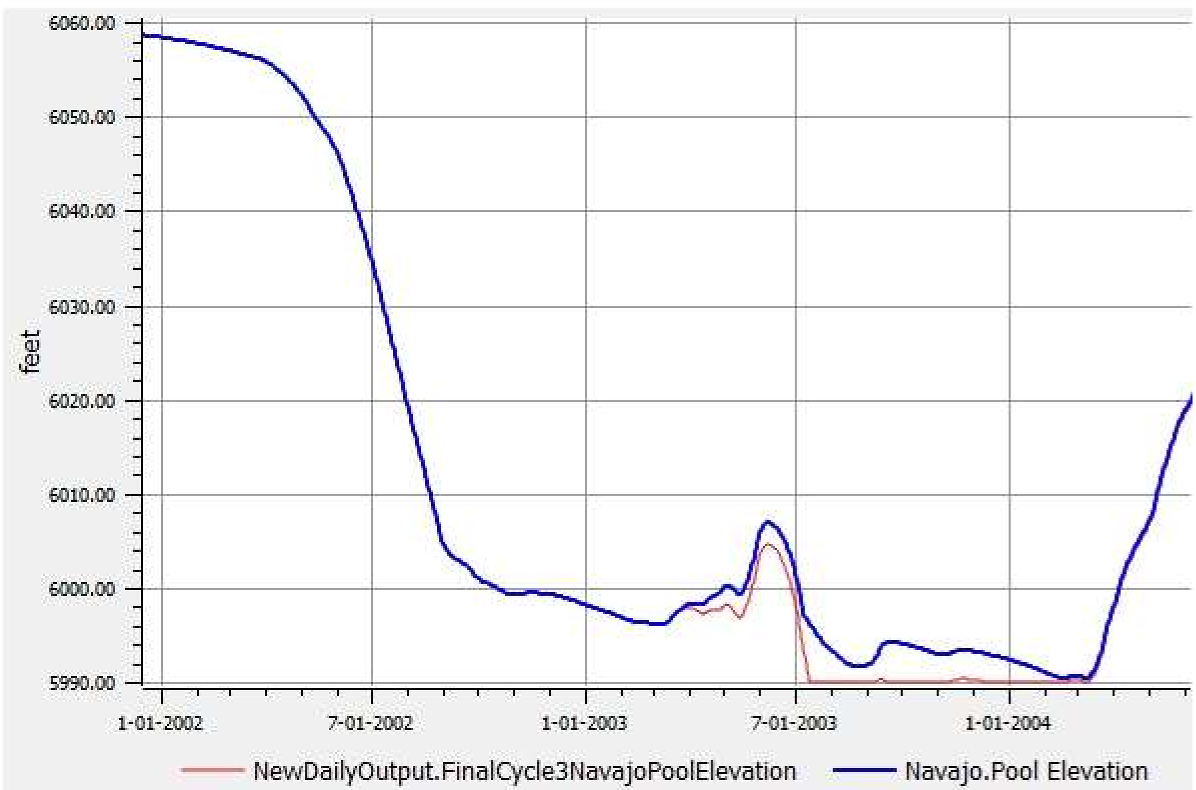


Figure 5-4: Example of Simulated Navajo Reservoir Shortage Sharing Procedure Effects.

5.3.5 Navajo Indian Irrigation Project (NIIP)

The Navajo Indian Irrigation Project (NIIP) is the largest water user in the San Juan basin. NIIP diverts water directly out of Navajo Reservoir through a dedicated outlet structure to irrigate up to 110,630 acres of land at full project build-out, which is scheduled to occur by 2040. The NIIP water rights are defined in the 2013 “Partial Final Judgement and Decree of the Water Rights of the Navajo Nation” (“Partial Final Decree”), with a full project 10-year average annual depletion of 270,000 acre-feet/year (afy) and a maximum annual depletion of 310,500 acre-feet. The diversion volume limits defined in the decree are sufficiently high that they are not limiting with the model assumed 80% efficiency. The maximum NIIP diversion rate is 1800 cfs.

As part of the USFWS’ 2009 Biological Opinion (BO) and Reclamation’s 2009 Record of Decision (ROD) on the Planning Report and Final Environmental Impact Statement (PR/FEIS) for the Navajo-Gallup Supply Project (NGWSP), discussed next, the “Navajo Depletion Guarantee” was incorporated. The Depletion Guarantee can require reductions in the total Navajo Nation depletions in the basin of up to 20,782 afy to accommodate the NGWSP if/when the basin’s total depletions reach the “depletion threshold” as defined in the BO. For SJBHM modeling purposes, under the SJBHM Baseline demands scenario, it is currently assumed that the depletion threshold has been reached and that the maximum Depletion Guarantee reduction in Navajo Nation water use is in effect during each model year. For SJBHM modeling purposes, it is further assumed that the depletion reduction requirement would be applied solely to NIIP, which leads to an average annual NIIP depletion demand of 249,218 afy.

The NIIP demand generation procedure described below has been developed within the SJRIP RiverWare model in a flexible way to facilitate model runs of various demand scenarios. NIIP demands can now be adjusted effortlessly and efficiently within a model run to simulate various target demand levels. Additionally, the NIIP demands used in previous generations of the SJRIP RiverWare model have been adjusted several times to meet certain average annual depletion targets. Additionally, the NIIP demands had previously been “pre-shorted” in necessary years to eliminate or reduce the modeled shortages during years when shortages had occurred in past model runs. To remain applicable with the dynamic representation of shortage sharing new to Gen 4 of the SJRIP RiverWare model, the simulated NIIP demands now must be the full depletion requests that would be met if no shortages occurred. Using these full demands and dynamic shorting also allows for much greater flexibility as the model will short the appropriate water users dynamically during model runs, rather than having static shortages present within the water user’s demands themselves.

5.3.5.1 NIIP Demand Calculation Procedure

NIIP demands are generated at the beginning of a model run by the SJRIP RiverWare model’s initialization rules through adjustment of the “NIIP base depletion requests”. These base depletion requests are the raw monthly NIIP depletion requests (in acre-feet/month) that are calculated from NIIP Net Irrigation Requirement (NIR) rates, a constant NIIP total irrigated area of 110,630 acres, and an incidental loss rate of 0.1353. The base NIR rates were calculated specifically for NIIP with Reclamation’s Blaney-Criddle ET model and have been used for all modeling done with the Gen 4 SJRIP RiverWare model. However, due to the adjustments made to the NIIP demands through the targeting process, the specific NIR rates used have limited overall importance and only effect the monthly distribution of each year’s demands.

