# San Juan / Dolores River Basin Water Resources Planning Model User's Manual



**November 2005**

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# 1.  Introduction

## 1.1    Background

The Colorado Decision Support System (CDSS) consists of a database of hydrologic and administrative information related to water use in Colorado, and a variety of tools and models for reviewing, reporting, and analyzing the data. The CDSS water resources planning models, of which the San Juan / Dolores River Basin Water Resources Planning Model (San Juan Model) is one, are water allocation models which determine availability of water to individual users and projects, based on hydrology, water rights, and operating rules and practices. They are implementations of "StateMod", a code developed by the State of Colorado for application in the CDSS project. The San Juan Model "Baseline" data set, which this document describes, extends from the most currently available hydrologic year back to 1909. It simulates current demands, current infrastructure and projects, and the current administrative environment as though they had been in place throughout the modeled period.

The San Juan Model was developed as a tool to test the impacts of proposed diversions, reservoirs, water rights and/or changes in operations and management strategies.  The model simulates proposed changes using a highly variable physical water supply constrained by administrative water rights. The Baseline data set can serve as the starting point, demonstrating condition of the stream absent the proposed change but including all current conditions. It is presumed that the user will compare the Baseline simulation results to results from a model to which he has added the proposed features, to determine their performance and effects.

## 1.2    Development of the San Juan / Dolores River Basin Water Resources Planning Model

The San Juan Model was developed in a series of phases that spanned 1996 through the present. The earliest effort, designated Phase II following a Phase I scoping task, accomplished development of a calibrated model that simulated an estimated 75 percent of water use in the basin, leaving the remaining 25 percent of the use "in the gage".  The original model study period was 1975 through 1991, which also served as the model's calibration period.

The objective of the CDSS endeavor was to represent all potential consumptive use within Colorado, and estimate actual consumptive use under water supply limitations.  Therefore in Phase IIIa, the previously unmodeled 25 percent use was added to the model as 27 aggregations of numerous small users.  With the introduction of this demand, the calibration was reviewed and refined.  The objective of Phase IIIb was to extend the model study period, using automated data filling techniques as well as "old-fashioned" research in the State's Records office to estimate or obtain historical gage and diversion information.  The data set was extended back to 1909, and since the data were by then available, forward through 1996.  The calibration was again reviewed, now using through the period 1975 through 1996.

The State continues to refine the San Juan Model.  In 2005, the study period was extended through 2003, the "variable efficiency" method was added for determining irrigation consumptive use and return flows,

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and a daily version was created.  In addition, based on revisions to irrigated acreage, the aggregations of small users were revised and increased to 42. Calibration was reviewed after each major enhancement.

## 1.3    Results

The key results of the San Juan Model efforts are as follows:

- A water resources planning model has been developed that can make comparative analyses of historical and future water management policies in the San Juan and Dolores River Basins.  The model includes 100% of the basin's surface water use.

- The model has been calibrated for a study period extending from calendar years 1975 to 2003.

- The calibration in the Historical scenario is considered very good, based on a comparison of historical to simulated streamflows, reservoir contents, and diversions.

- A Calculated data set has been prepared where historical irrigation demands are replaced by calculated demands, which represent the amount of water crops would have used if given a full supply. These demands are the basis for the Baseline data set.  The Calculated monthly simulation results were compared to historical streamflows, reservoir contents, and diversions. The comparison is considered good.

- A Baseline data set has been prepared which, unlike the Historical and Calculated data sets, assumes all existing water resources systems were on-line and operational for calendar years 1909 to 2003.  This Baseline set is an appropriate starting point for evaluating various "what if" scenarios over a long hydrologic time period containing dry, average, and wet hydrologic cycles.

- Input data for the San Juan Model using a daily time-step has been developed.  As with the monthly model, the daily model may be operated to represent the Historical, Calculated, and Baseline scenarios by using the appropriate response file.   The purpose of the daily Baseline model data set is to capture daily variations in streamflow and call regime. Depending on the "what if" question the user wishes to investigate, a daily time-step may provide more detail regarding water availability.

## 1.4    Future Enhancements

The San Juan Model was developed to include 100 percent of the basin's consumptive use through a combination of explicit and aggregated structures.  The San Juan Model could be enhanced in the future by incorporating additional information gained by consulting with the division engineer, the U.S. Bureau of Reclamation, and other major water users regarding historical and future reservoir operations.

## 1.5    Acknowledgements

CDSS is a project of the Colorado Water Conservation Board (CWCB), with support from the Colorado Division of Water Resources. The San Juan Model has been developed and enhanced at different stages by Riverside Technology, Inc., Boyle Engineering Corporation, Leonard Rice Engineers, and CWCB staff.

# 2. What's in This Document

## 2.1 Scope of this Manual

This reference manual describes the CDSS San Juan / Dolores River Water Resources Planning Model, an application of the generic water allocation model StateMod and one component of the Colorado Decision Support System. It is intended for the reader who:

- Wants to understand basin operations and issues through review of the model

- Needs to evaluate the model's applicability to a particular planning or management issue

- Intends to use the model to analyze a particular San Juan / Dolores River Basin development or management scenario

- Is interested in estimated conditions in the San Juan / Dolores River Basin under current development over a range of hydrologic conditions, as simulated by this model; and in understanding assumptions embedded in the modeling estimates.

For this manual to be most effective, the reader should have access to a complete set of data files for the San Juan Model, as well as other CDSS documentation as needed (see below).

The manual describes content and assumptions in the model, implementation issues encountered, approaches used to estimate parameters, and results of both calibrating and simulating with the model. Only very general information is provided on the mechanics of assembling data sets, using various CDSS tools.

## 2.2 Manual Contents

The manual is divided into the following sections:

**Section 3 San Juan / Dolores River Basin** – describes the physical setting for the model, reviews very generally water resources development and issues in the basin.

**Section 4 Modeling Approach** – provides an overview of methods and techniques used in the San Juan Model, addressing an array of typical modeling issues such as:

- Aerial extent and spatial detail, including the model network diagram

- Study period

- Aggregation of small structures

- Data filling methods

- Simulation of processes related to irrigation use, such as delivery loss, soil moisture storage, crop consumptive use, and returns of excess diversions

- Development of baseflows

- Calibration methods

Much of Section 4 is common to the other CDSS West Slope models and the Rio Grande model, although the section refers specifically to the San Juan Model.

**Section 5 Baseline Data Set** – refers to the Monthly Baseline data set input files for simulating under current demands, current infrastructure and projects, and the current administrative environment, as though they were in place throughout the modeled period. The data set is generic with respect to future projects, and could be used as the basis against which to compare a simulation that includes a new use or operation. The user is advised, before appropriating the data set, to become fully aware of how demands and operations are represented. Elements of these are subject to interpretation, and could legitimately be represented differently.

This section is organized by input file. The first is the response file, which lists all other files and therefore serves as a table of contents within the section. The content, source of data, and particular implementation issues are described for each file in specific detail.

**Section 6 Baseline Results** – presents summarized results of the Monthly Baseline simulation. It shows the state of the basin as the San Juan Model characterizes it under Baseline conditions. Both total flow and flow legally available to new development are presented for key sites.

**Section 7 Calibration** – describes the calibration process and demonstrates the model's ability to replicate historical conditions under historical demand and operations. Comparisons of streamflow, diversions, and reservoir levels are presented.

**Section 8 Daily Baseline Results –** describes the Daily Baseline data set and presents summarized results of the Daily Baseline simulation. It shows the state of the basin as the San Juan Model characterizes it under Baseline conditions, and compares available and simulated flows to the Monthly Baseline simulation.

**Appendices A through C** – present historical technical memoranda specific to the San Juan Model, written at various phases of the model's development. The body of the manual contains references to other CDSS technical memos that are more general in scope, which are available at the CDSS website.

**Appendix D** – discusses the comparison of historical measured data to the Calculated data set simulation. The Calculated data set expands on the historical calibration by using calculated irrigation demands based on crop requirements, in lieu of demands based on historical irrigation diversions. Comparisons of streamflow, diversions, and reservoir levels are presented.

**Appendix E** – discusses the comparison of historical measured data to the Daily Historical data set simulation. The daily time-step is capable of simulating diversions based on the large and small flow events that occur within a monthly time step. Comparisons of streamflow, diversions, and reservoir levels are presented.

There is some overlap of topics both within this manual and between this and other CDSS documentation. To help the user take advantage of all sources, pointers are included as applicable under the heading "**Where To Find More Information**," throughout the manual.

## 2.3    What's in other CDSS documentation

The user may well find the need to supplement this manual with information from other CDSS documentation. This is particularly true for the reader who wants to:

- Make significant changes to the San Juan Model to implement specific future operations

- Introduce changes that require regenerating the baseflow data file

- Regenerate input files using the Data Management Interface (DMI) tools and HydroBase

- Develop a StateMod model for a different basin

An ample body of documentation exists for CDSS, and is still growing. A user's biggest challenge may be in efficiently finding the information he needs. This list of descriptions is intended to help in selecting the most relevant data source:

**Basin Information** – the report "San Juan / Dolores River Basin Information" provides information on specific structures, operations, and practices within the basin. While the information was gathered in support of the planning model when it was first undertaken, it is widely useful to anyone doing any kind of water resources investigation or analysis.

**CDSS Procedures Manual** (under development) – provides an overview of the CDSS modeling environment, encompassing not only the water resources planning model, but StateCU, StateWB, and the CDSS groundwater model. The documentation describes file naming conventions and directory structures for an integrated CDSS development environment; procedures for assembling data sets; and conventions in engineering approach that have been adopted in CDSS.  Following the standards presented in this documentation will promote consistency among CDSS models.

**DMI user documentation** – user documentation for the **StateDMI** and **TSTool** is currently available, and covers all aspects of executing these codes against the HydroBase database. (Creating data sets for StateMod is only one aspect of their capabilities.) The DMIs preprocess some of the StateMod input data. For example, **StateDMI** computes coefficients for distributing baseflow gains throughout the model and can aggregate water rights for numerous small structures. **TSTool** fills missing time series data and computes headgate demands for irrigation structures. Thus the documentation, which explains algorithms for these processes, is helpful in understanding assumptions embedded in the planning models. In addition, the documentation is essential for the user who is modifying and regenerating input files using the DMI's.

**StateMod documentation** – the StateMod user manual describes the model in generic terms and specific detail. Section 3 Model Description and Section 7 - Technical Notes offer the best descriptions of StateMod functionality, and would enhance the San Juan Model user's understanding of results. If the user is modifying input files, he should consult Section 4 - Input Description to determine how to format

files. To analyze model results in detail, he should review Section 5 - Output Description, which describes the wide variety of reports available to the user.

**Self-documented input files** – an important aspect of the StateMod input files is that their genesis is documented in the files themselves. Command files that directed the DMI's creation of the files are echoed in the file header. Generally, the model developers have incorporated comments in the command file that explain use of options, sources of data, etc.

**Technical Memoranda** – many aspects of the modeling methods adopted in CDSS were explored in feasibility or pilot studies before being implemented. Historical technical memoranda for these activities are available on the CDSS website:

- Phase IIIb Task Memorandum 10.1 – Data Extension Feasibility

- Task Memorandum 10.2 – Evaluate Extension of Historical Data

- Task Memorandum 11.5 – Characterize Streamflow Data

- Task Memorandum 11.7 – Verify Diversion Estimates

- Task Memorandum 11.10 – Fill Missing Baseflow Data (include Mixed Station Model user instruction)

- Daily Yampa Model Task Memorandum 2 – Pilot Study

- Daily Yampa Model Task Memorandum 3 – Selecting a Daily or Monthly Model

- Variable Efficiency Evaluation Task Memorandum 1.3 – Run StateMod to create baseflows using the Variable Efficiency and Soil Moisture Accounting Approach

- Variable Efficiency Evaluation Task Memorandum 1.5 – Compare StateMod Variable Efficiency and Soil Moisture Accounting Historical Model Results to Previous CDSS Model Results and Historical Measurements

- CDSS Memorandum "Colorado River Basin Representative Irrigation Return Flow Patterns"

- Task Memorandum 2.03.13 – Non-Irrigation (Other Uses) Consumptive Uses and Losses in the Dolores and San Juan River Basin

- Consumptive Uses and Losses Report, Comparison between StateCU CU & Losses Report and the USBR CU & Losses Report (1971-2000)

# 3. The San Juan / Dolores River Basin

The San Juan and Dolores River basins lie in the southwest corner of Colorado, with the headwaters of both rivers originating in the San Juan Mountains. The San Juan River flows southwest to Navajo Reservoir, leaves the state in Archuleta County, and reaches the Colorado River. The Dolores River basin is located directly north of the San Juan River basin. The Dolores River flows southwest to McPhee Reservoir and then continues northward before exiting the state in Mesa County. The San Juan and Dolores River basins encompass all of San Miguel, Dolores, Montezuma and La Plata counties, and parts of Mesa, Montrose, San Juan, Hinsdale, Mineral, and Archuleta counties in Colorado. **Figure 3.1** is a map of the basin.

## 3.1    Physical Geography

The San Juan River basin extends into portions of New Mexico on the south and Utah to the west, contributing approximately 23,000 square miles of drainage area to the San Juan River at the gage in Bluff, Utah. About one third of this area, or 7,200 square miles, lies within Colorado. Elevations within the basin range from over 13,000 feet in the headwaters at the continental divide, to about 4,050 feet near the city of Bluff, Utah. The lowest point in the basin within Colorado is in the Four Corners area, with an elevation at about 4,800 feet. The major tributaries to the San Juan River include the Navajo River, Piedra River, Los Pinos River, Animas River, Florida River, La Plata River, Mancos River, and McElmo Creek. Average annual streamflow for years 1971 to 1991 in the San Juan River above Navajo Reservoir is about 427,500 acre-feet. Prior to completion in 1971 of the San Juan-Chama project, which diverts water from the San Juan River basin to the Rio Grande basin in New Mexico, the annual average streamflow above Navajo Reservoir was 457,900 acre-feet. At the Bluff, Utah gage, the annual average streamflow is 1,863,000 acre-feet. This value is not adjusted for flow regulation caused by Navajo Reservoir since 1962.

The Dolores River rises in the San Juan National Forest near Bolam Pass, just north of the San Juan River basin. Some elevations around the headwater areas lie above 13,700 feet. The river flows southwest to McPhee Reservoir where it turns to flow to the northwest until it leaves Colorado and eventually joins the Colorado River near Cisco, Utah. The drainage area upstream of the gage at Cisco is approximately 4,580 square miles. The drainage area upstream of the most downstream Colorado gage on the Dolores River, at Gateway, Colorado is about 4,350 square miles. Major tributaries to the Dolores River include the West Fork of the Dolores, Lost Canyon Creek, Disappointment Creek, West Paradox Creek, and the San Miguel River, which is discussed separately below. The mean annual flow at Cisco, Utah for the 32 years prior to the construction of McPhee Reservoir in 1986 was 612,200 acre-feet. After construction the mean annual flow was 555,386 acre-feet between 1986 and 1993. The San Miguel River is a major tributary to the Dolores River, which it joins near the town of Uravan, Colorado. The San Miguel headwaters begin near the town of Telluride in the Uncompahgre National Forest where peaks are over 13,400 feet. The drainage area of the San Miguel River above the gage at Uravan is approximately 1,499 square miles. Average annual flow at this gage is about 273,100 acre-feet. Major tributaries to the San Miguel River

include South Fork, Fall Creek, Leopard Creek, Beaver Creek, Horsefly Creek, Naturita Creek, and Tabegauche Creek.
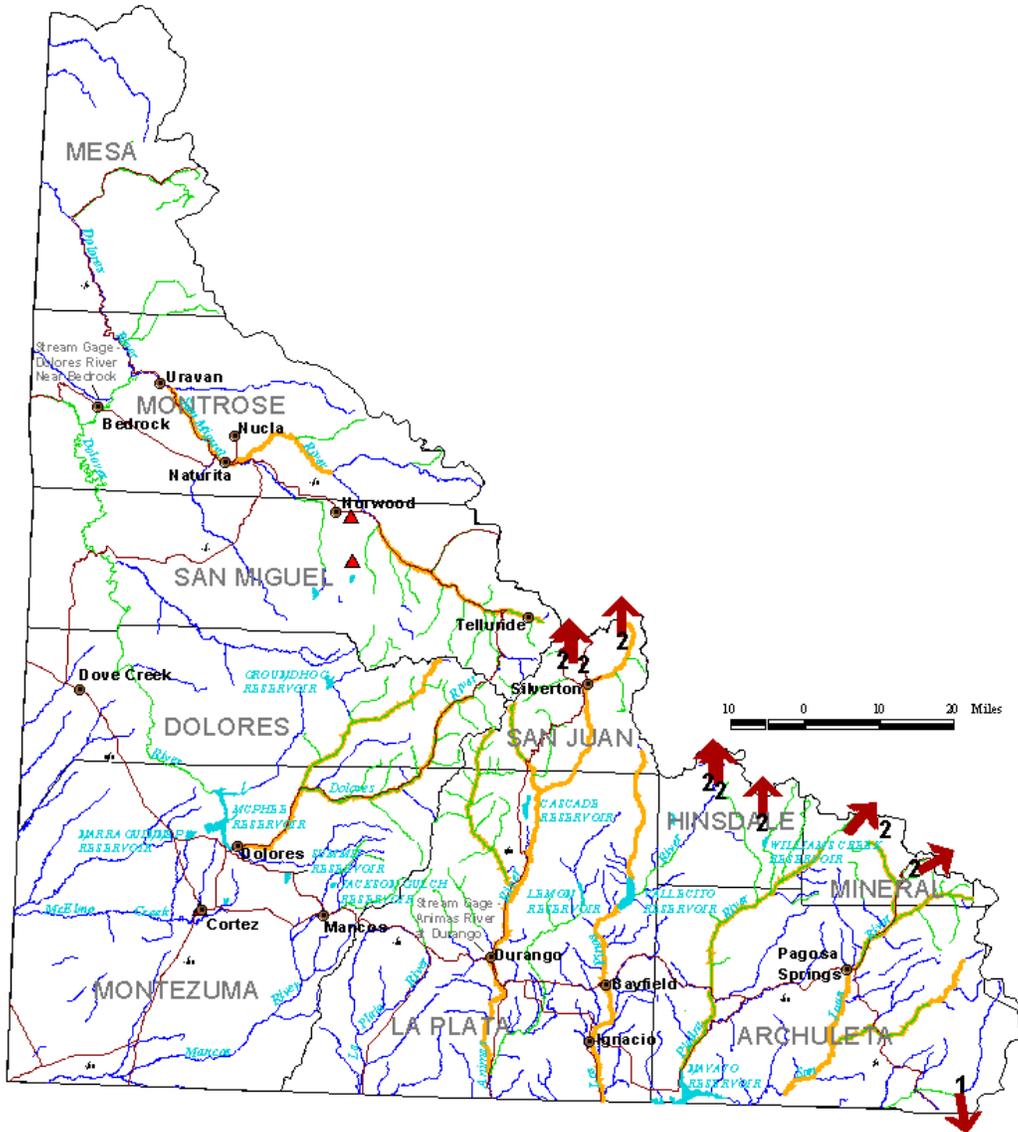


**Figure 3.1 – San Juan and Dolores River Basins**

## 3.2    Human and Economic Factors

The area remains relatively sparsely populated, with the 2003 census estimates placing the combined populations of San Miguel, Dolores, Montezuma and La Plata Counties at approximately 79,543.  Durango and Cortez are the major population centers in the basin, with approximately 13,900 and 8,000 residents respectively. Dolores, La Plata and Montezuma Counties grew by just around 25 percent from 1990 to 2000, whereas San Miguel County grew by over 45 percent in the same time period. Population growth is concentrated along the San Juan Skyway including Cortez and Durango, as well as in the Telluride Canyon. This growth attests to the importance of recreation-based activities, as the ski area and other outdoor recreation opportunities draws people and increase tourism within the basin.  Tourism serves as an important part of the basin's economy.

The principal water use in both the San Juan and Dolores river basins is irrigation. The total irrigated acreage in 2000 was approximately: 200,000 acres in the San Juan basin; 13,000 acres in the Dolores basin; and 23,000 acres in the San Miguel basin**.** Non-agricultural diversions in the San Juan Model include power generation at Cascade Reservoir (Electra Lake), the Ames-Ilium Hydro Project and the Nucla Power Plant; the municipal water supply for the city of Durango and the towns of Mancos, Animas, Rico, Fairfield, and Cortez; and parts of the Montezuma Valley Irrigation Company diversions.

Several diversions from rivers in the San Juan Model are exported from the basin. These diversions include the San Juan-Chama Project, which diverts from the Rio Blanco, Little Navajo, and Navajo Rivers for use in the Rio Grande basin. Other smaller diversions transport water from the San Juan, Piedra, Los Pinos, and Animas rivers for delivery to basins outside of the San Juan
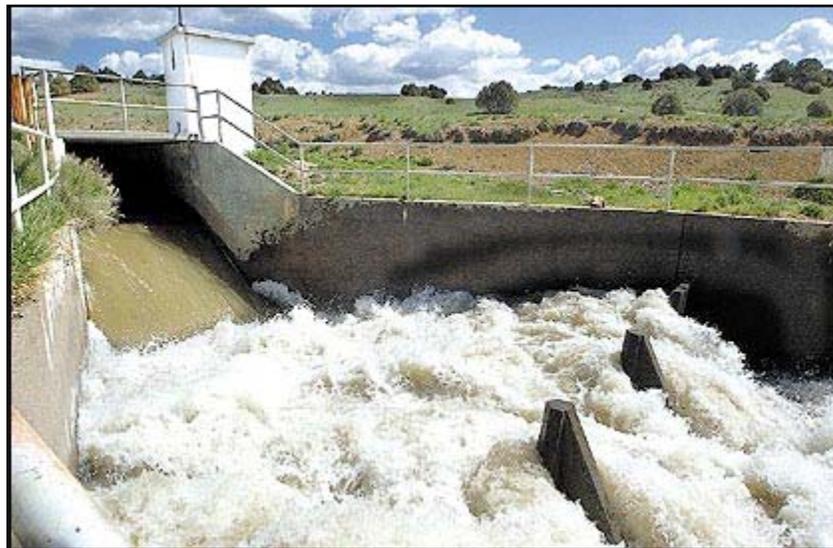


*Part of the San Juan-Chama Project, the Azotea Tunnel outlet in New Mexico*

River basin. The San Juan Model includes many diversions that transfer water from one tributary basin to another within the model. Several diversions from the San Juan and Animas rivers that are physically located in New Mexico have been included in the San Juan Model. These provide water for large irrigation projects in New Mexico and two power plants downstream of Navajo Reservoir.

The San Juan Model includes 13 explicitly modeled reservoirs as well as 10 aggregated reservoirs and 7 aggregated stock ponds. The explicitly modeled reservoirs are distributed geographically as follows: four in the San Miguel basin (Gurley, Miramonte, Trout Lake, and Lake Hope), four in the Dolores basin (Groundhog, McPhee, Summit and Narraguinnep), and five in the San Juan basin (Jackson Gulch, Cascade, Vallecito, Lemon, and Navajo). The smallest two are Lake Hope and Trout Lake with storage volumes of 2,315 and 3,422 acre-feet, respectively. The largest is Navajo Reservoir with storage of over 1.7 million acre-feet. Navajo Reservoir lies mostly outside of the State of Colorado, but was included in the model because of its impact on water distribution within the San Juan and Colorado River basins.

## 3.3     Water Resources Development

The San Juan and Dolores River basins have had substantial water resources developments in the form of storage projects and pipelines developed by private groups and federal agencies. **Table 3.1** presents a timeline of key developments within the basin.

**Table 3.1 - Key Water Resources Developments**

| Date | Project | Agency |
|---|---|---|
| Early 1940's | Pine River Project - Vallecito Reservoir | USBR |
| Late 1940's | Mancos Project - Jackson Gulch Reservoir | USBR |
| Late 1950's | Colorado River Storage Project - Navajo Reservoir | USBR |
| 1964 | Florida Project - Lemon Reservoir | USBR |
| 1972 | San Juan-Chama Project | USBR |
| 1985 | Dolores Project - McPhee Reservoir | USBR |

## 3.4     Water Rights Administration and Operations

Historical water rights have been administered in the San Juan and Dolores River basins according to the prior appropriation doctrine. Some special cases of water rights administration are as follows:

- The San Juan-Chama Project diverts water from the Rio Blanco, Little Navajo, and Navajo rivers in Colorado for export to the Rio Grande basin in New Mexico. The project does not have absolute decreed water rights in Colorado and is administered as the most junior right on the system within the state. Minimum streamflow bypass requirements on each of the streams are administered as just senior to the diversions for this project.

- Indian water rights exist in the San Juan basin. They are relatively senior and are modeled via the prior appropriation doctrine like any other water rights in the basin.

- Navajo Reservoir and several large diversions from the San Juan River in New Mexico are included in the San Juan Model, although they are not administered by the State of Colorado.  They are administered within the model as junior in priority to all Colorado water rights.

- The La Plata Compact governs the distribution of water on the La Plata River between the states of Colorado and New Mexico. The administration is dependent upon the streamflow at two gaging stations: 1) Hesperus Station (USGS No. 09365500) and 2) Interstate Station (USGS No. 9366500). During the year from December 1 to February 14, each state has the right to use all water within its boundaries. For the remainder of the year, February 15 to November 30, allocation for La Plata River water is performed according to the following guidelines:

  1. If the flow at Interstate Station is greater than or equal to 100 cubic feet per second (cfs), each state has unrestricted rights to all water within its boundaries.

  2. If the flow at Interstate Station is less than 100 cfs, the State of Colorado shall deliver at the Interstate Station a quantity of water equal to one-half of the mean flow at the Hesperus Station for the preceding day, not to exceed 100 cfs.

During periods of extreme low flow, the guidelines above may be superseded by a method of administration that allows the delivery of all available water successively to each state in alternating periods. When flow at the Hesperus Station is less than 30 cfs, the lower reaches of the La Plata will run dry, and Colorado cannot deliver any water in accordance with No. 2 above.

## 3.5     Section 3 References

1. Colorado River Decision Support System San Juan River Basin Water Resources Planning Model, Boyle Engineering Corporation, November 1999.

2. San Juan / Dolores River Basin Facts, Colorado Water Conservation Board, available at http://cwcb.state.co.us

3. Census and Population Estimate Data, Colorado Demography Office, available at http://dola.colorado.gov/demog/Demog.cfm

4. Azotea Tunnel picture by Richard Pipes, San Juan-Chama Project, as covered by the Albuquerque Journal, available at http://www.abqjournal.com/water/

5. San Juan and Dolores River Basin Information Report, November 2005.

# 4.  Modeling Approach

This section describes the approach taken in modeling the San Juan / Dolores River Basin, from a general perspective. It addresses scope and level of detail of this model in both the space and time domains, and describes how certain hydrologic processes are parameterized.

## 4.1     Modeling Objectives

The objective of the San Juan Modeling effort was to develop a water allocation and accounting model that water resources professionals can apply to evaluations of planning issues or management alternatives. The resulting "Baseline" input data set is one representation of current water use, demand, and administrative conditions, which can serve as the base in paired runs comparing river conditions with and without proposed future changes. By modifying the Baseline data set to incorporate the proposed features to be analyzed, the user can create the second input data set of the pair.

The model estimates the basin's current consumptive use by simulating 100 percent of basin demand. This objective was accomplished by representing large or administratively significant structures at model nodes identified with individual structures, and representing many small structures at "aggregated" nodes. Although the model was first developed and calibrated for the period from 1975 forward, the data set was extended backward to 1909, creating a long-term data set reflecting a wide variety of hydrologic subsequences and conditions.

Another objective of the CDSS modeling effort was to achieve good calibration, demonstrated by agreement between historical and simulated streamflows, reservoir contents, and diversions when the model was executed with historical demands and operating rules. This objective was achieved, as demonstrated in Section 5.

## 4.2     Model coverage and extent

### 4.2.1.          Network Diagram

Figures 4.1 and 4.2 combined show the network diagram for the San Juan / Dolores River model. It includes over 460 nodes for both river systems.  For the San Juan River, the network begins with the headwaters of the East Fork of the San Juan River and ends at the streamflow gage near Bluff, Utah. The Dolores River network begins at its headwaters near Bolam Pass in the San Juan National Forest. The San Miguel joins the Dolores just downstream of Bedrock, Colorado. The Dolores network ends at the streamflow gage near Gateway, Colorado.

## 4.2.2. Diversion Structures

### 4.2.2.1 Key Diversion Structures

Early in the CDSS process it was decided that, while all consumptive use should be represented in the models, it was not practical to model each and every water right or diversion structure individually. Seventy-five percent of use in the basin, however, should be represented at strictly correct river locations relative to other users, with strictly correct priorities relative to other users. With this objective in mind, key structures to be "explicitly" modeled were identified by:

- Identifying net absolute water rights for each structure and accumulating each structure's decreed amounts

- Ranking structures according to net total absolute water rights

- Identifying the decreed amount at 75 percent of the basinwide total decreed amount in the ranked list

- Generating a structures/water rights list consisting of structures at or above the threshold decreed amount

- Field verifying structures/water rights, or confirming their significance with basin water commissioners, and making adjustments

Based on this procedure, 5 cubic feet per second (cfs) was selected as the cutoff value for the San Juan River basin and 6.5 cfs was selected as the cutoff for the Dolores River basin. Key diversion structures are generally those with total absolute water rights equal to or greater than these cutoffs. The San Juan Model includes approximately 200 key diversion structures in Colorado. Over 40 key structures diverting off the mainstem San Juan River in New Mexico, Arizona and Utah are also included.

Groups of key structures on the same tributary that operate in a similar fashion to satisfy a common demand are sometimes combined into "diversion systems". Diversion systems are modeled the same as other key structures.

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**Where to find more information**

- Section 3 of the CDSS document "San Juan / Dolores River Basin Information" lists candidate key structures and in some cases indicates why structures were or were not designated as "key". These decisions were often based on Water Commissioner input, which is also documented in the San Juan / Dolores Basin Information Section "Basin Meeting Notes".

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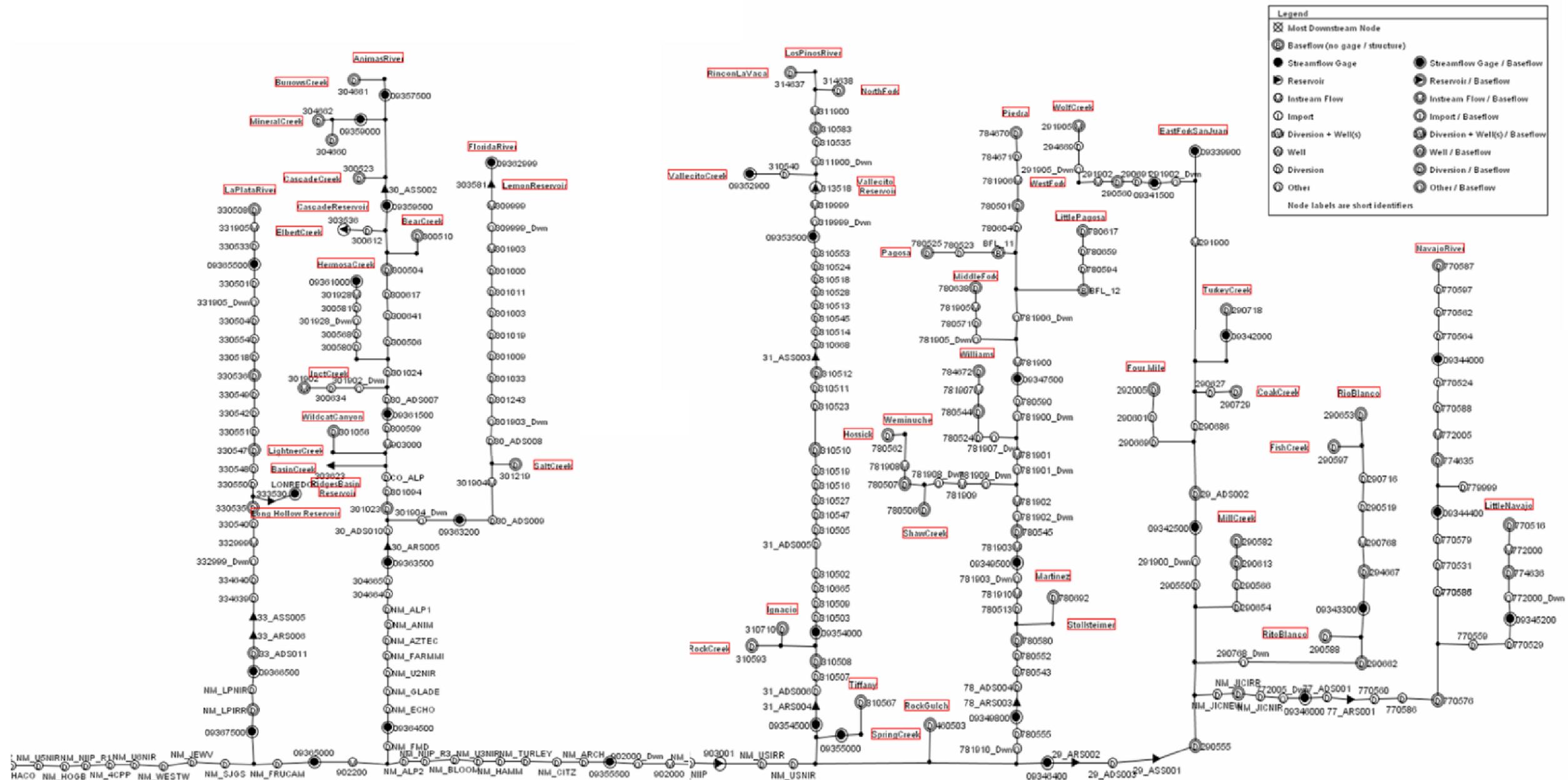
**Figure 4.1 Network Diagram – San Juan / Dolores Planning Model from San Juan Headwaters to La Plata River Confluence**
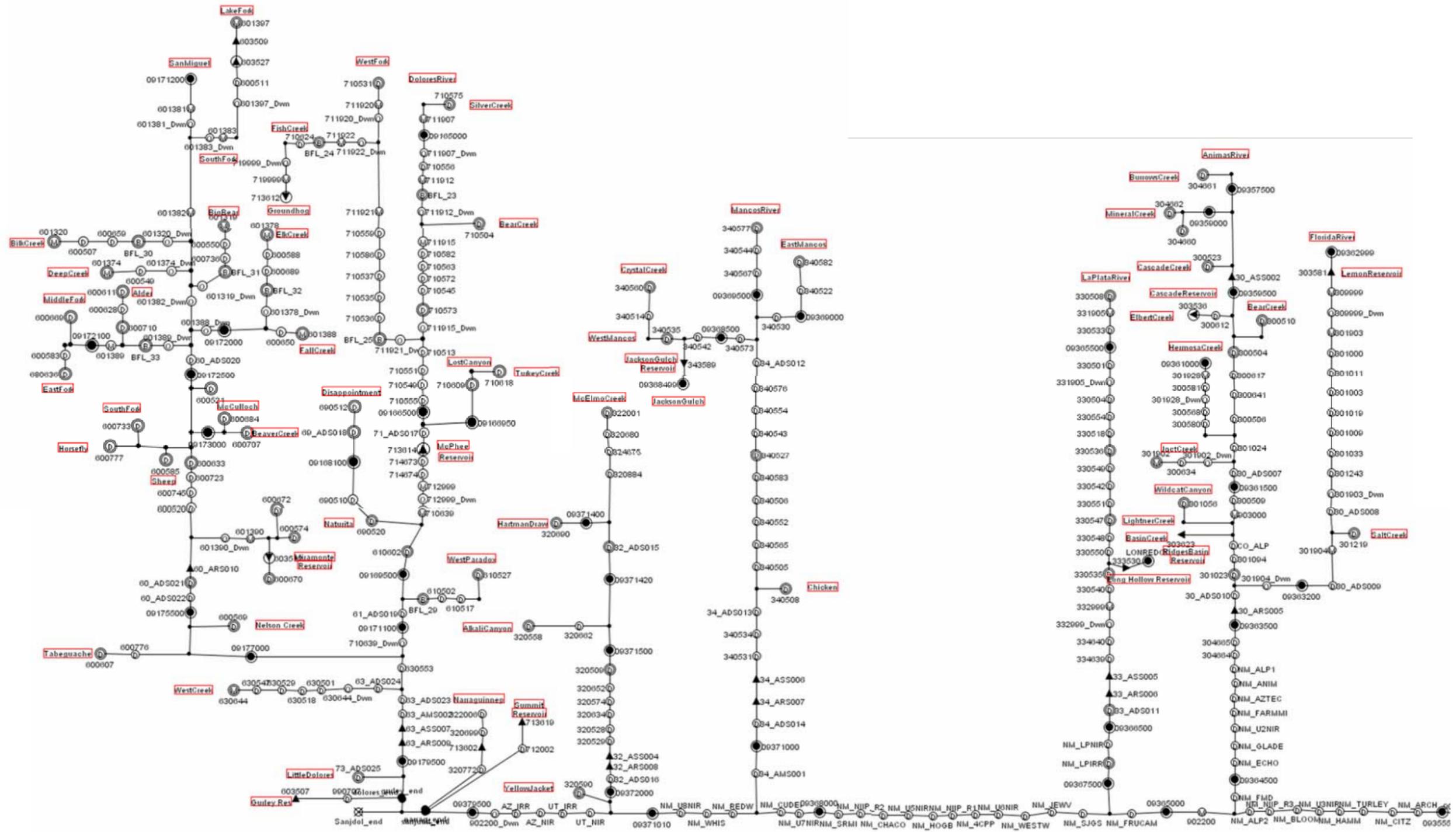
**Figure 4.2 Network Diagram – San Juan / Dolores Planning Model from Animas River Confluence to Bluff, plus Dolores and San Miguel Rivers**

### 4.2.2.2    Aggregation Of Irrigation Structures

In general, the use associated with irrigation diversions having total absolute rights less than 5 cfs in the San Juan River basin and 6.5 cfs in the Dolores River basin were included in the model at "aggregated nodes." These nodes represent the combined historical diversions, demand, and water rights of many small structures within a prescribed sub-basin. The aggregation boundaries were based generally on tributary boundaries, gage location, critical administrative reaches, and instream flow reaches. To the extent possible, aggregations were devised so that they represented no more than 2,200 irrigated acres. In the San Juan Model, 25 aggregated nodes were identified, representing around 35,000 acres of irrigated crops. These nodes were placed in the model at the most downstream position within the aggregated area.

Aggregated irrigation nodes were attributed all the water rights associated with their constituent structures. Their historical diversions were developed by summing the historical diversions of the individual structures, and their irrigation water requirement is based on the total acreage associated with the aggregation.

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**Where to find more information**

- Appendix A includes a memorandum describing the task in which irrigation structures were aggregated. It includes a table showing what diversion structures are included in each aggregation, and a description of where they are located in the model network.

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### 4.2.2.3    Municipal and Industrial Uses

Two nodes in the model represent the combined small diversions for municipal, industrial, and livestock use (M&I); one on the San Juan River in Water District 32 and the other on the Dolores River in Water District 63. Total non-irrigation consumptive use in the San Juan / Dolores basin was estimated, as documented in the CDSS task memorandum "Non-Irrigation (Other Uses) Consumptive Uses and Losses in the Dolores and San Juan River Basins." Consumptive use of the key M&I diversions in the model was subtracted from this basinwide M&I consumption, to derive the basinwide consumptive use attributable to small M&I users. This value was distributed to Water Districts 32 and 63 in accordance with a general distribution of M&I use.

The two aggregated M&I nodes in the San Juan Model represent approximately 2,400 af of consumptive use, a small percentage of the basin total use. These diversions have a priority of 1.0 (very senior) in the model, and a decreed amount that greatly exceeds their demands. In other words, these structures' diversions are not limited by their water right. The monthly demands (which are set to the consumptive use rather than diversion amount) were set in accordance with results of the CDSS memorandum cited above.

Several diversions for municipal and industrial use are modeled explicitly in the San Juan Model.  These explicitly modeled municipal diversions include the Town of Durango, Town of Mancos, Original Rico Flume, the Town of Cortez, and the Town of Fairfield.  These municipal diversions have an estimated average annual consumptive use of approximately 4,600 acre-feet.  Three industrial diversions for power generation are explicitly modeled including Power Canal No. 1, Ames Hydro Project, and Nucla Power Diversion.  These diversions are non-consumptive.

**Where to find more information**

- Appendix B includes a memorandum describing the task in which municipal and industrial uses were aggregated.

### 4.2.3.     Reservoirs

#### 4.2.3.1     Key Reservoirs

Reservoirs with decreed capacities equal to or in excess of 4,000 acre-feet are considered key reservoirs, and are explicitly modeled.  There are 13 key reservoirs with a combined total capacity of approximately 2,350,000 af, or 96 percent of the total absolute storage rights of the basin.  Two reservoirs with capacity of less than 4,000 acre-feet are included in the 13 key reservoirs and are explicitly modeled because they are served by diversions that exceed the cut-off rate as indicated in the previous section.

#### 4.2.3.2     Aggregation of Reservoirs

In keeping with CDSS's objective of representing all consumptive use in the basin, the evaporation losses associated with small reservoirs were incorporated using 17 aggregated reservoir structures.

Ten structures were used to represent all the adjudicated, absolute storage rights in the database that are otherwise unaccounted for.  Table 4.1 below summarizes storage capacity for the ten reservoirs. Surface area for the reservoirs was developed assuming they are straight-sided pits with a depth of 25 feet, based on available dam safety records.

**Table 4.1**
**Aggregated Reservoirs**

| ID | WD | Name | Capacity (AF) | % |
|---|---|---|---|---|
| 29_ARS002 | 29 | ARS002_SanJuan | 2,761 | 5 |
| 30_ARS005 | 30 | ARS005_Animas | 3,359 | 7 |
| 31_ARS004 | 31 | ARS004_LosPinos | 504 | 1 |
| 32_ARS008 | 32 | ARS008_McElmo | 1,005 | 2 |
| 33_ARS006 | 33 | ARS006_LaPlata | 2,465 | 5 |
| 34_ARS007 | 34 | 31_ARS007_Mancos | 2,830 | 6 |
| 60_ARS010 | 60 | ARS010_SMiguel | 11,529 | 22 |
| 63_ARS009 | 63 | ARS009_Dolores | 10,392 | 20 |
| 77_ARS001 | 77 | ARS001_Navajo | 874 | 2 |
| 78_ARS003 | 78 | ARS003_PiedraR | 15,611 | 30 |
| | | Total | 51,330 | 100 |

The seven remaining reservoirs represented stockpond use, as documented in CDSS Task 2.09.13 Memorandum "Non-Irrigation (Other Uses) Consumptive Uses and Losses in the Dolores and San Juan River Basins". The total storage was divided into seven aggregated stockponds, located to correspond with the major stock-use areas. The stockponds were modeled as 10-foot deep straight-sided pits.

Neither the aggregated reservoirs nor the stockponds release to the river in the models. They evaporate, however, and fill to replace the evaporated amount. The effects of small reservoirs filling and releasing are left "in the gage" in the model, and are reflected in CDSS baseflow computations. The aggregated reservoirs are assigned storage rights with a priority of 1.0 (very senior) so that the evaporation use is not constrained by water rights.

**Table 4.2**
**Aggregated Stockponds**

| ID | WD | Name | Capacity (AF) | % |
|---|---|---|---|---|
| 29_ASS001 | 29 | ASS001_SanJuan | 4,233 | 12 |
| 30_ASS002 | 30 | ASS002_AnimasR | 2,469 | 7 |
| 31_ASS003 | 31 | ASS003_LosPinos | 1,411 | 4 |
| 32_ASS004 | 32 | ASS004_McElmo | 16,930 | 48 |
| 33_ASS005 | 33 | ASS005_LaPlata | 2,116 | 6 |
| 34_ASS006 | 34 | ASS006_Mancos | 7,760 | 22 |
| 63_ASS007 | 63 | ASS007_Dolores | 352 | 1 |
| | | Total | 35,271 | 100 |

### 4.2.4. Instream Flow Structures

The model includes 49 instream flow reaches representing instream flow rights held by CWCB, minimum reservoir release agreements, and filings by the U.S. Department of the Interior. These are only a subset of the total CWCB tabulation of rights because many instream flow decrees are for stream reaches very high in the basin, above the model network.

## 4.3 Modeling Period

The San Juan Model data set extends from 1909 through 2003 and operates on USGS water year (October 1 through September 30). The calibration period was 1975 through 2003, a period selected because historical diversion data were readily available in electronic format for key structures. In addition, the period reflects most recent operations in the basin, and includes both drought (1977, 1989-1992, 2000-2003) and wet cycles (1983-1985). Note that many of the input files have data available through 2004, however, USBR reservoir data and data for New Mexico diversions was not available at the time of this documentation, so model input and results are presented through 2003.

As one goes back in time within the data set, more and more data are estimated. Before extending the data set, a feasibility study was done which included a survey of available data and methods for data extension. The scope of the study included all five western slope planning models.

## 4.4 Data Filling

In order to extend the data set to 1909, a substantial amount of reservoir content, diversion, demand, and baseflow time series data needed to be estimated. In many areas of the San Juan / Dolores basin, HydroBase data begins in 1975, although for some structures there is additional, earlier historical data. Therefore, major structures were selected for additional investigation outside the database, or outside the

standard CDSS data tables in the case of reservoir contents. CDSS tools were then developed to automate the estimation process for the remaining structures. This section describes data filling and extension for the San Juan Model.

### 4.4.1.    Historical Data Extension For Major Structures

#### 4.4.1.1    Historical Diversions

Fourteen major diversions in the San Juan / Dolores River basin were identified as warranting additional investigation to find actual diversion records prior to 1975, as shown in Table 4.3.  Most of the structures had diversion records stored in HydroBase from November, 1975 through the current year.  Available records prior to 1975 were digitized from SEO and USBR records to complete historic diversions

**Table 4.3**
**Investigated and Extended Major Structures**

| WDID | Name | 1909-2004 Annual Diversion |
|---|---|---|
| 310665 | Spring Creek Ditch | 59,802 |
| 714674 | Main Canal No. 2 (Great Cut) | 65,328 |
| 714673 | Main Canal No. 1 (Dolores Tunnel) | 60,017 |
| 600633 | Highline Canal + Enl | 28,119 |
| 301011 | Florida Farmers Ditch + Florida Canal | 33,677 |
| 310519 | King Ditch | 22,375 |
| 310547 | Robert Morrison Ditch | 17,385 |
| 300506 | Animas Consolidated Ditch | 16,556 |
| 300617 | Reid Ditch | 13,717 |
| 320772 | MVIC U Lateral | 63,823 |
| 324675 | MVIC Dolores Tunnel | 55,118 |

#### 4.4.1.2    Historical Reservoir Contents

Historical reservoir content data is limited in HydroBase.  Therefore, historical information for the major reservoirs was collected from several sources, including the U.S. Bureau of Reclamation and reservoir owners and operators.  It was necessary to include data from sources other than HydroBase for each of the explicitly modeled reservoirs.

## 4.4.2. Automated Time Series Filling

An automated procedure was adopted to fill time series (i.e., historical diversions, demand, historical reservoir contents, reservoir targets, and irrigation water requirement) input to the model. It is a refinement over using an overall monthly average as the estimated value. Each month of the modeling period has been categorized as an Average, Wet, or Dry month based on the gage flow at long-term "indicator" gages in the San Juan / Dolores River basin. A data point missing for a Wet March, for example, is then filled with the average of only the Wet Marches in the partial time series, rather than all Marches.

The process of developing the Average, Wet, and Dry designation for each month is referred to as "streamflow characterization". There are five streamflow characterizations in the San Juan / Dolores River basin, based on five indicator gages: San Juan River at Pagosa Springs (09342500), Animas River at Durango (09361500), La Plata River at Hesperus (09365500), Dolores River at Dolores (09166500), and San Miguel River near Placerville (09172500). The characterization for the San Juan gage is used when filling in time series for structures in Districts 29, 46, 77 and 78.  The Animas gage characterization pertains to Districts 30 and 31. The La Plata gage characterization pertains to Districts 33 and 34. The Dolores gage characterization pertains to Districts 32, 69, and 71. The San Miguel gage characterization pertains to Districts 60, 61, 63, and 73.

Months with gage flows at or below the $25^{th}$ percentile for that month are characterized as "Dry", while months at or above the $75^{th}$ percentile are characterized as "Wet", and months with flows in the middle are characterized as "Average".

- When historical diversion records are filled, a constraint is added to the estimation procedure. The estimated diversion may not exceed the water rights that were available to the diversion at the time. For example, if a ditch was enlarged and a junior right added to it in the 1950's, then a diversion estimate for 1935 cannot exceed the amount of the original right. The date of first use is derived from the administration number of the water right, which reflects the appropriation date.

- Crop irrigation water requirements for each diversion are calculated for the period 1950 through the current year, based on historical climate data and current irrigated acreage and crop type.  Irrigation water requirements are filled back to 1909 using the wet/dry/average approach adopted for historic diversion.

### 4.4.3.      Baseflow Filling

A typical approach to filling missing hydrologic sequences in the process of basin modeling is to develop regression models between historical stream gages. The best fitting model is then applied to estimate missing data points in the dependent gage's record. Once gage flow time series are complete, observed or estimated diversions, changes in storage, and so forth are added to or subtracted from the gage value to produce an estimated naturalized flow or baseflow.

The typical approach was deemed inadequate for a study period that extended over decades and greatly changed operating environments. Gage relationships derived from late-century gage records probably are not applicable to much earlier conditions, because the later gages reflect water use that may not have been occurring at the earlier time. The CDSS approach is therefore to estimate baseflows at all points where actual gage records are available, and then correlate between naturalized flows, as permitted by availability of data. Ideally, since baseflows do not reflect human activity, the relationship between two sets of baseflows is independent of the resource use and can be applied to any period.

Baseflow filling is carried out more or less automatically using the USGS Mixed Station Model, enhanced for this application under the CDSS project. The name refers to its ability to fill many series, using data from all available stations.  Many independent stations can be used to fill one time series, but only one station is used to fill each individual missing value.  The Mixed Station Model fits each combination of dependent and independent variable with a linear regression relationship on log-transformed values, using the common period of record. For each point to be filled, the model then selects the regression that yields the least standard error of prediction

(SEP), among all eligible correlations.  Note that TSTool is being enhanced to include the functionality of the Mixed Station Model for future modeling updates.

The further one goes back in time, the fewer gage records exist to create baseflow series that can serve as independent variables.  In 1920, there were five gages in the San Juan / Dolores River basin that have enough continuity in records to be used in the modeling effort. By 1950, the number of gages used in the model with data increased to 29.  Approximately 48 percent of the gage site baseflows are filled.

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**Where to find more information**

- The task memorandum documenting application of the Mixed Station Model to CDSS baseflows is entitled "Subtask 11.10 Fill Missing Baseflows" (*Appendix E.8*) and is in the CDSS (*Technical Papers).* It describes a sensitivity investigation of the use of historical gage data in lieu of baseflow estimates when the latter is unavailable.

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## 4.5    Consumptive Use And Return Flow Amounts

The related values, consumptive use and return flow, are key components of both baseflow estimation and simulation in water resources modeling. StateMod's baseflow estimating equation includes a term for return flows. Imports and reservoir releases aside, water that was in the gage historically is either natural runoff or delayed return flow. To estimate the natural runoff, or more generally, the baseflow, one must estimate return flow. During simulation, return flows affect availability of water in the stream in both the month of the diversion and subsequent months.

For non-irrigation uses, consumptive use is the depletive portion of a diversion, the amount that is taken from the stream and removed from the hydrologic system by virtue of the beneficial use. The difference between the diversion and the consumptive use constitutes the return flow to the stream.

For irrigation uses, the relationship between crop consumptive use and return flow is complicated by interactions with the water supply stored in the soil, i.e., the soil moisture reservoir, and losses not attributable to crop use. This is explained in greater detail below.

### 4.5.1.        Variable Efficiency Of Irrigation Use

Generally, the efficiency of irrigation structures in the San Juan Model is allowed to vary through time, up to a specified maximum efficiency. Setting aside soil moisture dynamics for the moment, the predetermined crop irrigation water requirement is met out of the simulated headgate diversion, and efficiency (the ratio of consumed water to diverted water) falls where it may – up to the specified maximum efficiency. If the diversion is too small to meet the irrigation requirement at the maximum efficiency, maximum efficiency becomes the controlling parameter. Crop consumption is limited to the diverted amount times maximum efficiency, and the balance of the diversion, less 6 percent of the non-consumed water, returns to the stream.

The 6 percent of non-consumed water represents water lost to the hydrologic system altogether, through, for example, non-crop consumptive use, deep groundwater storage, or evaporation. Note that for the San Juan Model, 6 percent of non-consumed water represents approximately 10 percent of basin-wide crop consumptive use. This value is recommended as an appropriate estimate of incidental use for the CRDSS basins, and is the same value used in the StateCU estimate of Consumptive Use and Losses in the Colorado River Basin. (Consumptive Uses and Losses Report, Comparison between StateCU CU & Losses Report and the USBR CU & Losses Report (1998-1995), October 1999, Leonard Rice Engineers)

The model is supplied with time series of irrigation water requirements for each structure, based on its crop type and irrigated acreage. This information can be generated using the CDSS StateCU model. Maximum efficiency is also input to the model. For the San Juan / Dolores River basin maximum efficiency is estimated to be 60 percent. Exceptions include Dolores Project recipients that primarily irrigate with sprinklers.

Headgate diversion is determined by the model, and is calculated in each time step as the minimum of 1) the water right, 2) available supply, 3) diversion capacity, and 4) headgate demand. Headgate demand is input as a time series for each structure. During calibration, headgate demand for each structure is simply its historical diversion time series. In the Baseline data set, headgate demand is set to the irrigation water requirement for the specific time step and structure, divided by the historical efficiency for that month of the year. Historical efficiency is defined as the smaller of 1) average historical diversion for the month, divided by average irrigation water requirement, and 2) maximum efficiency. In other words, if water supply is generally plentiful, the headgate demand reflects the water supply that has been typical in the past; and if water supply is generally limiting, it reflects the supply the crop needs in order to satisfy potential ET at the maximum efficiency.

Now StateMod also accounts for water supply available to the crop from the soil. Soil moisture capacity acts as a small reservoir, re-timing physical consumption of the water, and affecting the amount of return flow in any given month. Soil moisture capacity is input to the model for each irrigation structure, based on NRCS mapping. Formally, StateMod accounts for water supply to the crop as follows:

Let **DIV** be defined as the river diversion, $\eta_{max}$ be defined as the maximum system efficiency, and let **CU$_i$** be defined as the crop irrigation water requirement.

Then,   $SW = DIV * \eta_{max;}$        (Max available water to crop)

when   $SW \geq CU_i$:            (Available water to crop is sufficient to meet crop demand)

$CU_w = CU_i$            (Water supply-limited CU = Crop irrigation water requirement)

$SS_f = SS_i + min[(SS_m - SS_i),(SW - CU_w)]$      (Excess available water fills soil reservoir)

$SR = DIV - CU_w - (SS_f - SS_i)$   (Remaining diversion is "non-consumed")

$TR = 0.97 * SR$            (Non-consumed less incidental loss is total return flow)

when   SW < CU$_i$:                                (Available water to Crop is not sufficient to meet crop demand)

   CU$_w$ = SW + min [(CU$_i$ - SW), SS$_i$]       (Water supply-limited CU = available water to crop + available soil storage)

   SS$_f$ = SS$_i$ - min[(CU$_i$ - SW), SS$_i$]    (Soil storage used to meet unsatisfied crop demand)

   SR = DIV - SW                                   (Remaining diversion is "non-consumed")

   TR = 0.97 * SR                                  (Non-consumed less incidental loss is total return flow)

where  **SW**  is maximum water available to meet crop demand

   **CU$_w$** is water supply limited consumptive use;

   **SS$_m$** is the maximum soil moisture reservoir storage;

   **SS$_i$** is the initial soil moisture reservoir storage;

   **SS$_f$** is the final soil moisture reservoir storage;

   **SR** is the diverted water in excess of crop requirement (non-consumed water);

   **TR** is the total return to the stream attributable to this month's diversion.

For the following example, assume the maximum system efficiency is 60 percent, therefore a maximum of 60 percent of the diverted amount can be delivered and available to the crop. When this amount exceeds the irrigation water requirement, the balance goes to the soil moisture reservoir, up to its capacity. Additional non-consumed water returns to the stream, subject to 5 percent incidental loss. In this case, the crop needs are completely satisfied, and the water supply-limited consumptive use equals the irrigation water requirement.

When 60 percent of the diverted amount (the water delivered and available to meet crop demands) is less than the irrigation water requirement, the crop pulls water out of soil moisture storage, limited by the available soil moisture and the unsatisfied irrigation water requirement. Water supply-limited consumptive use is the sum of diverted water available to the crop and supply taken from soil moisture, and may be less than the crop water requirement. Total return flow is the 60 percent of the diversion deemed unable to reach the field (non-consumed), less 5 percent incidental loss.

With respect to consumptive use and return flow, aggregated irrigation structures are treated as described above, where the irrigation water requirement is based on total acreage for the aggregate.

## 4.5.2. Constant Efficiency For Other Uses And Special Cases

In specific cases, the San Juan Model applies an assumed, specified annual or monthly efficiency to a diversion in order to determine consumptive use and return flows. Although the efficiency may vary by month, the monthly pattern is the same in each simulation year. This approach is applied to municipal, industrial, transbasin users, and reservoir feeder canals. It can also apply to irrigation diversions for which irrigation water requirement has not been developed.

In the San Juan Model, irrigation water requirements have been developed for all irrigation diversions in Colorado. The one major transbasin diversion (San Juan-Chama Project) and 10 minor transbasin diversions in the San Juan Model have been assigned a diversion efficiency of 1.00 in all months. During both baseflow estimation and simulation, the entire amount of the diversion is assumed to be removed from the hydrologic system. The explicitly modeled municipal systems, including Durango, Cortez, Dolores, Mancos, Rico, and Fairfield have been assigned monthly efficiencies representing municipal consumptive use patterns. The two aggregated municipal demands have been modeled using historical consumptive use, not withdrawls, and efficiencies have been set to 100 percent.

Reservoir feeders and other carriers that do not irrigate lands have been assigned a diversion efficiency of zero in all months, reflecting that 100 percent of the diversions "return" to the reservoirs. These feeders include the following:
- Cascade Canal
- Narraguinnep Reservoir Inlet
- Jackson Gulch Inlet Canal
- Naturita Canal
- Paxton Ditch
- Summit Ditch
- Turkey Creek Ditch

Three non-consumptive diversions for hydropower generation are included in the model and have been assigned an efficiency of zero. They include Power Canal No. 1, Ames Hydro Project, and Nucla Power Diversion.

Key structures diverting off the mainstem San Juan in New Mexico, Arizona and Utah are assigned monthly efficiencies provided by the USBR, with the exception of the Hammond Ditch, the 4-Corners Power Plant, and the Navajo Indian Irrigation Project (NIIP). Depletions for the Hammond Ditch and the 4-Corners Power Plant were provided by the USBR, therefore they are simulated using the variable efficiency approach. The NIIP diversion return flows are increasing over time as the ground water table is building, therefore diversions are modeled as 100 percent consumptive and associated return flows, provided by the USBR, are "imported" back to the river as negative diversions.

Finally, every structure in the model, including irrigation structures operating by variable efficiency, has monthly efficiencies assigned to it in the model input files. For irrigation structures, these are average monthly efficiencies based on historical diversions and historical crop water requirement over the period 1975 through 2003, but may not exceed the assigned

maximum efficiency. These are used by DMI components of CDSS to create time series of headgate demands for input to the model, as described in Section 4.9.1.

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**Where to find more information**

- StateCU documentation describes different methods for estimating irrigation water requirement for structures, for input to the StateMod model.

- Section 7 of the StateMod documentation has subsections that describe "Variable Efficiency Considerations" and "Soil Moisture Accounting"

- Section 5 of this manual describes the input files where the parameters for computing consumptive use and return flow amounts are specified:

  - Irrigation water requirement in the Irrigation Water Requirement file (Section 5.5.3)

  - Headgate demand in the Direct Diversion Demand file (Section 5.4.4)

  - Historical efficiency in the Direct Diversion Station file (Section 5.4.1)

  - Maximum efficiency in the CU Time Series file (Section 5.5.2)

  - Soil moisture capacity in the Structure Parameter file (Section 5.5.1)

  - Loss to the hydrologic system in the Delay Table file (Section 5.4.2)

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## 4.6     Disposition of Return Flows

### 4.6.1.        Return Flow Timing

Return flow timing is specified to the model by specifying what percentage of the return flow accruing from a diversion reaches the stream in the same month as the diversion, and in each month following the diversion month. Four different return flow patterns are used in the San Juan / Dolores model. One pattern represents instantaneous (or within the same month as the diversion) returns and is applied to municipal and non-consumptive diversions.

The other patterns are generalized irrigation return patterns, applicable to irrigated lands "close" to the stream (center of acreage is approximately 1,000 feet from the stream), and "further" from the stream (center of acreage is approximately 2,000 feet from the stream). They were developed using the Glover analytical solution for parallel drain systems. The State's Analytical Steam Depletion Model (September, 1978), which is widely used in determining return flows for water rights transfers and augmentation plans, permits this option for determining accretion factors. The two irrigation patterns used in Colorado representing "close" and "further" include a 5 percent incidental loss.  New Mexico, Arizona, and Utah irrigation structures use a "close" delay pattern that includes a 10 percent incidental loss.

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The Glover analysis requires these input parameters:

T = Transmissivity in gallons per day per foot (gpd/ft). Transmissivity is the product of hydraulic conductivity (K) in feet per day, saturated thickness (b) in feet, and the appropriate conversion factor.

S = Specific Yield as a fraction

W = Distance from stream to impervious boundary in feet (ft)

x = Distance from point of recharge to stream in feet (ft)

Q = Recharge Rate in gallons per minute (gpm)

Regionalized values for the aquifer parameters were determined by selecting ten representative sites throughout the west slope, based partly on the ready availability of geologic data, and averaging them. The analysis estimated generalized transmissivity as 48,250 gpd/ft, specific yield as 0.13, and distance from the stream to the alluvial boundary as 3,500 ft. The Glover analysis was then executed for both 1,000 feet from the recharge center to the stream, and 2,000 feet from the recharge center to the stream.

It was assumed that the resulting pattern applies to only half of the return flow, and that the other half returns within the month via the surface (tailwater returns, headgate losses, etc.). Combining surface water returns with groundwater returns resulted in the two irrigation return patterns shown in Table 4.4 and graphed in Figure 4.3. A third return flow pattern was included for the San Juan Model to reflect returns to Long Hollow from irrigation on Red Mesa. As shown in Table 4.4, this pattern reflects a longer period of return through the ground water system. Month 1 is the month in which the diversion takes place. Note that Figure 4.3 reflects 100 percent of unused water returning to the river, both from surface runoff and subsurface flow. For each CDSS basin, the first month's return flow percent will be reduced to recognize incidental loss. As discussed above, incidental losses in the San Juan / Dolores model are estimated to be 6 percent of unused water, as shown in Table 4.4.

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**Where to find more information**
- CDSS Memorandum "Colorado River Basin Representative Irrigation Return Flow Patterns", Leonard Rice Engineers, January, 2003. *(Technical Papers)*

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### 4.6.2.       Return Flow Locations

Return flow locations were determined during the original data gathering, by examining irrigated lands mapping and USGS topographical maps, and confirming locations with Division 7 and 4 personnel. Some return flow locations were modified during calibration.

**Table 4.4**
**Percent of Return Flow Entering Stream in Month _n_ after Diversion (6% loss)**

| Month _n_ | For Lands "Close" to Stream (%) | For lands "Further" from Stream (%) | For Lands Returning to Long Hollow (%) |
|-----------|--------------------------------|--------------------------------------|-----------------------------------------|
| 1 | 72.6 | 54.4 | 1.3 |
| 2 | 11.3 | 14.5 | 1.5 |
| 3 | 3.2 | 7.2 | 1.6 |
| 4 | 2.2 | 5.0 | 3.0 |
| 5 | 1.6 | 3.7 | 3.0 |
| 6 | 1.2 | 2.7 | 3.0 |
| 7 | 0.8 | 2.0 | 3.0 |
| 8 | 0.6 | 1.5 | 3.0 |
| 9 | 0.5 | 1.1 | 3.0 |
| 10 | 0 | 0.8 | 3.0 |
| 11 | 0 | 0.6 | 3.0 |
| 12 | 0 | 0.5 | 3.0 |
| 13 - 14 | 0 | 0 | 2.7 |
| 15 - 36 | 0 | 0 | 2.6 |
| Total | 94 | 94 | 94 |
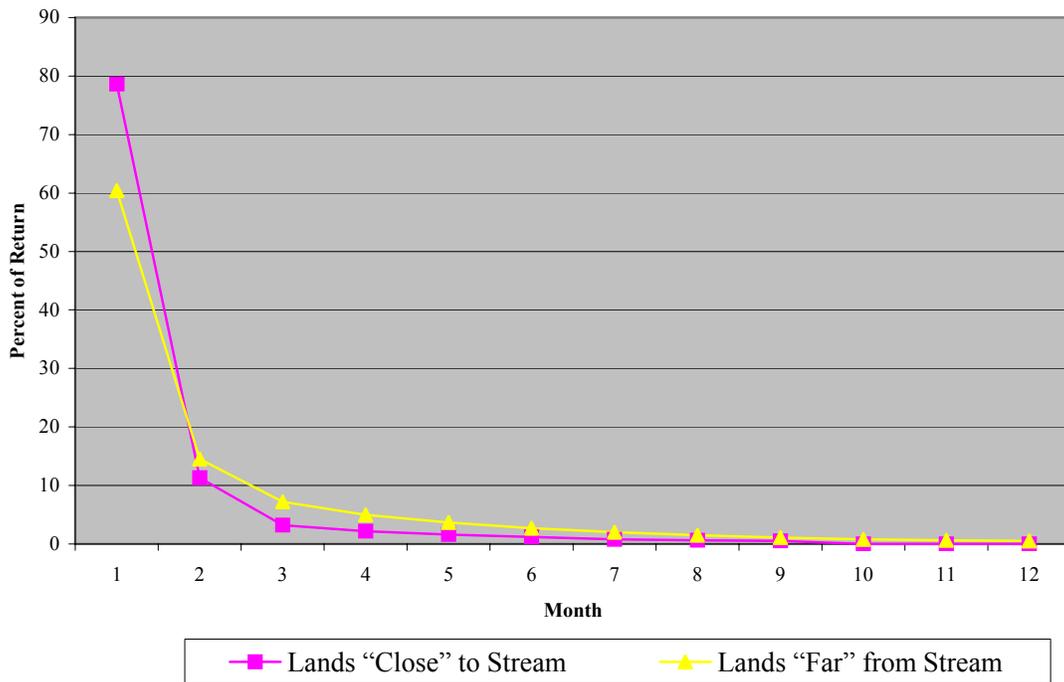


**Figure 4.3 Percent of Return in Months After Division**

## 4.7    Baseflow Estimation

In order to simulate river basin operations, the model must have at hand the amount of water that would have been in the stream if none of the operations being modeled had taken place. These undepleted flows are called "baseflows". The term is used in favor of "virgin flow" or "naturalized flow" because it recognizes that some historical operations can be left "in the gage", with the assumption that those operations and impacts will not change in the hypothetical situation being simulated.

Given data on historical depletions and reservoir operations, StateMod can estimate baseflow time series at specified discrete inflow nodes. This process was executed prior to executing any simulation, and the resulting baseflow file became part of the input data set for subsequent simulations. Baseflow estimation requires three steps: 1) adjust USGS stream gage flows using historical records of operations to get baseflow time series at gaged points, for the gage period of record; 2) fill the baseflow time series by regression against other baseflow time series; 3) distribute baseflow gains above and between gages to user-specified, ungaged inflow nodes. These three steps are described below.

### 4.7.1.    Baseflow Computations At Gages

Baseflow at a site where historical gage data is available is computed by adding historical values of all upstream depletive effects to the gaged value, and subtracting historical values of all upstream augmenting effects from the gaged value:

$$Q_{baseflow} = Q_{gage} + Diversions – Returns – Imports +/- \Delta Storage + Evap +/- \Delta Soil\ Moisture$$

Historical diversions, imports, and reservoir contents are provided directly to StateMod to make this computation. Evaporation is computed by StateMod based on historical evaporation rates and reservoir contents. Return flows and soil storage are similarly computed based on diversions, crop water requirements, and/or efficiencies as described in Section 4.5, and return flow parameters as described in Section 4.6.

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**Where to find more information**

- When StateMod is executed to estimate baseflows at gages, it creates a Baseflow Information file *(\*.xbi)* that shows this computation for each gage and each month of the time step.

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### 4.7.2.    Baseflow Filling

Wherever gage records are missing, baseflows are estimated as described in Section 4.4.3 - Baseflow Filling.

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### 4.7.3. Distribution Of Baseflow To Ungaged Points

In order for StateMod to have a water supply to allocate in tributary headwaters, baseflow must be estimated at all ungaged headwater nodes. In addition, baseflow gains between gages are modeled as entering the system at ungaged points, to better simulate the river's growth due to generalized groundwater contributions and unmodeled tributaries. As a matter of convention, key reservoir nodes were designated baseflow nodes in order for the model to "see" all the water supply estimated to be available at the site. During calibration, other ungaged nodes were sometimes made baseflow nodes to better simulate a water supply that would support historical operations.



$$BFungaged = BF_1 + \frac{(A*P)ungaged}{(A*P)_3 - (A*P)_2 - (A*P)_1} *(BF_3 - BF_2 - BF_1)$$

KEY:

Area for $(A*P)_1$

Area for $(A*P)_2$

Area for $(A*P)_3$

Area for $(A*P)_{ungaged}$
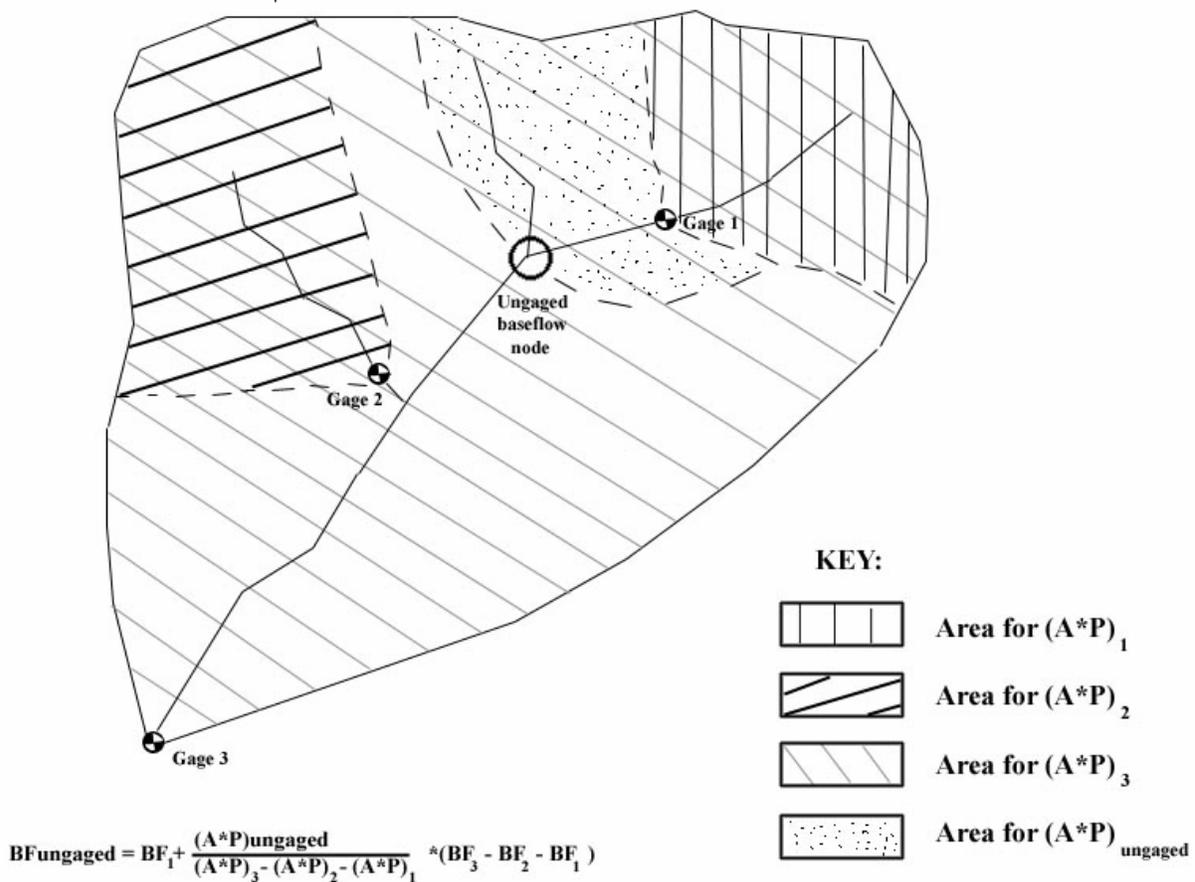
**Figure 4.4 Hypothetical Basin Illustration**

StateMod has an operating mode in which, given baseflows at gaged sites and physical parameters of the gaged and ungaged sub-basins, it distributes baseflow gains spatially. The default method ("gain approach") for assigning baseflow to ungaged locations pro-rates baseflow gain above or between gages according to the product of drainage area and average annual precipitation. That is, each gage is assigned an "Area*Precipitation" (A*P) term, equal to the product of total area above the gage, and average annual precipitation over the gage's entire drainage area. Ungaged baseflow points are assigned an incremental "A*P", the product of the incremental drainage area above the ungaged baseflow point and below any upstream gages, and

the average annual precipitation over that area. Figure 4.4 illustrates a hypothetical basin and the areas associated with each of three gages and an ungaged location.

The portion of the baseflow gain below Gages 1 and 2 and above Gage 3, at the Ungaged location between the gages, is the gage-to-gage baseflow gain ($BF_3$ minus ($BF_2 + BF_1$)) times the ratio $(A*P)_{ungaged}/[(A*P)_{downstream\ gage} - \Sigma (A*P)_{upstream\ gage(s)}]$. Total baseflow at the ungaged location is equal to this term, plus the sum of baseflows at upstream gages. In the example there is only one upstream gage, having baseflow $BF_1$.

A second option for estimating headwater baseflows was sometimes invoked if the default method created results that did not seem credible. This method, referred to as the "neighboring gage approach", created a baseflow time series by multiplying the baseflow series at a specified gage by the ratio $(A*P)_{headwater}/(A*P)_{gage}$. This approach was effective, for example, for an ungaged tributary parallel and close to a gaged tributary.

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**Where to find more information**

- Documentation for **StateDMI** describes computation of baseflow distribution parameters based on A*P, incremental A*P, and the network configuration.

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## 4.8    Calibration Approach

Calibration is the process of simulating the river basin under historical conditions, and judiciously adjusting parameter estimates to achieve agreement between observed and simulated values of streamgages, reservoir levels, and diversions. The San Juan Model was calibrated in a two-step process described below. The issues encountered and results obtained are described in Section 7.

### 4.8.1.    First Step Calibration

In the first calibration run, the model was executed with relatively little freedom with respect to operating rules. Headgate demand was simulated by historical diversions, and historical reservoir contents served as operational targets. The reservoirs would not fill beyond the historical content even if water was legally and physically available. Operating rules caused the reservoir to release to satisfy beneficiaries' demands, but if simulated reservoir content was higher than historical after all demand was satisfied, the reservoir released water to the river to achieve the historical end-of-month content. In addition, multiple-headgated collection systems would feature the historical diversion as the demand at each diversion point.

The objective of the first calibration run was to refine baseflow hydrology and return flow locations before introducing uncertainties related to rule-based operations. Diversion shortages, that is, the inability of a water right to divert what it diverted historically, indicated possible problems with the way baseflows were represented or with the location assigned to return flows back to the river. Baseflow issues were also evidenced by poor simulation of the historical

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gages.  Generally, the parameters that were adjusted related to the distribution of baseflows (i.e., A*P parameters or the method for distributing baseflows to ungaged locations), and locations of return flows.

### 4.8.2.　　Second Step Calibration

In the second calibration run, constraints on reservoir operations were relaxed. As in the first calibration run, reservoirs were simulated only for the period in which they were on-line historically. Reservoir storage was limited only by water right and availability, and generally, reservoir releases were controlled by downstream demands. Exceptions were made for reservoirs known to operate by power or flood control curves, or other unmodeled considerations. In these cases, targets were developed to express the operation.  For multi-structures in the San Juan Model, the centralized demand was placed at the final destination nodes, and priorities and legal availability govern diversions from the various headgates.

The objective of the second calibration step was to refine operational parameters. For example, poor calibration at a reservoir might indicate poor representation of administration or operating objectives. Calibration was evaluated by comparing simulated gageflows, reservoir contents, and diversions with historical observations of these parameters.

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**Where to find more information**

- Section 7 of this document describes calibration of the San Juan Model.

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## 4.9　　Baseline Data Set

The Baseline data set is intended as a generic representation of recent conditions on the Dolores and San Juan Rivers, to be used for "what if" analyses. It represents one interpretation of current use, operating, and administrative conditions, as though they prevailed throughout the modeling period. All existing water resources systems are on line and operational in the model from 1909 forward, as are junior rights and modern levels of demand. The data set is a starting point, which the user may choose to add to or adapt for a given application or interpretation of probable demands and near-term conditions.

### 4.9.1.　　Calculated Irrigation Demand

In the Baseline data set, irrigation demand is set to a time series determined from crop irrigation water requirement and average irrigation efficiency for the structure. This "Calculated Demand" is an estimate of the amount of water the structure would have diverted absent physical or legal availability constraints. Thus if more water was to become available to the diverter under a proposed new regime, the model would show the irrigator with sufficient water rights diverting more than he did historically.

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Calculated demands must account for both crop needs and irrigation practices. Monthly calculated demand for 1975 through 2003 is generated directly, by taking the maximum of crop irrigation water requirement divided by average monthly irrigation efficiency, and historic diversions. The irrigation efficiency may not exceed the defined maximum efficiency (50 percent), however, which represents a practical upper limit on efficiency for flood irrigation systems. Thus calculated demand for a perennially shorted diversion (irrigation water requirement divided by diversions is, on average, greater than 0.50) will be greater than the historical diversion for at least some months. By estimating demand to be the maximum of calculated demand and historical diversions, such irrigation practices as diverting to fill the soil moisture zone or diverting for stock watering can be mimicked more accurately.

Prior to 1975, calculated demands were filled using the automated time series filling technique described in Section 4.4.2. This is done because historical diversion records are generally not available until 1975 in the San Juan basin.

### 4.9.2. Municipal And Industrial Demand

Municipal and industrial demands were set to recent values or averages of recent records.

### 4.9.3. Transbasin Demand

Transbasin diversion demands were set to average monthly diversions over the period 1975-1991.

### 4.9.4. Reservoirs

All reservoirs are represented as being on-line throughout the study period, at their current capacities. Initial reservoir contents were set to full. During simulation, StateMod sizes reservoir releases to satisfy unmet headgate demand, assuming the reservoir is a supplemental supply to direct flow rights. (StateMod has the option of sizing releases to meet irrigation water requirement at maximum efficiency, but that style of operation is not characteristic of the San Juan River basin reservoirs.)

# 5. Baseline Data Set

This section describes each StateMod input file in the Baseline Data Set. The data set, described in more general terms in Section 4.9, is expected to be a starting point for users who want to apply the San Juan River water resources planning model to a particular management issue. Typically, the investigator wants to understand how the river regime would change under a new use or different operations.  The change needs to be quantified relative to how the river would look today absent the new use or different operation, which may be quite different from the historical record. The Baseline data set provides a basis against which to compare future scenarios. Users may opt to modify the Baseline data set for their own interpretation of current or near-future conditions. For instance, they may want to look at the effect of conditional water rights on available flow.  The following detailed, file-by-file description is intended to provide enough detail that this can be done with confidence.

This section is divided into several subsections:

- Section 5.1 describes the response file, which lists names of the rest of the data files. The section tells briefly what is contained in each of the named files, so refer to it if you need to know where to find specific information.

- Section 5.2 describes the control file, which sets execution parameters for the run.

- Section 5.3 includes four files that together specify the river system. These files express the model network and baseflow hydrology.

- Section 5.4 includes files that define characteristics of the diversion structures in the model: physical characteristics, irrigation parameters, historical diversions, demand, and water rights.

- Section 5.5 includes files that further define irrigation parameters for diversion structures.

- Section 5.6 includes files that define characteristics of the reservoir structures in the model: physical characteristics, evaporation parameters, historical contents, operational targets, and water rights.

- Section 5.7 includes files that define characteristics of instream flow structures in the model: location, demand, and water rights.

- Section 5.8 describes the operating rights file, which specifies operations other than simple diversions, on-stream reservoir storage, and instream flow reservations. For example, the file specifies rules for reservoir releases to downstream users, diversions by exchange, and movement of water from one reservoir to another.

## 5.1 Response File (*.rsp)

The response file is created by hand using a text editor, and lists all the other files in the data set. StateMod reads the response file first, and then "knows" what files to open to get the rest of the input data. The list of input files is slightly different depending on whether StateMod is being run to generate baseflows or to simulate. Since the "Baseline data set" refers to a particular simulation scenario, the response file for the Baseline is presented first; it is followed by a description of the files used for baseflow generation.

### 5.1.1 For Baseline Simulation

The listing below shows the file names in *sj2004B.rsp*, describes contents of each file, and shows the subsection of this chapter where the file is described in more detail.

| File Name | Description | Reference |
|-----------|-------------|-----------|
| sj2004.ctl | Control file – specifies execution parameters, such as run title, modeling period, options switches | Section 5.2 |
| sj2004.rin | River network file – lists every model node and specifies connectivity of network | Section 5.3.1 |
| sj2004B.res | Reservoir station file – lists physical reservoir characteristics such as volume, area-capacity table, and some administration parameters | Section 5.6.1 |
| sj2004B.dds | Direct diversion station file – contains parameters for each diversion structure in the model, such as diversion capacity, return flow characteristics, and irrigated acreage served | Section 5.4.1 |
| sj2004.ris | River station file – lists model nodes, both gaged and ungaged, where hydrologic inflow enters the system | Section 5.3.2 |
| sj2004.ifs | Instream flow station file – lists instream flow reaches | Section 5.7.1 |
| sj2004.ifr | Instream flow right file – gives decreed amount and administration number of instream flow rights associated with instream flow reaches | Section 5.7.3 |
| sj2004.rer | Reservoir rights file – lists storage rights for all reservoirs | Section 5.6.5 |

| File Name | Description | Reference |
|-----------|-------------|-----------|
| sj2004.ddr | Direct diversion rights file – lists water rights for direct diversion | Section 5.4.5 |
| sj2004B.opr | Operational rights file – specifies many different kinds of operations that are more complex than a direct diversion or an on-stream storage right. Operational rights can specify, for example, a reservoir release for delivery to a downstream diversion point, a reservoir release to allow diversion by exchange at a point which is not downstream, or a direct diversion to fill a reservoir via a feeder | Section 5.8 |
| sj2004.eva | Evaporation file – gives monthly rates for net evaporation from free water surface | Section 5.6.2 |
| sj2004x.xbm | Baseflow data file – time series of undepleted flows at all nodes listed in *sj2004.ris* | Section 5.3.5 |
| sj2004B.ddm | Monthly demand file – monthly time series of headgate demands for each direct diversion structure | Section 5.4.4 |
| sj2004.ifa | Instream flow demand file – gives the decreed monthly instream flow rates | Section 5.7.2 |
| sj2004.dly | Delay Table – contains several return flow patterns that express how much of the return flow accruing from diversions in one month reach the stream in each of the subsequent months, until the return is extinguished | Section 5.4.2 |
| sj2004B.tar | Reservoir target file – monthly time series of maximum and minimum targets for each reservoir. A reservoir may not store above its maximum target, and may not release below the minimum target | Section 5.6.4 |
| sj2004.ipy | CU Irrigation Parameter Yearly file – maximum efficiency and irrigated acreage by year and by structure, for variable efficiency structures | Section 5.5.2 |
| sj2004B.iwr | Irrigation Water Requirement file – monthly time series of crop water requirement by structure, for variable efficiency structures | Section 5.5.3 |
| sj2004.str | StateCU Structure file – soil moisture capacity by structure, for variable efficiency structures | Section 5.5.1 |
| sj2004.eom | Reservoir End of month contents file – Monthly time series of historical reservoir contents | Section 5.6.3 |
| sj2004.rib | Baseflow Parameter file – gives coefficients and related gage ID's for each baseflow node, with which StateMod computes baseflow gain at the node | Section 5.3.3 |
| sj2004.rih | Historical streamflow file – Monthly time series of streamflows at modeled gages | Section 5.3.4 |
| sj2004.ddh | Historical Diversions – Monthly time series of historical diversions | Section 5.4.3 |
| sj2004.gis | GIS file | n/a |

### 5.1.2        For Generating Baseflow

The baseflow file (*.xbm) that is part of the Baseline data set was created by StateMod and the Mixed Station Model in three steps which are described in Sections 4.7.1 through 4.7.3. In the first step, StateMod estimates baseflows at gaged locations, using the files listed in the response file sj2004.rsp. The baseflow response file calls for different reservoir station, operational rights, and reservoir target files from the Baseline response file, in all cases to reflect strictly historical data.

The baseflow time series created in the first run are all partial series, because gage data is missing some of the time for all gages. The Mixed Station Model is used to fill the series, creating a complete series of baseflows at gages in a file named sj2004.xbf. The response file for the third step, in which StateMod distributes baseflow to ungaged points, is named sj2004x.rsp. The only difference between the first-step response file sj2004.rsp and third-step response file sj2004x.rsp is that the sj2004.xbf file replaces the historical gage file sj2004.rih.

## 5.2    Control File (*.ctl)

The control file is hand-created using a text editor. It contains execution parameters for the model run, including the starting and ending year for the simulation, the number of entries in certain files, conversion factors, and operational switches. Many of the switches relate to either debugging output, or to integrated simulation of groundwater and surface water supply sources. The latter was developed for the Rio Grande basin and is not a feature of the San Juan Model. Control file switches are all specifically described in the StateMod documentation. The simulation period parameters (starting and ending year) are the ones that users most typically adjust.

## 5.3    River System Files

### 5.3.1        River Network File (*.rin)

The river network file is created by StateDMI, which reads in a hand-edited file (sj2004.net) that specifies the model network.

The river network file describes the location and connectivity of each node in the model. Specifically, it is a list of each structure ID and name, along with the ID of the next structure downstream. It is an inherent characteristic of the network that, with the exception of the downstream terminal node, each node has exactly one downstream node.

Figures 4.1 and 4.2 in Section 4.2.1 illustrate the network, which starts at the major tributaries to the San Juan River, including the East Fork San Juan, Rio Blanco, Piedra River, Los Pinos River, Animas River, La Plata River, Mancos River, and McElmo Creek. The last represented node on the San Juan River is the San Juan River near Bluff, Utah Gage. The Dolores River and its major tributaries, including the San Miguel River, are represented through the Dolores River at Gateway gage near the Colorado-Utah state line.

River gage nodes are labeled with United States Geological Survey (USGS) stream gaging station numbers (i.e., 09000000). In general, diversion and reservoir structure identification numbers are composed of Water District number followed by the State Engineer's four-digit structure ID. Instream flow water rights are also identified by the Water District number followed by the assigned State Engineer's four-digit identifier. Table 5.1 shows how many nodes of each type are in the San Juan Model.

**Table 5.1**
**River Network Elements**

| Type | Number |
|---|---|
| Diversion | 327 |
| Instream Flow | 49 |
| Reservoirs | 32 |
| Stream Gages | 59 |
| | |
| Total | 467 |

**Where to find more information**

- StateDMI documentation gives the file layout and format for the *.net* file.

### 5.3.2 River Station File (*.ris)

The river station file is also created by StateDMI. It lists the model's baseflow nodes, both gaged and ungaged. These are the discrete locations where streamflow is added to the modeled system.

There are 59 gages in the model and 124 ungaged baseflow locations, for a total of 183 hydrologic inflows to the San Juan River model. Ungaged baseflow nodes include all ungaged headwater nodes, 9 key reservoir nodes, 6 aggregated diversion nodes, and any other nodes where calibration revealed a need for it. In the last case, a portion of the water that was simulated as entering the system further down (e.g., at the next gage) was moved up the system to the ungaged point.

### 5.3.3 Baseflow Parameter File (*.rib)

The baseflow parameter file has an entry for each ungaged baseflow node in the model, specifying coefficients, or "proration factors", used to calculate the baseflow gain at that point. StateDMI computes proration factors based on the network structure and Area*Precipitation values supplied for both gages and ungaged baseflow nodes. This information is in the network file which is input to StateDMI. Under the default "gain approach", described in Section 4.7.3, the factors reflect the ratio of the product of incremental area and local average precipitation above the ungaged point to the product of incremental area and local average precipitation for the entire gage-to-gage reach.

At some locations, the hydrograph developed using the gain approach showed an attenuated shape that was not representative of a "natural" hydrograph. This occurred in headwater areas where the hydrograph is dominated by runoff from spring snowmelt. In these situations, baseflow was determined as a function of baseflow at a nearby stream gage, specified by the user. Ideally, this "neighboring gage" was from a drainage basin with similar physiographic characteristics. Baseflow at the ungaged site was assumed to be in the same proportion to baseflow at the nearby gage as the product of area and average precipitation at the two locations. This procedure, referred to as the "neighboring gage approach", was applied to these structures:

| Tributary Name | Baseflow WDID | Neighboring Gage |
|---|---|---|
| Mill Creek | 290582 | 09343300 |
| Rito Blanco | 290588 | 09343300 |
| Mill Creek | 290613 | 09343300 |
| Coal Creek | 290729 | 09339900 |
| Four Mile Creek | 292005 | 09342000 |
| Bear Creek | 300510 | 09357500 |
| Wildcat Canyon | 301056 | 09357500 |
| Salt Creek | 301219 | 09357500 |
| Junction Creek | 301902 | 09357500 |
| Elbert Creek | 303536 | 09357500 |
| Rock Creek | 310593 | 09355000 |
| Ignacio Draw | 310710 | 09355000 |
| Los Pinos River | 314637 | 09352900 |
| Stollsteimer Creek | 320558 | 09371500 |
| Chicken Creek | 340508 | 09371000 |
| West Fork Mancos River | 340535 | 09368500 |
| Crystal Creek | 340560 | 09368500 |
| Beaver Creek | 460503 | 09355000 |
| Saltado Creek | 600521 | 09173000 |
| Basin Creek | 600569 | 09173000 |
| Naturita Creek | 600574 | 09173000 |
| Horsefly Creek | 600585 | 09173000 |
| Tabeguache Creek | 600607 | 09173000 |
| Leopard Creek | 600611 | 09172500 |
| Leopard Creek | 600669 | 09173000 |
| Naturita Creek | 600670 | 09173000 |
| Naturita Creek | 600672 | 09173000 |
| Horsefly Creek | 600733 | 09173000 |
| Horsefly Creek | 600777 | 09175500 |
| Big Bear Creek | 601319 | 09171200 |
| Bilk Creek | 601320 | 09171200 |
| Deep Creek | 601374 | 09171200 |
| Fall Creek | 601378 | 09172500 |
| Fall Creek | 601388 | 09172500 |
| Lake Fork | 601397 | 09171200 |

| Tributary Name | Baseflow WDID | Neighboring Gage |
|---|---|---|
| Lake Fork | 603527 | 09171200 |
| West Paradox Creek | 610527 | 09165000 |
| Paradox Creek | BFL_29 | 09165000 |
| West Creek | 630644 | 09177000 |
| Horsefly Creek | 680636 | 09173000 |
| Little Dolores River | 73_ADS025 | 09177000 |
| Bear Creek | 710504 | 09165000 |
| West Dolores River | 710531 | 09165000 |
| Groundhog Creek | 713612 | 09165000 |
| Weminuche Creek | 780562 | 09352900 |
| Tiffany Arroyo | 780692 | 09352900 |

In addition, a straight proration was used when an appropriate "neighboring gage" could not be identified due to unique characteristics of a structures' drainage basin. For the structures in the following table, a percent of downstream baseflow to be applied at the structure location was directly set in StateDMI.

| Tributary Name | Baseflow WDID | Baseflow Percent | Downstream Gage |
|---|---|---|---|
| North Fork Los Pinos River | 314638 | 20 % | 09353500 |
| Cascade Creek | 300523 | 40 % | 09361500 |

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**Where to find more information**

- StateDMI documentation gives the file layout and format for the *.net* file.

- Section 4.7.3 describes how baseflows are distributed spatially.

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### 5.3.4    Historical Streamflow File (*.rih)

Created by **TSTool**, the historical streamflow file contains historical gage records for 1909-2003, for the modeled gages. These are used for baseflow stream generation and to create comparison output that is useful during model calibration. All records are taken directly from USGS tables in the database. Missing values, when the gage was not in operation, are denoted as such, using the value "-999." Table 5.2 lists the USGS gages used, their periods of record, and their average annual flows over the period of record. Large periods of missing data are specified, however, most gages listed have days, months, or years missing within the full period.

## 5.3.5      Baseflow File (*.xbm)

The baseflow file contains estimates of base streamflows throughout the modeling period, at the locations listed in the river station file. Baseflows represent the conditions upon which simulated diversion, reservoir, and minimum streamflow demands are superimposed. StateMod estimates baseflows at stream gages, during the gage's period of record, from historical streamflows, diversions, end-of-month contents of modeled reservoirs, and estimated consumption and return flow patterns. It then distributes baseflow at gage sites to ungaged locations using proration factors representing the fraction of the reach gain estimated to be tributary to a baseflow point.

Table 5.3 compares historical gage flows with simulated baseflows for the 23 gages that operated continuously during the calibration period (1975-2003). The difference between the two represents estimated historical consumptive use upstream of the gage over this period.  As shown, baseflows at gage 09355000 – Spring Creek at La Boca are less than historical flows, representing the significant imports to that tributary from the Los Pinos River.

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### Where to find more information

- Sections 4.7.1 through 4.7.3 explain how StateMod and the Mixed Station Model are used to create baseflows.

- When StateMod is executed to estimate baseflows at gages, it creates a Baseflow Information file *(*.xbi)* that shows this computation for each gage and each month of the time step.

- When the Mixed Station Model is used to fill baseflows, it creates two reports, *sj2004.sum* and *sj2004.sts*. The first indicates which stations were used to estimate each missing data point, and the second compares statistics of the unfilled time series with statistics of the filled series for each gage.

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**Table 5.2**
**Historical Average Annual Flows for Modeled San Juan Stream Gages**

| Gage ID | Gage Name | Period of Record | Historical Flow (acre-feet/year) |
|---------|-----------|------------------|-----------------------------------|
| 09339900 | East Fork San Juan River above Sand Creek | 1957 – 2004 | 64,418 |
| 09341500 | West Fork San Juan River near Pagosa Springs | 1936 – 1960 1985 – 1987 | 85,876 |
| 09342000 | Turkey Creek near Pagosa Springs | 1938 – 1949 | 27,408 |
| 09342500 | San Juan River at Pagosa Springs | 1936 – 2004 | 266,848 |
| 09343300 | Rio Blanco below Blanco Diversion Dam near Pagosa Springs | 1972 – 2004 | 33,479 |
| 09344000 | Navajo River at Banded Peak Ranch near Chromo | 1937 – 2004 | 78,515 |
| 09344400 | Navajo River below Oso Diversion Dam nr Chromo | 1972 – 2004 | 47,650 |

| Gage ID | Gage Name | Period of Record | Historical Flow (acre-feet/year) |
|---|---|---|---|
| 09345200 | Little Navajo River below Oso Diversion Dam near Chromo | 1972 – 1996 | 6,261 |
| 09346000 | Navajo River at Edith | 1913 –1995 | 92,853 |
| 09346400 | San Juan River near Carracas | 1963 – 2004 | 443,017 |
| 09347500 | Piedra River at Bridge Ranger Sta. near Pagosa Springs | 1937 – 1941 1947 – 1954 | 74,082 |
| 09349500 | Piedra River near Piedra | 1940 – 1972 | 221,509 |
| 09349800 | Piedra River near Arboles | 1963 – 2004 | 287,013 |
| 09352900 | Vallecito Creek near Bayfield | 1963 – 2004 | 104,672 |
| 09353500 | Los Pinos River near Bayfield | 1928 – 1986 | 260,163 |
| 09354000 | Los Pinos River at Bayfield | 1931 – 1961 | 164,227 |
| 09354500 | Los Pinos River at La Boca | 1952 – 2004 | 168,486 |
| 09355000 | Spring Creek at La Boca | 1952 – 2004 | 22,867 |
| 09355500 | San Juan River near Archuleta | 1956 – 2004 | 840,304 |
| 09357500 | Animas River at Howardsville | 1936 – 2004 | 75,717 |
| 09359000 | Mineral Creek near Silverton | 1937 – 1949 | 76,835 |
| 09359500 | Animas River above Tacoma | 1946 – 1956 | 386,231 |
| 09361000 | Hermosa Creek near Hermosa | 1921 – 1928 1941 – 1982 | 97,070 |
| 09361500 | Animas River at Durango | 1913 – 2004 | 592,141 |
| 09362999 | Florida River above Lemon Reservoir (USBR data) | 1965 – 2004 | 6,103 |
| 09363200 | Florida River at Bondad | 1957 – 1963 1968 – 1983 | 55,705 |
| 09363500 | Animas River near Cedar Hill, NM | 1935 – 1996 | 670,087 |
| 09364500 | Animas River at Farmington, NM | 1914 – 2004 | 623,461 |
| 09365000 | San Juan River at Farmington, NM | 1931 – 2004 | 1,489,067 |
| 09365500 | La Plata River at Hesperus | 1918 – 2004 | 31,750 |
| LONREDCO | Long Hollow at the Mouth near Red Mesa | 1988 – 2004 | 5,405 |
| 09366500 | La Plata River at CO-NM State Line | 1921 – 2004 | 25,348 |
| 09367500 | La Plata River near Farmington, NM | 1939 – 2004 | 20,542 |
| 09368000 | San Juan at Shiprock | 1935 – 2004 | 1,497,364 |
| 09369500 | Middle Mancos River near Mancos | 1939 – 1951 | 5,766 |
| 09369000 | East Mancos River near Mancos | 1938 – 1951 | 8,092 |
| 09368499 | Above Jackson Gulch Reservoir (USBR data) | 1973 – 2004 | 875 |
| 09368500 | West Mancos River near Mancos | 1939 – 1953 | 28,563 |
| 09371000 | Mancos River near Towaoc | 1922 – 1943 1952 – 2004 | 36,405 |
| 09371010 | San Juan River at Four Corners | 1978 – 2004 | 1,561,580 |
| 09371400 | Hartman Draw at Cortez | 1979 – 1986 | 10,151 |
| 09371420 | McElmo Creek above Alkali Canyon near Cortez | 1973 – 1986 | 19,406 |
| 09371500 | McElmo Creek near Cortez | 1951 – 1954 1983 – 2004 | 40,644 |
| 09372000 | McElmo Creek near CO-UT State Line | 1952 – 2004 | 36,664 |
| 09379500 | San Juan River near Bluff | 1928 – 2004 | 1,634,884 |
| 09165000 | Dolores River below Rico | 1952 – 2004 | 96,426 |
| 09166500 | Dolores River at Dolores | 1911 – 1912 1922 – 2004 | 310,326 |

| Gage ID | Gage Name | Period of Record | Historical Flow (acre-feet/year) |
|---|---|---|---|
| 09166950 | Lost Canyon Creek near Dolores | 1985 – 2004 | 15,213 |
| 09168100 | Disappointment Creek near Dove Creek | 1958 – 1986 | 15,345 |
| 09169500 | Dolores River at Bedrock | 1918 – 1922 1972 – 2004 | 282,994 |
| 09171100 | Dolores River near Bedrock | 1972 – 2004 | 282,315 |
| 09171200 | San Miguel River near Telluride | 1960 – 1965 | 45840 |
| 09172000 | Fall Creek near Fall Creek | 1942 – 1959 | 17842 |
| 09172100 | Leopard Creek at Noel | 1956 – 1963 | 1988 |
| 09172500 | San Miguel River near Placerville | 1911 – 1912 1931 – 1934 1943 – 2004 | 225397 |
| 09173000 | Beaver Creek near Norwood | 1942 –1967 1976 – 1981 | |
| 09175500 | San Miguel River at Naturita | 1918 – 1929 1941 – 1981 | 287544 |
| 09177000 | San Miguel River at Uravan | 1955 – 1962 1974 – 1994 1997 – 2004 | 251042 |
| 09179500 | Dolores River at Gateway | 1937 – 1954 | 679758 |

**Table 5.3**
**Baseflow Comparison**
**1975-2003 Average (acre-feet/yr)**

| Gage ID | Gage Name | Baseflow | Historical | Difference |
|---|---|---|---|---|
| 09342500 | San Juan River at Pagosa Springs | 300,708 | 283,880 | 16,828 |
| 09343300 | Rio Blanco bl Blanco Div Dam nr Pagosa | 73,615 | 34,450 | 39,165 |
| 09344000 | Navajo Riv at Banded Pk Ranch nr Chromo | 84,501 | 83,902 | 599 |
| 09344400 | Navajo River bl Oso Div Dam nr Chromo | 95,145 | 48,284 | 46,861 |
| 09346400 | San Juan River near Carracas | 563,337 | 449,666 | 113,671 |
| 09349800 | Piedra River near Arboles | 317,031 | 305,465 | 11,566 |
| 09352900 | Vallecito Creek near Bayfield | 106,037 | 106,037 | 0 |
| 09354500 | Los Pinos River at La Boca | 330,443 | 188,403 | 142,040 |
| 09355000 | Spring Creek at La Boca | 14,658 | 24,124 | -9,466 |
| 09355500 | San Juan River near Archuleta, NM | 1,230,519 | 875,505 | 355,014 |
| 09357500 | Animas River near Howardsville | 77,719 | 77,578 | 141 |
| 09364500 | Animas River at Farmington,NM | 735,197 | 644,023 | 91,174 |
| 09365000 | San Juan River at Farmington,NM | 1,957,360 | 1,489,692 | 467,668 |
| 09365500 | La Plata River at Hesperus | 33,905 | 30,970 | 2,935 |
| 09366500 | La Plata River at Colorado-NM Stateline | 46,082 | 27,452 | 18,630 |
| 09367500 | La Plata River near Farmington, NM | 50,813 | 23,548 | 27,265 |
| 09368499 | Jackson Gulch Reservoir Inflow | 10,687 | 10,687 | 0 |
| 09371000 | Mancos River near Towaoc | 58,492 | 39,123 | 19,369 |
| 09372000 | McElmo Creek near Colorado-UT Stateline | 37,180 | 39,385 | -2,205 |
| 09379500 | San Juan River near Bluff | 2,106,424 | 1,563,647 | 542,777 |
| 09166500 | Dolores River at Dolores | 321,152 | 317,356 | 3,796 |
| 09169500 | Dolores River at Bedrock | 450,936 | 270,404 | 180,532 |
| 09171100 | Dolores River near Bedrock | 465,121 | 279,550 | 185,571 |

## 5.4    Diversion Files

### 5.4.1        Direct Diversion Station File (*.dds)

StateDMI is used in several steps to create the direct diversion station file.

The direct diversion station file describes the physical properties of each diversion simulated in the San Juan Model.  Table 5.4 is a summary of the San Juan Model's diversion station file contents, including each structure's diversion capacity, irrigated acreage served in 2000, and average annual system efficiency. This parameter is summarized from data in the diversion demand file rather than the diversion station file, but it is included here as an important characteristic of each diversion station. In addition to the tabulated parameters, the file also specifies return flow nodes and average monthly efficiencies. The table also includes average annual headgate demand. Table 5.4 identifies diversion systems in the table notes.

Generally, the diversion station ID and name, diversion capacity, and irrigated acreage are gathered from HydroBase by StateDMI. Return flow locations are specified to StateDMI in a hand-edited file sj2004.rtn. The return flow locations and distribution were based on discussions with Division 7 and Division 4 personnel as well as calibration efforts. StateDMI computes monthly system efficiency for irrigation structures from historical diversions and historical crop irrigation requirements, and writes them into the final *.dds file.

For non-irrigation structures, monthly efficiency is specified by the user as input to StateDMI. Baseline irrigation demand is assigned to primary structures of multi-structure systems, therefore primary and secondary structures of multi-structure systems are assigned the average monthly efficiencies calculated for the irrigation system based on irrigation water requirements and water delivered from all sources. If efficiency is constant for each month, it can also be specified in the hand-edited file sj2004.rtn.

Note that unknown capacity is set to 999 by StateDMI.  This number is significantly large so as not to limit diversions. Monthly demands for New Mexico, Arizona, and Utah are provided by the USBR, however no acreage was provided for irrigation structures.  Unknown acreage is set to -999 by StateDMI.

**Table 5.4**
**Direct Flow Diversion Summary Average**
**1975-2003**

| # | Model ID # | Name | Cap (cfs) | 2000 Irrig. Acres | Average System Efficiency (percent) | Average Annual Demand (af) |
|---|---|---|---|---|---|---|
| 1 | 290519 [8)] | BEIGHLEY NO 1_DIVSYS | 34 | 34 | 43 | 1702 |
| 2 | 290550 | C H LOUCKS DITCH | 40 | 17 | 2 | 4686 |
| 3 | 290555 | CARR DITCH | 15 | 249 | 20 | 1754 |
| 4 | 290560 | CHAPSON AND HOWE DITCH | 22 | 464 | 50 | 2738 |
| 5 | 290566 | COLTON AND MONTROY DITCH | 20 | 98 | 38 | 1565 |
| 6 | 290582 | DOWELL DITCH | 12 | 185 | 43 | 581 |

| # | Model ID # | Name | Cap (cfs) | 2000 Irrig. Acres | Average System Efficiency (percent) | Average Annual Demand (af) |
|---|---|---|---|---|---|---|
| 7 | 290588 | ECHO DITCH | 35 | 1665 | 60 | 4519 |
| 8 | 290597 | FISH CREEK DITCH | 14 | 133 | 18 | 1175 |
| 9 | 290601 [9] | FOUR-MILE_DIVSYS | 42 | 1448 | 60 | 9782 |
| 10 | 290613 [1] | HALLETT DITCH | 6 | 49 | 12 | 0 |
| 11 | 290627 | J M ROSS AND STURGILL D | 12 | 116 | 60 | 873 |
| 12 | 290653 | LONG HORN AND MEE DITCH | 14 | 5 | 60 | 879 |
| 13 | 290654 | LONG MEADOW DITCH | 7 | 26 | 31 | 308 |
| 14 | 290662 | MARTINEZ AND MARTINEZ D | 8 | 37 | 29 | 554 |
| 15 | 290669 | MESA DITCH | 30 | 384 | 60 | 2301 |
| 16 | 290686 | PARK DITCH | 68 | 1083 | 12 | 19939 |
| 17 | 290691 | PHILLIPPS DITCH | 4 | 113 | 55 | 392 |
| 18 | 290716 | SISSON-STEPHENS DITCH | 11 | 108 | 52 | 980 |
| 19 | 290718 | SNOWBALL DITCH | 32 | 1149 | 40 | 6142 |
| 20 | 290729 | STURGILL DITCH | 6 | 55 | 46 | 425 |
| 21 | 292005 | DUTTON DITCH | 12 | 788 | 59 | 3467 |
| 22 | 294667 [4] | USBR_BLANCO_R_DIVERSION | 520 | 0 | 100 | 0 |
| 23 | 294669 [4] | TREASURE PASS DIVR DITCH | 8 | 0 | 100 | 270 |
| 24 | 29_ADS002 | 29_ADS002_SJuanR@PagosaS | 3152 | 1631 | 55 | 7354 |
| 25 | 29_ADS003 | 29_ADS003_SJuanR@Carracs | 4191 | 1716 | 51 | 14943 |
| 26 | 300504 | AMBOLD-WALLACE DITCH | 13 | 280 | 10 | 2739 |
| 27 | 300506 | ANIMAS CONSOLIDATED D | 97 | 1246 | 13 | 33706 |
| 28 | 300509 [6] | ANIMAS DIVERSION CANAL | 600 | 0 | 0 | 0 |
| 29 | 300510 | BEAR CREEK DITCH | 9 | 43 | 23 | 1450 |
| 30 | 300523 [2] | CASCADE CANAL | 393 | 0 | 0 | 0 |
| 31 | 300568 | HERMOSA COMPANY DITCH | 25 | 99 | 16 | 5306 |
| 32 | 300580 | JOHN THOMAS DITCH | 12 | 11 | 4 | 2906 |
| 33 | 300581 | J P LAMB DITCH | 30 | 0 | 13 | 0 |
| 34 | 300612 [3] | POWER CANAL NO 1 | 168 | 0 | 0 | 25719 |
| 35 | 300617 | REID DITCH | 93 | 1122 | 18 | 25341 |
| 36 | 300634 | SITES DITCH | 40 | 48 | 14 | 1399 |
| 37 | 300641 | SULLIVAN-WALLACE DITCH | 14 | 27 | 9 | 3569 |
| 38 | 301000 [3] | DURANGO CITY PIPELINE | 13 | 0 | 36 | 3788 |
| 39 | 301003 | HARRIS-PATTERSON DITCH | 12 | 85 | 44 | 767 |
| 40 | 301009 | MCCLUER AND MURRAY DITCH | 12 | 49 | 41 | 850 |
| 41 | 301011 [10] | Florida_Farmers/Florida_ | 296 | 15980 | 60 | 46123 |
| 42 | 301019 | PIONEER DITCH | 18 | 322 | 46 | 1787 |
| 43 | 301023 | ANIMAS DITCH | 65 | 1013 | 14 | 16847 |
| 44 | 301024 [3] | ANIMAS PMP STA & FOR MN | 5 | 0 | 36 | 5621 |
| 45 | 301033 | BANKS-TYNER DITCH | 7 | 202 | 57 | 908 |
| 46 | 301056 [1] | BODO PINE RIDGE DITCH | 7 | 121 | 51 | 0 |
| 47 | 301094 | EAST MESA DITCH | 26 | 1204 | 34 | 7122 |
| 48 | 301219 | SITES-KERN DITCH | 20 | 897 | 60 | 3225 |
| 49 | 301243 | TYNER EAST SIDE DITCH | 15 | 178 | 35 | 1043 |
| 50 | 304660 [4] | CARBON LAKE DITCH | 5 | 0 | 100 | 284 |
| 51 | 304661 [4] | MINERAL POINT DITCH | 11 | 0 | 100 | 162 |

| # | Model ID # | Name | Cap (cfs) | 2000 Irrig. Acres | Average System Efficiency (percent) | Average Annual Demand (af) |
|---|---|---|---|---|---|---|
| 52 | 304662 [4] | RED MOUNTAIN DITCH | 6 | 0 | 100 | 74 |
| 53 | 304664 [4] | RALSTON DITCH | 32 | 0 | 40 | 4453 |
| 54 | 304665 [4] | TWIN ROCK DITCH | 23 | 20 | 40 | 4278 |
| 55 | 30_ADS007 | 30_ADS007_AnimasR@Durang | 1137 | 1227 | 32 | 9893 |
| 56 | 30_ADS008 | 30_ADS008_FloridaRabvSal | 76 | 896 | 59 | 7774 |
| 57 | 30_ADS009 | 30_ADS009_FloridaR@Bonda | 45 | 568 | 35 | 4241 |
| 58 | 30_ADS010 | 30_ADS010_AnimasR@StLine | 96 | 559 | 21 | 15583 |
| 59 | 310502 | CEANABOO DITCH | 28 | 541 | 54 | 4150 |
| 60 | 310503 | COMMISSIONER DITCH | 16 | 264 | 28 | 3198 |
| 61 | 310505 [11] | DR MORRISON_DIVSYS | 160 | 1878 | 38 | 20945 |
| 62 | 310507 | LA BOCA DITCH | 28 | 479 | 25 | 3471 |
| 63 | 310508 | SEVERO DITCH | 23 | 329 | 24 | 2984 |
| 64 | 310509 | SPRING CREEK DITCH | 300 | 2480 | 34 | 15720 |
| 65 | 310510 | BEAN DITCH | 15 | 89 | 37 | 1074 |
| 66 | 310511 | THOMPSON-EPPERSON DITCH | 120 | 1719 | 56 | 10400 |
| 67 | 310512 | LOS PINOS IRG DITCH | 26 | 289 | 24 | 3751 |
| 68 | 310513 | WOMMER IRRIGATION DITCH | 20 | 194 | 22 | 2629 |
| 69 | 310514 | BEAR CR AND PINE R DITCH | 33 | 614 | 39 | 3646 |
| 70 | 310516 | HIGBEE IRRIGATION DITCH | 5 | 6 | 22 | 336 |
| 71 | 310518 | MYERS AND ASHER DITCH | 8 | 77 | 37 | 842 |
| 72 | 310519 | KING DITCH | 159 | 4341 | 46 | 28376 |
| 73 | 310523 [12] | SCHRODER IRG_DIVSYS | 80 | 2988 | 53 | 17396 |
| 74 | 310524 | FARRELL DITCH | 20 | 173 | 42 | 1087 |
| 75 | 310527 | ISLAND DITCH | 2 | 20 | 56 | 114 |
| 76 | 310528 | BENNETT-MYERS IRR DITCH | 15 | 87 | 22 | 1494 |
| 77 | 310535 | KIRKPATRICK DITCH | 17 | 190 | 60 | 947 |
| 78 | 310540 | MCLOYD DITCH | 16 | 103 | 25 | 1340 |
| 79 | 310545 | CATLIN DITCH | 15 | 58 | 60 | 186 |
| 80 | 310547 | ROBERT MORRISON DITCH | 111 | 4798 | 53 | 28493 |
| 81 | 310553 | MCBRIDE DITCH | 8 | 29 | 44 | 230 |
| 82 | 310567 [1] | CAMPBELL DITCH | 5 | 140 | 29 | 0 |
| 83 | 310583 | PORTER DITCH | 50 | 66 | 42 | 620 |
| 84 | 310593 | SEMLER DITCH E AND E | 7 | 82 | 54 | 462 |
| 85 | 310665 | SPRING CREEK DITCH | 300 | 15776 | 29 | 69757 |
| 86 | 310668 | SULLIVAN DITCH | 14 | 344 | 55 | 1970 |
| 87 | 310710 | IGNACIO CREEK DITCH | 8 | 176 | 45 | 1084 |
| 88 | 314637 [4] | WEMINUCHE PASS DITCH | 40 | 0 | 100 | 1397 |
| 89 | 314638 [4] | PINE R WEMINUCHE PASS D | 20 | 0 | 100 | 474 |
| 90 | 31_ADS005 | 31_ADS005_LPinosR@DryCrk | 69 | 572 | 60 | 5582 |
| 91 | 31_ADS006 | 31_ADS006_LPinosR@StLine | 1100 | 1868 | 33 | 13817 |
| 92 | 320509 | BLACK DIKE DITCH | 9 | 92 | 14 | 1258 |
| 93 | 320528 | COTTONWOOD DITCH NO 1 | 13 | 139 | 9 | 3237 |
| 94 | 320529 | COTTONWOOD DITCH NO 2 | 15 | 184 | 7 | 3617 |
| 95 | 320558 | EATON DITCH | 1090 | 118 | 17 | 1716 |
| 96 | 320574 | HAMBELTON DITCH | 16 | 163 | 8 | 4801 |

| # | Model ID # | Name | Cap (cfs) | 2000 Irrig. Acres | Average System Efficiency (percent) | Average Annual Demand (af) |
|---|---|---|---|---|---|---|
| 97 | 320590 | ISMAY DITCH | 11 | 64 | 12 | 1101 |
| 98 | 320634 | MURRAY-ZWICKER-TOZER D | 8 | 64 | 5 | 2225 |
| 99 | 320652 | ROCK CREEK DITCH | 42 | 473 | 7 | 11569 |
| 100 | 320662 | SCHALLES DITCH | 7 | 58 | 14 | 1214 |
| 101 | 320680 [3)] | TOWN OF CORTEZ | 999 | 0 | 36 | 2869 |
| 102 | 320690 | WILSON DITCH | 20 | 677 | 37 | 3157 |
| 103 | 320699 [2)] | NARRAGUINNEP RES INLET | 999 | 0 | 0 | 0 |
| 104 | 320772 | MVI_U_lateral | 999 | 13317 | 36 | 79161 |
| 105 | 320884 | TOWAOC CANAL | 135 | 6690 | 39 | 18589 |
| 106 | 322001 [3)] | DOLORES WATER DIVR HGT | 999 | 0 | 36 | 832 |
| 107 | 322006 | DOVE CREEK CANAL | 999 | 24796 | 60 | 75719 |
| 108 | 324675 | Dolores_Tunnel | 999 | 15949 | 54 | 78954 |
| 109 | 32_ADS015 | 32_ADS015_McELmCkabvAlka | 2083 | 1340 | 36 | 7228 |
| 110 | 32_ADS016 | 32_ADS016_McElmoCrkNrStL | 1091 | 1017 | 38 | 6509 |
| 111 | 330501 | LA PLATA IRG DITCH | 9 | 107 | 14 | 2018 |
| 112 | 330504 | HAY GULCH DITCH | 20 | 1350 | 50 | 7316 |
| 113 | 330508 | LA PLATA R & CHERRY CR D | 40 | 1732 | 60 | 6808 |
| 114 | 330518 | AMMONS DITCH | 6 | 171 | 60 | 1300 |
| 115 | 330533 | PINE RIDGE DITCH | 16 | 91. | 51 | 2466 |
| 116 | 330535 | SOONER VALLEY DITCH | 10 | 327 | 36 | 1165 |
| 117 | 330536 | H H DITCH | 85 | 3859 | 54 | 15516 |
| 118 | 330540 | ENTERPRISE ENLARGEMENT D | 6 | 68 | 35 | 681 |
| 119 | 330542 | SLADE DITCH | 40 | 2153 | 54 | 9713 |
| 120 | 330547 | JOSEPH FREED DITCH | 40 | 1788 | 55 | 6271 |
| 121 | 330548 | REVIVAL DITCH | 12 | 295 | 55 | 1387 |
| 122 | 330549 | TREANOR DITCH | 67 | 2835 | 56 | 9485 |
| 123 | 330550 | WARREN-VOSBURGH DITCH | 8 | 489 | 58 | 2239 |
| 124 | 330551 | TOWNSITE DITCH | 20 | 1105 | 57 | 2265 |
| 125 | 330554 | BIG STICK DITCH | 50 | 1668 | 57 | 6350 |
| 126 | 334639 [4)] | ENTERPRISE ENLARGEMENT D | 6 | 0 | 40 | 539 |
| 127 | 334640 [4)] | PIONEER DITCH | 6 | 0 | 40 | 757 |
| 128 | 33_ADS011 | 33_ADS011_LaPlataRiver | 1068 | 1489 | 52 | 4536 |
| 129 | 340505 | BEAVER DITCH | 14 | 301 | 47 | 1818 |
| 130 | 340506 | BOSS DITCH | 10 | 136 | 48 | 972 |
| 131 | 340508 | CARPENTER AND MITCHELL D | 10 | 390 | 55 | 1762 |
| 132 | 340514 | CRYSTAL CREEK DITCH | 15 | 567 | 52 | 1934 |
| 133 | 340522 | EAST MANCOS HIGHLINE D. | 12 | 179 | 56 | 1013 |
| 134 | 340527 | FRANK DITCH | 6 | 285 | 38 | 734 |
| 135 | 340530 | GILES DITCH | 12 | 142 | 39 | 1423 |
| 136 | 340531 | GLASGOW & BREWER DITCH | 7 | 376 | 59 | 1858 |
| 137 | 340534 | HENRY BOLEN DITCH | 20 | 453 | 47 | 2876 |
| 138 | 340535 [2)] | JACKSON GULCH INLET CNL | 225 | 0 | 0 | 0 |
| 139 | 340542 | LEE AND BURKE DITCH | 12 | 271 | 50 | 1332 |
| 140 | 340543 | LEE DITCH | 14 | 138 | 54 | 1450 |
| 141 | 340544 | LONG PARK DITCH | 8 | 232 | 54 | 1589 |

| # | Model ID # | Name | Cap (cfs) | 2000 Irrig. Acres | Average System Efficiency (percent) | Average Annual Demand (af) |
|---|---|---|---|---|---|---|
| 142 | 340552 | NO 6 DITCH | 8 | 296 | 53 | 1648 |
| 143 | 340554 | RATLIFF AND ROOT DITCH | 35 | 1515 | 57 | 7601 |
| 144 | 340560 | RUSH RESERVOIR DITCH | 375 | 600 | 53 | 4000 |
| 145 | 340565 | SHEEK DITCH | 12 | 546 | 54 | 2956 |
| 146 | 340567 | SMOUSE DITCH | 4 | 74 | 51 | 237 |
| 147 | 340573 [3] | TOWN OF MANCOS DITCH | 4 | 0 | 36 | 775 |
| 148 | 340576 | WEBBER DITCH | 55 | 1719 | 55 | 8247 |
| 149 | 340577 | WEBER RESERVOIR INLET D | 10 | 61 | 44 | 1050 |
| 150 | 340582 [13] | WILLIAMS DITCH_DIVSYS | 7 | 171 | 60 | 804 |
| 151 | 340583 | WILLIS DITCH | 6 | 236 | 52 | 1141 |
| 152 | 34_ADS012 | 34_ADS012_ManRabvWMancos | 10478 | 716 | 60 | 4068 |
| 153 | 34_ADS013 | 34_ADS013_ManRabvChicken | 166 | 374 | 60 | 1744 |
| 154 | 34_ADS014 | 34_ADS014_MancosRNrStLin | 1611 | 740 | 48 | 25054 |
| 155 | 34_AMS001 | 34_MUNICIPAL | 1 | 0 | 100 | 1080 |
| 156 | 460503 [1] | BRIGGS DITCH | 12 | 19 | 29 | 0 |
| 157 | 600507 | ALEXANDER DITCH | 15 | 87 | 60 | 1047 |
| 158 | 600511 [3] | AMES ILIUM HYDRO PROJ | 100 | 0 | 0 | 10883 |
| 159 | 600520 | B C D DITCH | 4 | 29 | 6 | 939 |
| 160 | 600521 | BEAVER MESA DITCH | 31 | 935 | 60 | 3631 |
| 161 | 600549 | CARR WADDLE DITCH | 8 | 191 | 60 | 974 |
| 162 | 600550 | CARRIERE DITCH | 12 | 112 | 60 | 1468 |
| 163 | 600569 | CRAVER DITCH | 12 | 154 | 43 | 1041 |
| 164 | 600574 | DENISON DITCH | 8 | 64 | 56 | 586 |
| 165 | 600583 | EAGLE DITCH | 11 | 513 | 60 | 1509 |
| 166 | 600585 | EASTON DITCH | 6 | 227 | 57 | 1840 |
| 167 | 600588 | ELK CREEK DITCH | 14 | 85 | 25 | 1126 |
| 168 | 600607 | GLENCOE DITCH | 17 | 560 | 58 | 2001 |
| 169 | 600611 | GOLD RUN DITCH | 7 | 161 | 50 | 915 |
| 170 | 600628 | HASTINGS DITCH | 6 | 76 | 42 | 633 |
| 171 | 600633 | HIGHLINE CANAL | 145 | 6013 | 23 | 38831 |
| 172 | 600650 | J & M HUGHES DITCH | 30 | 1823 | 60 | 10218 |
| 173 | 600659 | KINLEY DITCH | 6 | 39 | 42 | 551 |
| 174 | 600669 | LEOPARD CREEK DITCH | 5 | 305 | 60 | 967 |
| 175 | 600670 | LILYLANDS CANAL | 99 | 4039 | 60 | 8545 |
| 176 | 600672 | LONE CONE DITCH | 187 | 535 | 39 | 4522 |
| 177 | 600684 | MCCOLLOCH SCOTT DITCH | 13 | 27 | 30 | 662 |
| 178 | 600689 | MIDDLE ELK CREEK DITCH | 20 | 75 | 24 | 995 |
| 179 | 600707 [2] | NATURITA CANAL | 960 | 0 | 0 | 18157 |
| 180 | 600710 | NEILSON DITCH | 7 | 73 | 60 | 303 |
| 181 | 600723 [3] | NUCLA POWER PLANT DITCH | 61 | 0 | 0 | 1446 |
| 182 | 600733 [2] | PAXTON DITCH | 54 | 0 | 0 | 441 |
| 183 | 600736 | PLEASANT VALLEY DITCH | 20 | 617 | 53 | 2513 |
| 184 | 600745 | REED CHATFIELD DITCH | 8 | 31 | 7 | 920 |
| 185 | 600776 | TEMPLETON DITCH | 4 | 20 | 9 | 605 |
| 186 | 600777 | THEO NETHERLY DITCH NO1 | 11 | 45 | 49 | 318 |

| # | Model ID # | Name | Cap (cfs) | 2000 Irrig. Acres | Average System Efficiency (percent) | Average Annual Demand (af) |
|---|---|---|---|---|---|---|
| 187 | 60_ADS020 | 60_ADS020_SMiguelNrPlacr | 1126 | 1022 | 55 | 9046 |
| 188 | 60_ADS021 | 60_ADS021_SMiguelabvWNat | 20 | 1368 | 54 | 4946 |
| 189 | 60_ADS022 | 60_ADS022_SMiguel@Naturi | 1127 | 3998 | 40 | 10673 |
| 190 | 610502 | GALLOWAY DIVSYS | 13 | 259 | 41 | 1559 |
| 191 | 610517 | SOUTH MIDWAY DITCH | 18 | 419 | 39 | 1932 |
| 192 | 610527 | RAY DITCH | 25 | 1111 | 42 | 3568 |
| 193 | 610602 [1] | A E L R P & PL | 8 | 0 | 41 | 0 |
| 194 | 61_ADS019 | 61_ADS019_DoloresRNrBedr | 49 | 1110 | 34 | 6315 |
| 195 | 630501 | BARTHOLOMEW AND HATCH D | 232 | 93 | 14 | 2495 |
| 196 | 630518 | CLIFF RANCH DITCH | 8 | 89 | 20 | 1876 |
| 197 | 630529 | HARMS AND HAZEL DITCH | 7 | 75 | 31 | 1014 |
| 198 | 630547 | NOLAN DITCH | 8 | 27 | 48 | 568 |
| 199 | 630553 | RED CROSS DITCH | 5 | 7 | 60 | 454 |
| 200 | 63_ADS023 | 63_ADS023_DoloresR@Gatew | 2076 | 558 | 49 | 6087 |
| 201 | 63_ADS024 | 63_ADS024_WestCreek | 948 | 1594 | 39 | 10830 |
| 202 | 63_AMS002 | 63_MUNICIPAL | 2 | 0 | 100 | 1296 |
| 203 | 680636 [4] | LEOPARD CREEK DITCH | 21 | 416 | 100 | 1260 |
| 204 | 690510 | HORSESHOE DITCH | 20 | 359 | 40 | 2328 |
| 205 | 690512 | KNIGHT-EMBLING DITCH | 10 | 214 | 60 | 1294 |
| 206 | 690520 | PINE ARROYA DITCH | 11 | 78 | 43 | 1089 |
| 207 | 69_ADS018 | 69_ADS018_Disappointment | 3148 | 565 | 60 | 3639 |
| 208 | 710504 | BEAR CREEK DITCH | 12 | 36 | 36 | 602 |
| 209 | 710513 | BURCH AND LONGWILL DITCH | 9 | 154 | 31 | 933 |
| 210 | 710531 | EAST EDER DITCH | 12 | 74 | 40 | 413 |
| 211 | 710535 | GARBARINO NO 1 DITCH | 4 | 23 | 38 | 212 |
| 212 | 710536 | GARBARINO NO 2 DITCH | 3 | 22 | 48 | 222 |
| 213 | 710537 | GARBARINO NO 3 DITCH | 3 | 23 | 37 | 214 |
| 214 | 710545 | GOULD & MORIARITY DITCH | 10 | 111 | 41 | 877 |
| 215 | 710549 | ILLINOIS DITCH | 8 | 114 | 26 | 1402 |
| 216 | 710551 | ITALIAN DITCH | 8 | 19 | 52 | 301 |
| 217 | 710555 | KEYSTONE DITCH | 9 | 71 | 30 | 825 |
| 218 | 710556 | KING NO 1 DITCH | 8 | 41 | 60 | 236 |
| 219 | 710559 | KOENIG DITCH | 8 | 75 | 52 | 406 |
| 220 | 710563 | LINDSTROM DITCH | 8 | 44 | 38 | 455 |
| 221 | 710572 | MONUMENT ROCK DITCH | 8 | 89 | 49 | 582 |
| 222 | 710573 | MORIARITY DITCH | 12 | 161 | 56 | 798 |
| 223 | 710575 [3] | ORIGINAL RICO FLUME | 4 | 0 | 36 | 283 |
| 224 | 710582 | QUARRY NO 1 DITCH | 8 | 35 | 23 | 640 |
| 225 | 710586 | RIEVA DITCH | 8 | 20 | 36 | 352 |
| 226 | 710609 [4] | SUMMIT DITCH | 135 | 0 | 0 | 3415 |
| 227 | 710618 [4] | TURKEY CREEK DITCH | 80 | 0 | 0 | 1217 |
| 228 | 710624 | WEST EDER DITCH | 10 | 114 | 60 | 647 |
| 229 | 712002 | SUMMIT RES OUTLET | 76 | 4142 | 53 | 18589 |
| 230 | 714673 [2] | MAIN CANAL NO 1 | 348 | 0 | 0 | 0 |
| 231 | 714674 [2] | MAIN CANAL NO 2 | 999 | 0 | 0 | 0 |

| # | Model ID # | Name | Cap (cfs) | 2000 Irrig. Acres | Average System Efficiency (percent) | Average Annual Demand (af) |
|---|---|---|---|---|---|---|
| 232 | 71_ADS017 | 71_ADS017_DoloRabvMcPhee | 2385 | 864 | 59 | 6591 |
| 233 | 73_ADS025 | 73_ADS025_LittleDoloresR | 177 | 2015 | 55 | 13173 |
| 234 | 770516 | CONFAR AND RUSSELL DITCH | 11 | 37 | 47 | 331 |
| 235 | 770524 | EAKLOR DITCH | 18 | 296 | 45 | 2247 |
| 236 | 770529 | ELMER DITCH NO 1 | 19 | 334 | 56 | 1601 |
| 237 | 770531 | ENTERPRISE DITCH | 40 | 233 | 36 | 2848 |
| 238 | 770536 | FITZHUGH DITCH | 15 | 106 | 52 | 814 |
| 239 | 770559 | MIDLAND DITCH | 25 | 173 | 53 | 948 |
| 240 | 770560 | MONTOYA DITCH | 10 | 21 | 6 | 418 |
| 241 | 770562 | NAVAJO MEADOW DITCH | 16 | 10 | 21 | 542 |
| 242 | 770564 | NAVAJO RIVER DITCH | 20 | 52 | 26 | 690 |
| 243 | 770576 | SHAHAN IRRIGATION DITCH | 11 | 16 | 15 | 387 |
| 244 | 770579 | SOUTH SIDE DITCH | 20 | 119 | 11 | 2221 |
| 245 | 770585 | UNDERWOOD DITCH | 8 | 60 | 46 | 381 |
| 246 | 770586 | UNDERWOOD DITCH NO 2 | 10 | 13 | 59 | 535 |
| 247 | 770587 | UPPER CAMP DITCH | 11 | 26 | 12 | 995 |
| 248 | 770588 | UPPER NAVAJO DITCH | 7 | 91 | 39 | 449 |
| 249 | 770597 | NEW BOND HOUSE D(NAVAJO) | 15 | 20 | 5 | 1149 |
| 250 | 774635 [4] | USBR_NAVAJO_DIVERSION | 950 | 0 | 100 | 0 |
| 251 | 774636 [4] | USBR_LITTLE_NAVAJO_DIVR | 670 | 0 | 100 | 0 |
| 252 | 779999 [4] | SanJ_Chama_Summary_Node | 950 | -999 | 100 | 109846 |
| 253 | 77_ADS001 | 77_ADS001_NavajoRiver | 187 | 1726 | 52 | 5658 |
| 254 | 780501 | ABRAHAM DAVIS DITCH | 18 | 396 | 50 | 2107 |
| 255 | 780506 [1] | BARNES DITCH | 12 | 2 | 58 | 0 |
| 256 | 780507 | BARNES-MEUSER AND SHAW D | 20 | 1306 | 58 | 5169 |
| 257 | 780513 | BUCKSKIN-NAILOR DITCH | 20 | 173 | 7 | 3106 |
| 258 | 780523 [1] | CARL AND WEBB DITCH | 6 | 75 | 16 | 0 |
| 259 | 780524 [1] | CIMARRON DITCH | 15 | 232 | 31 | 0 |
| 260 | 780525 [1] | CLAYTON-REED DITCH | 11 | 10 | 9 | 0 |
| 261 | 780543 | EUGENIO GALLEGOS DITCH | 6 | 48 | 11 | 481 |
| 262 | 780544 | F S MOCKLER DIVSYS | 15 | 434 | 31 | 2223 |
| 263 | 780545 | FARROW AND PETERSON D | 30 | 72 | 4 | 4052 |
| 264 | 780552 | GALLEGOS HOME DITCH | 8 | 40 | 13 | 857 |
| 265 | 780555 | GEORGE S MCDONALD DITCH | 7 | 61 | 30 | 516 |
| 266 | 780562 | HOSSACK CREEK DITCH | 14 | 197 | 51 | 892 |
| 267 | 780571 | BESS GIRL DITCH | 15 | 300 | 53 | 1850 |
| 268 | 780580 | M E AND M DITCH | 17 | 141 | 24 | 1179 |
| 269 | 780590 [1] | NICKLES BROTHERS DITCH | 12 | 29 | 9 | 0 |
| 270 | 780594 [1] | PAGOSA DITCH | 15 | 28 | 16 | 0 |
| 271 | 780604 | PIEDRA FALLS DITCH | 26 | 392 | 16 | 6637 |
| 272 | 780617 | STEVENS&CLAYTON DITCH | 18 | 383 | 9 | 7067 |
| 273 | 780638 | TONER AND STEVENS DITCH | 13 | 449 | 50 | 1711 |
| 274 | 780659 [1] | LITTLE PAGOSA CREEK DIVR | 25 | 21 | 16 | 0 |
| 275 | 780692 [3] | FAIRFIELD MUN. WATER SYS | 3 | 0 | 36 | 646 |
| 276 | 784670 [4] | DON LAFONT DITCH NO 1 | 10 | 0 | 100 | 85 |

| # | Model ID # | Name | Cap (cfs) | 2000 Irrig. Acres | Average System Efficiency (percent) | Average Annual Demand (af) |
|---|---|---|---|---|---|---|
| 277 | 784671 [4] | DON LAFONT DITCH NO 2 | 10 | 0 | 100 | 235 |
| 278 | 784672 [4] | WILLIAMS CR SQ PASS DIVR | 10 | 0 | 100 | 155 |
| 279 | 78_ADS004 | 78_ADS004_PiedraRiver | 2216 | 3836 | 57 | 12921 |
| 280 | 990707 | GURLEY_IRRIG | 960 | 17457 | 52 | 48555 |
| 281 | AZ_IRR [4] | AZ_IR | 9999 | -999 | 100 | 0 |
| 282 | AZ_NIR [3] | AZ_NIR | 9999 | -999 | 100 | 0 |
| 283 | CO_ALP [5] | CO_ALP_Demands | 999 | -999 | 36 | 0 |
| 284 | NM_4CPP [3] | FourCornersPP | 99 | -999 | 100 | 46987 |
| 285 | NM_ABVARCH | AboveArchuleta | 5 | -999 | 40 | 0 |
| 286 | NM_ALP1 [5] | NM_ALP_Animas_Demand | 999 | -999 | 36 | 0 |
| 287 | NM_ALP2 [5] | NM_ALP_SanJuan_Demand | 999 | -999 | 36 | 0 |
| 288 | NM_ANIM | NM_AnimasIrr | 378 | -999 | 60 | 49857 |
| 289 | NM_ARCH | ArchuletaDitch | 1 | -999 | 40 | 238 |
| 290 | NM_AZTEC [3] | AztecMI | 9999 | -999 | 50 | 5014 |
| 291 | NM_BLOOM [3] | BloomfieldMI | 90 | -999 | 50 | 5001 |
| 292 | NM_CHACO | ChacoIrr | 132 | -999 | 40 | 0 |
| 293 | NM_CITZ | CitizenDitch | 105 | -999 | 40 | 19054 |
| 294 | NM_CUDEI | CudeiCanal | 11 | -999 | 40 | 2207 |
| 295 | NM_ECHO | EchoDitch | 33 | -999 | 40 | 3960 |
| 296 | NM_FARMMI [3] | FarmingtoNM_I | 9999 | -999 | 50 | 10030 |
| 297 | NM_FMD | FarmersMutual | 99 | -999 | 40 | 22063 |
| 298 | NM_FRUCAM | FruitlandAndCambridge | 87 | -999 | 40 | 20208 |
| 299 | NM_GLADE | FarmingtonGlade | 18 | -999 | 40 | 828 |
| 300 | NM_HAMM | Hammond | 98 | -999 | 30 | 33902 |
| 301 | NM_HOGB | Hogback | 137 | -999 | 40 | 30565 |
| 302 | NM_JEWV | JewettValley | 32 | -999 | 40 | 7220 |
| 303 | NM_JICIRR | JicarillaIrri | 40 | -999 | 35 | 5464 |
| 304 | NM_JICNEW | JicarillaNew | 99999 | -999 | 100 | 6803 |
| 305 | NM_JICNIR [3] | JicarillaNonIr | 9999 | -999 | 90 | 379 |
| 306 | NM_LPIRR | LowerLaPlataIrr | 113 | -999 | 40 | 27988 |
| 307 | NM_LPNIR [3] | LaPlataNonIr | 9999 | -999 | 50 | 2706 |
| 308 | NM_NIIP | NIIP | 1800 | -999 | 80 | 315494 |
| 309 | NM_NIIP_R1 [7] | NIIP Ojo Return | 9999 | -999 | 100 | 0 |
| 310 | NM_NIIP_R2 [7] | NIIP Chaco Return | 9999 | -999 | 100 | 0 |
| 311 | NM_NIIP_R3 [7] | NIIP Gallegos Return | 9999 | -999 | 100 | 0 |
| 312 | NM_REDW | RedWash | 8 | -999 | 40 | 0 |
| 313 | NM_SJGS [3] | SJPowerPlant | 80 | -999 | 100 | 16200 |
| 314 | NM_SRMI [3] | ShiprockMI | 9999 | -999 | 50 | 1445 |
| 315 | NM_TURLEY | TurleyDitch | 6 | -999 | 40 | 1194 |
| 316 | NM_U2NIR [3] | NM_U2NonIr | 9999 | -999 | 50 | 1787 |
| 317 | NM_U3NIR [3] | NM_U3NonIr | 9999 | -999 | 50 | 1653 |
| 318 | NM_U5NIR [3] | NM_U5NonIr | 9999 | -999 | 50 | 0 |
| 319 | NM_U6NIR [3] | NM_U6NonIr | 9999 | -999 | 50 | 650 |
| 320 | NM_U7NIR [3] | NM_U7NonIr | 9999 | -999 | 50 | 398 |
| 321 | NM_U8NIR [3] | NM_U8NonIr | 9999 | -999 | 60 | 0 |

| # | Model ID # | Name | Cap (cfs) | 2000 Irrig. Acres | Average System Efficiency (percent) | Average Annual Demand (af) |
|---|---|---|---|---|---|---|
| 322 | NM_USIRR [3] | USNavajoIrr | 42 | -999 | 40 | 3431 |
| 323 | NM_USNIR [3] | USNavajoNonIr | 9999 | -999 | 50 | 1076 |
| 324 | NM_WESTW | Westwater | 2 | -999 | 40 | 305 |
| 325 | NM_WHIS | WhiskeyCreek | 2 | -999 | 40 | 0 |
| 326 | UT_IRR [4] | UT_IRR | 9999 | -999 | 100 | 5771 |
| 327 | UT_NIR [3] | UT_NIR | 9999 | -999 | 100 | 0 |

1) Secondary Structure of a Multi-Structure Irrigation System
2) Reservoir Feeder or Carrier Ditch
3) Municipal/Industrial Diversion
4) Basin Export
5) Node for Future Modeling of Animas-La Plata Demands
6) Node for Future Modeling of Animas-La Plata Reservoir Carrier
7) Return Flow Node
8) Beighly No 1 Diversion System includes structures 290519, 290520, 290521, 290522, 290523, 290524, and 290525
9) Four Mile Diversion System includes structures 290601and 290687
10) Florida Farmers/Florida Canal Diverison system includes structures 301011 and 301013
11) Dr Morrison Diversion System includes structures 310505 and 310664
12) Schroder Irrigation Diversion System includes structures 310523, 310515, and 310550
13) Williams Ditch Diversion System includes structures 340582,340501

### 5.4.1.1    Key Structures

Key diversion structures are those that are modeled explicitly, that is, the node associated with a key structure represents that single structure only.  In the San Juan Model, diversion structures with water rights totaling 5 cfs or more in the San Juan basin and 6 cfs or more in the Dolores basin were generally designated key structures.  They are identified by a six-digit number which is a combination of water district number and structure ID from the State Engineer's structure and water rights tabulations.

The majority of the diversion structures in the San Juan basin are for irrigation. Structures diverting for non-irrigation use are noted in Table 5.4 and include structures that carry water to reservoirs or other structure's irrigation demands, municipal and industrial structures, and transbasin export structures.

Average historical monthly efficiencies for each structure appear in the diversion station file; however, StateMod operates in the "variable efficiency" mode for most irrigation structures, in which case, the values are not used during simulation.  Efficiency in any give month of the simulation is a function of the amount diverted that month, and the consumptive use, as limited by the water supply.

For municipal, industrial, carriers, and transbasin diverters, StateMod uses the efficiencies in the diversion station file directly during simulation to compute consumptive use and return flows. Diversion efficiency is set to values consistent with the type of use based on engineering judgment, or, if available, user information. Municipal structures are assigned efficiencies that vary by month to reflect indoor and outdoor use patterns.  Reservoir feeders

and other carriers are assigned an efficiency of 0 percent, meaning their diversions are delivered without loss. Exports from the basin are assigned an efficiency of 100 percent because there are no return flows to the basin. Constant monthly or annual efficiencies for New Mexico, Arizona and Utah diversions were provided by USBR for most irrigation, municipal, and industrial structures. The two exceptions include the Hammond Ditch (NM_HAMM) and the Four Corners Power Plant (NM_4CPP). For these two structures, the USBR provided both headgate demands and depletions which vary over the model period.

Diversion capacity is stored in HydroBase for most structures and is generally taken directly from the database. Capacities and irrigated acreage are accumulated by StateDMI for defined diversion systems. In preparing the direct diversion station file, however, StateDMI determines whether historical records of diversion indicate diversions greater than the database capacity. If so, the diversion capacity is modified to reflect the recorded diversion. Diversion capacities for New Mexico, Arizona, and Utah diversions were provided by the USBR.

Return flow parameters in the diversions station file specify the nodes at which return flows will re-enter the stream, and divide the returns among several locations as appropriate. The locations were determined primarily case-by-case based on topography, locations of irrigated acreage, and conversations with water commissioners and users. Return flow locations for structures in New Mexico, Arizona, and Utah were provided by the USBR.

**Where to find more information**

- When StateMod is executed in the "data check" mode, it generates an *.xtb file which contains summary tables of input. On of these tables gives the return flow locations and percent of return flow to each location, for every diversion structure in the model. Another table provides the information shown in Table 5.4.

- Section 4.2.2.1 describes how key structures were selected.

- Section 4.5 describes the variable efficiency approach for irrigation structures, and describes how diversions, consumptive use, and efficiency interact in the model for different types of structures.

### 5.4.1.2    Aggregate Structures

Small structures within specific sub-basin were combined and represented at aggregated nodes. Aggregated irrigation structures were given the identifiers "WD_ADSxxx", where "WD" is the Water District number, and "ADS" stands for Aggregated Diversions San Juan; the "xxx" ranges from 001 to 025. Similarly, aggregated municipal and industrial structures were named "WD_AMSxxx" for Aggregated Municipal San Juan.

For aggregated M&I diversions, efficiency was set to 100 percent because demands were modeled as depletions.

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**Where to find more information**

- Section 4.2.2.2 describes how small irrigation structures were aggregated into larger structures

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### 5.4.1.3 Special Structures

#### 5.4.1.3.1 San Juan-Chama Project

The San Juan Chama Project was developed by the U.S. Bureau of Reclamation (USBR) as a participating project of the Colorado River Storage Project (CRSP). The project diverts water from tributaries of the San Juan River in the Colorado River basin for delivery to the Rio Grande basin. The water is used for municipal, domestic and industrial purposes in central New Mexico and also provides a supplemental irrigation supply to approximately 92,500 acres. The San Juan Chama Project was designed to yield an average of about 110,000 acre-feet per year.

There are three principal diversion facilities on tributary streams in Colorado. The Blanco Diversion Dam (294667) diverts from Rio Blanco and delivers the water into the Blanco Tunnel. The Blanco Tunnel delivers water to the Oso Tunnel, which also diverts water from the Little Navajo River at the Little Oso Diversion Dam (774636). The Oso Tunnel delivers water to the Azotea Tunnel, which also diverts water from the Navajo River at the Oso Diversion Dam (774635).

Baseline demand for the San Juan Chama project is assigned to the San Juan Chama Summary Node (779999). The individual diversion structures on the tributaries are modeled as carriers to the summary node demand.

#### 5.4.1.3.2 MVIC and the Dolores Project

The Montezuma Valley Irrigation Company irrigates lands in the McElmo Creek basin primarily with water imported from the Dolores River. Water was historically delivered from direct diversion rights and from Groundhog Reservoirs via two structures; Main Canal No 1 (714673) and Main Canal No 2 (714674). With the construction of the Dolores Project, water from McPhee Reservoir is also delivered for increased irrigation and municipal use. Main Canals No 1 and 2 operate as carriers, with no baseline demand. Main Canal No 1 carries water to MVIC Dolores Tunnel irrigation demand (324675), Towaoc Canal irrigation demand (320884), the

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City of Dolores demand (322001), and the Town of Cortez (320680) demand. Main Canal No 2 carries water for storage in MVIC's Narraguinnep Reservoir, to MVIC U-Lateral irrigation demand (320772), and to Dove Creek Canal irrigation demand (322006). MVIC U-Lateral demand can also be satisfied from Narraguinnep Reservoir.

### 5.4.1.3.3 *Summit Irrigation Company*

The Summit Reservoir system is a privately-owned system of canals and reservoirs that imports water from the Dolores River basin for irrigation purposes in the upper reaches of the McElmo Creek drainage. Summit Ditch (710609) and Turkey Creek Ditch (710608) carry water for storage in the Summit Reservoir System and to the Summit irrigation demand node (322006). Summit irrigation demand can also be satisfied from the Summit Reservoir System.

### 5.4.1.3.4 *Future Use Diversion Structures*

Several diversion structures in the network are "placeholders" for modeling future anticipated demands in the San Juan basin. Strictly speaking, they are not part of the Baseline data set because their demands are set to zero or their rights are either absent or turned off. The diversion structures that fall into this category, and their potential configurations, are:

- CO_ALP, NM_ALP1, and NM_ALP2 are included in the model so future demands on the Animas-La Plata Project Ridges Basin Reservoir in Colorado and New Mexico can be accounted for. In addition, the future diversion structure to carry water from the Animas River to Ridges Basin Reservoir (300509) is also included.

## 5.4.2 Return Flow Delay Tables (*.dly)

The sj2004.dly file, which is hand-built with a text editor, describes the estimated re-entry of return flows into the river system. The irrigation return patterns are based on Glover analysis for generalized characteristics of the alluvium, and have been applied in all the west slope basin models. The return flow patterns also account for surface water return. Percent return flow in the first month for the Glover-derived patterns was adjusted to reflect 6 percent loss of returns due to non-crop consumption or evaporation, termed "incidental losses". In all cases, these lag times represent the combined impact of surface and subsurface returns.

The 6 percent of non-consumed water, used to represent incidental loss, is based on a recommendation used in the Colorado River Consumptive Uses and Losses Report, developed for the Colorado Water Conservation Board (Consumptive Uses and Losses Report, Comparison between StateCU CU & Losses Report and the USBR CU & Losses Report (1998-1995), October 1999, Leonard Rice Engineers). In the CU and Losses Report, incidental losses are estimated to be 10 percent of basin-wide crop consumptive use. However, StateMod applies a loss factor to unused diverted water, not crop consumptive use. Therefore, an equivalent loss

factor was developed for non-consumed diverted water from the results of the StateCU consumptive use analyses performed in support of the San Juan Model as follows:

StateCU Total Basin Crop Consumptive Use (Ave 1975 – 2003) = 350,880 acre-feet

> Incidental loss = 10% of Total Crop CU = 35,088 acre-feet
>
> StateCU Unused Water (Ave 1975 – 2003) = 556,993
>
> Incidental Loss as percent of Unused Water = 35,088 / 556,993 = 6%

Five patterns available in this file are used in the San Juan Model, as shown in Table 5.5. Pattern 1 represents returns from irrigated lands relatively close to a live stream or drain (<1200 feet). Pattern 2 should be used for irrigation further from a live stream (>1200 feet). Pattern 3 represents ground water returns to Long Hollow from irrigation on Red Mesa. Pattern 4 represents immediate returns, as for municipal and industrial uses. Pattern 5 is applicable to snowmaking diversions (not used in the San Juan Model). Pattern 6 represents no diversion incidental loss for lands irrigated close to a live stream. New Mexico, Arizona, and Utah structures are assigned Pattern 6, as incidental losses for these structures are represented in their demands and depletions.

**Table 5.5**
**Percent of Return Flow Entering Stream in Months Following Diversion**

| Month n | Pattern 1 | Pattern 2 | Pattern 3 | Pattern 4 | Pattern 5 | Pattern 6 |
|---------|-----------|-----------|-----------|-----------|-----------|-----------|
| 1 | 72.6 | 54.4 | 1.3 | 100 | 0 | 78.6 |
| 2 | 11.3 | 14.5 | 1.5 | 0 | 0 | 11.3 |
| 3 | 3.2 | 7.2 | 1.6 | 0 | 0 | 3.2 |
| 4 | 2.2 | 5.0 | 3.0 | 0 | 0 | 2.2 |
| 5 | 1.6 | 3.7 | 3.0 | 0 | 100 | 1.6 |
| 6 | 1.2 | 2.7 | 3.0 | 0 | 0 | 1.2 |
| 7 | 0.8 | 2.0 | 3.0 | 0 | 0 | 0.8 |
| 8 | 0.6 | 1.5 | 3.0 | 0 | 0 | 0.6 |
| 9 | 0.5 | 1.1 | 3.0 | 0 | 0 | 0.5 |
| 10 | 0 | 0.8 | 3.0 | 0 | 0 | 0 |
| 11 | 0 | 0.6 | 3.0 | 0 | 0 | 0 |
| 12 | 0 | 0.5 | 3.0 | 0 | 0 | 0 |
| 13 – 14 | 0 | 0 | 2.7 | 0 | 0 | 0 |
| 15 - 36 | 0 | 0 | 2.6 | 0 | 0 | 0 |
| Total | 94 | 94 | 94 | 100 | 100 | 100 |
| *Note: Month 1 is the same month as diversion* | | | | | | |

**Where to find more information**

- Section 4.6.1 describes how irrigation return flow delay patterns were developed.

### 5.4.3 Historical Diversion File (\*.ddh)

The historical diversion file contains time series of diversions for each structure. The file is created by StateDMI, which also fills missing records as described in Section 4.4.2. The file is used by StateMod for baseflow estimations at stream gage locations, and for comparison output that is useful during calibration.

The file is also referenced by StateDMI when developing average efficiency values for the diversion station file, and headgate demand time series for the diversion demand file.

#### *5.4.3.1 Key Structures*

For most explicitly modeled irrigation and M&I structures, StateDMI accesses HydroBase for historical diversion records. Historical diversions are accumulated by StateDMI for defined diversion systems. For certain structures, the data was assembled from other sources or developed from database data into a time-series file which StateDMI can be directed to read. These include Dolores Project diversions plus other larger diverters as follows:

| WDID | Name |
| --- | --- |
| 324675 | Dolores Tunnel |
| 320772 | MVI U Lateral |
| 714673 | Main Canal  No 1 |
| 714674 | Main Canal No 2 |
| 301003 | Harris-Patterson Ditch |
| 301009 | McClure and Murray Ditch |
| 301011 | Florida Canal |
| 301019 | Pioneer Ditch |
| 301033 | Banks-Tyner Ditch |
| 301243 | Tyner East Side Ditch |
| 310665 | Spring Creek Ditch |
| 600633 | Highline Canal Enlargement |
| 310519 | King Ditch |

| | |
|---|---|
| 310547 | Robert Morrison Ditch |
| 300506 | Animas Consolidated Ditch |
| 300617 | Reid Ditch |
| 600777 | Theo Netherly Ditch No 1 |

The following carrier and summary structures have their historical use represented at other nodes, diversions are set to zero. In addition, all future use structures, which include Animas La Plata structures, have historical diversions set to zero because they did not divert historically.

| WDID | Name |
|---|---|
| 320699 | Narraguinnep Reservoir Feeder |
| 779999 | San Juan Chama Summary Node |
| 301024 | Animas Pump Station |

Historical diversions for the following transbasin diversions were extracted from USGS or DNR streamflow records in HydroBase, as shown, which are more complete than records stored in HydroBase under the WDID.

| WDID | Name | USGS or DNR Streamgage |
|---|---|---|
| 294669 | Treasure Pass Diversion Ditch | 09341000 |
| 314637 | Weminuche Pass Ditch | 09351500 |
| 314638 | Pine River Weminuche Pass Ditch | 09351000 |
| 784670 | Don LaFont Ditch No 1 | DLFDT1CO |
| 784671 | Don LaFont Ditch No 2 | 09347000 |
| 784672 | Williams Creek Squaw Pass Ditch | 09348000 |

In addition, historical diversions for New Mexico, Arizona and Utah were provided by the USBR in time-series file which StateDMI is directed to read.

### 5.4.3.2    Aggregate Structures

Aggregated irrigation structures are assigned the sum of the constituent structures' historical diversion records from the database.

Two nodes in the model represent the combined small diversion for municipal, industrial, and livestock use in two water districts in the basin. These structures are modeled as diverting only the depletive portion of their diversions, and consuming all of it. Thus estimated historic diversions are equivalent to estimated consumptive use. Total non-irrigation consumptive use in the San Juan / Dolores basin was estimated, as documented in the task memorandum "Non-Irrigation (Other Uses) Consumptive Uses and Losses in the Dolores and San Juan River Basins". Consumptive use of the key municipal and industrial

diversion in the model was subtracted from this basin wide M&I consumption, to derive the basin wide consumptive use attributable to small M&I users. This value was distributed to Water Districts 34 and 63 in accordance with a general distribution of M&I use. The use is the same each year of the study.

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**Where to find more information**

- The feasibility study for the data extension is documented in two task memos, which are collected in the CDSS *(Technical Papers)*:

  -Data Extension Feasibility *(Appendix E.1)*

  -Evaluate Extension of Historical Data *(Appendix E.2)*

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### 5.4.4 Direct Diversion Demand File (*.ddm)

Created by StateDMI, this file contains time series of demand for each structure in the model. Demand is the amount of water the structure "wants" to divert during simulation. Thus demand differs from historical diversions, as it represents what the structure would divert in order to get a full water supply. Table 5.4 in Section 5.4.1 lists average annual demand for each diversion structure. Note that the Baseline demands do not include demands associated with conditional water rights.

#### 5.4.4.1 Key Structures

Irrigation demand was computed as the maximum of crop irrigation water requirement divided by average monthly efficiency for the structure or historical diversions, as described in Section 4.9.1. Note that the irrigation water requirement is based on actual climate data beginning in 1950. Prior to that, it is filled using the automatic data filling algorithm described in Section 4.4.2. Monthly efficiency is the average efficiency over the efficiency period (1976 through 2003) but capped at 0.60.

New Mexico, Arizona, and Utah baseline demands were provided by the USBR. Transbasin and municipal and industrial demands were set to recent values or averages of recent records.

#### 5.4.4.2 Aggregate Structures

Aggregated irrigation structure demand is computed as for key irrigation structures. The only difference is that the irrigated acreage, which is the basis of irrigation water requirement, is the sum of irrigated acreage for constituent structures. Similarly, filled diversions are summed across all constituent structures, and average efficiency is based on efficiency of the

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aggregation as a unit.  Demand for aggregated M&I structures is the same as in the historical diversion file.

### 5.4.4.3    Special Structures

#### 5.4.4.3.1    San Juan Chama Project

Total demand for the San Juan Chama Project was placed at the San Juan Chama Summary Node (779999).  Demands at the individual diversion structures (294667, 774635, and 774636) were set to zero.  Diversions to the summary node are driven by operating rules.

#### 5.4.4.3.2    MVIC and Dolores Project

Demands associated with MVIC and the Dolores Project increased or began when McPhee Reservoir was completed in 1984.  Irrigation demand was computed as the maximum of crop irrigation water requirement (based on current acreage) divided by 1984 through 2003 average monthly efficiency for MVIC U-Lateral (320772), MVIC Dolores Tunnel (324675), Towaoc Canal (320884), and Dove Creek Canal (322006).

#### 5.4.4.3.3    Florida Project

Demands associated with structures receiving supplemental water from the Florida Project increased when Lemon Reservoir was completed in the early 1960s. Irrigation demand was computed as the maximum of crop irrigation water requirement (based on current acreage) divided by 1975 through 2003 average monthly efficiency for the 301003, 301009, 301011, 301019, 301033, and 301243.

#### 5.4.4.3.4    Navajo Indian Irrigation Project

The Navajo Indian Irrigation Project (NIIP) began irrigating lands in New Mexico during the mid 1970s.  NIIP has estimated that during the beginning years of irrigation, unused irrigation water did not return to the San Juan River, but instead built up the ground water table.  NIIP has provided time-series of irrigation returns (considered "negative" diversions in the historical calibration model) from NIIP irrigation to three model nodes, NM_NIIP_R1, NM_NIIP_R2, and NM_NIIP_R3. Baseline demand for these return flow nodes was set to zero.

#### 5.4.4.3.5    Reserved Indian Rights and Fallow Lands

Colorado Indian tribes have decreed "reserved" water rights associated with defined irrigated acreage.  Demands associated with these lands, and fallow lands identified in the 1993 irrigated acreage assessment, were estimated based on irrigation water

requirements and aggregate structures historical efficiencies and included in seven aggregate structures baseline demands as follows:

| WDID | Additional Acreage |
|------|--------------------|
| 77_ADS001 | 89 |
| 29_ADS003 | 1,901 |
| 78_ADS004 | 2,436 |
| 31_ADS006 | 798 |
| 30_ADS010 | 1,469 |
| 33_ADS011 | 2,391 |
| 34_ADS014 | 8,461 |

### *5.4.4.3.6        Carrier Structures and Multistructures*

Demands for reservoir carrier structures, Summit Reservoir System carrier structures, and MVIC/Dolores Project carrier structures are set to zero. Irrigation demand for multistructures is placed on the primary structure node, and secondary structures are set to zero. Note that diversions through these carrier structures are driven by operating rules.

### *5.4.4.4        Future Use Diversion Structures*

Demands for future depletion nodes are zeroed out, as they are not active in the Baseline data set.

## 5.4.5        Direct Diversion Right File (*.ddr)

The direct diversion right file contains water rights information for each diversion structure in the model. StateDMI creates the diversion right file based on the structure list in the diversion station file. Note that the Baseline direct diversion right file does not include conditional water rights.

The information in this file is used during simulation to allocate water in the right sequence or priority and to limit the allocation by decreed amount. The file is also an input to StateDMI when it is filling historical diversion time series. Based on the appropriation dates expressed in the administration number in the rights file, StateDMI determines the total amount of the water right during the time of the missing data, and constrains the diversion estimate accordingly. For example, suppose a ditch has two decrees, one for 2.5 cfs with an appropriation date of 1886, and the other for 6 cfs with an appropriation data of 1932. When StateDMI estimates diversions prior to 1932, it limits them to a maximum rate of 2.5 cfs for the month, regardless of the average

from available diversion records.  This approach was adopted so the water development of the study period could be simulated.


### 5.4.5.1 Key Structures

Water rights for explicitly modeled structures were taken from HydroBase and match the State Engineer's official water rights tabulation. Water rights for each individual structure in a diversion system are included under the defined diversion system identifier. In addition, many structures have been assigned a "free river right", with an extremely junior administration number of 99999.99999 and a decreed amount of 999.0 cfs.  These rights allow structures to divert more than their decreed water rights under free river conditions, provided their demand is unsatisfied and water is legally available.

### 5.4.5.2 Aggregate Structures

In the San Juan Model, aggregated structures can include more than 70 individual structures. Therefore, aggregated irrigation structures were assigned up to 13 water rights, one for each of 13 water right (administration) classes.  The decreed amount for a given water right class was set to the sum of all water rights that 1) were associated with individual structures included in the aggregated irrigation structure, and 2) had an administration number that fell within the water right class.  The administration number for each right was calculated to be the weighted average by summing the product of each administration number and decree and dividing by the total decree within the water right class.  For example, given 2 water rights; one for 10 cfs at an administration number of 1 and one for 2 cfs at an administration number of 4, the weighted administration number would be $(10 \times 1 + 4 \times 2) / (10 + 2) = 1.5$.

Aggregated M&I water rights were assigned an amount equal to their depletions and assigned an administration number of 1.00000.

### 5.4.5.3 Special Diversion Rights

#### 5.4.5.3.1 San Juan Chama Project

The San Juan Chama diversions do not have decreed water rights in Colorado. The San Juan Chama diversions were given water rights equal to each tunnel's capacity and assigned administration numbers junior to all water rights in Colorado (99999.00000), but senior to the New Mexico diversions.

#### 5.4.5.3.2 MVIC and the Dolores Project

Some of the Dolores River direct diversion rights for MVIC and Dolores Project users are assigned in HydroBase to structure WDIDs in the McElmo Creek basin (MVIC U-Lateral, etc.).  These  rights were re-assigned to the Dolores River

structures (Main Canals No 1 and 2) and used in conjunction with operating rules to meet the MVIC and Dolores Project demands.

### 5.4.5.3.3 New Mexico, Arizona, and Utah Structures

New Mexico structures were assigned large water rights (either 500 or 999 cfs) based on information provided by the USBR with administration numbers of 99999.00001. They are junior to all Colorado structures water rights except "free river rights."

### 5.4.5.3.4 Navajo Indian Irrigation Project

The NIIP return flow nodes (NM_NIIP_R1, NM_NIIP_R2, and NM_NIIP_R3) are assigned a senior priority of 1.00001 with a decree of 999 to assure that return flows are "imported" to the river in the historical calibration simulation.

### 5.4.5.3.5 Miscellaneous Structures

Fairfield Municipal water right is not stored in HydroBase. The water right was set to the Fairfield Municipal (780692) structure as follows: 999 cfs with an administration number of 22962.19157.

The Jackson Gulch Inlet Canal water right is not stored in HydroBase. The water right was set to the Jackson Gulch Inlet Canal (340535) structure as follows: 3.91 cfs with an administration number of 9997.00000.

A non-decreed Indian water right was set for the Thompson-Epperson Ditch (310511) as follows: 999 cfs with and administration number of 6781.00000.

A non-decreed existing use water right for the J P Lamb Ditch (300581) is set to assure the existing use is considered senior to a downstream instream flow right as follows: 999 cfs with and administration number of 49136.99999.

### 5.4.5.3.6 Future Use Diversion Structures

Animas-La Plata carrier and demand structures are provided with their conditional water right administration number of 32386.00000 in the direct diversion rights file. The three demand nodes (CO_ALP, NM_ALP1, and NM_ALP2) are assigned 999 cfs and the diversion to Ridges Basin Reservoir (300509) is assigned 600 cfs. Because there is no demand for these structures in the baseline demand file, the structures have no impact on the river.

## 5.5     Irrigation Files

The irrigation files provide parameters used during simulation to compute on-farm consumptive use, and return flow volumes related to a given month's diversions.

### 5.5.1          StateCU Structure File (*.str)

This file gives the soil moisture capacity of each irrigation structure for which efficiency varies, in inches per inch of soil depth.  It is required for StateMod's soil moisture accounting in both baseflow and simulation modes.  Soil moisture capacity values were gathered from Natural Resources Conservation Service (NRCS) mapping.  The file was created by StateDMI.

### 5.5.2          Irrigation Parameter Yearly (*.ipy)

This file contains conveyance efficiency and maximum application efficiency by irrigation type for each irrigation structure for which efficiency varies, and each year of the study period.  The file also contains acreage by irrigation type – either flood or sprinkler.  In the San Juan basin, all acreage has been assigned flood irrigation type. Maximum system efficiency (includes both conveyance and application efficiencies) is estimated to be 60 percent for Colorado structures with the exception of MVIC/Dolores Project structures. Acreage under structures MVIC U-Lateral (320772), MVIC Dolores Tunnel (324675), Towaoc Canal (320884) and Dove Creek Canal (322006) are mostly irrigated with sprinklers, therefore maximum system efficiency for these lands is estimated to be 70 percent.  Because overall system efficiency is considered, conveyance efficiency is set to 1.0 and maximum flood application efficiency is set to the system efficiencies outlined here.  This file was created by StateDMI.

### 5.5.3          Irrigation Water Requirement File (*.iwr)

Data for the irrigation water requirement file is generated by StateCU for the period 1950 through 2003, then filled and formatted in StateMod file format using TSTool.  StateCU was executed using the SCS modified Blaney-Criddle monthly evapotranspiration option with TR-21 crop parameters for lands irrigated below elevation 6500 feet.  For structures irrigating pasture grass above 6500 feet, StateCU was executed using the original Blaney-Criddle method with high-altitude crop coefficients, as described in the SPDSS 59.2 Task Memorandum *Develop Locally Calibrated Blaney-Criddle Crop Coefficients*, March 2005. Acreage for each structures was set to the acreage defined 2000 for the entire study period.The irrigation water requirement file contains the time series of monthly irrigation water requirements for structures whose efficiency varies through the simulation.

## 5.6 Reservoir Files

### 5.6.1 Reservoir Station File (*.res)

This file describes physical properties and some administrative characteristics of each reservoir simulated in the San Juan basin. It is assembled by StateDMI, using a considerable amount of information provided in the commands file. Fourteen key reservoirs were modeled explicitly. Seventeen aggregated reservoirs and stock ponds account for evaporation from numerous small storage facilities.

The modeled reservoirs are listed below with their capacity and their number of accounts or pools.

| #  | ID #      | Name                      | Capacity (af) | # of Owners |
|----|-----------|---------------------------|---------------|-------------|
| 1  | 29_ARS002 | ARS002_SanJuan            | 2,761         | 1           |
| 2  | 29_ASS001 | ASS001_SanJuan            | 4,233         | 1           |
| 3  | 303536    | CASCADE RESERVOIR         | 23,468        | 2           |
| 4  | 303581    | LEMON RESERVOIR           | 39,792        | 5           |
| 5  | 303623    | Ridges Basin Reservoir    | 120,000       | 1           |
| 6  | 30_ARS005 | ARS005_Animas             | 3,359         | 1           |
| 7  | 30_ASS002 | ASS002_Animas             | 2,469         | 1           |
| 8  | 313518    | VALLECITO RESERVOIR       | 125,441       | 4           |
| 9  | 31_ARS004 | ARS004_LosPinos           | 504           | 1           |
| 10 | 31_ASS003 | ASS003_LosPinos           | 1,411         | 1           |
| 11 | 32_ARS008 | ARS008_McElmo             | 1,005         | 1           |
| 12 | 32_ASS004 | ASS004_McElmo             | 16,930        | 1           |
| 13 | 333530    | Long Hollow Reservoir     | 5,400         | 1           |
| 14 | 33_ARS006 | ARS006_LaPlata            | 2,465         | 1           |
| 15 | 33_ASS005 | ASS005_LaPlata            | 2,116         | 1           |
| 16 | 343589    | JACKSON GULCH RESERVOIR   | 9,977         | 4           |
| 17 | 34_ARS007 | ARS007_Mancos             | 2,830         | 1           |
| 18 | 34_ASS006 | ASS006_Mancos             | 7,760         | 1           |
| 19 | 603507    | GURLEY RESERVOIR          | 10,039        | 2           |
| 20 | 603509    | LAKE HOPE RESERVOIR       | 2,315         | 1           |
| 21 | 603512    | MIRAMONTE RESERVOIR       | 6,852         | 1           |
| 22 | 603527    | TROUT LAKE RESERVOIR      | 3,422         | 2           |
| 23 | 60_ARS010 | ARS010_SMiguel            | 11,529        | 1           |
| 24 | 63_ARS009 | ARS009_Dolores            | 10,392        | 1           |
| 25 | 63_ASS007 | ASS007_Dolores            | 352           | 1           |
| 26 | 713602    | NARRAGUINNEP RESERVOIR    | 18,960        | 1           |
| 27 | 713612    | GROUNDHOG RESERVOIR       | 22,011        | 3           |
| 28 | 713614    | MCPHEE RESERVOIR          | 380,905       | 7           |
| 29 | 713619    | SUMMIT RESERVOIR          | 5,508         | 2           |
| 30 | 77_ARS001 | ARS001_Navajo             | 874           | 1           |

| 31 | 78_ARS003 | 003_Piedra | 15,611 | 1 |
| 32 | 903001 | Navajo Reservoir | 1,701,300 | 2 |

### 5.6.1.1 Key Reservoirs

Parameters related to the physical attributes of key reservoirs include inactive storage where applicable, total storage, area-capacity data, applicable evaporation/precipitation stations, and initial reservoir contents. For explicitly modeled reservoirs, storage and area-capacity information were obtained from either the Division Engineer or the reservoir owners. Initial contents for all reservoirs are set to average September end-of-month contents over the period 1975 through 1996. After filling dead pools, initial contents are prorated to reservoir accounts based on account size.

Administrative information includes reservoir account ownership, administrative fill date, and evaporation charge specifications. This information was obtained from interview with the Division Engineer, local water commissioners, and in most cases, the owner/operator of the individual reservoirs.

### 5.6.1.2 Aggregate Reservoirs

The amount of storage for aggregate reservoirs and stockponds is based on storage decrees and the CDSS Task 1.14-23 Memorandum "Non-Irrigation (Other Uses) Consumptive Uses and Losses in the Dolores and San Juan River Basins" (see Appendix B). Surface area for the aggregate reservoirs was developed assuming they are straight-sided pits with a depth of 25 feet for aggregate reservoirs and a depth of 10 feet for aggregate stockponds. Initial contents were set to full.

### 5.6.1.3 Reservoir Accounts

Except as noted below, San Juan Model reservoirs are modeled with only one active account.

#### 5.6.1.3.1 Lemon Reservoir

Lemon Reservoir (303581) Lemon Reservoir, constructed by the USBR in the early 1960s as a part of the Colorado River Storage Project (CRSP), stores surplus water available during spring runoff months and releases for late season irrigation demands. The reservoir has a total active capacity of 39,030 acre-feet, and has a decreed storage right of 40,240 acre-feet. There is also a second fill storage right of 7,760 acre-feet. A subsequent refill decree remains conditional. There are seven major irrigation structures on the Florida River cumulatively decreed for over 200 cfs which represent the structures that use the majority of the project water in the reservoir. For this model, these structures have been divided into Groups A and B. Group A accounts for 5.9 percent of the project water, and consists of 5 ditches: Harris Patterson (301003), Pioneer (301019), McCluer-Murray (301009), Banks-Tyner (301033), and Tyner-East Side (301243). Group B accounts for 94.1 percent of the project supply and

consists of only two diversions that are operated as a single demand, Florida Farmers/Florida Canal (301011). The U.S. Government has also reserved an account for 2,900 acre-feet.

### 5.6.1.3.2 Vallecito Reservoir

Vallecito Reservoir is the principal feature of the Pine River Project, constructed by the USBR in the early 1940s. The project is managed by the Pine River Irrigation District and supplies water to late season irrigation demands. The reservoir has a decreed storage right of 129,674 acre-feet. One-sixth of the active storage is owned by the Southern Ute Indian Tribe. For this reason, the reservoir is modeled with two active accounts, one for the Indian Tribe, the other for general irrigation.

### 5.6.1.3.3 Jackson Gulch Reservoir

Jackson Gulch Reservoir is the principal feature of the Mancos Project, constructed by the USBR in the late 1940s. Jackson Gulch has a storage capacity of 9,980 acre-feet, with an active capacity of 9,630 acre-feet. The reservoir is filled by diversions from the Jackson Gulch Inlet Canal (340535) located on the West Mancos River approximately 2.5 miles upstream from the reservoir. The U.S. Government has reserved 200 acre-feet of storage and 120 acre-feet are reserved for use by Mesa Verde National Park. For this reason, the reservoir is modeled with three active accounts, Mesa Verde, USA and the remaining storage for general irrigation.

### 5.6.1.3.4 McPhee Reservoir System and Dolores Project

The operation of the Dolores Project and the Groundhog and Narraguinnep reservoirs is the most complicated operation in the San Juan and Dolores basins. The project involves many agricultural, municipal, and transbasin diversions, as well as individual tunnels and carrier structures that carry water for multiple users. McPhee Reservoir is the principal feature of the Dolores Project, located on the main stem of the Dolores, just downstream of the town of Dolores. The storage in McPhee Reservoir, Groundhog Reservoir and Narraguinnep Reservoir is allocated as follows:

| Reservoir | Acct | Owner | Capacity (acre-feet) |
|-----------|------|-------|----------------------|
| McPhee Reservoir | 1 | MVIC | 105,500 |
| McPhee Reservoir | 2 | Ute Tribe | 23,300 |
| McPhee Reservoir | 3 | Dove Creek | 55,200 |
| McPhee Reservoir | 4 | Municipal | 8,700 |
| McPhee Reservoir | 5 | Fishery | 29,300 |
| McPhee Reservoir | 6 | Unallocated | 6,600 |
| McPhee Reservoir | 7 | Dead Pool | 152,200 |
| **McPhee Total** | | | **380,800** |
| | | | |
| Groundhog Reservoir | 1 | MVIC | 19,411 |

| Reservoir | Acct | Owner | Capacity (acre-feet) |
|---|---|---|---|
| Groundhog Reservoir | 2 | McPhee Ex | 2,300 |
| Groundhog Reservoir | 3 | Dead Pool | 300 |
| **Groundhog Total** | | | **22,011** |
| | | | |
| Narraguinnep Res. | 1 | General Irrigation | 18,900 |

The Montezuma Valley Irrigation Company (MVIC) capacity of 105,500 acre-feet represents the maximum delivery of project water that would be available through MVIC's senior rights. McPhee Reservoir currently has a conditional storage right of 750,000 acre-feet but no absolute water rights. For this model, McPhee Reservoir has been assigned a storage right of 381,200 acre-feet, which represents the actual physical capacity of the reservoir.

Groundhog Reservoir is modeled with two accounts. An exchange pool of 2,300 acre-feet has been set aside by agreement between MVIC and the Dolores Water Conservancy District. Since the construction of McPhee Reservoir, MVIC has reportedly not required water from Groundhog. An exchange agreement with the conservancy district provides for a release of 2,300 acre-feet of storage from Groundhog which protects a continuance of historical diversions of water rights on the upper Dolores River that are junior to the senior rights of the MVIC. For simplicity, this water is released to the system in July and August.

Narraguinnep Reservoir is an off-channel reservoir used to supplement late season irrigation supplies. It is modeled as one account for general irrigation releases. Prior to construction of the McPhee Reservoir, Groundhog and Narraguinnep reservoirs were used extensively to supplement irrigation demands from the river. This supplemental irrigation water is not used as often now that McPhee Reservoir can usually meet late season irrigation demands. Based on discussion with the MVIC, releases are made from McPhee Reservoir first, then Narraguinnep, then Groundhog.

### 5.6.2 Net Evaporation File (*.eva)

The evaporation file contains monthly average evaporation data (12 values that are applied in every year). The annual net reservoir evaporation was estimated by subtracting the weighted average effective monthly precipitation from the estimated gross monthly free water surface evaporation. Annual estimates of gross free water surface evaporation were taken from the National Oceanic and Atmospheric Administration (NOAA) Technical Report NWS 33. The annual estimates of evaporation were distributed to monthly values based on elevation through the distributions listed in Table 5.6. These monthly distributions are used by the State Engineer's Office.