The NIIP consumptive use demand volume is calculated by NIR * acreage, and the incidental loss volume is calculated by its ratio * consumptive use. The total NIIP depletion request is the sum of the consumptive use and incidental loss. Without any targeting adjustments, the average annual Depletion Requests calculated from the NIIP base depletion requests through the full model period is only 237,922 ac-ft. The monthly depletion request volumes are disaggregated to daily flow requests using monthly averages. The diversion request equals the depletion request divided by the efficiency, and a delivery efficiency of 80% is assumed for all units.

The NIIP demand targeting process begins with the base monthly depletion and diversion requests calculated by the process described above. The objective of the targeting process is to create a set of monthly depletion and diversion demands for the full model period that meet the target average annual depletion demand and remain reasonably consistent with the model period's corresponding historical hydrometeorological conditions used to define the NIIP base NIR rates, while respecting the various limitations defined in the partial final decree. Simply put, the targeting process works by scaling the timeseries of base monthly demands so that the target demand level is met. The process applies the scaling as uniformly as possible, however it limits the scaling as necessary to not exceed the maximum diversion rate of 1800 cfs and to not exceed the maximum annual depletion volume of 310,500 acre-feet. Note that this process works for target NIIP average annual depletion demands above or below the base demand level.

After the total NIIP demands are calculated, they are divided by percentages between three NIIP simulation areas (or "units"), distinguished by the location of their return flows, as shown in Table 5-9. These divisions were recommended by Keller-Bliesner Engineering in August 2018 based on a NIIP return flow distribution analysis.

5.3.5.2 NIIP Return Flow Calculations

The SJRIP RiverWare model simulates return flows from NIIP irrigation as follows:

1. Daily NIIP Return Flow = Diversion - Depletion
2. The model assumes that 80% of the return flow from each NIIP Unit goes to the Unit's corresponding GW storage object and 20% returns to surface water. The original source of the 80/20 split numbers is unknown but has been used in the model for some time now. Based on historical observed NIIP data, the annual percentages seem to vary considerably, ranging from 2% to 26% for the "surface water return/total return" ratio since 2000, and averaging 12%.
3. The return flow locations in the model network are as follows:
    a. NIIP Unit 3 return flows (both GW and SW) return directly below the Bloomfield M&I water user diversion.
    b. NIIP Unit 5 return flows (both GW and SW) return above the San Juan Generating Station water user diversion.
    c. NIIP Unit 6 return flows (both GW and SW) return directly below the Hogback and Cudei water user diversion.

Table 5-9: NIIP Unit Demand and Return Flow Split Percentages and Return Flow Locations.

NIIP Unit	Demand Split Percentage	Return Flow Location	SJRIP RiverWare Return Flow Node
Unit 3	32.3%	Gallegos	DIV_NMBLOOM
Unit 5	32.4%	Ojo Amarillo	RET_NMSJGS
Unit 6	35.3%	Chaco	DIV_NMCUDEI

5.3.5.3 NIIP Groundwater Storage Objects

A considerable amount of NIIP return flow enters the ground water system. There are 3 groundwater objects used in the model to simulate the inflows and outflows to and from groundwater due to NIIP. The groundwater objects represent groundwater storage similar to a very basic reservoir, tracking inflow, outflow, and storage. The groundwater inflow to each object is linked directly to the groundwater portion of each unit's return flow. The outflow to the river system from each groundwater storage object are assumed to be constant and are calibrated so that the overall model run average annual NIIP groundwater depletion equals a desired value. Thus, the simulated groundwater storage outflow rates vary by model scenario and configuration.

For the purposes of the SJBHM Baseline scenario, it is assumed that the NIIP groundwater interaction will reach an approximate dynamic equilibrium where the total inflows are relatively equal to the total outflows over a long period of time. It is recognized, however, that inflows and outflows from this groundwater system will vary based on NIIP demands and deliveries and hydrologic conditions, and thus the groundwater storage levels will vary. For the SJBHM Baseline scenario, the simulated constant groundwater outflow rates are calibrated so that the end of run groundwater storage equals the beginning of run groundwater storage, and thus the average annual net NIIP groundwater depletion will equal 0 acre-feet/year. An example of simulated NIIP groundwater storage levels from a calibrated SJBHM Baseline scenario run is shown in Figure 5-5. Note that the actual groundwater storage volumes are unknown and are not important, but initial and ending values of 100,000 acre-feet are used.

For the purposes of the SJBHM Current Conditions scenario, it is assumed that the average annual NIIP groundwater depletion is 10,600 acre-feet. This value is used to be consistent with those used during the Navajo-Gallup Water Supply Project PR/FEIS modeling, which reflects a net surface water system loss into the groundwater system as groundwater levels increase before an equilibrium is reached, and has not been updated based on actual groundwater measurements since it was originally derived. In order to achieve this average groundwater depletion in the model, the simulated groundwater outflow rates for the SJBHM Current Conditions scenario are calibrated such that the average annual NIIP groundwater depletion through the run equals 10,600 acre-feet. It should be noted that there still is simulated outflow from the groundwater storage to the surface water system, however its overall average is lower than the inflow to the groundwater system, which results in the net depletion to surface water system.

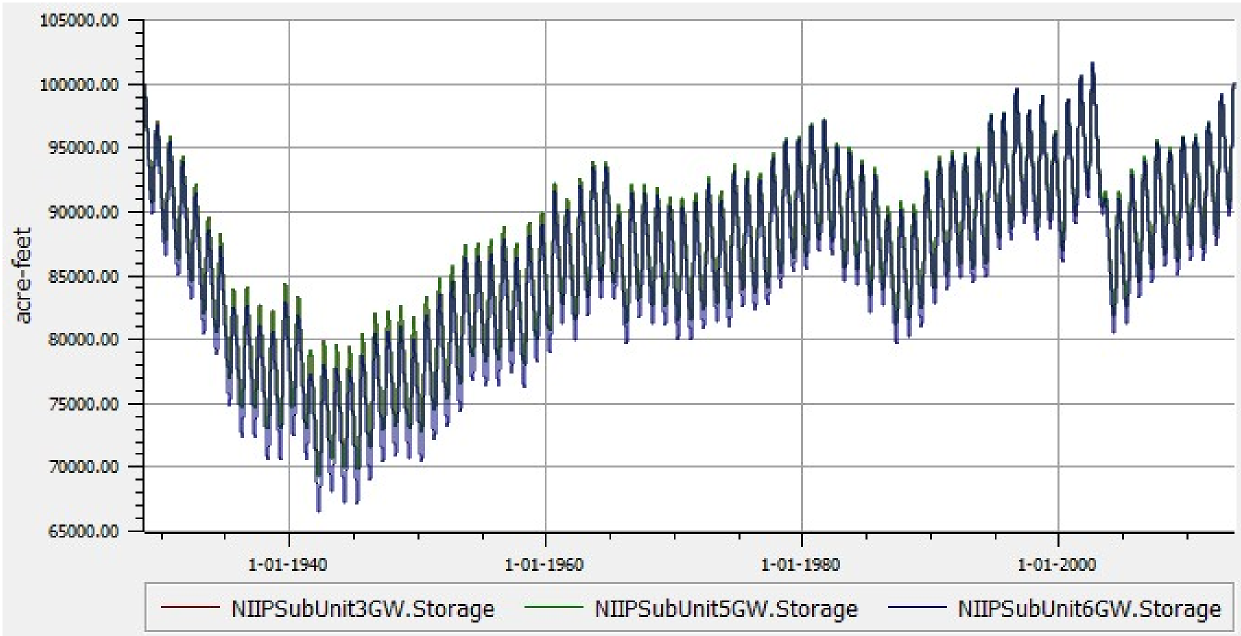


Figure 5-5: NIIP Groundwater Storage through a SJBHM Baseline Scenario Run.

5.3.6 Navajo-Gallup Water Supply Project (NGWSP)

The Navajo-Gallup Water Supply Project (NGWSP) is a M&I water supply project that will convey water from Navajo Reservoir and the San Juan River to the eastern section of the Navajo Nation, the southwestern part of the Jicarilla Apache Nation, and the City of Gallup, New Mexico. The project consists of two separate canal lateral systems, the Cutter Lateral that diverts from the NIIP system from Navajo Reservoir, and the San Juan Lateral that diverts from the San Juan River downstream of Fruitland, NM.

The full project is designed with an average annual depletion of 35,893 acre-feet/year. However, the NGWSP BO and ROD incorporate the Navajo Depletion Guarantee, discussed in Section 5.3.5 above, which may require reductions in other Navajo Nation water uses (e.g. NIIP) in the San Juan basin to accommodate the NGWSP if and when the basin as a whole reaches the depletion threshold level as defined in the BO.

To accommodate various SJBHM demand scenarios, the NGWSP demands can easily be turned on or off in the SJRIP RiverWare model. Please see Section 5.6.2 below for description of the NGWSP demands, the Navajo Depletion Guarantee requirements, and the related NIIP demand levels that are currently represented within the SJBHM. For SJRIP RiverWare model runs that include NGWSP, the simulation procedures are as follows.

5.3.6.1 Navajo-Gallup Water Supply Project Demand Calculation Procedure

1. Distribute Total Annual NG Depletion Demand (35,893 ac-ft) to monthly average depletion flow demands (cfs) using the monthly ratios.

2. Distribute up to the Cutter Lateral capacity (6.416 cfs) of the demand to the Cutter Lateral diversion from Navajo Reservoir through the NIIP outlet. For the NG Cutter Lateral, Diversion Request = Depletion Request due to the assumption of 100% efficiency, and thus there are no return flows from this portion of the NG diversion.
3. The remaining balance of the Total NG Depletion Demand (Remaining Depletion Demand = Total Depletion Demand – Cutter Demand) is applied on the San Juan River on the "NavajoGallupBalance" water user node, right below the PNM SJ Generating Station water user.
4. For the NavajoGallupBalance water user, the Diversion Demand is calculated from the Depletion Demand by dividing the Depletion Demand by the efficiency (Diversion Request = Depletion Request / Efficiency).
5. The return flow from the NavajoGallupBalance water user on any given day of the model run is calculated by Diversion – Depletion. This results in a return flow of 1,871 ac-ft/year in years without any shortages, consistent with the number in NGWSP EIS Attachment I. No lagging or routing effects on these return flows is assumed and thus any given day's return flow is the same day's diversion – depletion.

NGWSP Total Annual Depletion Demand*:* 35,893 ac-ft

NGWSP Monthly Demand Distribution Ratios:

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.07	0.06	0.09	0.07	0.09	0.10	0.10	0.10	0.10	0.08	0.07	0.07

- Used to distribute the total Navajo Gallup Annual Depletion Demand to monthly average flows.

NGWSP Cutter Lateral Capacity = 6.416 cfs (4,645 ac-ft/year)

NGWSP Cutter Lateral Efficiency = 1.00

- From the NGWSP EIS App. I, pg. I-4, "The Cutter diversion would require 4,645 AFY with no return flow to the San Juan River", thus assuming 100% efficiency.

NGWSP San Juan Lateral Diversion Efficiency = 0.9435

- Calculated from total annual diversion and depletion numbers on NGWSP EIS Att. I, pg I-4 after removing the Cutter Lateral portions. (35,893-4,645) / (37,764-4,645) = 0.9435

5.3.7 La Plata River Operations, La Plata Compact, and Long Hollow Reservoir

The La Plata Compact governs the distribution of water in the La Plata River between Colorado and New Mexico. The La Plata Compact, La Plata River operations and users in Colorado, and Long Hollow Reservoir operations are simulated within San Juan StateMod and described in the San Juan StateMod documentation. There are four New Mexico water users on the La Plata River that are simulated in the SJRIP RiverWare model, which are discussed later in the documentation.

5.3.8 Dolores Project

The Dolores Project and McPhee Reservoir operations are simulated in detail within the San Juan StateMod model and described in the San Juan StateMod model documentation. Thus, the net effects of the imports from the Dolores basin on the McElmo Creek flows in the San Juan basin are reflected in the San Juan StateMod boundary inflows. The SJRIP RiverWare model itself does not explicitly simulate any aspects of the Dolores Project.

5.4 Simulation of Water Users Demands, Diversions, and Return Flows

5.4.1 Distinction between Demands, Diversions, and Depletions

Diversions refer to the amount of water diverted from the river, and depletions are the amount of realized loss of water from the system. Typically, depletion equals (=) diversion minus (-) return flow, however return flows may not accrue back to the system on the day that the diversions were made, or to the same river reach from which they were made.

In terms of the SJRIP RiverWare model, water user demands are the defined daily *diversion requests* and *depletion requests* of the water users, or the full amount of flow that the water users would like to divert and deplete on each day of the model run to fully meet their water supply needs. These demands can be either fully defined as model inputs or can be calculated within the model based on other input data and characteristics of the water users. The SJRIP RiverWare model uses several different methods for defining and simulating water user demands that vary based on the type of water user.

In contrast to the water user demands, the model simulated diversions and depletions are the amount of water supplied to the water user on each day of the model run and are dependent on the basin's available water supply. If sufficient water supply is available, the demands will be fully met, and the simulated diversions and depletions will be equal to the requests. However, if there is insufficient water supply available, the demands will not fully be met, and a shortage will exist.