**Table 5.6**
**Monthly Distribution of Evaporation as a**
**Function of Elevation (percent)**

| Month | Greater than 6,500 feet | Less than 6,500 feet |
|---|---|---|
| Jan | 3.0 | 1.0 |
| Feb | 3.5 | 3.0 |
| Mar | 5.5 | 6.0 |
| Apr | 9.0 | 9.0 |
| May | 12.0 | 12.5 |
| Jun | 14.5 | 15.5 |
| Jul | 15.0 | 16.0 |
| Aug | 13.5 | 13.0 |
| Sep | 10.0 | 11.0 |
| Oct | 7.0 | 7.5 |
| Nov | 4.0 | 4.0 |
| Dec | 3.0 | 1.5 |

Three evaporation stations were used in the calculation of annual net evaporation in the San Juan Model:

1. Gateway 1 SE, Uravan (10003) was used to calculate evaporation for the following reservoirs: 32_ARS008, 32_ASS004, Gurley, Lake Hope, Miramonte, Trout Lake, 60_ARS010, 63_ARS009, 63_ASS007, Narraguinnep, Groundhog, McPhee, and Summit.
2. Arboles (10004) was used to calculate evaporation for the following reservoirs: Ridges Basin, and Navajo.
3. San Juan (10007) was used to calculate evaporation for the following reservoirs: 29_ARS002, 29_ASS001, Cascade, Lemon, 30_ARS005, 30_ASS002, Vallecito, 31_ARS004, 31_ASS003, Long Hollow, 33_ARS006, 33_ASS005, Jackson Gulch, 34_ARS007, 34_ASS006, 77_ARS001, and 78_ARS003.

The resulting net monthly free water surface evaporation estimates used in the San Juan Model are as follows:

| Station | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10003 | 0.13 | 0.04 | -0.02 | -0.03 | 0.05 | 0.11 | 0.22 | 0.33 | 0.48 | 0.43 | 0.32 | 0.28 | 2.34 |
| 10004 | 0.14 | 0.07 | 0.05 | 0.05 | 0.06 | 0.12 | 0.19 | 0.28 | 0.34 | 0.36 | 0.21 | 0.23 | 2.10 |
| 10007 | 0.03 | -0.15 | -0.16 | -0.08 | -0.07 | -0.01 | 0.15 | 0.29 | 0.41 | 0.29 | 0.07 | 0.08 | 0.85 |

### 5.6.3    End-Of-Month Content File (*.eom)

The end-of-month content file contains historical end-of-month storage contents for all reservoirs in the reservoir station file.  The historical EOM reservoir contents in this file are used by StateMod when estimating baseflow to reverse the effects of reservoir storage and evaporation on gaged streamflows, and to produce comparison output useful for calibration.  The file is created by **TSTool**, which reads data from HydroBase and can fill it under a variety of user-specified algorithms.

#### 5.6.3.1    Key Reservoirs

Data for the San Juan Model key reservoirs was either provided by Division 7, Division 4, reservoir owners, the USBR, or generated by converting sporadic daily observations stored in HydroBase to month-end data.  Missing end-of-month contents were filled with the average of available values for months with the same hydrologic condition.  For reservoirs with little or no historical data available, and for off-channel reservoirs, end-of-month contents were set to reservoir capacity. Table 5.7 presents the on-line date for each reservoir and the primary data source for end-of-month contents.  Historical contents in the *.eom file are set to zero prior to the on-line date.

**Table 5.7**
**Reservoir On-line Dates and EOM Contents Data Source**

| WDID | Reservoir Name | On-Line Date | Primary Data Source |
|------|----------------|--------------|---------------------|
| 303536 | Cascade Reservoir | 1906 | HydroBase Daily |
| 303581 | Lemon Reservoir | 1963 | USBR |
| 303623 | Ridges Basin Reservoir | N/A | N/A |
| 313518 | Vallecito Reservoir | 1941 | USBR |
| 333503 | Long Hollow Reservoir | N/A | N/A |
| 343589 | Jackson Gulch Reservoir | 1949 | USBR |
| 603507 | Gurley Reservoir | 1961 | Capacity Used |
| 603509 | Lake Hope Reservoir | 1903 | Capacity Used |
| 603512 | Miramonte Reservoir | 1978 | Capacity Used |
| 603527 | Trout Lake Reservoir | 1954 | HydroBase Daily |
| 713602 | Narraguinnep Reservoir | 1908 | Capacity Used |
| 713612 | Groundhog Reservoir | 1905 | HydroBase Daily |
| 713614 | McPhee Reservoir | 1985 | USBR |
| 713619 | Summit Reservoir | 1905 | Capacity Used |
| 903001 | Navajo Reservoir | 1963 | USBR |

### 5.6.3.2 Aggregate Reservoirs

Aggregated reservoirs were assigned contents equal to their capacity, because there is no actual data. Aggregated reservoirs are modeled as though in operation throughout the study period.

## 5.6.4 Reservoir Target File (*.tar)

The reservoir target file contains minimum and maximum target storage limits for all reservoirs in the reservoir station file. The reservoir may not store more than the maximum target, or release to the extent that storage falls below the minimum target. In the Baseline data set, the minimum targets were set to zero for all reservoirs, and the maximum targets were set to capacity for all reservoirs that operate primarily for agricultural and municipal diversion storage. Maximum targets were set to operational targets according to rule curves provided by USBR for Lemon and Vallecito reservoirs. Cascade, Trout, and Navajo reservoirs operate for hydropower generation. For these reservoirs, maximum targets were set to historical end-of-month contents. Ridges Basin and Long Hollow reservoirs maximum storage targets were set to zero. This effectively disables the structures with regard to having an impact on the river.

## 5.6.5 Reservoir Right File (*.rer)

The reservoir right file contains the water rights associated with each reservoir in the reservoir station file. Specifically, the parameters for each storage right include the reservoir, administration number, decreed amount, the account(s) to which exercise of the right accrues, and whether the right is used as a first or second fill.

### 5.6.5.1 Key Reservoirs

In general, water rights for explicitly modeled reservoirs were taken from HydroBase and correspond to the State Engineer's official water rights tabulation. In addition, the key reservoirs were assigned a "free water right", with an extremely junior administration number to allow storage under free river conditions.

### 5.6.5.2 Aggregate Reservoirs

Aggregated reservoirs and stock ponds were assigned a decreed amount equal to their capacity, and an administration number 1.00000.

### 5.6.5.3 Special Reservoir Rights

#### 5.6.5.3.1 Navajo Reservoir

Navajo Reservoir (683675) has a New Mexico storage right that is not listed in HydroBase. Navajo Reservoir has a decreed absolute storage right for 1,708,600

acre-feet.  This right is set in the model with an administration number of 99999.00003.

### 5.6.5.3.2 Ridges Basin Reservoir

Ridges Basin Reservoir (303623) was just recently constructed and has a conditional storage right.  This conditional right was set in the model for 223,520 acre-feet with an administration number of 32386.00000.

### 5.6.5.3.3 Long Hollow Reservoir

Long Hollow Reservoir (333530) is a proposed reservoir, and has two conditional storage rights.  These conditional rights were set in the model for 1,200 acre-feet with an administration number of 47481.45077 and for 4,200 acre-feet with an administration number of 52595.45077.

## 5.7 Instream Flow Files

### 5.7.1 Instream Station File (*.ifs)

Forty-nine instream flow reaches are defined in this file, which is created in StateDMI.  The file specifies an instream flow station and downstream terminus node for each reach, through which instream flow rights can exert a demand in priority.  Table 5.8 lists each instream flow station included in the San Juan Model along with their location and maximum daily demand.  These rights represent decrees acquired by CWCB, with the exception of instream flow stations listed under the following section.

### 5.7.1.1 Special Instream Flow Stations

Several modeled instream flow stations were not obtained from HydroBase as follows:
- An instream flow node was added to reflect minimum bypass requirements at Lemon Reservoir (309999).
- An instream flow node was added to reflect minimum bypass requirements at the carrier to Ridges Basin Reservoir (903000).
- An instream flow node was added to reflect minimum reservoir releases at Vallecito Reservoir (319999) made to avoid cavitation.
- An instream flow node was added to the La Plata River at the Colorado-New Mexico state line to facilitate incorporation of the La Plata River Compact in the StateMod Model (332999).
- An instream flow node was added below McPhee Reservoir to reflect fish and wildlife demands (712999).
- An instream flow node was added downstream of Groundhog Reservoir to simplify the exchange of irrigation water from Groundhog Reservoir to miscellaneous users on the Dolores River (719999).

- An instream flow node was added on the Little Navajo River downstream of the San Juan Chama diversion to reflect bypass requirements of the project (772000).
- Two instream flow nodes were added downstream of Navajo Reservoir to reflect the minimum release from the reservoir during irrigation season and winter months and to accommodate operational releases to San Juan Power (902000 and 902200).

### 5.7.2 Instream Demand File (*.ifa)

Instream flow demands were developed from decreed amounts and comments in the State Engineer's water rights tabulation. Twelve monthly instream flow demands were used for each year of the simulation. The file contains monthly demands for each instream flow structure included in the San Juan Model.

### 5.7.3 Instream Right File (*.ifr)

Water rights for each instream flow reach modeled in the San Juan Model are contained in the instream flow right file, and shown in Table 5.8. Note that the decree represents the maximum demand, which may vary throughout the year. These data were obtained from the CWCB instream flow database with the exception of instream flow reaches listed under the following section.

**Table 5.8**
**Instream Flow Summary**

| # | ID | Name | Decree (cfs) |
|---|------|------|------|
| 1 | 290768 | RIO BLANCO MIN FLOW | 29.00 |
| 2 | 291900 | SAN JUAN RIVER MIN FLOW | 50.00 |
| 3 | 291902 | WEST FK SAN JUAN R MIN F | 25.00 |
| 4 | 291905 | WOLF CREEK MIN FLOW | 11.00 |
| 5 | 301902 | JUNCTION CREEK | 15.00 |
| 6 | 301903 | FLORIDA RIVER | 14.00 |
| 7 | 301904 | FLORIDA RIVER | 20.00 |
| 8 | 301928 | HERMOSA CR(LOWER REACH) | 37.00 |
| 9 | 309999 | Lemon_Res_Rel_USA | 4.00 |
| 10 | 311900 | LOS PINOS RIVER | 32.00 |
| 11 | 319999 | Vallecito_Res_Winter | 0.00 |
| 12 | 331905 | LA PLATA RIVER | 9.00 |
| 13 | 332999 | LaPlata_Compact_ISF | 100.00 |
| 14 | 601319 | BIG BEAR CREEK | 2.00 |
| 15 | 601320 | BILK CREEK | 3.00 |
| 16 | 601374 | DEEP CREEK | 4.00 |
| 17 | 601378 | ELK CREEK | 2.50 |
| 18 | 601381 | SAN MIGUEL RIVER | 6.50 |
| 19 | 601382 | SAN MIGUEL RIVER | 20.00 |
| 20 | 601383 | SOUTH FK SAN MIGUEL R | 9.00 |
| 21 | 601388 | FALL CREEK | 5.00 |
| 22 | 601389 | LEOPARD CREEK | 2.50 |
| 23 | 601390 | NATURITA CREEK | 3.00 |

| # | ID | Name | Decree (cfs) |
|---|---|---|---|
| 24 | 601397 | LAKE FK SAN MIGUEL RIV | 2.50 |
| 25 | 630644 | WEST CREEK | 6.00 |
| 26 | 710639 | DOLORES MINIMUM FLOW | 78.00 |
| 27 | 711907 | DOLORES RIVER | 20.00 |
| 28 | 711912 | DOLORES RIVER | 35.00 |
| 29 | 711915 | DOLORES RIVER | 50.00 |
| 30 | 711920 | WEST FORK DOLORES RIVER | 10.00 |
| 31 | 711921 | WEST FORK DOLORES RIVER | 17.00 |
| 32 | 711922 | FISH CREEK | 3.00 |
| 33 | 712999 | McPhee_ISF_Fish&Wild | 70.00 |
| 34 | 719999 | GroundHog/McPhee_Ex | 0.00 |
| 35 | 772000 | Little_Navajo-Chama_B | 27.00 |
| 36 | 772005 | NAVAJO RIVER MIN FLOW | 92.00 |
| 37 | 781900 | PIEDRA RIVER MIN FLOW | 30.00 |
| 38 | 781901 | PIEDRA RIVER MIN FLOW | 44.00 |
| 39 | 781902 | PIEDRA RIVER MIN FLOW | 53.00 |
| 40 | 781903 | PIEDRA RIVER MIN FLOW | 70.00 |
| 41 | 781905 | MID FK PIEDRA R MIN FLOW | 11.00 |
| 42 | 781906 | EAST FK PIEDRA R MIN FL | 10.00 |
| 43 | 781907 | WILLIAMS CREEK MIN FLOW | 14.00 |
| 44 | 781908 | WEMINUCHE CR MIN FLOW | 9.00 |
| 45 | 781909 | WEMINUCHE CR MIN FLOW | 18.00 |
| 46 | 781910 | PIEDRA RIVER MIN FLOW | 70.00 |
| 47 | 902000 | Navajo_Res_Min_Rel | 250.00 |
| 48 | 902200 | Navajo_Res_Animas_Min_Re | 500.00 |
| 49 | 903000 | RidgesBasin_Min_Bypass | 225.00 |

### 5.7.3.1    *Special Instream Flow rights*

Several modeled instream flow water rights were not obtained from HydroBase as follows:
- The instream flow right used to represent the minimum reservoir release requirements at Lemon Reservoir (309999) was set to 4.00 cfs with an administration number of 51499.42185.
- The instream flow right used to represent the minimum bypass requirement at the carrier structure tot Ridges Basin Reservoir (903000) was set to 225.0 cfs with an administration number of 32385.99999.
- The instream flow right used to represent the minimum winter releases at Vallecito Reservoir (319999) was turned "off". The demand is met entirely by an operating rule.
- The instream flow right used to represent the La Plata River Compact (332999), in conjunction with an operating rule, was set to 100.0 cfs with the senior administration number of 0.00001.
- The instream flow right used to represent the fish and wildlife bypass requirements below McPhee Reservoir was set to 70.9 cfs with an administration number of 45776.00010.

- The instream flow right used to represent the irrigation exchange from Groundhog Reservoir (719999) was turned "off". The demand is met entirely by an operating rule.
- The instream flow right used to represent the bypass requirement on the Little Navajo River downstream of the San Juan Chama diversion (772000) was set to 27.0 cfs with an administration number just senior to the diversion of 99998.99999
- The instream flow rights used to represent the minimum release from Navajo Reservoir were set to 250.0 cfs and 500.0 cfs respectively, both with administration number of 99999.00002.

## 5.8    Operating Rights File (*.opr)

The operating rights file specifies all operations that are more complicated than a direct diversion or storage in an on-stream reservoir. Typically, these are reservoir operations involving two or more structures, such as a release from a reservoir to a diversion structure, a release from on reservoir to a second reservoir, or a diversion to an off-stream reservoir. The file is created by hand, and the user is required to assign each operating right an administration number consistent with the structures' other rights and operations.

In the San Juan Model, seven different types of operating rights are used:

- **Type 1** – a release from storage to the stream to satisfy an instream flow demand. In the San Juan Model, this rule is used to satisfy minimum reservoir release requirements at McPhee, Groundhog, Vallecito, Lemon and Navajo Reservoirs.
- **Type 2** – a release from storage to the stream, for shepherded delivery to a downstream diversion or carrier. Typically, the reservoir supply is supplemental, and its release is given an administration number junior to direct flow rights at the destination structure. A release is made only if demand at the diversion structure is not satisfied after direct flow rights have diverted.
- **Type 3** – a release from storage directly to a carrier (a ditch or canal as opposed to the river), for delivery to a diversion station. Typically, the reservoir supply is supplemental, and its release is given an administration number junior to direct flow rights at the destination structure. A release is made only if demand at the diversion structure is not satisfied after direct flow rights have diverted.
- **Type 4** – a release from storage in exchange for a direct diversion elsewhere in the system. The release can occur only to the extent that legally available water occurs in the exchange reach. Typically, the storage water is supplemental, and is give an administration number junior to direct flow rights at the diverting structure.
- **Type 9** – a release from storage to the river to meet a reservoir target. This operation is used in the San Juan Baseline data set for the reservoirs that operate for flood control or power generation (Lemon, Vallecito, Cascade, Trout, and Navajo.) Targets allow maximum control of reservoir levels by storage rights and releases to meet demands.
- **Type 11** – a direct flow diversion to another diversion or reservoir through an intervening carrier. It uses the administration number and decreed amount of the direct flow right associated with the carrier, regardless of the administration number assigned to the operating right itself. In the San Juan Model, the Type 11 operating right is used both as a direct flow diversion to another diversion and as a direct flow diversion to a reservoir. For example, this rule type is

used to deliver water from the Dolores River through Main Canal No 1 to meet MVIC-U Lateral demands.  This rule type is also used to deliver water to Summit Reservoir through the Turkey Creek Canal; the demand is Summit Reservoir's capacity.

- **Type 13** – The type 13 operating rule allows an instream flow to operate based on its location on the river and the flow at a remote location. In the San Juan Model, the Type 13 operating rule is used to represent the requirements of the La Plata Compact. This compact, in general, defines Colorado's commitment to deliver water to New Mexico based on the flow at the upstream La Plata River at Hesperus index gage.

- **Type 22** – The type 22 operating rule directs StateMod to consider soil moisture in the variable efficiency accounting.  For structures with crop irrigation water requirements, excess diverted water not required by the crops during the month of diversion will be stored in the soil reservoir zone, up to the soil reservoir's available capacity.  If diversions are not adequate to meet crop irrigation water requirements during the month of diversion, water can be withdrawn from the soil reservoir to meet unsatisfied demands.  The depth of the soil zone is defined in the control file (*.ctl).  For the San Juan model, the effective soil depth or root zone was set to 3 feet.  As discussed in section 5.5.1, the available water content, in inches per inch, is defined for each irrigating structure in the StateCU structure file (*.str).

For all type 2, 3, 4, and 11 operating rules where water is released from a reservoir or diverted by a carrier to irrigation, the variable iopsou(4,1) in the operating file has been set to "1".  This directs StateMod to release water only when an irrigation water requirement exists.  When an irrigation water requirement exists, the operating rule will attempt to release the full amount required to satisfy the headgate demand defined in the *.ddm file.  The variable efficiency algorithm will then determine the actual efficiency of the released water.

The presentation of operating rights for the San Juan Model is generally organized according to the projects involved:

| **Section** | **Description** |
|---|---|
| 5.8.1 | San Juan Chama Project |
| 5.8.2 | Summit Reservoir System |
| 5.8.3 | MVIC  /Dolores Project |
| 5.8.4 | Vallecito Reservoir |
| 5.8.5 | Lemon Reservoir |
| 5.8.6 | Jackson Gulch Reservoir |
| 5.8.7 | Navajo Reservoir |
| 5.8.8 | Cascade Reservoir |
| 5.8.9 | Gurley Reservoir |
| 5.8.10 | Trout Lake and Lake Hope |
| 5.8.11 | Multiple Structures Irrigating Same Acreage |

### 5.8.1 San Juan Chama-Project

The San Juan-Chama Project diverts water from tributaries of the San Juan River in the Colorado River basin for export to the Rio Grande River basin. The diversion structures in the project do not have decreed Colorado water rights, and were assigned administration numbers that are junior to all Colorado water rights in the model.

Six operating rights are used to simulate San Juan-Chama operations:

| Right # | Destination | Carriers | Admin # | Right Type | Description |
|---|---|---|---|---|---|
| 1 | USBR Blanco Diversion | Little Navajo Diversion, Navajo Diversion, SJ-Chama Summary | 99999.00000 | 11 | Carrier to diversion |
| 2 | USBR Little Navajo Diversions | Navajo Diversion, SJ-Chama Summary | 99999.00000 | 11 | Carrier to diversion |
| 3 | USBR Navajo Diversion | SJ-Chama Summary | 99999.00000 | 11 | Carrier to diversion |
| 4 | San Juan Chama Summary | Little Navajo Diversion, Navajo Diversion | 99999.00000 | 11 | Carrier to diversion |
| 5 | San Juan-Chama Summary | Navajo Diversion | 99999.00000 | 11 | Carrier to diversion |
| 6 | San Juan-Chama Summary | | 99999.00000 | 11 | Carrier to diversion |

Operating rules 1 through 3 divert water from the Rio Blanco, Little Navajo, and Navajo rivers, respectively, based on demand at each of the individual diversion points. Each rule is constrained through each of the subsequent structures downslope of the diversion point. The capacities of each segment of the project were set equal to the cumulative amount of water that could potentially pass through it, up to the 950 cfs capacity of the final tunnel, Azotea. An administration number of 99999.00000 was assigned to these structures in order to be junior to other Colorado water rights. These rules are active only in the historical scenario – they are disabled for the Baseline data set.

Operating rules 4 through 6 carry water from the San Juan-Chama collection points to meet the total demand at the San Juan-Chama Summary structure. The San Juan-Chama Summary structure takes water from the Rio Blanco, Little Navajo, and Navajo basins.

### 5.8.2    Summit Reservoir System

Summit Reservoir System sits at the top of the drainage divide between the Dolores River, McElmo Creek, and the Mancos River. Summit Reservoir (713619) is filled by two direct flow diversions from District 71: the Turkey Creek Ditch and the Summit Ditch. The Summit Reservoir system also includes several smaller reservoirs and ditches; however because of their relatively small size they are not explicitly modeled. Summit Reservoir is operated with two accounts.

| Acct | Owner | Capacity (acre-feet) |
|------|-------|----------------------|
| 1 | General Irrigation | 4,708 |
| 2 | Inactive Recreation Pool | 400 |

Eight operating rules are used to simulate Overland Ditch and Reservoir operations:

| Right # | Destination | Account or Carrier | Admin # | Right Type | Description |
|---------|-------------|--------------------|---------|------------|-------------|
| 1 | Summit Reservoir | Turkey Creek D | 13346.00001 | 11 | Carrier to reservoir |
| 2 | Summit Reservoir | Turkey Creek D | 30667.20169 | 11 | Carrier to reservoir |
| 3 | Summit Reservoir | Summit Ditch | 30667.23176 | 11 | Carrier to reservoir |
| 4 | Summit Reservoir Outlet | Turkey Creek D | 13346.00000 | 11 | Carrier to diversion |
| 5 | Summit Reservoir Outlet | Turkey Creek D | 30667.20168 | 11 | Carrier to diversion |
| 6 | Summit Reservoir Outlet | Summit Ditch | 30667.23175 | 11 | Carrier to diversion |
| 7 | Summit Reservoir Outlet | 1 | 30667.23177 | 3 | Release to direct diversion |

Operating rules 1 through 3 carry water from the supply ditches to fill Summit Reservoir. The Turkey Creek Ditch has two water rights to fill the reservoir, while Summit Reservoir has one.

Operating rules 4 through 6 carry the water from the supply ditches directly to the irrigation demand at the reservoir outlet.

Operating rule 7 operates the reservoir releases to meet the irrigation demand. The administration number is junior to the three direct use rights.

### 5.8.3    MVIC / Dolores Project

The operation of the MVIC and the Dolores Project, including McPhee (713614), Groundhog (713612) and Narraguinnep (713602) reservoirs, is the most complicated operation in the San Juan and Dolores basins. The project involves many agricultural, municipal, and transbasin diversions, as well as individual tunnels and carrier structures that carry water for multiple users. McPhee Reservoir is the principal feature of the Dolores Project, located on the main stem of the Dolores, just downstream of the town of Dolores. The Montezuma Valley Irrigation Company

(MVIC) capacity of 105,500 acre-feet represents the maximum delivery of project water that would be available through MVIC's senior rights.

Groundhog Reservoir is modeled with two accounts. An exchange pool of 2,300 acre-feet has been set aside by agreement between MVIC and the Dolores Water Conservancy District. An exchange agreement with the conservancy district provides for a release of 2,300 acre-feet of storage from Groundhog which protects a continuance of historical diversions of water rights on the upper Dolores River that are junior to the senior rights of the MVIC. For simplicity, this agreement is modeled as an instream flow demand during July and August.

Narraguinnep Reservoir is an off-channel reservoir used to supplement late season irrigation supplies. It is modeled as one account for general irrigation releases. Prior to construction of the McPhee Reservoir, Groundhog and Narraguinnep reservoirs were used extensively to supplement irrigation demands from the river. This supplemental irrigation water is not used as often now that McPhee Reservoir can usually meet late season irrigation demands. Based on discussion with the MVIC, releases are made from McPhee Reservoir first, then Narraguinnep, then Groundhog.

| Reservoir | Acct | Owner | Capacity (acre-feet) |
|-----------|------|-------|----------------------|
| McPhee | 1 | MVIC | 105,500 |
| McPhee | 2 | Ute Tribe | 23,300 |
| McPhee | 3 | Dove Creek | 55,200 |
| McPhee | 4 | Municipal | 8,700 |
| McPhee | 5 | Fishery | 29,300 |
| McPhee | 6 | Unallocated | 7,150 |
| McPhee | 7 | Inactive | 151,705 |
| | | | |
| Groundhog | 1 | MVIC | 19,411 |
| Groundhog | 2 | McPhee Exchange | 2,300 |
| Groundhog | 3 | Dead Pool | 300 |
| | | | |
| Narraguinnep | 1 | MVIC | 18,900 |

Thirty operating rules are used to simulate MVIC and Dolores Project operations. They are split below into the seventeen direct right operations, the eight McPhee Reservoir operations, and the five Groundhog/Narraguinnep operations.

## Direct Right Operations

| Right # | Destination | Account or Carrier | Admin # | Right Type | Description |
|---|---|---|---|---|---|
| 1 | MVIC Dolores Tunnel | Main Canal No 1 | 13113.00000 | 11 | Carrier to diversion |
| 2 | MVIC Dolores Tunnel | Main Canal No 1 | 30667.13113 | 11 | Carrier to diversion |
| 3 | MVIC U Lateral | Main Canal No 2 | 13113.00000 | 11 | Carrier to diversion |
| 4 | MVIC U Lateral | Main Canal No 2 | 30667.13113 | 11 | Carrier to diversion |
| 5 | MVIC U Lateral | Main Canal No 2 | 11444.00000 | 11 | Carrier to diversion |
| 6 | Narraguinnep Reservoir | Main Canal No 1 | 13113.00000 | 11 | Carrier to diversion |
| 7 | Narraguinnep Reservoir | Main Canal No 1 | 11444.00000 | 11 | Carrier to diversion |
| 8 | Narraguinnep Reservoir | Main Canal No 1 | 30667.13113 | 11 | Carrier to diversion |
| 9 | Town of Cortez | Main Canal No 1 | 10743.00000 | 11 | Carrier to diversion |
| 10 | Town of Cortez | Main Canal No 1 | 11063.00000 | 11 | Carrier to diversion |
| 11 | Town of Cortez | Main Canal No 1 | 11839.00000 | 11 | Carrier to diversion |
| 12 | Town of Cortez | Main Canal No 1 | 12204.00000 | 11 | Carrier to diversion |
| 13 | Town of Cortez | Main Canal No 1 | 30667.13113 | 11 | Carrier to diversion |
| 14 | Montezuma Water Company | Main Canal No 1 | 11444.00000 | 11 | Carrier to diversion |
| 15 | Montezuma Water Company | Main Canal No 1 | 11453.00000 | 11 | Carrier to diversion |
| 16 | Montezuma Water Company | Main Canal No 1 | 30667.13113 | 11 | Carrier to diversion |
| 17 | Montezuma Water Company | Main Canal No 1 | 45117.00000 | 11 | Carrier to diversion |

Operating rules 1 and 2 provide Dolores River water to the MVIC Dolores Tunnel irrigation demand through the two water rights of Main Canal No. 1. These rights are mainly for use by the MVIC.

Operating rules 3, 4, and 5 provide Dolores River water through Main Canal No. 2 (now known as the Great Cut Dike) to the MVIC U Lateral irrigation demand. Note that operating rules 3 and 4 provide an alternate point of diversion for the same water rights in operating rules 1 and 2.

Operating rules 6, 7 and 8 provide Dolores River water to Narraguinnep Reservoir through Main Canal No. 1.

Operating rules 9 through 12 provide Dolores River water to the Town of Cortez through the town's four water rights. Operating rule 13 provides Dolores River water to the Town of Cortez using one of the Montezuma Water Company junior water rights. This water is carried through Main Canal No. 1.

Operating rules 14 through 17 provide Dolores River water to the Montezuma Water Company via their four water rights. This water is carried through Main Canal No. 1.

**McPhee Reservoir Operations**

| O | Right # | Destination | Account or Carrier | Admin # | Right Type | Description |
|---|---|---|---|---|---|---|
| p | 1 | MVIC Dolores Tunnel | 1 | 30667.13114 | 3 | Release to carrier |
| e | 2 | MVIC U Lateral | 1 | 30667.13114 | 3 | Release to carrier |
| r a | 3 | Towaoc Canal | 2 | 1.00000 | 3 | Release to carrier |
| t | 4 | Town of Cortez | 4 | 12204.00001 | 3 | Release to carrier |
| i | 5 | Montezuma Water Company | 4 | 45117.00001 | 3 | Release to carrier |
| n g | 6 | Dove Creek Canal | 3 | 1.00000 | 3 | Release to carrier |
| | 7 | McPhee Fish and Wildlife | 5 | 45776.00001 | 1 | Release to instream flow |
| r u | 8 | Reservoir to Target | All | 99999.99999 | 9 | Release to river by target |

Operating rule 1 delivers water from McPhee Reservoir to the MVIC Dolores Tunnel irrigation demand through Main Canal No 1. The administration number has been set just junior to MVIC's most junior direct water right.

Operating rule 2 delivers water from McPhee Reservoir to the MVIC U Lateral irrigation demand through Main Canal No 2. The administration number has been set just junior to MVIC's most junior direct water right.

Operating rule 3 delivers water from McPhee Reservoir to Towaoc Canal irrigation demand through Main Canal No 1. Towaoc Canal has no decreed water rights and obtains all its water from McPhee Reservoir therefore it has been given the senior water right.

Operating rules 4 and 5 deliver water from McPhee Reservoir to Cortez and Montezuma Water Company demand through Main Canal No 1. The administration numbers have been set just junior to their most junior direct water rights.

Operating Rule 6 delivers water from McPhee Reservoir to Dove Creek Canal irrigation demand through Main Canal No 2. Dove Creek Canal has no decreed water rights and obtains all its water from McPhee Reservoir therefore it has been given the senior water right.

Operating rule 7 delivers water from McPhee Reservoir to an instream flow demand on the Dolores River downstream of the reservoir.

Operating rule 8 releases water from all accounts, proportionally, to meet the historical end-of-month target values at McPhee Reservoir. For the Baseline data set, end-of-month targets for McPhee Reservoir are set to capacity, so releases to target are never made.

**Groundhog/Narraguinnep Reservoir Operations**

| Right # | Destination | Account or Carrier | Admin # | Right Type | Description |
|---|---|---|---|---|---|
| 1 | MVIC Dolores Tunnel | Groundhog - 1 | 30667.13115 | 2 | Release to river to carrier |
| 2 | MVIC U Lateral | Groundhog - 1 | 30667.13115 | 2 | Release to river to carrier |
| 3 | Groundhog Misc Users | Groundhog - 2 | 1.00000 | 1 | Release to instream flow |
| 4 | Groundhog Target | Groundhog - 4 | 99999.99999 | 9 | Release to river by target |
| 5 | MVIC U Lateral | Narraguinnep | 29151.00001 | 3 | Release to carrier |

Operating rule 1 releases water from Groundhog Reservoir to Main Canal No 1 to meet MVIC Dolores Tunnel irrigation demands. The administration numbers have been set just junior to the release from McPhee.

Operating rule 1 releases water from Groundhog Reservoir to Main Canal No 2 to meet MVIC U Lateral irrigation demands. The administration numbers have been set just junior to the release from McPhee.

Operating rule 3 is a simplified approach to operating the 2,300 acre-feet exchange between Groundhog Reservoir and miscellaneous water users on the Dolores River, whose demands is represented by an instream flow demand in July and August. It has been give the senior administration number.

Operating rule 4 releases water from all accounts, proportionally, to meet the historical end-of-month target values at Groundhog Reservoir. For the Baseline data set, end-of-month targets for Groundhog Reservoir are set to capacity, so releases to target are never made.

Operating rule 5 delivers water from Narraguinnep Reservoir to MVIC U Lateral irrigation demands. The administration numbers have been set just junior to Groundhog Reservoirs junior storage right.

## 5.8.4　　　Vallecito Reservoir

Vallecito Reservoir (313518) is the principal feature of the Pine River Project, constructed by the USBR in the early 1940s. The project is managed by the Pine River Irrigation District and supplies water to late season irrigation demands. The reservoir capacity is 125,441 acre-feet. The reservoir has a decreed storage right of 108,062 acre-feet and is modeled with a second "free" right to allow a second fill. One-sixth of the active storage is owned by the Southern Ute Indian Tribe. For this reason, the reservoir is modeled with two active accounts, one for the Indian Tribe, the other for general irrigation.

| Acct | Owner | Capacity (acre-feet) |
|------|-------|---------------------|
| 1 | Indian Water | 20,900 |
| 2 | General Irrigation | 100,298 |
| 3 | Inactive | 4,243 |
| 4 | Dead Pool | 4,300 |

Six of the structures that receive project water from Vallecito Reservoir are Indian-owned irrigation ditches, while 20 are non-Indian owned. Note that some of the 26 ditches are modeled together as diversion systems that irrigate common lands and have similar irrigation practices. Twenty-four operating rules are used to simulate Vallecito Reservoir operations.

| Right # | Destination | Account | Admin # | Right Type | Description |
|---|---|---|---|---|---|
| 1 | Farrel Ditch | 2 | 51499.33238 | 2 | Release to diversion |
| 2 | McBride Ditch | 2 | 51499.33238 | 2 | Release to diversion |
| 3 | Bennett-Myers Irr Ditch | 2 | 51499.33238 | 2 | Release to diversion |
| 4 | Myers and Asher Ditch | 2 | 51499.33238 | 2 | Release to diversion |
| 5 | Wommer Irrigation Ditch | 2 | 51499.33238 | 2 | Release to diversion |
| 6 | Catlin Ditch | 2 | 51499.33238 | 2 | Release to diversion |
| 7 | Bear Creek and Pine R Ditch | 2 | 51499.33238 | 2 | Release to diversion |
| 8 | Sullivan Ditch | 2 | 51499.33238 | 2 | Release to diversion |
| 9 | Los Pinos Irr Ditch | 2 | 51499.33238 | 2 | Release to diversion |
| 10 | Thompson-Epperson Ditch | 2 | 51499.33238 | 2 | Release to diversion |
| 11 | Schroder Irr Ditch | 2 | 51499.33238 | 2 | Release to diversion |
| 12 | Bean Ditch | 2 | 51499.33238 | 2 | Release to diversion |
| 13 | King Ditch | 2 | 51499.33238 | 2 | Release to diversion |
| 14 | Higbee Irrigation Ditch | 2 | 51499.33238 | 2 | Release to diversion |
| 15 | Island Ditch | 2 | 51499.33238 | 2 | Release to diversion |
| 16 | Robert Morrison Ditch | 2 | 51499.33238 | 2 | Release to diversion |
| 17 | Spring Creek Ditch | 2 | 51499.33238 | 2 | Release to diversion |
| 18 | Dr Morrison Ditch | 1 | 6781.00001 | 2 | Release to diversion |
| 19 | Ceanaboo Ditch | 1 | 6781.00001 | 2 | Release to diversion |
| 20 | Spring Creek Ditch | 1 | 6781.00001 | 2 | Release to diversion |
| 21 | La Boca Ditch | 1 | 6781.00001 | 2 | Release to diversion |
| 22 | Severo Ditch | 1 | 6781.00001 | 2 | Release to diversion |
| 23 | Vallecito Minimum Release | 2 | 31361.99999 | 1 | Release to instream flow |
| 24 | Vallecito Target | All | 99999.99999 | 9 | Release to river by target |

Operating rules 1 through 17 deliver project water to non-Indian owned ditches on the Pine River. These structures have all been assigned the same administration number just junior to the most junior direct flow right in the group. The King Ditch (310519) has a direct flow administration number of 51499.33237.

Operating rules 18 through 22 deliver project water to the Indian-owned ditches on the Pine River. These ditches hold the number one priority on the Los Pinos River, although they are modeled using their administration number according to the prior appropriation doctrine like any other water right in the model.

Operating rule 23 releases storage water from Vallecito Reservoir to meet operational guidelines at the outlet works. According to the USBR, releases through the outlet works have been

maintained at approximately 50 cfs to minimize cavitation at the regulating gates during the winter season. It is assigned an administration number just senior to its storage right.

Operating rule 28 releases water to meet operational targets per USBR operations. The junior administration number insures this is the last operating rule to fire.

### 5.8.5 Lemon Reservoir

Lemon Reservoir (303581), constructed by the USBR in the early 1960s as a part of the Colorado River Storage Project (CRSP), stores surplus water available during spring runoff months and releases for late season irrigation demands. The majority of the irrigated area is located on the Florida Mesa, adjacent to the Florida River. The reservoir has a total active capacity of 39,792 acre-feet, and decreed storage rights of 40,240 acre-feet and 7,760 acre-feet.

| Acct | Owner | Capacity (acre-feet) |
|------|-------|----------------------|
| 1 | Group A | 2,134 |
| 2 | Group B | 33,996 |
| 3 | USA | 2,900 |
| 4 | Inactive | 761 |
| 5 | Dead Pool | 1,110 |

The reservoir is maintained at a fairly constant level during the fall, with releases made in January, February, and March to provide flood control capacity. Releases from the reservoir are maintained below 1,000 cfs to protect the Florida River downstream. The U.S. Government has agreed to maintain a minimum streamflow of 4 cfs in the river below the dam downstream of the Florida Farmers Ditch.

There are seven major irrigation structures on the Florida River cumulatively decreed for over 200 cfs which represent the structures that use the majority of the project water in the reservoir. For this model, these structures have been divided into Groups A and B. Group A accounts for 5.9 percent of the project water, and consists of 5 ditches. Group B accounts for 94.1 percent of the project supply and consists of only two diversions that are operated as a single diversion system, Florida Farmers/Florida Canal (301011). These operations are represented by eight operating rules.

| Right # | Destination | Account | Admin # | Right Type | Description |
|---|---|---|---|---|---|
| 1 | Harris-Patterson Ditch | 1 | 26974.22967 | 2 | Release to diversion |
| 2 | Pioneer Ditch | 1 | 26974.22967 | 2 | Release to diversion |
| 3 | McCluer and Murray Ditch | 1 | 26974.22967 | 2 | Release to diversion |
| 4 | Banks-Tyner Ditch | 1 | 26974.22967 | 2 | Release to diversion |
| 5 | Tyner East Side Ditch | 1 | 26974.22967 | 2 | Release to diversion |
| 6 | Florida Farmers/Florida Canal | 2 | 35219.00001 | 2 | Release to diversion |
| 7 | Lemon Minimum Release | 3 | 51499.42186 | 1 | Release to instream flow |
| 8 | Lemon Target | All | 99999.99999 | 9 | Release to river by target |

Operating rules 1 through 5 release water to Group A irrigation demand. The administration number for this group is just junior to the most junior direct flow right in the group. The Tyner East Side Ditch (301243) has a direct flow administration number of 26974.22966.

Operating rule 6 releases water to Group B (Florida Farmers/Florida Canal) irrigation demand. The administration number for this group is just junior to the most junior direct flow right for both ditches. This administration number allows these ditches to receive water from direct flow rights before taking water from storage.

Operating rule 7 releases storage water from the reservoir to meet the minimum streamflow.

Operating rule 9 releases water to meet operational targets per USBR operations. The junior administration number insures this is the last operating rule to fire.

## 5.8.6 Jackson Gulch Reservoir

Jackson Gulch Reservoir (343589) is the principal feature of the Mancos Project, constructed by the USBR in the late 1940s. Jackson Gulch has a storage capacity of 9,977 acre-feet. The reservoir is filled by diversions from the Jackson Gulch Inlet Canal (340535) located on the West Mancos River approximately 2.5 miles upstream from the reservoir. Some of the rights for the inlet canal were either transferred to the inlet canal from other irrigation ditches, or have named the canal as an alternate point of diversion.

| Acct | Owner | Capacity (acre-feet) |
|---|---|---|
| 1 | Project | 9,486 |
| 2 | USA | 200 |
| 3 | Mesa_Verde | 120 |
| 4 | Inactive | 167 |

Twenty-eight operating rules are used to simulate Mancos Project operations:

| Right # | Destination | Account or Carrier | Admin # | Right Type | Description |
|---|---|---|---|---|---|
| 1 | Jackson Gulch Reservoir | Jackson Inlet | 31715.00000 | 11 | Carrier to storage |
| 2 | Jackson Gulch Reservoir | Jackson Inlet | 51499.44559 | 11 | Carrier to storage |
| 3 | Jackson Gulch Reservoir | Jackson Inlet | 14015.00000 | 11 | Carrier to storage |
| 4 | Jackson Gulch Reservoir | Jackson Inlet | 11093.00000 | 11 | Carrier to storage |
| 5 | Jackson Gulch Reservoir | Jackson Inlet | 11823.00000 | 11 | Carrier to storage |
| 6 | Jackson Gulch Reservoir | Jackson Inlet | 11489.00000 | 11 | Carrier to storage |
| 7 | Jackson Gulch Reservoir | Jackson Inlet | 9997.00000 | 11 | Carrier to storage |
| 8 | Lee and Burke Ditch | 1 | 36712.00001 | 2 | Release to diversion |
| 9 | Webber Ditch | 1 | 36712.00001 | 2 | Release to diversion |
| 10 | Ratliff and Root Ditch | 1 | 36712.00001 | 2 | Release to diversion |
| 11 | Lee Ditch | 1 | 36712.00001 | 2 | Release to diversion |
| 12 | Frank Ditch | 1 | 36712.00001 | 2 | Release to diversion |
| 13 | Willis Ditchy | 1 | 36712.00001 | 2 | Release to diversion |
| 14 | Boss Ditch | 1 | 36712.00001 | 2 | Release to diversion |
| 15 | NO 6 Ditch | 1 | 36712.00001 | 2 | Release to diversion |
| 16 | Sheek Ditch | 1 | 36712.00001 | 2 | Release to diversion |
| 17 | Beaver Ditch | 1 | 36712.00001 | 2 | Release to diversion |
| 18 | Henry Bolen Ditch | 1 | 36712.00001 | 2 | Release to diversion |
| 19 | Crystal  Creek Ditch | 1 | 36712.00001 | 4 | Exchange to diversion |
| 20 | Long Park Ditch | 1 | 36712.00001 | 4 | Exchange to diversion |
| 21 | Smouse Ditch | 1 | 36712.00001 | 4 | Exchange to diversion |
| 22 | Williams Ditch | 1 | 36712.00001 | 4 | Exchange to diversion |
| 23 | East Mancos Highline D. | 1 | 36712.00001 | 4 | Exchange to diversion |
| 24 | Rush Reservoir Ditch | 1 | 36712.00001 | 4 | Exchange to diversion |
| 25 | Weber Reservoir Inlet D | 1 | 36712.00001 | 4 | Exchange to diversion |
| 26 | Town of Mancos Ditch | 1 | 36712.00001 | 2 | Release to diversion |
| 27 | Carpenter and Mitchell | 1 | 36712.00001 | 3 | Release to carrier |
| 28 | Jackson Gulch Target | All | 99999.99999 | 9 | Release to river by target |

Operating rules 1 through 7 fill the reservoir through direct flow rights from the West Mancos River at structure 340535.

Operating rules 8 through 18, and rule 26, release water directly for irrigation demands while rules 19 through 25 provide reservoir water by exchange. All reservoir releases were assigned a single administration number just junior to the most junior direct flow rights in the group. The Ratliff and Root Ditch has a direct flow administration number of 36712.00000.

Operating rule 27 supplies water to the Carpenter and Mitchell Ditch on Chicken Creek through a carrier ditch. The Carpenter and Mitchell Ditch (340508) is located on Chicken Creek, a tributary to the Mancos River. It actually receives Jackson Gulch water via a relatively small reservoir and carrier ditch not explicitly modeled. For simplicity, this structure is modeled to receive project water directly from Jackson Gulch Reservoir.

Operating rule 28 releases water from all accounts, proportionally, to meet the historical end-of-month target values at Jackson Gulch Reservoir. For the Baseline data set, end-of-month targets for Jackson Gulch Reservoir are set to capacity, so releases to target are never made.

### 5.8.7 Navajo Reservoir

Navajo Reservoir (903001) was constructed by the USBR in the late 1950s as a component of the Colorado River Storage Project. The reservoir holds a junior New Mexico storage permit with a 1955 priority. For the San Juan Model, the reservoir is assigned an administration number junior to all existing Colorado water rights. The reservoir is modeled with an active and inactive storage account.

| Acct | Owner | Capacity (acre-feet) |
|------|-------|---------------------|
| 1 | Available | 1,075,625 |
| 2 | Inactive | 625,675 |

Twenty operating rules are used to simulate Navajo Reservoir operations:

| Right # | Destination | Account or Carrier | Admin # | Right Type | Description |
|---|---|---|---|---|---|
| 1 | NIIP | 1 | 1.00001 | 2 | Release to diversion |
| 2 | San Juan Power | 1 | 99999.00002 | 2 | Release to diversion |
| 3 | Citizens Ditch | 1 | 99999.00002 | 2 | Release to diversion |
| 4 | Hammond Ditch | 1 | 99999.00002 | 2 | Release to diversion |
| 5 | Fruitland | 1 | 99999.00002 | 2 | Release to diversion |
| 6 | Jewitt V. | 1 | 99999.00002 | 2 | Release to diversion |
| 7 | 4 Corners Power Plant | 1 | 99999.00002 | 2 | Release to diversion |
| 8 | Hogback | 1 | 99999.00002 | 2 | Release to diversion |
| 9 | Cudei NIR | 1 | 99999.00002 | 2 | Release to diversion |
| 10 | Bloomfield | 1 | 99999.00002 | 2 | Release to diversion |
| 11 | Archuleta | 1 | 99999.00002 | 2 | Release to diversion |
| 12 | Turley | 1 | 99999.00002 | 2 | Release to diversion |
| 13 | NM 3 NIR | 1 | 99999.00002 | 2 | Release to diversion |
| 14 | West Water | 1 | 99999.00002 | 2 | Release to diversion |
| 15 | NM_U6 NIR | 1 | 99999.00002 | 2 | Release to diversion |
| 16 | Shiprock MI | 1 | 99999.00002 | 2 | Release to diversion |
| 17 | NM_U7 NIR | 1 | 99999.00002 | 2 | Release to diversion |
| 18 | 250 IFS | 1 | 99999.00002 | 1 | Release to instream flow |
| 19 | 525 IFS | 1 | 99999.00002 | 1 | Release to instream flow |
| 20 | Navajo to Target | All | 99999.99999 | 9 | Release to river by target |

Operating rules 1 through 17 release water from the reservoir to meet demands for New Mexico users. NIIP receives water directly from the reservoir through a headgate operated by the Navajo Agricultural Products Industry, therefore is give a senior administration number. Other reservoir releases were assigned a single administration number just junior to the administration number assigned to New Mexico direct diversion rights.

Operating rules 18 and 19 satisfy reservoir minimum releases requirements. Based on interviews with the USBR, a release of approximately 525 cfs during the irrigation season, together with the inflows from the Animas River, was sufficient to satisfy all of the downstream demands without having to call out the reservoir. When the Animas River is unusually low, additional releases from the reservoir are made. Rule 18 releases water to a 250 cfs instream flow right located just downstream of the reservoir and NIIP diversion node. Rule 19 releases to a 525 cfs instream flow right on the San Juan River downstream of the Animas confluence. This second right was given an administration number junior to the first so that releases would be made in years when the inflow from the Animas River is low.

Operating rule 20 releases water from all accounts, proportionally, to meet the historical end-of-month target values at Navajo Reservoir.

### 5.8.8　　　Cascade Reservoir

Cascade Reservoir (300523) is the principal feature of the Tacoma Project and is owned and operated by Public Service Company of Colorado. The reservoir is located on Elbert Creek, a tributary to the Animas River. The principal source of supply for the reservoir is transbasin water diverted from Big Cascade Creek via the Cascade Canal (300523). Non-consumptive releases for power are made through Power Canal No. 1 (300612).  Cascade Reservoir is modeled with one active account.

| Acct | Owner | Capacity (acre-feet) |
|------|-------|----------------------|
| 1 | Project | 22,364 |
| 2 | Inactive | 1,100 |

Four operating rules are used to simulate Cascade Reservoir operations:

| Right # | Destination | Account or Carrier | Admin # | Right Type | Description |
|---------|-------------|--------------------|---------|------------|-------------|
| 1 | Cascade Reservoir | Cascade Canal | 26974.19267 | 11 | Carrier to reservoir |
| 2 | Power Canal No 1 | Cascade Canal | 26974.19266 | 11 | Carrier to diversion |
| 3 | Power Canal No 1 | 1 | 26974.19268 | 2 | Release to diversion |
| 4 | Cascade to Target | All | 99999.99999 | 2 | Release to river by target |

Operating rule 1 diverts water through the Cascade Canal to the reservoir for storage.

Operating rule 2 diverts water through the Cascade Canal directly to meet the Power Canal demands. This rule ties the inflow to the reservoir directly to the outlet works of the reservoir.

Operating rule 3 releases water in Cascade Reservoir to meet the Power Canal demands. The administration number for this rule is just junior to the direct flow delivered in operating rule 2. This assures that demands are met from direct diversions prior to releasing water from storage.

Operating rule 4 releases water from all accounts, proportionally, to meet the historical end-of-month target values at Cascade Reservoir.  This operating rule is turned off in the Baseline data set, as release requirements are driven by Power Canal demands.

### 5.8.9　　　Gurley Reservoir

Gurley Reservoir (603507) is located on a tributary to the San Miguel River and is used to provide supplemental irrigation to approximately 20,000 acres in the area near Norwood, Colorado. The reservoir has an active capacity of about 9,540 acre-feet. It has a small tributary drainage area and receives most of its supply via the Naturita Canal (600707). Because the individual structures that irrigate from Gurley Reservoir have small decreed amounts, their diversions have been incorporated into the model as a diversion system node (990707).

| Acct | Owner | Capacity (acre-feet) |
|------|-------|----------------------|
| 1 | Irrigation | 9,539 |
| 2 | Dead Pool | 500 |

Nine operating rules are used to simulate Gurley Reservoir operations:

| Right # | Destination | Account or Carrier | Admin # | Right Type | Description |
|---------|-------------|--------------------|---------|------------|-------------|
| 1 | Gurley Irr Divsystem | 1 | 32811.31641 | 2 | Release to diversion |
| 2 | Gurley to Target | All | 99999.99999 | 9 | Release to river by target |
| 3 | Gurley Reservoir | Naturita Canal | 20889.00000 | 11 | Carrier to storage |
| 4 | Gurley Reservoir | Naturita Canal | 23681.20889 | 11 | Carrier to storage |
| 5 | Gurley Reservoir | Naturita Canal | 23681.23212 | 11 | Carrier to storage |
| 6 | Gurley Reservoir | Naturita Canal | 23681.23215 | 11 | Carrier to storage |
| 7 | Gurley Reservoir | Naturita Canal | 28911.28052 | 11 | Carrier to storage |
| 8 | Gurley Reservoir | Naturita Canal | 30604.30604 | 11 | Carrier to storage |
| 9 | Gurley Reservoir | Naturita Canal | 32811.31726 | 11 | Carrier to storage |

Operating rule 1 releases water from the reservoir to meet the irrigation demands. The demands for the aggregate demand node 990707 were estimated from the recorded historical diversions of the Naturita Canal.

Operating rule 2 releases water from all accounts, proportionally, to meet the historical end-of-month target values at Gurley Reservoir.

Operating rules 3 through 9 fill the reservoir with the seven rights of the Naturita Canal. For the Baseline data set, end-of-month targets for Gurley Reservoir are set to capacity, so releases to target are never made.

## 5.8.10     Trout Lake and Lake Hope

Trout Lake (603527) and Lake Hope (603509) reservoirs are used together by the Public Service Company of Colorado for power generation at the Ames and Nucla power plants (600511 and 600723). Trout Lake delivers storage water to both plants. The Ames plant also receives storage water from Lake Hope in late summer and fall. Trout Lake is modeled with an active and dead pool, and Lake Hope has an active pool only.

| Reservoir | Acct | Owner | Capacity (acre-feet) |
|-----------|------|-------|----------------------|
| Trout Lake | 1 | Active | 2,504 |
| Trout Lake | 2 | Dead Pool | 918 |
| Lake Hope | 1 | Active | 1,037 |

Five operating rules are used to simulate Trout Lake and Lake Hope power operations:

| Right # | Destination | Reservoir | Admin # | Right Type | Description |
|---------|-------------|-----------|---------|------------|-------------|
| 1 | Ames Power | Trout | 30604.15158 | 2 | Release to diversion |
| 2 | Ames Power | Hope | 30604.15159 | 2 | Release to diversion |
| 3 | Nucla Power | Trout | 38468.00001 | 2 | Release to diversion |
| 4 | Lake Hope to Target | Hope | 99999.99999 | 9 | Release to river by target |
| 5 | Trout Lake to Target | Trout | 99999.99999 | 9 | Release to river by target |

Operating rule 1 releases water from Trout Lake to satisfy demands at Ames power plant. The administration number assigned is just senior to releases to Ames from Lake Hope.

Operating rule 2 releases water from Lake Hope to satisfy demands at Ames power plant. The administration number for this rule is just junior to the Ames power plant direct diversion right.

Operating rules 3 releases water from Trout Lake to satisfy demands at Nucla Power Plant. The administration number for this rule is junior to Nucla's direct diversion rights.

Operating rules 4 and 5 releases water from all accounts, proportionally, to meet the historical end-of-month target values at Lake Hope and Trout Lake, respectively. For the Baseline data set, end-of-month targets for Lake Hope are set to capacity, so releases to target are never made.

### 5.8.11    Multistructures Irrigating the Same Acreage

Several parcels of irrigated land in the San Juan and Dolores River basins receive irrigation water from multiple diversion structures often on different tributaries. The historical diversions at these multiple structures are modeled at their respective historical headgate locations for baseflow generation and the Historical calibration (see Section 7). In the Baseline data set, total demand for these lands are assigned to a primary structure, and diversions from the individual headgates are driven by operating rules.  The sources for each operating rule are the direct flow rights at each structure. Twenty-six operating rules are used to simulate multistructure operations.  Multistructures in the San Juan Model are as follows:

| Primary Structure | Secondary Structure |
|---|---|
| 290686 – Park Ditch | 290613 – Hallett Ditch |
| 300506 – Animas Consolidated Ditch | 300581 – J P Lamb Ditch |
| 310665 – Spring Creek Ditch | 460503 – Briggs Ditch |
| | 310567 – Campbell Ditch |
| 330533 – Pine Ridge Ditch | 301056 – Bodo Pine Ridge Ditch |
| 610502 – Galloway Ditch | 610602 – A E L R P & PL |
| 780507 – Barnes-Meuser and Shaw Ditch | 780506 – Barnes Ditch |
| 780544 – F S Mockler Irri Ditch | 780524 – Cimarron Ditch |
| 780604 – Piedra Falls Ditch | 780659 – Little Pagosa Creek Diversion |
| | 780523 – Carl and Webb Ditch |
| | 780594 – Pagosa Ditch |
| 780617 – Stevens and Clayton Ditch | 780525 – Clayton-Reed Ditch |
| | 780590 – Nickles Brothers Ditch |

# 6. Baseline Results

The "Baseline" data set simulates current demands, current infrastructure and projects, and the current administrative environment, as though they had been in place throughout the modeled period. This section summarizes the state of the river as the San Juan Model characterizes it, under these assumptions.

## 6.1 Baseline Streamflows

Table 6.1 shows the average annual flow from the Baseline simulation for each gage, based on the entire simulation period (1909 – 2003). In general, this value is lower than the historical average, because demand has risen and the development of storage has re-timed the supply so that more of the demand can be met. The second value in the table is the average annual available flow, as identified by the model. Available flow at a point is water that is not needed to satisfy instream flows or downstream diversion demand; it represents the water that could be diverted by a new water right. The available flow is always less than the total simulated flow.

The Baseline data set, and corresponding results, does not include any consideration for Colorado River Compact obligations, nor are conditional water rights represented in the Baseline data set. The La Plata Compact obligations, however, are represented in the simulation. Variations of the Baseline data set could include conditional rights within the San Juan and Dolores basins, and would likely result in less available flow than presented here.

Temporal variability of the historical and Baseline simulated flows is illustrated in Figures 6.1 through 6.10 for selected gages. Each figure shows two graphs: overlain hydrographs of historical gage flow, simulated gage flow, and simulated available flow for 1975 through 2003; and an average annual hydrograph based on the entire modeling period. The annual hydrograph is a plot of monthly average flow values, for the three parameters. The gages selected for these figures have a fairly complete record between 1975 and 2003.

Baseline flows are generally higher than historical flows during the irrigation season on tributaries with significant storage and on tributary gages upstream of senior diverters. This is, in part, due to increased reservoir releases and bypassed flow required to meet the higher Baseline demands. In addition, many of the reservoirs included in the San Juan Model came on-line during the simulation period. Their ability to re-regulate natural flow and provide supplemental water during the late irrigation season is not represented in the historical record for much of the study period, therefore not fully represented in the 1909 through 2003 graphs.

On the Los Pinos River, average monthly simulated flows exceed historical gaged flows during the irrigation season. This flow represents return flows as a result of increased use of Vallecito storage water to meet Baseline demands. Similarly, average monthly simulated and available flows on McElmo Creek exceed historical gaged flows during the irrigation season. This flow represents return flows from increased use associated with the Dolores Project. These increased return flows are available for downstream use.

**Table 6.1**
**Simulated and Available Baseline Average Annual Flows for San Juan Model Gages**
**(1909-2003)**

| Gage ID | Gage Name | Simulated Flow (af) | Simulated Available Flow (af) |
|---|---|---|---|
| 09339900 | East Fork San Juan River above Sand Creek | 66,765 | 43,208 |
| 09341500 | West Fork San Juan River near Pagosa Springs | 118,591 | 70,726 |
| 09342000 | Turkey Creek near Pagosa Springs | 25,363 | 17,586 |
| 09342500 | San Juan River at Pagosa Springs | 274,530 | 162,916 |
| 09343300 | Rio Blanco bl Blanco Div Dam nr Pagosa Springs | 7,472 | 3,116 |
| 09344000 | Navajo River at Banded Peak Ranch near Chromo | 82,128 | 24,398 |
| 09344400 | Navajo River below Oso Diversion Dam nr Chromo | 54,219 | 25,808 |
| 09345200 | Little Navajo River bl Oso Diversion Dam nr Chromo | 2,892 | 582 |
| 09346000 | Navajo River at Edith | 63,008 | 30,866 |
| 09346400 | San Juan River near Carracas | 403,692 | 239,931 |
| 09347500 | Piedra River at Bridge Ranger Sta. nr Pagosa Springs | 78,709 | 44,163 |
| 09349500 | Piedra River near Piedra | 247,059 | 141,499 |
| 09349800 | Piedra River near Arboles | 294,692 | 177,281 |
| 09352900 | Vallecito Creek near Bayfield | 108,562 | 30,755 |
| 09353500 | Los Pinos River near Bayfield | 277,929 | 79,081 |
| 09354000 | Los Pinos River at Bayfield | 149,426 | 95,512 |
| 09354500 | Los Pinos River at La Boca | 188,616 | 110,956 |
| 09355000 | Spring Creek at La Boca | 23,236 | 8,634 |
| 09355500 | San Juan River near Archuleta | 631,009 | 437,979 |
| 09357500 | Animas River at Howardsville | 78,393 | 66,184 |
| 09359000 | Mineral Creek near Silverton | 74,168 | 61,232 |
| 09359500 | Animas River above Tacoma | 442,946 | 313,022 |
| 09361000 | Hermosa Creek near Hermosa | 98,030 | 73,944 |
| 09361500 | Animas River at Durango | 593,859 | 424,245 |
| 09362999 | Florida River above Lemon Reservoir (USBR data) | 70,763 | 8,771 |
| 09363200 | Florida River at Bondad | 62,644 | 43,372 |
| 09363500 | Animas River near Cedar Hill, NM | 700,544 | 458,012 |
| 09364500 | Animas River at Farmington, NM | 640,461 | 464,446 |
| 09365000 | San Juan River at Farmington, NM | 1,258,608 | 779,453 |
| LONREDCO | Long Hollow at the Mouth near Red Mesa | 5,540 | 1,985 |

| Gage ID | Gage Name | Simulated Flow (af) | Simulated Available Flow (af) |
|---|---|---|---|
| 09365500 | La Plata River at Hesperus | 29,935 | 3,434 |
| 09366500 | La Plata River at CO-NM State Line | 22,066 | 10,079 |
| 09367500 | La Plata River near Farmington, NM | 21,437 | 17,636 |
| 09368000 | San Juan at Shiprock | 1,292,389 | 860,197 |
| 09369500 | Middle Mancos River near Mancos | 4,930 | 3,732 |
| 09369000 | East Mancos River near Mancos | 7,537 | 4,183 |
| 09368499 | Above Jackson Gulch Reservoir (USBR data) | 10,875 | 1,132 |
| 09368500 | West Mancos River near Mancos | 27,026 | 6,982 |
| 09371000 | Mancos River near Towaoc | 28,406 | 26,754 |
| 09371010 | San Juan River at Four Corners | 7,594 | 6,976 |
| 09371400 | Hartman Draw at Cortez | 19,297 | 18,132 |
| 09371420 | McElmo Creek above Alkali Canyon near Cortez | 41,077 | 27,769 |
| 09371500 | McElmo Creek near Cortez | 43,863 | 42,213 |
| 09372000 | McElmo Creek near CO-UT State Line | 1,368,126 | 956,267 |
| 09379500 | San Juan River near Bluff | 1,475,308 | 1,475,308 |
| 09165000 | Dolores River below Rico | 104,036 | 37,307 |
| 09166500 | Dolores River at Dolores | 327,086 | 78,008 |
| 09166950 | Lost Canyon Creek near Dolores | 10,911 | 4,802 |
| 09168100 | Disappointment Creek near Dove Creek | 14,399 | 10,510 |
| 09169500 | Dolores River at Bedrock | 183,362 | 137,690 |
| 09171100 | Dolores River near Bedrock | 193,434 | 148,269 |
| 09171200 | San Miguel River near Telluride | 51,534 | 45,412 |
| 09172000 | Fall Creek near Fall Creek | 13,736 | 10,100 |
| 09172100 | Leopard Creek at Noel | 2,356 | 1,128 |
| 09172500 | San Miguel River near Placerville | 172,256 | 151,866 |
| 09173000 | Beaver Creek near Norwood | 7,469 | 7,272 |
| 09175500 | San Miguel River at Naturita | 221,119 | 214,889 |
| 09177000 | San Miguel River at Uravan | 255,643 | 248,653 |
| 09179500 | Dolores River at Gateway | 499,802 | 499,802 |

**USGS Gage 09342500 - San Juan River at Pagosa Springs**
**Gaged, Simulated, and Available Flows (1975-2003)**
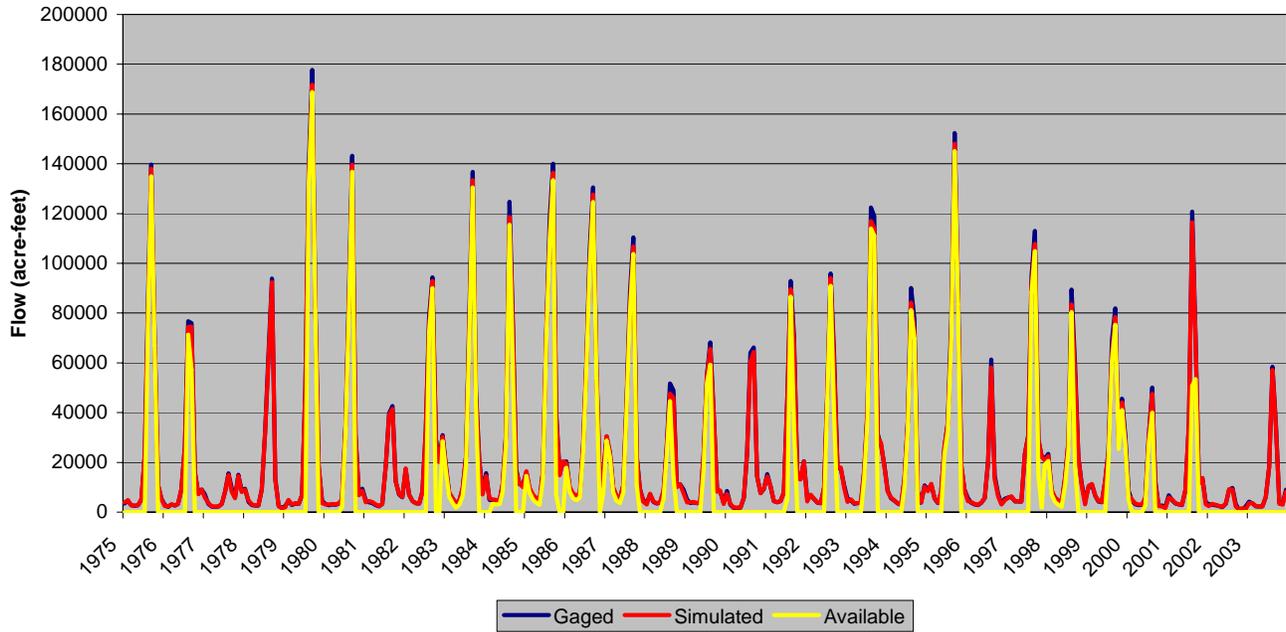


**USGS Gage 09342500 - San Juan River at Pagosa Springs**
**Gaged, Simulated, and Available Monthly Average Flows (1909-2003)**
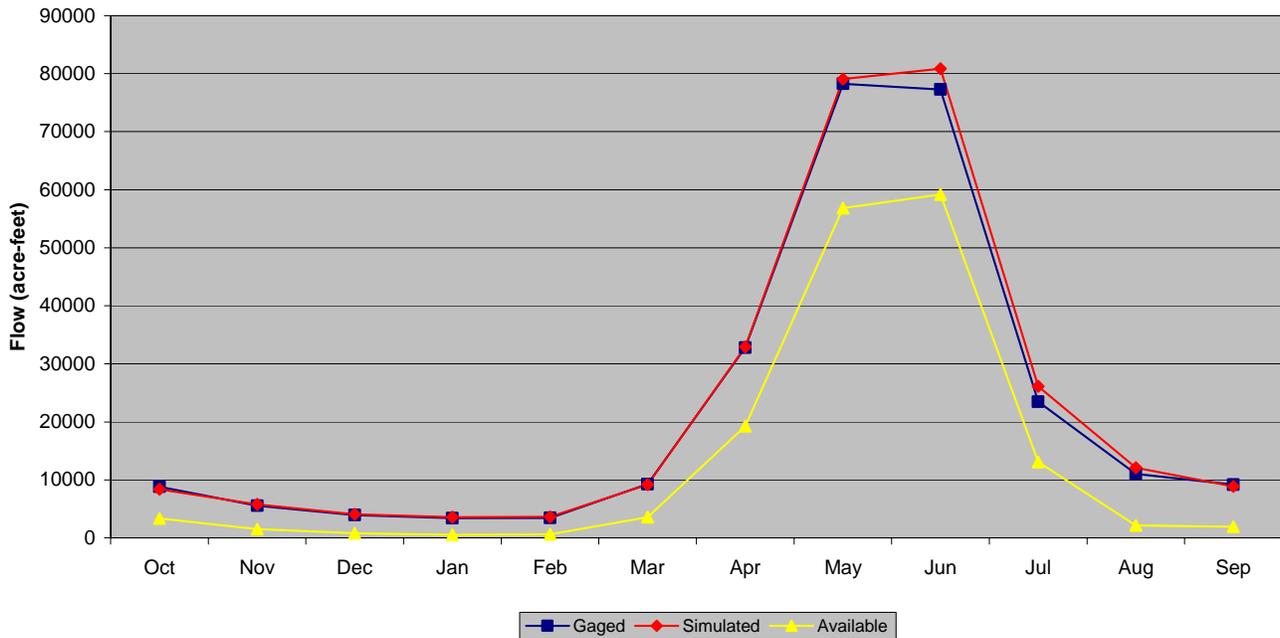


**Figure 6.1 Baseline Results – San Juan River at Pagosa Springs**

**USGS Gage 09346400 - San Juan River near Carracus**
**Gaged, Simulated, and Available Flows (1975-2003)**
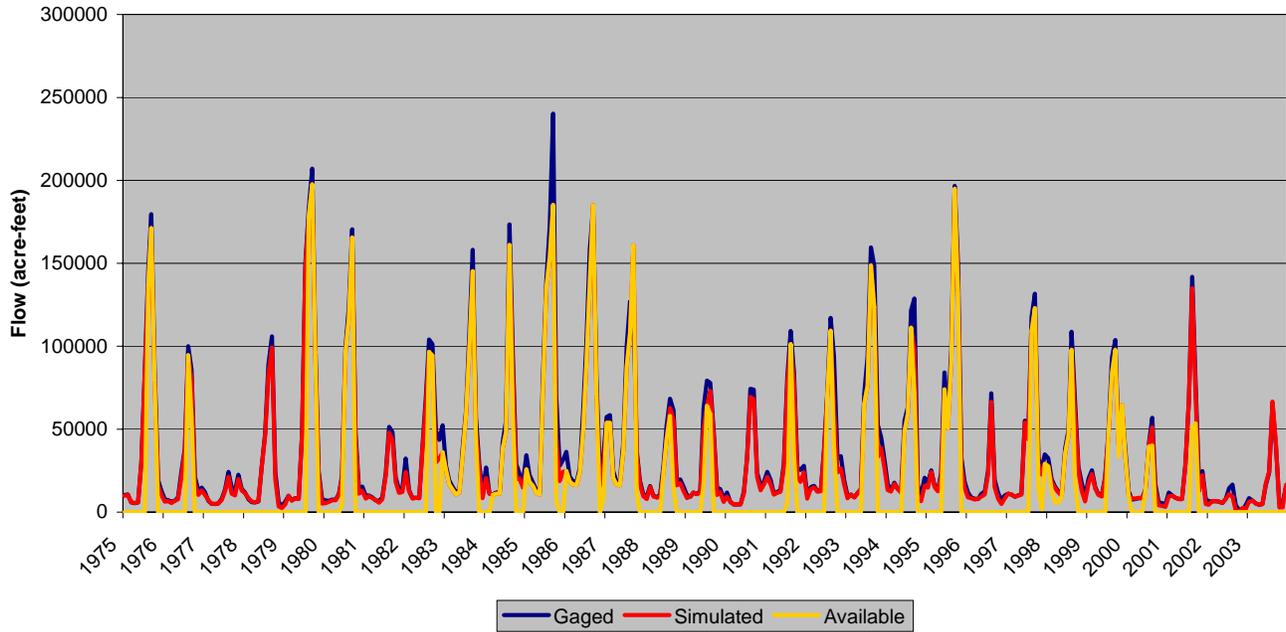


**USGS Gage 09346400 - San Juan River near Carracus**
**Gaged, Simulated, and Available Monthly Average Flows (1909-2003)**
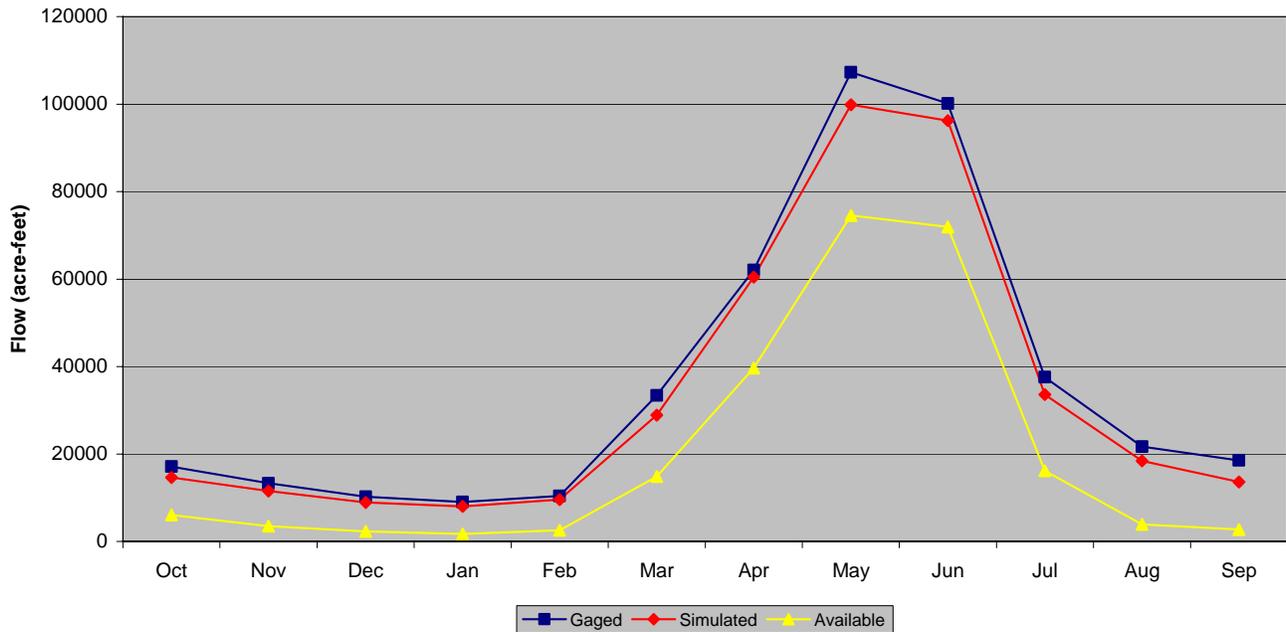
**Figure 6.2 Baseline Results – San Juan River near Carracus**

USGS Gage 09349800 - Piedra River near Arboles
Gaged, Simulated, and Available Flows (1975-2003)
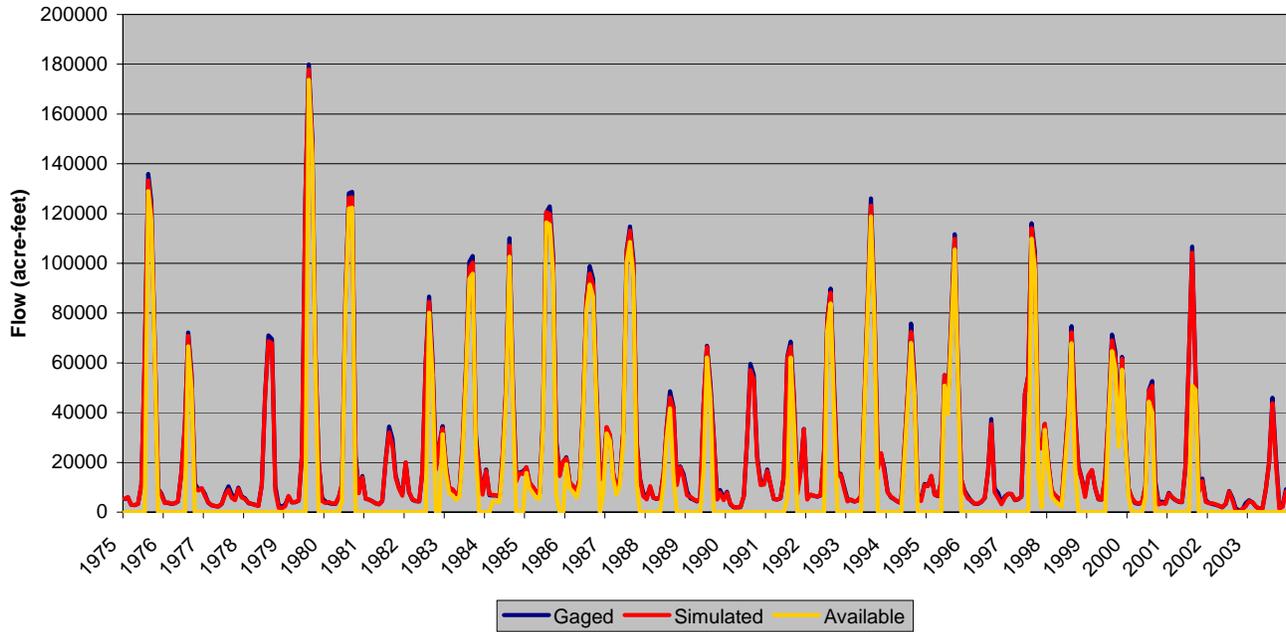


USGS Gage 09349800 - Piedra River near Arboles
Gaged, Simulated, and Available Monthly Average Flows (1909-2003)
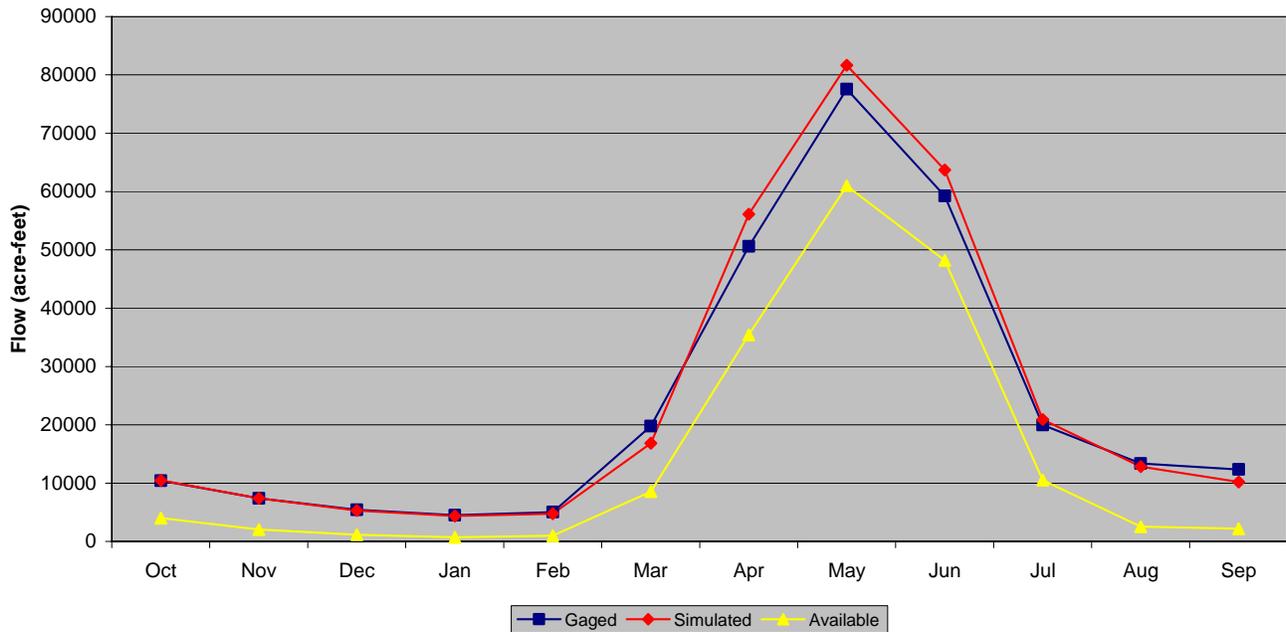
**Figure 6.3 Baseline Results – Piedra River near Arboles**

**USGS Gage 09354500 - Los Pinos River at La Boca**
**Gaged, Simulated, and Available Flows (1975-2003)**
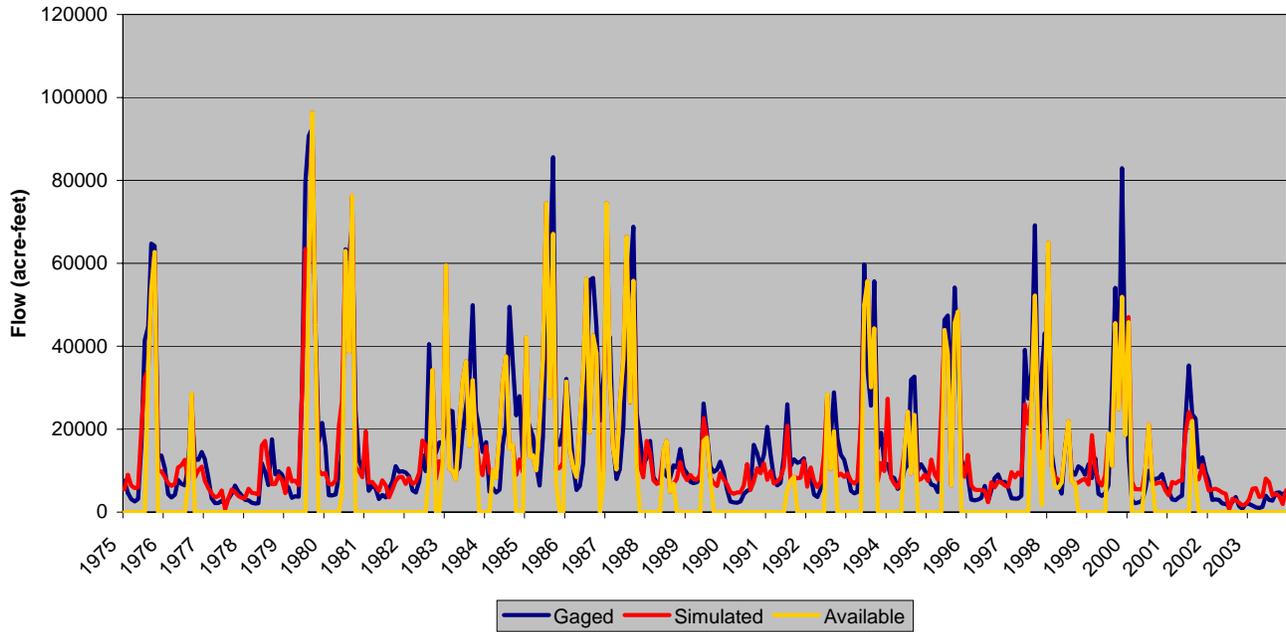


**USGS Gage 09354500 - Los Pinos River at La Boca**
**Gaged, Simulated, and Available Monthly Average Flows (1909-2003)**
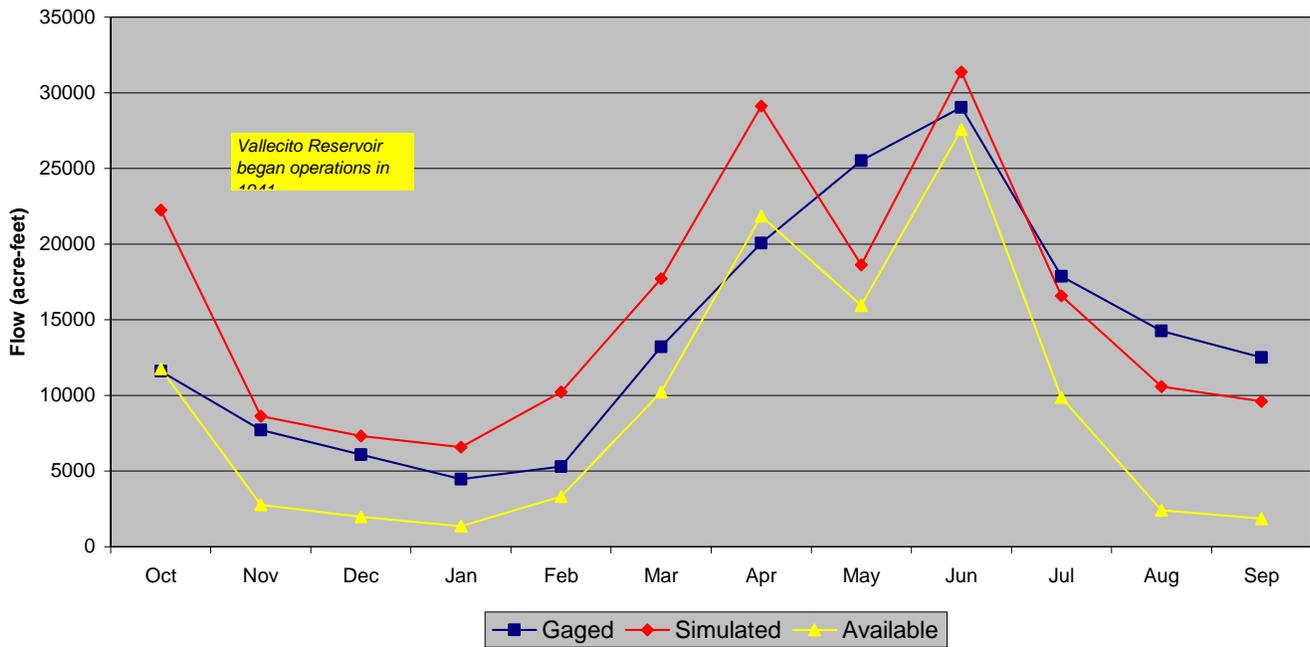


**Figure 6.4 Baseline Results – Los Pinos River at La Boca**

**USGS Gage 09361500 - Animas River at Durango**
**Gaged, Simulated, and Available Flows (1975-2003)**
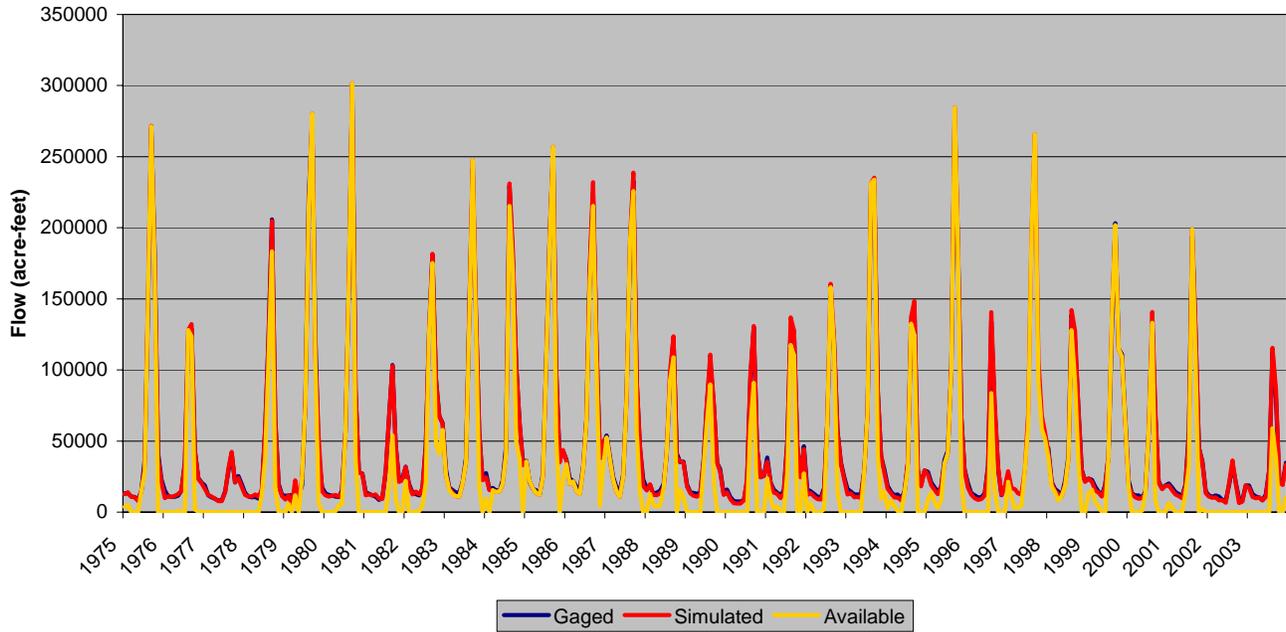