Because of the way that the San Juan River system is operated and the possibility of severe drought periods limiting the water supply available in the system, which has been highlighted by the inclusion of the 2002-2003 drought into the SJRIP model period from the period used at the programs conception, it is unreasonable to expect the resulting simulated depletion volumes to match certain numbers exactly (i.e., decreed average annual volumes) from model run to model run. This is not only due to the fact that shortages have and will exist, but also due to the fact that the model run period has been updated several times since the program began and demands (e.g., agricultural demands) are often a function of the hydrologic and meteorological conditions present in the basin in a given year.

To illustrate this point, consider a model scenario and run period where no shortages exist, but then a single year is added to the model period. Now consider that the depletion demand of an agricultural user in the new year, which is dependent on that year's crop irrigation requirement rate, is lower than the average of the previous model period. Even if that demand is fully met during the new model run, the overall average annual simulated depletion over the updated full period will decrease due simply to the fact that the demand was lower in the added year. If it was desired that the resulting overall average depletion volume was to remain unchanged from that of the previous period, the demands in the new model run throughout the entire period would have to be increased to force the overall average annual depletion to remain unchanged. However, doing this would cause the simulated demand scenarios to have now changed between the previous and the updated model runs, as the demand of the water user in the corresponding years between model runs would now be different. This would effectively render comparisons between the two model runs inappropriate.

What can be expected to be the same between model runs are methods used to calculate the water user demands. Even the average annual simulated demands themselves cannot be expected to remain at a constant number throughout changing model run periods except when those annual demands are simulated as being the same for each year of the model run. Rather than expecting a simulated resulting average annual depletion to remain at a constant number across variable run periods and model scenarios, the reliability of the system to meet demands across alternative model scenarios of the same model period should be evaluated. Additionally, the metric used to evaluate the system's ability to meet demands should not be the resulting overall average depletion, but the resulting simulated shortages in meeting the demand.

5.4.2 New Mexico Agricultural Water Users

The demands of New Mexico agricultural water users are simulated using the "Irrigation Request" method provided in SJRIP RiverWare's water user objects. This method is referred to as the "ETAC" method within the SJBHM, as its primary inputs are the water user's evapotranspiration (ET) and irrigated acres (AC). The input parameters used for these water users are shown below in Table 5-10. The inputs used for each water user were provided by the New Mexico Office of the State Engineer (NMOSE). The ET rates are calculated using NM's monthly Blaney-Criddle ET model. The only input changed to differentiate the baseline scenario demands from the current conditions scenario demands is the irrigated area. The same values are used for both scenarios for all other inputs.

Table 5-10: Input Parameters Used to Calculate New Mexico Agricultural Water User Demands

Input Parameter	Notes
Irrigated Area (acres)	Annual timeseries
Evapotranspiration Rate (in/day)	Daily timeseries disaggregated from monthly average input rates
Maximum Flow Capacity (cfs)	Typically the ditch/canal capacity or maximum water right rate
Incidental Loss Rate (%)	Based on the water user's irrigation methods. Assumed to be constant.
Efficiency (%)	Based on the water user's irrigation methods. Assumed to be constant.

Daily evapotranspiration rates are disaggregated from input monthly crop irrigation requirement (CIR) rates in the SJRIP RiverWare model using a custom "spline" interpolation method that maintains the total monthly amounts of CIR. This method is illustrated in the SJRIP RiverWare Historical model section of the documentation in Figure 4-2. Please note that while the figure shows disaggregated flow rates, the same method is also used to disaggregate CIR rates.

Based on these input parameters, the SJRIP RiverWare model simulates the daily diversion and depletion requests of each of the water users as follows:

Depletion Requested = Irrigated Area × Evapotranspiration Rate × (1 + Incidental Loss Rate)

Diversion Requested = Depletion Requested / Efficiency

Return flows are simulated from the New Mexico agricultural water users. The total daily return flow generated from each water user is simply the daily diversion minus (-) depletion. This daily return flow is then lagged and distributed over the following 245 days utilizing the SJRIP RiverWare water user "impulse response" return flow method. The 245-day pattern is shown below in Figure 5-6. The aggregated, lagged return flows are returned to the appropriate river reach. These return flows may also be split between multiple return flow reaches. The return flow locations and splits were developed in previous model generation using GIS distributions of the irrigated areas of each water user.

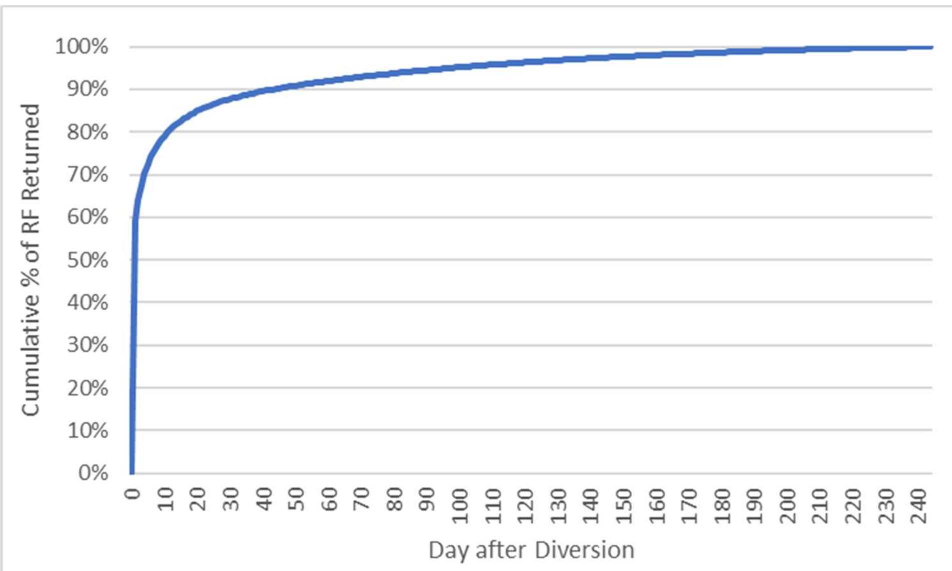


Figure 5-6: Return Flow Lagging and Temporal Distribution Pattern Used for Agricultural Water Users

5.4.3 New Mexico Municipal and Industrial Water Users

There are 13 New Mexico municipal and industrial water users simulated in the model, including two powerplants (the San Juan Generating Station and the Four Corners Power Plant), four municipalities (Bloomfield, Aztec, Farmington, and Shiprock), a Jicarilla non-irrigation depletion node above Navajo Reservoir, and 6 nodes representing aggregated minor non-irrigation depletions based on the units (areas) defined in the Colorado Uses and Losses (CU&L) reports. These water users are simulated with the simple "*daily diversion request equals (=) daily depletion request divided by (/) efficiency"* method and the resulting return flow is assumed to be returned to the river on the same day as the diversion occurs.

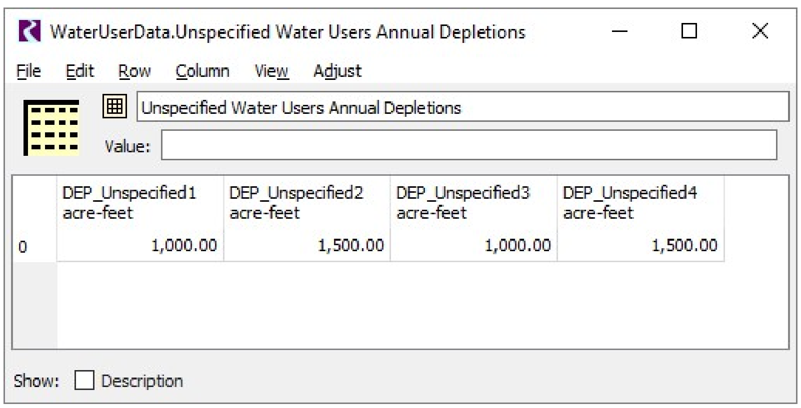
5.4.4 Colorado Animas River Water Users below Durango (from San Juan StateMod)

There are four water user objects on the Animas River in the overlapping model extents of the SJRIP RiverWare and San Juan StateMod models that must be present in both models. These are called SM East Mesa Ditch, SM Animas Ditch, SM Animas SUIT Reserved, and SM Aggregated Diversion. The resulting demands, diversions, depletions, and return flows of these water users are simulated within San Juan StateMod and are represented as inputs in the SJRIP RiverWare model, and the simulated ALP operations are subject to the criteria that these demands thus must be met.

5.4.5 Unspecified Depletions

The model includes unspecified minor depletions in four water users that total 5,000 acre-feet/year. These unspecified depletions are intended to cover an aggregation of smaller depletions that have been approved for inclusion in the baseline demand scenario. The annual depletion demands of each of these water users are shown below in Table 5-11. The annual volumes are assumed to be evenly distributed throughout the year. The diversion and depletion are assumed to be the same and there are no simulated return flows. These depletions are not included in the current conditions demand scenario.

Table 5-11: Unspecified Water Users Annual Depletions



	DEP_Unspecified1 acre-feet	DEP_Unspecified2 acre-feet	DEP_Unspecified3 acre-feet	DEP_Unspecified4 acre-feet
0	1,000.00	1,500.00	1,000.00	1,500.00

5.5 SJRIP Spring Peak Release Hydrograph Scheduling Scenarios

The SJRIP RiverWare model can be run with alternative methods of calculating each year's SJRIP available water volume and release hydrographs, including potential increased summer target baseflows and fall spike releases. The methods currently coded in the model are described below.

5.5.1 Interim Flow Recommendations – Reverse EWYST Method with Max Days at 5000 cfs ("Run C")

In this model run, the Available Water (AW) is calculated over an end of water year storage target (EWYST) at 6050 ft. The AW is shaped into a hydrograph that maximizes the number of 5,000 cfs days (up to 60 days) while using 3-day ramps up and 2-week ramps down. The remaining water over 6063 ft is evacuated through operational spill. The following procedures are used to calculate and set these

SJRIP releases. This is done by the model on March 1st of each year. The projected volumes used are for March 1 – September 30.

1. The minimum reservoir releases necessary to satisfy the year's NIIP diversions and the minimum target baseflows (TBF) are calculated.
2. Available Water for Spring Peak Release (over base release) = Current Storage + Projected Inflow - Projected Base Release - Projected Reservoir Evap - Projected NIIP diversion - Reservoir Storage @ 6050 ft elevation.
3. The spring peak release hydrograph is shaped as follows:
    a. Available Water = 3day ramp up + N x 5,000 cfs days + 2-week ramp down.
    b. Total number of 5,000 cfs days must be at least 21 days and is not to exceed 60 days.
    c. This release hydrograph is centered on the Animas Peak date.
4. Remaining AW over the 6063 ft EWYST is evacuated in the following order:
    a. If the hydrograph is at least 60 days at 5,000 cfs, then any remaining AW is first added to the front of the hydrograph, extending the total number of 5,000 cfs days in a nose. The hydrograph can be extended in this way as early as March 1st.
    b. If AW is left after this, or if there was no spring peak release, summer target baseflows are increased up to the summer target baseflow maximum of 1,000 cfs.
    c. If AW is left after this, the rest of the water is released as a spike release (short duration high volume), of 5,000 cfs, backing forward from September 30th to no earlier than September 1st.
5. If the calculated hydrograph is less than 21 days, no spring peak release is made, and the AW is evacuated through operational spill over an EWYST of 6063.

In addition to “Run C”, rules to simulate “Run A” (the “EWYST 6063 method”) and “Run B” (the “Reverse EWYST method”) are also present in the SJRIP RiverWare model. However, they are not described here as they were not selected by the SJRIP.

5.5.2 1999 SJRIP Flow Recommendations Decision Tree and Release Hydrographs

The operating rules that simulate the 1999 SJRIP Flow Recommendations decision tree and release hydrograph schedules can be simulated by the SJRIP RiverWare model. Using this method, each year’s available water is calculated following those procedures and the appropriate spring peak release hydrograph is selected and applied. Excess water above the highest release hydrograph is added onto the nose of the release.

5.6 SJBHM Water User Demands Scenarios

5.6.1 “SJBHM Baseline” and “SJBHM Current Conditions” Demand Scenarios

Just as the model can simulate the system under alternative operational scenarios, it can also run under different demand scenarios. There are currently two demand scenarios developed for use in the SJRIP RiverWare model.

- The ***"SJBHM Baseline Demands"*** scenario represents the anticipated maximum (or full buildout) water user demands and planned project operations in the San Juan River basin. This includes the simulation of basin projects, such as the Animas-La Plata project, at their planned full level operations and utilization, even though they may not be operating at that level in the present day. This also includes Tribal Reserved water rights.
- The ***"SJBHM Current Conditions Demands"*** scenario has recently been developed to reflect current or near future demand levels, or the levels that have been observed or are expected during approximately the 2010-2020 period. This scenario has been used to evaluate the performance of the SJRIP spring release hydrograph scheduling procedures in meeting the SJRIP flow recommendations under system conditions more like those currently present in the basin than those represented in the SJBHM Baseline demand scenario.

5.6.2 NIIP and NGWSP Demands and the Navajo Depletion Guarantee

As mentioned above, the "Navajo Depletion Guarantee" was incorporated through the USFWS' 2009 BO and Reclamation's 2009 ROD for the Navajo-Gallup Supply Project (NGWSP). The Depletion Guarantee can require reductions in the total Navajo Nation depletions in the basin of up to 20,782 afy to accommodate the NGWSP if and when the basin's total depletions reach the "depletion threshold" as defined in the BO. For SJBHM modeling purposes, under the SJBHM Baseline demands scenario, it is currently assumed that the depletion threshold has been reached and that the maximum Depletion Guarantee reduction in Navajo Nation water use is in effect during all model years. For SJBHM modeling purposes, it is further assumed that the depletion reduction requirement would be applied solely to NIIP, which leads to an average annual NIIP depletion demand of 249,218 afy. The model can also easily run a demand scenario with full NIIP demands and NGWSP demands turned off.