**USGS Gage 09361500 - Animas River at Durango**
**Gaged, Simulated, and Available Monthly Average Flows (1909-2003)**
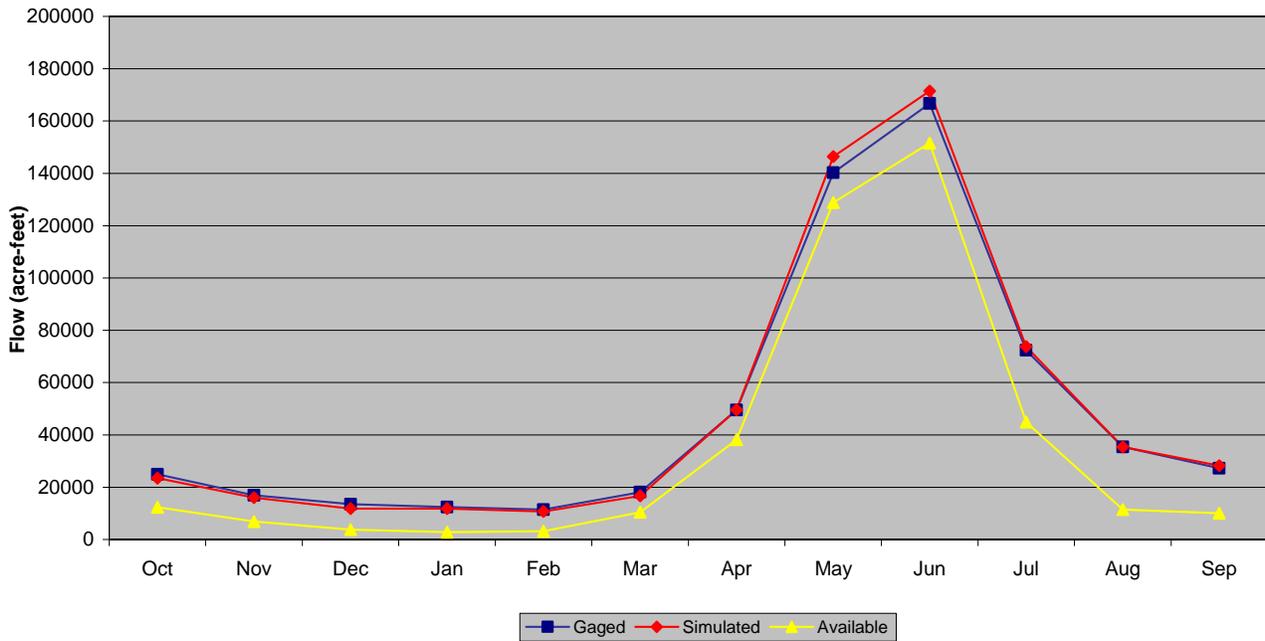


**Figure 6.5 Baseline Results – Animas River at Durango**

**USGS Gage 09366500 - La Plata River at Colorado-New Mexico Stateline**
**Gaged, Simulated, and Available Flows (1975-2003)**
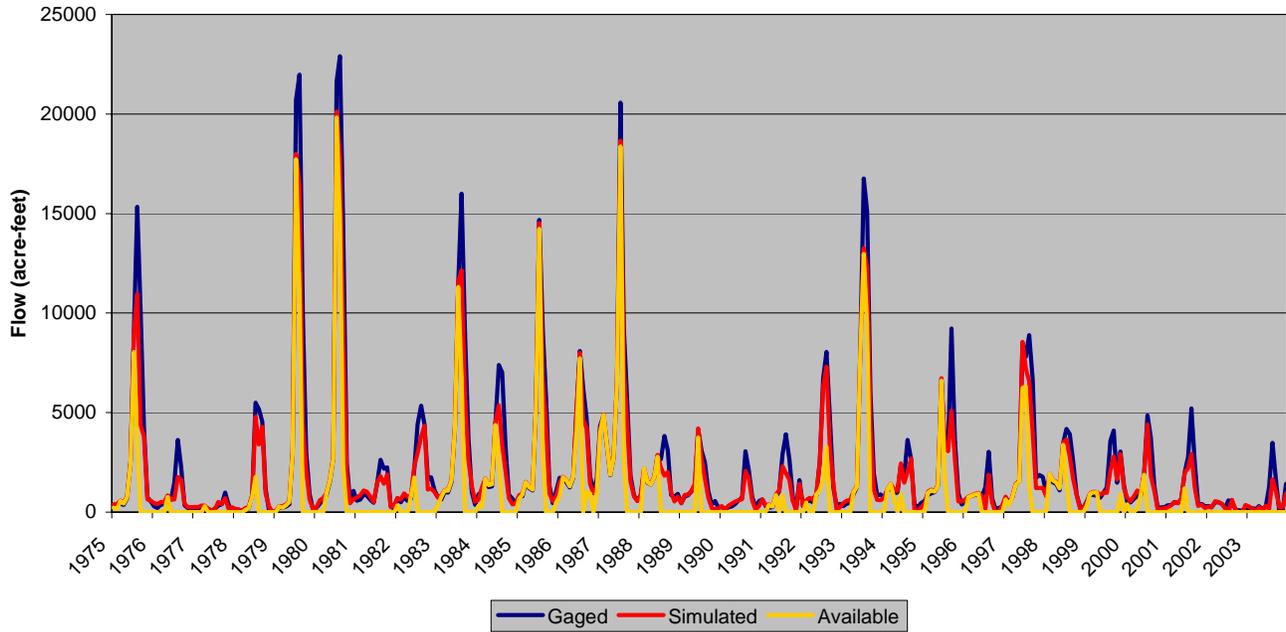


**USGS Gage 09366500 - La Plata River at Colorado-New Mexico Stateline**
**Gaged, Simulated, and Available Monthly Average Flows (1909-2003)**
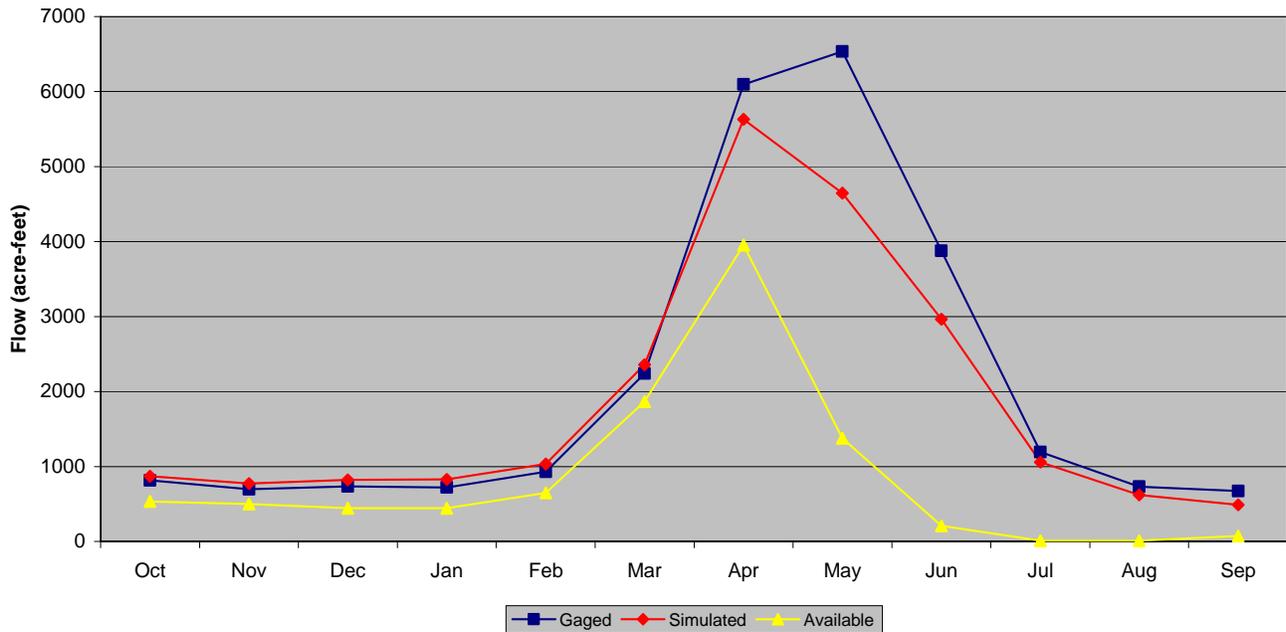


**Figure 6.6 Baseline Results – La Plata River at Colorado-New Mexico Stateline**

## USGS Gage 09371000 - Mancos River near Towaoc
### Gaged, Simulated, and Available Flows (1975-2003)
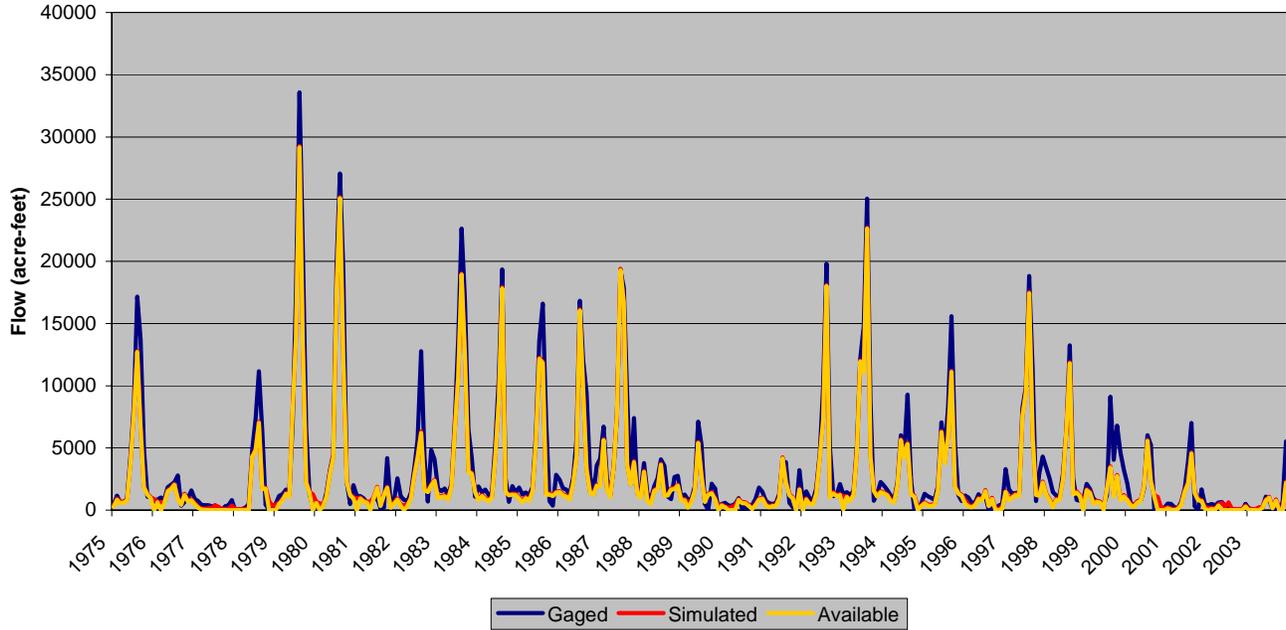


## USGS Gage 09371000 - Mancos River near Towaoc
### Gaged, Simulated, and Available Monthly Average Flows (1909-2003)
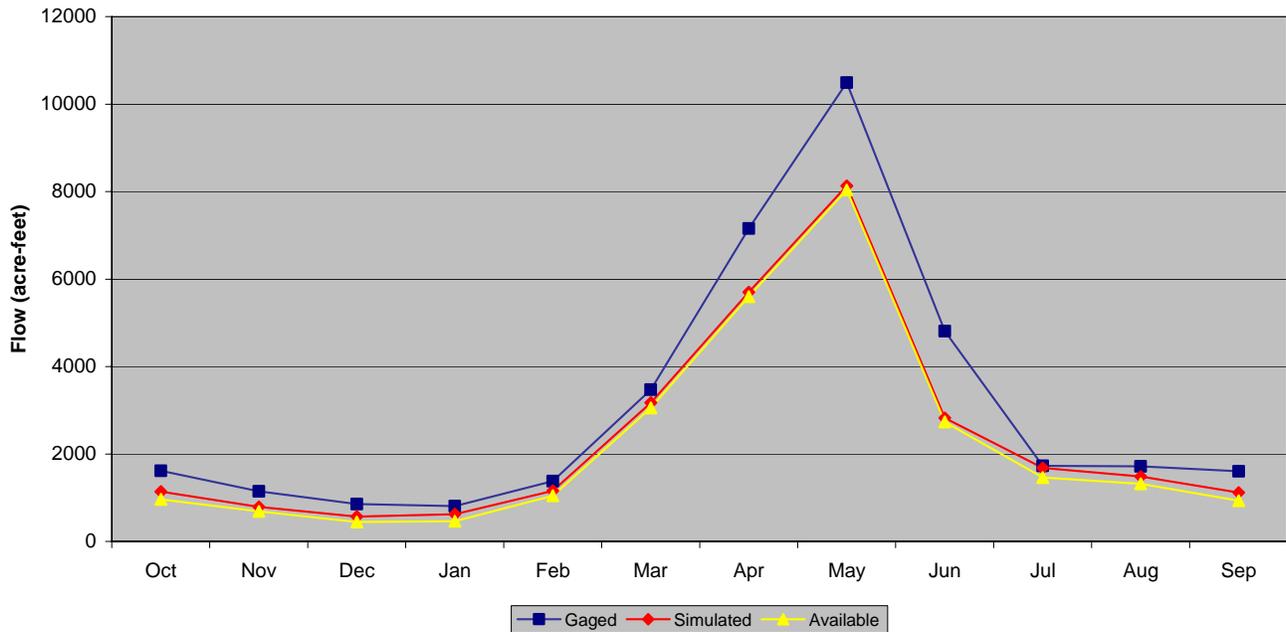


**Figure 6.7 Baseline Results – Mancos River near Towaoc**

**USGS Gage 09372000 - McElmo Creek at Colorado-Utah Stateline**
**Gaged, Simulated, and Available Flows (1975-2003)**



**USGS Gage 09372000 - McElmo Creek at Colorado-Utah Stateline**
**Gaged, Simulated, and Available Monthly Average Flows (1909-2003)**

McPhee Reservoir began operations in 1984
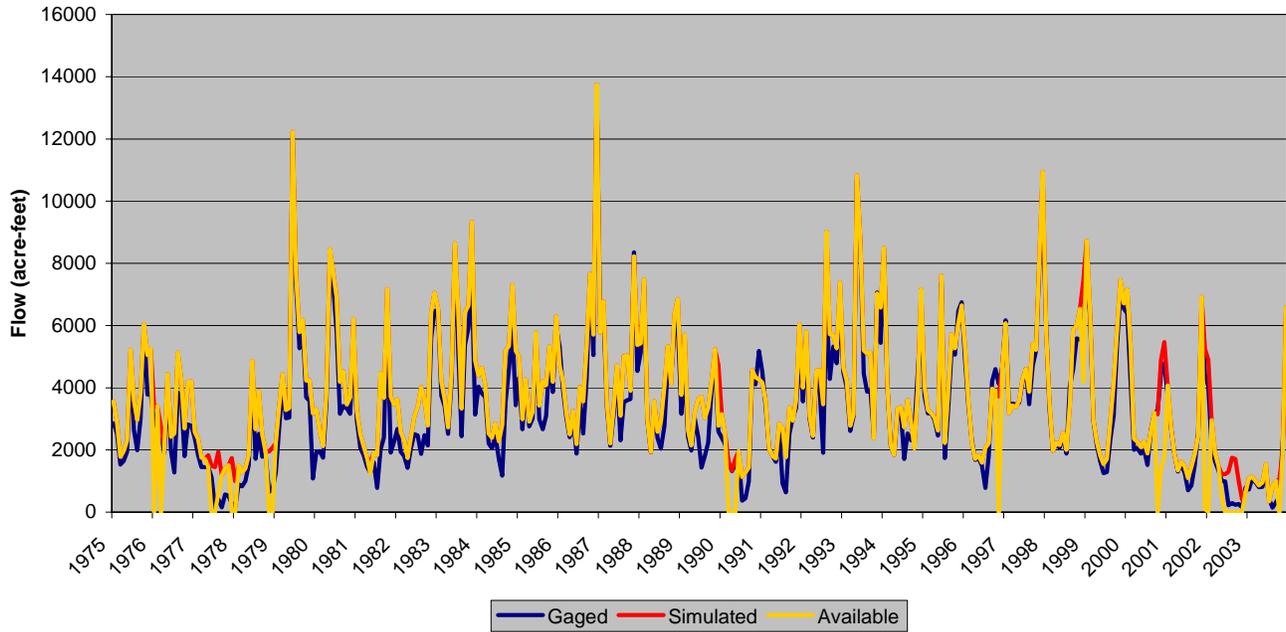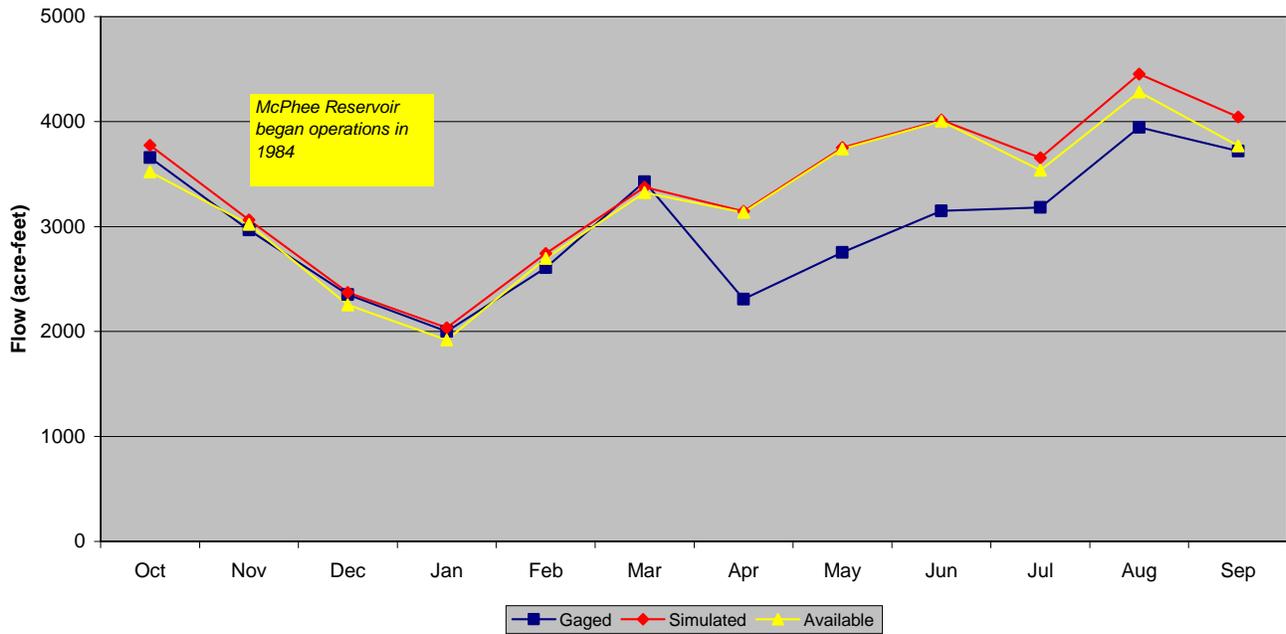
**Figure 6.8 Baseline Results – McElmo Creek at Colorado-Utah Stateline**

**USGS Gage 09171100 - Dolores River near Bedrock**
**Gaged, Simulated, and Available Flows (1975-2003)**
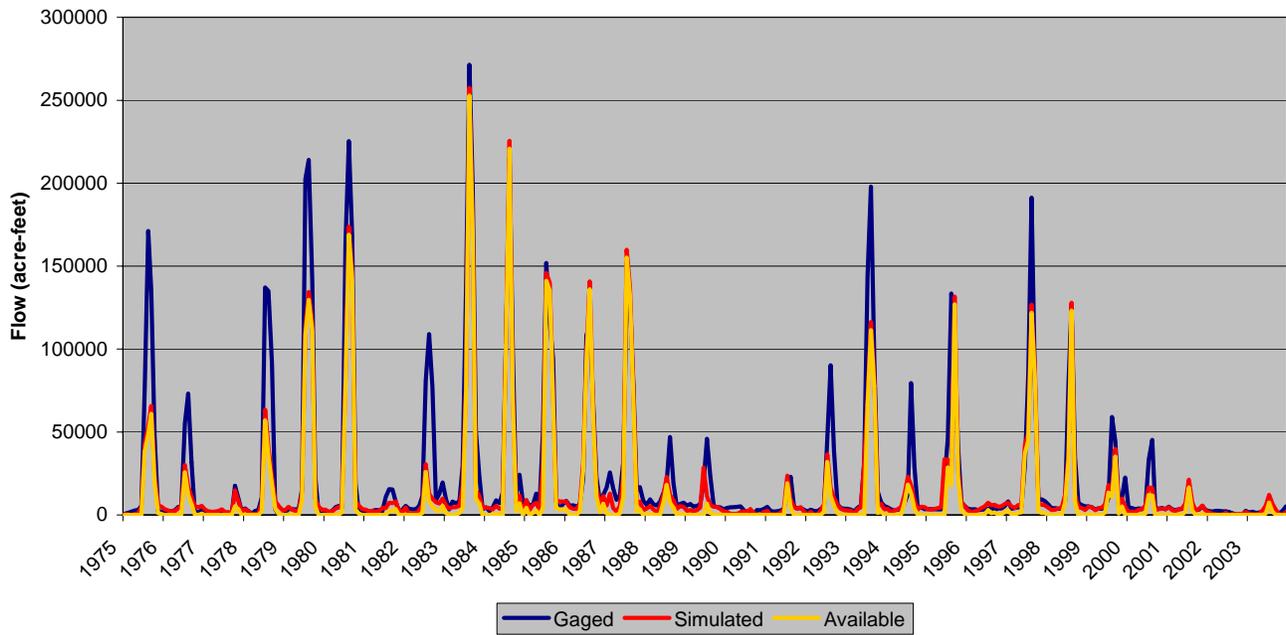


**USGS Gage 09171100 - Dolores River near Bedrock**
**Gaged, Simulated, and Available Monthly Average Flows (1909-2003)**
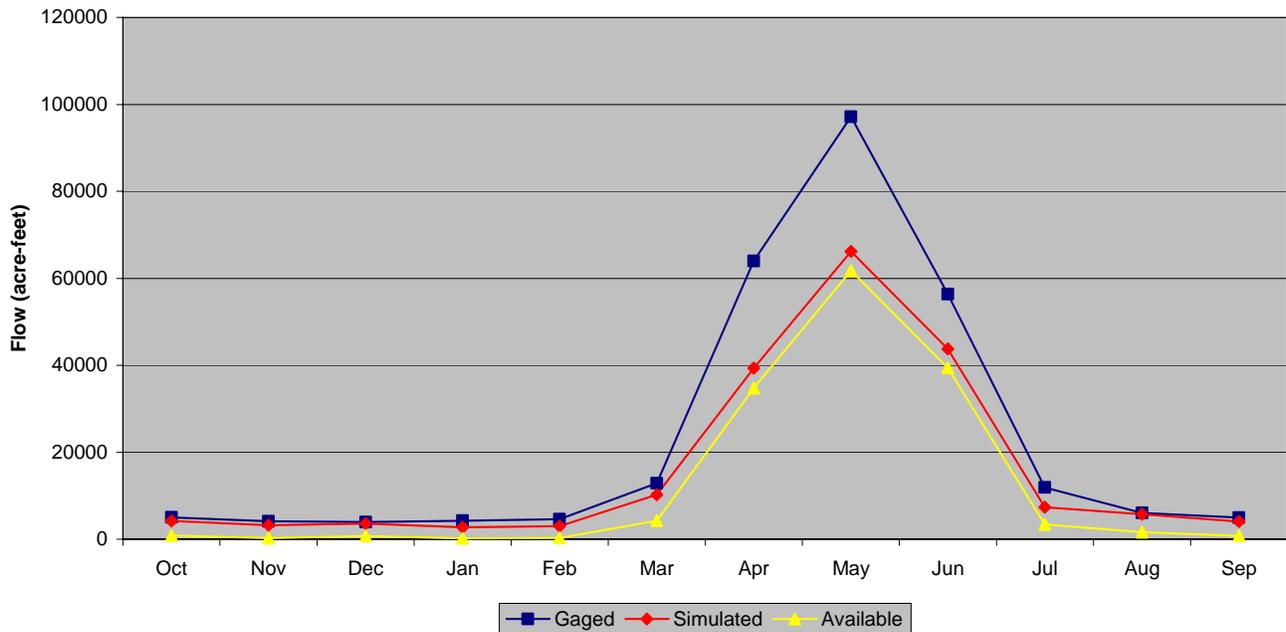


**Figure 6.9 Baseline Results – Dolores River near Bedrock**

**USGS Gage 09177000 - San Miguel River at Uravan**
**Gaged, Simulated, and Available Flows (1975-2003)**
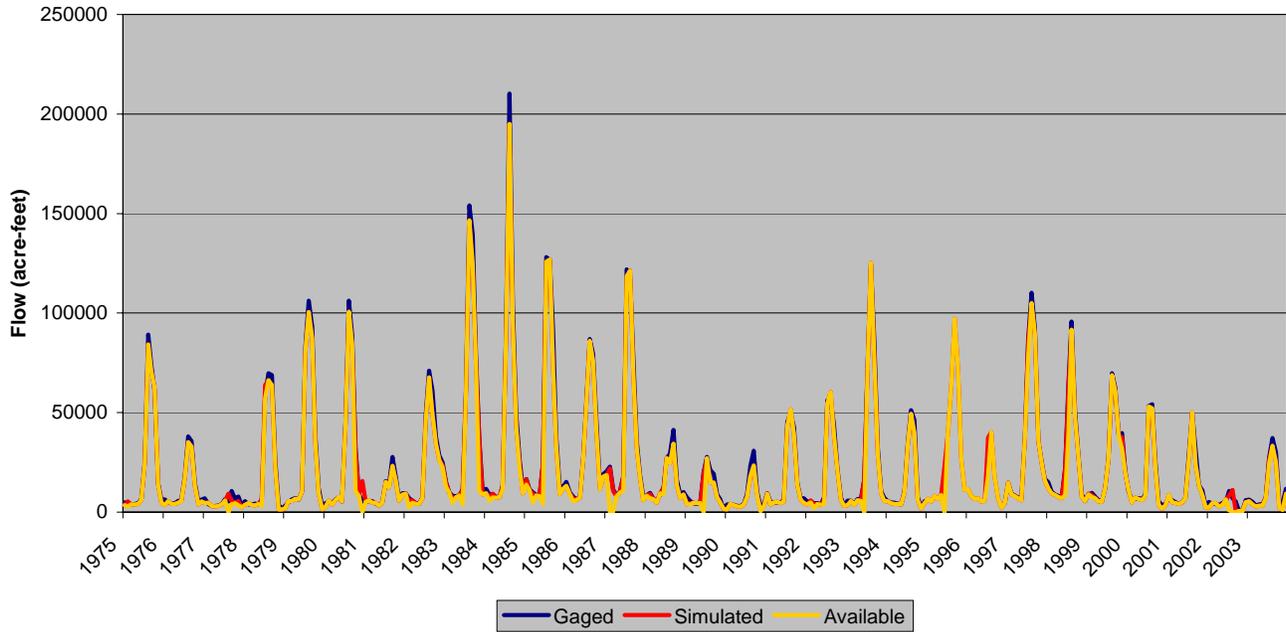


**USGS Gage 09177000 - San Miguel River at Uravan**
**Gaged, Simulated, and Available Monthly Average Flows (1909-2003)**
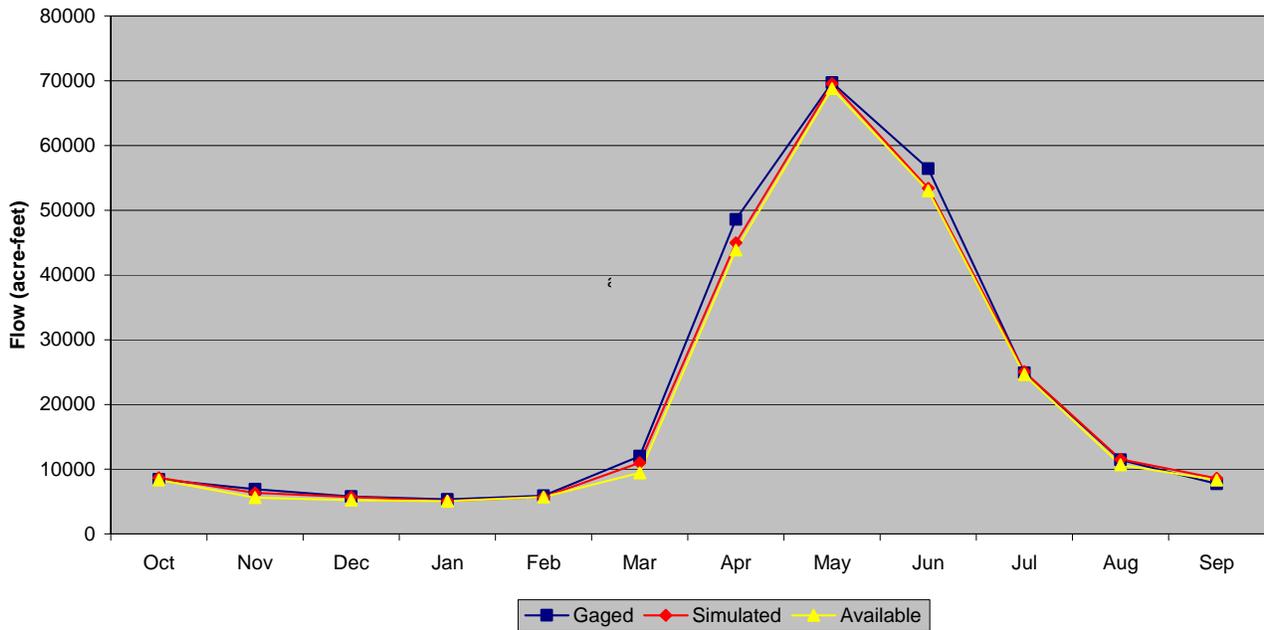


**Figure 6.10 Baseline Results – San Miguel River at Uravan**

# 7. Calibration

Calibration is the process of executing the model under historical conditions, and modifying estimated parameters to improve agreement between the model results and the historical record. This section describes the general approach taken in calibrating the San Juan Model. It describes specific areas of the basin that were worked on, and it presents summaries comparing modeled results for 1975 through 2003 with historical values for the period. Diversion, depletion, and reservoir use data for the portion of the model that extends into New Mexico were provided by New Mexico and used directly without review. Therefore, the model calibration focuses on the portion of the model in Colorado.

## 7.1   Calibration Process

The San Juan Model was calibrated in a two-step process, based on the period 1975 through 2003. In the first step, demands were set to historical diversions, and reservoir levels were constrained to their historical levels. Reservoir storage was limited to the historical monthly content for each month. Reservoirs released water upon demand, but if the demand-driven operations left more water in a reservoir than it had historically, the model released enough water to the stream to achieve its historical end-of-month contents. In this step, the basic hydrology was assessed, and in general, baseflow distribution parameters and return flow characteristics were modified.

Reviewing the model run consisted of comparing simulated gage flows with historical flows, and determining where and why diversion shortages occurred. For example, a shortage might occur because a user's water right is limiting. But it might also occur because water is physically unavailable or the water right is called out. In this typical calibration problem, there may be too little baseflow in a tributary reach to support historical levels of diversion in the model. Gains may not occur in the system until the next downstream gage, bypassing the shorted structures. Because the historical diversion and consumption do not occur in the model, the model then overestimates flow at the downstream gage. Baseflow distribution parameters must be adjusted such that more water enters the system within the tributary, and typically, incremental inflow below the tributary is reduced. The first step of calibration might also expose errors such as incorrect placement of a gage, or incorrect treatment of imports.

In the second step, reservoirs responded to demands and were permitted to seek the level required to meet the demands. Model results were again reviewed, this time focusing on the operations. For example, operating criteria in the form of monthly targets might be added for reservoirs that operate for unmodeled reasons such as flood control, hydropower generation, or winter maintenance. As another example, where reservoir history revealed that annual administration was not strictly observed, the annual administration feature was removed.

The model at the conclusion of the second step is considered the calibrated model.

## 7.2 Historical Data Set

Calibration is based on supplying input that represents historical conditions, so that resulting gage and diversion values can be compared with the historical record. This data set is referred to as the "Historical data set", and it is helpful to understand how it differs from the Baseline data set described in Section 5.

### 7.2.1. Direct Diversion Station and Demand File

A primary difference in data sets is the representation of demands (*.ddm file). For calibration, both irrigation and non-irrigation demands were set to historical diversions; to the extent they were known. Gaps in the diversion records were filled using the automatic data filling algorithm described in Section 4.4.2.  This demand reflects both limitations in the water supply and the vagaries of operations that cannot be predicted – headgate maintenance, dry-up periods, and so on.

Demands for irrigation multistructures were placed at the point of diversion. In the Baseline data set, these demands were placed at the destination node, and operating rules drove the diversion from the individual headgates.  This includes San Juan-Chama project demands, which are placed on the individual tunnels, not at the San Juan-Chama summary node.

Return flows from the Navajo Indian Irrigation Project (NIIP) are input into the Historical model as negative baseflows in the demand file at three return flow locations. In the Baseline data set, these return flow "demands" were set to zero, and return flows from NIIP irrigation are based on diversions and irrigation efficiency.  The difference between Historical and Baseline representation of NIIP return flows also necessitates having both a baseline direct diversion station file (*B.dds) and an historical direct diversion station file.  In the Baseline file, NIIP diversion efficiency is set to 80 percent, with the remaining 20 percent of unused water returning to the three NIIP return flow nodes.  In the Historical file, NIIP diversion efficiency is set to 100 percent, and return flows are "imported" to the river as negative diversions.

### 7.2.2. Irrigation Water Requirement File

Irrigation water requirement file for the Historical data set is based on historical irrigated acreage, whereas the Baseline irrigation water requirement is based on current levels of irrigated acreage.  This affects structures that came on-line during the study period, or significantly increased acreage during the study period.  The largest differences in irrigation water requirement are for structures receiving water from the Dolores Project, including MVIC structures, Dove Creek Canal, and Towaoc Canal.

### 7.2.3. Reservoir Station File and Reservoir Target File

In the Historical data set, reservoirs are inactive prior to onset of their historical operations. Initial contents in the reservoir file (*.res) are set their historical end-of-month content in September, 1908, and storage targets (*.tar file) are set to zero until the reservoir actually began to fill. In the first calibration step, storage targets assume the value of the historical end-of-month

contents, but in the second calibration step, irrigation reservoirs' storage targets are set to capacity for all reservoirs that operate primarily for agricultural and municipal diversion storage, as soon as those reservoirs came on-line.  Maximum targets were set to operational targets according to rule curves provided by USBR for Lemon and Vallecito reservoirs when those reservoirs came on-line. Cascade, Trout, and Navajo reservoirs operate for hydropower generation.  For these reservoirs, maximum targets were set to historical end-of-month contents.  If capacity of a reservoir changed midway through the study period, the Historical model takes the enlargement into account (not applicable in the San Juan Model.)

### 7.2.4.  Operational Rights File

The reservoir storage target file (*.tar) and the operating rules file (*.opr) work together to constrain reservoir operations in the first calibration step. The operational rights include rules to release water that remains in the reservoir above historical levels (specified in the target file) after all demand-driven releases are made. In the second calibration step, release-to-target rules in the *.opr file remain on, but do not fire for most reservoirs, as targets are set to capacity.  The exceptions are noted above in Section 7.2.3. In the initial calibration run, when water is released to a downstream diversion, enough water is released to meet the diverter's historical diverted amount, regardless of the efficiency of that operation or whether crop irrigation water requirements have been satisfied.  In the second step calibration, enough water is released to meet the historical diverted amount only if there is deficit crop irrigation water requirement. Section 5.8 describes each operating rule used in the Baseline and Historical calibration simulations.

Differences between the Baseline data set and the Historical data set are summarized in Table 7.1.

**Table 7.1**
**Comparison of Baseline and Historical (Calibration) Files**

| Input File | Baseline Data Set | Historical Data Set |
|---|---|---|
| Demand (*.ddm) | ▪ Irrigation structures – "Calculated" demand for full supply, based on historical efficiency<br><br>▪ Non-irrigation structures – estimated current demand<br><br>▪ Demands placed on primary structures of multistructure systems and demands placed at carrier structure headgates | ▪ Historical diversions<br><br>▪ Historical diversions for multistructures and San Juan-Chama structures are set at individual diversion headgates |
| Reservoir station (*.res) | ▪ Initial content = average September end-of month content | ▪ Initial content = September 1908 end-of-month content, 0 if prior to construction |
| Reservoir target (*.tar) | ▪ Current maximum capacity except reservoirs that release for flood control or power generation | ▪ First step – historical eom contents, 0 prior to construction<br><br>▪ Second step – 0 prior to construction, historical maximum capacity except reservoirs that release for flood control or power generation |
| Operational right (*.opr) | ▪ Operating rules drive diversions to demand destination through multi-structure and carrier structures<br><br>▪ Reservoir releases are made to irrigation structures to satisfy headgate demands only if crop irrigation water requirements have not been met by other sources. | ▪ Release-to-target operations allow reservoirs to release to target contents<br><br>▪ Step 1 calibration, reservoir releases are made to irrigation structures to satisfy headgate demands regardless if crop irrigation water requirements have been met. |

## 7.3    Calibration Issues

This section describes areas of the model that have been investigated in the various calibration efforts of the San Juan Model. Note that in general, simulating using the variable efficiency approach improved basin-wide calibration from previous efforts.

### 7.3.1.  Aggregated Structures and Diversion Systems

Several revisions have taken place to aggregated structures throughout the modeling process, generally in attempt to reduce shortages.  The 1993 Irrigated Acreage Coverage, used as the basis for the aggregation of smaller structures, was supplemented by a 2000 irrigated acreage assessment after the initial modeling efforts were completed. As a result of the second acreage snap-shot, some structures were removed as key and added to aggregates. In addition, several structures were combined into diversion systems to represent lands served by more than one ditch on the same tributary.  These efforts helped to reduce shortages to aggregate structures and to structures with overlapping acreage.

### 7.3.2.  Baseflows

Significant effort was taken to accurately calculate baseflows at streamgages and then distribute the baseflow gains to upstream locations. Negative baseflows are calculated when too much water is "removed" or not enough water is "added" to historical streamgages. In the historical calibration simulation, this resulted in areas were simulated gage flows were high because when negative baseflows are set to zero, the total amount of water in the system is not conserved. In areas were negative baseflows were calculated during the period when diversion records are available, this was addressed by revising the amount of return flows that accrued upstream of a gage. Overall, the amount of negative baseflows was reduced by more than 50 percent in the recent model update.

Most baseflow gains realized at stream gages are distributed to ungaged locations using the "gain approach" where the gain between gages is distributed upstream based on an area/precipitation proration. This approach does not work well for ungaged tributaries that have relatively small flow compared to the downstream gaged data.  Many of these smaller drainages are included in the San Juan Model, especially in the San Miguel and Dolores basins.  The "neighboring gage" approach distributes actual baseflow (not gain) from a gaged location to upstream ungaged tributaries. Twenty additional baseflow nodes were assigned the "neighboring gage" approach during the recent model update.  This reduced negative baseflows and resulted in better calibration of simulated versus historical diversions on the smaller ungaged tributaries.

### 7.3.3.  McElmo Creek

McElmo Creek calibration has significantly improved through the modeling process.  In the first modeling phases, both Narraguinnep and Summit Reservoirs were modeled as tributary to McElmo Creek, and treated as baseflow nodes. The estimated changes in historical reservoir

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storage were significant components in the baseflow calculations. Discussion with water users indicated that the reservoirs do not fill from or spill to McElmo Creek. Only return flows from reservoir releases to irrigation contribute to McElmo Creek flows. Both of these reservoirs are essentially "off-channel" and are filled with exported water from the Dolores Basin. Historical diversions into the reservoirs are available; however, reservoir release records and end-of-month content records are limited.

During the recent modeling phase, these reservoirs were modeled off-channel; therefore changes in storage did not affect McElmo Creek flows. Simulated streamflow at the McElmo Creek near the Colorado-Utah Stateline improved significantly. Previous modeling phases resulted in simulated average annual streamflows 13 percent higher than historical, whereas the current model simulation results in the same average annual flow as historical.

### 7.3.4. San Miguel River

Most of the modeled diversions in the San Miguel River basin are on ungaged tributaries or tributaries with limited gaged data. Some diversions on smaller tributaries are significantly shorted. In each modeling phase, effort was expended to better represent irrigation use. Efforts for the current model centered around baseflows, as discussed in Section 7.3.2 above. Previous modeling phases resulted in average annual shortages in the San Miguel River basin of 12 percent, whereas the current model simulated shortages average 1 percent.

### 7.3.5. Dolores River

Similar to the San Miguel River Basin, many of the modeled diversions in the Dolores River basin are on ungaged tributaries or tributaries with limited gaged data. Some diversions on smaller tributaries are significantly shorted. In each modeling phase, effort was expended to better represent irrigation use. Efforts for the current model centered around baseflows, as discussed in Section 7.3.2 above. Previous modeling phases resulted in average annual shortages in the Dolores River basin of 15 percent, whereas the current model simulated shortages average 6 percent.

## 7.4    Calibration Results

Calibration of the San Juan Model is considered very good, with most streamflow gages deviating less than one percent from historical values on an average annual basis. More than half the diversion structures' shortages are at or below 1 percent on an annual basis, and the basinwide shortage in Colorado is around 1 percent per year, on average. Simulated reservoir contents are representative of historical values.

### 7.4.1. Water Balance

Table 7.2 summarizes the water balance for the San Juan Model, for the calibration period (1975-2003). Note that this is not an indication of use only in Colorado; New Mexico's use is also included. Following are observations based on the summary table:

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- Stream water inflow to the basin averages 3.0 million acre-feet per year, and stream water outflow averages 2.14 million acre-feet per year.

- Annual diversions amount to approximately 1.4 million acre-feet on average, indicating that there is extensive re-diversion of return flows in the basin.

- Approximately 756,000 acre-feet per year are consumed.

- The column labeled "Inflow – Outflow" represents the net result of gain (inflow, return flows, and negative change in reservoir and soil moisture contents) less outflow terms (diversions, outflow, evaporation, and positive changes in storage), and indicates that the model correctly conserves mass.

**Table 7.2**
**Average Annual Water Balance for Calibrated San Juan Model 1975-2003(af/yr)**

| Month | Stream Inflow | Return | From Soil Moisture | Total Inflow | Diversions | Resvr Evap | Stream Outflow | Resvr Change | To Soil Moisture | Soil Moisture Change | Total Outflow | Inflow - Outflow | CU |
|-------|---------|--------|--------|---------|---------|--------|---------|---------|--------|--------|---------|--------|--------|
| OCT | 99,894 | 50,615 | 1,955 | 152,464 | 69,213 | 2,349 | 94,168 | -15,220 | 1,562 | 392 | 152,464 | 0 | 28,840 |
| NOV | 72,326 | 25,866 | 17 | 98,209 | 22,198 | 400 | 70,509 | 5,085 | 1,788 | -1,770 | 98,209 | 0 | 5,762 |
| DEC | 55,480 | 19,820 | 0 | 75,300 | 17,511 | -133 | 56,552 | 1,371 | 836 | -836 | 75,300 | 0 | 4,611 |
| JAN | 59,487 | 17,405 | 0 | 76,892 | 16,638 | 105 | 61,240 | -1,090 | 586 | -586 | 76,892 | 0 | 4,654 |
| FEB | 79,505 | 14,583 | 1 | 94,089 | 15,312 | 682 | 81,623 | -3,528 | 497 | -496 | 94,089 | 0 | 5,068 |
| MAR | 165,409 | 14,938 | 74 | 180,420 | 22,302 | 1,911 | 145,129 | 11,005 | 887 | -813 | 180,420 | 0 | 10,294 |
| APR | 423,710 | 25,886 | 3,191 | 452,787 | 72,130 | 4,320 | 329,668 | 43,479 | 3,298 | -107 | 452,787 | 0 | 46,174 |
| MAY | 734,308 | 78,428 | 8,043 | 820,779 | 231,570 | 6,960 | 500,480 | 73,726 | 4,207 | 3,836 | 820,779 | 0 | 139,782 |
| JUN | 688,658 | 109,217 | 8,162 | 806,037 | 305,099 | 9,608 | 454,080 | 29,087 | 1,695 | 6,467 | 806,037 | 0 | 188,073 |
| JUL | 286,095 | 110,267 | 4,641 | 401,003 | 263,416 | 8,620 | 162,476 | -38,151 | 1,103 | 3,538 | 401,003 | 0 | 150,927 |
| AUG | 160,466 | 103,183 | 1,373 | 265,022 | 213,110 | 4,716 | 93,560 | -47,737 | 3,664 | -2,292 | 265,022 | 0 | 102,466 |
| SEP | 135,447 | 83,129 | 2,237 | 220,814 | 148,695 | 4,595 | 90,519 | -25,233 | 1,653 | 584 | 220,814 | 0 | 69,764 |
| | | | | | | | | | | | | | |
| AVG | 2,960,785 | 653,337 | 29,694 | 3,643,816 | 1,397,193 | 44,132 | 2,140,001 | 32,794 | 21,775 | 7,919 | 3,643,816 | 0 | 756,415 |

*Note:* Consumptive Use (CU) = Diversion (Divert) * Efficiency + Reservoir Evaporation (Evap)

## 7.4.2. Streamflow Calibration Results

Table 7.3 summarizes the annual average streamflow for water years 1975 through 2003, as estimated in the calibration run. It also shows average annual values of actual gage records for comparison. Both numbers are based only on years for which gage data are complete. Figures 7.1 through 7.10 (at the end of this section) graphically present monthly streamflow estimated by the model compared to historical observations at key streamgages in both time-series format and as scatter graphs. When only one line appears on the time-series graph, it indicates that the simulated and historical results are the same at the scale presented. The "goodness of fit" is indicated by the $R^2$ value shown on each scatter graph.

Calibration based on streamflow simulation for gages in Colorado is generally very good in terms of both annual volume and monthly pattern. Exceptions include the smaller tributaries of Lost Canyon and Beaver Creek. These exceptions do not affect mainstem or major tributary calibration. Note that calibration of New Mexico gages is poor in some cases; particularly at the La Plata River at Farmington gage and at the San Juan River near Archuleta gage. As noted previously, calibration efforts did not extend to the New Mexico portion of the model.

Simulation of streamflow on the Los Pinos River below Vallecito Reservoir accurately models annual volume, but the monthly patterns vary from gaged. Vallecito Reservoir is modeled using a forecasting curve provided by the USBR that is intended to mimic operational storage targets. It appears that the rule curve is used only as a guideline by the USBR, and decisions based on other factors drive actual operations. Step 1 calibration results, when Vallecito Reservoir was "releasing to targets" of historical end-of-month contents, are also shown on Figure 7.4, Los Pinos River below Vallecito Reservoir, further reinforcing the conclusion regarding the effect of Vallecito forecasting on streamgages below the reservoir.

**Table 7.3**
**Historical and Simulated Average Annual Streamflow Volumes (1975-2003)**
**Calibration Run (acre-feet/year)**

| Gage ID | Historical | Simulated | Historical -Simulated | | Gage Name |
| | | | Volume | Percent | |
|---|---|---|---|---|---|
| 09339900 | 64,983 | 64,983 | 0 | 0 | East Fork San Juan River above Sand Creek |
| 09341500 | 171,819 | 171,819 | 0 | 0 | West Fork San Juan River nr Pagosa Springs |
| 09342000 | *No gage during calibration period* | | | | Turkey Creek near Pagosa Springs |
| 09342500 | 283,880 | 284,039 | -159 | 0 | San Juan River at Pagosa Springs |
| 09343300 | 34,450 | 34,450 | 0 | 0 | Rio Blanco bl Blanco Div Dam nr Pagosa Sprgs |
| 09344000 | 83,902 | 83,903 | -1 | 0 | Navajo River at Banded Peak Ranch nr Chromo |
| 09344400 | 48,284 | 48,339 | -55 | 0 | Navajo River bl Oso Diversion Dam nr Chromo |
| 09345200 | 6,390 | 6,402 | -12 | 0 | Little Navajo River bl Oso Div Dam nr Chromo |
| 09346000 | 67,275 | 67,358 | -83 | 0 | Navajo River at Edith |
| 09346400 | 449,666 | 449,668 | -2 | 0 | San Juan River near Carracas |
| 09347500 | *No gage during calibration period* | | | | Piedra River at Bridge Ranger Sta. nr Pagosa Sprgs |
| 09349500 | *No gage during calibration period* | | | | Piedra River near Piedra |
| 09349800 | 305,465 | 305,274 | 191 | 0 | Piedra River near Arboles |
| 09352900 | 106,037 | 106,037 | 0 | 0 | Vallecito Creek near Bayfield |

| Gage ID | Historical | Simulated | Historical -Simulated Volume | Percent | Gage Name |
|---|---|---|---|---|---|
| 09353500 | 299,267 | 297,772 | 1,495 | 0 | Los Pinos River near Bayfield |
| 09354000 | *No gage during calibration period* | | | | Los Pinos River at Bayfield |
| 09354500 | 188,403 | 189,273 | -870 | 0 | Los Pinos River at La Boca |
| 09355000 | 24,124 | 24,164 | -40 | 0 | Spring Creek at La Boca |
| 09355500 | 875,505 | 882,354 | -6,849 | -1 | San Juan River near Archuleta |
| 09357500 | 77,578 | 77,579 | -1 | 0 | Animas River at Howardsville |
| 09359000 | *No gage during calibration period* | | | | Mineral Creek near Silverton |
| 09359500 | *No gage during calibration period* | | | | Animas River above Tacoma |
| 09361000 | 96,957 | 96,957 | 0 | 0 | Hermosa Creek near Hermosa |
| 09361500 | 583,380 | 583,330 | 50 | 0 | Animas River at Durango |
| 09362999 | 73,870 | 73,870 | 0 | 0 | Florida River ab Lemon Reservoir (USBR data) |
| 09363200 | 58,564 | 60,377 | -1,813 | -3 | Florida River at Bondad |
| 09363500 | 707,576 | 708,208 | -632 | 0 | Animas River near Cedar Hill, NM |
| 09364500 | 644,023 | 646,159 | -2,136 | 0 | Animas River at Farmington, NM |
| 09365000 | 1,489,692 | 1,494,352 | -4,660 | 0 | San Juan River at Farmington, NM |
| LONREDCO | 5,471 | 5,365 | 106 | 2 | Long Hollow at the Mouth near Red Mesa |
| 9365500 | 30,970 | 30,995 | -25 | 0 | La Plata at Hesperus |
| 09366500 | 27,452 | 27,609 | -157 | -1 | La Plata River at CO-NM State Line |
| 09367500 | 23,548 | 27,305 | -3,757 | -16 | La Plata River near Farmington, NM |
| 09368000 | 1,510,482 | 1,525,482 | -15,000 | -1 | San Juan at Shiprock |
| 09369500 | *No gage during calibration period* | | | | Middle Mancos River near Mancos |
| 09369000 | *No gage during calibration period* | | | | East Mancos River near Mancos |
| 09368499 | 10,687 | 10,687 | 0 | 0 | Above Jackson Gulch Reservoir (USBR data) |
| 09368500 | *No gage during calibration period* | | | | West Mancos River near Mancos |
| 09371000 | 39,123 | 39,080 | 43 | 0 | Mancos River near Towaoc |
| 09371010 | 1,600,019 | 1,601,980 | -1,961 | 0 | San Juan River at Four Corners |
| 09371400 | 10,063 | 10,063 | 0 | 0 | Hartman Draw at Cortez |
| 09371420 | 19,270 | 19,212 | 58 | 0 | McElmo Creek above Alkali Canyon nr Cortez |
| 09371500 | 42,789 | 42,934 | -145 | 0 | McElmo Creek near Cortez |
| 09372000 | 39,385 | 39,462 | -77 | 0 | McElmo Creek near CO-UT State Line |
| 09379500 | 1,563,647 | 1,565,265 | -1,618 | 0 | San Juan River near Bluff |
| 09165000 | 97,155 | 97,159 | -4 | 0 | Dolores River below Rico |
| 09166500 | 317,356 | 317,934 | -578 | 0 | Dolores River at Dolores |
| 09166950 | 15,240 | 12,151 | 3,089 | 20 | Lost Canyon Creek near Dolores |
| 09168100 | 20,926 | 20,939 | -13 | 0 | Disappointment Creek near Dove Creek |
| 09169500 | 270,404 | 266,268 | 4,136 | 2 | Dolores River at Bedrock |
| 09171100 | 279,550 | 275,455 | 4,095 | 1 | Dolores River near Bedrock |
| 09171200 | *No gage during calibration period* | | | | San Miguel River near Telluride |
| 09172000 | *No gage during calibration period* | | | | Fall Creek near Fall Creek |
| 09172100 | *No gage during calibration period* | | | | Leopard Creek at Noel |
| 09172500 | 181,283 | 182,045 | -762 | 0 | San Miguel River near Placerville |
| 09173000 | 7,212 | 8,081 | -869 | -12 | Beaver Creek near Norwood |
| 09175500 | 199,166 | 200,998 | -1,832 | -1 | San Miguel River at Naturita |
| 09177000 | 273,243 | 272,395 | 848 | 0 | San Miguel River at Uravan |
| 09179500 | *No gage during calibration period* | | | | Dolores River at Gateway |

### 7.4.3. Diversion Calibration Results

Table 7.4 summarizes the average annual shortage for water years 1975 through 2003, by tributary or sub-basin in Colorado. Table 7.6 (at the end of this section) shows the average annual shortages for water years 1975 through 2003 by structure (including New Mexico structures).  On a basin-wide basis, average annual diversions differ from historical diversions by around 1 percent in the calibration run in Colorado.

**Table 7.4**
**Historical and Simulated Average Annual Diversions by Sub-basin (1975-2003)**
**Calibration Run (acre-feet/year)**

| Tributary or Sub-basin | Historical | Simulated | Historical minus Simulated Volume | Percent |
|---|---|---|---|---|
| Navajo-Blanco Rivers | 109,866 | 109,698 | 168 | 0% |
| San Juan | 44,906 | 43,900 | 1,006 | 2% |
| Piedra River | 29,636 | 29,341 | 296 | 1% |
| Los Pinos River | 201,279 | 200,649 | 630 | 0% |
| Animas and Florida Rivers | 178,259 | 176,184 | 2,075 | 1% |
| La Plata River | 32,185 | 31,546 | 639 | 2% |
| Mancos River (includes MVIC/Dolores Project  and Summit Irrigation Use) | 35,449 | 35,000 | 448 | 1% |
| McElmo Creek | 204,795 | 203,962 | 833 | 0% |
| San Miguel River | 119,088 | 117,860 | 1,229 | 1% |
| Dolores River | 51,624 | 48,671 | 2,954 | 6% |
| **Basin Total** | **1,007,087** | **996,810** | **10,277** | **1%** |

### 7.4.4. Reservoir Calibration Results

Figures 7.11 through 7.15 (located at the end of this chapter) present reservoir EOM contents estimated by the model compared to historical observations at selected reservoirs. The following can be observed:

- Vallecito Reservoir operational targets, provided by the USBR, appear to better represent actual operations in recent years, as demonstrated by simulation results. Operations likely evolved during the calibration period.

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- Lemon Reservoir operational targets, provided by the USBR, do not appear to mimic historical operations, as demonstrated by simulation results.

## 7.4.5. Consumptive Use Calibration Results

Crop consumptive use is estimated by StateMod and reported in the consumptive use summary file (*.xcu) for each diversion structure in the scenario. This file includes consumptive use for municipal and industrial diversions in addition to agricultural consumptive use. The crop consumptive use estimated by StateCU is reported in the water supply-limited summary file (*.wsl) for each agricultural diversion structure in the basin. Therefore, to provide a one-to-one comparison, only structures in the StateCU analysis are included.

Table 7.5 shows the comparison of StateCU estimated crop consumptive use compared to StateMod estimate of crop consumptive use for explicit structures, aggregate structures, and total in Colorado. As shown, both explicit and aggregate structure consumptive use match StateCU results very well. Historical diversions are used by StateCU to estimate supply-limited (actual) consumptive use. The approximately 1 percent difference is consistent with the overall basin diversion shortages simulated by the model.

**Table 7.5**
**Average Annual Crop Consumptive Use Comparison (1975-2003)**

| Comparison | StateCU Results (af/yr) | Calibration Run Results (af/yr) | % Difference |
|---|---|---|---|
| Explicit Structures | 297,025 | 284,241 | 1% |
| Aggregate Structures | 53,855 | 51,431 | 1% |
| Basin Total | 350,880 | 335,672 | 1% |

**Table 7.6**
**Historical and Simulated Average Annual Diversions (1975-2003)**
**Calibration Run (acre-feet/year)**

| WDID | Historical | Simulated | Historical - Simulated Volume | Percent | Name |
|---|---|---|---|---|---|
| 290519 | 1,241 | 1,238 | 3 | 0% | BEIGHLEY NO 1_DIVSYS |
| 290550 | 3,789 | 3,232 | 558 | 15% | C H LOUCKS DITCH |
| 290555 | 1,419 | 1,382 | 37 | 3% | CARR DITCH |
| 290560 | 1,963 | 1,939 | 24 | 1% | CHAPSON AND HOWE DITCH |
| 290566 | 1,142 | 1,090 | 52 | 5% | COLTON & MONTROY DITCH |
| 290582 | 402 | 402 | 0 | 0% | DOWELL DITCH |
| 290588 | 2,247 | 2,245 | 1 | 0% | ECHO DITCH |
| 290597 | 878 | 878 | 0 | 0% | FISH CREEK DITCH |
| 290601 | 3,914 | 3,894 | 21 | 1% | FOUR-MILE_DIVSYS |
| 290613 | 255 | 255 | 1 | 0% | HALLETT DITCH |
| 290627 | 415 | 415 | 0 | 0% | J M ROSS AND STURGILL D |
| 290653 | 319 | 317 | 1 | 0% | LONG HORN AND MEE DITCH |
| 290654 | 207 | 207 | 0 | 0% | LONG MEADOW DITCH |

| WDID | Historical | Simulated | Historical - Simulated | | Name |
| | | | Volume | Percent | |
|---|---|---|---|---|---|
| 290662 | 420 | 412 | 9 | 2% | MARTINEZ AND MARTINEZ D |
| 290669 | 1,029 | 1,012 | 17 | 2% | MESA DITCH |
| 290686 | 8,858 | 8,809 | 49 | 1% | PARK DITCH |
| 290691 | 250 | 249 | 2 | 1% | PHILLIPPS DITCH |
| 290716 | 650 | 650 | 0 | 0% | SISSON-STEPHENS DITCH |
| 290718 | 5,178 | 5,010 | 168 | 3% | SNOWBALL DITCH |
| 290729 | 307 | 306 | 1 | 0% | STURGILL DITCH |
| 292005 | 1,075 | 1,006 | 69 | 6% | DUTTON DITCH |
| 294667 | 38,096 | 38,096 | 0 | 0% | USBR_BLANCO_R_DIVERSION |
| 294669 | 208 | 208 | 0 | 0% | TREASURE PASS DIVR DITCH |
| 29_ADS002 | 5,803 | 5,796 | 8 | 0% | 29_ADS002_SJuanR@PagosaS |
| 29_ADS003 | 6,554 | 6,554 | 0 | 0% | 29_ADS003_SJuanR@Carracs |
| 300504 | 2,101 | 2,101 | 0 | 0% | AMBOLD-WALLACE DITCH |
| 300506 | 25,287 | 25,258 | 30 | 0% | ANIMAS CONSOLIDATED D |
| 300509 [1] | 0 | 0 | 0 | 0% | ANIMAS DIVERSION CANAL |
| 300510 | 1,168 | 1,168 | 0 | 0% | BEAR CREEK DITCH |
| 300523 [1] | 0 | 0 | 0 | 0% | CASCADE CANAL |
| 300568 | 4,545 | 4,454 | 91 | 2% | HERMOSA COMPANY DITCH |
| 300580 | 2,483 | 2,439 | 44 | 2% | JOHN THOMAS DITCH |
| 300581 | 3,248 | 3,186 | 63 | 2% | J P LAMB DITCH |
| 300612 | 25,719 | 25,460 | 260 | 1% | POWER CANAL NO 1 |
| 300617 | 22,024 | 21,617 | 406 | 2% | REID DITCH |
| 300634 | 1,139 | 1,139 | 0 | 0% | SITES DITCH |
| 300641 | 2,922 | 2,895 | 26 | 1% | SULLIVAN-WALLACE DITCH |
| 301000 | 4,221 | 4,205 | 16 | 0% | DURANGO CITY PIPELINE |
| 301003 | 828 | 826 | 2 | 0% | HARRIS-PATTERSON DITCH |
| 301009 | 871 | 840 | 30 | 3% | MCCLUER & MURRAY DITCH |
| 301011 | 46,136 | 45,661 | 475 | 1% | Florida_Farmers/Florida_Canal |
| 301019 | 1,787 | 1,703 | 84 | 5% | PIONEER DITCH |
| 301023 | 15,017 | 14,993 | 24 | 0% | ANIMAS DITCH |
| 301024 | 0 | 0 | 0 | 0% | ANIMAS PMP STA & FOR MN |
| 301033 | 912 | 847 | 64 | 7% | BANKS-TYNER DITCH |
| 301056 | 293 | 293 | 0 | 0% | BODO PINE RIDGE DITCH |
| 301094 | 6,274 | 6,242 | 32 | 1% | EAST MESA DITCH |
| 301219 | 1,321 | 1,212 | 110 | 8% | SITES-KERN DITCH |
| 301243 | 1,126 | 998 | 129 | 11% | TYNER EAST SIDE DITCH |
| 304660 | 297 | 297 | 0 | 0% | CARBON LAKE DITCH |
| 304661 | 141 | 141 | 1 | 0% | MINERAL POINT DITCH |
| 304662 | 91 | 91 | 0 | 0% | RED MOUNTAIN DITCH |
| 304664 | 4,453 | 4,453 | 0 | 0% | RALSTON DITCH |
| 304665 | 4,278 | 3,151 | 1,127 | 26% | TWIN ROCK DITCH |
| 30_ADS007 | 8,836 | 8,836 | 0 | 0% | 30_ADS007_AnimasR@Durang |
| 30_ADS008 | 4,731 | 4,671 | 60 | 1% | 30_ADS008_FloridaRabvSal |
| 30_ADS009 | 3,577 | 3,448 | 129 | 4% | 30_ADS009_FloridaR@Bonda |
| 30_ADS010 | 6,906 | 6,906 | 0 | 0% | 30_ADS010_AnimasR@StLine |
| 310502 | 3,316 | 3,316 | 0 | 0% | CEANABOO DITCH |
| 310503 | 2,808 | 2,692 | 117 | 4% | COMMISSIONER DITCH |

| WDID | Historical | Simulated | Historical - Simulated | | Name |
| | | | Volume | Percent | |
|---|---|---|---|---|---|
| 310505 | 19,031 | 19,031 | 0 | 0% | DR MORRISON_DIVSYS |
| 310507 | 3,086 | 3,086 | 0 | 0% | LA BOCA DITCH |
| 310508 | 2,585 | 2,585 | 0 | 0% | SEVERO DITCH |
| 310509 | 13,434 | 13,434 | 0 | 0% | SPRING CREEK DITCH |
| 310510 | 979 | 979 | 0 | 0% | BEAN DITCH |
| 310511 | 8,745 | 8,745 | 0 | 0% | THOMPSON-EPPERSON DITCH |
| 310512 | 3,638 | 3,638 | 0 | 0% | LOS PINOS IRG DITCH |
| 310513 | 2,581 | 2,581 | 0 | 0% | WOMMER IRRIGATION DITCH |
| 310514 | 3,358 | 3,358 | 0 | 0% | BEAR CR AND PINE R DITCH |
| 310516 | 255 | 255 | 0 | 0% | HIGBEE IRRIGATION DITCH |
| 310518 | 706 | 706 | 0 | 0% | MYERS AND ASHER DITCH |
| 310519 | 25,558 | 25,558 | 0 | 0% | KING DITCH |
| 310523 | 15,190 | 15,190 | 0 | 0% | SCHRODER IRG_DIVSYS |
| 310524 | 965 | 965 | 0 | 0% | FARRELL DITCH |
| 310527 | 86 | 86 | 0 | 0% | ISLAND DITCH |
| 310528 | 1,356 | 1,356 | 0 | 0% | BENNETT-MYERS IRR DITCH |
| 310535 | 595 | 593 | 2 | 0% | KIRKPATRICK DITCH |
| 310540 | 1,016 | 992 | 24 | 2% | MCLOYD DITCH |
| 310545 | 261 | 261 | 0 | 0% | CATLIN DITCH |
| 310547 | 22,776 | 22,769 | 7 | 0% | ROBERT MORRISON DITCH |
| 310553 | 189 | 189 | 0 | 0% | MCBRIDE DITCH |
| 310567 | 322 | 322 | 0 | 0% | CAMPBELL DITCH |
| 310583 | 449 | 300 | 149 | 33% | PORTER DITCH |
| 310593 | 344 | 344 | 0 | 0% | SEMLER DITCH E AND E |
| 310665 | 59,680 | 59,680 | 0 | 0% | SPRING CREEK DITCH |
| 310668 | 1,555 | 1,555 | 0 | 0% | SULLIVAN DITCH |
| 310710 | 879 | 879 | 0 | 0% | IGNACIO CREEK DITCH |
| 314637 | 1,109 | 931 | 179 | 16% | WEMINUCHE PASS DITCH |
| 314638 | 449 | 353 | 96 | 21% | PINE R WEMINUCHE PASS D |
| 31_ADS005 | 3,976 | 3,920 | 56 | 1% | 31_ADS005_LPinosR@DryCrk |
| 31_ADS006 | 9,463 | 9,461 | 2 | 0% | 31_ADS006_LPinosR@StLine |
| 320509 | 977 | 974 | 3 | 0% | BLACK DIKE DITCH |
| 320528 | 2,729 | 2,711 | 17 | 1% | COTTONWOOD DITCH NO 1 |
| 320529 | 2,944 | 2,939 | 5 | 0% | COTTONWOOD DITCH NO 2 |
| 320558 | 1,407 | 1,336 | 71 | 5% | EATON DITCH |
| 320574 | 4,152 | 4,016 | 136 | 3% | HAMBELTON DITCH |
| 320590 | 850 | 833 | 17 | 2% | ISMAY DITCH |
| 320634 | 1,914 | 1,772 | 142 | 7% | MURRAY-ZWICKER-TOZER D |
| 320652 | 10,013 | 9,979 | 34 | 0% | ROCK CREEK DITCH |
| 320662 | 961 | 881 | 80 | 8% | SCHALLES DITCH |
| 320680 | 2,952 | 2,941 | 11 | 0% | TOWN OF CORTEZ |
| 320690 | 2,606 | 2,583 | 23 | 1% | WILSON DITCH |
| 320699 [1] | 0 | 0 | 0 | 0% | NARRAGUINNEP RES INLET |
| 320772 | 71,256 | 71,256 | 0 | 0% | MVI_U_lateral |
| 320884 | 5,229 | 5,229 | 0 | 0% | TOWAOC CANAL |
| 322001 | 631 | 631 | 0 | 0% | DOLORES WATER DIVR HGT |
| 322006 | 18,896 | 18,896 | 0 | 0% | DOVE CREEK CANAL |

| WDID | Historical | Simulated | Historical - Simulated | | Name |
| | | | Volume | Percent | |
|---|---|---|---|---|---|
| 324675 | 59,392 | 59,392 | 0 | 0% | Dolores_Tunnel |
| 32_ADS015 | 6,003 | 5,904 | 99 | 2% | 32_ADS015_McELmCkabvAlka |
| 32_ADS016 | 5,402 | 5,401 | 1 | 0% | 32_ADS016_McElmoCrkNrStL |
| 330501 | 1,726 | 1,687 | 39 | 2% | LA PLATA IRG DITCH |
| 330504 | 5,626 | 5,529 | 97 | 2% | HAY GULCH DITCH |
| 330508 | 2,403 | 2,391 | 12 | 1% | LA PLATA R & CHERRY CR D |
| 330518 | 373 | 372 | 1 | 0% | AMMONS DITCH |
| 330533 | 984 | 969 | 15 | 1% | PINE RIDGE DITCH |
| 330535 | 708 | 701 | 6 | 1% | SOONER VALLEY DITCH |
| 330536 | 4,874 | 4,818 | 56 | 1% | H H DITCH |
| 330540 | 487 | 478 | 9 | 2% | ENTERPRISE ENLARGEMENT |
| 330542 | 3,413 | 3,259 | 153 | 4% | SLADE DITCH |
| 330547 | 2,767 | 2,618 | 148 | 5% | JOSEPH FREED DITCH |
| 330548 | 514 | 506 | 8 | 1% | REVIVAL DITCH |
| 330549 | 1,925 | 1,899 | 26 | 1% | TREANOR DITCH |
| 330550 | 760 | 751 | 9 | 1% | WARREN-VOSBURGH DITCH |
| 330551 | 618 | 598 | 20 | 3% | TOWNSITE DITCH |
| 330554 | 1,954 | 1,913 | 41 | 2% | BIG STICK DITCH |
| 334639 | 539 | 539 | 1 | 0% | ENTERPRISE ENLARGEMENT |
| 334640 | 757 | 757 | 0 | 0% | PIONEER DITCH |
| 33_ADS011 | 1,758 | 1,758 | 0 | 0% | 33_ADS011_LaPlataRiver |
| 340505 | 1,442 | 1,433 | 9 | 1% | BEAVER DITCH |
| 340506 | 1,003 | 999 | 4 | 0% | BOSS DITCH |
| 340508 | 758 | 754 | 3 | 0% | CARPENTER & MITCHELL D |
| 340514 | 755 | 740 | 15 | 2% | CRYSTAL CREEK DITCH |
| 340522 | 622 | 609 | 13 | 2% | EAST MANCOS HIGHLINE D. |
| 340527 | 588 | 587 | 1 | 0% | FRANK DITCH |
| 340530 | 1,204 | 1,132 | 71 | 6% | GILES DITCH |
| 340531 | 1,142 | 1,010 | 131 | 12% | GLASGOW & BREWER DITCH |
| 340534 | 2,517 | 2,514 | 2 | 0% | HENRY BOLEN DITCH |
| 340535 [1] | 0 | 0 | 0 | 0% | JACKSON GULCH INLET CNL |
| 340542 | 1,028 | 1,028 | 0 | 0% | LEE AND BURKE DITCH |
| 340543 | 598 | 597 | 0 | 0% | LEE DITCH |
| 340544 | 702 | 692 | 10 | 1% | LONG PARK DITCH |
| 340552 | 1,079 | 1,074 | 6 | 1% | NO 6 DITCH |
| 340554 | 4,347 | 4,347 | 0 | 0% | RATLIFF AND ROOT DITCH |
| 340560 | 1,658 | 1,590 | 69 | 4% | RUSH RESERVOIR DITCH |
| 340565 | 1,804 | 1,797 | 7 | 0% | SHEEK DITCH |
| 340567 | 138 | 130 | 8 | 6% | SMOUSE DITCH |
| 340573 | 754 | 754 | 0 | 0% | TOWN OF MANCOS DITCH |
| 340576 | 5,365 | 5,364 | 1 | 0% | WEBBER DITCH |
| 340577 | 675 | 626 | 48 | 7% | WEBER RESERVOIR INLET D |
| 340582 | 264 | 263 | 2 | 1% | WILLIAMS DITCH_DIVSYS |
| 340583 | 827 | 823 | 4 | 0% | WILLIS DITCH |
| 34_ADS012 | 1,498 | 1,496 | 2 | 0% | 34_ADS012_ManRabvWMancos |
| 34_ADS013 | 688 | 684 | 4 | 1% | 34_ADS013_ManRabvChicken |
| 34_ADS014 | 2,913 | 2,898 | 16 | 1% | 34_ADS014_MancosRNrStLin |

| WDID | Historical | Simulated | Historical - Simulated | | Name |
| | | | Volume | Percent | |
| --- | --- | --- | --- | --- | --- |
| 34_AMS001 | 1,080 | 1,057 | 23 | 2% | 34_MUNICIPAL |
| 460503 | 2,139 | 2,137 | 2 | 0% | BRIGGS DITCH |
| 600507 | 291 | 284 | 7 | 2% | ALEXANDER DITCH |
| 600511 | 10,918 | 10,854 | 63 | 1% | AMES ILIUM HYDRO PROJ |
| 600520 | 802 | 801 | 0 | 0% | B C D DITCH |
| 600521 | 1,120 | 1,008 | 111 | 10% | BEAVER MESA DITCH |
| 600549 | 167 | 167 | 0 | 0% | CARR WADDLE DITCH |
| 600550 | 715 | 666 | 49 | 7% | CARRIERE DITCH |
| 600569 | 706 | 706 | 0 | 0% | CRAVER DITCH |
| 600574 | 410 | 408 | 2 | 0% | DENISON DITCH |
| 600583 | 520 | 249 | 271 | 52% | EAGLE DITCH |
| 600585 | 336 | 336 | 0 | 0% | EASTON DITCH |
| 600588 | 856 | 855 | 1 | 0% | ELK CREEK DITCH |
| 600607 | 320 | 318 | 2 | 1% | GLENCOE DITCH |
| 600611 | 665 | 660 | 5 | 1% | GOLD RUN DITCH |
| 600628 | 487 | 384 | 103 | 21% | HASTINGS DITCH |
| 600633 | 33,141 | 32,929 | 212 | 1% | HIGHLINE CANAL |
| 600650 | 1,634 | 1,568 | 66 | 4% | J & M HUGHES DITCH |
| 600659 | 381 | 370 | 11 | 3% | KINLEY DITCH |
| 600669 | 402 | 225 | 177 | 44% | LEOPARD CREEK DITCH |
| 600670 | 3,039 | 2,849 | 190 | 6% | LILYLANDS CANAL |
| 600672 | 3,262 | 2,997 | 265 | 8% | LONE CONE DITCH |
| 600684 | 519 | 498 | 21 | 4% | MCCOLLOCH SCOTT DITCH |
| 600689 | 757 | 750 | 6 | 1% | MIDDLE ELK CREEK DITCH |
| 600707 | 18,157 | 17,776 | 381 | 2% | NATURITA CANAL |
| 600710 | 173 | 172 | 2 | 1% | NEILSON DITCH |
| 600723 | 1,446 | 1,446 | 0 | 0% | NUCLA POWER PLANT DITCH |
| 600733 | 441 | 426 | 15 | 3% | PAXTON DITCH |
| 600736 | 1,700 | 1,695 | 5 | 0% | PLEASANT VALLEY DITCH |
| 600745 | 737 | 735 | 2 | 0% | REED CHATFIELD DITCH |
| 600776 | 451 | 451 | 0 | 0% | TEMPLETON DITCH |
| 600777 | 231 | 226 | 5 | 2% | THEO NETHERLY DITCH NO1 |
| 60_ADS020 | 5,043 | 5,043 | 0 | 0% | 60_ADS020_SMiguelNrPlacr |
| 60_ADS021 | 1,352 | 1,352 | 0 | 0% | 60_ADS021_SMiguelabvWNat |
| 60_ADS022 | 8,385 | 8,385 | 0 | 0% | 60_ADS022_SMiguel@Naturi |
| 610502 | 1,128 | 1,108 | 21 | 2% | GALLOWAY DIVSYS |
| 610517 | 1,373 | 1,362 | 11 | 1% | SOUTH MIDWAY DITCH |
| 610527 | 2,246 | 2,139 | 107 | 5% | RAY DITCH |
| 610602 | 372 | 360 | 12 | 3% | A E L R P & PL |
| 61_ADS019 | 5,315 | 5,306 | 9 | 0% | 61_ADS019_DoloresRNrBedr |
| 630501 | 2,690 | 1,865 | 825 | 31% | BARTHOLOMEW & HATCH D |
| 630518 | 1,545 | 1,258 | 287 | 19% | CLIFF RANCH DITCH |
| 630529 | 839 | 698 | 141 | 17% | HARMS AND HAZEL DITCH |
| 630547 | 402 | 355 | 46 | 12% | NOLAN DITCH |
| 630553 | 259 | 259 | 0 | 0% | RED CROSS DITCH |
| 63_ADS023 | 4,754 | 4,754 | 0 | 0% | 63_ADS023_DoloresR@Gatew |
| 63_ADS024 | 8,824 | 8,562 | 262 | 3% | 63_ADS024_WestCreek |

| WDID | Historical | Simulated | Historical - Simulated | | Name |
|---|---|---|---|---|---|
| | | | Volume | Percent | |
| 63_AMS002 | 1,296 | 1,273 | 23 | 2% | 63_MUNICIPAL |
| 680636 | 1,260 | 928 | 332 | 26% | LEOPARD CREEK DITCH |
| 690510 | 1,474 | 1,434 | 41 | 3% | HORSESHOE DITCH |
| 690512 | 598 | 564 | 34 | 6% | KNIGHT-EMBLING DITCH |
| 690520 | 651 | 628 | 24 | 4% | PINE ARROYA DITCH |
| 69_ADS018 | 1,269 | 1,261 | 8 | 1% | 69_ADS018_Disappointment |
| 710504 | 432 | 366 | 67 | 15% | BEAR CREEK DITCH |
| 710513 | 746 | 730 | 16 | 2% | BURCH & LONGWILL DITCH |
| 710531 | 311 | 262 | 49 | 16% | EAST EDER DITCH |
| 710535 | 147 | 113 | 34 | 23% | GARBARINO NO 1 DITCH |
| 710536 | 154 | 118 | 36 | 23% | GARBARINO NO 2 DITCH |
| 710537 | 159 | 115 | 44 | 28% | GARBARINO NO 3 DITCH |
| 710545 | 688 | 676 | 11 | 2% | GOULD & MORIARITY DITCH |
| 710549 | 1,157 | 1,025 | 133 | 11% | ILLINOIS DITCH |
| 710551 | 215 | 213 | 2 | 1% | ITALIAN DITCH |
| 710555 | 603 | 484 | 119 | 20% | KEYSTONE DITCH |
| 710556 | 121 | 113 | 8 | 7% | KING NO 1 DITCH |
| 710559 | 266 | 225 | 41 | 16% | KOENIG DITCH |
| 710563 | 320 | 260 | 60 | 19% | LINDSTROM DITCH |
| 710572 | 422 | 352 | 70 | 17% | MONUMENT ROCK DITCH |
| 710573 | 549 | 492 | 57 | 10% | MORIARITY DITCH |
| 710575 | 54 | 45 | 9 | 17% | ORIGINAL RICO FLUME |
| 710582 | 476 | 406 | 69 | 15% | QUARRY NO 1 DITCH |
| 710586 | 262 | 214 | 47 | 18% | RIEVA DITCH |
| 710609 [1] | 0 | 0 | 0 | 0% | SUMMIT DITCH |
| 710618 [1] | 0 | 0 | 0 | 0% | TURKEY CREEK DITCH |
| 710624 | 254 | 202 | 51 | 20% | WEST EDER DITCH |
| 712002 | 6,480 | 6,286 | 194 | 3% | SUMMIT RES OUTLET |
| 714673 [1] | 0 | 0 | 0 | 0% | MAIN CANAL NO 1 |
| 714674 [1] | 0 | 0 | 0 | 0% | MAIN CANAL NO 2 |
| 71_ADS017 | 3,048 | 2,852 | 196 | 6% | 71_ADS017_DoloRabvMcPhee |
| 73_ADS025 | 7,501 | 7,497 | 4 | 0% | 73_ADS025_LittleDoloresR |
| 770516 | 235 | 228 | 8 | 3% | CONFAR & RUSSELL DITCH |
| 770524 | 1,658 | 1,658 | 0 | 0% | EAKLOR DITCH |
| 770529 | 1,213 | 1,174 | 38 | 3% | ELMER DITCH NO 1 |
| 770531 | 2,103 | 2,103 | 0 | 0% | ENTERPRISE DITCH |
| 770536 | 582 | 582 | 0 | 0% | FITZHUGH DITCH |
| 770559 | 706 | 678 | 27 | 4% | MIDLAND DITCH |
| 770560 | 277 | 276 | 1 | 0% | MONTOYA DITCH |
| 770562 | 369 | 369 | 0 | 0% | NAVAJO MEADOW DITCH |
| 770564 | 449 | 449 | 0 | 0% | NAVAJO RIVER DITCH |
| 770576 | 263 | 263 | 0 | 0% | SHAHAN IRRIGATION DITCH |
| 770579 | 1,674 | 1,664 | 10 | 1% | SOUTH SIDE DITCH |
| 770585 | 284 | 284 | 0 | 0% | UNDERWOOD DITCH |
| 770586 | 326 | 324 | 2 | 1% | UNDERWOOD DITCH NO 2 |
| 770587 | 686 | 686 | 0 | 0% | UPPER CAMP DITCH |
| 770588 | 316 | 316 | 0 | 0% | UPPER NAVAJO DITCH |

| WDID | Historical | Simulated | Historical - Simulated | | Name |
|---|---|---|---|---|---|
| | | | Volume | Percent | |
| 770597 | 869 | 859 | 10 | 1% | NEW BOND HOUSE (NAVAJO) |
| 774635 | 44,772 | 44,718 | 54 | 0% | USBR_NAVAJO_DIVERSION |
| 774636 | 3,992 | 3,990 | 2 | 0% | USBR_LITTLE_NAVAJO_DIVR |
| 779999 [1] | 0 | 0 | 0 | 0% | SanJ_Chama_Summary_Node |
| 77_ADS001 | 5,239 | 5,239 | 0 | 0% | 77_ADS001_NavajoRiver |
| 780501 | 1,489 | 1,468 | 21 | 1% | ABRAHAM DAVIS DITCH |
| 780506 | 670 | 638 | 32 | 5% | BARNES DITCH |
| 780507 | 703 | 695 | 7 | 1% | BARNES-MEUSER & SHAW D |
| 780513 | 2,583 | 2,572 | 12 | 0% | BUCKSKIN-NAILOR DITCH |
| 780523 | 469 | 462 | 7 | 2% | CARL AND WEBB DITCH |
| 780524 | 355 | 344 | 11 | 3% | CIMARRON DITCH |
| 780525 | 1,067 | 926 | 141 | 13% | CLAYTON-REED DITCH |
| 780543 | 346 | 346 | 0 | 0% | EUGENIO GALLEGOS DITCH |
| 780544 | 773 | 766 | 7 | 1% | F S MOCKLER DIVSYS |
| 780545 | 3,297 | 3,297 | 0 | 0% | FARROW AND PETERSON D |
| 780552 | 673 | 666 | 7 | 1% | GALLEGOS HOME DITCH |
| 780555 | 375 | 375 | 0 | 0% | GEORGE S MCDONALD DITCH |
| 780562 | 608 | 605 | 3 | 0% | HOSSACK CREEK DITCH |
| 780571 | 1,402 | 1,402 | 0 | 0% | BESS GIRL DITCH |
| 780580 | 933 | 927 | 6 | 1% | M E AND M DITCH |
| 780590 | 597 | 595 | 2 | 0% | NICKLES BROTHERS DITCH |
| 780594 | 272 | 271 | 0 | 0% | PAGOSA DITCH |
| 780604 | 2,285 | 2,283 | 2 | 0% | PIEDRA FALLS DITCH |
| 780617 | 1,881 | 1,862 | 19 | 1% | STEVENS&CLAYTON DITCH |
| 780638 | 1,365 | 1,358 | 7 | 1% | TONER AND STEVENS DITCH |
| 780659 | 359 | 359 | 0 | 0% | LITTLE PAGOSA CREEK DIVR |
| 780692 | 755 | 755 | 0 | 0% | FAIRFIELD MUN. WATER SYS |
| 784670 | 48 | 45 | 2 | 5% | DON LAFONT DITCH NO 1 |
| 784671 | 136 | 134 | 3 | 2% | DON LAFONT DITCH NO 2 |
| 784672 | 242 | 236 | 6 | 2% | WILLIAMS CR SQ PASS DIVR |
| 78_ADS004 | 5,954 | 5,954 | 0 | 0% | 78_ADS004_PiedraRiver |
| 990707 | 18,265 | 17,941 | 324 | 2% | GURLEY_IRRIG |
| AZ_IRR | 0 | 0 | 0 | 0% | AZ_IR |
| AZ_NIR | 0 | 0 | 0 | 0% | AZ_NIR |
| CO_ALP | 0 | 0 | 0 | 0% | CO_ALP_Demands |
| NM_4CPP | 29,972 | 29,799 | 173 | 1% | FourCornersPP |
| NM_ABVARCH | 13 | 13 | 0 | 0% | AboveArchuleta |
| NM_ALP1 | 0 | 0 | 0 | 0% | NM_ALP_Animas_Demand |
| NM_ALP2 | 0 | 0 | 0 | 0% | NM_ALP_SanJuan_Demand |
| NM_ANIM | 34,924 | 34,372 | 551 | 2% | NM_AnimasIrr |
| NM_ARCH | 165 | 164 | 1 | 1% | ArchuletaDitch |
| NM_AZTEC | 5,483 | 5,406 | 77 | 1% | AztecMI |
| NM_BLOOM | 1,483 | 1,465 | 18 | 1% | BloomfieldMI |
| NM_CHACO | 0 | 0 | 0 | 0% | ChacoIrr |
| NM_CITZ | 17,687 | 17,411 | 276 | 2% | CitizenDitch |
| NM_CUDEI | 1,975 | 1,946 | 29 | 1% | CudeiCanal |
| NM_ECHO | 2,969 | 2,918 | 50 | 2% | EchoDitch |

| WDID | Historical | Simulated | Historical - Simulated | | Name |
| --- | --- | --- | --- | --- | --- |
| | | | Volume | Percent | |
| NM_FARMMI | 13,075 | 12,897 | 178 | 1% | FarmingtoNM_I |
| NM_FMD | 18,328 | 17,972 | 357 | 2% | FarmersMutual |
| NM_FRUCAM | 13,711 | 13,526 | 186 | 1% | FruitlandAndCambridge |
| NM_GLADE | 452 | 442 | 10 | 2% | FarmingtonGlade |
| NM_HAMM | 21,405 | 21,175 | 229 | 1% | Hammond |
| NM_HOGB | 21,802 | 21,374 | 428 | 2% | Hogback |
| NM_JEWV | 6,383 | 6,238 | 145 | 2% | JewettValley |
| NM_JICIRR | 131 | 128 | 3 | 2% | JicarillaIrri |
| NM_JICNEW | 0 | 0 | 0 | 0% | JicarillaNew |
| NM_JICNIR | 190 | 185 | 5 | 3% | JicarillaNonIr |
| NM_LPIRR | 17,874 | 13,055 | 4,819 | 27% | LowerLaPlataIrr |
| NM_LPNIR | 5,445 | 2,331 | 3,114 | 57% | LaPlataNonIr |
| NM_NIIP | 127,870 | 127,870 | 0 | 0% | NIIP |
| NM_NIIP_R1 | -5,377 | -5,377 | 0 | 0% | NIIP Ojo Return |
| NM_NIIP_R2 | -1,320 | -1,320 | 0 | 0% | NIIP Chaco Return |
| NM_NIIP_R3 | -4,863 | -4,863 | 0 | 0% | NIIP Gallegos Return |
| NM_REDW | 0 | 0 | 0 | 0% | RedWash |
| NM_SJGS | 16,026 | 16,026 | 0 | 0% | SJPowerPlant |
| NM_SRMI | 0 | 0 | 0 | 0% | ShiprockMI |
| NM_TURLEY | 1,144 | 1,126 | 18 | 2% | TurleyDitch |
| NM_U2NIR | 1,828 | 1,780 | 49 | 3% | NM_U2NonIr |
| NM_U3NIR | 495 | 486 | 9 | 2% | NM_U3NonIr |
| NM_U5NIR | 0 | 0 | 0 | 0% | NM_U5NonIr |
| NM_U6NIR | 25,998 | 25,614 | 384 | 1% | NM_U6NonIr |
| NM_U7NIR | 419 | 413 | 6 | 1% | NM_U7NonIr |
| NM_U8NIR | 0 | 0 | 0 | 0% | NM_U8NonIr |
| NM_USIRR | 1,638 | 1,585 | 54 | 3% | USNavajoIrr |
| NM_USNIR | 715 | 700 | 15 | 2% | USNavajoNonIr |
| NM_WESTW | 285 | 274 | 11 | 4% | Westwater |
| NM_WHIS | 0 | 0 | 0 | 0% | WhiskeyCreek |
| UT_IRR | 6,880 | 6,795 | 85 | 1% | UT_IRR |
| UT_NIR | 0 | 0 | 0 | 0% | UT_NIR |
| **Basin Total** | **1,427,523** | **1,403,412** | **24,110** | **1.7%** | |

1) Carrier Structures – demand and use accounted for at user structure

**USGS Gage 09342500 - San Juan River at Pagosa Springs**
**Gaged versus Simulated Flow (1975-2003)**
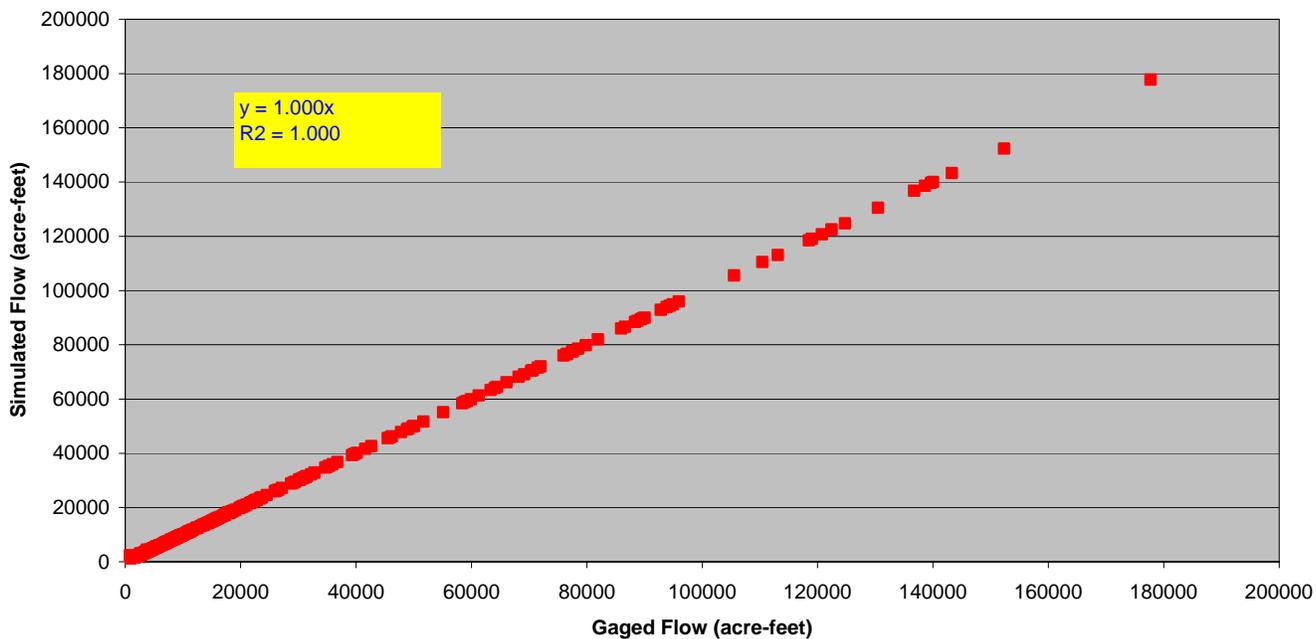
$y = 1.000x$
$R2 = 1.000$



**USGS Gage 09342500 - San Juan River at Pagosa Springs**
**Gaged and Simulated Flows (1975-2003)**
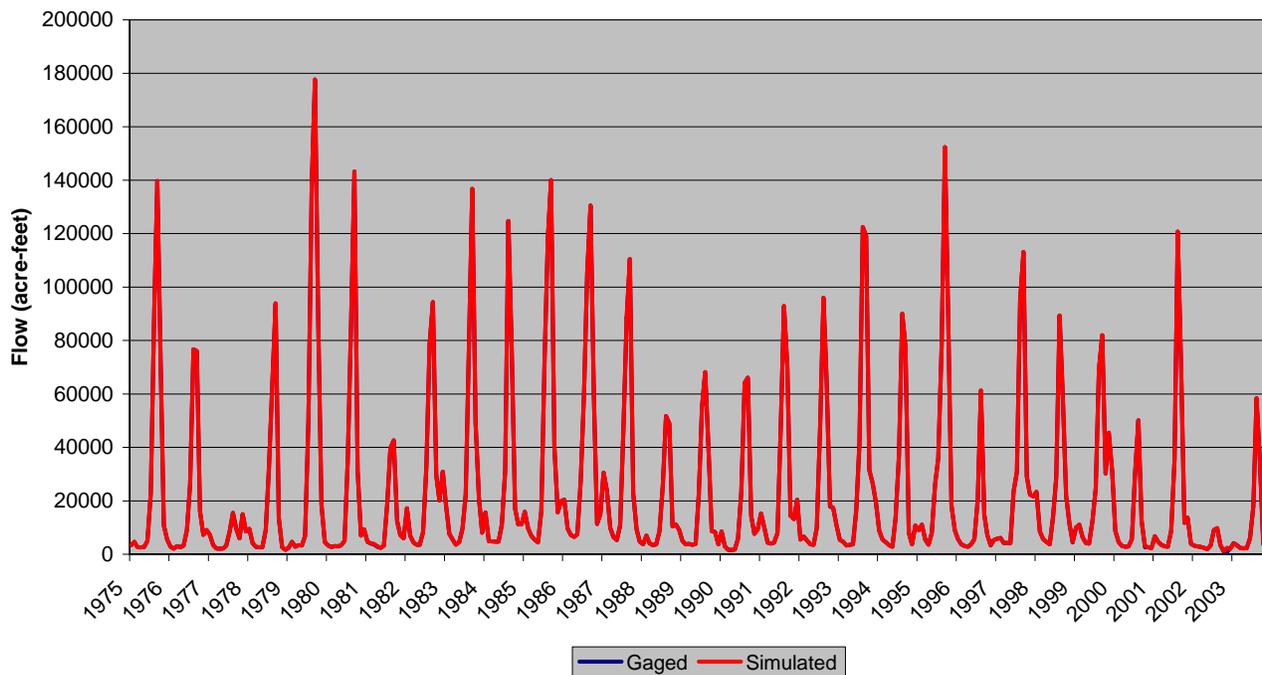
**Figure 7.1 Streamflow Calibration – San Juan River at Pagosa Springs**

**USGS Gage 09346400 - San Juan River near Carracus**
**Gaged versus Simulated Flow (1975-2003)**

$y = 1.001x$
$R2 = 1.000$
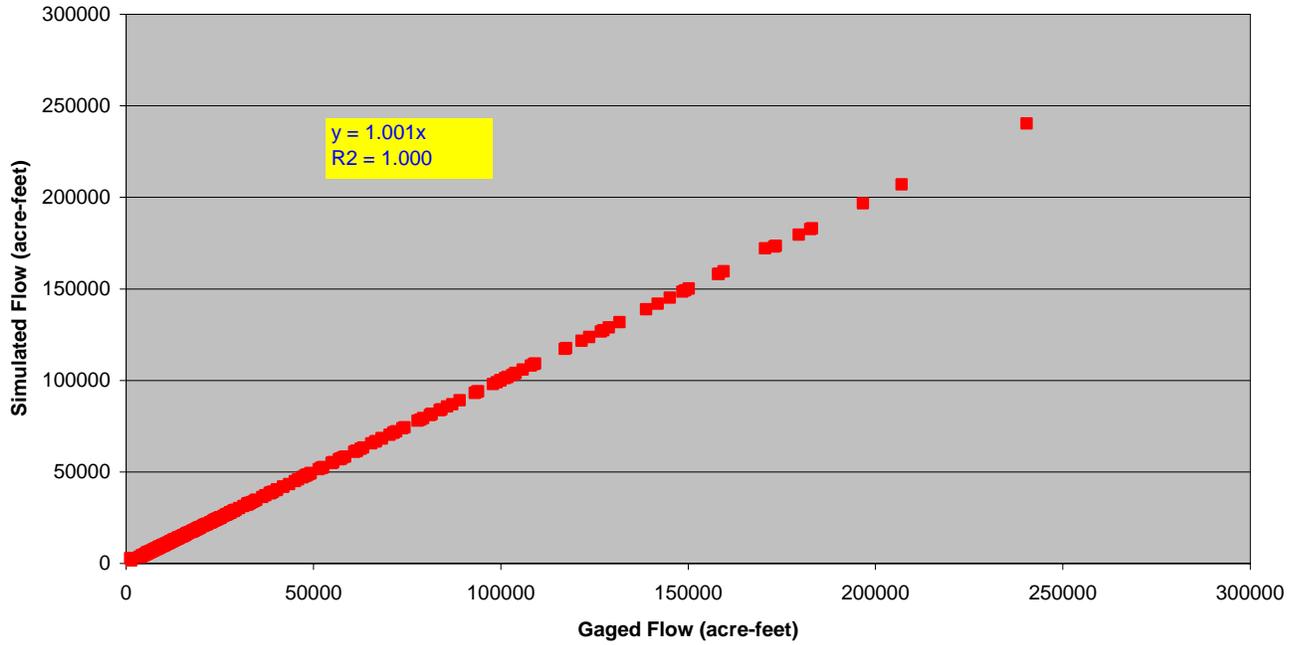
**USGS Gage 09346400 - San Juan River near Carracus**
**Gaged and Simulated Flows (1975-2003)**
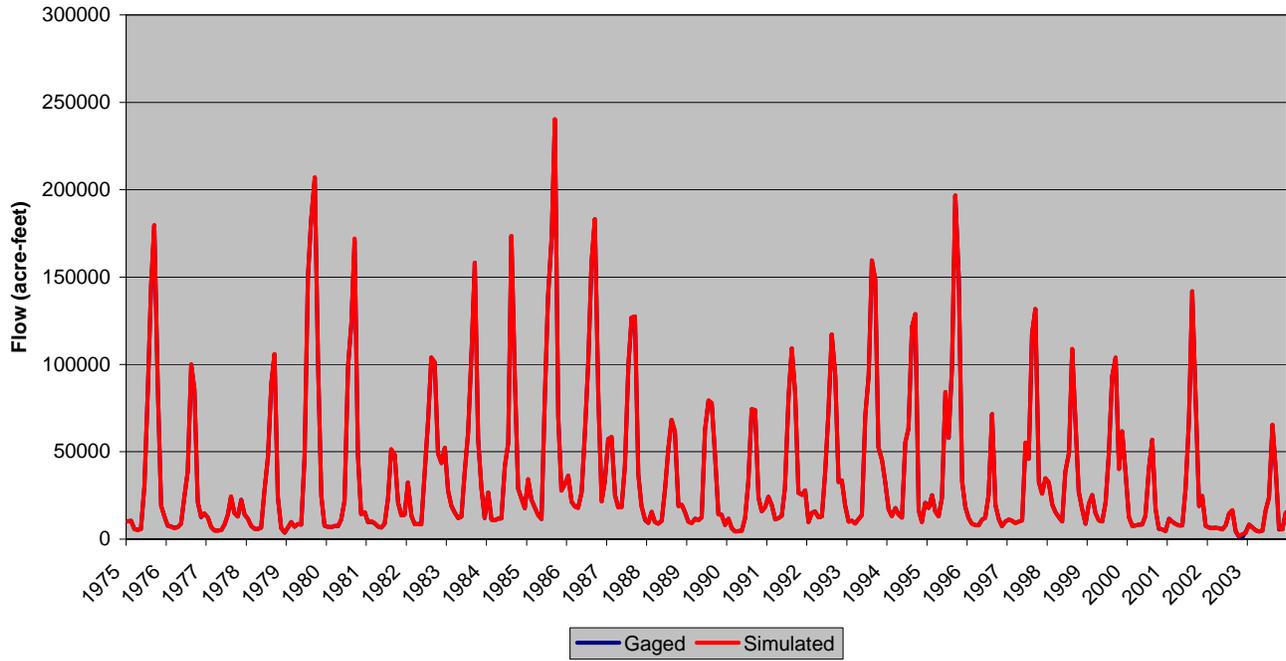
**Figure 7.2 Streamflow Calibration – San Juan River near Carracus**

## USGS Gage 09349800 - Piedra River near Arboles
## Gaged versus Simulated Flow (1975-2003)



y = 1.000x
R2 = 1.000
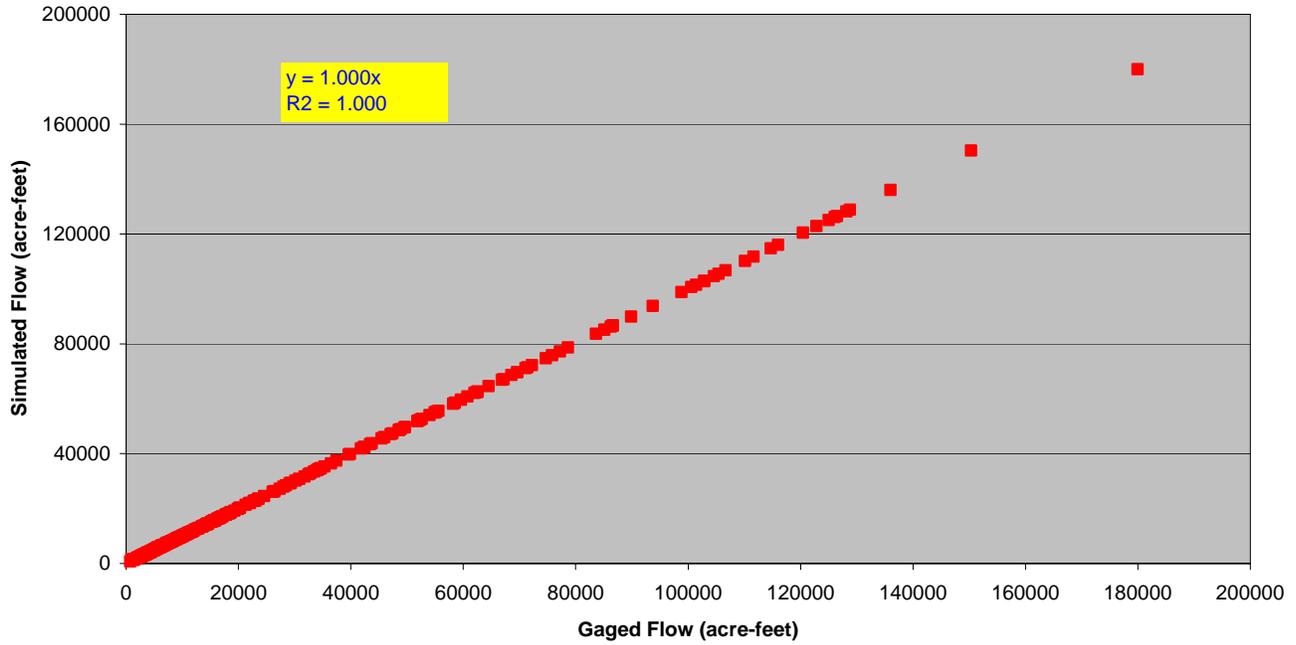
## USGS Gage 09349800 - Piedra River near Arboles
## Gaged and Simulated Flows (1975-2003)
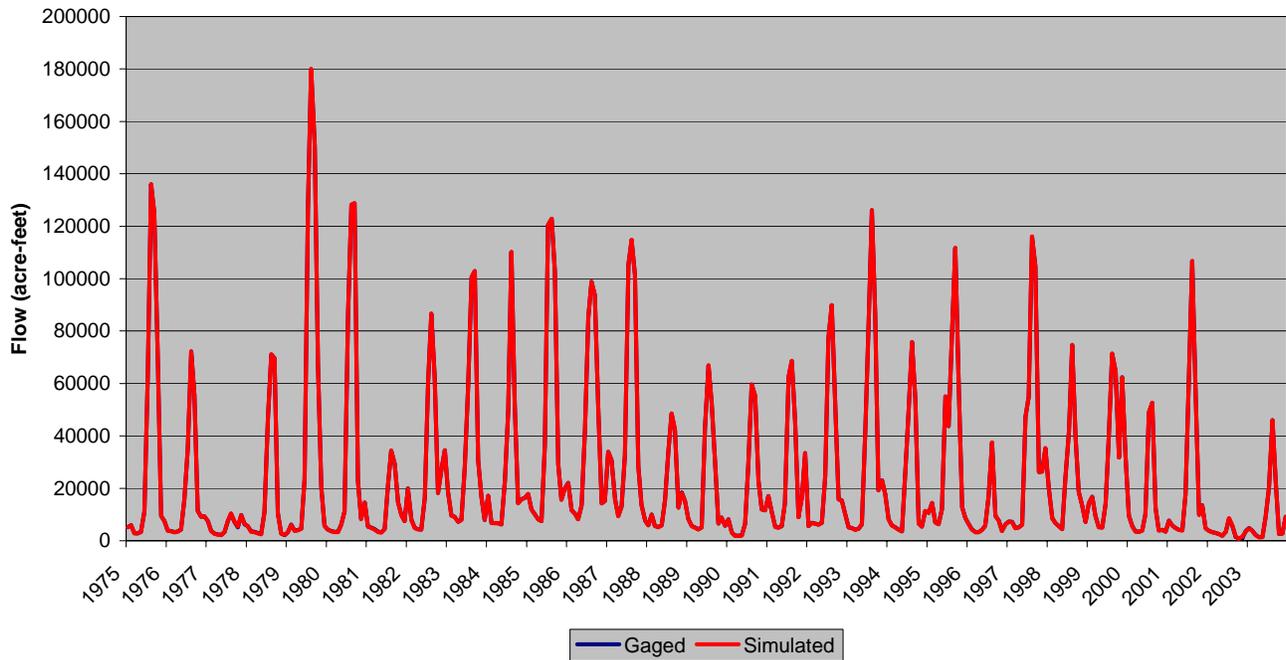


**Figure 7.3 Streamflow Calibration – Piedra River near Arboles**

**USGS Gage 09354500 - Los Pinos River at La Boca**
**Gaged versus Simulated Flow (1975-2003)**
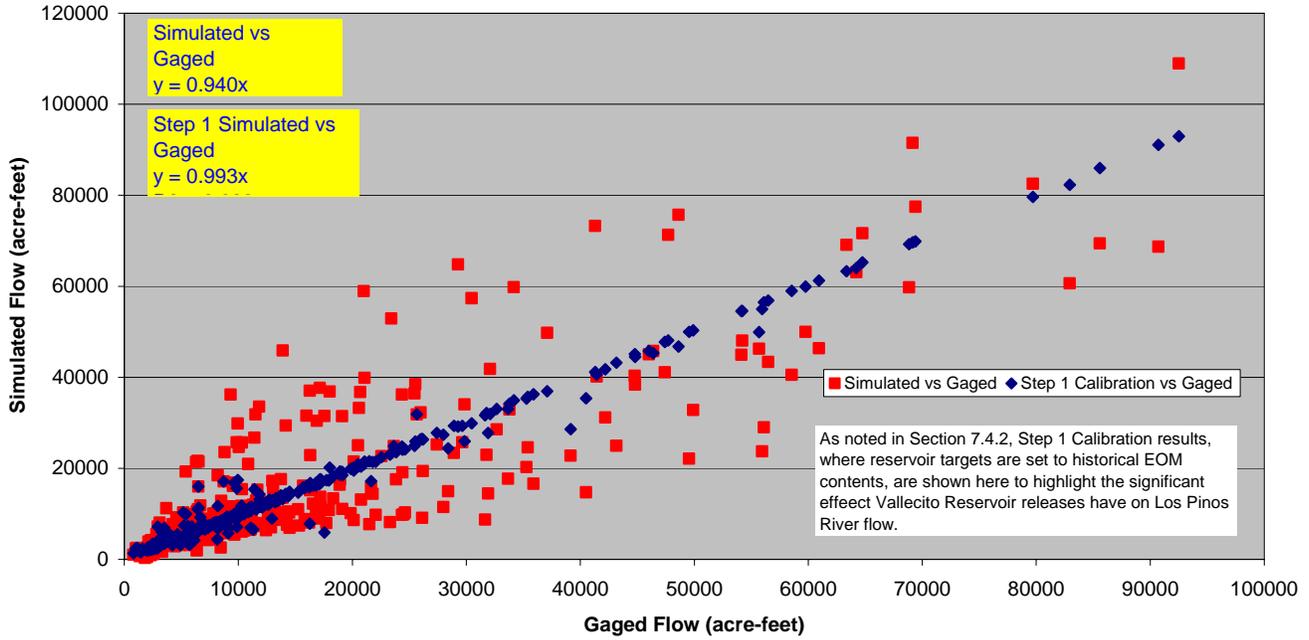
Simulated vs
Gaged
y = 0.940x

Step 1 Simulated vs
Gaged
y = 0.993x

Simulated vs Gaged     ◆ Step 1 Calibration vs Gaged

As noted in Section 7.4.2, Step 1 Calibration results,
where reservoir targets are set to historical EOM
contents, are shown here to highlight the significant
effeect Vallecito Reservoir releases have on Los Pinos
River flow.



**USGS Gage 09354500 - Los Pinos River at La Boca**
**Gaged and Simulated Flows (1975-2003)**
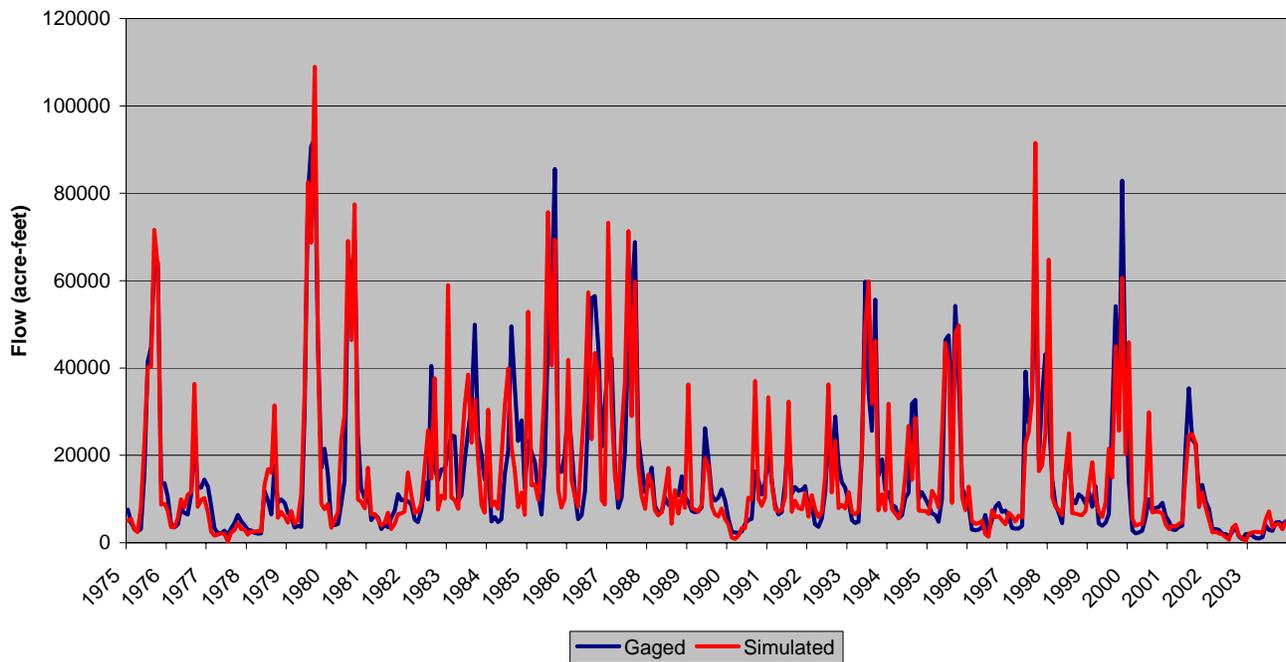
Gaged — Simulated

**Figure 7.4 Streamflow Calibration – Los Pinos River at  La Boca**

**USGS Gage 09361500 - Animas River at Durango**
**Gaged versus Simulated Flow (1975-2003)**

y = 1.000x
R2 = 1.000
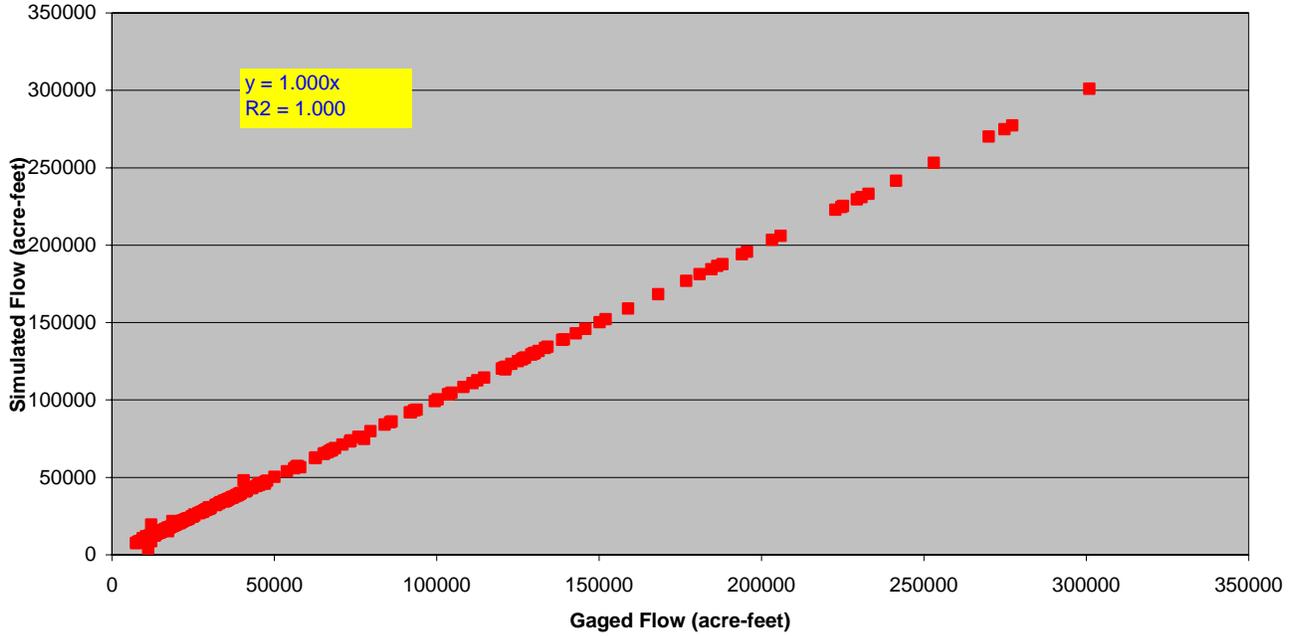


**USGS Gage 09361500 - Animas River at Durango**
**Gaged and Simulated Flows (1975-2003)**
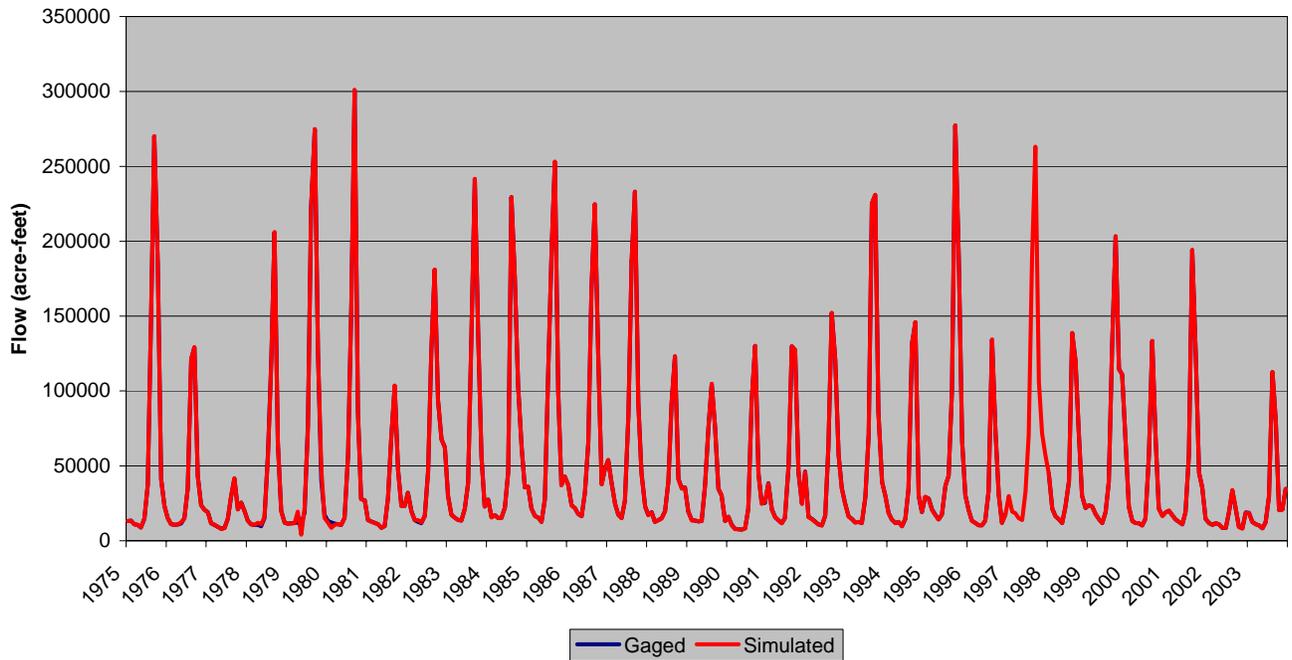
**Figure 7.5 Streamflow Calibration – Animas River at Durango**

**USGS Gage 09366500 - La Plata River at Colorado-New Mexico Stateline**
**Gaged versus Simulated Flow (1975-2003)**
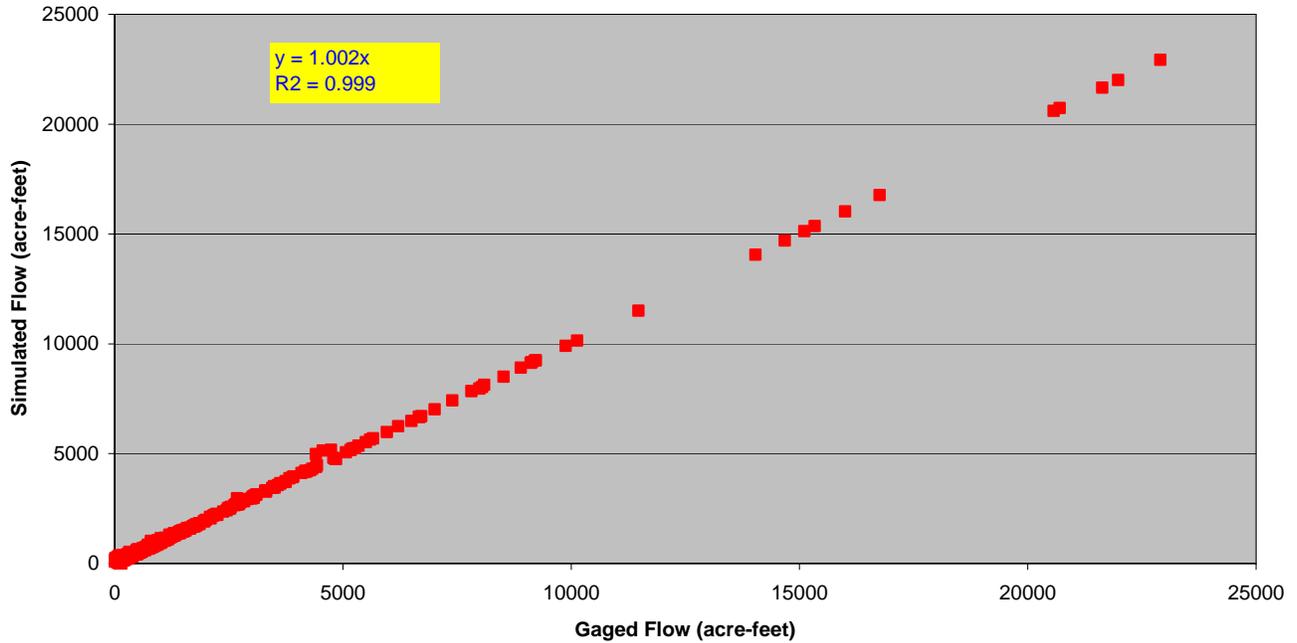


**USGS Gage 09366500 - La Plata River at Colorado-New Mexico Stateline**
**Gaged and Simulated Flows (1975-2003)**
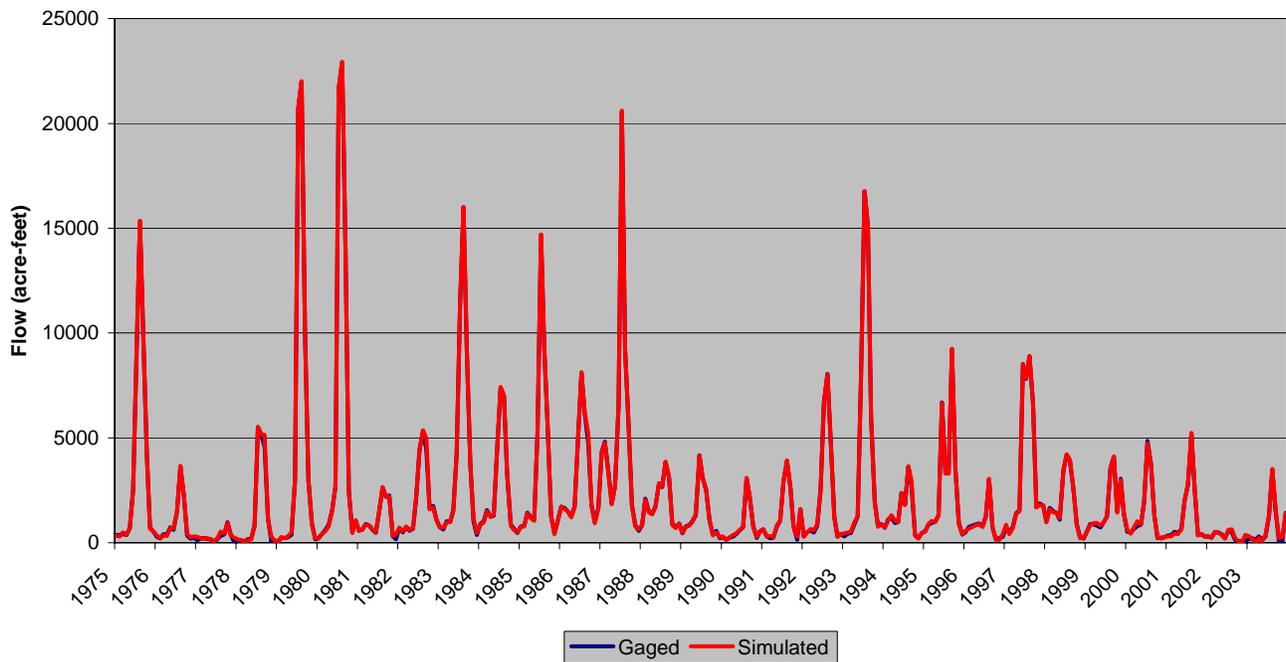


**Figure 7.6 Streamflow Calibration – La Plata River at Colorado-New Mexico Stateline**
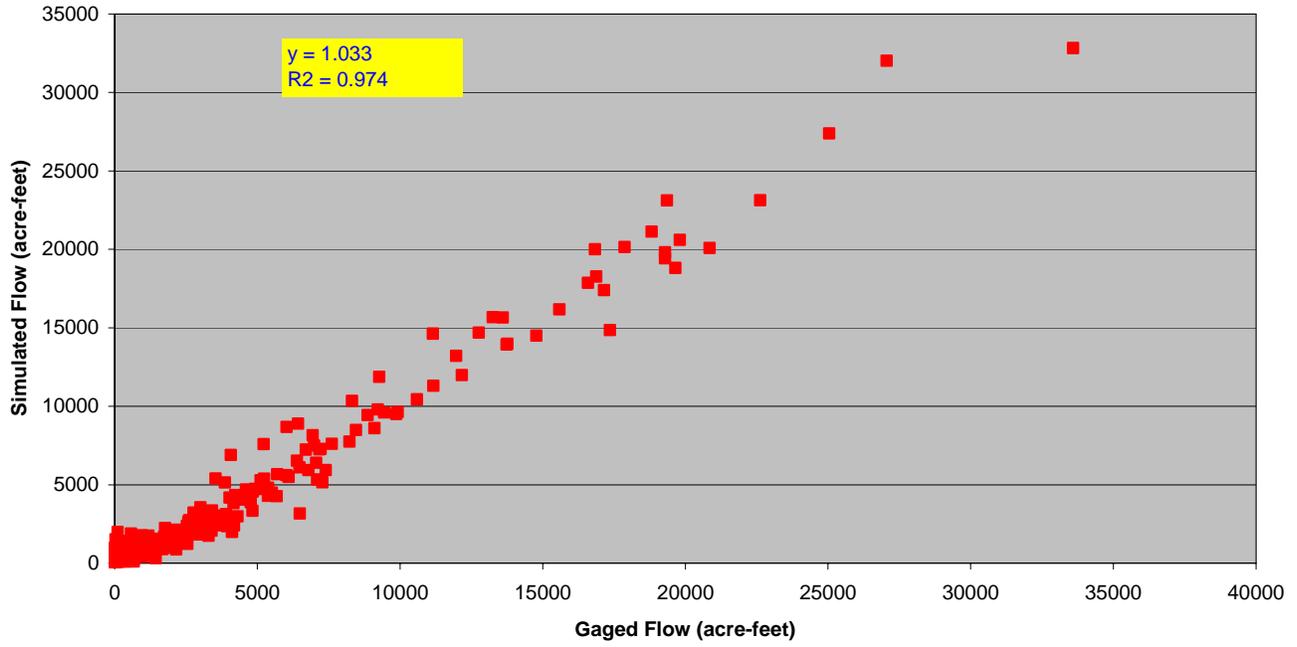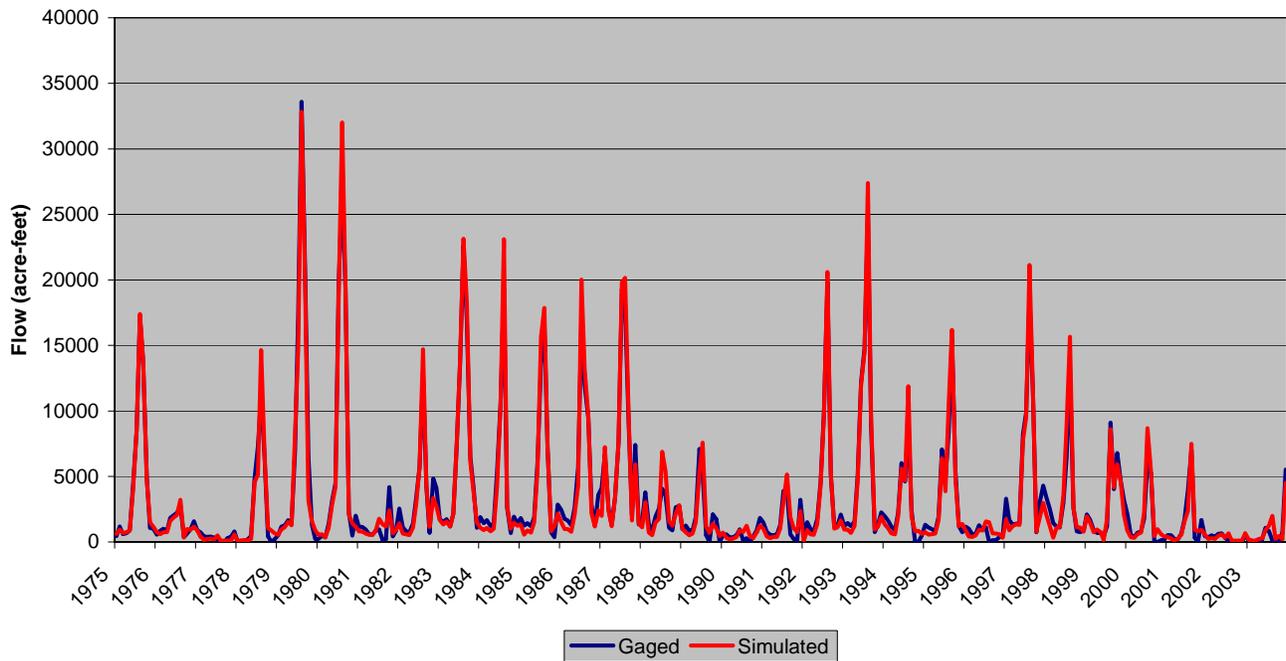
**Figure 7.7 Streamflow Calibration – Mancos River near Towaoc**

## USGS Gage 09372000 - McElmo Creek at Colorado-Utah Stateline
## Gaged versus Simulated Flow (1975-2003)
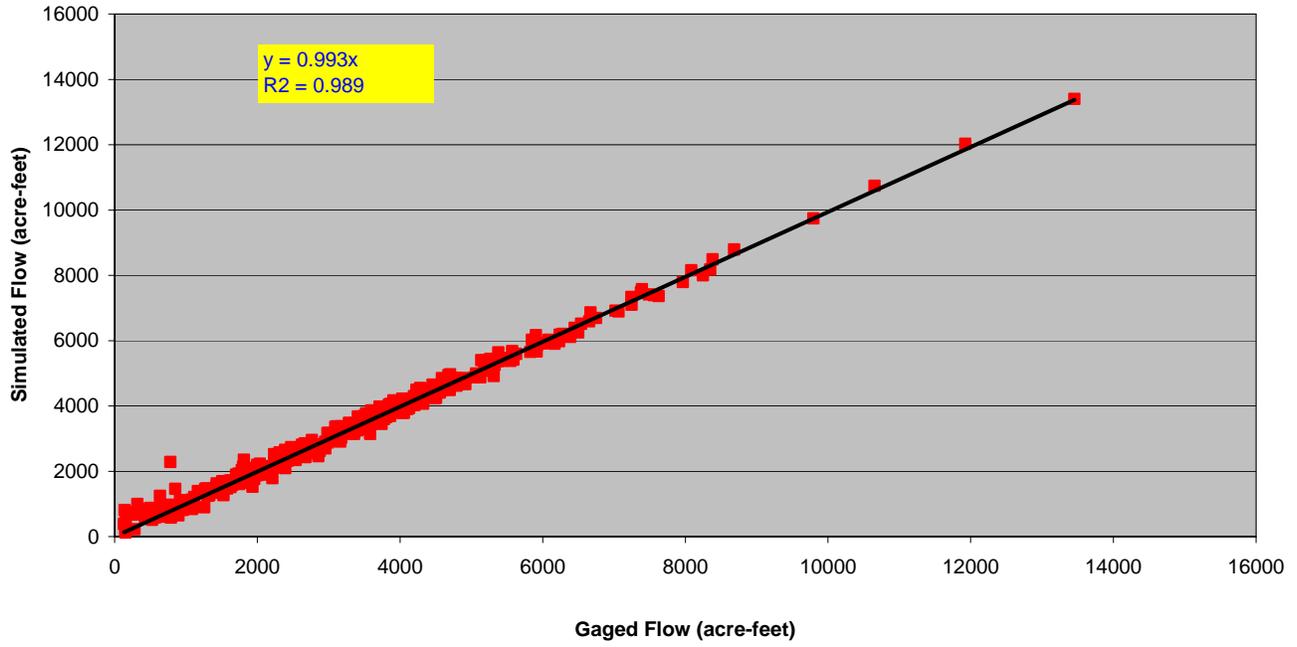


## USGS Gage 09372000 - McElmo Creek at Colorado-Utah Stateline
## Gaged and Simulated Flows (1975-2002)
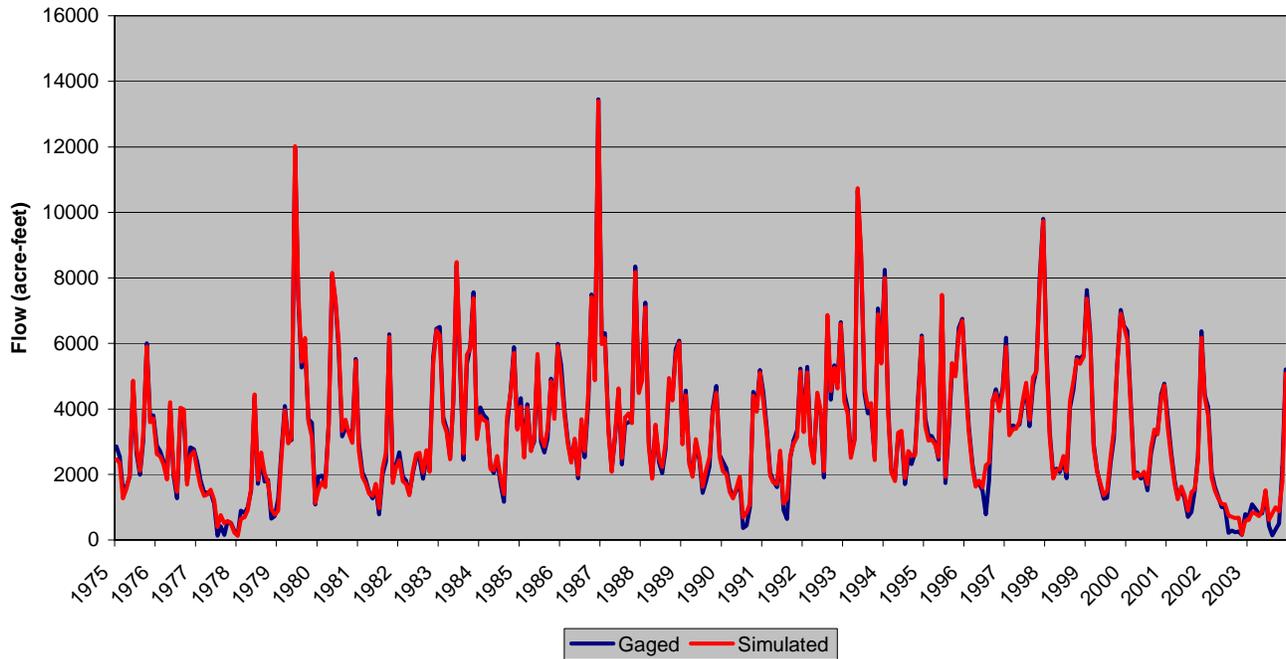


**Figure 7.8 Streamflow Calibration – McElmo Creek at Colorado-Utah Stateline**

**USGS Gage 09171100 - Dolores River near Bedrock**
**Gaged versus Simulated Flow (1975-2003)**

y = 0.999x
R2 = 0.973
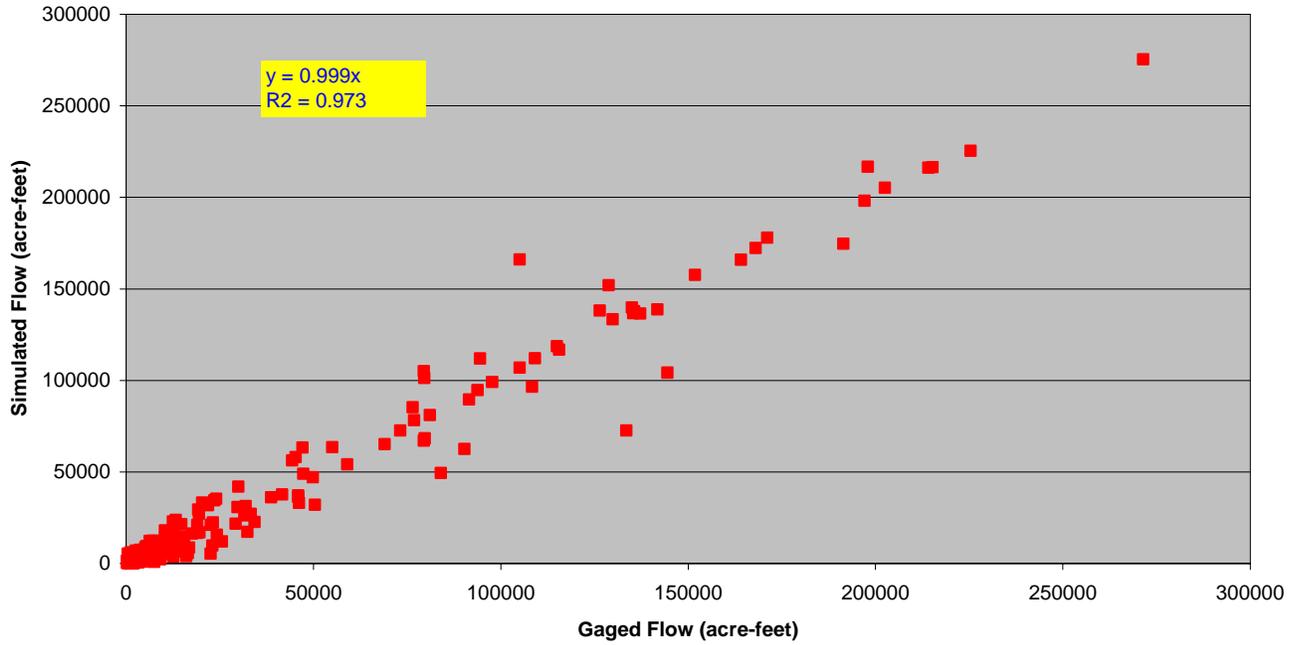


**USGS Gage 09171100 - Dolores River near Bedrock**
**Gaged and Simulated Flows (1975-2003)**
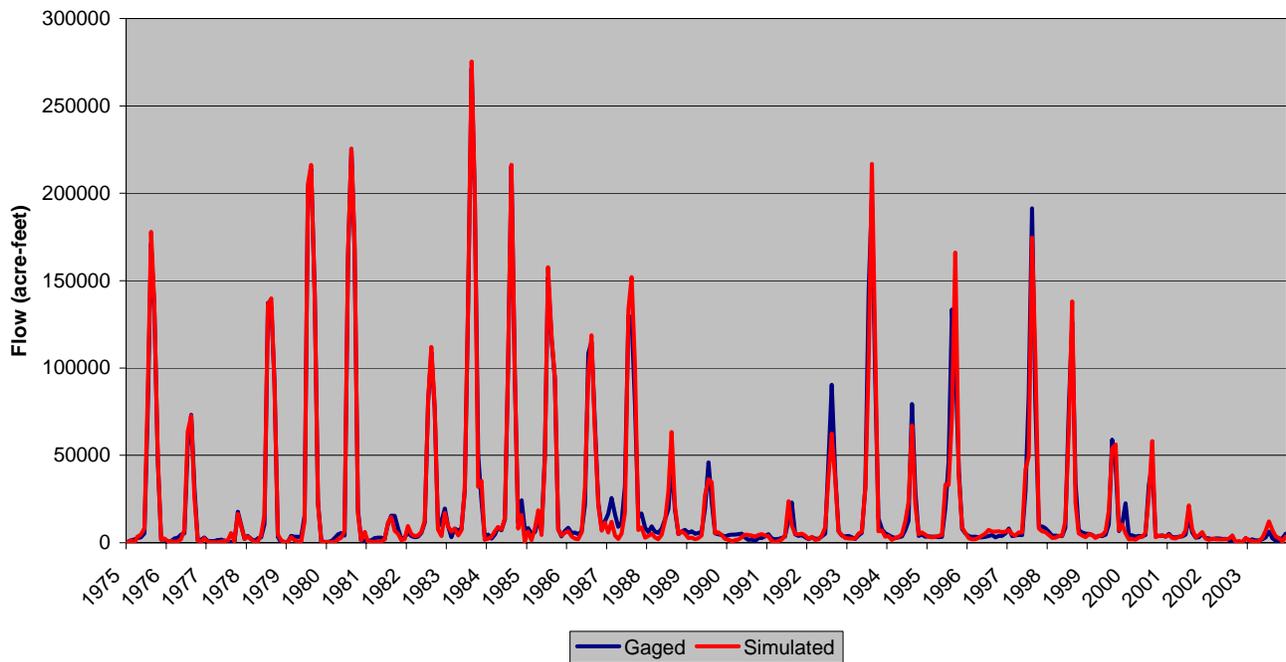
**Figure 7.9 Streamflow Calibration – Dolores River near Bedrock**

**USGS Gage 09177000 - San Miguel River at Uravan**
**Gaged versus Simulated Flow (1975-2003)**

y = 0.996x
R2 = 0.998
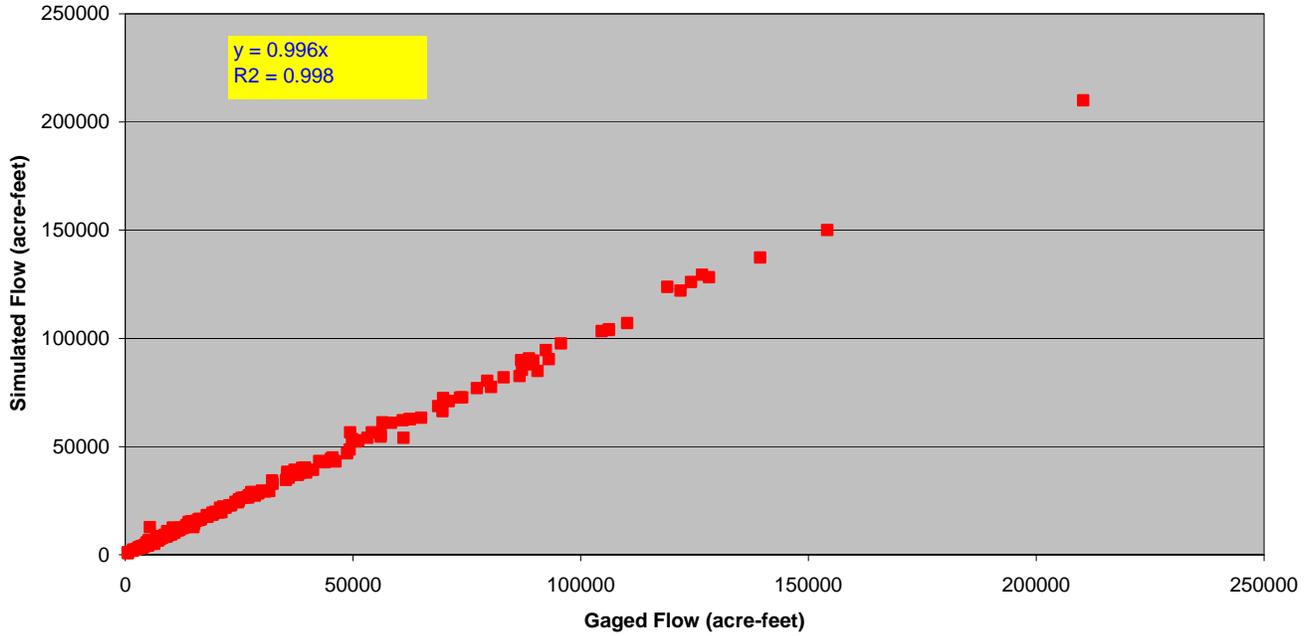


**USGS Gage 09177000 - San Miguel River at Uravan**
**Gaged and Simulated Flows (1975-2003)**
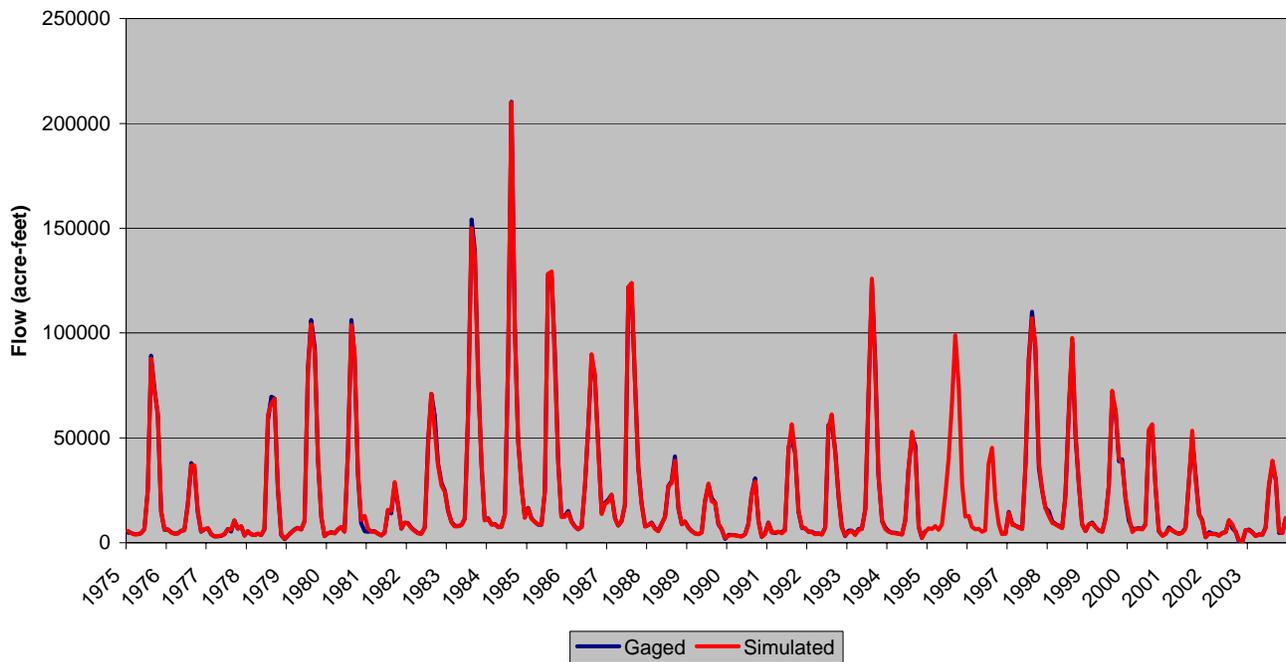
**Figure 7.10 Streamflow Calibration – San Miguel River at Uravan**

**313518 - Vallecito Reservoir**
**Gaged and Simulated EOM Contents (1975-2003)**
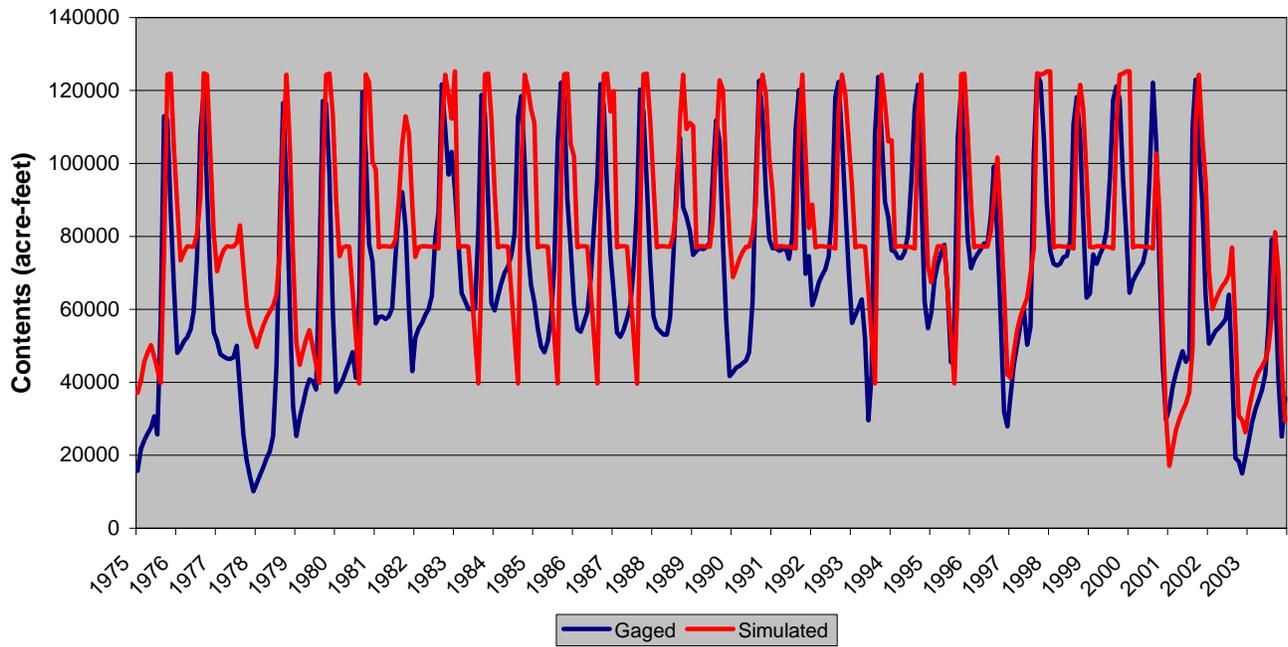
**Figure 7.11 Reservoir Calibration – Vallecito Reservoir**



**303581 - Lemon Reservoir**
**Gaged and Simulated EOM Contents (1975-2003)**
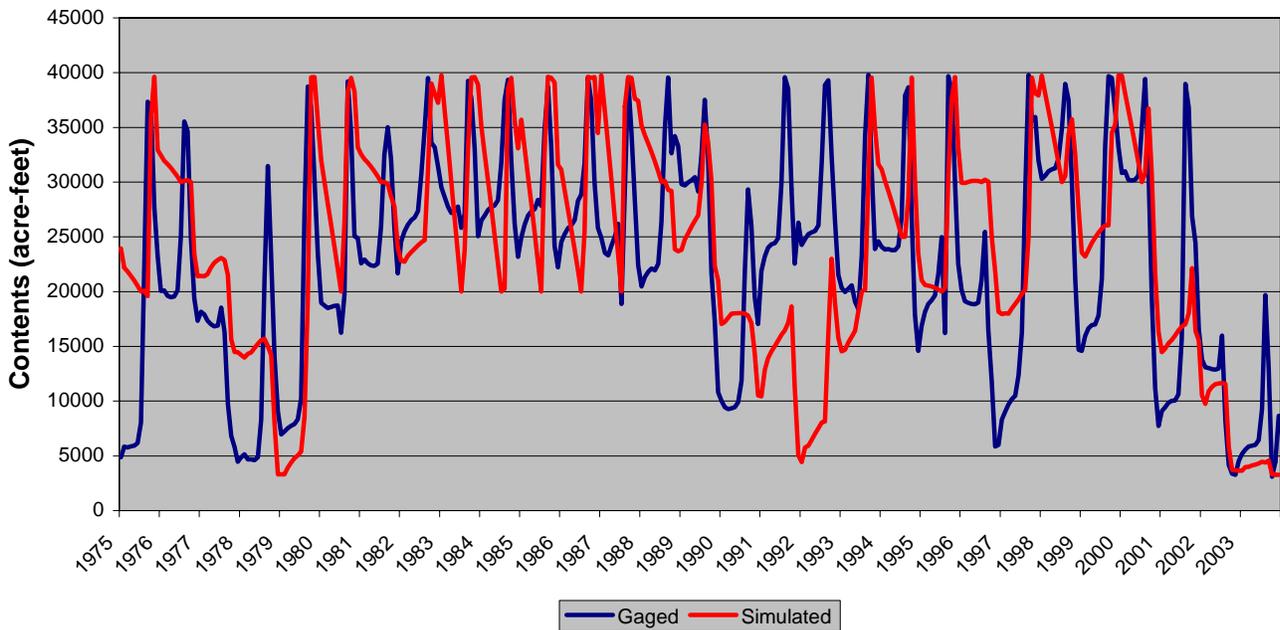
**Figure 7.12 Reservoir Calibration – Lemon Reservoir**

**303536 - Cascade Reservoir**
**Gaged and Simulated EOM Contents (1975-2003)**
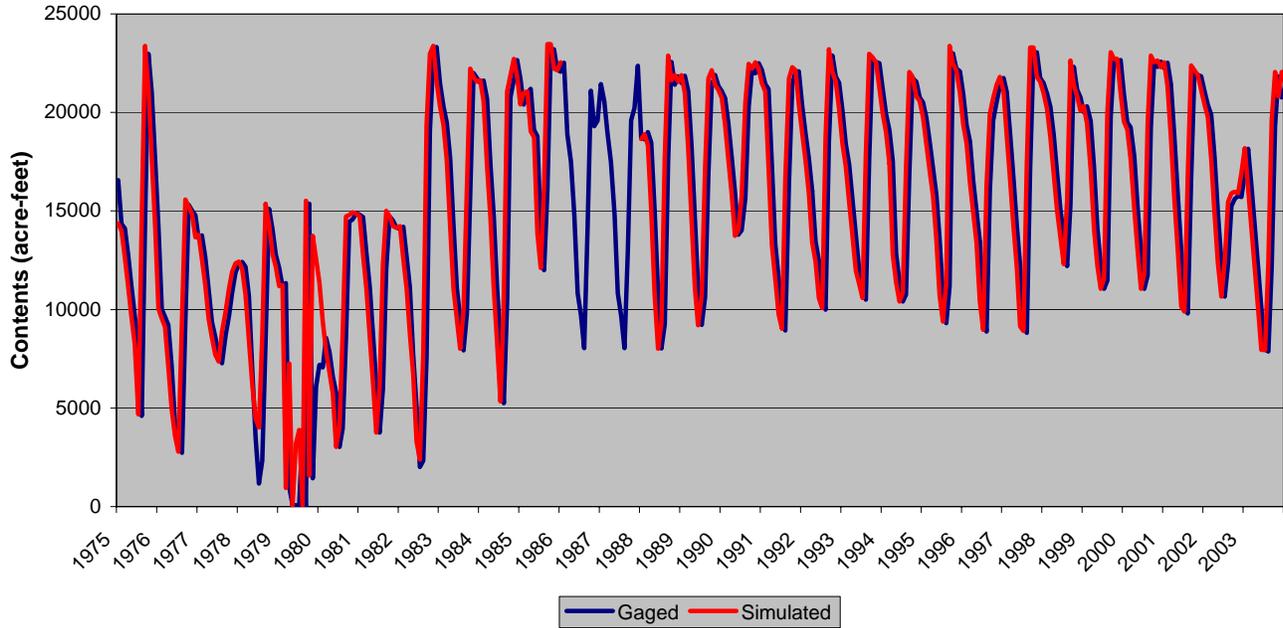
**Figure 7.13 Reservoir Calibration – Cascade Reservoir**



**343589 - Jackson Gulch Reservoir**
**Gaged and Simulated EOM Contents (1975-2003)**
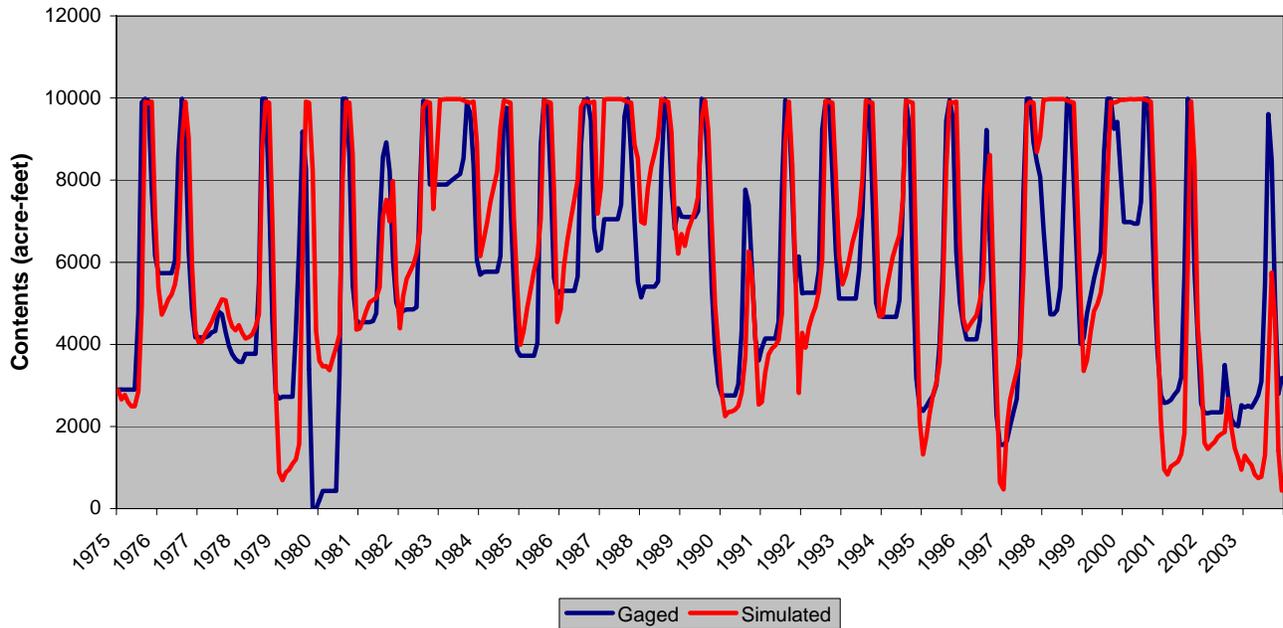
**Figure 7.14 Reservoir Calibration – Jackson Gulch Reservoir**

**713614 - McPhee Reservoir**
**Gaged and Simulated EOM Contents (1975-2003)**
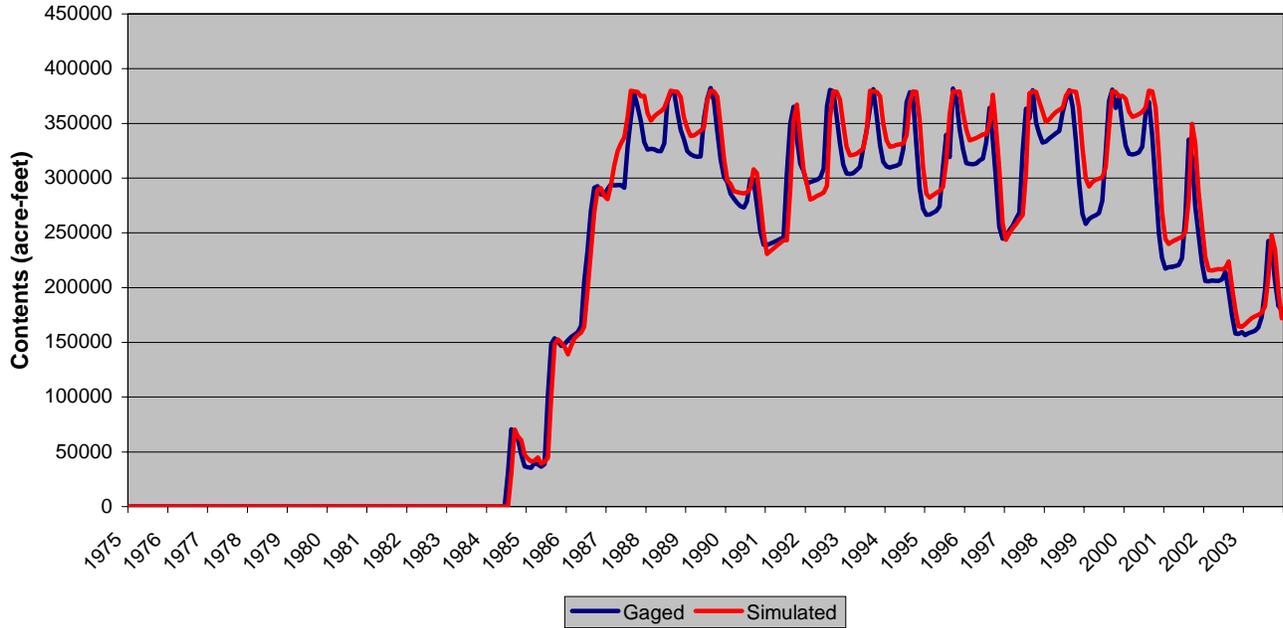


**Figure 7.15 Reservoir Calibration – McPhee Reservoir**

# 8. Daily Baseline Results

The "Daily Baseline" data set simulates current demands, current infrastructure and projects, and the current administrative environment, as though they had been in place throughout the modeled period on a daily time-step. The purpose of the Daily model data set is to capture daily variations in streamflow and call regime. The simulation period for the Daily model is 1975 through 2003. This is the period for which diversion data, and associated irrigation efficiencies, are most complete.

The most difficult part of developing a basin model is understanding the system. By first developing a monthly model, the system operation was investigated without the volume of information ultimately required for a daily model. The Daily model was developed to be able to simulate large and small flow events that occur within a monthly time step. Therefore, although daily baseflows are used, other terms required for daily analysis, such as diversion demands and reservoir targets, are developed using a simplified approach.

Daily baseflows are estimated using StateMod's Daily Pattern approach. StateMod calculates each day's baseflow by disaggregating monthly baseflows using the daily pattern of flow at selected historical gages. These "pattern gages" are representative of baseflows in subbasins throughout the San Juan and Dolores River basins.

Monthly Baseline demands were disaggregated to daily demands by connecting the midpoints of the monthly demand data. Reservoir targets were disaggregated by connecting the end points of monthly target data. Instream flow demands were disaggregated by setting them to the average daily value. Daily return flow delay patterns were used. The operating rights file is the same file used in the monthly Baseline simulation.

## 8.1    Daily Baseline Data Set

This section describes unique StateMod input files in the Daily Baseline Data Set. The data set is expected to be a starting point for users who want to apply the San Juan Model to a particular management issue on a daily basis. As with the monthly Baseline Data set, the investigator may want to understand how the river regime would change under a new use or different operations. The change needs to be quantified relative to how the river would look today absent the new use or different operation, which may be quite different from the historical record. The Daily Baseline data set provides a basis against which to compare future scenarios. Users may opt to modify the Daily Baseline data set for their own interpretation of current or near-future conditions.

The daily Baseline data set, and corresponding daily results, does not include any consideration for Colorado River Compact obligations, nor are conditional water rights represented in the daily Baseline data set. The La Plata Compact obligations, however, are represented in the simulation. Variations of the daily Baseline data set could include conditional rights within the San Juan and Dolores River basins, and would likely result in less available flow than presented here.

The following detailed, file-by-file description is intended to provide enough detail that this can be done with confidence. Only files that are different from the Baseline Data Set are described here. Other Baseline Data Set files are described in Section 5.

This section is divided into the following subsections:

- Section 8.1.1 describes the response file, which simply lists names of the rest of the data files. The section tells briefly what is contained in each of the named files, and whether they are different in the Daily Baseline data set.

- Section 8.1.2 describes the control file, which sets the execution parameter for the daily simulation.

- Section 8.1.3 describes the two streamflow files that define the disaggregation of monthly baseflow files.

- Section 8.1.4 includes files that define the methodology for disaggregating monthly demands and reservoir targets for the daily simulation.

- Section 8.1.5 describes the daily return flow delay pattern file.

**Where to find more information**

- The CDSS Technical memorandum "CDSS Daily Yampa Model – Task 2 Pilot Study" described the investigation into StateMod's daily modeling approaches and the recommended approach for subsequent daily modeling of CDSS basins.

- For generic information on every daily input file listed below, see the StateMod documentation. It describes how input parameters are used, as well as format of the files.

- The input files used in both the Baseline data set and the Daily Baseline data set are described in detail in Section 5 – Baseline Data Set.

### 8.1.1.        Response File (*.rsp)

The response file (sjdlyB.rsp) contains the names of all other data files required to run the model. New file names have been used for the files that are used only in daily modeling. The file is changed by hand-editing. Many files are used in both the monthly Baseline and Daily Baseline simulations and the applicable sections are referenced.

| File Name | Description | Reference |
|-----------|-------------|-----------|
| sjdly.ctl | Control file – specifies execution parameters, such as run title, modeling period, options switches | Section 8.1.2 |
| sj2004.rin | River network file – lists every model node and specifies connectivity of network | Section 5.3.1 |
| sj2004B.res | Reservoir station file – lists physical reservoir characteristics such as volume, area-capacity table, and some administration parameters | Section 5.6.1 & Section 8.1.4 |
| sj2004B.dds | Direct diversion station file – contains parameters for each diversion structure in the model, such as diversion capacity, return flow characteristics, and irrigated acreage served | Section 5.4.1 & Section 8.1.4 |
| sj2004.ris | River station file – lists model nodes, both gaged and ungaged, where hydrologic inflow enters the system | Section 5.3.2 & Section 8.1.3 |
| sj2004.ifs | Instream flow station file – lists instream flow reaches | Section 5.7.1 |
| sj2004.ifr | Instream flow right file – gives decreed amount and administration number of instream flow rights associated with instream flow reaches | Section 5.7.3 |
| sj2004.rer | Reservoir rights file – lists storage rights for all reservoirs | Section 5.6.5 |
| sj2004.ddr | Direct diversion rights file – lists water rights for direct diversion | Section 5.4.5 |
| sj2004B.opr | Operational rights file – specifies many different kinds of operations that are more complex than a direct diversion or an onstream storage right. Operational rights can specify, for example, a reservoir release for delivery to a downstream diversion point, a reservoir release to allow diversion by exchange at a point which is not downstream, or a direct diversion to fill a reservoir via a feeder | Section 5.8 |
| sj2004.eva | Evaporation file – gives monthly rates for net evaporation from free water surface | Section 5.6.2 |
| sj2004x.xbm | Baseflow data file – time series of undepleted flows at all nodes listed in *sj2004.ris* | Section 5.3.5 |
| sj2004B.ddm | Monthly demand file – monthly time series of headgate demands for each direct diversion structure | Section 5.4.4 |
| sj2004.ifa | Instream flow demand file – gives the decreed monthly instream flow rates | Section 5.7.2 |
| sj2004.dly | Delay Table – contains several return flow patterns that express how much of the return flow accruing from diversions in one month reach the stream in each of the subsequent months, until the return is extinguished | Section 5.4.2 |
| sj2004B.tar | Reservoir target file – monthly time series of maximum and minimum targets for each reservoir. A reservoir  may not store above its maximum target, and may not release below the | Section 5.6.4 |

| File Name | Description | Reference |
|---|---|---|
| | minimum target | |
| sj2004.ipy | CU Irrigation Parameter Yearly file – maximum efficiency and irrigated acreage by year and by structure, for variable efficiency structures | Section 5.5.2 |
| sj2004B.iwr | Irrigation Water Requirement file – monthly time series of crop water requirement by structure, for variable efficiency structures | Section 5.5.3 |
| sj2004.str | CU Structure file – soil moisture capacity by structure, for variable efficiency structures | Section 5.5.1 |
| sj2004.eom | Reservoir End of month contents file – Monthly time series of historical reservoir contents | Section 5.6.3 |
| sj2004.rib | Baseflow Parameter file – gives coefficients and related gage ID's for each baseflow node, with which StateMod computes baseflow gain at the node | Section 5.3.3 |
| sj2004.rih | Historical streamflow file – Monthly time series of streamflows at modeled gages | Section 5.3.4 |
| sj2004.ddh | Historical Diversions – Monthly time series of historical diversions | Section 5.4.3 |
| sj2004.gis | GIS file | N/a |
| sj2004.out | Output control file | N/a |
| sj2004.rid | Daily historical streamflow file | Section 8.1.3 |
| sj2004.dld | Daily return flow delay pattern file | Section 8.1.5 |

### 8.1.2. Control File

The control file, which is created and maintained by editing manually, contains information that controls the model simulation. Only one change was made to the monhly Baseline control file. The *iday* variable was set to "1" to indicate the simulation should be performed using a daily time-step.

### 8.1.3. River System Files

The daily pattern approach can be described as distributing monthly baseflows to daily baseflows based on the daily distribution of selected historical gages, or pattern gages. Statemod disaggregates the monthly baseflows by multiplying the daily historical gage flow $QD_{gage}$ by the factor $QM_{bf}/QM_{gage}$, where $QM_{bf}$ is the monthly baseflow and $QM_{gage}$ is the monthly historical gage flow.

Two files work in conjunction to define the daily baseflows used in the Daily Baseline simulations; the river station file (sj2004.ris) and the daily streamflow file (sj2004.rid). The river station file assigns each baseflow node to a representative historical streamflow gage with daily flow records in the daily streamflow file. Representative streamflow gages were identified based on the following criteria:

- Completeness of Daily Records. The streamflow gages within the San Juan Model were reviewed for completeness of daily records over the 1975 through 2003 study period. Note that although the recommended daily modeling period for the CRDSS basins is 1975 through 2003, many streamflow gages in the San Juan and Dolores River basins have continuous records extending from the early 1900s.
- Basin and Baseflow Representation. Representative pattern gages were then selected based on the location and minimal upstream effects. Ideally, pattern gages should closely represent baseflows – they should have minimal influence from upstream diversions or storage. In the San Juan basin this generally means they are relatively upstream on the tributaries.
- Historic Flow and Baseflow Comparison. Average historical monthly flows were compared to the average baseflows calculated using StateMod to quantify the upstream effects and verify the gage selections.

Table 8.1 shows the historical gages selected for use as pattern gages, and their period of record. The daily historic streamflow file (*.rid) contains daily streamflows extracted from HydroBase for these gages. Baseflow nodes in each sub-basin or drainage were assigned to the pattern gages in the river station file (*.ris) as shown. Figure 8.1 displays the assignments of pattern gages.

**Table 8.1**
**Daily Pattern Gages Used for San Juan Model Sub-basins**

| Recommended Pattern Gage | Gage Period of Record | Basin Subdivision Assignment |
|---|---|---|
| 09344000 – Navajo River at Banded Peak Ranch near Chromo | 1937 - 2003 | Navajo River Basin (District 77) |
| 09339900 – East Fork San Juan River above Sand Creek | 1957 - 2003 | San Juan River Basin and Piedra River Basin (Districts 29 & 78) |
| 09352900 – Vallecito Creek near Bayfield | 1963 - 2003 | Los Pinos River Basin and Navajo Reservoir (Districts 31 & 46) |
| 09365500 – La Plata River at Hesperus | 1918 - 2003 | La Plata River Basin (District 33) |
| 09357500 – Animas River near Howardsville | 1936 - 2003 | Animas River Basin (District 30) |
| 09371000 – Mancos River near Towaoc | 1921 - 1943 1952 - 2003 | McElmo Creek Basin and Mancos River Basin (Districts 32 & 34) |
| 09166500 – Dolores River at Dolores | 1922 - 2003 | Paradox Creek, Disappointment Creek, and West Dolores Creek Basins (Districts 61, 69, & 71) |
| 09172500 – San Miguel River near Placerville | 1931 - 1934 1942 - 2003 | San Miguel River Basin and Dolores River Basin (Districts 60 & 63) |

**Where to find more information**

- Documentation for **StateDMI** describes the assignments of pattern gages to baseflow nodes.

- The StateMod documentation describes the procedure used to disaggregate monthly baseflows to daily baseflows.

- Appendix C includes a memorandum describing the task in which pattern gages were selected for the daily San Juan/Dolores modeling efforts.
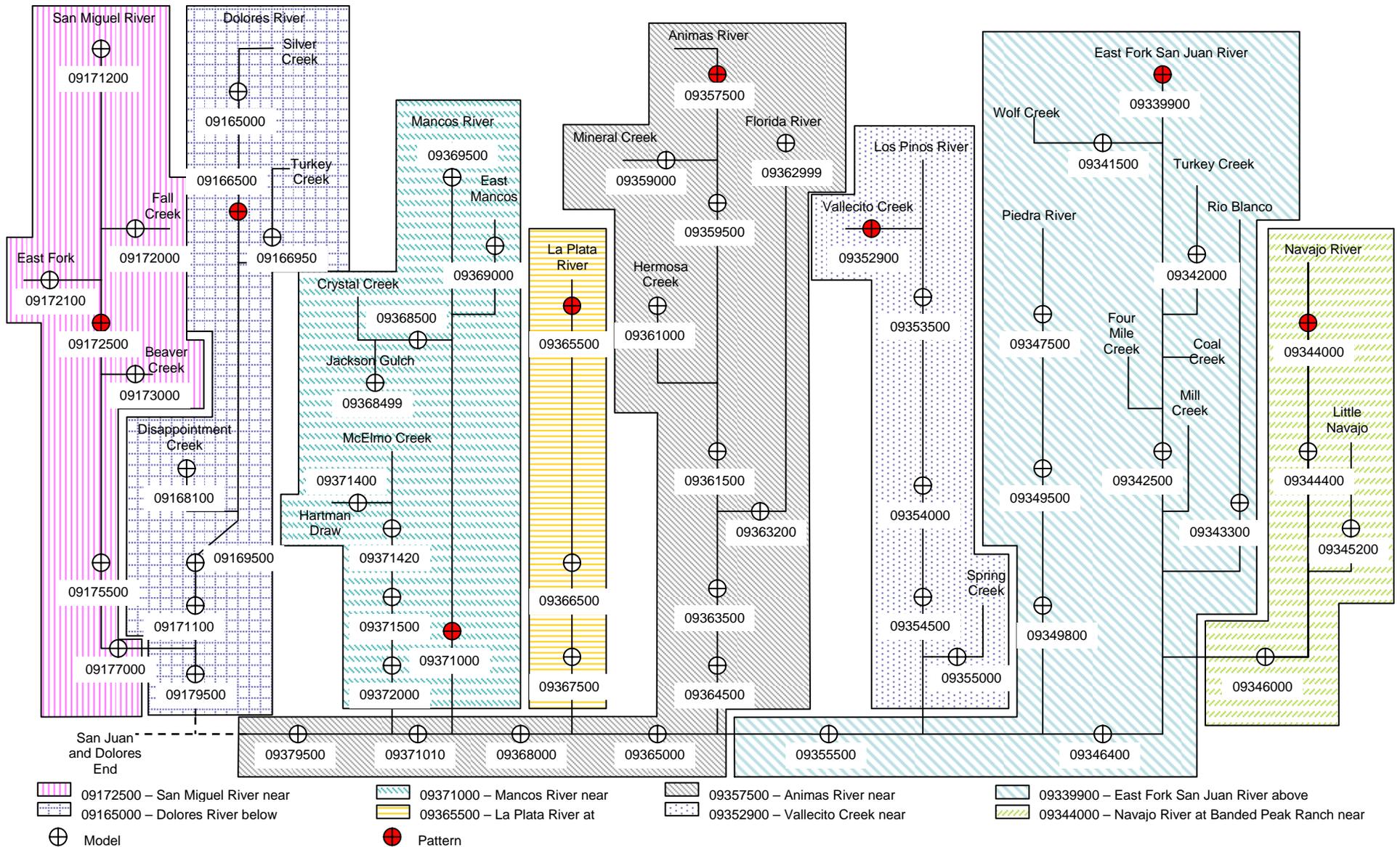
**Figure 8.1 – Recommended Application of Daily Pattern Gages**

### 8.1.4.　　　　Daily Demands and Reservoir Targets

The daily flag variable (*cdividy)* was set equal to "4" for all diversion stations in the direct
diversion station file (sj2004.dds). This flag instructs StateMod, while in daily simulation mode,
to disaggregate the monthly diversion demands found in the diversion demand file
(sj2004B.ddm) by connecting the midpoints of the monthly data.

The daily flag variable (*cresidy* ) was set equal to "5" for all reservoirs in the Baseline reservoir
station file (sj2004B.res).  This flag instructs StateMod, while in daily simulation mode, to
develop daily targets by linearly "connecting" monthly reservoir targets found in the reservoir
target file (sj2004B.tar).

The daily flag variable (*cifrdy*) was set equal to "0" for all instream flow nodes in the instream
flow station file (sj2004.ifs).  This flag instructs StateMod, while in daily simulation mode, to
disaggregate the monthly instream flow demand found in the monthly annual instream flow file
(sj2004.ifa) to daily values by setting them to the average daily value.

Note that the variables described in this section are set when developing the monthly Baseline
data set, but are only used by StateMod when the daily option is selected in the control file.

### 8.1.5.　　　　Daily Return Flow Delay Patterns File

The sj2004.dld file, which is hand-built with a text editor, describes the estimated re-entry of
return flows into the river system on a daily basis. They are the daily equivalent of the monthly
return flow patterns used in the Baseline simulation.

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**Where to find more information**

- CDSS Memorandum "Colorado River Basin Representative Irrigation Return
  Flow Patterns", Leonard Rice Engineers, January, 2003. *(Technical Papers)*

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## 8.2　Daily Baseline Streamflows

Table 8.2 shows, for each gage, the average annual available flow from the Daily Baseline simulation
compared to the average annual available flow from the Monthly Baseline simulation, based on the same
simulation period (1975 through 2003).  Available flow at a point is water that is not needed to satisfy
instream flows or downstream diversion demand; it represents the water that could be diverted by a new
water right. Daily simulation better represents large flow events that occur within a monthly time step.
and in general, available flow is greater for the daily simulation than the monthly simulation.  Junior

diverting structures can take advantage of these flows even if they are out-of-priority for much of the month.

Temporal variability of the Daily Baseline and Monthly Baseline simulated flows are illustrated in Figures 8.2 through 8.40 for three selected years for each of the daily pattern gages and for five additional downstream gages; San Juan River at Pagosa Springs, Piedra River near Arboles, Los Pinos River at La Boca, McElmo Creek near the Colorado-Utah Stateline, and Dolores River at Bedrock. The selected years represent wet (1995), average (1982) and dry (1977) years in the San Juan/Dolores basins. The historical gaged streamflow is also shown on these graphs. As shown, daily simulated streamflow represents the daily large and small flow events that occur within a monthly time step.

On average, Baseline demands are greater than historical demands; representing current levels of municipal and industrial use and full crop irrigation requirements. During the representative wet year, annual basin-wide Baseline demands are about 17 percent higher than historic demands. Simulated flows at the pattern gages, which are not affected by storage, are similar to gaged flows with slight monthly variations. However, simulated flows at gages below Vallecito Reservoirs and below Dolores Project uses vary significantly from gaged flows during the spring and summer months. As discussed in the Monthly Baseline Results (Section 6), Los Pinos gages are affected by the Vallecito Reservoir forecasting curve provided by the USBR to mimic general operations. Baseline simulated flows on lower Dolores River, McElmo Creek, and Mancos River include McPhee Reservoir operations, whereas the dry and average years selected and represented in the gage flow were prior to McPhee Reservoir completion.

During the representative dry year, annual basin-wide Baseline demands are almost 45 percent higher than historic demands. Simulated flows at the gages are lower than historical flows, with the exception of the McElmo Creek gage. Daily baseline simulated flows include return flows from McPhee deliveries that were seen in the historical gage, since McPhee reservoir was not completed until 1985.