The primary SJRIP RiverWare model demand options regarding NIIP, NGWSP, and the Navajo Depletion Guarantee are:

- ***"NIIP with Navajo Depletion Guarantee and NGWSP"*** – These demands are currently used in the SJBHM Baseline demand scenario. This uses a NIIP average annual depletion demand level of 249,218 afy and the full NGWSP depletion demand of 35,893 afy.
- ***"Full NIIP and No NGWSP"*** – This NIIP demand level uses with an average annual depletion demand of 270,000 afy and NGWSP demands are set to 0 afy.
- ***"Expected 2023 NIIP Depletions and NGWSP" –*** These demand levels are currently used in the SJBHM Current Conditions demand scenario. This uses a NIIP average annual depletion demand level of 207,166 afy (based on the NIIP build-out schedule for the year 2023) and the full NGWSP depletion demand of 35,893 afy.

A Note on the Navajo Depletion Guarantee's Depletion Threshold

Based on the SJBHM Baseline definition and modeling at the time of the BO (2009), the depletion threshold was determined to be an average depletion of 752,127 acre-feet. However, as part of the definition of the Depletion Guarantee and depletion threshold, the BO specifically states:

> *At the time that the depletion threshold condition for the basin is reached and the Depletion Guarantee must be implemented, the quantification of the threshold depletion amount (currently 752,127 acre-feet per year based on the baseline depletions identified*

> *in [NGWSP BO] Table 5 and as described above) will be recomputed using the baseline depletion amounts for the same identified baseline uses listed in [NGWSP BO] Table 5 that are estimated in the version of the San Juan River Basin Hydrology Model (SJRBHM) that is most recently available at that time so as to reflect any revisions or improvements in modeling that might be made in the future. Changes in the San Juan River Basin Recovery Implementation Program's (SJRRIP) flow recommendations for the San Juan River or in the status of listed species may result in reduction or removal of this Depletion Guarantee in the future, based upon reconsultation*. – USFWS NGWSP BO, pg 12.

Furthermore, the BO states:

> *The depletion levels discussed are conditioned upon current estimates of natural flow and baseline depletions for 1929-1993 and are subject to change as hydrology or models are updated. If such updates occur, a newly computed depletion guarantee shall be computed and utilized based upon the same depletion categories as described herein.* – USFWS NGWSP BO, pg 14.

There have been numerous SJBHM model and dataset improvements and updates since the 2009 NGWSP BO that may impact the SJBHM Baseline depletions. The most prominent of these changes may well be the extension of the SJBHM modeling period from 1929-1993 to 1929-2013. The 1994-2013 period added contains both very wet years (e.g., the late 1990s) and very dry periods (e.g., the early 2000s) that have had impacts on the SJBHM Baseline depletions. In particular, the inclusion of 2003 into the SJBHM model period introduced the first year that a water supply shortage was simulated. To date, the Depletion Guarantee's depletion threshold value has not been formally revisited. However, due to the current assumption that the SJBHM Baseline demand scenario represents the basin's state when the depletion threshold has been reached and the Depletion Guarantee is in effect for all model years, an updated and precise value of the depletion threshold is not required.

5.6.3 Animas-La Plata Project and Ridges Basin Demands

The SJBHM Baseline ALP depletion demands are shown below in Table 5-12, and sum to an annual total volume of 54,743 ac-ft, which when combined with simulated evaporation from Ridges Basin Reservoir is approximately the 57,100 ac-ft average annual design depletion of the project. The annual average demands are distributed to monthly demand volumes with a general monthly pattern that is the same for all ALP water users. The monthly depletion demand volumes are converted to daily average depletion flow demands within the model. The daily diversion demand is calculated by the depletion demand divided by the assumed efficiencies, which are also shown.

The ALP demands are currently assumed to be the same for each year of the model run. This represents a significant model limitation because ALP supplies will likely be utilized in a variable manner from year to year depending on the water supply from its water users' other sources. In wet years other sources may cover their demands fully, resulting in very little draw on ALP storages, while in dry years with limited native flow supplies the ALP supplies will likely be drawn on heavily to meet demands. The result will likely be high year to year variability in ALP operations and annual depletions that average the 57,100 ac-ft annual design depletion over a long-period.

Additionally, the model's current representation of ALP deliveries to its water users is also limited. The ALPDurango demand is simulated with a water user object that diverts directly from the Animas River at the Durango Pumping Plant, and the ALPAztec, ALPFarmington, ALPShiprock, ALPKirtland, and ALPBloomfield are simulated in a combined water user object near the bottom of the Animas River to reflect that they would be delivered via the Animas River, however, this does not reflect the actual diversion location of these users. The other ALP water users are currently simulated simply as direct diversions from Ridges Basin.

For both reasons mentioned above, the current ALP representation in the SJRIP RiverWare model is a great simplification of how the ALP and Ridges Basin will be operated and its resulting effects on the San Juan River. This process is currently being reviewed and may be updated.

Due to the limited current operations of the ALP project (as of 2018), ALP demands are not simulated in the SJBHM Current Conditions demand scenario. In this scenario, Ridges Basin reservoir operations are simulated to keep the reservoir full, and thus pumping only occurs to replace evaporation losses.

Table 5-12: Animas-La Plata Project SJBHM Baseline Depletion Demands

ALP Water User	**Annual Baseline Depletion Demand Volume, ac-ft**	**Assumed Efficiency[3], %**
ALPDurango	1247	50
UteDurango	5740	50
LaPlataRuralMI	1592	50
MancosResort	504	50
Coal	13917	50
AnimasFloridaMI	3659	50
RidgesBasinResort	419	100[1]
DgoRuralMI	673	50
GasPowerPlant	2294	50
ColoradoBalance	11988	50
ALPAztec	1747	50
ALPFarmington	5370	50
ALPShiprock	2334	50
ALPKirtland	997	50
ALPBloomfield	2261	50
Total[2]	54743	

1: Ridges Basin Resort Return Flows are assumed to accrue directly to RBR.
2: Simulated Ridges Basin evaporation brings this total to the full ~57,100 afy.
3: It is noted that the tribal efficiencies in this table are not consistent with those decreed for Case No. 2013CW3011. However, these assumed efficiencies have been used in the SJRIP RiverWare model for some time and thus are currently maintained for consistency. These may be updated in the future along with other ALP representation updates as mentioned above.