## Table 8.2
## Baseline Average Annual Flows for San Juan Model Gages (1975-2003)
## Daily Simulation Compared to Monthly Simulation

| Gage ID | Gage Name | Daily Simulated Available Flow (af) | Monthly Simulated Available Flow (af) | Difference Daily less Monthly (af) | % Difference |
|---|---|---|---|---|---|
| 09339900 | East Fork San Juan River above Sand Creek | 55,912 | 45,430 | 10,482 | 19% |
| 09341500 | West Fork San Juan River near Pagosa Springs | 87,198 | 73,714 | 13,484 | 15% |
| 09342000 | Turkey Creek near Pagosa Springs | 23,097 | 18,316 | 4,781 | 21% |
| 09342500 | San Juan River at Pagosa Springs | 189,590 | 172,932 | 16,657 | 9% |
| 09343300 | Rio Blanco below Blanco Diversion Dam near Pagosa Springs | 7,924 | 3,459 | 4,465 | 56% |
| 09344000 | Navajo River at Banded Peak Ranch near Chromo | 37,722 | 25,517 | 12,205 | 32% |
| 09344400 | Navajo River below Oso Diversion Dam nr Chromo | 38,376 | 26,070 | 12,306 | 32% |
| 09345200 | Little Navajo River below Oso Diversion Dam near Chromo | 1,225 | 615.1 | 610 | 50% |
| 09346000 | Navajo River at Edith | 44,541 | 30,971 | 13,570 | 30% |
| 09346400 | San Juan River near Carracas | 266,294 | 250,290 | 16,004 | 6% |
| 09347500 | Piedra River at Bridge Ranger Sta. near Pagosa Springs | 54,595 | 45,906 | 8,690 | 16% |
| 09349500 | Piedra River near Piedra | 163,177 | 148,047 | 15,130 | 9% |
| 09349800 | Piedra River near Arboles | 197,586 | 184,174 | 13,411 | 7% |
| 09352900 | Vallecito Creek near Bayfield | 29,963 | 27,329 | 2,634 | 9% |
| 09353500 | Los Pinos River near Bayfield | 79,776 | 73,398 | 6,378 | 8% |
| 09354000 | Los Pinos River at Bayfield | 102,290 | 91,120 | 11,170 | 11% |
| 09354500 | Los Pinos River at La Boca | 122,539 | 107,349 | 15,190 | 12% |
| 09355000 | Spring Creek at La Boca | 17,155 | 9,536 | 7,619 | 44% |
| 09355500 | San Juan River near Archuleta | 451,371 | 449,159 | 2,211 | 0% |
| 09357500 | Animas River at Howardsville | 70,195 | 65,557 | 4,638 | 7% |
| 09359000 | Mineral Creek near Silverton | 65,134 | 60,280 | 4,854 | 7% |
| 09359500 | Animas River above Tacoma | 319,659 | 302,798 | 16,861 | 5% |
| 09361000 | Hermosa Creek near Hermosa | 72,937 | 71,747 | 1,190 | 2% |
| 09361500 | Animas River at Durango | 444,076 | 424,599 | 19,477 | 4% |
| 09362999 | Florida River above Lemon Reservoir (USBR data) | 6,652 | 5,657 | 994 | 15% |
| 09363200 | Florida River at Bondad | 41,822 | 39,994 | 1,828 | 4% |

| Gage ID | Gage Name | Daily Simulated Available Flow (af) | Monthly Simulated Available Flow (af) | Difference Daily less Monthly (af) | % Difference |
|---|---|---|---|---|---|
| 09363500 | Animas River near Cedar Hill, NM | 472,110 | 451,914 | 20,196 | 4% |
| 09364500 | Animas River at Farmington, NM | 479,437 | 459,456 | 19,982 | 4% |
| 09365000 | San Juan River at Farmington, NM | 769,592 | 766,419 | 3,172 | 0% |
| LONREDCO | Long Hollow at the Mouth near Red Mesa | 4,457 | 3,282 | 1,176 | 26% |
| 09365500 | La Plata River at Hesperus | 2,863 | 2,496 | 366 | 13% |
| 09366500 | La Plata River at CO-NM State Line | 13,115 | 11,928 | 1,187 | 9% |
| 09367500 | La Plata River near Farmington, NM | 22,416 | 20,014 | 2,403 | 11% |
| 09368000 | San Juan at Shiprock | 838,651 | 837,859 | 793 | 0% |
| 09369500 | Middle Mancos River near Mancos | 4,559 | 3,981 | 577 | 13% |
| 09369000 | East Mancos River near Mancos | 5,519 | 4,553 | 967 | 18% |
| 09368499 | Above Jackson Gulch Reservoir (USBR data) | 1,982 | 856 | 1,127 | 57% |
| 09368500 | West Mancos River near Mancos | 9,003 | 7,145 | 1,858 | 21% |
| 09371000 | Mancos River near Towaoc | 30,821 | 28,859 | 1,962 | 6% |
| 09371010 | San Juan River at Four Corners | 8,462 | 7,372 | 1,091 | 13% |
| 09371400 | Hartman Draw at Cortez | 20,901 | 19,002 | 1,899 | 9% |
| 09371420 | McElmo Creek above Alkali Canyon near Cortez | 29,620 | 29,088 | 532 | 2% |
| 09371500 | McElmo Creek near Cortez | 42,244 | 43,483 | -1,239 | -3% |
| 09372000 | McElmo Creek near CO-UT State Line | 936,523 | 935,415 | 1,108 | 0% |
| 09379500 | San Juan River near Bluff | 1,423,079 | 1,422,525 | 554 | 0% |
| 09165000 | Dolores River below Rico | 36,603 | 33,532 | 3,070 | 8% |
| 09166500 | Dolores River at Dolores | 81,127 | 76,657 | 4,470 | 6% |
| 09166950 | Lost Canyon Creek near Dolores | 5,573 | 5,272 | 301 | 5% |
| 09168100 | Disappointment Creek near Dove Creek | 11,800 | 11,449 | 351 | 3% |
| 09169500 | Dolores River at Bedrock | 148,043 | 143,698 | 4,345 | 3% |
| 09171100 | Dolores River near Bedrock | 155,530 | 151,245 | 4,284 | 3% |
| 09171200 | San Miguel River near Telluride | 43,521 | 43,123 | 398 | 1% |
| 09172000 | Fall Creek near Fall Creek | 10,317 | 9,955 | 362 | 4% |
| 09172100 | Leopard Creek at Noel | 1,225 | 1,136 | 89 | 7% |
| 09172500 | San Miguel River near Placerville | 147,440 | 146,694 | 746 | 1% |
| 09173000 | Beaver Creek near Norwood | 6,707 | 6,641 | 66 | 1% |

| Gage ID | Gage Name | Daily Simulated Available Flow (af) | Monthly Simulated Available Flow (af) | Difference Daily less Monthly (af) | % Difference |
|---|---|---|---|---|---|
| 09175500 | San Miguel River at Naturita | 212,004 | 211,665 | 340 | 0% |
| 09177000 | San Miguel River at Uravan | 244,336 | 244,373 | -36 | 0% |
| 09179500 | Dolores River at Gateway | 491,800 | 487,460 | 4,340 | 1% |



**USGS Gage 09344000 - Navajo River at Banded Peak Ranch near Chromo**
**Monthly and Daily Baseline Simulation Flows - Wet Year 1995**
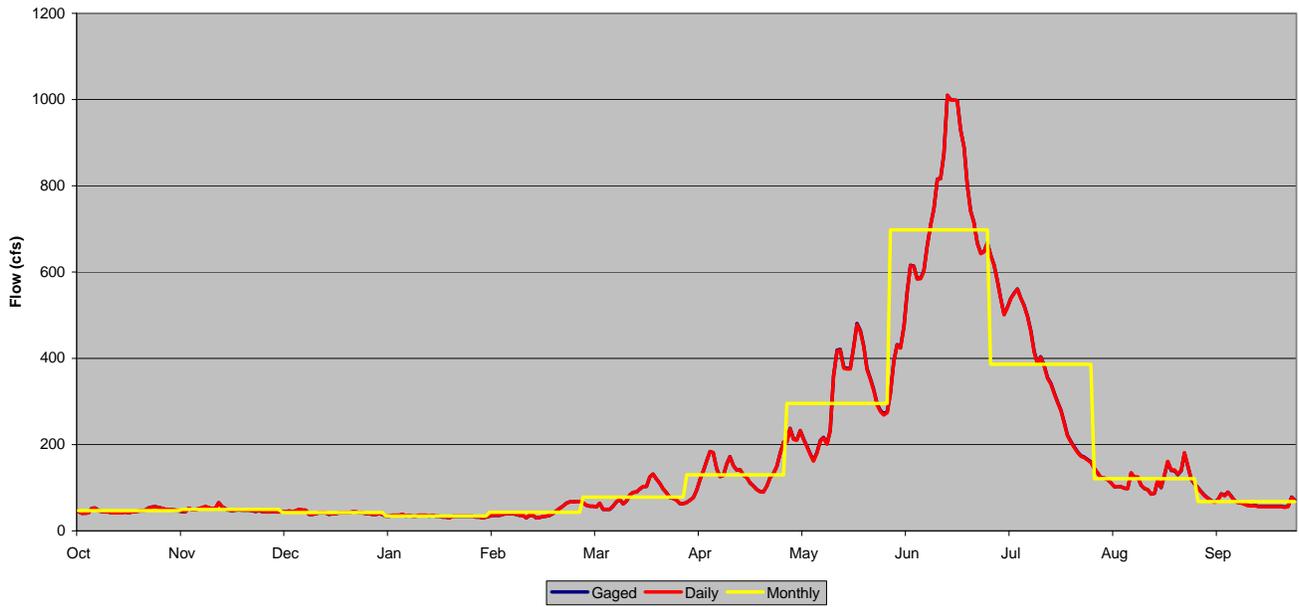
**Figure 8.2 Daily Baseline Comparison, Wet Year – Navajo River at Banded Peak Ranch**

**USGS Gage 09339900 - East Fork San Juan River above Sand Creek
Monthly and Daily Baseline Simulation Flows - Wet Year 1995**
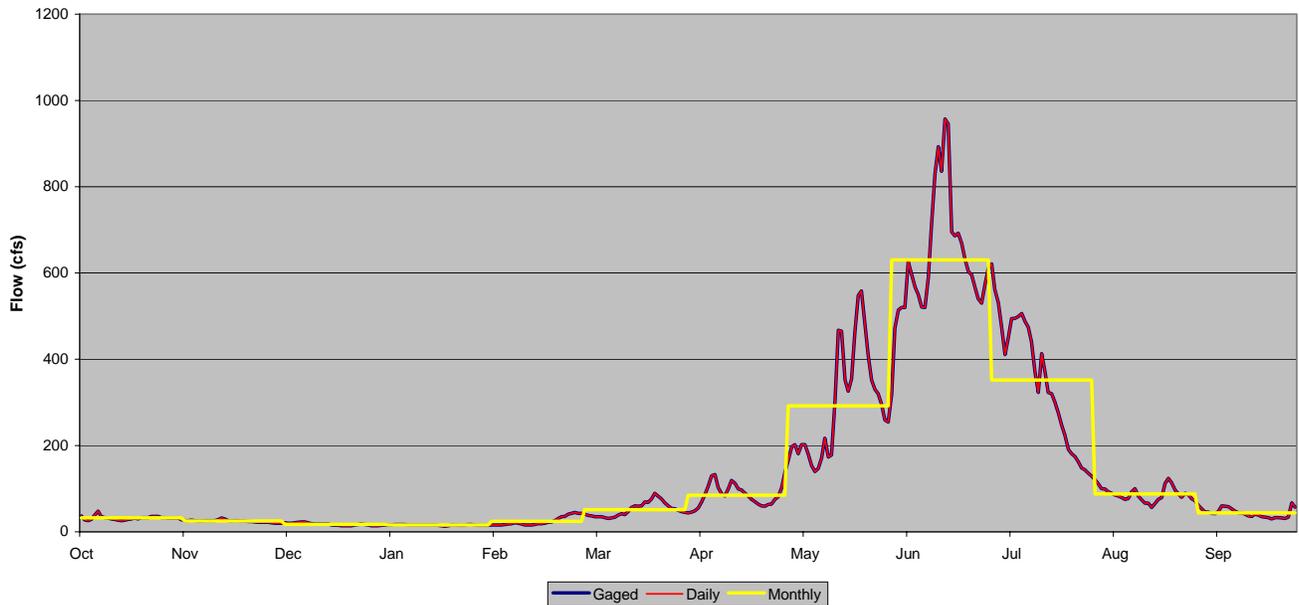
**Figure 8.3 Daily Baseline Comparison, Wet Year – East Fork San Juan above Sand Creek**



**USGS Gage 09342500 - San Juan River at Pagosa Springs
Monthly and Daily Baseline Simulation Flows - Wet Year 1995**
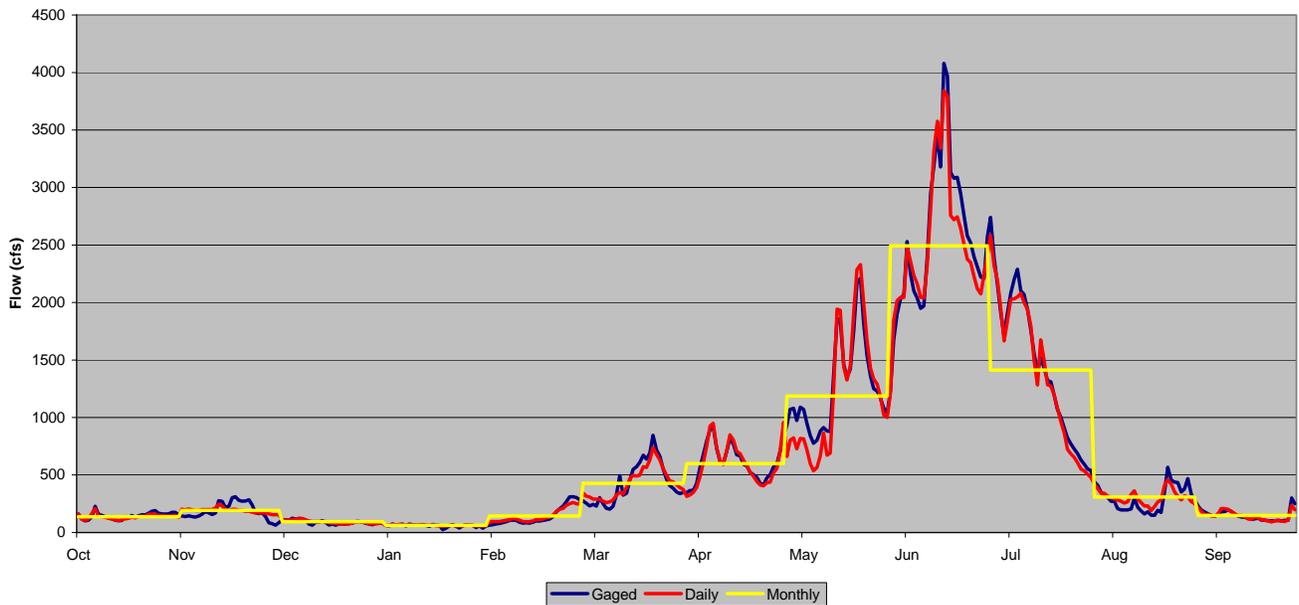
**Figure 8.4 Daily Baseline Comparison, Wet Year – San Juan River at Pagosa Springs**

**USGS Gage 09349800 - Piedra River near Arboles**
**Monthly and Daily Baseline Simulation Flows - Wet Year 1995**
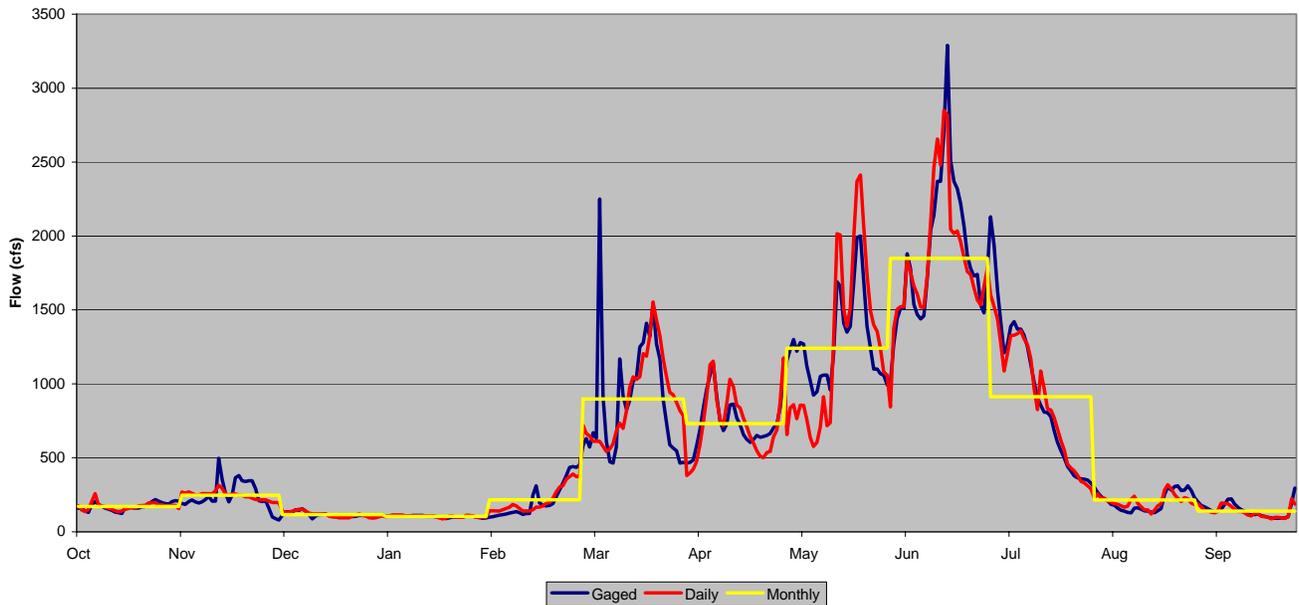


**Figure 8.5 Daily Baseline Comparison, Wet Year – Piedra River near Arboles**

**USGS Gage 09354500 - Los Pinos River at La Boca**
**Monthly and Daily Baseline Simulation Flows - Wet Year 1995**
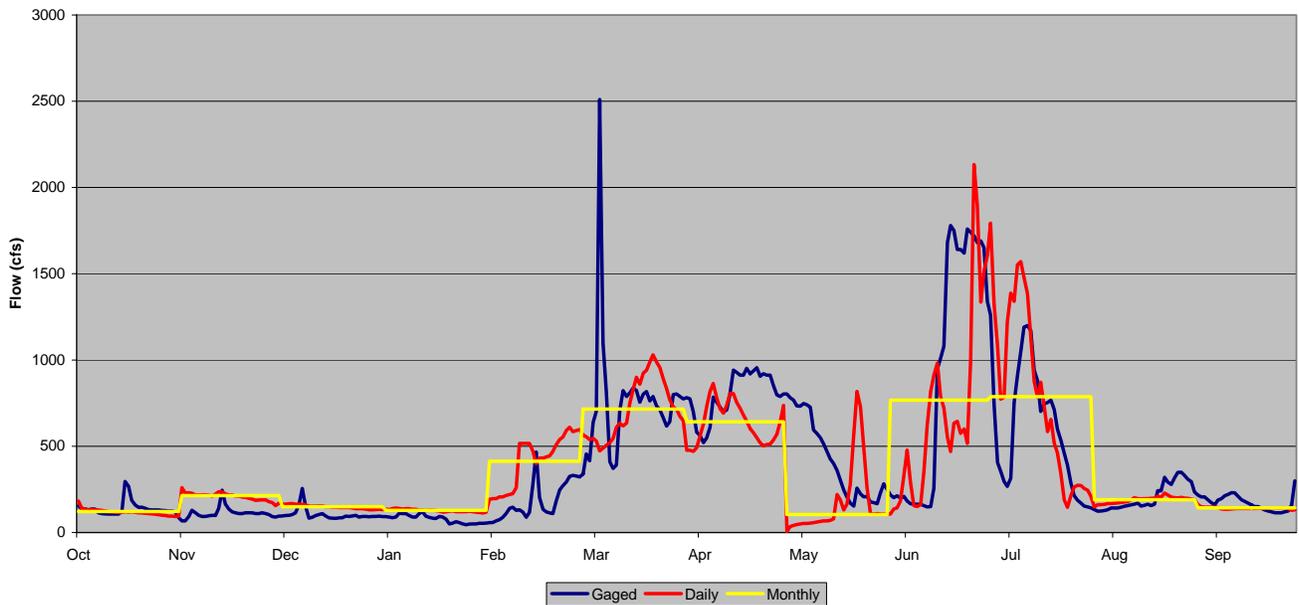


**Figure 8.6 Daily Baseline Comparison, Wet Year – Los Pinos River at La Boca**

**USGS Gage 09352900 - Vallecito Creek near Bayfield**
**Monthly and Daily Baseline Simulation Flows - Wet Year 1995**
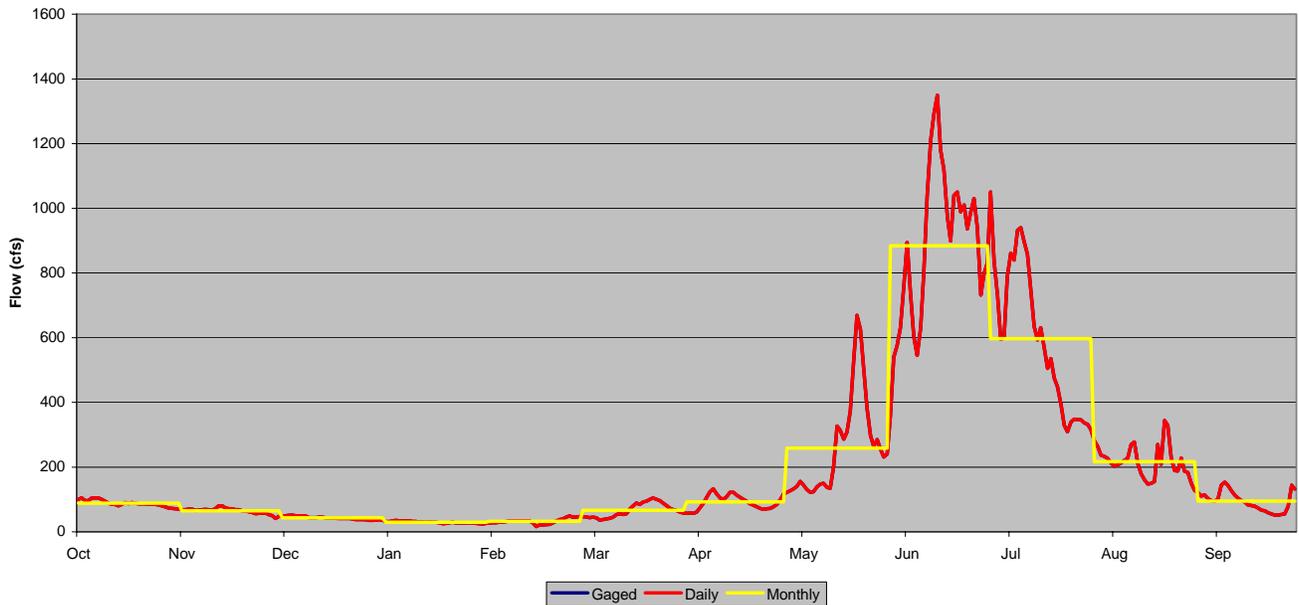
**Figure 8.7 Daily Baseline Comparison, Wet Year – Vallecito Creek near Bayfield**

**USGS Gage 09357500 - Animas River near Howardsville**
**Monthly and Daily Baseline Simulation Flows - Wet Year 1995**
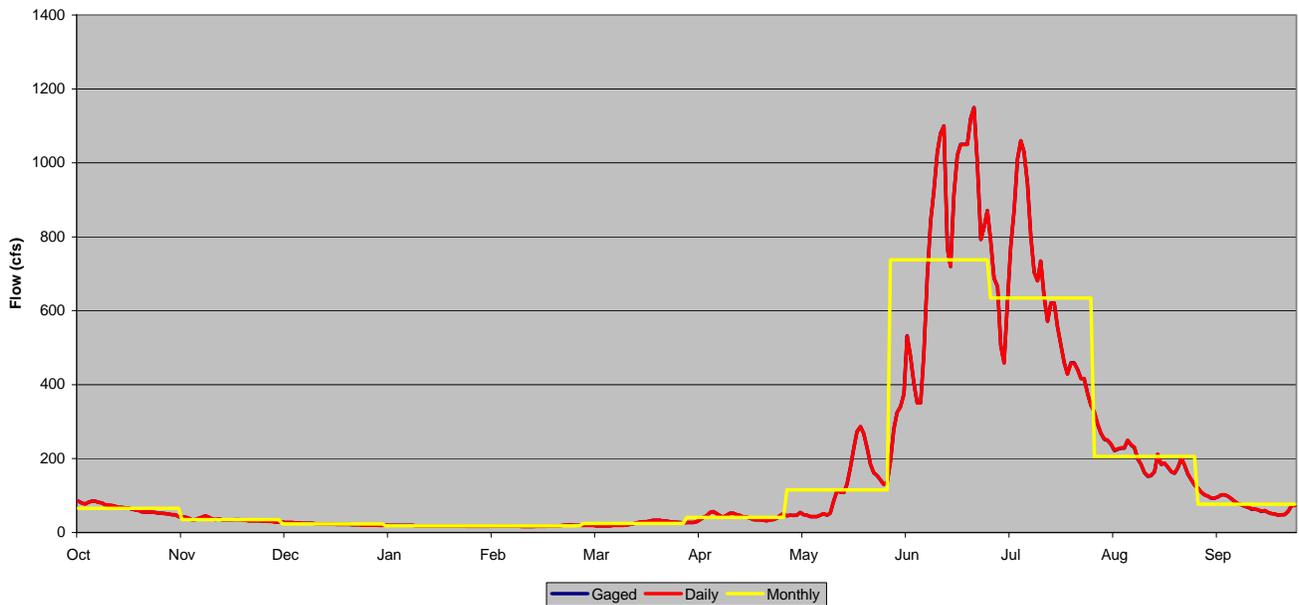
**Figure 8.8 Daily Baseline Comparison, Wet Year – Animas River near Howardsville**

**USGS Gage 09365500 - La Plata River at Hesperus**
**Monthly and Daily Baseline Simulation Flows - Wet Year 1995**
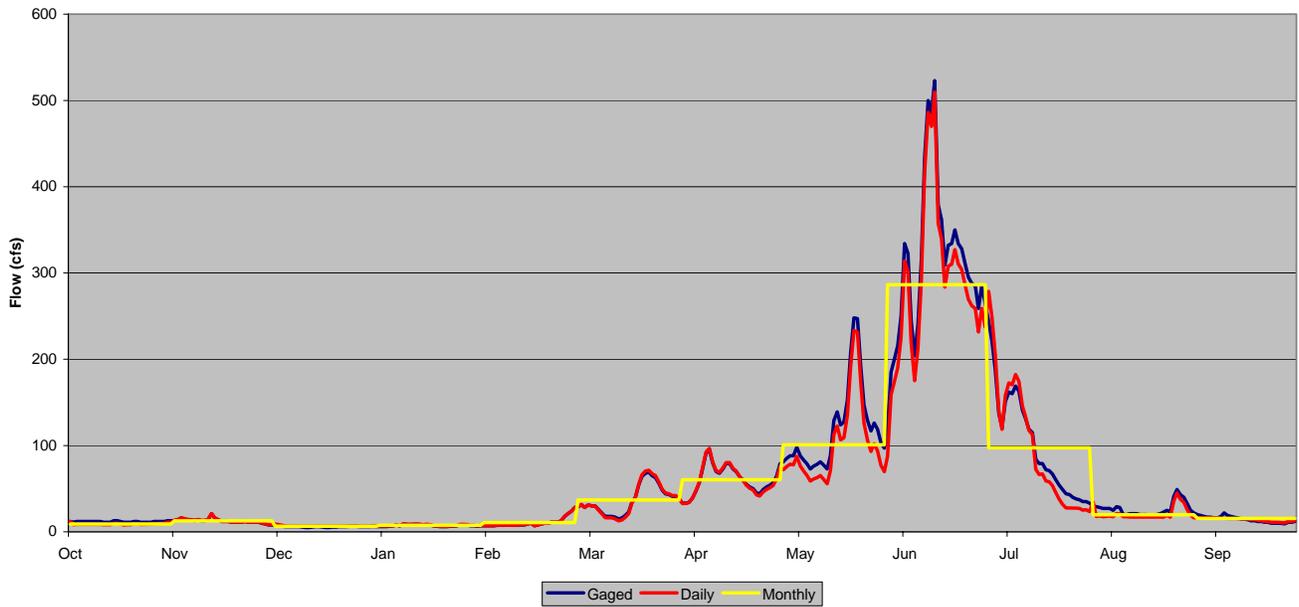


**Figure 8.9 Daily Baseline Comparison, Wet Year – La Plata River at Hesperus**

**USGS Gage 09371000 - Mancos River near Towaoc**
**Monthly and Daily Baseline Simulation Flows - Wet Year 1995**
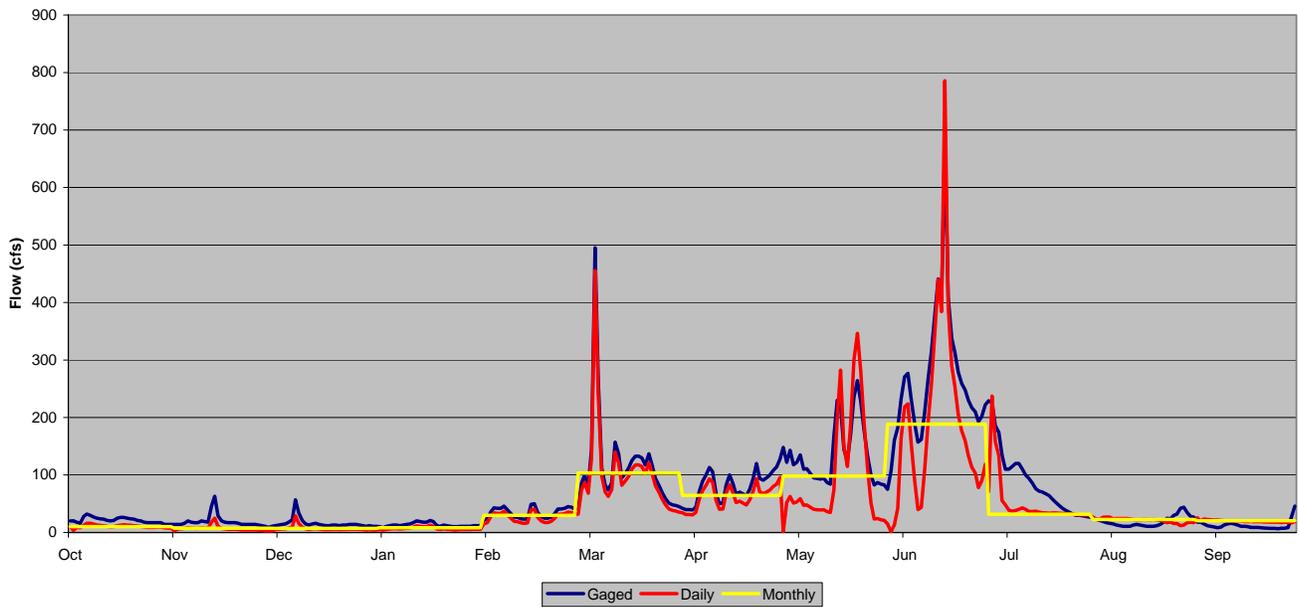


**Figure 8.10 Daily Baseline Comparison, Wet Year – Mancos River near Towaoc**

**USGS Gage 09372000 - McElmo Creek at the Colorado-Utah Stateline**
**Monthly and Daily Baseline Simulation Flows - Wet Year 1995**
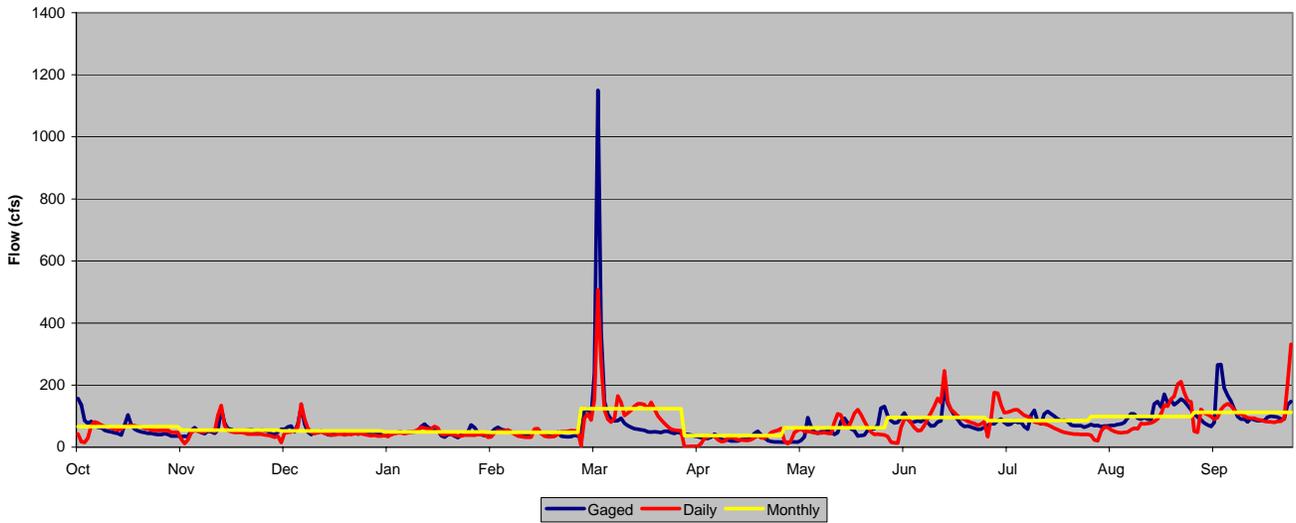
**Figure 8.11 Daily Baseline Comparison, Wet Year – McElmo Creek at CO-UT Stateline**



**USGS Gage 09166500 - Dolores River at Dolores**
**Monthly and Daily Baseline Simulation Flows - Wet Year 1995**
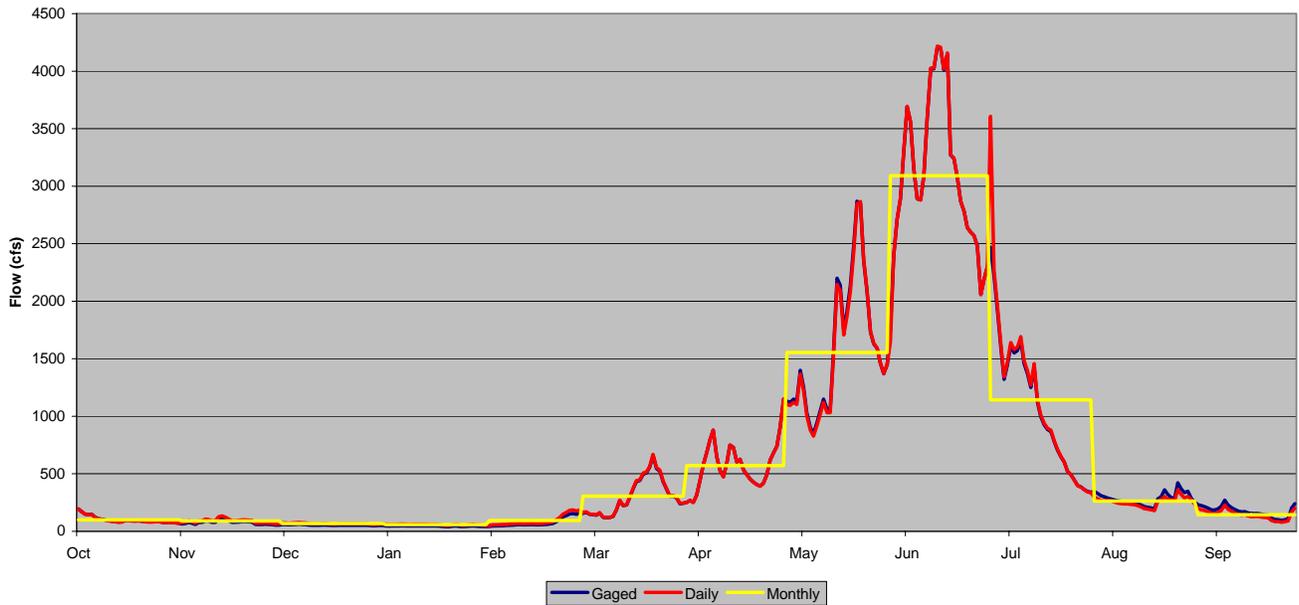
**Figure 8.12 Daily Baseline Comparison, Wet Year – Dolores River at Dolores**

**USGS Gage 09171100 - Dolores River at Bedrock**
**Monthly and Daily Baseline Simulation Flows - Wet Year 1995**
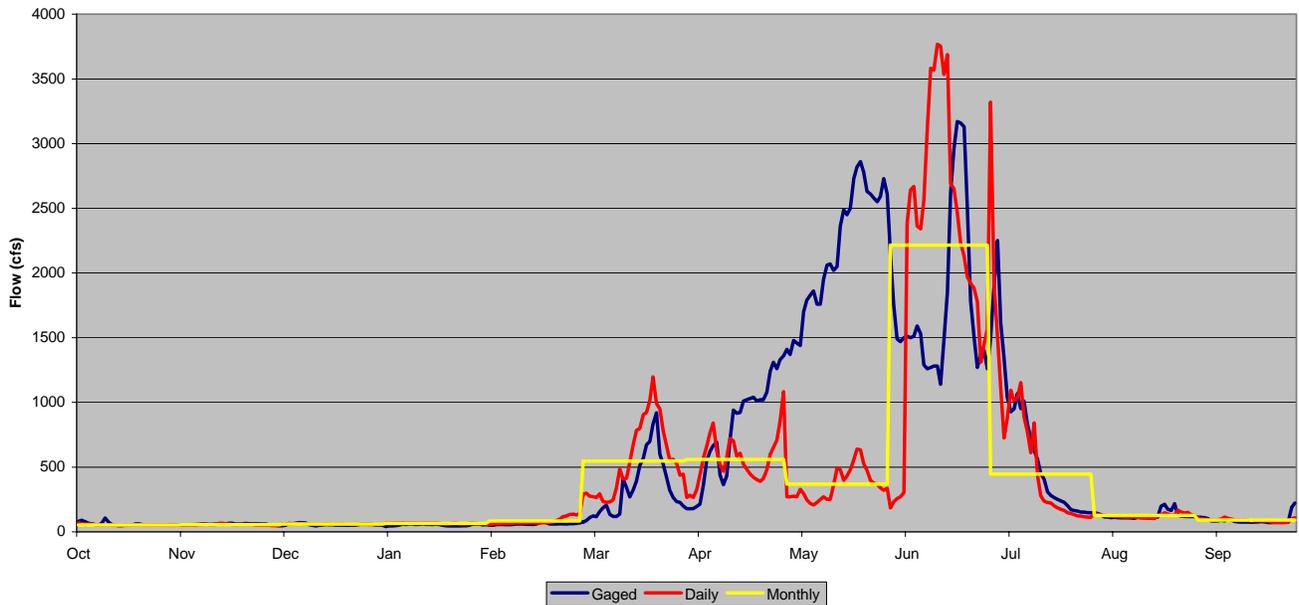
**Figure 8.13 Daily Baseline Comparison, Wet Year – Dolores River at Bedrock**



**USGS Gage 09172500 - San Miguel River near Placerville**
**Monthly and Daily Baseline Simulation Flows - Wet Year 1995**

.
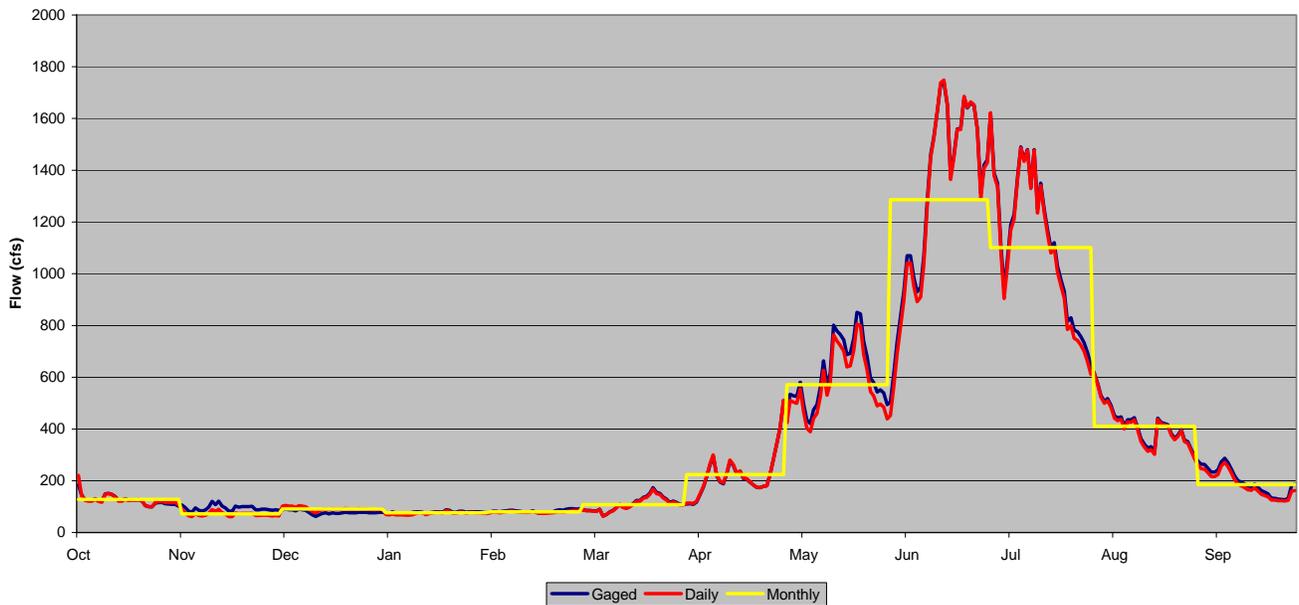
**Figure 8.14 Daily Baseline Comparison, Wet Year – San Miguel River near Placerville**

**USGS Gage 09344000 - Navajo River at Banded Peak Ranch near Chromo**
**Monthly and Daily Baseline Simulation Flows - Average Year 1982**
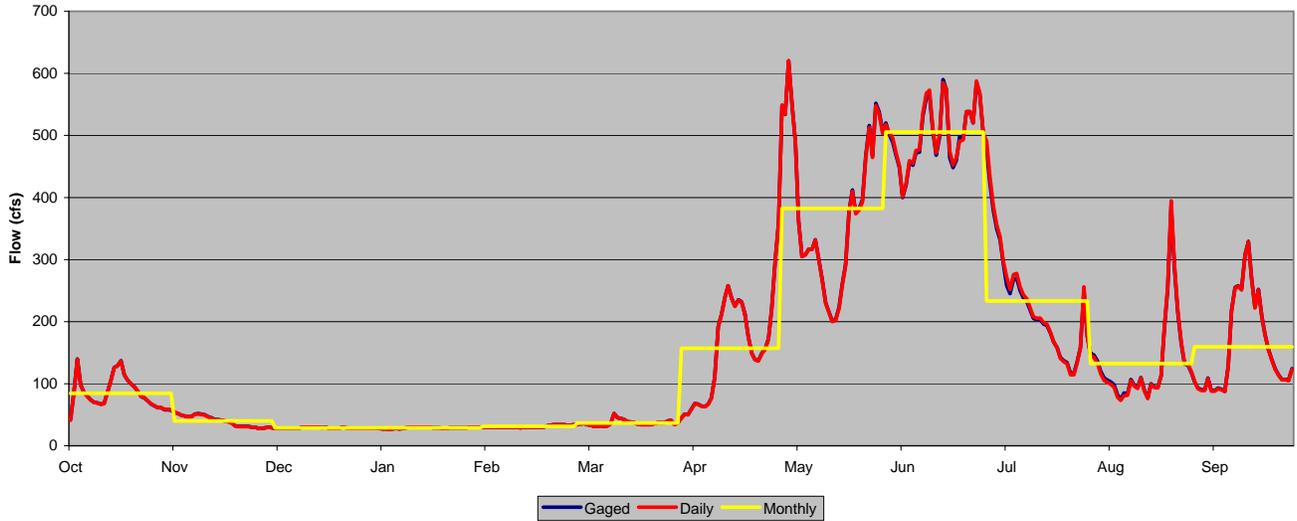
**Figure 8.15 Daily Baseline Comparison, Average Year – Navajo River at Banded Peak Ranch**

**USGS Gage 09339900 - East Fork San Juan River above Sand Creek**
**Monthly and Daily Baseline Simulation Flows - Average Year 1982**
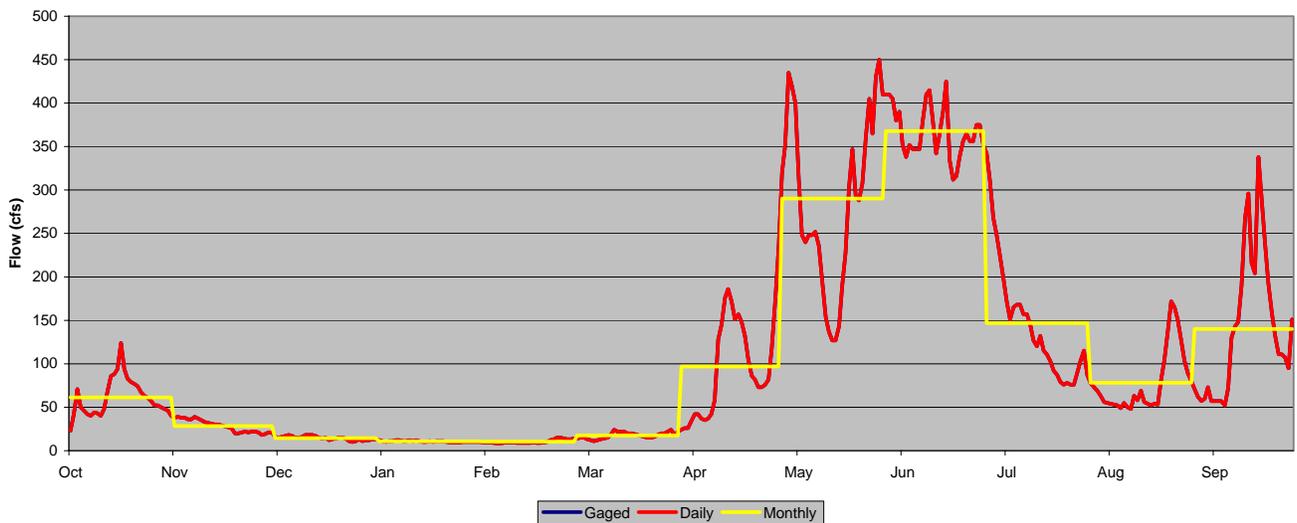
**Figure 8.16 Daily Baseline Comparison, Average Year – East Fork San Juan River ab Sand Creek**

**USGS Gage 09342500 - San Juan River at Pagosa Springs**
**Monthly and Daily Baseline Simulation Flows - Average Year 1982**
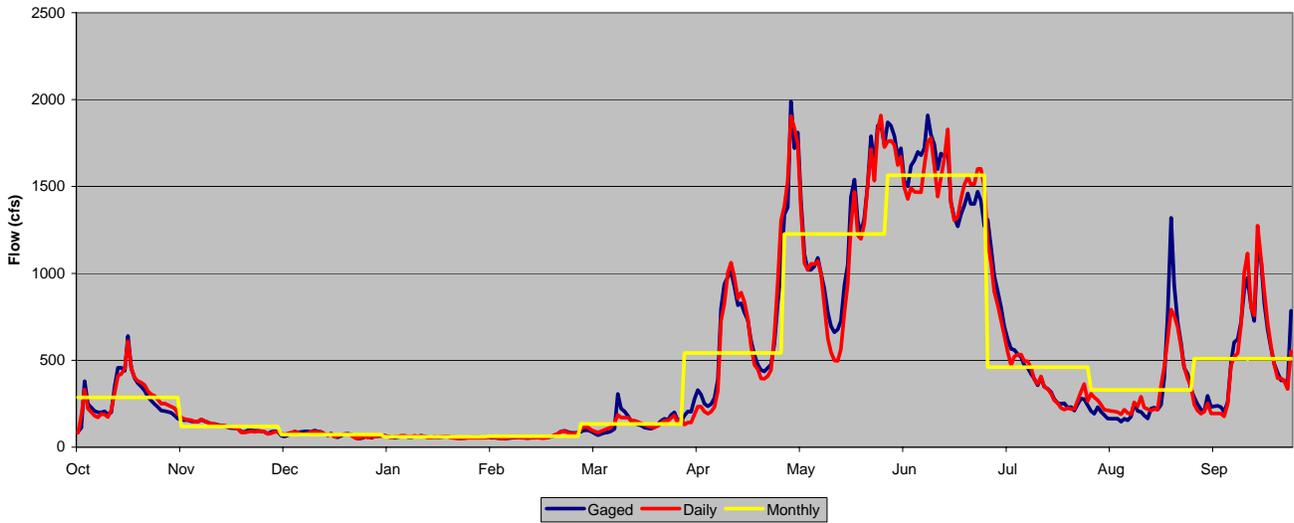


**Figure 8.17 Daily Baseline Comparison, Average Year – San Juan River at Pagosa Springs**

**USGS Gage 09349800 - Piedra River near Arboles**
**Monthly and Daily Baseline Simulation Flows - Average Year 1982**
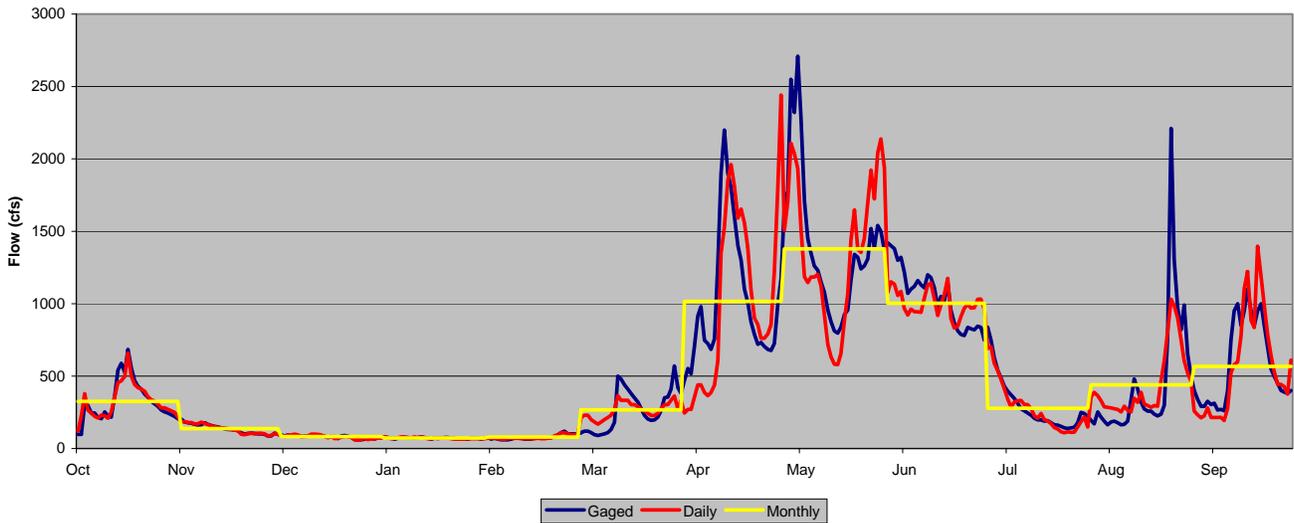


**Figure 8.18 Daily Baseline Comparison, Average Year – Piedra River near Arboles**

**USGS Gage 09354500 - Los Pinos River at La Boca**
**Monthly and Daily Baseline Simulation Flows - Average Year 1982**
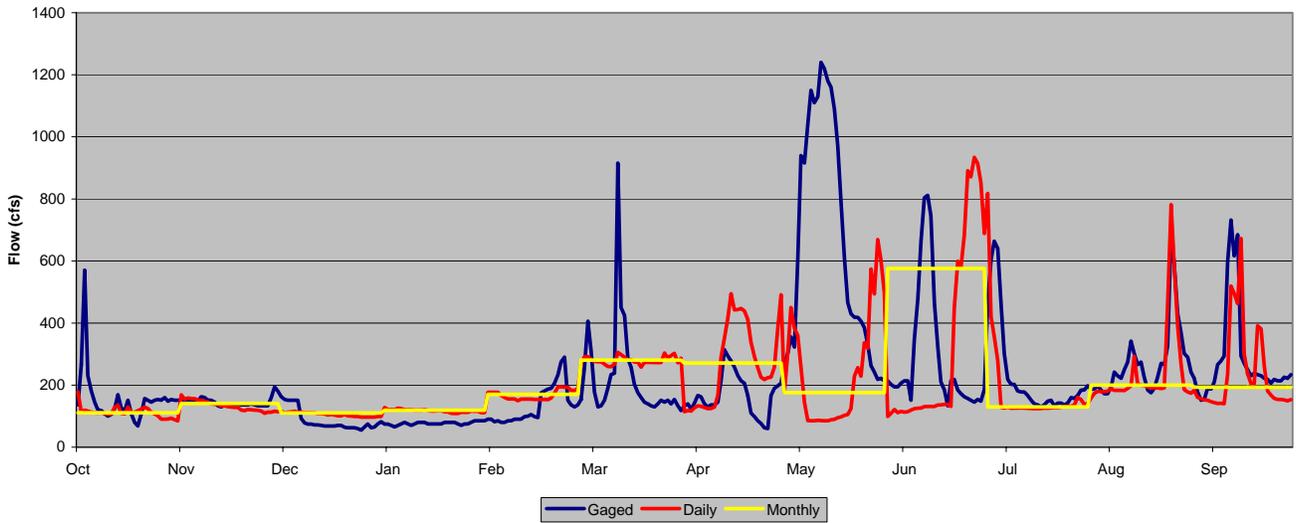
**Figure 8.19 Daily Baseline Comparison, Average Year – Los Pinos River at La Boca**



**USGS Gage 09352900 - Vallecito Creek near Bayfield**
**Monthly and Daily Baseline Simulation Flows - Average Year 1982**
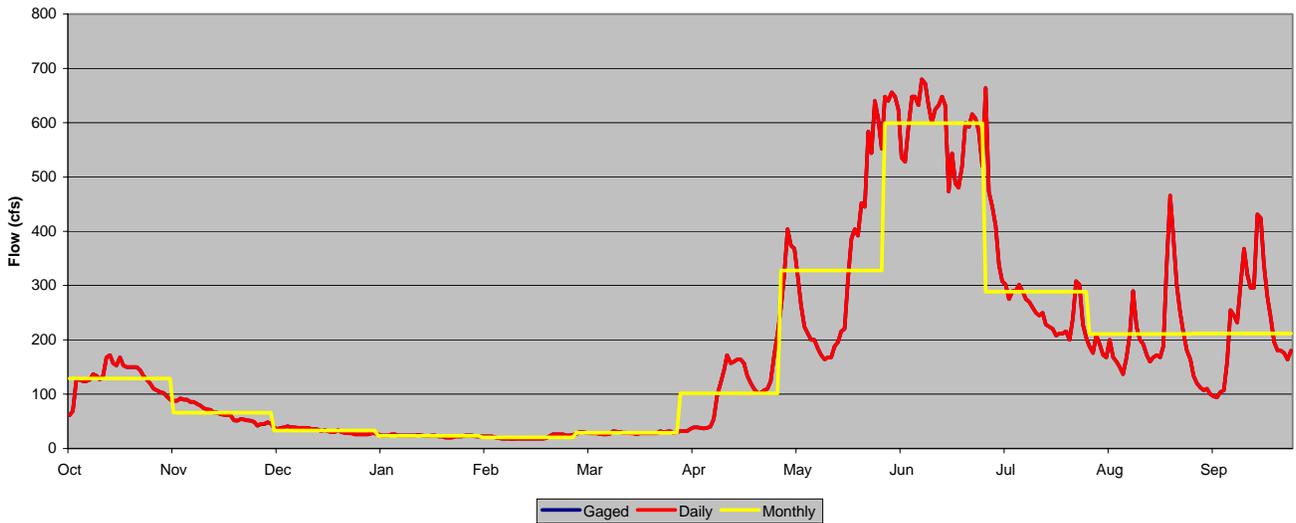
**Figure 8.20 Daily Baseline Comparison, Average Year – Vallecito Creek near Bayfield**

**USGS Gage 09357500 - Animas River near Howardsville**
**Monthly and Daily Baseline Simulation Flows - Average Year 1982**
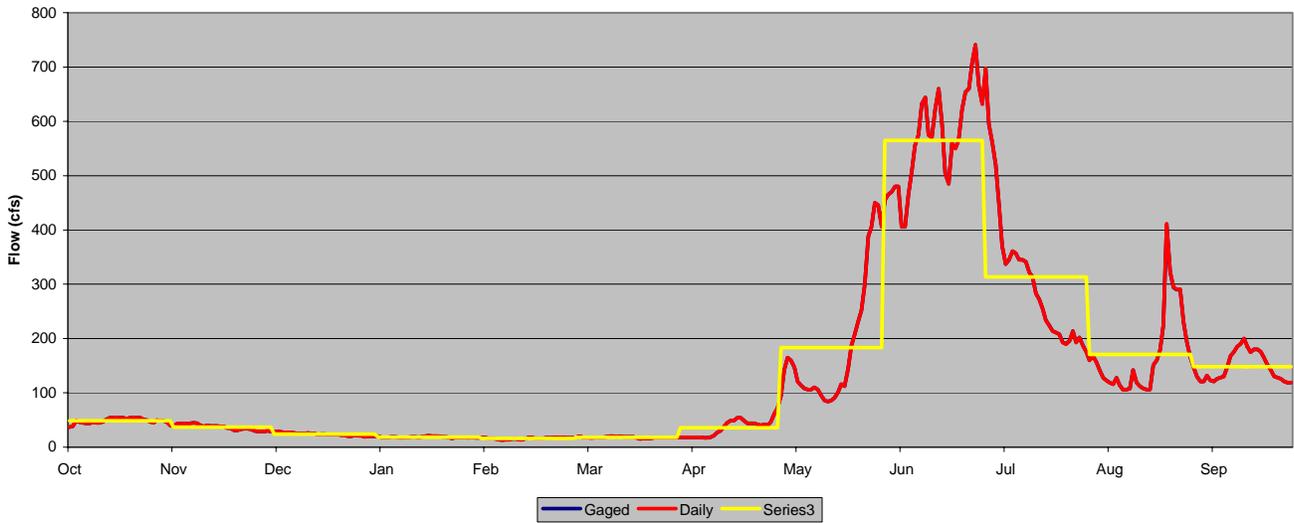
**Figure 8.21 Daily Baseline Comparison, Average Year – Animas River near Howardsville**



**USGS Gage 09365500 - La Plata River at Hesperus**
**Monthly and Daily Baseline Simulation Flows - Average Year 1982**
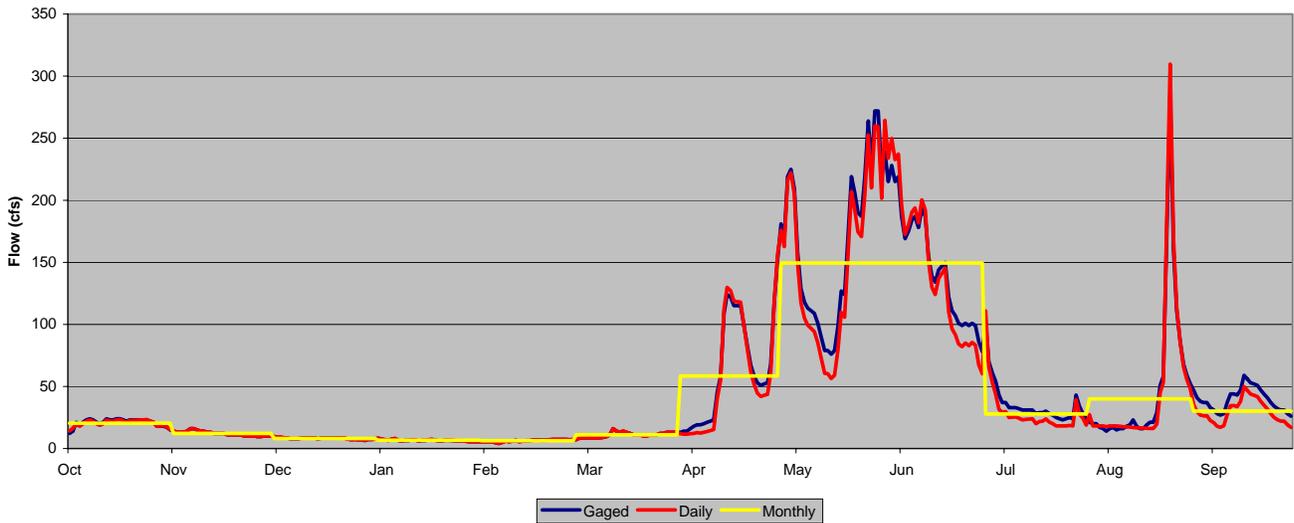
**Figure 8.22 Daily Baseline Comparison, Average Year – La Plata River at Hesperus**

**USGS Gage 09371000 - Mancos River near Towaoc**
**Monthly and Daily Baseline Simulation Flows - Average Year 1982**
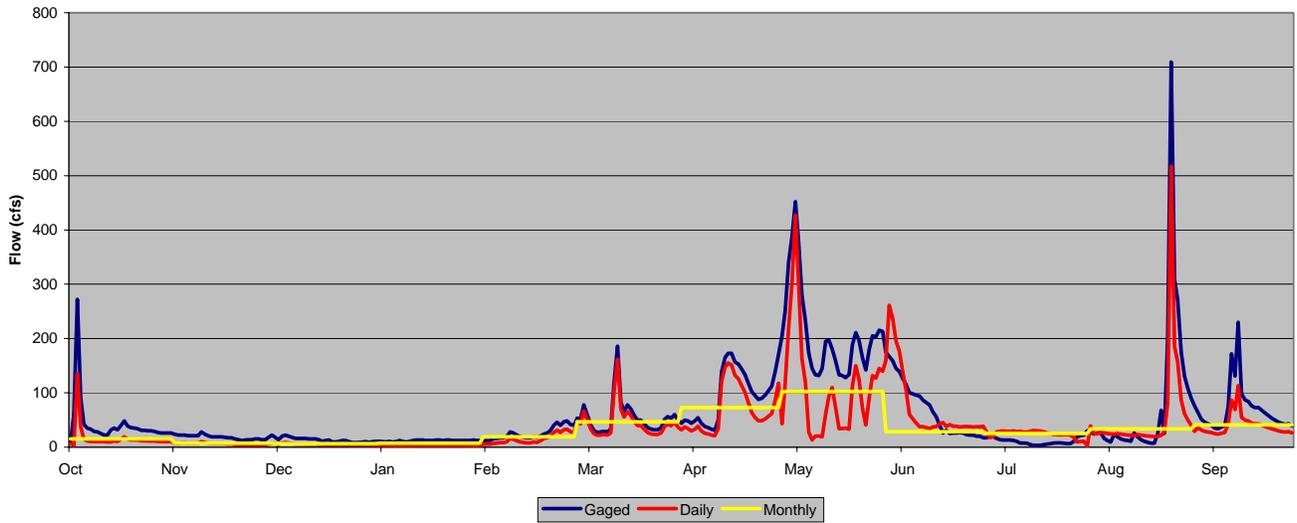


**Figure 8.23 Daily Baseline Comparison, Average Year – Mancos River near Towaoc**

**USGS Gage 09372000 - McElmo Creek at the Colorado-Utah Stateline**
**Monthly and Daily Baseline Simulation Flows - Average Year 1982**
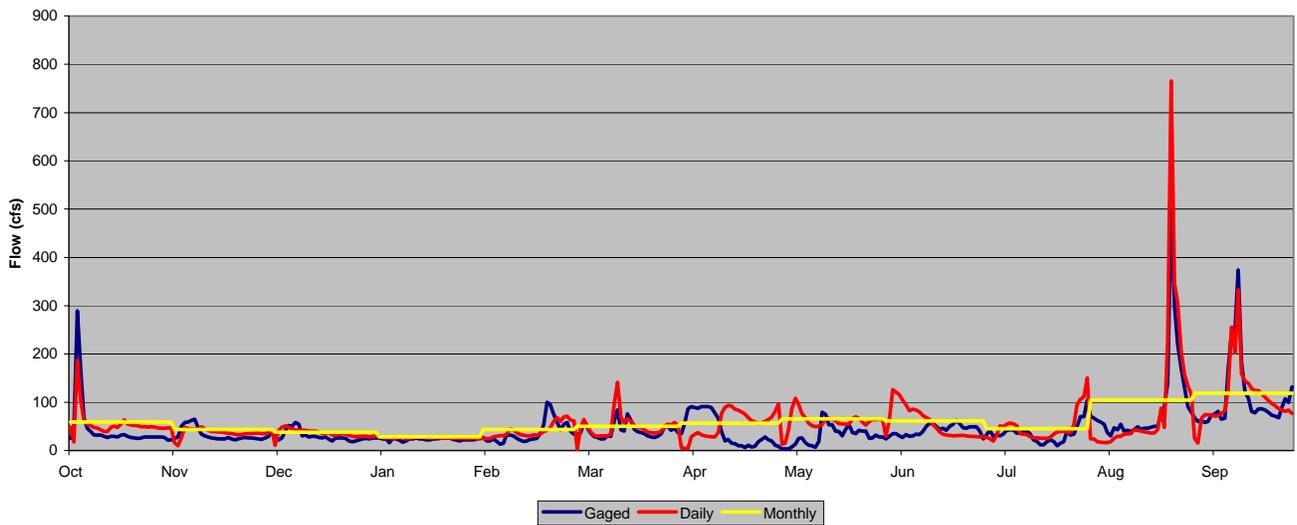


**Figure 8.24 Daily Baseline Comparison, Average Year – McElmo Creek at CO-UT Stateline**

**USGS Gage 09166500 - Dolores River at Dolores**
**Monthly and Daily Baseline Simulation Flows - Average Year 1982**
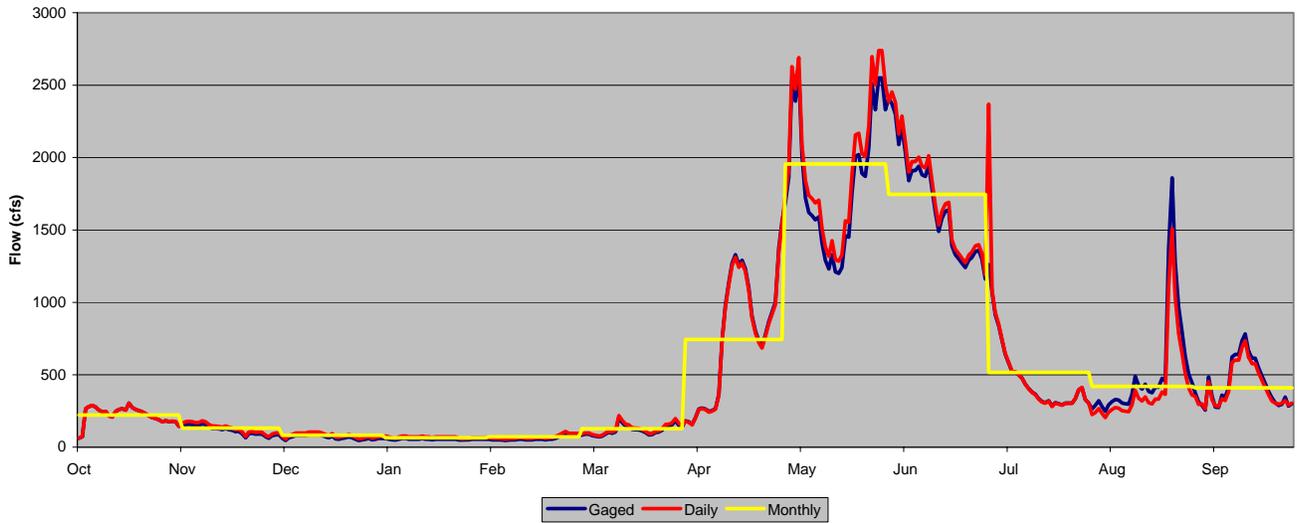
**Figure 8.25 Daily Baseline Comparison, Average Year – Dolores River at Dolores**



**USGS Gage 09171100 - Dolores River at Bedrock**
**Monthly and Daily Baseline Simulation Flows - Average Year 1982**
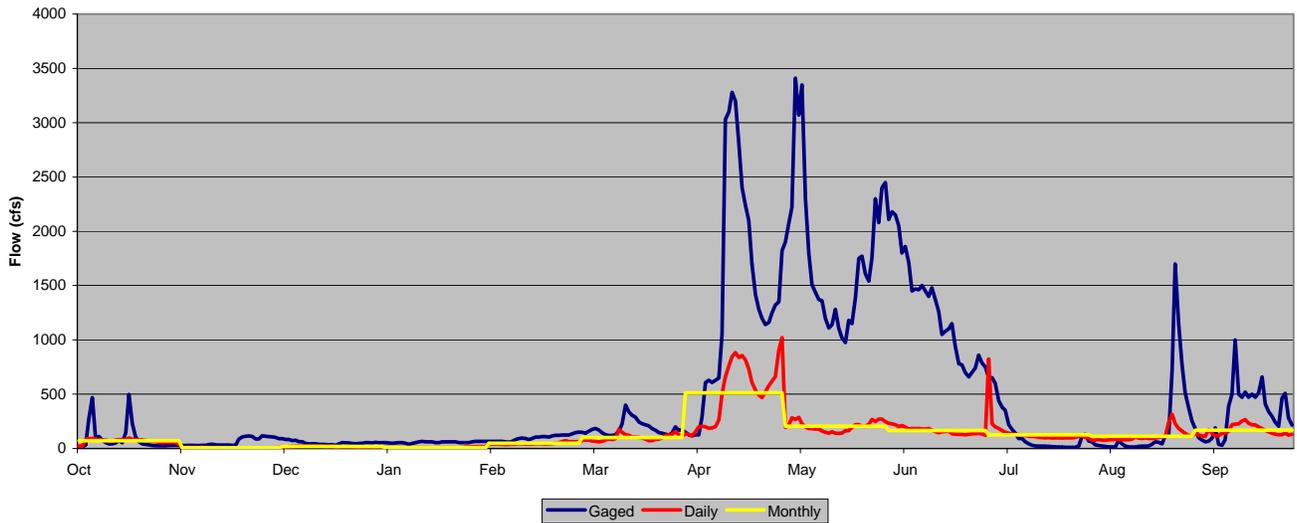
**Figure 8.26 Daily Baseline Comparison, Average Year – Dolores River at Bedrock**

**USGS Gage 09172500 - San Miguel River near Placerville**
**Monthly and Daily Baseline Simulation Flows - Average Year 1982**
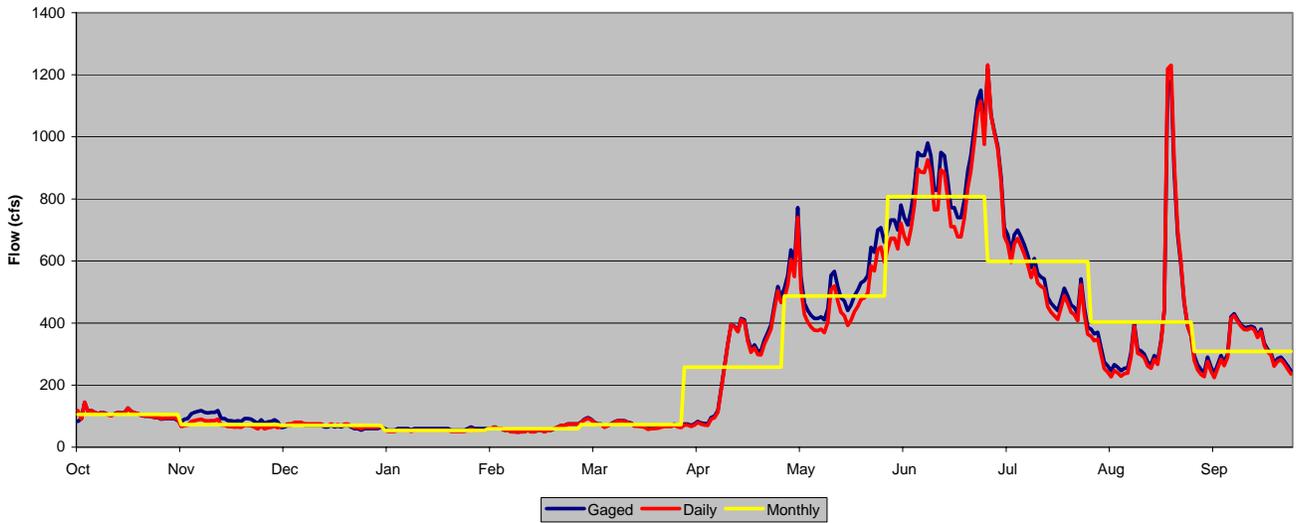
**Figure 8.27 Daily Baseline Comparison, Average Year – San Miguel River near Placerville**



**USGS Gage 09344000 - Navajo River at Banded Peak Ranch near Chromo**
**Monthly and Daily Baseline Simulation Flows - Dry Year 1977**
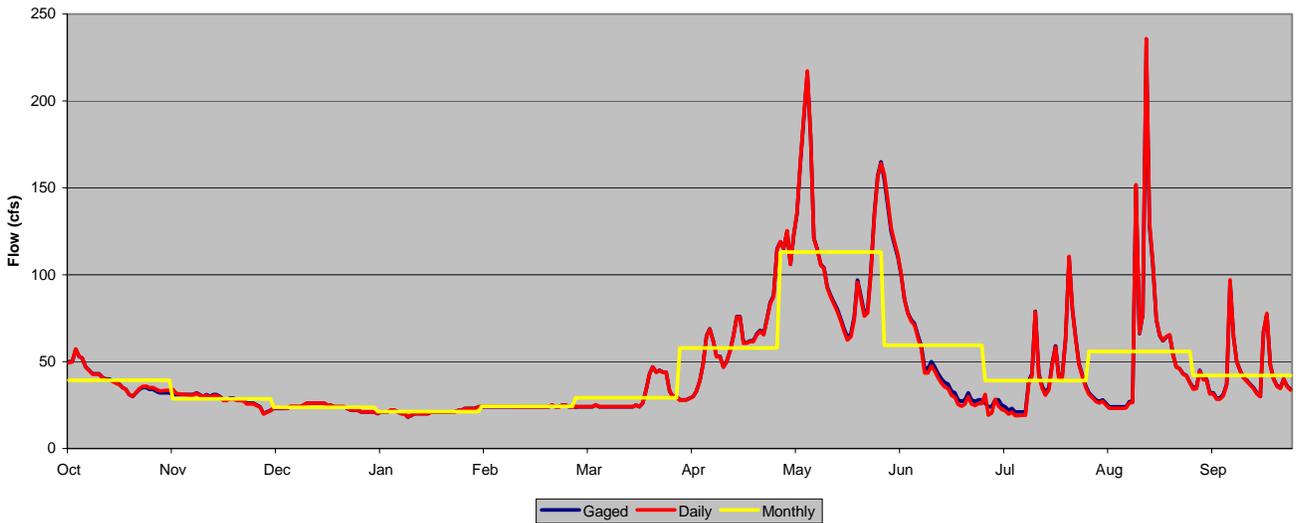
**Figure 8.28 Daily Baseline Comparison, Dry Year – Navajo River at Banded Peak Ranch**

**USGS Gage 09339900 - East Fork San Juan River above Sand Creek**
**Monthly and Daily Baseline Simulation Flows - Dry Year 1977**
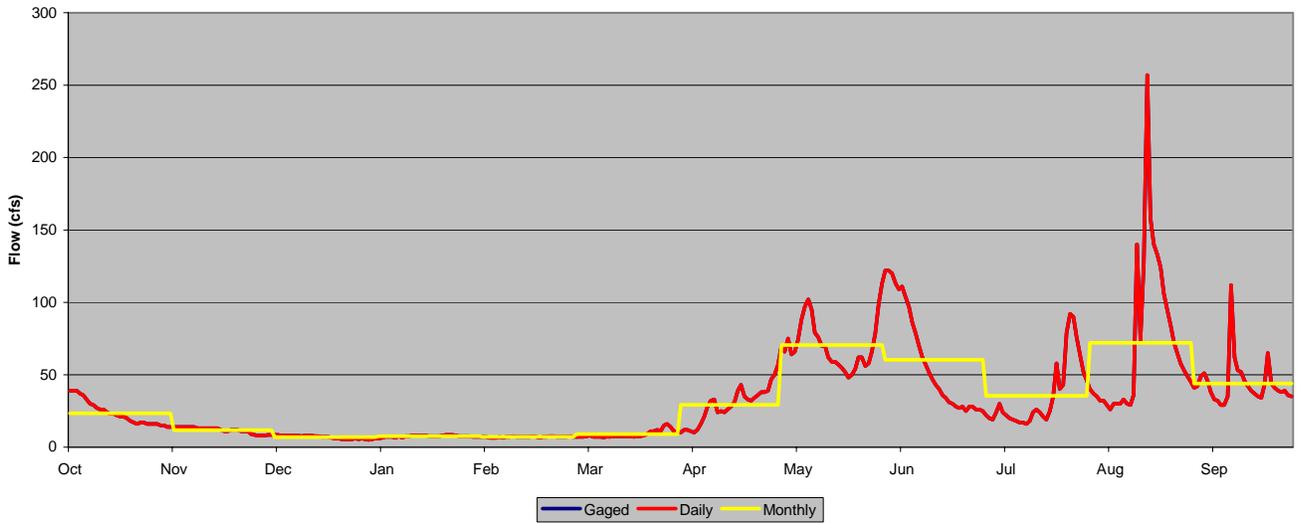
**Figure 8.29 Daily Baseline Comparison, Dry Year – East Fork San Juan River above Sand Creek**



**USGS Gage 09342500 - San Juan River at Pagosa Springs**
**Monthly and Daily Baseline Simulation Flows - Dry Year 1977**
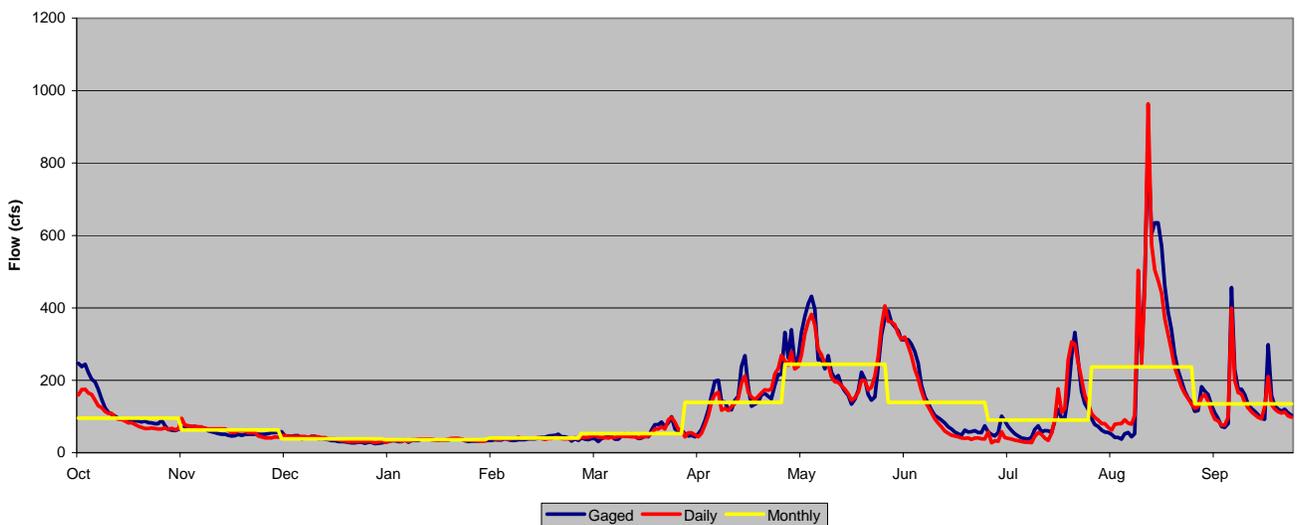
**Figure 8.30 Daily Baseline Comparison, Dry Year – San Juan River at Pagosa Springs**

**USGS Gage 09349800 - Piedra River near Arboles**
**Monthly and Daily Baseline Simulation Flows - Dry Year 1977**
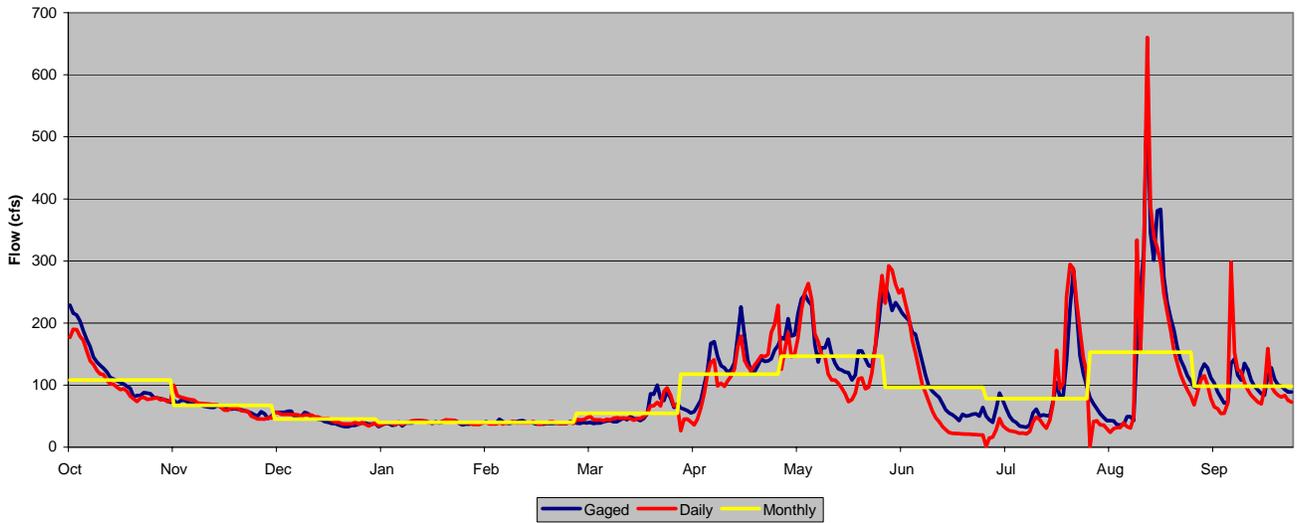


**Figure 8.31 Daily Baseline Comparison, Dry Year – Piedra River near Arboles**

**USGS Gage 09354500 - Los Pinos River at La Boca**
**Monthly and Daily Baseline Simulation Flows - Dry Year 1977**
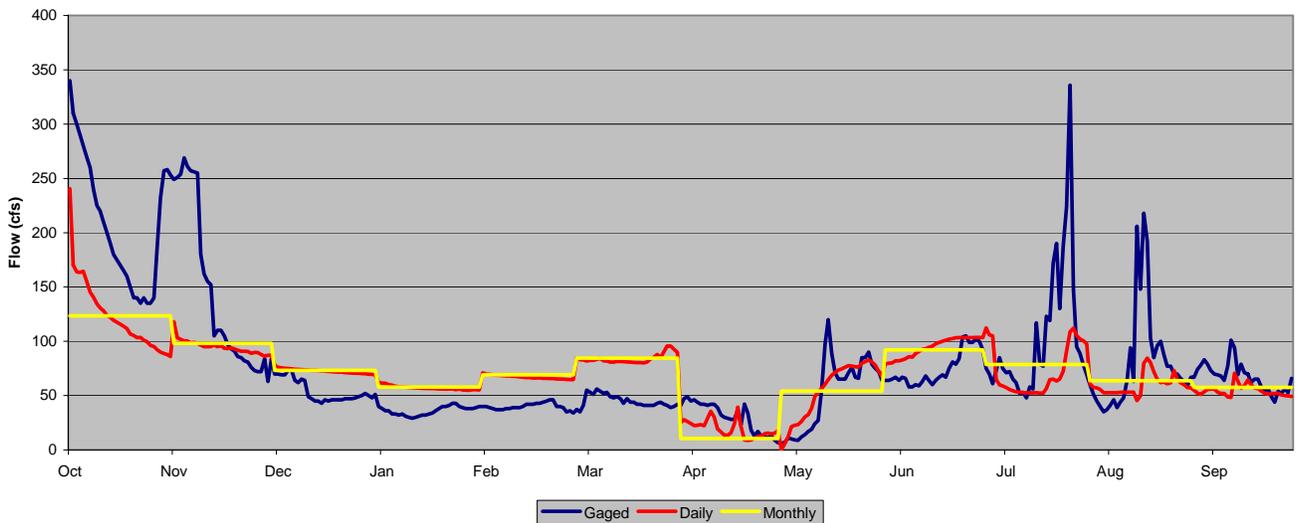


**Figure 8.32 Daily Baseline Comparison, Dry Year – Los Pinos River at La Boca**

**USGS Gage 09352900 - Vallecito Creek near Bayfield**
**Monthly and Daily Baseline Simulation Flows - Dry Year 1977**
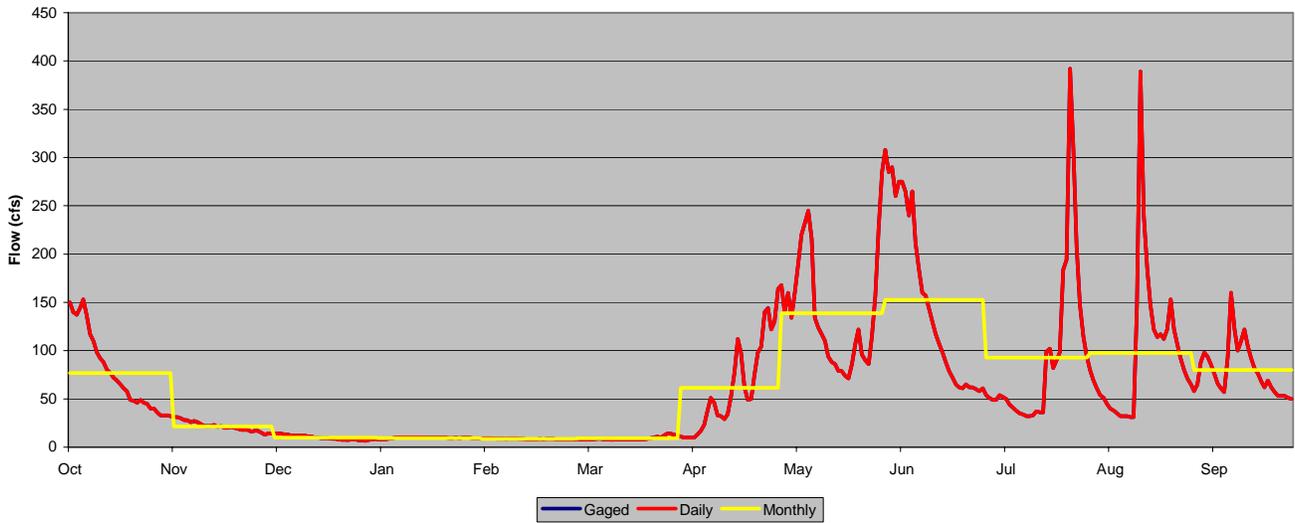