5.6.4 New Mexico Agricultural Water Users

The irrigated acres used by the SJRIP RiverWare model to calculate the New Mexico agricultural water user demands for both the SJBHM Baseline and Current Condition demand scenarios are shown below in Table 5-13. For both demand scenarios, the acres are used in conjunction with the ETAC process described previously in Section 5.4.2 to generate the daily demands used in the model. The baseline acreages were provided by the NMOSE. The current conditions acres were developed from recent historical irrigated acreages to reflect the water supply demands that are currently present in the basin. The table also shows the max diversion rate, incidental loss rate, and efficiencies used for each water user, which are used for both demand scenarios.

5.6.4.1 Tribal Agricultural Water Users in New Mexico

Not including NIIP which has been discussed previously, there are currently four water user objects in the model that represent tribal water users and projects with reserved water rights under the 2013 "Partial Final Judgement and Decree of the Water Rights of the Navajo Nation" ("Partial Final Decree") and/or other applicable decrees and documents. In the SJRIP RiverWare model, these water users are JicarillaIrr, FruitlandAndCambridge, Hogback, and CudeiCanal. Note that Hogback and Cudei are diverted from the same location, however are represented by two water user objects in the SJRIP RiverWare model.

The reserved water rights of the Fruitland-Cambridge and Hogback-Cudei Irrigation Projects defined in the Partial Final Decree include annual limits for both diversion and depletion volumes. For both projects, using these acreages within the ETAC methodology regularly leads to annual calculated demands that exceed the decreed volume limits. To account for these limits in years when this occurs, the baseline acres are reduced to the acreage that generates the maximum decreed annual demand volume. Additionally, the Hogback and Cudei depletions are limited to the values (12,100 and 900 afy, respectively) from the 2006 Navajo Reservoir Operations FEIS.

Conversely, there are also some years in which the baseline acres and ETAC demand methodology calculates annual demands that are lower than the decreed volumes. This occurs when the ET rates (provided by NMOSE) and ETAC method determine that the decreed acreage would be fully irrigated using less volume than the decreed annual volumes. This could be due to decreased crop irrigation needs due to factors such as above normal precipitation or below normal temperatures. In these years the water user demands are left at the lower values as the acreages are already at the decreed maximums. It is important to note that these years of lower annual demands do not in fact reflect water supply shortages.

Overall, due to the annual demands and depletions being limited by the decreed volumes in some years, while other years show simulated full demands lower than the decreed volumes, the average annual depletion volumes for these water users from a model run may not be equal to their decreed volumes, even if there are no shortage years present.

Finally, the JicarillaIrr water user in the SJRIP RiverWare model represents the Jicarilla tribal agricultural demand in New Mexico above Navajo Reservoir. The SJBHM Baseline scenario acreage of 740 acres for this water user was provided by NMOSE. This demand, along with the non-agricultural demand of the JicarillaNonIr water user, explicitly represents only a portion of the Jicarilla water rights throughout the

San Juan basin. Jicarilla water rights are used for flexible and variable uses throughout the basin, including leases to various non-tribal NM water users simulated within the SJRIP RiverWare model as well as both tribal and non-tribal water uses in Colorado represented within San Juan StateMod but not explicitly distinguishable as Jicarilla uses. Due to these issues and the infeasibility of distinguishing uses of Jicarilla water rights from other water users, it is assumed the water uses simulated with the JicarillaIrr and JicarillaNonIr water users in the SJRIP RiverWare model completes the representation of the full Jicarilla water rights in the basin when combined with their other, non-distinguishable water uses.

Table 5-13: Irrigated Acres Used for New Mexico Agricultural Water Users, SJBHM Baseline and Current Conditions Scenarios

SJRIP RiverWare Water User	Baseline Acres	Current Conditions Acres	Max Diversion, cfs	Incidental Loss Rate, %	Efficiency, %
NMPineRiverAreaIrr	720	406	n/a	19%	55%
JicarillaIrr	740	46	n/a	18%	50%
NMAnimasIrr	9392	4500	469.7	20%	59%
Ralston	401	401	10.6	20%	59%
TwinRocks	247	247	6.5	20%	59%
CitizenDitch	4000	2600	160.0	21%	67%
ArchuletaDitch	90	13	4.0	18%	50%
TurleyDitch	205	193	6.0	18%	52%
Hammond	3423	3423	90.0	24%	84%
EchoDitch	1335	404	32.7	21%	70%
Enterprise	90	50	4.6	22%	76%
Pioneer	146	80	6.5	22%	76%
LowerLaPlataIrr	4300	2800	113.2	19%	55%
FarmingtonGlade	890	74	18.3	18%	50%
FarmersMutual	3155	2100	110.0	18%	53%
JewettValley	1000	900	32.0	19%	53%
FruitlandAndCambridge[1]	3335	2000	100.0	18%	50%
Hogback[1,2]	7945	2700	204.7	18%	50%
CudeiCanal[1,2]	885	315	15.3	18%	50%

1: FruitlandAndCambridge, Hogback, and Cudei Baseline acreages reflect the maximums defined in the 2013 Partial Final Judgement and Decree of the Water Rights of the Navajo Nation. For these water users, the simulated demands in some model years may reflect reduced acreages in order to limit the annual depletion volume to the decreed volumetric limits.
2: Hogback and Cudei depletions are also limited to the values (12,100 and 900 afy, respectively) from the 2006 Navajo Reservoir Operations FEIS.

5.6.5 New Mexico Municipal and Industrial Water Users

The SJBHM Baseline and Current Condition scenario demands for municipal and industrial (and other non-agricultural) water users in New Mexico are shown below in Table 5-14. These annual demands are the sums of the monthly input demand volumes used, which are converted to daily average depletion flow demands within the model. The assumed efficiencies are also shown and are used for both scenarios. The daily diversion demand is calculated by the depletion demand divided by the efficiency. Please see the last paragraph of the previous section for discussion of the JicarillaNonIr water user.

Table 5-14: New Mexico Municipal and Industrial Water Users Depletion Demands, SJBHM Baseline and Current Conditions

Water User	Total Annual Baseline Depletion Demand Volume, ac-ft	Total Annual Current Conditions Depletion Demand Volume, ac-ft	Assumed Efficiency, %
JicarillaNonIr	341	341	90%
USNavajoNonIr	550	550	60%
DEP_NMU3NonIr	850	850	60%
BloomfieldMI	2500	2500	60%
AztecMI	2500	2500	60%
FarmingtonMI	5000	5000	60%
DEP_NMU2NonIr	900	900	60%
LaPlataNonIr	1350	1350	60%
SJGeneratingStation	16200	23933	100%
DEP_NMU6NonIr	325	325	60%
FourCornersPP	39000	28799	100%
ShiprockMI	1300	1300	60%
DEP_NMU7NonIr	200	200	60%
UtahIrr[1]	12297	12297	100%
1: The Utah irrigation demand is simulated with the same basic procedures and is included in this table for convenience. These depletions are located on the San Juan River in Utah between the Four Corners gage and the Bluff gage.			