**Figure 8.33 Daily Baseline Comparison, Dry Year – Vallecito Creek near Bayfield**

**USGS Gage 09357500 - Animas River near Howardsville**
**Monthly and Daily Baseline Simulation Flows - Dry Year 1977**
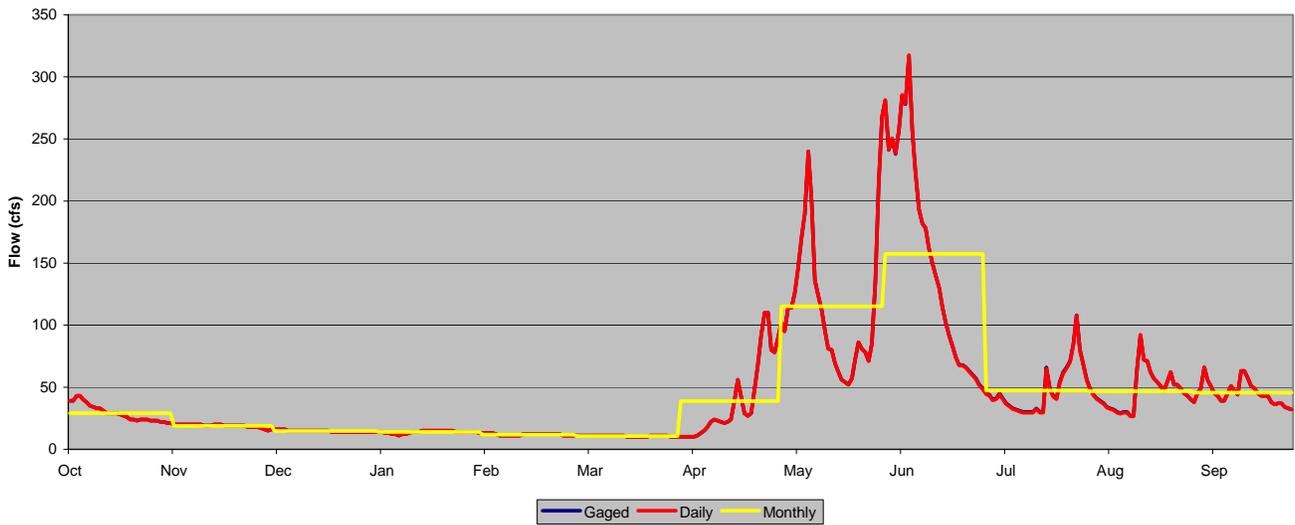


**Figure 8.34 Daily Baseline Comparison, Dry Year – Animas River near Howardsville**

**USGS Gage 09365500 - La Plata River at Hesperus**
**Monthly and Daily Baseline Simulation Flows - Dry Year 1977**
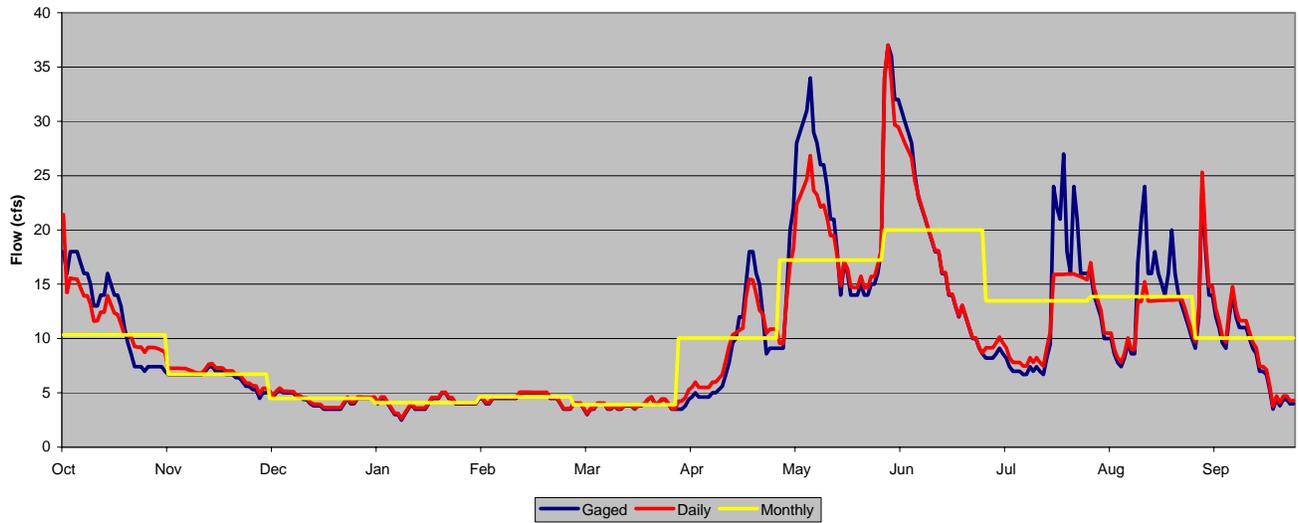
**Figure 8.35 Daily Baseline Comparison, Dry Year – La Plata River at Hesperus**



**USGS Gage 09371000 - Mancos River near Towaoc**
**Monthly and Daily Baseline Simulation Flows - Dry Year 1977**
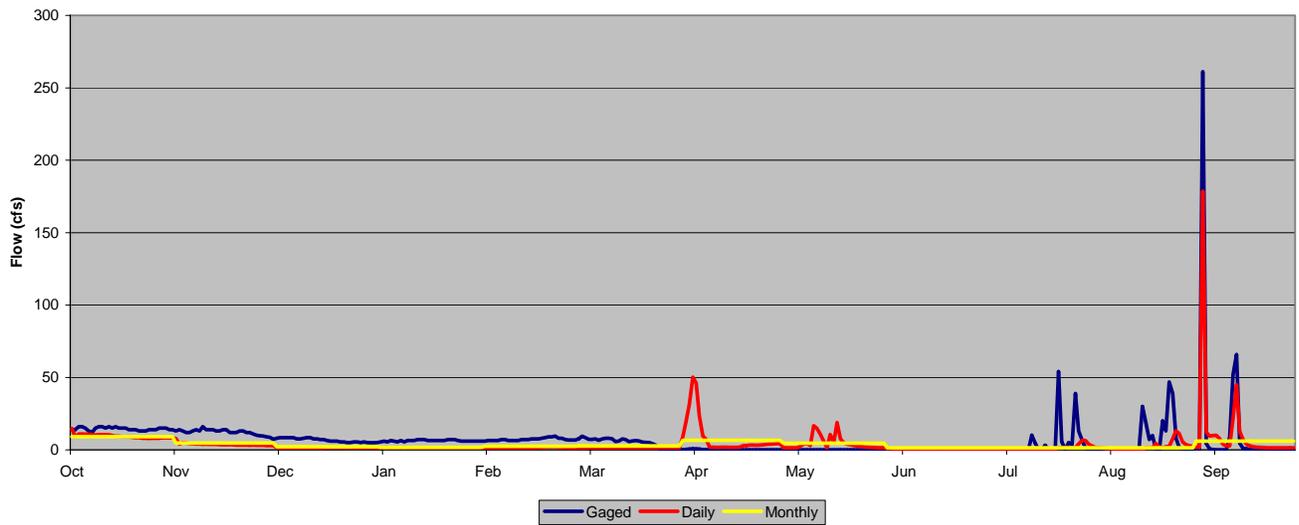
**Figure 8.36 Daily Baseline Comparison, Dry Year – Mancos River near Towaoc**

**USGS Gage 09372000 - McElmo Creek at the Colorado-Utah Stateline**
**Monthly and Daily Baseline Simulation Flows - Dry Year 1977**
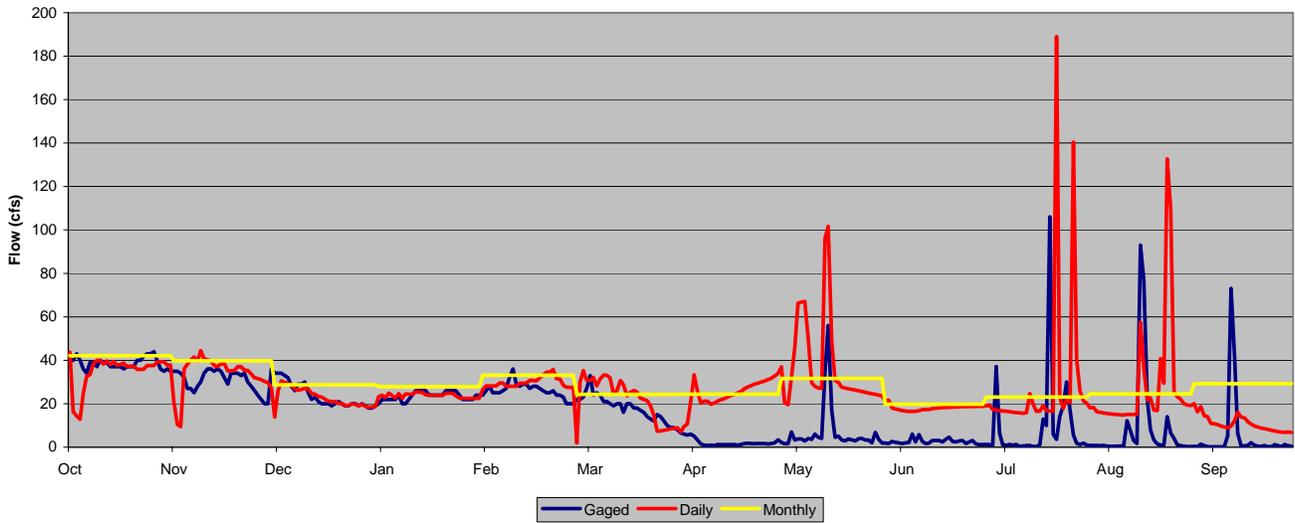
**Figure 8.37 Daily Baseline Comparison, Dry Year – McElmo Creek at CO/UT Stateline**



**USGS Gage 09166500 - Dolores River at Dolores**
**Monthly and Daily Baseline Simulation Flows - Dry Year 1977**
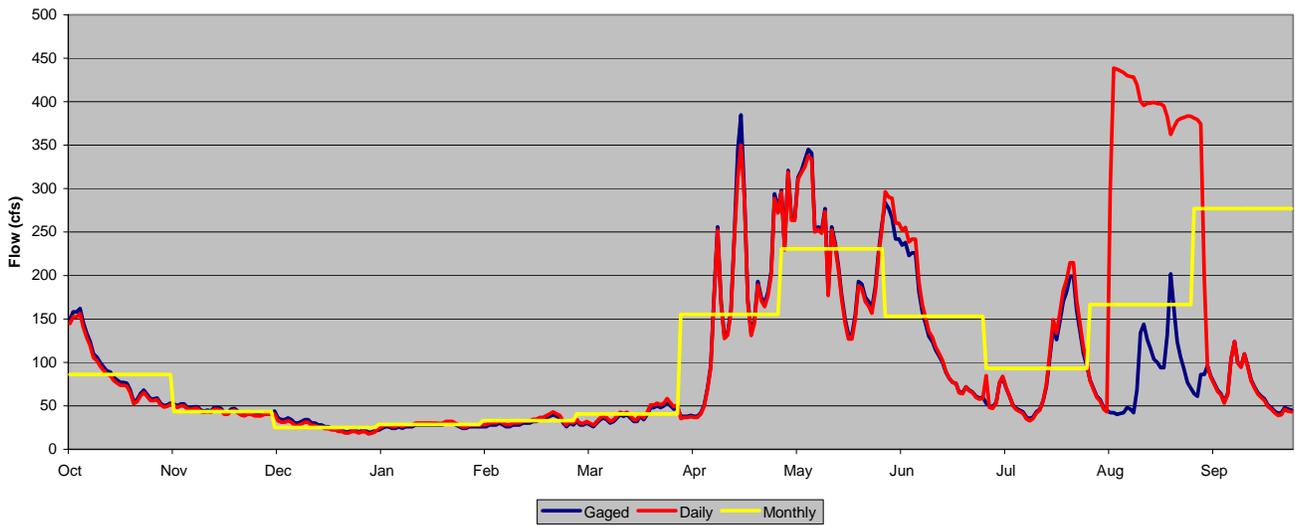
**Figure 8.38 Daily Baseline Comparison, Dry Year – Dolores River at Dolores**

**USGS Gage 09171100 - Dolores River at Bedrock**
**Monthly and Daily Baseline Simulation Flows - Dry Year 1977**
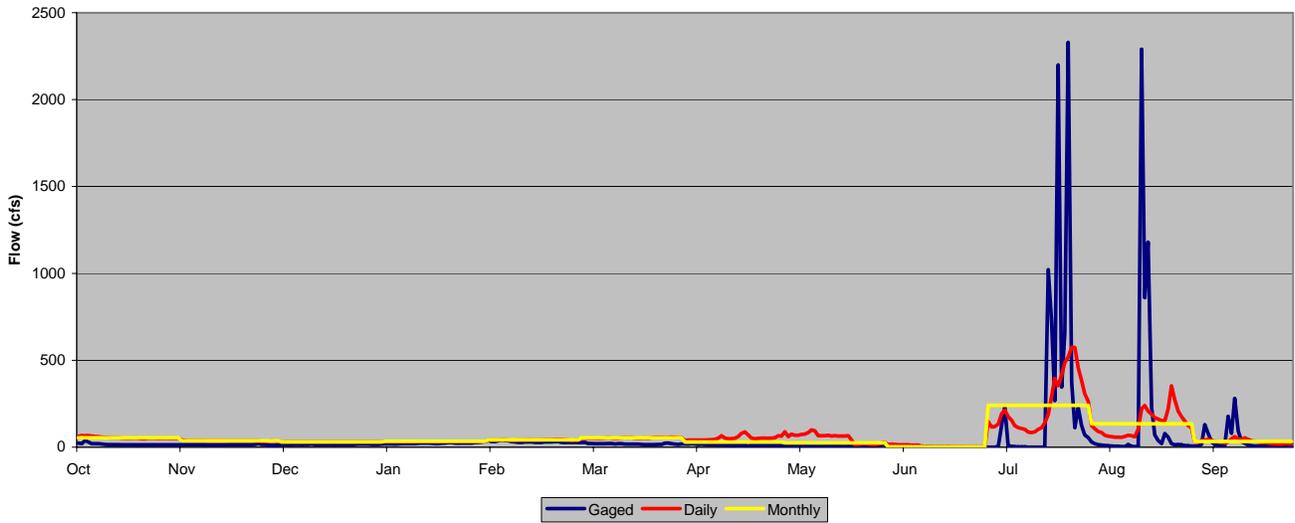
**Figure 8.39 Daily Baseline Comparison, Dry Year – Dolores River at Bedrock**



**USGS Gage 09172500 - San Miguel River near Placerville**
**Monthly and Daily Baseline Simulation Flows - Dry Year 1977**
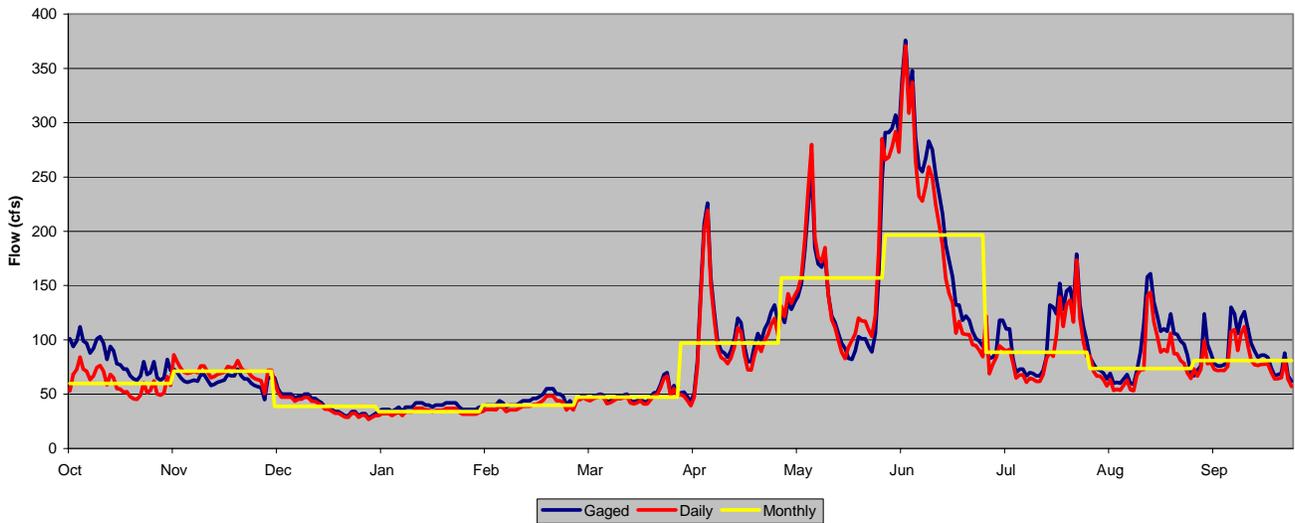
**Figure 8.40 Daily Baseline Comparison, Dry Year – San Miguel near Placerville**

Daily Baseline Results                                    8-31

# Appendix A

**Aggregation of Irrigation Diversion Structures**

**San Juan/Dolores Aggregated Irrigation Structures
StateCU and Water Budget Maintenance**

# CDSS Memorandum
# Final

**To:**        Ray Alvarado

**From:**    LRE, Erin Wilson

**Subject:**  San Juan and Dolores River Aggregated Irrigation Structures
             StateCU and Water Budget Maintenance - Task 10

**Date:**     June 22, 2004

## Introduction

The original CRDSS StateMod and StateCU modeling efforts were based on the 1993 irrigated acreage coverage developed during initial CRDSS efforts.  An irrigated acreage assessment representing year 2000 was recently performed for the CRDSS (western slope) basins. In each of the four Water Divisions (4, 5, 6, and 7), a portion of the 2000 acreage was tied to structures that did not have identified acreage in the 1993 coverage, therefore are not currently represented in the CRDSS models.  In addition, structures that were identified as "Key" during the initial CRDSS efforts, in part based on irrigated acreage from the 1993 assessment, were no longer shown as irrigated in 2000. As part of this task, key and aggregate structure lists for the western slope basins were revised to include 100 percent of the irrigated acreage based on both the 1993 and 2000 assessment.

As part of the re-aggregation task, discrepancies in both the 1993 and 2000 irrigated acreages were identified.  These discrepancies included:
- 1993 irrigated parcels were not assigned to a water source (structure)
- 1993 and 2000 parcels irrigating the same lands were assigned to different water sources
- Structures identified as "Key" during efforts based on the 1993 coverage were not shown as irrigated in 2000
- Structure identifiers were incorrectly assigned to water districts where the acreage is located, instead of where the headgate is located.  For example, acreage located in water district 40 was assigned by the water commissioner to structure 519.  In the 2000 irrigated acreage coverage, the full WDID was entered as 4000519.  However, the headgate for this structure is located in water district 41, and the correct WDID is 4100519.

Identified discrepancies were highlighted, and maps were sent to the Division Engineers for review.  Both the 1993 and 2000 irrigated acreage coverages in each Water Division were revised based on the Division Engineers' comments prior to revising the key and aggregated structures.

## Approach

The following approach was followed to update the designation of key and aggregated irrigated structures in the San Juan and Dolores basins.

1. Move Key structures to aggregations for future model updated based on comments received from the Division Engineer. In general, Key structures were removed if the Division Engineer indicated that they no longer irrigated lands in 2000 or where incorrectly assigned to irrigated lands in 1993.

2. Aggregate remaining irrigation structures identified in either the 1993 or 2000 irrigated acreage coverages based on the aggregate spatial boundaries defined during the previous San Juan and Dolores River Basin Aggregated Irrigation Structures."

## Results

**Table 1** indicates the number of structures in the updated aggregation and provides a comparison of the aggregated acreage from the previous modeling effort to the acreage assigned to the aggregation based on the 1993 Updated GIS coverage and the 2000 GIS coverage.

**Table 1**
**Updated Aggregation Summary**

| Aggregation ID | 1.1.1.1   Aggregation | # of Structures | Previous Acres | 1993 Acres | 2000 Acres |
|---|---|---|---|---|---|
| 77_ADS001 | NavajoRiver | 37 | 1,029 | 1,136 | 1,726 |
| 29_ADS002 | SJuanR@PagosaSpr | 47 | 1,568 | 1,594 | 1,631 |
| 29_ADS003 | SJuanR@Carracas | 76 | 1,245 | 1,480 | 1,716 |
| 78_ADS004 | PiedraRiver | 60 | 1,792 | 2,076 | 3,836 |
| 31_ADS005 | LPinosR@DryCrk | 24 | 1,553 | 1,383 | 572 |
| 31_ADS006 | LPinosR@StLine | 40 | 1,673 | 1,728 | 1,868 |
| 30_ADS007 | AnimasR@Durango | 44 | 1,518 | 1,348 | 1,227 |
| 30_ADS008 | FloridaRabvSaltC | 36 | 2,033 | 2,037 | 896 |
| 30_ADS009 | FloridaR@Bondad | 22 | 1,006 | 936 | 568 |
| 30_ADS010 | AnimasR@StLine | 44 | 1,080 | 1,046 | 559 |
| 33_ADS011 | LaPlataRiver | 33 | 1,321 | 1,510 | 1,489 |
| 34_ADS012 | ManRabvWMancos | 8 | 964 | 949 | 716 |
| 34_ADS013 | ManRabvChickenCk | 6 | 1,238 | 393 | 374 |
| 34_ADS014 | MancosRNrStLine | 7 | 1,239 | 1,113 | 740 |
| 32_ADS015 | McElmCkabvAlkali | 60 | 1,259 | 1,353 | 1,340 |
| 32_ADS016 | McElmoCrkNrStLin | 47 | 1,560 | 1,481 | 1,017 |
| 71_ADS017 | DolorRabvMcPheeR | 42 | 1,067 | 1,762 | 864 |
| 69_ADS018 | DisappointmentCk | 20 | 673 | 1,543 | 565 |
| 61_ADS019 | DoloresRNrBedrck | 20 | 1,514 | 1,529 | 1,110 |
| 60_ADS020 | SMiguelNrPlacrvl | 27 | 1,439 | 2,106 | 1,022 |
| 60_ADS021 | SMiguelabvWNatC | 7 | 1,192 | 1,097 | 1,368 |

| 60_ADS022 | SMiguel@Naturita | 49 | 1,713 | 1,912 | 3,998 |
|-----------|------------------|----|--------|--------|--------|
| 63_ADS023 | DoloresR@Gateway | 28 | 867 | 1,079 | 558 |
| 63_ADS024 | WestCreek | 40 | 1,152 | 1,310 | 1,594 |
| 73_ADS025 | LittleDoloresR | 36 | 2,578 | 3,070 | 2,016 |
| **Total** | | **861** | **34,273** | **37,130** | **33,405** |

Eleven structures identified as Key in the previous CRDSS efforts are now included in aggregated structures as follows:

- 2900604 – Fu Bar Ditch.  This structure has no acreage in the 1993coverage, but active diversion records.
- 6000678 – Lower Elk Creek Ditch. This structure has no acreage in the 1993 coverage, but active diversion records.
- 2900677 – O'Bannon Ditch.  This structure has no acreage in the 2000 coverage. Diversion comments indicate it is now used to fill reservoirs on Turkey Creek Ranch.
- 6900503 – Disappointment Ditch.  This structure has no acreage in the 2000 coverage. Diversion comments indicate water was available, but not taken.
- 6900504 – Evans Ditch.  This structure has no acreage in the 2000 coverage.  Diversion records end in 1997.
- 6900505 – Evans No 2 Ditch.  This structure has no acreage in the 2000 coverage. Diversion comments indicate this is an alternate point to 6900504.  Diversion records for both structures end in 1997.
- 7100544 – Goebel Ditch. This structure has no acreage in the 2000 coverage.  Diversion comments indicate the structure was not usable since 1967.  Diversion records begin again in 2002.
- 7800565 – JCR Ditch**.** This structure has no acreage in the 2000 coverage.  Diversion records are sporadic.
- 7800671 – JCR Ditch Alternate Point.  This structure has no acreage in the 2000 coverage.  It is an alternate point for 7800565 – JCR Ditch, which also has not reported acreage.
- 6000706 – Muddy Creek Ditch.  This structure has no acreage in the 2000 coverage. Diversion comments indicate structure was unusable in 2000.

Two structures previously modeled as key should be modeled as "diversion system" according to water commissioner comments.  These structures, and there associated system structures, include:

- 3100633 – Thompson-Epperson Ditch.  This structure has no acreage assigned in either the 1993 or the 2000 coverage.  It was previously assigned acreage from diversion record comments and modeled as a mult-structure with 3100511 – Thompson-Epperson Ditch. Diversion comments indicate that use for both records is shown under 3100511.  These two ditches should be modeled as a "diversion system" under WDID 3100511.
- 3400560 – Rush Reservoir Ditch.  This structure has no acreage assigned in 1993. Diversion comments indicate that acreage is accounted for under 3403585 - Bauer

Reservoir No 1. There is both 1993 and 2000 acreage assigned to 3403585. Model as diversion system under WDID 3400560.

The following structures previously modeled as key should be removed from the model as follows:
- 6000643 – Hughes Ditch. This structure has no acreage assigned in either the 1993 or 2000 coverages, no acreage reported in the diversion comments, and no diversion records since 1975.
- 6000713 – Nelson Creek Ditch. This structure has no acreage assigned in either the 1993 or 2000 coverages, no acreage reported in the diversion comments, and no diversion records since 1996.
- 6000827 – Johnson Ditch. This structure has no acreage assigned in either the 1993 or 2000 coverages. Diversion comments indicate this ditch is used for M&I in Uravan.

Figure 1 shows the spatial boundaries of each aggregation. **Exhibit A**, attached, lists the diversion structures represented in each aggregate.
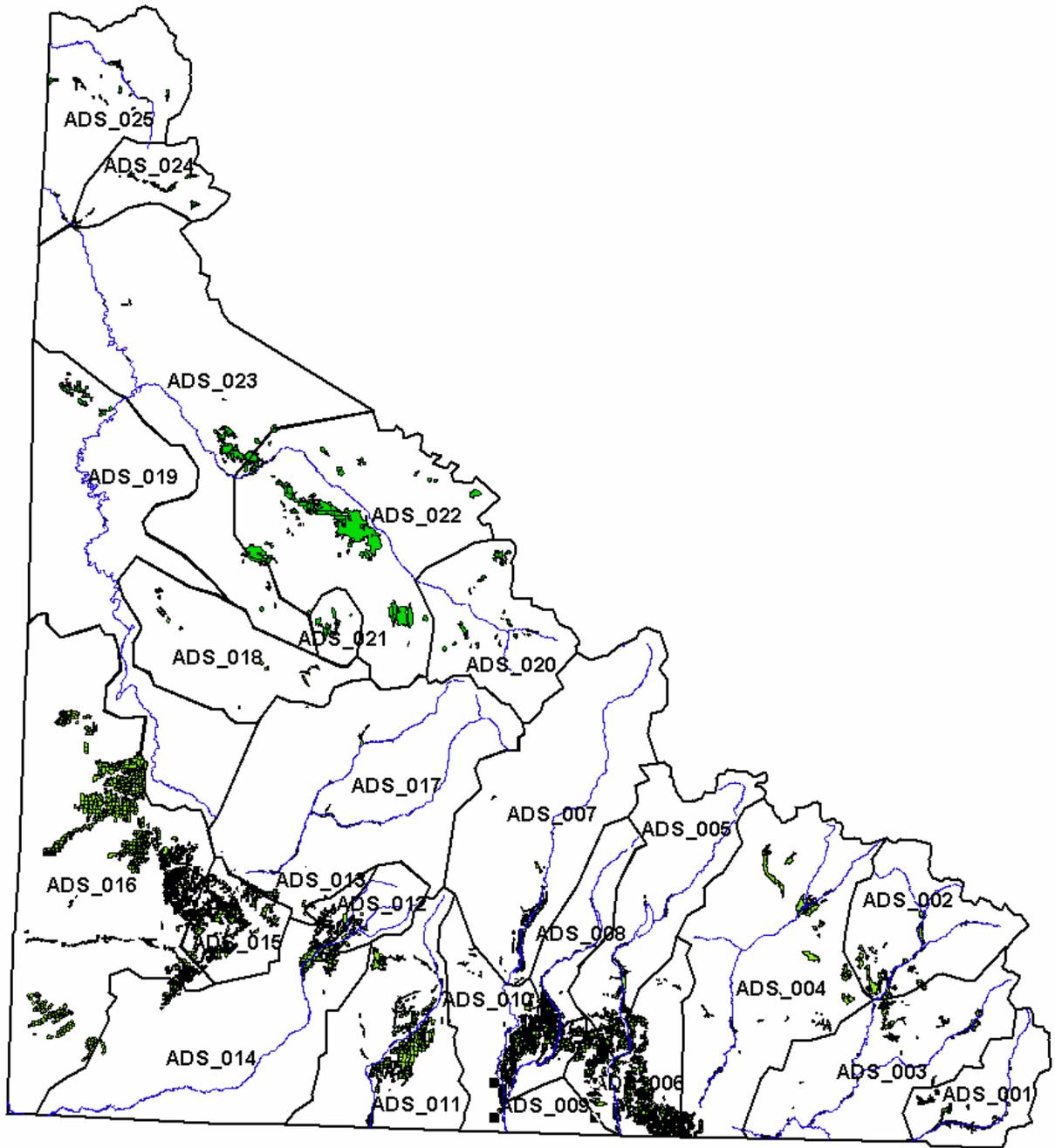
**Figure 1 – Aggregate Structure Boundaries**

## Comments and Concerns

**Table 2** shows the estimated total irrigated acreage associated with key and aggregated structures, by water district, for the original 1993 coverage, the updated 1993 coverage, and the 2000 coverage. The irrigated acreage increased by less than one percent between the updated 1993 coverage and the 2000 coverage.

**Table 2**
**San Juan and Dolores River Basin Acreage**

| Water District | Original 1993 Acreage | Updated 1993 Acreage | 2000 Acreage |
|---|---|---|---|
| 29 | 12,777 | 12,922 | 11,504 |
| 30 | 32,449 | 32,314 | 26,054 |
| 31 | 46,356 | 46,667 | 40,272 |
| 32 | 70,923 | 65,773 | 79,729 |
| 33 | 20,089 | 21,184 | 19,525 |
| 34 | 12,442 | 11,617 | 10,516 |
| 46 | 0 | 88 | 403 |
| 60 | 32,443 | 32,841 | 40,797 |
| 61 | 3,214 | 3,344 | 2,873 |
| 63 | 2,483 | 2,308 | 2,261 |
| 69 | 2,513 | 2,832 | 1,216 |
| 71 | 6,507 | 7,855 | 6,432 |
| 73 | 2,578 | 2,997 | 1,911 |
| 77 | 2,737 | 2,859 | 3,273 |
| 78 | 6,549 | 7,075 | 8,183 |
| Total | 254,060 | 252,675 | 254,947 |

## Recommendations

We recommend that consultants or State personnel performing future irrigated acreage updates understand the modeling concept of Key versus Aggregated structures. During updates, each Key structure should either be assigned to irrigated acreage, or an adequate explanation provided.

**EXHIBIT A**
**Diversion Structures in Aggregates**

| Aggregation ID | Aggregation Name | WDID | 1993 Acres | 2000 Acres |
|---|---|---|---|---|
| 77_ADS001 | NavajoRiver | 7700500 | 89.2 | 0 |
| | | 7700504 | 404.8 | 470 |
| | | 7700505 | 66.5 | 15.6 |
| | | 7700509 | 17.6 | 71.8 |
| | | 7700511 | 0 | 76 |
| | | 7700512 | 0 | 8.6 |
| | | 7700513 | 0 | 11.8 |
| | | 7700518 | 0 | 11.8 |
| | | 7700519 | 0 | 87 |
| | | 7700527 | 0 | 27.9 |
| | | 7700530 | 50.5 | 64.5 |
| | | 7700538 | 1.5 | 0 |
| | | 7700542 | 63.6 | 104.6 |
| | | 7700546 | 0 | 64.2 |
| | | 7700550 | 0 | 25.7 |
| | | 7700551 | 7.2 | 9.9 |
| | | 7700552 | 37.1 | 96.6 |
| | | 7700553 | 0.9 | 0 |
| | | 7700554 | 26.7 | 67.9 |
| | | 7700555 | 15.9 | 32.6 |
| | | 7700558 | 75.2 | 31.6 |
| | | 7700563 | 44.7 | 85 |
| | | 7700570 | 8.1 | 0 |
| | | 7700572 | 1.6 | 89.3 |
| | | 7700575 | 11.2 | 0 |
| | | 7700577 | 11.3 | 16.5 |
| | | 7700580 | 52.6 | 62 |
| | | 7700581 | 58.2 | 0 |
| | | 7700582 | 9.9 | 7.4 |
| | | 7700590 | 17.5 | 0 |
| | | 7700591 | 19.4 | 53 |
| | | 7700592 | 8.4 | 32.8 |
| | | 7700595 | 15.4 | 0 |
| | | 7700598 | 0 | 4.3 |
| | | 7700599 | 3.6 | 97.8 |
| | | 7703515 | 16.8 | 0 |
| | | 7705004 | 0.5 | 0 |
| 29_ADS002 | SJuanR@PagosaSpr | 2900501 | 0 | 58.4 |
| | | 2900506 | 0 | 66.2 |
| | | 2900547 | 0 | 72.2 |
| | | 2900552 | 46.5 | 0 |
| | | 2900553 | 254.2 | 72.2 |
| | | 2900565 | 36.2 | 15.8 |
| | | 2900570 | 92 | 7.6 |
| | | 2900571 | 130.5 | 76.8 |
| | | 2900573 | 0 | 30.4 |

| | | | | |
|---|---|---|---|---|
| | | 2900574 | 24.5 | 46.5 |
| | | 2900575 | 0 | 11.6 |
| | | 2900591 | 27.8 | 0 |
| | | 2900598 | 130 | 115.8 |
| | | 2900607 | 74 | 0 |
| | | 2900610 | 12.7 | 22.5 |
| | | 2900631 | 50.2 | 0 |
| | | 2900636 | 37.9 | 22.9 |
| | | 2900640 | 0 | 8.7 |
| | | 2900642 | 0 | 4.9 |
| | | 2900644 | 176.3 | 25.8 |
| | | 2900645 | 13.9 | 10.3 |
| | | 2900656 | 0 | 15 |
| | | 2900666 | 0 | 144.6 |
| | | 2900671 | 0 | 9.8 |
| | | 2900672 | 0 | 43.3 |
| | | 2900674 | 203.2 | 37.1 |
| | | 2900677 | 29.1 | 0 |
| | | 2900678 | 2.8 | 0 |
| | | 2900680 | 28.4 | 16.6 |
| | | 2900685 | 0 | 72.2 |
| | | 2900696 | 12.7 | 24.1 |
| | | 2900698 | 0 | 23.7 |
| | | 2900702 | 114.5 | 168 |
| | | 2900725 | 0 | 45.9 |
| | | 2900728 | 0 | 16.6 |
| | | 2900730 | 0 | 7.6 |
| | | 2900734 | 0 | 13.4 |
| | | 2900735 | 0 | 26.1 |
| | | 2900755 | 12.9 | 29.1 |
| | | 2900758 | 83.4 | 61.7 |
| | | 2900760 | 0 | 54.1 |
| | | 2900793 | 0 | 16.6 |
| | | 2900801 | 0 | 60.2 |
| | | 2900911 | 0 | 57.4 |
| | | 2900932 | 0 | 7.4 |
| | | 2901909 | 0 | 3.8 |
| | | 2902007 | 0 | 8 |
| 29_ADS003 | SJuanR@Carracas | 2900505 | 0 | 6.9 |
| | | 2900508 | 0 | 24.8 |
| | | 2900509 | 0 | 24 |
| | | 2900515 | 14.7 | 0 |
| | | 2900528 | 0 | 3.5 |
| | | 2900532 | 2.4 | 0 |
| | | 2900539 | 13.1 | 0 |
| | | 2900549 | 49.8 | 0 |
| | | 2900554 | 45 | 0 |
| | | 2900558 | 39.8 | 0 |
| | | 2900561 | 20.2 | 0 |

| | | | |
|---|---|---|---|
| | | 2900563 | 7.2 | 0 |
| | | 2900564 | 1.8 | 0 |
| | | 2900567 | 4.9 | 0 |
| | | 2900576 | 0 | 21.7 |
| | | 2900577 | 0 | 9.5 |
| | | 2900578 | 0 | 2.1 |
| | | 2900583 | 12.6 | 0 |
| | | 2900604 | 0 | 14 |
| | | 2900605 | 11.5 | 0 |
| | | 2900615 | 38.7 | 0 |
| | | 2900618 | 16.2 | 14.4 |
| | | 2900632 | 20.3 | 0 |
| | | 2900633 | 15.4 | 49.4 |
| | | 2900634 | 48.3 | 58.1 |
| | | 2900635 | 79.5 | 0 |
| | | 2900646 | 0 | 88.1 |
| | | 2900647 | 19.2 | 0 |
| | | 2900652 | 67.8 | 0 |
| | | 2900655 | 0 | 36.9 |
| | | 2900663 | 30.9 | 6.8 |
| | | 2900665 | 12.1 | 61.5 |
| | | 2900673 | 31.3 | 41 |
| | | 2900681 | 0 | 43.9 |
| | | 2900694 | 41.1 | 243.3 |
| | | 2900695 | 4.2 | 0 |
| | | 2900705 | 14.5 | 5.8 |
| | | 2900710 | 12.5 | 200.4 |
| | | 2900711 | 111.2 | 199.6 |
| | | 2900713 | 0 | 92.2 |
| | | 2900714 | 28.9 | 0 |
| | | 2900722 | 0 | 41.5 |
| | | 2900732 | 4.2 | 0 |
| | | 2900742 | 40.5 | 40.7 |
| | | 2900745 | 71 | 54.1 |
| | | 2900753 | 44.9 | 38.7 |
| | | 2900754 | 11.7 | 0 |
| | | 2900759 | 12.5 | 0 |
| | | 2900761 | 4.4 | 13.4 |
| | | 2900762 | 3 | 5.5 |
| | | 2900764 | 0 | 12.3 |
| | | 2900766 | 10.5 | 0 |
| | | 2900785 | 4.6 | 0 |
| | | 2900786 | 8.5 | 0 |
| | | 2900787 | 3.9 | 0 |
| | | 2900790 | 2.5 | 0 |
| | | 2900791 | 2.9 | 0 |
| | | 2900792 | 7.3 | 0 |
| | | 2900795 | 1.8 | 0 |
| | | 2900798 | 2.4 | 0 |

| | | 2900802 | 168.6 | 23 |
|---|---|---|---|---|
| | | 2900803 | 2.3 | 0 |
| | | 2900804 | 3.7 | 0 |
| | | 2900805 | 32.2 | 3.5 |
| | | 2900809 | 2.6 | 0 |
| | | 2900810 | 10.9 | 8.5 |
| | | 2900818 | 0 | 24.3 |
| | | 2900819 | 3.7 | 0 |
| | | 2900822 | 0 | 10.9 |
| | | 2900834 | 0 | 8.5 |
| | | 2900838 | 36.1 | 10.7 |
| | | 2900845 | 1.5 | 0 |
| | | 2900846 | 20.6 | 37.5 |
| | | 2900851 | 2 | 0 |
| | | 2902003 | 139.7 | 134.9 |
| | | 2905002 | 4.7 | 0 |
| 78_ADS004 | PiedraRiver | 4600523 | 0 | 31.5 |
| | | 4600524 | 0 | 1.8 |
| | | 4600525 | 0 | 10.9 |
| | | 4600532 | 0 | 1 |
| | | 7800500 | 6.7 | 8.4 |
| | | 7800504 | 0 | 38.2 |
| | | 7800505 | 0 | 68.8 |
| | | 7800508 | 3.8 | 0 |
| | | 7800510 | 0 | 62.9 |
| | | 7800511 | 0 | 16.2 |
| | | 7800515 | 207 | 118.9 |
| | | 7800519 | 97.6 | 473 |
| | | 7800526 | 17.3 | 17 |
| | | 7800528 | 0 | 84.6 |
| | | 7800535 | 16 | 0 |
| | | 7800536 | 10.4 | 11.4 |
| | | 7800538 | 101.1 | 810.7 |
| | | 7800539 | 32.1 | 14.8 |
| | | 7800541 | 0 | 28.9 |
| | | 7800546 | 41.9 | 0 |
| | | 7800549 | 5.5 | 39.1 |
| | | 7800557 | 0 | 102.6 |
| | | 7800558 | 57.7 | 63.3 |
| | | 7800565 | 66.2 | 0 |
| | | 7800566 | 34.3 | 37.1 |
| | | 7800568 | 0 | 170 |
| | | 7800569 | 26.5 | 64.9 |
| | | 7800572 | 240.2 | 383.7 |
| | | 7800575 | 15.1 | 13.1 |
| | | 7800576 | 0 | 57.8 |
| | | 7800579 | 25.8 | 27 |
| | | 7800582 | 6.2 | 0 |
| | | 7800583 | 10 | 0 |

| | | | | |
|---|---|---|---|---|
| | | 7800585 | 22.3 | 0 |
| | | 7800593 | 16.6 | 0 |
| | | 7800595 | 40.4 | 0 |
| | | 7800600 | 142 | 0 |
| | | 7800602 | 10.8 | 0 |
| | | 7800607 | 20.5 | 50.5 |
| | | 7800608 | 20.2 | 25.2 |
| | | 7800610 | 0 | 7 |
| | | 7800611 | 37.1 | 39.5 |
| | | 7800612 | 8.4 | 16.7 |
| | | 7800616 | 27.7 | 14.6 |
| | | 7800635 | 6.3 | 0 |
| | | 7800642 | 11.6 | 0 |
| | | 7800643 | 41.8 | 0 |
| | | 7800647 | 13.9 | 0 |
| | | 7800648 | 5.1 | 11.1 |
| | | 7800652 | 0 | 1.4 |
| | | 7800656 | 0 | 77 |
| | | 7800661 | 6.5 | 18 |
| | | 7800669 | 25 | 0 |
| | | 7800671 | 54.1 | 0 |
| | | 7800675 | 412.7 | 639.6 |
| | | 7800677 | 5.4 | 0 |
| | | 7800687 | 4 | 0 |
| | | 7800699 | 0 | 41.2 |
| | | 7800722 | 0 | 94.6 |
| | | 7803638 | 122.2 | 41.5 |
| 31_ADS005 | LPinosR@DryCrk | 3100500 | 7.1 | 0 |
| | | 3100522 | 50.1 | 0 |
| | | 3100526 | 12.4 | 0 |
| | | 3100530 | 58.3 | 64 |
| | | 3100533 | 0 | 42 |
| | | 3100534 | 23.6 | 0 |
| | | 3100542 | 0 | 2.1 |
| | | 3100558 | 16.1 | 28.2 |
| | | 3100565 | 211.5 | 0 |
| | | 3100566 | 36 | 0 |
| | | 3100585 | 50.3 | 0 |
| | | 3100588 | 12.6 | 17.1 |
| | | 3100602 | 127.9 | 105.9 |
| | | 3100611 | 43.2 | 0 |
| | | 3100628 | 26.1 | 0 |
| | | 3100629 | 21.8 | 0 |
| | | 3100659 | 427.3 | 113 |
| | | 3100697 | 5.9 | 0 |
| | | 3100705 | 44 | 0 |
| | | 3100708 | 90.5 | 79.4 |
| | | 3100772 | 10.3 | 10.8 |
| | | 3100840 | 91.7 | 100.1 |

| | | 3100841 | 16.1 | 0 |
|---|---|---|---|---|
| | | 3103712 | 0 | 9.7 |
| 31_ADS006 | LPinosR@StLine | 3100506 | 407.5 | 272.9 |
| | | 3100531 | 0 | 6.2 |
| | | 3100548 | 0 | 62.2 |
| | | 3100552 | 0 | 20.4 |
| | | 3100560 | 119.7 | 225.9 |
| | | 3100561 | 41.2 | 38.3 |
| | | 3100570 | 24.7 | 0 |
| | | 3100571 | 31.3 | 0 |
| | | 3100572 | 29 | 32.9 |
| | | 3100575 | 156.5 | 51 |
| | | 3100582 | 225.4 | 213.9 |
| | | 3100601 | 169.2 | 64.8 |
| | | 3100645 | 0 | 95.9 |
| | | 3100655 | 138 | 211.2 |
| | | 3100658 | 54.1 | 5.2 |
| | | 3100672 | 97.3 | 58.6 |
| | | 3100681 | 81.3 | 87.8 |
| | | 3100717 | 11.3 | 9.1 |
| | | 3100766 | 38.5 | 34.5 |
| | | 3100822 | 4.2 | 0 |
| | | 3100834 | 7 | 19.8 |
| | | 3100854 | 4.3 | 0 |
| | | 4600501 | 0 | 14.2 |
| | | 4600502 | 0 | 24 |
| | | 4600505 | 38.7 | 24.5 |
| | | 4600506 | 0 | 10.1 |
| | | 4600508 | 41.3 | 0 |
| | | 4600511 | 0 | 64.7 |
| | | 4600512 | 0 | 18.8 |
| | | 4600513 | 0 | 17.1 |
| | | 4600520 | 0 | 9 |
| | | 4600521 | 0 | 57.8 |
| | | 4600522 | 0 | 12.2 |
| | | 4600527 | 0 | 13.5 |
| | | 4600528 | 7.8 | 0 |
| | | 4600529 | 0 | 16.1 |
| | | 4600530 | 0 | 30.1 |
| | | 4600533 | 0 | 12.2 |
| | | 4600544 | 0 | 28.8 |
| | | 4600550 | 0 | 4.4 |
| 30_ADS007 | AnimasR@Durango | 3000502 | 58.7 | 14.2 |
| | | 3000503 | 17.1 | 77.4 |
| | | 3000505 | 19.4 | 1.6 |
| | | 3000516 | 0 | 16.7 |
| | | 3000518 | 5.8 | 0 |
| | | 3000521 | 57.3 | 50.3 |
| | | 3000525 | 71.2 | 36.6 |

| | | 3000532 | 9.7 | 3.1 |
|---|---|---|---|---|
| | | 3000537 | 134.3 | 18 |
| | | 3000538 | 64.2 | 0 |
| | | 3000539 | 9.6 | 9.5 |
| | | 3000540 | 0 | 2.1 |
| | | 3000543 | 156.7 | 163.8 |
| | | 3000547 | 123.1 | 9.3 |
| | | 3000549 | 0 | 22 |
| | | 3000551 | 0 | 6.6 |
| | | 3000583 | 0 | 1.8 |
| | | 3000584 | 19.4 | 0 |
| | | 3000585 | 69.1 | 206.5 |
| | | 3000590 | 5.5 | 0 |
| | | 3000593 | 2.7 | 0 |
| | | 3000595 | 2.3 | 18.2 |
| | | 3000611 | 16.6 | 2.6 |
| | | 3000614 | 23.3 | 17.9 |
| | | 3000615 | 2.5 | 9.6 |
| | | 3000632 | 0 | 4.2 |
| | | 3000637 | 5.2 | 0 |
| | | 3000638 | 0 | 11.1 |
| | | 3000642 | 0 | 7 |
| | | 3000643 | 98.8 | 3 |
| | | 3000644 | 23.2 | 13.7 |
| | | 3000645 | 47.4 | 3.6 |
| | | 3000649 | 34.7 | 0 |
| | | 3000659 | 9.3 | 0 |
| | | 3000663 | 0 | 245.1 |
| | | 3000684 | 0 | 4.4 |
| | | 3000694 | 34.3 | 25.1 |
| | | 3000747 | 29.7 | 75.7 |
| | | 3000752 | 44.1 | 51.6 |
| | | 3000762 | 8.1 | 0 |
| | | 3001126 | 0 | 47.8 |
| | | 3001128 | 110.4 | 35.4 |
| | | 3001266 | 23.2 | 11.1 |
| | | 3003538 | 11.2 | 0 |
| 30_ADS008 | FloridaRabvSaltC | 3000668 | 0 | 6.7 |
| | | 3001001 | 31.7 | 0 |
| | | 3001002 | 37.9 | 29.6 |
| | | 3001004 | 67 | 77.2 |
| | | 3001008 | 77.6 | 77.1 |
| | | 3001010 | 26.7 | 32.9 |
| | | 3001012 | 25.5 | 57.4 |
| | | 3001014 | 50.8 | 0 |
| | | 3001015 | 27.5 | 49 |
| | | 3001017 | 16.1 | 40.4 |
| | | 3001062 | 25.1 | 0 |
| | | 3001067 | 150.5 | 43 |

| | | 3001111 | 54.3 | 4.7 |
|---|---|---|---|---|
| | | 3001121 | 32.7 | 0 |
| | | 3001150 | 30.8 | 0 |
| | | 3001162 | 76.6 | 0 |
| | | 3001165 | 44.4 | 44.5 |
| | | 3001169 | 21 | 0 |
| | | 3001176 | 20.5 | 10.4 |
| | | 3001196 | 79.2 | 96.9 |
| | | 3001199 | 15.1 | 0 |
| | | 3001210 | 5.3 | 5 |
| | | 3001215 | 21.6 | 14.3 |
| | | 3001224 | 132.6 | 100.4 |
| | | 3001230 | 190.9 | 0 |
| | | 3001237 | 73.2 | 0 |
| | | 3001244 | 102.6 | 0 |
| | | 3001245 | 56.1 | 0 |
| | | 3001253 | 10.2 | 0 |
| | | 3001287 | 107.1 | 0 |
| | | 3001405 | 6.1 | 0 |
| | | 3001406 | 20.6 | 0 |
| | | 3001423 | 79.9 | 35.9 |
| | | 3001457 | 13 | 0 |
| | | 3001481 | 256.1 | 170.8 |
| | | 3006231 | 50.7 | 0 |
| 30_ADS009 | FloridaR@Bondad | 3001026 | 283.1 | 138.7 |
| | | 3001035 | 30.6 | 32.5 |
| | | 3001044 | 26.4 | 0 |
| | | 3001059 | 11.1 | 0 |
| | | 3001110 | 7.9 | 0 |
| | | 3001113 | 119.5 | 0 |
| | | 3001142 | 4.2 | 0 |
| | | 3001170 | 13.2 | 0 |
| | | 3001175 | 33.5 | 37.7 |
| | | 3001181 | 6.5 | 0 |
| | | 3001218 | 12.2 | 0 |
| | | 3001220 | 120.3 | 166.3 |
| | | 3001222 | 37.8 | 0 |
| | | 3001265 | 4.5 | 0 |
| | | 3001330 | 31.8 | 72.1 |
| | | 3001334 | 3.5 | 0 |
| | | 3001344 | 21.5 | 39.3 |
| | | 3001347 | 45.8 | 12.9 |
| | | 3001349 | 59 | 5.4 |
| | | 3001362 | 2 | 0 |
| | | 3001368 | 6 | 0 |
| | | 3001369 | 55.9 | 63.5 |
| 30_ADS010 | AnimasR@StLine | 3000533 | 112.3 | 0 |
| | | 3000665 | 0 | 3.3 |
| | | 3001038 | 19.4 | 0 |

| | | 3001049 | 9.2 | 0 |
|---|---|---|---|---|
| | | 3001052 | 21.9 | 0 |
| | | 3001053 | 20.6 | 0 |
| | | 3001055 | 63.3 | 0 |
| | | 3001066 | 0 | 5.2 |
| | | 3001068 | 114.7 | 60.9 |
| | | 3001071 | 17.6 | 0 |
| | | 3001074 | 56.5 | 46.7 |
| | | 3001076 | 0 | 31.8 |
| | | 3001081 | 2.6 | 0 |
| | | 3001093 | 0 | 27.9 |
| | | 3001104 | 1.8 | 0 |
| | | 3001105 | 2 | 0 |
| | | 3001107 | 7.2 | 0 |
| | | 3001118 | 26.8 | 0 |
| | | 3001119 | 29.7 | 40.5 |
| | | 3001124 | 12.9 | 12 |
| | | 3001132 | 22.5 | 23 |
| | | 3001135 | 76.5 | 36.5 |
| | | 3001139 | 80.1 | 50.7 |
| | | 3001146 | 12.3 | 1.2 |
| | | 3001198 | 3.9 | 0 |
| | | 3001205 | 16.7 | 5.2 |
| | | 3001206 | 17.2 | 0 |
| | | 3001211 | 6.4 | 4.4 |
| | | 3001212 | 5.3 | 5.9 |
| | | 3001225 | 4.9 | 0 |
| | | 3001227 | 4.1 | 46.4 |
| | | 3001228 | 58.2 | 39.7 |
| | | 3001234 | 5.7 | 7.5 |
| | | 3001325 | 43.8 | 0 |
| | | 3001345 | 5.7 | 0 |
| | | 3001415 | 0 | 3.9 |
| | | 3001416 | 0 | 6.1 |
| | | 3001427 | 9.522 | 6.3 |
| | | 3001430 | 0 | 24.3 |
| | | 3001446 | 19.8 | 20.2 |
| | | 3001483 | 59.8 | 29.5 |
| | | 3001496 | 32.8 | 0 |
| | | 3004665 | 42.1 | 19.7 |
| 33_ADS011 | LaPlataRiver | 3300502 | 62.2 | 41.7 |
| | | 3300503 | 0 | 12.7 |
| | | 3300505 | 41.4 | 18.1 |
| | | 3300506 | 0 | 36.7 |
| | | 3300509 | 0 | 25.5 |
| | | 3300513 | 60.8 | 96.6 |
| | | 3300515 | 34.3 | 51.6 |
| | | 3300517 | 20.2 | 18.7 |
| | | 3300519 | 0 | 39.5 |

| | | 3300522 | 15.3 | 128.1 |
|---|---|---|---|---|
| | | 3300523 | 78.8 | 30.5 |
| | | 3300527 | 35.2 | 4.3 |
| | | 3300530 | 88 | 85.2 |
| | | 3300537 | 117.5 | 0 |
| | | 3300539 | 96.8 | 132.5 |
| | | 3300541 | 142.3 | 125.5 |
| | | 3300546 | 123.3 | 120.2 |
| | | 3300555 | 12 | 10.7 |
| | | 3300556 | 75.2 | 79.8 |
| | | 3300557 | 107.9 | 112.5 |
| | | 3300558 | 68.1 | 52 |
| | | 3300565 | 44.5 | 42.3 |
| | | 3300567 | 35.5 | 65.8 |
| | | 3300570 | 101 | 0 |
| | | 3300574 | 0 | 28.5 |
| | | 3300583 | 31.8 | 34.4 |
| | | 3300584 | 18.7 | 0 |
| | | 3300592 | 32.5 | 39.6 |
| | | 3300594 | 3.7 | 4 |
| | | 3300596 | 13.3 | 12.1 |
| | | 3300614 | 49.6 | 8.3 |
| | | 3300626 | 0 | 19.8 |
| | | 3300673 | 0 | 11.5 |
| 34_ADS012 | ManRabvWMancps | 3400517 | 54 | 0 |
| | | 3400525 | 63.4 | 136.9 |
| | | 3400532 | 22.1 | 0 |
| | | 3400562 | 68.6 | 75.2 |
| | | 3400566 | 138.9 | 114.4 |
| | | 3400569 | 291.5 | 265.4 |
| | | 3403589 | 0 | 81.2 |
| | | 3403594 | 310 | 43.2 |
| 34_ADS013 | ManRabvChickenCk | 3400538 | 158.8 | 160.3 |
| | | 3400563 | 33.5 | 30 |
| | | 3403587 | 17.2 | 0 |
| | | 3403588 | 30.1 | 0 |
| | | 3403590 | 152.9 | 139.6 |
| | | 3403592 | 0 | 43.7 |
| 34_ADS014 | MancosRNrStLine | 3400519 | 14.5 | 20.9 |
| | | 3400524 | 65.5 | 0 |
| | | 3400546 | 193.4 | 0 |
| | | 3400575 | 61.6 | 24.1 |
| | | 3400581 | 118.3 | 25.3 |
| | | 3400599 | 40.3 | 44.2 |
| | | 3403586 | 619.7 | 625 |
| 32_ADS015 | McElmCkabvAlkali | 3200506 | 22.1 | 17.3 |
| | | 3200510 | 3.5 | 0 |
| | | 3200511 | 38.4 | 19.4 |
| | | 3200512 | 106.6 | 28.8 |

| | | | |
|---|---|---|---|
| | | 3200517 | 5.7 | 0 |
| | | 3200522 | 63.4 | 0 |
| | | 3200523 | 11.7 | 0 |
| | | 3200530 | 33.4 | 47.3 |
| | | 3200532 | 16.3 | 5.9 |
| | | 3200536 | 77.3 | 0 |
| | | 3200540 | 29.8 | 0 |
| | | 3200548 | 5.5 | 1.6 |
| | | 3200550 | 101.4 | 14.4 |
| | | 3200556 | 88 | 298 |
| | | 3200562 | 11.6 | 0 |
| | | 3200565 | 5.3 | 0 |
| | | 3200569 | 20.2 | 12.6 |
| | | 3200572 | 57.9 | 56.2 |
| | | 3200577 | 9.3 | 0 |
| | | 3200578 | 6.8 | 0 |
| | | 3200580 | 15.9 | 9 |
| | | 3200584 | 26.9 | 0 |
| | | 3200585 | 8.5 | 0 |
| | | 3200586 | 10.8 | 0 |
| | | 3200587 | 34.3 | 61.4 |
| | | 3200595 | 16.8 | 0 |
| | | 3200600 | 22.8 | 13.7 |
| | | 3200601 | 2.8 | 0 |
| | | 3200613 | 34.6 | 0 |
| | | 3200615 | 21.3 | 0 |
| | | 3200616 | 0 | 13.7 |
| | | 3200617 | 0 | 24.2 |
| | | 3200622 | 5.1 | 0 |
| | | 3200635 | 55.5 | 55 |
| | | 3200636 | 0 | 208 |
| | | 3200641 | 12.3 | 0 |
| | | 3200644 | 90.2 | 85.3 |
| | | 3200646 | 12.1 | 11.3 |
| | | 3200653 | 6.2 | 0 |
| | | 3200654 | 11.2 | 0 |
| | | 3200657 | 14.9 | 0 |
| | | 3200658 | 9.7 | 0 |
| | | 3200672 | 65.1 | 56.4 |
| | | 3200675 | 31.2 | 27.8 |
| | | 3200685 | 7.5 | 0 |
| | | 3200706 | 15.4 | 7.2 |
| | | 3200707 | 21.8 | 0 |
| | | 3200710 | 0 | 32.9 |
| | | 3200714 | 14 | 0 |
| | | 3200720 | 23.8 | 2.5 |
| | | 3200725 | 3.5 | 0 |
| | | 3200734 | 5.2 | 0 |
| | | 3200757 | 28.2 | 21.7 |

| | | 3200766 | 0 | 21.4 |
|---|---|---|---|---|
| | | 3200785 | 4.8 | 0 |
| | | 3200809 | 6.7 | 0 |
| | | 3200925 | 0 | 55.2 |
| | | 3200944 | 0 | 28.8 |
| | | 3200945 | 0 | 34.1 |
| | | 3200967 | 0 | 69.1 |
| 32_ADS016 | McElmoCrkNrStLin | 3200501 | 13.6 | 0 |
| | | 3200505 | 9.7 | 0 |
| | | 3200513 | 56 | 92.3 |
| | | 3200515 | 9.6 | 0 |
| | | 3200520 | 44.8 | 48.8 |
| | | 3200524 | 21.8 | 0 |
| | | 3200525 | 5.8 | 0 |
| | | 3200551 | 10 | 0 |
| | | 3200552 | 5.2 | 0 |
| | | 3200554 | 18.6 | 0 |
| | | 3200559 | 5.5 | 0 |
| | | 3200560 | 19.6 | 36.3 |
| | | 3200563 | 56.2 | 0 |
| | | 3200564 | 58.9 | 8.1 |
| | | 3200573 | 56.5 | 60.3 |
| | | 3200582 | 7.5 | 0 |
| | | 3200588 | 24.9 | 28.4 |
| | | 3200589 | 5.3 | 0 |
| | | 3200592 | 70.1 | 69 |
| | | 3200594 | 155 | 137 |
| | | 3200596 | 11.7 | 3.4 |
| | | 3200597 | 4.8 | 5.2 |
| | | 3200598 | 3.8 | 0 |
| | | 3200605 | 24.3 | 0 |
| | | 3200612 | 141.9 | 158 |
| | | 3200618 | 1.9 | 0 |
| | | 3200619 | 26.5 | 16.6 |
| | | 3200625 | 26.6 | 0 |
| | | 3200632 | 13.9 | 9.5 |
| | | 3200639 | 15.6 | 0 |
| | | 3200643 | 9.7 | 4.5 |
| | | 3200649 | 24.4 | 0 |
| | | 3200660 | 29.3 | 29.6 |
| | | 3200661 | 6.9 | 7.3 |
| | | 3200665 | 110.7 | 78.3 |
| | | 3200666 | 5.8 | 0 |
| | | 3200667 | 199.8 | 0 |
| | | 3200671 | 29.8 | 15.9 |
| | | 3200673 | 39.4 | 32.7 |
| | | 3200681 | 0 | 37.6 |
| | | 3200686 | 7.3 | 0 |
| | | 3200693 | 66 | 0 |

| | | 3200708 | 5.2 | 0 |
|---|---|---|---|---|
| | | 3200737 | 16.7 | 0 |
| | | 3200773 | 0 | 2.1 |
| | | 3200893 | 0 | 136.1 |
| | | 3205022 | 4.7 | 0 |
| 71_ADS017 | DolorRabvMcPheeR | 7100502 | 40.5 | 0 |
| | | 7100517 | 10.9 | 8.4 |
| | | 7100519 | 4 | 9.8 |
| | | 7100523 | 33.4 | 0 |
| | | 7100532 | 15.9 | 0 |
| | | 7100534 | 17.4 | 17.6 |
| | | 7100544 | 48 | 0 |
| | | 7100546 | 39.8 | 0 |
| | | 7100547 | 65.8 | 56.1 |
| | | 7100548 | 50.3 | 0 |
| | | 7100552 | 7.4 | 0 |
| | | 7100553 | 35 | 44.5 |
| | | 7100558 | 11.4 | 11.1 |
| | | 7100560 | 38.3 | 0 |
| | | 7100562 | 12.3 | 30.9 |
| | | 7100565 | 36.6 | 0 |
| | | 7100567 | 111.2 | 101.1 |
| | | 7100576 | 35.9 | 21.1 |
| | | 7100579 | 38 | 0 |
| | | 7100580 | 5.2 | 6 |
| | | 7100584 | 13.8 | 0 |
| | | 7100587 | 67.6 | 0 |
| | | 7100588 | 64.2 | 82.3 |
| | | 7100589 | 47.5 | 58.3 |
| | | 7100590 | 65.3 | 0 |
| | | 7100591 | 10.6 | 0 |
| | | 7100592 | 24.2 | 0 |
| | | 7100593 | 21.5 | 10.3 |
| | | 7100595 | 8.5 | 0 |
| | | 7100599 | 26.1 | 0 |
| | | 7100601 | 60.6 | 35 |
| | | 7100603 | 25 | 26.4 |
| | | 7100608 | 11 | 5.6 |
| | | 7100613 | 28.2 | 0 |
| | | 7100614 | 0 | 1.3 |
| | | 7100621 | 63.3 | 0 |
| | | 7100659 | 0 | 3.6 |
| | | 7102001 | 55.7 | 0 |
| | | 7102004 | 369.2 | 287 |
| | | 7103607 | 98.6 | 0 |
| | | 7103610 | 18.3 | 22.2 |
| | | 7103617 | 25.5 | 25.5 |
| 69_ADS018 | DisappointmentCk | 6900501 | 90.3 | 82.4 |
| | | 6900502 | 28.9 | 33.2 |

| | | | | |
|---|---|---|---|---|
| | | 6900503 | 368.9 | 0 |
| | | 6900504 | 224.7 | 0 |
| | | 6900505 | 8.5 | 0 |
| | | 6900508 | 33.4 | 0 |
| | | 6900509 | 41.7 | 0 |
| | | 6900511 | 0 | 104.3 |
| | | 6900513 | 238 | 48 |
| | | 6900514 | 8.7 | 11.7 |
| | | 6900515 | 25 | 32.7 |
| | | 6900516 | 19.2 | 0 |
| | | 6900521 | 139 | 0 |
| | | 6900523 | 10.3 | 0 |
| | | 6900524 | 21.6 | 0 |
| | | 6900525 | 77.7 | 22.7 |
| | | 6900526 | 36.1 | 0 |
| | | 6900527 | 59.5 | 77.5 |
| | | 6900529 | 63.8 | 70.3 |
| | | 6903531 | 47.9 | 81.7 |
| 61_ADS019 | DoloresRNrBedrck | 6100506 | 431.5 | 514.1 |
| | | 6100507 | 48 | 0 |
| | | 6100510 | 39 | 0 |
| | | 6100511 | 22.6 | 0 |
| | | 6100512 | 201.9 | 235.1 |
| | | 6100530 | 0 | 19.7 |
| | | 6100533 | 7.1 | 0 |
| | | 6100534 | 10.7 | 0 |
| | | 6100536 | 0 | 41.3 |
| | | 6100537 | 132.7 | 0 |
| | | 6100539 | 83.2 | 51.7 |
| | | 6100543 | 0 | 55.3 |
| | | 6100547 | 0 | 33 |
| | | 6100551 | 0 | 61 |
| | | 6100553 | 369.4 | 0 |
| | | 6100558 | 99.4 | 0 |
| | | 6100663 | 0 | 6.3 |
| | | 6105000 | 24.1 | 0 |
| | | 6105010 | 0 | 66 |
| | | 7100616 | 59.3 | 26.9 |
| 60_ADS020 | SMiguelNrPlacrvl | 6000502 | 219.4 | 0 |
| | | 6000505 | 290.8 | 117.2 |
| | | 6000524 | 20.5 | 2.2 |
| | | 6000530 | 16 | 0 |
| | | 6000542 | 59.6 | 0 |
| | | 6000576 | 72.8 | 40.4 |
| | | 6000586 | 28 | 0 |
| | | 6000594 | 11.6 | 0 |
| | | 6000608 | 166.7 | 188.5 |
| | | 6000617 | 11.7 | 0 |
| | | 6000627 | 87.8 | 93.4 |

| | | 6000629 | 63.7 | 0 |
|---|---|---|---|---|
| | | 6000652 | 9.4 | 0 |
| | | 6000678 | 0 | 80.4 |
| | | 6000693 | 105.1 | 63.5 |
| | | 6000706 | 0 | 124.8 |
| | | 6000725 | 88.7 | 92.4 |
| | | 6000741 | 145.3 | 37.3 |
| | | 6000794 | 32.5 | 11.1 |
| | | 6000797 | 9.4 | 0 |
| | | 7100511 | 72 | 0 |
| | | 7100539 | 31.5 | 0 |
| | | 7100561 | 0 | 38.7 |
| | | 7100564 | 188.5 | 0 |
| | | 7100607 | 374.8 | 0 |
| | | 7100636 | 0 | 55.7 |
| | | 7100637 | 0 | 76.4 |
| 60_ADS021 | SMiguelabvWNatC | 6000537 | 45.5 | 20.1 |
| | | 6000618 | 105.8 | 88.8 |
| | | 6000653 | 58.7 | 43.3 |
| | | 6000665 | 265.9 | 356.8 |
| | | 6000721 | 74 | 335.7 |
| | | 6000768 | 166 | 0 |
| | | 6001164 | 381.1 | 523.6 |
| 60_ADS022 | SMiguel@Naturita | 6000518 | 19.6 | 0 |
| | | 6000526 | 5.5 | 10.4 |
| | | 6000532 | 0.5 | 0 |
| | | 6000560 | 8.5 | 0 |
| | | 6000563 | 15.1 | 37.4 |
| | | 6000577 | 133.3 | 92.9 |
| | | 6000582 | 227.6 | 450.2 |
| | | 6000587 | 21.7 | 181.6 |
| | | 6000598 | 0 | 266.8 |
| | | 6000604 | 0.5 | 0 |
| | | 6000613 | 55.6 | 65.4 |
| | | 6000614 | 75.5 | 0 |
| | | 6000623 | 118.2 | 0 |
| | | 6000624 | 326.5 | 49.2 |
| | | 6000625 | 0 | 63 |
| | | 6000634 | 67 | 137.7 |
| | | 6000648 | 0 | 81.8 |
| | | 6000655 | 0 | 81.6 |
| | | 6000657 | 30.9 | 0 |
| | | 6000685 | 0 | 132.2 |
| | | 6000698 | 2.8 | 0 |
| | | 6000701 | 0 | 154.6 |
| | | 6000702 | 0 | 530.5 |
| | | 6000717 | 5.5 | 0 |
| | | 6000718 | 8.8 | 0 |
| | | 6000720 | 25 | 21.1 |

| | | 6000730 | 45 | 119.2 |
|---|---|---|---|---|
| | | 6000732 | 31.8 | 0 |
| | | 6000738 | 27.8 | 8.1 |
| | | 6000754 | 6.8 | 0 |
| | | 6000763 | 81.7 | 0 |
| | | 6000765 | 1.9 | 0 |
| | | 6000771 | 50.1 | 0 |
| | | 6000783 | 61 | 0 |
| | | 6000785 | 1.3 | 0 |
| | | 6000786 | 46.4 | 0 |
| | | 6000792 | 149 | 189.2 |
| | | 6000802 | 0 | 28.8 |
| | | 6000803 | 46.3 | 0 |
| | | 6000814 | 95.3 | 160.8 |
| | | 6000820 | 1 | 0 |
| | | 6000830 | 6.3 | 0 |
| | | 6000831 | 3.6 | 0 |
| | | 6000867 | 0 | 50.1 |
| | | 6000990 | 0 | 69.3 |
| | | 6001171 | 7 | 20.3 |
| | | 6001239 | 71.1 | 595 |
| | | 6001316 | 30.3 | 0 |
| | | 6001627 | 0 | 400.6 |
| 63_ADS023 | DoloresR@Gateway | 6000523 | 30.7 | 0 |
| | | 6000527 | 43.4 | 0 |
| | | 6000540 | 49.8 | 0 |
| | | 6000568 | 27.8 | 0 |
| | | 6000570 | 0 | 15.3 |
| | | 6000599 | 3.4 | 0 |
| | | 6000639 | 30.7 | 0 |
| | | 6000674 | 39.5 | 0 |
| | | 6000688 | 112.6 | 0 |
| | | 6000735 | 185.6 | 219.3 |
| | | 6000744 | 15.9 | 0 |
| | | 6000798 | 8.6 | 0 |
| | | 6000812 | 46.8 | 0 |
| | | 6000816 | 0 | 40.6 |
| | | 6000928 | 34.2 | 0 |
| | | 6001622 | 0 | 12.5 |
| | | 6300500 | 7.2 | 0 |
| | | 6300502 | 85.3 | 59.5 |
| | | 6300514 | 43.3 | 23.1 |
| | | 6300517 | 25.4 | 0 |
| | | 6300519 | 11.9 | 97.1 |
| | | 6300524 | 6.5 | 0 |
| | | 6300542 | 45.4 | 53.8 |
| | | 6300550 | 125.6 | 0 |
| | | 6300551 | 13.8 | 0 |
| | | 6300563 | 28.2 | 36.5 |

| | | 6300571 | 45.7 | 0 |
|---|---|---|---|---|
| | | 6300574 | 12.1 | 0 |
| 63_ADS024 | WestCreek | 6300504 | 17.3 | 10.1 |
| | | 6300506 | 36.3 | 43.7 |
| | | 6300507 | 20.5 | 29.5 |
| | | 6300509 | 9.6 | 5.1 |
| | | 6300510 | 8.4 | 0 |
| | | 6300511 | 14.3 | 0 |
| | | 6300512 | 15.3 | 0 |
| | | 6300515 | 72.4 | 111.6 |
| | | 6300520 | 114.6 | 52.7 |
| | | 6300523 | 3.8 | 3.6 |
| | | 6300525 | 16.5 | 17.3 |
| | | 6300527 | 58.7 | 104.2 |
| | | 6300530 | 19.9 | 69.3 |
| | | 6300531 | 53.6 | 0 |
| | | 6300532 | 5.8 | 2.1 |
| | | 6300533 | 10.8 | 11.6 |
| | | 6300534 | 27.1 | 0 |
| | | 6300536 | 8.8 | 0 |
| | | 6300537 | 5 | 6 |
| | | 6300538 | 67.9 | 47.8 |
| | | 6300539 | 11.2 | 13.8 |
| | | 6300540 | 32.4 | 33.3 |
| | | 6300549 | 56.2 | 65 |
| | | 6300552 | 237.3 | 252.1 |
| | | 6300554 | 3.6 | 3 |
| | | 6300558 | 80.4 | 77.4 |
| | | 6300560 | 36.2 | 42 |
| | | 6300562 | 27.9 | 26 |
| | | 6300564 | 33.3 | 133.9 |
| | | 6300565 | 65.4 | 140.3 |
| | | 6300566 | 13.4 | 30.5 |
| | | 6300567 | 13.4 | 64.5 |
| | | 6300570 | 10.3 | 0 |
| | | 6300572 | 55.8 | 41.5 |
| | | 6300573 | 12.1 | 8.1 |
| | | 6300577 | 2.9 | 0 |
| | | 6300597 | 10.7 | 10 |
| | | 6300682 | 7.1 | 0 |
| | | 6300735 | 0 | 60.2 |
| | | 6303643 | 13.8 | 78 |
| 73_ADS025 | LittleDoloresR | 6300526 | 8.3 | 9 |
| | | 6300575 | 49.8 | 96 |
| | | 6300576 | 15.4 | 0 |
| | | 7300501 | 73.9 | 57.4 |
| | | 7300503 | 34.2 | 0 |
| | | 7300504 | 161.1 | 149.6 |
| | | 7300505 | 236 | 231.7 |

| | | 7300506 | 83.1 | 49.4 |
|---|---|---|---|---|
| | | 7300508 | 91.4 | 0 |
| | | 7300509 | 24.5 | 27.8 |
| | | 7300511 | 33.6 | 0 |
| | | 7300512 | 198.7 | 149.2 |
| | | 7300513 | 57 | 0 |
| | | 7300514 | 0 | 37.4 |
| | | 7300515 | 117.6 | 98.7 |
| | | 7300516 | 106.9 | 104.7 |
| | | 7300517 | 18.2 | 20 |
| | | 7300519 | 193 | 0 |
| | | 7300520 | 138.6 | 0 |
| | | 7300521 | 15 | 12.4 |
| | | 7300522 | 28.6 | 0 |
| | | 7300530 | 92 | 52.2 |
| | | 7300531 | 87.9 | 30.1 |
| | | 7300532 | 85.1 | 71.4 |
| | | 7300533 | 60.5 | 204.3 |
| | | 7300534 | 39.1 | 52.3 |
| | | 7300535 | 144.1 | 185.1 |
| | | 7300537 | 567.7 | 186.9 |
| | | 7300538 | 133 | 136.9 |
| | | 7300540 | 114.8 | 0 |
| | | 7300541 | 16.7 | 18.9 |
| | | 7300542 | 3.8 | 0 |
| | | 7300543 | 9.7 | 10.3 |
| | | 7300561 | 3.5 | 0 |
| | | 7300566 | 14.1 | 10.5 |
| | | 7300605 | 13.3 | 13.5 |
| **Total** | | | **37,130** | **33,405** |

# Appendix B

**Aggregation of Non-Irrigation Structures**

**1. CDSS Memorandum 6.10**
**San Juan/Dolores Basin Aggregated Municipal and Industrial Use**

**2. CDSS Memorandum 6.11**
**San Juan/Dolores Basin Aggregated Reservoirs and Stock Ponds**

# Section D.4
# Final

TO:        File

FROM:      Ray R. Bennett

SUBJECT:   **Subtask 6.10 San Juan/Dolores River Basin**
           **Aggregated Municipal and Industrial Use**

## Introduction

This memo describes the results of Subtask 6.10 San Juan/Dolores River Basin
Aggregated Municipal and Industrial Use. The objective of this task was as follows:

> *Aggregate municipal and industrial uses not explicitly modeled in Phase II to*
> *simulate their  depletive effects in the basin.*

## Approach and Results

Phase II Modeled M&I Use - **Table 1** presents the 1975 to 1991 average annual
Municipal and Industrial depletions modeled in Phase II.

**TABLE 1**
Phase II Explicitly Modeled M&I Consumptive Use (acre-feet)

| Ditch | San Juan | Dolores | Total |
|---|---|---|---|
| Durango City (301000) | 2536 | 0 | 2,536 |
| Town of Mancos (340573) | 489 | 0 | 489 |
| Original Rico Flume (710575) | 0 | 104 | 104 |
| Town of Cortez (320680) | 1,531 | 0 | 1,531 |
| Total | 4,556 | 104 | 4,660 |

**Phase II Consumptive Uses and Loss Estimates**  The following table presents the
categories and values of M&I consumptive use presented in the task memorandum 2.09-
13 "Non-Evapotranspiration (Other Uses) Consumptive Uses and Losses in the Dolores
and San Juan River Basin" (11/26/96).

**Phase II Consumptive Use and Loss M&I Consumptive Use**

| Category | San Juan | Dolores | Total |
|----------|----------|---------|-------|
| Municipal | 4,202 | 791 | 4,993 |
| Mineral | 392 | 17 | 409 |
| Livestock | 1037 | 598 | 1,635 |
| **Total** | **5,631** | **1,406** | **7,037** |

**Aggregated M&I Diversion**  Based on the above data and the relatively small amount of consumption, two aggregated M&I demands were added to the model; one (32_AMS001) for the San Juan River Basin above the Towaoc-Highline Canal (320884) and above San Juan near Bluff, Utah stream flow gage (09379500); and another (63_AMS002) for the Dolores River Basin just above the Dolores River at Gateway, CO gage (09179500). Exhibit 1 of Section D.6 is a network diagram which includes the aggregated M&I demand.

As summarized below, the San Juan Aggregated M&I Demand (32_AMS001) was assigned a depletive demand (efficiency of 100%) **of 1,075 af/yr**. (5,631 af - 4,556 af) distributed evenly over 12 months. The Dolores Aggregated M&I Demand (63_AMS002) was assigned depletive demand (efficiency of 100%) of **1,302 af/yr**. (1,406 af - 104 af) distributed evenly over 12 months. Both aggregated M&I demands were assigned a water right of 2 cfs and a senior administration number of 1.

The monthly aggregated demand files were built in an editor using a StateMod format. They were named *32_AMS001.stm* and *63_AMS002.stm* for the San Juan and Dolores respectively. These time series were incorporated in the demand files by using a -replace option with **demandts**.

**Phase III Aggregated M&I Consumptive Use Summary**

| Basin | Aggregated M&I ID | Depletive Demand (af/yr) | Water Right (cfs) |
|-------|-------------------|--------------------------|-------------------|
| San Juan | 32_AMS001 | 1,075 | 2 |
| Dolores | 63_AMS002 | 1,302 | 2 |
| **Total** | | **2,377** | **4** |

**Section D.5**
**Final**


TO:         File

FROM:     Ray Alvarado

SUBJECT:  **Subtask 6.11-San Juan/Dolores River Basin**
          **Aggregated Reservoirs and Stock Ponds**



**Introduction**

This memorandum describes the approach and results obtained under Subtask 6.11,
Aggregate Reservoirs and Stock Ponds. The objective of this task was as follows:

> *Aggregate reservoirs and stock ponds not explicitly modeled in Phase II to allow*
> *simulation of   effects of minor reservoirs and stock ponds in the basin.*



**Approach and Results**

**Reservoirs and Stock Ponds:  Table 1** presents the net absolute storage rights that were
modeled in Phase II, those to be added as aggregated reservoirs in Phase IIIa, and stock
ponds to be added as aggregated stock ponds in Phase IIIa. The Phase II reservoir
information was obtained from the Phase II reservoir rights file, *sanjuan.rer*. The
absolute decree amount presented in **Table 1** for "Total Aggregated Reservoirs " was
produced by running **watright** with basin=sanjuan and basin=dolores with the -aggres
option. The storage presented in **Table 1** for the "Total Aggregated Stock Ponds" was
taken from the year 2 Task Memorandum 2.09-13 "Consumptive Use Model Non-
Irrigation (Other Uses) Consumptive Uses and Losses in the Dolores and San Juan River
Basins" (11/26/96).

**TABLE 1**

| Phase | Reservoir | Absolute Decree (af) | Percent Total |
|---|---|---|---|
| Phase II | CASCADE RESERVOIR | 23,254 | 3% |
| Phase II | LEMON RESERVOIR | 48,000 | 6% |
| Phase II | VALLECITO RESERVOIR | 129,674 | 16% |
| Phase II | JACKSON GULCH | 11,365 | 1% |
| Phase II | GURLEY RESERVOIR | 8,233 | 1% |
| Phase II | NATURITA RESERVOIR | 3,000 | <1% |
| Phase II | LAKE HOPE RESERVOIR | 2,315 | <1% |
| Phase II | MIRAMONTE RESERVOIR | 6,851 | 1% |
| Phase II | TROUT LAKE RESERVOIR | 3,186 | <1% |
| Phase II | NARRAGUINNEP | 22,455 | 3% |
| Phase II | GROUNDHOG RESERVOIR | 21,709 | 3% |
| Phase II | MCPHEE RESERVOIR | 381,200 | 48% |
| Phase II | SUMMIT RESERVOIR | 4,442 | 1% |
| Subtotal | | 665,684 | 84% |
| Phase III | Total Aggregated Reservoirs | 94,703 | 12% |
| Phase III | Total Aggregated Stock Ponds | 35,271 | 4% |
| Subtotal | | 129,974 | 16% |
| Total | | 795,658 | 100% |

**Number of Structures and Locations:** Based on general location, the Phase IIIa reservoirs and stock ponds were incorporated into the model as 8 aggregated structures. The Total Aggregated Reservoirs represent numerous small reservoirs that are administered as stock ponds. Five aggregated reservoirs were used to model the absolute decreed storage not already modeled in Phase II. Storage was assigned to the five non-operational reservoirs equally as shown in **Table 2**. The Total Aggregated Stock Ponds were modeled as three non-operational reservoirs; total capacity was partitioned to the three nodes equally, also shown in **Table 2**.

Each aggregated reservoir and stock pond was assigned one account and an initial storage equal to their capacity. Each aggregated reservoir and stock pond was assumed to be 10 foot deep. The eight aggregated structures were modeled as exempt from an annual one-fill limit. Each aggregated reservoir and stock pond was assigned a 2 point area-capacity curve. The first curve point is zero capacity and zero area. The second point on the area-capacity table is total capacity with the area equal to the total capacity divided by 10. The net evaporation station as described in Phase II San Juan River basin documentation (Section 4.3.2.1 "Estimation of Annual Net Evaporation") was assigned to each structure at 100 percent. All other parameters were left as the default to each structure.

# TABLE 2

### Aggregate Reservoirs

| Model ID | Name | Capacity (AF) | Percent |
|---|---|---|---|
| 63_ARS001 | 63_ARS001_Dolores | 18,941 | 20 |
| 30_ARS002 | 30_ARS002_Animas | 18,941 | 20 |
| 31_ARS003 | 31_ARS003_LosPinos | 18,941 | 20 |
| 78_ARS004 | 78_ARS004_Piedra | 18,941 | 20 |
| 29_ARS005 | 29_ARS005_SanJuan | <u>18,941</u> | <u>20</u> |
| | Total | 94,703 | 100 |

### Aggregate Stock Ponds

| Model ID | Name | Capacity (AF) | Percent |
|---|---|---|---|
| 30_ASS001 | 30_ASS001_Animas | 11,757 | 33.3 |
| 31_ASS002 | 31_ASS002_LosPinos | 11,757 | 33.3 |
| 78_ASS003 | 78_ASS003_Piedra | <u>11,757</u> | <u>33.3</u> |
| | Total | 35,271 | 100 |

**Target Contents, and End-of-Month Data:** Each aggregated reservoir and stock pond was designed to maintain maximum volume, filling to account for evaporation losses. The end-of-month data used in the baseflow calculations was set to the target values.

**Water Rights:** Water rights associated with each aggregated reservoir and aggregated stock pond were assigned an administration number equal to 1.

# Appendix C

**Pattern Streamgages**

**CDSS Daily San Juan Model –Recommendation of Pattern Streamgages**

# CDSS Memorandum
# Final

**To:** Ray Alvarado and Ray Bennett

**From:** Mary Presecan and Erin Wilson

**Subject:** CDSS Daily San Juan – Dolores River Basin Model – Recommendation of Pattern Streamgages

**Date:** November 23, 2004


## Introduction

The purpose of this memorandum is to outline the approach used to select pattern streamgages within the San Juan and Dolores Basins for the daily model. These pattern gages will be used in the San Juan – Dolores River Basin Model to disaggregate monthly baseflow estimate results to daily baseflows at baseflow gages.


## Background

Boyle Engineering completed a pilot study for the CDSS Daily Yampa Model, in which they determined that the best approach to creating a daily model was to use the daily pattern approach (see September 28, 2001 "CDSS Daily Yampa Model – Task 2 Pilot Study" by Meg Frantz and Linda Williams).

The daily pattern approach can be described as distributing monthly baseflows to daily baseflows based on the daily distribution of selected historical gages, or pattern gages. StateMod is used to disaggregate the monthly baseflows by multiplying the daily historical gage flow $QD_{gage}$ by the factor $QM_{bf}/QM_{gage}$, where $QM_{bf}$ is the monthly baseflow and $QM_{gage}$ is the monthly historical gage flow.

For this approach, monthly demands are disaggregated to daily demands by connecting the midpoints of the monthly data. Reservoir targets are disaggregated by connecting the endpoints of end of month contents. Instream flow demands are disaggregated by setting them to the average daily value.

The Scope of Work for the San Juan River Basin StateMod Update defined the daily model simulation period to be 1975 through 2003. This is consistent with CDSS daily modeling efforts in both the Yampa and Gunnison River Basins. However, the San Juan – Dolores River Basin Model will be used in conjunction with the United States Bureau of Reclamation (USBR) RiverWare model to evaluate the San Juan Recovery Implementation Program. The USBR RiverWare model uses a simulation period of 1929 through 2000. Therefore, LRE recommended to the State that our efforts to determine pattern gages should consider a similar simulation period. Based on this consideration, LRE reviewed streamflow records for the model

gages back to 1929 and found that streamflow records for potential pattern gages was consistently available only through 1936. Therefore, LRE recommended, and the State approved the recommendation to develop a daily model that can simulate for 1936 through 2003. Note that calibration and documentation efforts will focus on the original scoped period from 1975 through 2003.

## Approach

The daily streamflow pattern gages were selected for use in the San Juan - Dolores River Basin Model by using the following approach:

1) ***Review Completeness of Daily Records*** - The streamflow gages within the San Juan - Dolores River Basin Model were reviewed for completeness of daily records over the 1936 through 2003 simulation period for the purpose of minimizing the need to fill missing daily data.

2) ***Select Representative Gages*** - Representative gages were selected based on representative location and minimal upstream effects for the purpose of using the historical record to disaggregate baseflows.

3) ***Compare Historical Flows and StateMod Calculated baseflows*** – To further support the selection of representative gages, average historical monthly flows were compared to the average baseflows calculated using StateMod to quantify the upstream effects and verify the gage selections from Step 2. Gages exhibiting historical flow similar to baseflow indicate minimal influence by humans (i.e., diversion for irrigation, storage, etc.).

4) ***Fill Missing Daily Data*** – Selected pattern gages missing daily data over the 1936 through 2003 simulation period were filled using the TSTool regression algorithms for the purpose of completing the diversion record fro 1936 through 2003.

5) ***Generate the Historical Daily Streamflow File*** – The historical daily streamflow file, *sj2004.rid*, was created using the command file *sj_rid.TSTool*.

## Results - Review Completeness of Daily Records

The Monthly San Juan - Dolores River Basin Model uses a total of fifty-eight streamgages to develop baseflows. These gages were reviewed to determine which gages should be selected for the daily pattern gages. Two primary criteria were used in the selection of daily pattern gages:

(1) Completeness of the daily data set over the simulation period (1936 – 2003),
(2) Location of the gage.

Of the fifty-eight gages in the San Juan - Dolores River Basin Model, three of the model gages were StateMod files previously developed, i.e., the gage data was not available in HydroBase. The period of record for the remaining 55 gages is presented in Table 1.