5.6.6 Colorado Water Users

The demands and deliveries of the water users in Colorado are simulated in the San Juan StateMod model. The San Juan StateMod scenarios are described in Section 3.5 of this documentation and in more detail in the full San Juan StateMod model documentation. The San Juan StateMod boundary inflows used by the SJRIP RiverWare model for each demand scenario reflect the appropriate, corresponding San Juan StateMod demand scenario.

- The San Juan StateMod “Baseline with Tribal Reserved Scenario” is used with the “SJBHM Baseline” demand scenario.
- The San Juan StateMod “Baseline without Tribal Reserved Scenario” is used with the “SJBHM Current Conditions” demand scenario, as it does not contain the reserved, future tribal water uses that do not currently exist in the basin.

6 References

Colorado Water Conservation Board (CWCB). 2016. San Juan/Dolores River Basin Water Resources Planning Model User's Manual. State of Colorado.

Colorado Water Conservation Board (CWCB) and Colorado Division of Water Resources (DWR). 2018. Colorado's Decision Support Systems. State of Colorado. https://www.colorado.gov/cdss

Colorado Water Conservation Board (CWCB) and Colorado Division of Water Resources (DWR). 2018. StateMod. State of Colorado. https://www.colorado.gov/pacific/cdss/statemod

Colorado Water Conservation Board (CWCB) and Colorado Division of Water Resources (DWR). 2018. TSTool. State of Colorado. https://www.colorado.gov/pacific/cdss/tstool

Holden, P. B. 1999. Flow recommendations for the San Juan River. San Juan River Basin Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM.

Open Water Foundation. 2018. TSTool. http://openwaterfoundation.org/software-tools/tstool

San Juan River Basin Recovery Implementation Program (SJRIP). 2018. DRAFT Revised Navajo Dam Operating Procedures for the 1999 San Juan River Flow Recommendations. San Juan River Basin Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, New Mexico.

State of New Mexico, San Juan County, The Eleventh Judicial District Court. 2013. Partial Final Judgement and Decree of the Water Rights of the Navajo Nation.

U.S. Bureau of Reclamation (Reclamation). 2016. PROVISIONAL Upper Colorado River Basin Consumptive Uses and Losses Report 2011-2015.

U.S. Bureau of Reclamation (Reclamation). 2000. Animas-La Plata Final Supplemental Environment Impact State and Record of Decision. https://www.usbr.gov/uc/envdocs/eis/animas/fseis/

U.S. Bureau of Reclamation (Reclamation). 2004. DRAFT San Juan Recovery Implementation Program Hydrology Documentation, Hydrology Data and Models. "Gen 3" SJBHM Documentation.

U.S. Bureau of Reclamation (Reclamation). 2004 (revised 2012). Upper Colorado River Basin Consumptive Uses and Losses Report 1996-2000.

U.S. Bureau of Reclamation (Reclamation). 2005. Upper Colorado River Basin Consumptive Uses and Losses Report 1971-1995.

U.S. Bureau of Reclamation. 2006. Record of decision for the Navajo Reservoir Operations, Navajo Unit – San Juan River New Mexico, Colorado, Utah Final Environmental Impact Statement.

U.S. Bureau of Reclamation (Reclamation). 2009. Navajo-Gallup Water Supply Project Planning Report and Final Environmental Impact Statement and Record of Decision. https://www.usbr.gov/uc/envdocs/eis/navgallup/FEIS/

U.S. Bureau of Reclamation (Reclamation). 2011 (revised 2012). Upper Colorado River Basin Consumptive Uses and Losses Report 2001-2005.

U.S. Bureau of Reclamation (Reclamation). 2012 (revised 2013). PROVISIONAL Upper Colorado River Basin Consumptive Uses and Losses Report 2006-2010.

U.S. Bureau of Reclamation (Reclamation). 2016. PROVISIONAL Upper Colorado River Basin Consumptive Uses and Losses Report 2011-2015.

U.S. Fish and Wildlife Service (USFWS). 1998. Consultation Handbook, Procedures for Conducting Consultation and Conference Under Section 7 of the Endangered Species Act.

U.S. Fish and Wildlife Service (USFWS). 1999. Biological Assessment for Completion of the Navajo Indian Irrigation Project.

U.S. Fish and Wildlife Service (USFWS). 2000. Final Biological Opinion for Animas-La Plata Project, Colorado and New Mexico.

U.S. Fish and Wildlife Service (USFWS). 2006. Final Biological Opinion for Navajo Reservoir Operations, Colorado River Storage Project, Colorado-New Mexico-Utah.

U.S. Fish and Wildlife Service (USFWS). 2009. Final Biological Opinion for the Navajo-Gallup Water Supply Project, U.S. Bureau of Reclamation, Durango, Colorado.

U.S. Geological Survey (USGS). National Water Information System. http://waterdata.usgs.gov/nwis/

Zagona, E.A., et al. 2001. RiverWare: A generalized tool for complex reservoir system modeling. JAWRA Journal of the American Water Resources Association 37.4: 939 913-929. https://www.riverware.org

Appendix A MAY 1, 2008 LETTER FROM SJRIP PROGRAM COORDINATOR TO SJRIP COORDINATION COMMITTEE

Included as separate file.

Appendix B SAN JUAN/DOLORES RIVER BASIN WATER RESOURCES PLANNING MODEL USER'S MANUAL

Included as separate file.

Appendix C SUMMARY OF CURRENT UTILIZED SAN JUAN STATEMOD OUTPUT BY SCENARIO

Included as separate file.

Appendix D SAN JUAN STATEMOD NETWORK DIAGRAM NOTATED WITH SJRIP RIVERWARE MODEL INTERFACING FOR SJBHM

Included as separate file.

Appendix E SAN JUAN STATEMOD OUTPUT USED FOR SJBHM REPORTING

Included as separate file.

Appendix F SJRIP RIVERWARE HISTORICAL MODEL CALCULATED LOCAL INFLOW RESULTS AND VALIDATION

Included as separate file.

Appendix G SJRIP RiverWare Model Network Schematic

Included as separate file.

Appendix H 2017-2020 Shortage Sharing Recommendations

Included as separate file.

Appendix I SJRIP RiverWare Model User's Guide

Included as separate file.

Appendix J Current State of SJRIP RiverWare Model, November 2020

Included as separate file.

Appendix K SJBHM Progress Reports and Changelogs

Included as separate file.

Appendix L Most Recent SJBHM Result Workbooks, November 2020

Included as separate file.