**Table 1**
**Model Gages and Available Period of Record**

| USGS Gage ID | USGS Gage Name | Available Period of Record[a/b/] |
|---|---|---|
| 09166500 | DOLORES RIVER AT DOLORES | 1896 – 1903 1922 - 2003 |
| 09165000 | DOLORES RIVER BELOW RICO | 1952 - 2003 |
| 09166950 | LOST CANYON CREEK NEAR DOLORES | 1984 - 2003 |
| 09168100 | DISAPPOINTMENT CREEK NEAR DOVE CREEK, CO | 1957 - 1986 |
| 09169500 | DOLORES RIVER AT BEDROCK | 1918 - 1922 1971 - 2003 |
| 09171100 | DOLORES RIVER NEAR BEDROCK | 1971 - 2003 |
| 09171200 | SAN MIGUEL RIVER NEAR TELLURIDE, CO. | 1960 - 1965 |
| 09172000 | FALL CREEK NEAR FALL CREEK, CO. | 1941 - 1959 |
| 09172100 | LEOPARD CREEK AT NOEL, CO. | 1956 - 1963 |
| 09172500 | SAN MIGUEL RIVER NEAR PLACERVILLE | 1931 - 1934 1942 - 2003 |
| 09173000 | BEAVER CREEK NEAR NORWOOD | 1942 - 1967 1975 - 1981 |
| 09175500 | SAN MIGUEL RIVER AT NATURITA, CO. | 1918 - 1929 1941 - 1981 |
| 09177000 | SAN MIGUEL RIVER AT URAVAN, CO. | 1954 - 1962 1974 - 2003 |
| 09179500 | DOLORES RIVER AT GATEWAY, CO. | 1937 - 1954 |
| 09339900 | EAST FORK SAN JUAN RIVER ABOVE SAND CREEK | 1957 - 2003 |
| 09341500 | WEST FORK SAN JUAN RIVER NEAR PAGOSA SPRINGS | 1936 - 1960 1985 - 1987 |
| 09342000 | TURKEY CREEK NEAR PAGOSA SPRINGS, CO. | 1937 - 1949 |
| 09342500 | SAN JUAN RIVER AT PAGOSA SPRINGS | 1936 - 2003 |
| 09343300 | RIO BLANCO BELOW BLANCO DIVERSION DAM NEAR PAGOSA | 1971 - 2003 |
| 09344000 | NAVAJO RIVER AT BANDED PEAK RANCH NEAR CHROMO | 1937 - 2003 |
| 09344400 | NAVAJO RIVER BELOW OSO DIVERSION DAM NEAR CHROMO | 1971 - 2003 |
| 09345200 | LITTLE NAVAJO R BL L OSO DIV DAM, NR CHRROMO, CO | 1971 - 1996 |
| 09346000 | NAVAJO RIVER AT EDITH, CO. | 1913 - 1928 1936 - 1996 |
| 09346400 | SAN JUAN RIVER NEAR CARRACAS | 1962 - 2003 |
| 09347500 | PIEDRA R AT BRIDGE RNGR STA, NR PAGOSA SPGS, CO | 1937 - 1941 1947 - 1954 |
| 09349500 | PIEDRA RIVER NEAR PIEDRA, CO. | 1940 - 1975 |
| 09349800 | PIEDRA RIVER NEAR ARBOLES | 1962 - 2003 |
| 09352900 | VALLECITO CREEK NEAR BAYFIELD | 1963 - 2003 |
| 09353500 | LOS PINOS RIVER NEAR BAYFIELD, CO | 1928 - 1986 |
| 09354500 | LOS PINOS RIVER AT LA BOCA | 1951 - 2003 |
| 09355000 | SPRING CREEK AT LA BOCA | 1951 - 2003 |
| 09355500 | SAN JUAN RIVER NEAR ARCHULETA, NM | 1955 - 2002 |
| 09357500 | ANIMAS RIVER NEAR HOWARDSVILLE | 1936 - 2003 |
| 09359000 | MINERAL CREEK NEAR SILVERTON, CO | 1937 - 1949 |
| 09359500 | ANIMAS RIVER ABOVE TACOMA, CO | 1946 - 1956 |
| 09361000 | HERMOSA CREEK NEAR HERMOSA | 1921 - 1928 1941 - 1982 |
| 09361500 | ANIMAS RIVER AT DURANGO | 1912 - 2003 |
| 09362750 | FLORIDA RIVER ABOVE LEMON RESERVOIR NEAR DURANGO | 1973 - 2003 |

| 09363200 | FLORIDA RIVER AT BONDAD | 1957 - 1963<br>1968 - 1983 |
|---|---|---|
| 09363500 | ANIMAS RIVER NEAR CEDAR HILL, NM | 1934 - 1996 |
| 09364500 | ANIMAS RIVER AT FARMINGTON, NM | 1920 - 1925<br>1931 - 2002 |
| 09365000 | SAN JUAN RIVER AT FARMINGTON, NM | 1931 - 2003 |
| 09365500 | LA PLATA RIVER AT HESPERUS | 1918 - 2003 |
| 09366500 | LA PLATA RIVER AT THE COLORADO-NEW MEXICO STATELINE | 1921 - 2003 |
| 09367500 | LA PLATA RIVER NEAR FARMINGTON, NM | 1938 - 2002 |
| 09368500 | WEST MANCOS RIVER NEAR MANCOS, CO | 1939 - 1953 |
| 09369000 | EAST MANCOS RIVER NEAR MANCOS, CO | 1937 - 1951 |
| 09369500 | MIDDLE MANCOS RIVER NEAR MANCOS, CO | 1936 - 1951 |
| 09371000 | MANCOS RIVER NEAR TOWAOC | 1921 - 1943<br>1952 - 2003 |
| 09371400 | HARTMAN DRAW AT CORTEZ, CO | 1978 - 1986 |
| 09371420 | MCELMO CREEK ABOVE ALKALI CANYON, NR CORTEZ, CO | 1973 - 1986 |
| 09371500 | MCELMO CREEK NEAR CORTEZ, CO | 1927 - 1929<br>1941 - 1943<br>1951 - 1954<br>1983 - 1993 |
| 09372000 | MCELMO CREEK NEAR COLORADO-UTAH STATE LINE | 1951 - 2003 |
| 09379500 | SAN JUAN RIVER NEAR BLUFF, UT | 1928 - 2003 |
| 09371010 | SAN JUAN RIVER AT FOUR CORNERS, CO | 1978 – 2002 |
| a/  Years are identified in water year.<br>b/  The identified period of record may include short periods (less than two years) with incomplete daily data. | | |

## Results - Select Representative Gages

The location of the gage was the second criterion for selecting pattern gages.  The historical flows at the selected pattern gages needed to be as close to baseflow conditions as possible. Gages located downstream of key reservoirs, imports, or gages affected by large upstream diversions were not as favorable for pattern gages as gages located above these structures.  Gages located downstream of such structures are impacted by the fluctuations of reservoirs, the amount of water imported, or quantities and timing of diversions and associated return flows, therefore the historical flows are not representative of baseflow conditions.

Eight streamflow gages from the list above were identified as being located where historical flows would be similar to baseflow conditions and having significant availability of data throughout the simulation period of 1936 through 2003.  These eight selected pattern gages were assigned to represent all of the sub-basins in the San Juan - Dolores River Basin Model.  Table 2 identifies the pattern gages selected and sub-basin in the San Juan - Dolores River Basin Model represented by that gage.

**Table 2**
**Recommended Daily Pattern Gages for San Juan and Dolores River Sub-basins**

| Recommended Pattern Gage | Basin Subdivision |
|---|---|
| 09166500 – Dolores River at Dolores | Paradox Creek, Disappointment Creek, and West Dolores Creek Basins (Districts 61, 69, & 71) |
| 09172500 – San Miguel River near Placerville | San Miguel River Basin and Dolores River Basin (Districts 60 & 63) |
| 09339900 – East Fork San Juan River above Sand Creek | San Juan River Basin and Piedra River Basin (Districts 29 & 78) |
| 09344000 – Navajo River at Banded Peak Ranch near Chromo | Navajo River Basin (District 77) |
| 09352900 – Vallecito Creek near Bayfield | Los Pinos River Basin and Navajo Reservoir (Districts 31 & 46) |
| 09365500 – La Plata River at Hesperus | La Plata River Basin (District 33) |
| 09357500 – Animas River near Howardsville | Animas River Basin (District 30) |
| 09371000 – Mancos River near Towaoc | McElmo Creek Basin and Mancos River Basin (Districts 32 & 34) |

A brief description of why each pattern gage was chosen to represent the corresponding sub-basins and specifics on missing data, if any, follows:

- Gage 09166500, Dolores River at Dolores, was selected to represent Water Districts 61, 69, and 71 which includes Paradox Creek, Disappointment Creek, West Fork Dolores Creek, and associated tributaries including Fish Creek, Silver Creek, Bear Creek, and Turkey Creek. This gage has a complete set of daily data available throughout the simulation period of 1936 through 2003 and is located relatively high on the West Fork Dolores River. While there is a model gage located upstream of gage 09166500 (gage 09165000), daily data was not available at the upstream gage throughout the simulation period.

- Gage 09172500, San Miguel River near Placerville, was selected to represent Water Districts 60 and 63 which include the San Miguel River basin and the Dolores River basin. This pattern gage is located high in the San Miguel River basin and is not significantly impacted by large diversion for irrigation to the west. The Dolores River basin is represented by this gage because of the close proximity to the San Miguel River Basin. Gage 091725000 has data available from 1931 through 1934 and 1942 through 2003. For use as a pattern streamgage, gage 091725000 should be filled.

- Gage 09339900 was selected to represent Water Districts 29 and 78, which include the San Juan River basin and Piedra River Basin. Tributaries in the San Juan River basin represented by this gage include Wolf Creek, Turkey Creek, Coal Creek, Four Mile Creek, and Mill Creek. Tributaries on the Piedra River represented by this gage include Pagosa Creek, Little Pagosa, Middle Fork, and Shaw Creek. The gage is not influenced by any key reservoirs, imports, or exports and is located high in the basin. Gage 09339900 has data available from 1957 through 2003, excepting 1997 and 1998. For use as a pattern streamgage, gage 09339900 requires data filling. Due to the proximity of the Piedra River basin to the San Juan River and the similar geophysical characteristics, it was determined that gage 09339900 is a more accurate representation of baseflow conditions in the Piedra River basin.

- Gage 09344000 was selected to represent all of Water District 77, which includes the Navajo River and the Little Navajo River. Gage 09344000 is the highest gage in the system and has available data from 1937 through 2003. For use as a pattern gage, filling of data for 1936 is required.

- Gage 09352900 was selected to represent Water Districts 31 and 46, the Los Pinos River basin and Navajo Reservoir, respectively. Tributaries to the Los Pinos River also represented by this gage include Vallecito Creek and Rock Creek. Gage 09352900 is located high on Vallecito Creek, a tributary to the Los Pinos River, and is not influenced by any upstream key reservoirs, imports, or exports. Daily data is available for gage 09352900 from 1963 through 2003. For use as a pattern gage, this gage required data filling from 1936 through 1962.

- Gage 09365500 was selected to represent Water District 33, the La Plata River basin. This gage is located high in the district and has a limited amount of influence from upstream diversions. Gage 09365500 has a complete set of daily data throughout the simulation period of 1936 through 2003.

- Gage 09357500 was selected to represent Water District 30, the Animas River basin. Tributaries to the Animas River also represented in this gage include Florida River, Salt Creek, Mineral Creek, Cascade Creek, Bear Creek, Hermosa Creek, Junction Creek, and Lightner Creek. This gage is effected minimally by Mineral Point Ditch, a minor transmountain diversion upstream of the streamgage. Gage 09357500 has a complete set of daily data throughout the simulation period of 1936 through 2003.

- Gage 09371000 was selected to represent McElmo Creek Basin and Mancos River Basin, Water Districts 32 and 34, respectively. Geographically, this gage is located lower in the basin, however it is the only gage in both water districts with a complete set of data for the simulation period. To ensure that gage 09371000 was a representative pattern gage for Water Districts 32 and 34, historical average monthly baseflows (determined using StateMod) for gage 09371000 were compared to the actual historical average monthly flows for gage 09371000, as shown on Figure 1. While the magnitude of the historical average monthly baseflows determined using StateMod is greater than the measured historical monthly diversions, the monthly pattern of flows is similar. Therefore, it was determined that gage 09371000 accurately represents the baseflow pattern in the McElmo Creek Basin and the Mancos River Basin.

- Gage 09339900, East Fork San Juan River above Sand Creek was selected to represent the mainstem of the San Juan River down to the confluence with the Animas River. After the confluence with the Animas River, gage 09357500 was selected as representative of the mainstem San Juan River.

To determine which gage would best represent the mainstem of the San Juan River, historical monthly flow patterns of selected pattern gages in the Animas River Basin, Los Pinos River Basin, and San Juan River Basin were compared to determine if the baseflow pattern from each of these basins was similar. The comparison of representative pattern gages 09357500, 09352900, and 09339900 found that the baseflow streamflow pattern varied little between the selected basin, as shown on Figure 2. Based on this analysis it was determined that the San Juan River mainstem pattern flows were not significantly influenced by the contribution from one particular basin.
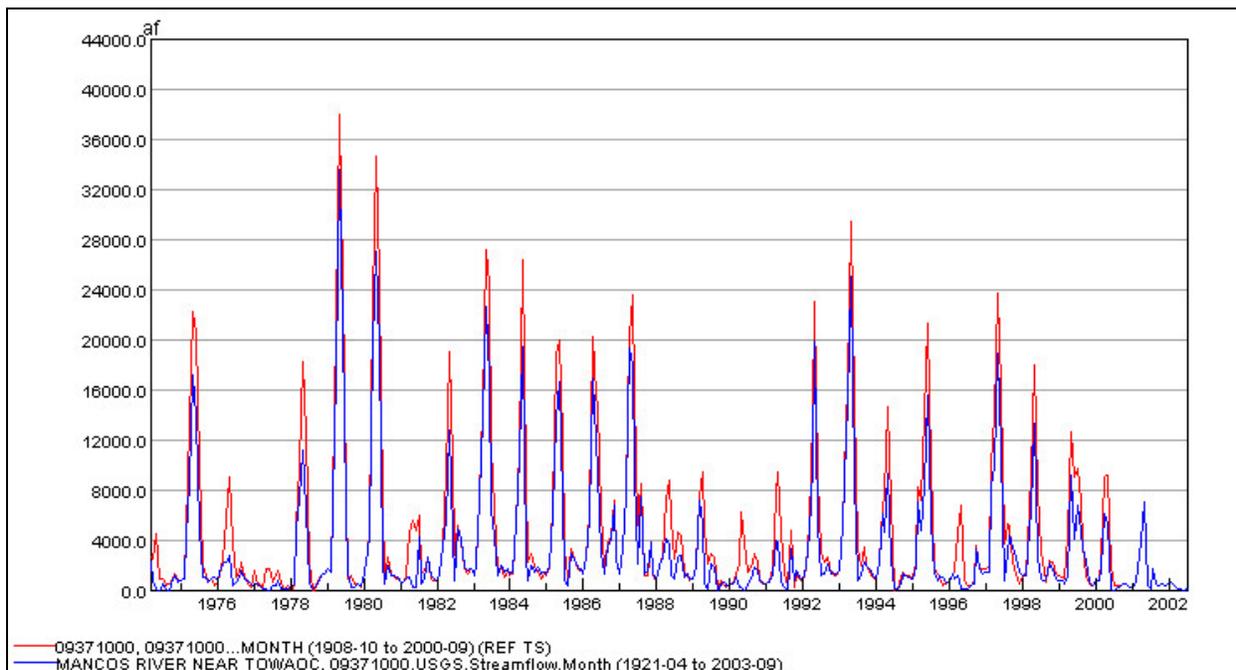
*Figure 1 – Comparison of 09371000 StateMod developed baseflows and 09371000 historical flows*
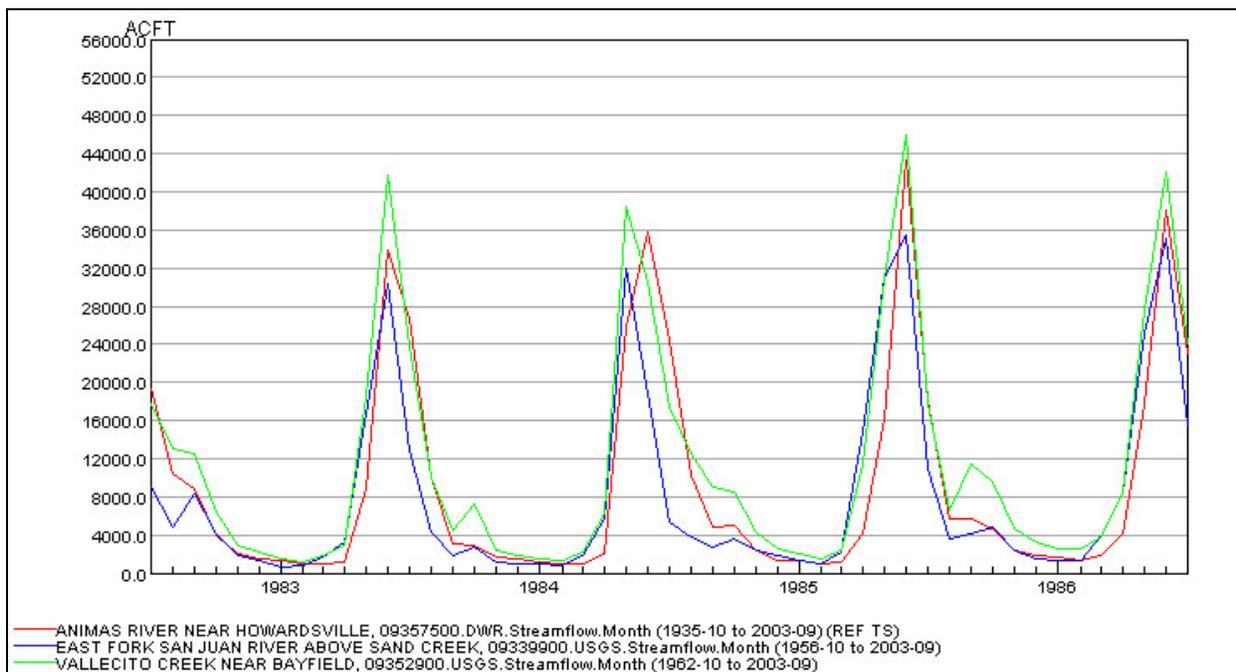


*Figure 2 – Comparison of historical flows at gages 09357500, 09339900, and 09352900 for determination of which gage would best represent the mainstem of the San Juan River.*

Figure 3, attached, illustrates all of the gages with in the San Juan - Dolores River Basin Model and the recommended pattern gages that will be used to represent each in the daily model.

## Results - Compare Historical Flows and StateMod Calculated Baseflows

Each of the selected pattern gages was analyzed to determine how well the historical flow at the gage represented the calculated baseflow at the gage. This step is important because historical flow data is used to disaggregate baseflows; gages exhibiting similar historical flow and baseflow indicate minimal external influence. An analysis period of 1975 through 2002 was selected for this comparison because of the consistent availability of actual data throughout this period. Table 3 compares the historical flow and StateMod determined baseflow at each of these selected pattern gages. The difference between the baseflow and the historical flow represents the amount of consumptive use above the selected gage.

**Table 3**
**Comparison of Calculated Baseflow and Historical Flow at Selected Pattern Gages**

| Station ID | Station Name | Period of Record | Average Annual Baseflow (af)[a/] | Average Annual Historical Flow (af)[b/] | Difference (af) | Difference (%) |
|---|---|---|---|---|---|---|
| 09166500 | Dolores River at Dolores | 1975 – 2000 | 28,156.7 | 27,917.6 | 239.1 | 0.84 |
| 09172500 | San Miguel River near Placerville | 1975 – 2000[c/] | 16,163.6 | 15,621.6 | 542.0 | 3.4 |
| 09339900 | East Fork San Juan River above Sand Creek | 1975 – 2000[d/] | 5,738.3 | 5,704.8 | 33.5 | 0.6 |
| 09344000 | Navajo River at Banded Peak Ranch near Chromo | 1975 – 2000 | 7,347.0 | 7,302.4 | 44.6 | 0.6 |
| 09352900 | Vallecito Creek near Bayfield | 1975 – 2000 | 9,152.0 | 9,152.0 | 0.0 | 0.0 |
| 09365500 | La Plata River at Hesperus | 1975 – 2000 | 2,948.7 | 2,707.7 | 241.0 | 8.2 |
| 09357500 | Animas River near Howardsville | 1975 – 2000 | 6,710.3 | 6,698.4 | 11.9 | 0.2 |
| 09371000 | Mancos River near Towaoc | 1975 – 2000 | 4,894.5 | 3,542.5 | 1,352.0 | 27.6 |

[a/] Averaging period is 1975 through 2000. Source is file sjx_nsm.xbm, dated 9/15/2004
[b/] Averaging period is 1975 through 2000. Source file is HydroBase..
[c/] Gage 09172500 is missing three days of data in December of water year 1994.
[d/] Gage 09339900 is missing data for water years 1997 and 1998.

## Results - Fill Missing Daily Data

Five of the eight selected pattern gages required filling for a portion of the 1936 through 2003 simulation period. The missing daily data was filled in using the monthly linear regression option in TSTool, in which daily data is used to generate a monthly regression fit (i.e., January daily data is used to generate a regression equation for the month of January). Several independent gages were investigated for each dependent gage, and the gage with the best correlation was selected as described below.

Gage 09172500 was missing data for water years 1936 through 1941 and on three days in December of water year 1994. Gage 09166500 was selected as the independent gage for correlating to gage 09172500. The correlation between these two gages exhibited an $R^2$ ranging from 0.24 in the winter months to 0.92 in the summer months.

Gage 09371000 was missing data for water years 1944 through 1951. Gage 09369500 was selected as the independent gage for correlating to gage 09371000. The correlation between these two gages exhibited an $R^2$ ranging from 0.33 to 0.94.

Gage 09352900 was missing data for water years 1936 through 1962. Gage 09357500 was selected as the independent gage for correlating to gage 09352900. The correlation between these two gages exhibited an $R^2$ ranging from 0.37 in the winter months to 0.85 in the summer months.

Gage 09339900 was missing data for water years 1936 through 1956. Gage 09342500 was selected as the independent gage for correlating to gage 09339900. The correlation between these two gages exhibited an $R^2$ ranging from 0.70 in the winter months to 0.98 in the summer months.

Gage 0934400 was missing data for water year 1936. Gage 09346000 was selected as the independent gage for correlating to gage 09344000. The correlation between these two gages exhibited an $R^2$ ranging from 0.33 in the winter months to 0.94 in the summer months.


## Results - Generate the Historical Daily Streamflow File

As part of this task, a daily historical streamflow file was created using the command file *sj_rid.TSTool,* as provided in Attachment A. The resulting output file, *sj2004.rid* fills the missing daily data for the five identified incomplete gages, selects the remaining five pattern gages, and selects an additional 15 other gages for use in model calibration and comparison of simulated flow to historical flow. No attempt was made to fill missing data for the 15 calibration gages. The output period identified in the *sj2004.rid* corresponds with the project simulation period of water year 1936 through 2003.


## Conclusions

The Daily Pattern approach was selected to develop the daily model for the San Juan – Dolores River Basin. Eight streamgages within the basin were selected as pattern gages, which will be used to disaggregate monthly baseflows to daily baseflows for the remaining gages in the daily model. These eight streamgages were selected based on the completeness of the daily data set over the simulation period (1936 – 2003), representation of various model areas, and minimal influence from upstream storage, import, or export. The streamgages selected and the sub-basin that they will represent are summarized in Table 2 and illustrated in Figure 3.

**Comments and Concerns**

When comparing the historical streamgage flows to the baseflows calculated from StateMod (see Table 3), gage 09371000 exhibited a 27.6 percent difference.  This larger percent difference between historical streamgage flows and calculated baseflows is attributable to upstream depletions.  Even with the depletions upstream, the average monthly pattern for these gages is similar between the historical flows and calculated baseflows, therefore the gage is believed to be an appropriate pattern gage.

# Figure 3 – Selected Pattern Streamgages and Representative Sub-basins



San Miguel River
09171200
09165000

Dolores River
Silver Creek
09166500
Turkey Creek
09166950

Mancos River
09369500
East Mancos
09369000

Animas River
09357500

Mineral Creek
09359000

Florida River
09362999

Los Pinos River
Vallecito Creek
09352900

East Fork San Juan River
09339900

Wolf Creek
09341500

Turkey Creek

Fall Creek
09172000

East Fork
09172100
09172500

Beaver Creek
09173000

Crystal Creek
09368500

Jackson Gulch
09368499

McElmo Creek
09371400

La Plata River
09365500

Hermosa Creek
09361000

09359500

09353500

Rio Blanco

Navajo River
09344000

Piedra River
09347500

Four Mile Creek

Coal Creek

09342000

Mill Creek

Little Navajo

Disappointment Creek
09168100

09169500

09175500

09171100

09177000

09179500

Hartman Draw
09371420

09371500
09371000

09372000

09366500

09367500

09361500

09363200

09363500

09364500

09354000

Spring Creek
09354500

09355000

09349500

09349800

09343300

09342500

09344400

09345200

09346000

San Juan and Dolores End

09379500    09371010    09368000    09365000    09355500    09346400

09172500 – San Miguel River near
09165000 – Dolores River below

09371000 – Mancos River near
09365500 – La Plata River at

09357500 – Animas River near
09352900 – Vallecito Creek near

09339900 – East Fork San Juan River above
09344000 – Navajo River at Banded Peak Ranch near

⊕ Model          ⊕ Pattern

November 23, 2004

<div align="center">**Attachment A**</div>

**File Type:** TSTool Command File for Regressing and Filling Missing Daily Data, Selection of Pattern Gages, and Selection of Calibration and Comparison Gages
**File Name:** sj_rid.TSTool

```
# San Juan - Dolores River Basin Model
# Data file Generated October 11, 2004
# Purpose of File -
# Selection of Pattern Gages for Model
# Fill daily data for 5 Pattern Gages with missing daily data
# Identify and select comparison gages
#
#
# Set Water Year and Output Period of 10/01/1935 - 9/30/2003
setOutputYearType(Water)
setOutputPeriod(10/01/1935,09/30/2003)
#
#
# Regress and Fill Daily Data for 09172500, 09371000, 09352900, 09339900, and 09344000
# 09172500 - SAN MIGUEL RIVER NEAR PLACERVILLE
09172500.USGS.Streamflow.Day~HydroBase
# 09166500 - DOLORES RIVER AT DOLORES
09166500.USGS.Streamflow.Day~HydroBase
fillRegression(09172500.USGS.Streamflow.Day,09166500.USGS.Streamflow.Day,MonthlyEqu
ations,Log,*,*,10/01/1935,09/30/2003)
free(TSID="09166500.USGS.Streamflow.Day")
# 09339900 - EAST FORK SAN JUAN RIVER ABOVE SAND CREEK
09339900.USGS.Streamflow.Day~HydroBase
# 09342500 - SAN JUAN RIVER AT PAGOSA SPRINGS
09342500.USGS.Streamflow.Day~HydroBase
fillRegression(09339900.USGS.Streamflow.Day,09342500.USGS.Streamflow.Day,MonthlyEqu
ations,Log,*,*,10/01/1935,09/30/2003)
free(TSID="09342500.USGS.Streamflow.Day")
# 09371000 - MANCOS RIVER NEAR TOWAOC
09371000.USGS.Streamflow.Day~HydroBase
# 09369500 - MIDDLE MANCOS RIVER NEAR MANCOS, CO.
09369500.USGS.Streamflow.Day~HydroBase
fillRegression(09371000.USGS.Streamflow.Day,09369500.USGS.Streamflow.Day,MonthlyEqu
ations,Log,*,*,10/01/1935,09/30/2003)
free(TSID="09369500.USGS.Streamflow.Day")
# 09352900 - VALLECITO CREEK NEAR BAYFIELD
09352900.USGS.Streamflow.Day~HydroBase
# 09357500 - ANIMAS RIVER NEAR HOWARDSVILLE
09357500.DWR.Streamflow.Day~HydroBase
```

fillRegression(09352900.USGS.Streamflow.Day,09357500.DWR.Streamflow.Day,MonthlyEquations,Log,*,*,10/01/1935,09/30/2003)
free(TSID="09357500.DWR.Streamflow.Day")
# 09344000 - NAVAJO RIVER AT BANDED PEAK RANCH NEAR CHROMO
09344000.DWR.Streamflow.Day~HydroBase
# 09346000 - NAVAJO RIVER AT EDITH, CO.
09346000.USGS.Streamflow.Day~HydroBase
fillRegression(09344000.DWR.Streamflow.Day,09346000.USGS.Streamflow.Day,MonthlyEquations,Log,*,*,10/01/1935,09/30/2003)
free(TSID="09346000.USGS.Streamflow.Day")
#
#
# Select Additional Pattern Gages
# 09357500 - ANIMAS RIVER NEAR HOWARDSVILLE
09357500.DWR.Streamflow.Day~HydroBase
# 09365500 - LA PLATA RIVER AT HESPERUS
09365500.DWR.Streamflow.Day~HydroBase
# 09166500 - DOLORES RIVER AT DOLORES
09166500.USGS.Streamflow.Day~HydroBase
#
#
# Select Calibration and Comparison Gages
# 09372000 - MCELMO CREEK NEAR COLORADO-UTAH STATE LINE
09372000.USGS.Streamflow.Day~HydroBase
# 09171100 - DOLORES RIVER NEAR BEDROCK
09171100.USGS.Streamflow.Day~HydroBase
# 09177000 - SAN MIGUEL RIVER AT URAVAN, CO.
09177000.USGS.Streamflow.Day~HydroBase
# 09371010 - SAN JUAN RIVER AT FOUR CORNERS, CO
09371010.USGS.Streamflow.Day~HydroBase
# 09379500 - SAN JUAN RIVER NEAR BLUFF, UT
09379500.USGS.Streamflow.Day~HydroBase
# 09367500 - LA PLATA RIVER NEAR FARMINGTON, NM.
09367500.USGS.Streamflow.Day~HydroBase
# 09365000 - SAN JUAN RIVER AT FARMINGTON, NM
09365000.USGS.Streamflow.Day~HydroBase
# 09364500 - ANIMAS RIVER AT FARMINGTON, NM
09364500.USGS.Streamflow.Day~HydroBase
# 09355500 - SAN JUAN RIVER NEAR ARCHULETA, NM
09355500.USGS.Streamflow.Day~HydroBase
# 09354500 - LOS PINOS RIVER AT LA BOCA
09354500.USGS.Streamflow.Day~HydroBase
# 09349800 - PIEDRA RIVER NEAR ARBOLES
09349800.USGS.Streamflow.Day~HydroBase
# 09346400 - SAN JUAN RIVER NEAR CARRACAS
09346400.USGS.Streamflow.Day~HydroBase

```
# 09346000 - NAVAJO RIVER AT EDITH, CO.
09346000.USGS.Streamflow.Day~HydroBase
# 09343300 - RIO BLANCO BELOW BLANCO DIVERSION DAM NEAR PAGOSA
09343300.DWR.Streamflow.Day~HydroBase
# 09342500 - SAN JUAN RIVER AT PAGOSA SPRINGS
09342500.USGS.Streamflow.Day~HydroBase
#
#
# Generate StateMod format file
writeStateMod("..\sj2004.rid",*)
```

# Appendix D

**Simulation Results with Calculated Irrigation Demand**

# Calculated Data Set

The "Calculated Data Set" is a data set that was created to further look at simulation of the San Juan Model. The unique characteristic of this data set is the demand file. Demand for irrigation users in this scenario is estimated outside the model, based on crop consumptive use of historical acreage and historical efficiency. Unlike the Baseline data set, the scenario is historical in the sense that is uses historical operating rules, and reservoirs come on-line when they did historically, but the irrigation demand is not strictly historical. In the Historical calibration run, demand was set to historical diversions, so that it reflects an irrigator's operational decisions or circumstances that are unrelated to use by crops. For example, if a headgate was damaged in spring flooding and didn't become usable until several weeks into the normal irrigation season, it would be reflected in historical diversions, therefore in the Historical calibration data set. Demand in the Calculated data set reflects the theoretical crop needs - that is the amount that needs to be diverted if the crop is to acquire a full supply.

## Calculated Demand

Calculated demands must account for both crop needs and irrigation practices. Monthly calculated demand for 1975 through 2003 is generated directly, by taking the maximum of crop irrigation water requirement divided by average monthly irrigation efficiency, and historic diversions. The irrigation efficiency may not exceed the defined maximum efficiency (60 percent), however, which represents an estimated practical upper limit on efficiency for flood irrigation systems in the San Juan and Dolores basins. Thus Calculated demand for a consistently shorted structure, and demand for months when a structure historically operated more efficiently than the average, will be greater than the historical diversion. By estimating demand to be the maximum of calculated demand and historical diversions, such irrigation practices as diverting to fill the soil moisture zone or diverting for stock watering can be mimicked more accurately.

Calculated demands were filled using the automated time series filling technique described in Section 4.4.2 for the time period prior to 1975. This is done because historical diversion records are generally not available until 1975 in the San Juan and Dolores River basins. Basinwide Calculated demand in Colorado over the calibration period (1975-2003) amounts to 1,342,600 acre-feet per year on average. This compares with historical diversion which averaged 1,041,000 acre-feet per year over the same period. The Calculated demand represents an increase of more than 22 percent over historical diversions. Note that historical diversions for carriers and feeder canals, set to zero in the Calculated data set because demand is placed at the destination, are not included in the historical diversion average presented here.

Demands are calculated using the same methodology as the Baseline demands except Calculated demands are limited to historical water rights and historical acreage; whereas Baseline demands are estimated as if current irrigated acreage and water right regime were in place over the entire study period. For example, Baseline demands reflect irrigation requirements as if current MVIC/Dolores Project acreage was being irrigated for the study period, whereas Calculated demands reflect irrigation water requirements based on historical MVIC/Dolores Project lands increasing during the study period as McPhee Reservoir was constructed.

## Calculated Data Set Calibration Efforts

In previous modeling phases, calculated demands were calculated as irrigation water requirement divided by average efficiency. As noted above, this did not account for certain irrigation practices, such as spring diversions to fill the soil reservoir or "wet" canals. This method was also unable to account for winter diversions for stock watering. Calculate demands for the current model are calculated as the maximum of irrigation water requirement divided by average efficiency and historical diversion. This allowed better calibration of diversions and streamgages in the winter and early spring.

## Calculated Data Set Simulation Results

Simulation of the Calculated San Juan Model is considered good, with more than half of the streamflow gages deviating less than 1 percent from historical values on an average annual basis. The basinwide shortage in Colorado, determined by comparing simulated diversions to Calculated demand, is about 12 percent per year, on average. In Colorado, 15 percent more water is being diverted during Calculated simulation, determined by comparing simulated diversions to historic diversions. Simulated reservoir contents are representative of historical values.

### Water Balance Results

Table D.1 summarizes the water balance for the San Juan Model, for the calibration period (1975-2003). Note that this is not an indication of use only in Colorado; New Mexico's use is also included. Following are observations based on the summary table:

- Surface water inflow to the basin averages 2.96 million acre-feet per year, and stream outflow averages 2.12 million acre-feet per year.

- Annual diversions amount to approximately 1.56 million acre-feet on average, which is approximately 11 percent greater than diversions in the historical calibrated simulation.

- Approximately 803,000 acre-feet per year is consumed in the Calculated simulation. Note that this value is representative of the basin-wide consumptive use and losses and includes crop consumptive use, municipal and industrial consumptive use, reservoir evaporation, and 100 percent of exports from the basin.

- The column labeled "Inflow – Outflow" represents the net result of gain (inflow, return flows, and negative change in reservoir and soil moisture contents) less outflow terms (diversions, outflow, evaporation, and positive changes in storage), and indicates that the model correctly conserves mass.

**Table D.1**
**Average Annual Water Balance for Calculated Simulation 1975-2003 (af/yr)**

| Month | Stream Inflow | Return | From Soil Moisture | Total Inflow | Diversions | Resvr Evap | Stream Outflow | Resvr Change | To Soil Moisture | Soil Moisture Change | Total Outflow | Inflow - Outflow | CU |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| OCT | 99,894 | 64,536 | 871 | 165,301 | 87,022 | 2,353 | 90,687 | -15,632 | 1,111 | -240 | 165,301 | 0 | 31,309 |
| NOV | 72,326 | 30,042 | 10 | 102,379 | 22,393 | 430 | 73,740 | 5,805 | 1,561 | -1,551 | 102,379 | 0 | 5,807 |
| DEC | 55,480 | 22,126 | 0 | 77,606 | 17,484 | -99 | 59,127 | 1,093 | 670 | -670 | 77,606 | 0 | 4,631 |
| JAN | 59,487 | 19,084 | 0 | 78,572 | 16,645 | 127 | 63,166 | -1,366 | 471 | -471 | 78,572 | 0 | 4,674 |
| FEB | 79,505 | 15,805 | 0 | 95,311 | 15,372 | 704 | 82,905 | -3,671 | 416 | -416 | 95,311 | 0 | 5,088 |
| MAR | 165,409 | 16,103 | 18 | 181,530 | 22,855 | 1,948 | 145,849 | 10,860 | 797 | -779 | 181,530 | 0 | 10,396 |
| APR | 423,710 | 32,131 | 701 | 456,542 | 84,234 | 4,366 | 324,204 | 43,037 | 3,582 | -2,881 | 456,542 | 0 | 47,414 |
| MAY | 734,308 | 95,724 | 2,469 | 832,500 | 268,236 | 6,977 | 491,068 | 63,751 | 2,603 | -134 | 832,500 | 0 | 150,018 |
| JUN | 688,658 | 128,521 | 6,604 | 823,782 | 342,570 | 9,491 | 451,047 | 14,070 | 659 | 5,945 | 823,782 | 0 | 202,367 |
| JUL | 286,095 | 125,060 | 5,062 | 416,217 | 287,666 | 8,427 | 163,245 | -48,182 | 330 | 4,732 | 416,217 | 0 | 161,004 |
| AUG | 160,466 | 115,071 | 2,056 | 277,593 | 226,338 | 4,588 | 91,445 | -46,835 | 1,933 | 123 | 277,593 | 0 | 106,462 |
| SEP | 135,447 | 94,953 | 1,584 | 231,985 | 165,030 | 4,494 | 88,068 | -27,192 | 1,048 | 536 | 231,985 | 0 | 73,800 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| AVG | 2,960,785 | 759,157 | 19,375 | 3,739,316 | 1,555,844 | 43,806 | 2,124,551 | -4,260 | 15,180 | 4,194 | 3,739,316 | 0 | 802,970 |

*Note:* Consumptive Use (CU) = Diversion (Divert) * Efficiency + Reservoir Evaporation (Evap)

## Streamflow Results

Table D.2 summarizes the average annual streamflow for water years 1975 through 2003, as estimated in the Calculated calibration run. It also shows average annual values of actual gage records for comparison. Both numbers are based only on years for which gage data are complete. Figures D.1 through D.10 (at the end of this appendix) graphically present monthly streamflow estimated by the model compared to historical observations at key streamgages in both time-series format and as scatter graphs. When only one line appears on the time-series graph, it indicates that the simulated and historical results are the same at the scale presented. The "goodness of fit" is indicated by the $R^2$ value shown on each scatter graph.

Calculated calibration based on streamflow simulation is generally very good in terms of both annual volume and monthly pattern, and similar to the historical calibration results. As expected with higher demands, there is slightly less simulated flow at many gages. Exceptions include the Rio Blanco, Navajo, and Little Navajo Rivers below the San Juan-Chama diversions. In the Calculated scenario, the San Juan-Chama demand is placed at the San Juan-Chama Summary node and diversions from each tributary are met by operating rules; whereas in the historical scenario demand is placed at the individual diversions. Even though the same priority is given to the operating rules, the Rio Blanco operating rule is listed first and is operated first by StateMod. The result is that more of the demand is met from Rio Blanco, and less from Navajo and Little Navajo Rivers, than in the historical simulation.

**Table D.2**
**Historical and Simulated Average Annual Streamflow Volumes (1975-2003)**
**Calculated Simulation (acre-feet/year)**

| Gage ID | Historical | Simulated | Historical -Simulated Volume | Percent | Gage Name |
|---------|-----------|-----------|--------|---------|-----------|
| 09339900 | 64,983 | 64,983 | 0 | 0% | East Fork San Juan River above Sand Creek |
| 09341500 | 171,819 | 170,826 | 993 | 1% | West Fork San Juan River nr Pagosa Springs |
| 09342000 | *No gage during calibration period* | | | | Turkey Creek near Pagosa Springs |
| 09342500 | 283,880 | 275,691 | 8,189 | 3% | San Juan River at Pagosa Springs |
| 09343300 | 34,450 | 52,951 | -18,501 | -54% | Rio Blanco bl Blanco Div Dam nr Pagosa Sprgs |
| 09344000 | 83,902 | 83,694 | 208 | 0% | Navajo River at Banded Peak Ranch nr Chromo |
| 09344400 | 48,284 | 29,321 | 18,963 | 39% | Navajo River bl Oso Diversion Dam nr Chromo |
| 09345200 | 6,390 | 5,950 | 440 | 7% | Little Navajo River bl Oso Div Dam nr Chromo |
| 09346000 | 67,275 | 46,305 | 20,970 | 31% | Navajo River at Edith |
| 09346400 | 449,666 | 440,390 | 9,276 | 2% | San Juan River near Carracas |
| 09347500 | *No gage during calibration period* | | | | Piedra River at Bridge Ranger Sta. nr Pagosa Sprgs |
| 09349500 | *No gage during calibration period* | | | | Piedra River near Piedra |
| 09349800 | 305,465 | 300,779 | 4,686 | 2% | Piedra River near Arboles |
| 09352900 | 106,037 | 106,037 | 0 | 0% | Vallecito Creek near Bayfield |
| 09353500 | 299,267 | 295,784 | 3,483 | 1% | Los Pinos River near Bayfield |
| 09354000 | *No gage during calibration period* | | | | Los Pinos River at Bayfield |
| 09354500 | 188,403 | 179,260 | 9,143 | 5% | Los Pinos River at La Boca |
| 09355000 | 24,124 | 25,170 | -1,046 | -4% | Spring Creek at La Boca |
| 09355500 | 875,505 | 863,456 | 12,049 | 1% | San Juan River near Archuleta |

| Gage ID | Historical | Simulated | Historical -Simulated | | Gage Name |
| | | | Volume | Percent | |
|---|---|---|---|---|---|
| 09357500 | 77,578 | 77,579 | -1 | 0% | Animas River at Howardsville |
| 09359000 | *No gage during calibration period* | | | | Mineral Creek near Silverton |
| 09359500 | *No gage during calibration period* | | | | Animas River above Tacoma |
| 09361000 | 96,957 | 96,957 | 0 | 0% | Hermosa Creek near Hermosa |
| 09361500 | 583,380 | 583,334 | 46 | 0% | Animas River at Durango |
| 09362999 | 73,870 | 73,870 | 0 | 0% | Florida River ab Lemon Reservoir (USBR data) |
| 09363200 | 58,564 | 59,341 | -777 | -1% | Florida River at Bondad |
| 09363500 | 707,576 | 706,194 | 1,382 | 0% | Animas River near Cedar Hill, NM |
| 09364500 | 644,023 | 644,303 | -280 | 0% | Animas River at Farmington, NM |
| 09365000 | 1,489,692 | 1,473,668 | 16,024 | 1% | San Juan River at Farmington, NM |
| LONREDCO | 5,471 | 5,843 | -372 | -7% | Long Hollow at the Mouth near Red Mesa |
| 9365500 | 30,970 | 28,538 | 2,432 | 8% | La Plata at Hesperus |
| 09366500 | 27,452 | 24,105 | 3,347 | 12% | La Plata River at CO-NM State Line |
| 09367500 | 23,548 | 24,479 | -931 | -4% | La Plata River near Farmington, NM |
| 09368000 | 1,510,482 | 1,501,335 | 9,147 | 1% | San Juan at Shiprock |
| 09369500 | *No gage during calibration period* | | | | Middle Mancos River near Mancos |
| 09369000 | *No gage during calibration period* | | | | East Mancos River near Mancos |
| 09368499 | 10,687 | 10,687 | 0 | 0% | Above Jackson Gulch Reservoir (USBR data) |
| 09368500 | *No gage during calibration period* | | | | West Mancos River near Mancos |
| 09371000 | 39,123 | 33,934 | 5,189 | 13% | Mancos River near Towaoc |
| 09371010 | 1,600,019 | 1,577,865 | 22,154 | 1% | San Juan River at Four Corners |
| 09371400 | 10,063 | 9,333 | 730 | 7% | Hartman Draw at Cortez |
| 09371420 | 19,270 | 18,961 | 309 | 2% | McElmo Creek above Alkali Canyon nr Cortez |
| 09371500 | 42,789 | 42,825 | -36 | 0% | McElmo Creek near Cortez |
| 09372000 | 39,385 | 35,257 | 4,128 | 10% | McElmo Creek near CO-UT State Line |
| 09379500 | 1,563,647 | 1,538,645 | 25,002 | 2% | San Juan River near Bluff |
| 09165000 | 97,155 | 97,166 | -11 | 0% | Dolores River below Rico |
| 09166500 | 317,356 | 316,938 | 418 | 0% | Dolores River at Dolores |
| 09166950 | 15,240 | 10,913 | 4,327 | 28% | Lost Canyon Creek near Dolores |
| 09168100 | 20,926 | 19,664 | 1,262 | 6% | Disappointment Creek near Dove Creek |
| 09169500 | 270,404 | 260,888 | 9,516 | 4% | Dolores River at Bedrock |
| 09171100 | 279,550 | 269,367 | 10,183 | 4% | Dolores River near Bedrock |
| 09171200 | *No gage during calibration period* | | | | San Miguel River near Telluride |
| 09172000 | *No gage during calibration period* | | | | Fall Creek near Fall Creek |
| 09172100 | *No gage during calibration period* | | | | Leopard Creek at Noel |
| 09172500 | 181,283 | 173,442 | 7,841 | 4% | San Miguel River near Placerville |
| 09173000 | 7,212 | 9,263 | -2,051 | -28% | Beaver Creek near Norwood |
| 09175500 | 199,166 | 188,358 | 10,808 | 5% | San Miguel River at Naturita |
| 09177000 | 273,243 | 255,818 | 17,425 | 6% | San Miguel River at Uravan |
| 09179500 | *No gage during calibration period* | | | | Dolores River at Gateway |

## Diversion Results

Table D.3 summarizes the average annual simulated diversions, by tributary or sub-basin, compared to historical diversions for water years 1975 through 2003. Table D.5 (at the end of this appendix) shows the average annual shortages for water years 1975 through 2003 by structure.  On a basin-wide basis, average annual diversions in Colorado are greater than historical diversions by about 15 percent in the Calculated calibration run.  Basin wide, including New Mexico diversions, average annual diversions are 12 percent greater than historical diversions.

**Table D.3**
**Historical and Simulated Average Annual Diversions by Sub-basin (1975-2003)**
**Calculated Simulation (acre-feet/year)**

| Tributary or Sub-basin | Historical | Simulated | Historical minus Simulated | |
| --- | --- | --- | --- | --- |
| | | | Volume | Percent |
| Navajo-Blanco Rivers | 110,187 | 119,040 | -8,854 | -8% |
| San Juan | 44,906 | 63,573 | -18,667 | -42% |
| Piedra River | 29,636 | 44,445 | -14,809 | -50% |
| Los Pinos River | 201,279 | 226,788 | -25,509 | -13% |
| Animas and Florida Rivers | 178,259 | 192,650 | -14,391 | -8% |
| La Plata River | 32,185 | 39,358 | -7,173 | -22% |
| Mancos River (includes MVIC/Dolores Project  and Summit Irrigation Use) | 35,449 | 44,650 | -9,201 | -26% |
| McElmo Creek | 204,795 | 210,373 | -5,578 | -3% |
| San Miguel River | 119,088 | 149,706 | -30,618 | -26% |
| Dolores River | 51,624 | 63,260 | -11,636 | -23% |
| **Basin Total** | **1,007,407** | **1,153,843** | **-146,436** | **-15%** |

As noted previously, the Calculated demand in Colorado (not shown in Table D.3) represents an increase of more than 22 percent over historical diversions, compared to the Calculated simulated diversions shown in Table D.3, which represents a 15 percent increase over historical diversion.   In general, calculated demands are being met.  Shortage based on Calculated demand in Colorado, intended to better estimate crop needs, is 12 percent.

## Reservoir Results

Figures D.12 through D.15 (located at the end of this appendix) present reservoir end-of-month contents estimated by the model using the Calculated data set compared to historical observations at selected reservoirs. Most reservoirs exhibit slightly more use than in the Historical calibration simulation, as a result of higher Calculated demands.  Jackson Gulch Reservoir shows significant increase in use, as a result of higher irrigation demands.

## Consumptive Use Results

Crop consumptive use is estimated by StateMod and reported in the consumptive use summary file (*.xcu) for each diversion structure in the scenario. This file also includes consumptive use for municipal and industrial diversions. The crop consumptive use estimated by StateCU is reported in the water supply-limited summary file (*.wsl) for each agricultural diversion structure in the basin. Therefore, to provide a one-to-one comparison, only structures in the StateCU analysis are included.

Table D.4 shows the comparison of StateCU estimated potential crop consumptive use, StateCU estimated water-supply limited crop consumptive, and StateMod simulated crop consumptive use for the Calculated calibration. Table D.4 presents these values for explicit structures, aggregated structures, and total for the model in Colorado. Percent shortage values represent the difference between the amount of water the crops need to meet full demands (potential consumptive use) and what they received based on either historical diversions (StateCU results), or simulated diversions (Calculated StateMod results).

In the Calculated simulation, more of the potential consumptive use (crop demand) is met than in the StateCU analyses. Historical diversions are used by StateCU to estimate water supply-limited (actual) consumptive use. In the Calculated simulation, where demands are essentially set to meet potential CU, more water is being diverted compared to historical diversion. The approximate 10 percent increase in CU between StateCU results and Calculated simulation results could indicate any or a combination of the following:

- Historical irrigation practices do not take full advantage of water supply
- Historical irrigation practices do not utilize the entire potential growing season
- Blaney-Criddle methodology does not accurately reflect true crop demands

**Table D.4**
**Average Annual Crop Consumptive Use Comparison (1975-2003)**
**Calculated Simulation**

| Comparison | StateCU Potential CU (af/yr) | StateCU CU Results (af/yr) | StateCU Shortage (%) | Calculated Run CU Results (af/yr) | Calculated Run Shortage (%) |
|---|---|---|---|---|---|
| Explicit Structures | 420,502 | 297,025 | 29% | 329,944 | 22% |
| Aggregate Structures | 73,343 | 53,855 | 27% | 68,411 | 7% |
| Basin Total | 493,845 | 350,880 | 29% | 398,355 | 19% |

Not that the simulated crop consumptive use presented here represents only a portion of the approximately 802,970 acre-feet per year consumed in the basin, and reported above in Table D.1. The consumptive use reported in Table D.1 is representative of the total basin-wide consumptive use and losses in both Colorado and New Mexico, and includes municipal and industrial consumptive use, reservoir evaporation, and exports from the basin in addition to crop consumptive use.

**Table D.5**
**Historical and Simulated Average Annual Diversions (1975-2003)**
**Calculated Simulation (acre-feet/year)**

| WDID | Historical | Simulated | Historical - Simulated | | Name |
| | | | Volume | Percent | |
|---|---|---|---|---|---|
| 290519 | 1,241 | 1,687 | -446 | -36% | BEIGHLEY NO 1_DIVSYS |
| 290550 | 3,789 | 3,915 | -126 | -3% | C H LOUCKS DITCH |
| 290555 | 1,419 | 1,702 | -283 | -20% | CARR DITCH |
| 290560 | 1,963 | 2,710 | -748 | -38% | CHAPSON AND HOWE DITCH |
| 290566 | 1,142 | 1,496 | -354 | -31% | COLTON & MONTROY DITCH |
| 290582 | 402 | 529 | -127 | -31% | DOWELL DITCH |
| 290588 | 2,247 | 4,077 | -1,831 | -81% | ECHO DITCH |
| 290597 | 878 | 1,107 | -229 | -26% | FISH CREEK DITCH |
| 290601 | 3,914 | 7,788 | -3,874 | -99% | FOUR-MILE_DIVSYS |
| 290613 [2)] | 255 | 0 | 255 | 100% | HALLETT DITCH |
| 290627 | 415 | 865 | -451 | -109% | J M ROSS AND STURGILL D |
| 290653 | 319 | 874 | -556 | -174% | LONG HORN AND MEE DITCH |
| 290654 | 207 | 306 | -99 | -48% | LONG MEADOW DITCH |
| 290662 | 420 | 541 | -121 | -29% | MARTINEZ AND MARTINEZ D |
| 290669 | 1,029 | 1,756 | -727 | -71% | MESA DITCH |
| 290686 [3)] | 8,858 | 18,476 | -9,618 | -109% | PARK DITCH |
| 290691 | 250 | 384 | -134 | -53% | PHILLIPPS DITCH |
| 290716 | 650 | 972 | -322 | -49% | SISSON-STEPHENS DITCH |
| 290718 | 5,178 | 5,863 | -685 | -13% | SNOWBALL DITCH |
| 290729 | 307 | 398 | -91 | -30% | STURGILL DITCH |
| 292005 | 1,075 | 1,865 | -790 | -74% | DUTTON DITCH |
| 294667 [1)] | 38,096 | 0 | 0 | 0% | USBR_BLANCO_R_DIVERSION |
| 294669 | 208 | 208 | 0 | 0% | TREASURE PASS DIVR DITCH |
| 29_ADS002 | 5,803 | 7,302 | -1,499 | -26% | 29_ADS002_SJuanR@PagosaS |
| 29_ADS003 | 6,554 | 8,009 | -1,455 | -22% | 29_ADS003_SJuanR@Carracs |
| 300504 | 2,101 | 2,508 | -407 | -19% | AMBOLD-WALLACE DITCH |
| 300506 [3)] | 25,287 | 32,769 | -7,481 | -30% | ANIMAS CONSOLIDATED D |
| 300509 [1)] | 0 | 0 | 0 | 0% | ANIMAS DIVERSION CANAL |
| 300510 | 1,168 | 1,450 | -282 | -24% | BEAR CREEK DITCH |
| 300523 [1)] | 0 | 0 | 0 | 0% | CASCADE CANAL |
| 300568 | 4,545 | 5,083 | -538 | -12% | HERMOSA COMPANY DITCH |
| 300580 | 2,483 | 2,777 | -294 | -12% | JOHN THOMAS DITCH |
| 300581 [2)] | 3,248 | 0 | 3,248 | 100% | J P LAMB DITCH |
| 300612 | 25,719 | 25,460 | 260 | 1% | POWER CANAL NO 1 |
| 300617 | 22,024 | 24,866 | -2,843 | -13% | REID DITCH |
| 300634 | 1,139 | 1,398 | -259 | -23% | SITES DITCH |
| 300641 | 2,922 | 3,569 | -647 | -22% | SULLIVAN-WALLACE DITCH |
| 301000 | 4,221 | 4,205 | 16 | 0% | DURANGO CITY PIPELINE |
| 301003 | 828 | 765 | 62 | 8% | HARRIS-PATTERSON DITCH |
| 301009 | 871 | 824 | 47 | 5% | MCCLUER & MURRAY DITCH |
| 301011 | 46,136 | 45,629 | 506 | 1% | Florida_Farmers/Florida_Canal |
| 301019 | 1,787 | 1,695 | 92 | 5% | PIONEER DITCH |
| 301023 | 15,017 | 16,799 | -1,782 | -12% | ANIMAS DITCH |

| WDID | Historical | Simulated | Historical - Simulated | | Name |
| | | | Volume | Percent | |
|---|---|---|---|---|---|
| 301024 | 0 | 0 | 0 | 0% | ANIMAS PMP STA & FOR MN |
| 301033 | 912 | 836 | 76 | 8% | BANKS-TYNER DITCH |
| 301056 [2)] | 293 | 0 | 293 | 100% | BODO PINE RIDGE DITCH |
| 301094 | 6,274 | 7,078 | -804 | -13% | EAST MESA DITCH |
| 301219 | 1,321 | 2,402 | -1,080 | -82% | SITES-KERN DITCH |
| 301243 | 1,126 | 903 | 224 | 20% | TYNER EAST SIDE DITCH |
| 304660 | 297 | 297 | 0 | 0% | CARBON LAKE DITCH |
| 304661 | 141 | 141 | 1 | 0% | MINERAL POINT DITCH |
| 304662 | 91 | 91 | 0 | 0% | RED MOUNTAIN DITCH |
| 304664 | 4,453 | 4,453 | 0 | 0% | RALSTON DITCH |
| 304665 | 4,278 | 3,115 | 1,163 | 27% | TWIN ROCK DITCH |
| 30_ADS007 | 8,836 | 9,893 | -1,058 | -12% | 30_ADS007_AnimasR@Durang |
| 30_ADS008 | 4,731 | 7,054 | -2,323 | -49% | 30_ADS008_FloridaRabvSal |
| 30_ADS009 | 3,577 | 4,053 | -476 | -13% | 30_ADS009_FloridaR@Bonda |
| 30_ADS010 | 6,906 | 8,318 | -1,412 | -20% | 30_ADS010_AnimasR@StLine |
| 310502 | 3,316 | 4,150 | -834 | -25% | CEANABOO DITCH |
| 310503 | 2,808 | 3,028 | -220 | -8% | COMMISSIONER DITCH |
| 310505 | 19,031 | 20,945 | -1,914 | -10% | DR MORRISON_DIVSYS |
| 310507 | 3,086 | 3,471 | -385 | -12% | LA BOCA DITCH |
| 310508 | 2,585 | 2,984 | -398 | -15% | SEVERO DITCH |
| 310509 | 13,434 | 15,720 | -2,286 | -17% | SPRING CREEK DITCH |
| 310510 | 979 | 1,066 | -87 | -9% | BEAN DITCH |
| 310511 | 8,745 | 10,315 | -1,570 | -18% | THOMPSON-EPPERSON DITCH |
| 310512 | 3,638 | 3,711 | -73 | -2% | LOS PINOS IRG DITCH |
| 310513 | 2,581 | 2,599 | -18 | -1% | WOMMER IRRIGATION DITCH |
| 310514 | 3,358 | 3,589 | -232 | -7% | BEAR CR AND PINE R DITCH |
| 310516 | 255 | 335 | -80 | -31% | HIGBEE IRRIGATION DITCH |
| 310518 | 706 | 833 | -127 | -18% | MYERS AND ASHER DITCH |
| 310519 | 25,558 | 27,505 | -1,947 | -8% | KING DITCH |
| 310523 | 15,190 | 17,052 | -1,862 | -12% | SCHRODER IRG_DIVSYS |
| 310524 | 965 | 1,054 | -90 | -9% | FARRELL DITCH |
| 310527 | 86 | 111 | -24 | -28% | ISLAND DITCH |
| 310528 | 1,356 | 1,465 | -109 | -8% | BENNETT-MYERS IRR DITCH |
| 310535 | 595 | 899 | -304 | -51% | KIRKPATRICK DITCH |
| 310540 | 1,016 | 1,252 | -236 | -23% | MCLOYD DITCH |
| 310545 | 261 | 180 | 81 | 31% | CATLIN DITCH |
| 310547 | 22,776 | 27,636 | -4,860 | -21% | ROBERT MORRISON DITCH |
| 310553 | 189 | 223 | -33 | -18% | MCBRIDE DITCH |
| 310567 [2)] | 322 | 0 | 322 | 100% | CAMPBELL DITCH |
| 310583 | 449 | 354 | 96 | 21% | PORTER DITCH |
| 310593 | 344 | 454 | -110 | -32% | SEMLER DITCH E AND E |
| 310665 [3)] | 59,680 | 66,356 | -6,676 | -11% | SPRING CREEK DITCH |
| 310668 | 1,555 | 1,902 | -348 | -22% | SULLIVAN DITCH |
| 310710 | 879 | 1,060 | -181 | -21% | IGNACIO CREEK DITCH |
| 314637 | 1,109 | 926 | 184 | 17% | WEMINUCHE PASS DITCH |
| 314638 | 449 | 351 | 98 | 22% | PINE R WEMINUCHE PASS D |
| 31_ADS005 | 3,976 | 5,265 | -1,289 | -32% | 31_ADS005_LPinosR@DryCrk |

| WDID | Historical | Simulated | Historical - Simulated | | Name |
| | | | Volume | Percent | |
|---|---|---|---|---|---|
| 31_ADS006 | 9,463 | 10,961 | -1,498 | -16% | 31_ADS006_LPinosR@StLine |
| 320509 | 977 | 1,120 | -143 | -15% | BLACK DIKE DITCH |
| 320528 | 2,729 | 3,001 | -272 | -10% | COTTONWOOD DITCH NO 1 |
| 320529 | 2,944 | 3,559 | -614 | -21% | COTTONWOOD DITCH NO 2 |
| 320558 | 1,407 | 1,404 | 4 | 0% | EATON DITCH |
| 320574 | 4,152 | 4,205 | -53 | -1% | HAMBELTON DITCH |
| 320590 | 850 | 1,067 | -218 | -26% | ISMAY DITCH |
| 320634 | 1,914 | 1,840 | 74 | 4% | MURRAY-ZWICKER-TOZER D |
| 320652 | 10,013 | 11,419 | -1,406 | -14% | ROCK CREEK DITCH |
| 320662 | 961 | 1,054 | -93 | -10% | SCHALLES DITCH |
| 320680 | 2,952 | 2,812 | 140 | 5% | TOWN OF CORTEZ |
| 320690 | 2,606 | 2,920 | -313 | -12% | WILSON DITCH |
| 320699 [1] | 0 | 0 | 0 | 0% | NARRAGUINNEP RES INLET |
| 320772 | 71,256 | 71,256 | 0 | 0% | MVI_U_lateral |
| 320884 | 5,229 | 5,229 | 0 | 0% | TOWAOC CANAL |
| 322001 | 631 | 626 | 6 | 1% | DOLORES WATER DIVR HGT |
| 322006 | 18,896 | 18,611 | 285 | 2% | DOVE CREEK CANAL |
| 324675 | 59,392 | 59,392 | 0 | 0% | Dolores_Tunnel |
| 32_ADS015 | 6,003 | 6,374 | -370 | -6% | 32_ADS015_McELmCkabvAlka |
| 32_ADS016 | 5,402 | 6,288 | -886 | -16% | 32_ADS016_McElmoCrkNrStL |
| 330501 | 1,726 | 1,824 | -97 | -6% | LA PLATA IRG DITCH |
| 330504 | 5,626 | 6,080 | -454 | -8% | HAY GULCH DITCH |
| 330508 | 2,403 | 4,712 | -2,309 | -96% | LA PLATA R & CHERRY CR D |
| 330518 | 373 | 790 | -417 | -112% | AMMONS DITCH |
| 330533 [3] | 984 | 2,303 | -1,319 | -134% | PINE RIDGE DITCH |
| 330535 | 708 | 817 | -109 | -15% | SOONER VALLEY DITCH |
| 330536 | 4,874 | 5,108 | -234 | -5% | H H DITCH |
| 330540 | 487 | 499 | -12 | -3% | ENTERPRISE ENLARGEMENT |
| 330542 | 3,413 | 3,883 | -471 | -14% | SLADE DITCH |
| 330547 | 2,767 | 2,145 | 622 | 22% | JOSEPH FREED DITCH |
| 330548 | 514 | 593 | -79 | -15% | REVIVAL DITCH |
| 330549 | 1,925 | 2,242 | -317 | -16% | TREANOR DITCH |
| 330550 | 760 | 939 | -179 | -24% | WARREN-VOSBURGH DITCH |
| 330551 | 618 | 621 | -3 | 0% | TOWNSITE DITCH |
| 330554 | 1,954 | 2,319 | -365 | -19% | BIG STICK DITCH |
| 334639 | 539 | 507 | 33 | 6% | ENTERPRISE ENLARGEMENT |
| 334640 | 757 | 717 | 40 | 5% | PIONEER DITCH |
| 33_ADS011 | 1,758 | 3,260 | -1,502 | -85% | 33_ADS011_LaPlataRiver |
| 340505 | 1,442 | 1,510 | -68 | -5% | BEAVER DITCH |
| 340506 | 1,003 | 792 | 211 | 21% | BOSS DITCH |
| 340508 | 758 | 1,461 | -703 | -93% | CARPENTER & MITCHELL D |
| 340514 | 755 | 1,321 | -566 | -75% | CRYSTAL CREEK DITCH |
| 340522 | 622 | 680 | -58 | -9% | EAST MANCOS HIGHLINE D. |
| 340527 | 588 | 613 | -24 | -4% | FRANK DITCH |
| 340530 | 1,204 | 1,244 | -40 | -3% | GILES DITCH |
| 340531 | 1,142 | 1,440 | -299 | -26% | GLASGOW & BREWER DITCH |
| 340534 | 2,517 | 2,632 | -115 | -5% | HENRY BOLEN DITCH |

| WDID | Historical | Simulated | Historical - Simulated | | Name |
| | | | Volume | Percent | |
|---|---|---|---|---|---|
| 340535 [1] | 0 | 0 | 0 | 0% | JACKSON GULCH INLET CNL |
| 340542 | 1,028 | 1,221 | -193 | -19% | LEE AND BURKE DITCH |
| 340543 | 598 | 1,199 | -601 | -101% | LEE DITCH |
| 340544 | 702 | 1,074 | -372 | -53% | LONG PARK DITCH |
| 340552 | 1,079 | 1,468 | -388 | -36% | NO 6 DITCH |
| 340554 | 4,347 | 6,429 | -2,082 | -48% | RATLIFF AND ROOT DITCH |
| 340560 | 1,658 | 2,600 | -941 | -57% | RUSH RESERVOIR DITCH |
| 340565 | 1,804 | 2,368 | -564 | -31% | SHEEK DITCH |
| 340567 | 138 | 135 | 3 | 2% | SMOUSE DITCH |
| 340573 | 754 | 737 | 17 | 2% | TOWN OF MANCOS DITCH |
| 340576 | 5,365 | 6,877 | -1,512 | -28% | WEBBER DITCH |
| 340577 | 675 | 725 | -50 | -7% | WEBER RESERVOIR INLET D |
| 340582 | 264 | 553 | -289 | -109% | WILLIAMS DITCH_DIVSYS |
| 340583 | 827 | 982 | -154 | -19% | WILLIS DITCH |
| 34_ADS012 | 1,498 | 1,987 | -490 | -33% | 34_ADS012_ManRabvWMancos |
| 34_ADS013 | 688 | 1,017 | -329 | -48% | 34_ADS013_ManRabvChicken |
| 34_ADS014 | 2,913 | 2,531 | 382 | 13% | 34_ADS014_MancosRNrStLin |
| 34_AMS001 | 1,080 | 1,057 | 23 | 2% | 34_MUNICIPAL |
| 460503 [2] | 2,139 | 0 | 2,139 | 100% | BRIGGS DITCH |
| 600507 | 291 | 968 | -677 | -233% | ALEXANDER DITCH |
| 600511 | 10,918 | 10,854 | 63 | 1% | AMES ILIUM HYDRO PROJ |
| 600520 | 802 | 936 | -135 | -17% | B C D DITCH |
| 600521 | 1,120 | 2,761 | -1,642 | -147% | BEAVER MESA DITCH |
| 600549 | 167 | 960 | -793 | -475% | CARR WADDLE DITCH |
| 600550 | 715 | 1,315 | -599 | -84% | CARRIERE DITCH |
| 600569 | 706 | 1,019 | -313 | -44% | CRAVER DITCH |
| 600574 | 410 | 564 | -154 | -37% | DENISON DITCH |
| 600583 | 520 | 578 | -58 | -11% | EAGLE DITCH |
| 600585 | 336 | 1,378 | -1,042 | -310% | EASTON DITCH |
| 600588 | 856 | 1,086 | -230 | -27% | ELK CREEK DITCH |
| 600607 | 320 | 1,945 | -1,625 | -507% | GLENCOE DITCH |
| 600611 | 665 | 891 | -226 | -34% | GOLD RUN DITCH |
| 600628 | 487 | 435 | 52 | 11% | HASTINGS DITCH |
| 600633 | 33,141 | 35,506 | -2,365 | -7% | HIGHLINE CANAL |
| 600650 | 1,634 | 5,525 | -3,891 | -238% | J & M HUGHES DITCH |
| 600659 | 381 | 529 | -148 | -39% | KINLEY DITCH |
| 600669 | 402 | 461 | -59 | -15% | LEOPARD CREEK DITCH |
| 600670 | 3,039 | 4,915 | -1,875 | -62% | LILYLANDS CANAL |
| 600672 | 3,262 | 3,665 | -403 | -12% | LONE CONE DITCH |
| 600684 | 519 | 604 | -85 | -16% | MCCOLLOCH SCOTT DITCH |
| 600689 | 757 | 920 | -164 | -22% | MIDDLE ELK CREEK DITCH |
| 600707 | 18,157 | 11 | 18,146 | 100% | NATURITA CANAL |
| 600710 | 173 | 288 | -114 | -66% | NEILSON DITCH |
| 600723 | 1,446 | 1,446 | 0 | 0% | NUCLA POWER PLANT DITCH |
| 600733 | 441 | 416 | 26 | 6% | PAXTON DITCH |
| 600736 | 1,700 | 2,411 | -711 | -42% | PLEASANT VALLEY DITCH |
| 600745 | 737 | 889 | -152 | -21% | REED CHATFIELD DITCH |

| WDID | Historical | Simulated | Historical - Simulated | | Name |
| --- | --- | --- | --- | --- | --- |
| | | | Volume | Percent | |
| 600776 | 451 | 584 | -133 | -29% | TEMPLETON DITCH |
| 600777 | 231 | 318 | -87 | -37% | THEO NETHERLY DITCH NO1 |
| 60_ADS020 | 5,043 | 8,966 | -3,923 | -78% | 60_ADS020_SMiguelNrPlacr |
| 60_ADS021 | 1,352 | 4,515 | -3,164 | -234% | 60_ADS021_SMiguelabvWNat |
| 60_ADS022 | 8,385 | 10,284 | -1,899 | -23% | 60_ADS022_SMiguel@Naturi |
| 610502 [3] | 1,128 | 1,533 | -404 | -36% | GALLOWAY DIVSYS |
| 610517 | 1,373 | 1,802 | -429 | -31% | SOUTH MIDWAY DITCH |
| 610527 | 2,246 | 2,844 | -598 | -27% | RAY DITCH |
| 610602 [2] | 372 | 0 | 372 | 100% | A E L R P & PL |
| 61_ADS019 | 5,315 | 6,184 | -870 | -16% | 61_ADS019_DoloresRNrBedr |
| 630501 | 2,690 | 1,831 | 860 | 32% | BARTHOLOMEW & HATCH D |
| 630518 | 1,545 | 1,318 | 227 | 15% | CLIFF RANCH DITCH |
| 630529 | 839 | 703 | 135 | 16% | HARMS AND HAZEL DITCH |
| 630547 | 402 | 440 | -38 | -9% | NOLAN DITCH |
| 630553 | 259 | 444 | -185 | -71% | RED CROSS DITCH |
| 63_ADS023 | 4,754 | 6,016 | -1,262 | -27% | 63_ADS023_DoloresR@Gatew |
| 63_ADS024 | 8,824 | 9,923 | -1,100 | -12% | 63_ADS024_WestCreek |
| 63_AMS002 | 1,296 | 1,273 | 23 | 2% | 63_MUNICIPAL |
| 680636 | 1,260 | 928 | 332 | 26% | LEOPARD CREEK DITCH |
| 690510 | 1,474 | 1,944 | -470 | -32% | HORSESHOE DITCH |
| 690512 | 598 | 936 | -338 | -56% | KNIGHT-EMBLING DITCH |
| 690520 | 651 | 985 | -334 | -51% | PINE ARROYA DITCH |
| 69_ADS018 | 1,269 | 2,949 | -1,680 | -132% | 69_ADS018_Disappointment |
| 710504 | 432 | 400 | 32 | 7% | BEAR CREEK DITCH |
| 710513 | 746 | 881 | -134 | -18% | BURCH & LONGWILL DITCH |
| 710531 | 311 | 207 | 104 | 33% | EAST EDER DITCH |
| 710535 | 147 | 100 | 47 | 32% | GARBARINO NO 1 DITCH |
| 710536 | 154 | 117 | 37 | 24% | GARBARINO NO 2 DITCH |
| 710537 | 159 | 94 | 66 | 41% | GARBARINO NO 3 DITCH |
| 710545 | 688 | 862 | -174 | -25% | GOULD & MORIARITY DITCH |
| 710549 | 1,157 | 1,216 | -58 | -5% | ILLINOIS DITCH |
| 710551 | 215 | 294 | -80 | -37% | ITALIAN DITCH |
| 710555 | 603 | 514 | 89 | 15% | KEYSTONE DITCH |
| 710556 | 121 | 145 | -23 | -19% | KING NO 1 DITCH |
| 710559 | 266 | 221 | 45 | 17% | KOENIG DITCH |
| 710563 | 320 | 206 | 114 | 36% | LINDSTROM DITCH |
| 710572 | 422 | 509 | -88 | -21% | MONUMENT ROCK DITCH |
| 710573 | 549 | 615 | -66 | -12% | MORIARITY DITCH |
| 710575 | 54 | 23 | 31 | 58% | ORIGINAL RICO FLUME |
| 710582 | 476 | 381 | 94 | 20% | QUARRY NO 1 DITCH |
| 710586 | 262 | 180 | 82 | 31% | RIEVA DITCH |
| 710609 [1] | 0 | 0 | 0 | 0% | SUMMIT DITCH |
| 710618 [1] | 0 | 0 | 0 | 0% | TURKEY CREEK DITCH |
| 710624 | 254 | 371 | -118 | -46% | WEST EDER DITCH |
| 712002 | 6,480 | 8,198 | -1,717 | -27% | SUMMIT RES OUTLET |
| 714673 [1] | 0 | 0 | 0 | | MAIN CANAL NO 1 |
| 714674 [1] | 0 | 0 | 0 | | MAIN CANAL NO 2 |

| WDID | Historical | Simulated | Historical - Simulated Volume | Historical - Simulated Percent | Name |
|---|---|---|---|---|---|
| 71_ADS017 | 3,048 | 5,161 | -2,113 | -69% | 71_ADS017_DoloRabvMcPhee |
| 73_ADS025 | 7,501 | 10,913 | -3,411 | -45% | 73_ADS025_LittleDoloresR |
| 770516 | 235 | 273 | -38 | -16% | CONFAR & RUSSELL DITCH |
| 770524 | 1,658 | 2,240 | -582 | -35% | EAKLOR DITCH |
| 770529 | 1,213 | 1,473 | -260 | -21% | ELMER DITCH NO 1 |
| 770531 | 2,103 | 2,848 | -746 | -35% | ENTERPRISE DITCH |
| 770536 | 582 | 814 | -232 | -40% | FITZHUGH DITCH |
| 770559 | 706 | 856 | -150 | -21% | MIDLAND DITCH |
| 770560 | 277 | 398 | -121 | -44% | MONTOYA DITCH |
| 770562 | 369 | 537 | -167 | -45% | NAVAJO MEADOW DITCH |
| 770564 | 449 | 673 | -224 | -50% | NAVAJO RIVER DITCH |
| 770576 | 263 | 385 | -122 | -46% | SHAHAN IRRIGATION DITCH |
| 770579 | 1,674 | 2,148 | -473 | -28% | SOUTH SIDE DITCH |
| 770585 | 284 | 379 | -94 | -33% | UNDERWOOD DITCH |
| 770586 | 326 | 530 | -203 | -62% | UNDERWOOD DITCH NO 2 |
| 770587 | 686 | 978 | -291 | -42% | UPPER CAMP DITCH |
| 770588 | 316 | 429 | -113 | -36% | UPPER NAVAJO DITCH |
| 770597 | 869 | 1,116 | -248 | -29% | NEW BOND HOUSE (NAVAJO) |
| 774635 [1] | 44,772 | 0 | 44,772 | 100% | USBR_NAVAJO_DIVERSION |
| 774636 [1] | 3,992 | 0 | 3,992 | 100% | USBR_LITTLE_NAVAJO_DIVR |
| 779999 [3] | 0 | 86,807 | -86,807 | 0% | SanJ_Chama_Summary_Node |
| 77_ADS001 | 5,239 | 6,587 | -1,349 | -26% | 77_ADS001_NavajoRiver |
| 780501 | 1,489 | 2,024 | -535 | -36% | ABRAHAM DAVIS DITCH |
| 780506 [2] | 670 | 0 | 670 | 100% | BARNES DITCH |
| 780507 [3] | 703 | 4,520 | -3,818 | -543% | BARNES-MEUSER & SHAW D |
| 780513 | 2,583 | 3,071 | -488 | -19% | BUCKSKIN-NAILOR DITCH |
| 780523 [2] | 469 | 0 | 469 | 100% | CARL AND WEBB DITCH |
| 780524 [2] | 355 | 0 | 355 | 100% | CIMARRON DITCH |
| 780525 [2] | 1,067 | 0 | 1,067 | 100% | CLAYTON-REED DITCH |
| 780543 | 346 | 473 | -127 | -37% | EUGENIO GALLEGOS DITCH |
| 780544 [3] | 773 | 2,021 | -1,247 | -161% | F S MOCKLER DIVSYS |
| 780545 | 3,297 | 4,015 | -717 | -22% | FARROW AND PETERSON D |
| 780552 | 673 | 834 | -161 | -24% | GALLEGOS HOME DITCH |
| 780555 | 375 | 511 | -137 | -37% | GEORGE S MCDONALD DITCH |
| 780562 | 608 | 879 | -271 | -45% | HOSSACK CREEK DITCH |
| 780571 | 1,402 | 1,823 | -422 | -30% | BESS GIRL DITCH |
| 780580 | 933 | 1,164 | -231 | -25% | M E AND M DITCH |
| 780590 [2] | 597 | 0 | 597 | 100% | NICKLES BROTHERS DITCH |
| 780594 [2] | 272 | 0 | 272 | 100% | PAGOSA DITCH |
| 780604 [3] | 2,285 | 6,123 | -3,838 | -168% | PIEDRA FALLS DITCH |
| 780617 [3] | 1,881 | 5,384 | -3,504 | -186% | STEVENS&CLAYTON DITCH |
| 780638 | 1,365 | 1,698 | -333 | -24% | TONER AND STEVENS DITCH |
| 780659 [2] | 359 | 0 | 359 | 100% | LITTLE PAGOSA CREEK DIVR |
| 780692 | 755 | 754 | 1 | 0% | FAIRFIELD MUN. WATER SYS |
| 784670 | 48 | 45 | 2 | 5% | DON LAFONT DITCH NO 1 |
| 784671 | 136 | 126 | 10 | 8% | DON LAFONT DITCH NO 2 |
| 784672 | 242 | 228 | 14 | 6% | WILLIAMS CR SQ PASS DIVR |

| WDID | Historical | Simulated | Historical - Simulated | | Name |
|------|-----------|-----------|------------|---------|------|
| | | | Volume | Percent | |
| 78_ADS004 | 5,954 | 8,752 | -2,798 | -47% | 78_ADS004_PiedraRiver |
| 990707 | 18,265 | 21,670 | -3,405 | -19% | GURLEY_IRRIG |
| AZ_IRR | 0 | 0 | 0 | 0% | AZ_IR |
| AZ_NIR | 0 | 0 | 0 | 0% | AZ_NIR |
| CO_ALP | 0 | 0 | 0 | 0% | CO_ALP_Demands |
| NM_4CPP | 29,972 | 29,779 | 193 | 1% | FourCornersPP |
| NM_ABVARCH | 13 | 13 | 0 | 0% | AboveArchuleta |
| NM_ALP1 | 0 | 0 | 0 | 0% | NM_ALP_Animas_Demand |
| NM_ALP2 | 0 | 0 | 0 | 0% | NM_ALP_SanJuan_Demand |
| NM_ANIM | 34,924 | 34,372 | 551 | 2% | NM_AnimasIrr |
| NM_ARCH | 165 | 164 | 1 | 1% | ArchuletaDitch |
| NM_AZTEC | 5,483 | 5,406 | 77 | 1% | AztecMI |
| NM_BLOOM | 1,483 | 1,465 | 18 | 1% | BloomfieldMI |
| NM_CHACO | 0 | 0 | 0 | 0% | ChacoIrr |
| NM_CITZ | 17,687 | 17,411 | 276 | 2% | CitizenDitch |
| NM_CUDEI | 1,975 | 1,946 | 29 | 1% | CudeiCanal |
| NM_ECHO | 2,969 | 2,918 | 51 | 2% | EchoDitch |
| NM_FARMMI | 13,075 | 12,897 | 178 | 1% | FarmingtoNM_I |
| NM_FMD | 18,328 | 17,952 | 376 | 2% | FarmersMutual |
| NM_FRUCAM | 13,711 | 13,477 | 234 | 2% | FruitlandAndCambridge |
| NM_GLADE | 452 | 437 | 14 | 3% | FarmingtonGlade |
| NM_HAMM | 21,405 | 21,088 | 317 | 1% | Hammond |
| NM_HOGB | 21,802 | 21,374 | 428 | 2% | Hogback |
| NM_JEWV | 6,383 | 6,238 | 145 | 2% | JewettValley |
| NM_JICIRR | 131 | 128 | 3 | 2% | JicarillaIrri |
| NM_JICNEW | 0 | 0 | 0 | 0% | JicarillaNew |
| NM_JICNIR | 190 | 185 | 5 | 3% | JicarillaNonIr |
| NM_LPIRR | 17,874 | 11,520 | 6,353 | 36% | LowerLaPlataIrr |
| NM_LPNIR | 5,445 | 2,122 | 3,323 | 61% | LaPlataNonIr |
| NM_NIIP | 127,870 | 127,870 | 0 | 0% | NIIP |
| NM_NIIP_R1 | -5,377 | -5,377 | 0 | 0% | NIIP Ojo Return |
| NM_NIIP_R2 | -1,320 | -1,320 | 0 | 0% | NIIP Chaco Return |
| NM_NIIP_R3 | -4,863 | -4,863 | 0 | 0% | NIIP Gallegos Return |
| NM_REDW | 0 | 0 | 0 | 0% | RedWash |
| NM_SJGS | 16,026 | 16,027 | 0 | 0% | SJPowerPlant |
| NM_SRMI | 0 | 0 | 0 | 0% | ShiprockMI |
| NM_TURLEY | 1,144 | 1,126 | 18 | 2% | TurleyDitch |
| NM_U2NIR | 1,828 | 1,767 | 61 | 3% | NM_U2NonIr |
| NM_U3NIR | 495 | 483 | 12 | 2% | NM_U3NonIr |
| NM_U5NIR | 0 | 0 | 0 | 0% | NM_U5NonIr |
| NM_U6NIR | 25,998 | 25,551 | 447 | 2% | NM_U6NonIr |
| NM_U7NIR | 419 | 411 | 8 | 2% | NM_U7NonIr |
| NM_U8NIR | 0 | 0 | 0 | 0% | NM_U8NonIr |
| NM_USIRR | 1,638 | 1,580 | 58 | 4% | USNavajoIrr |
| NM_USNIR | 715 | 695 | 20 | 3% | USNavajoNonIr |
| NM_WESTW | 285 | 272 | 14 | 5% | Westwater |
| NM_WHIS | 0 | 0 | 0 | 0% | WhiskeyCreek |

| WDID | Historical | Simulated | Historical - Simulated | | Name |
|---|---|---|---|---|---|
| | | | Volume | Percent | |
| UT_IRR | 6,880 | 6,794 | 86 | 1% | UT_IRR |
| UT_NIR | 0 | 0 | 0 | 0% | UT_NIR |
| **Basin Total** | **1,427,523** | **1,544,284** | **-177,977** | **-12%** | |

1) Carrier Structures – demand and use accounted for at user structure
2) Secondary Structures – demand and use accounted for at primary structure
3) Primary Structure – demand and use for primary and secondary structures included

**USGS Gage 09342500 - San Juan River at Pagosa Springs**
**Gaged versus Simulated Flow (1975-2003)**
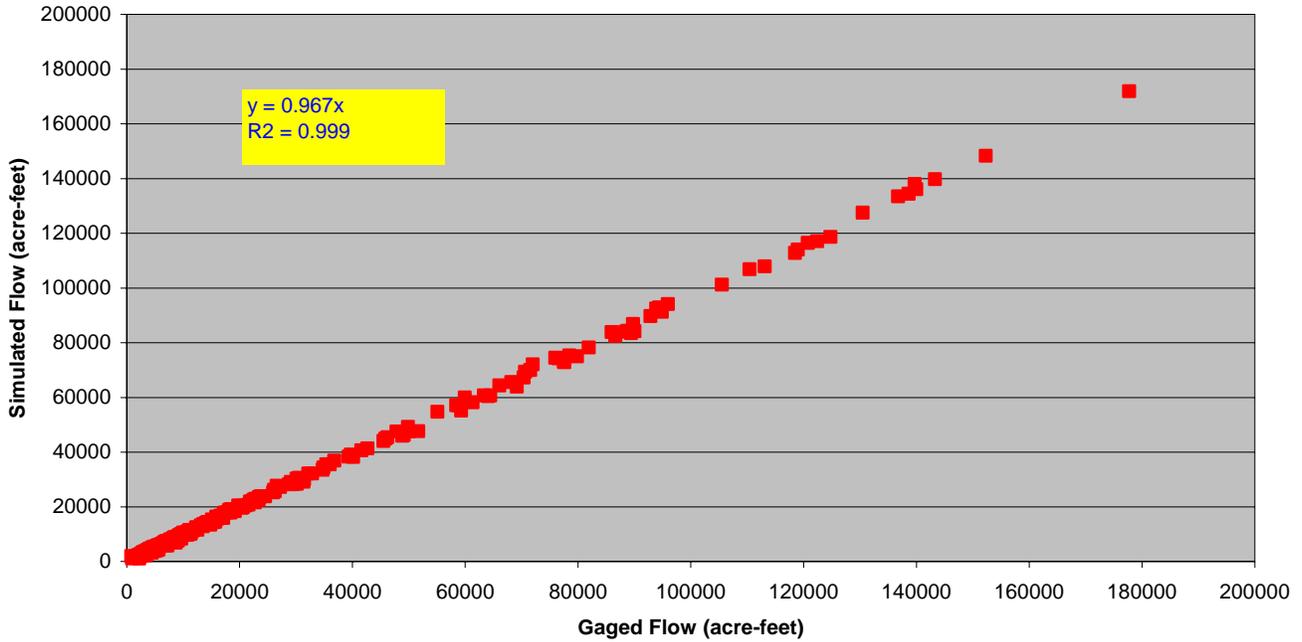
$y = 0.967x$
$R2 = 0.999$



**USGS Gage 09342500 - San Juan River at Pagosa Springs**
**Gaged and Simulated Flows (1975-2003)**
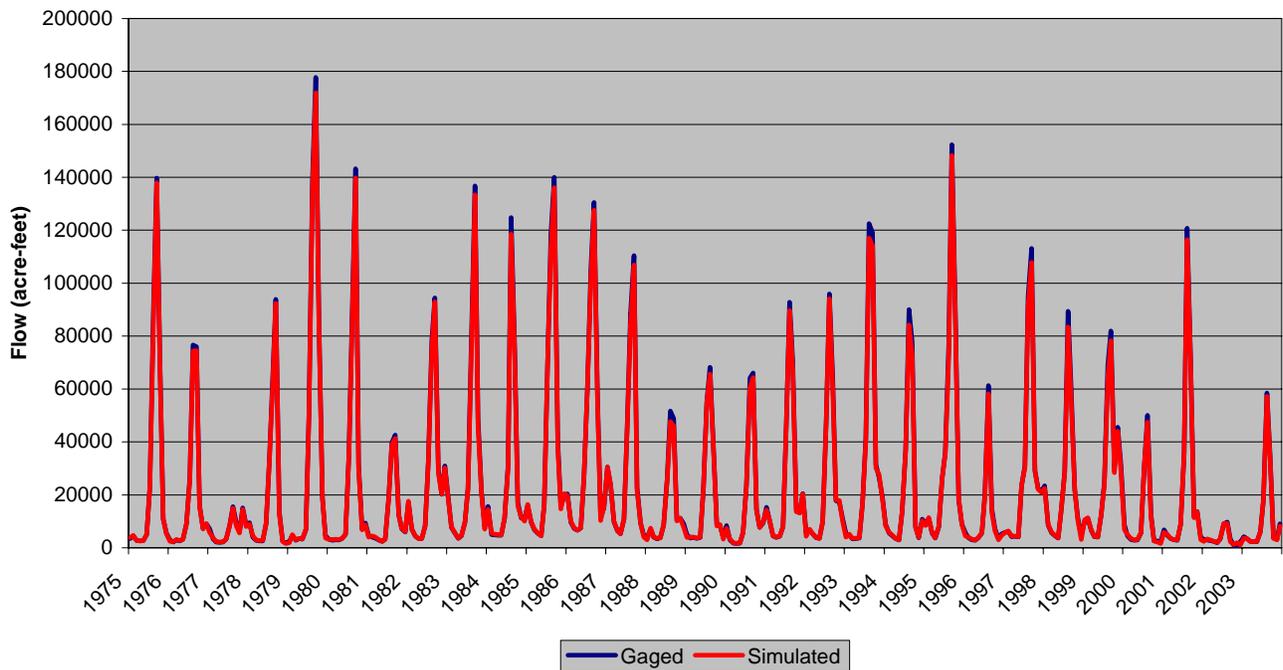
**Figure D.1 Calculated Streamflow Simulation – San Juan River at Pagosa Springs**

**USGS Gage 09346400 - San Juan River near Carracus**
**Gaged versus Simulated Flow (1975-2003)**

y = 0.976x
R2 = 0.999
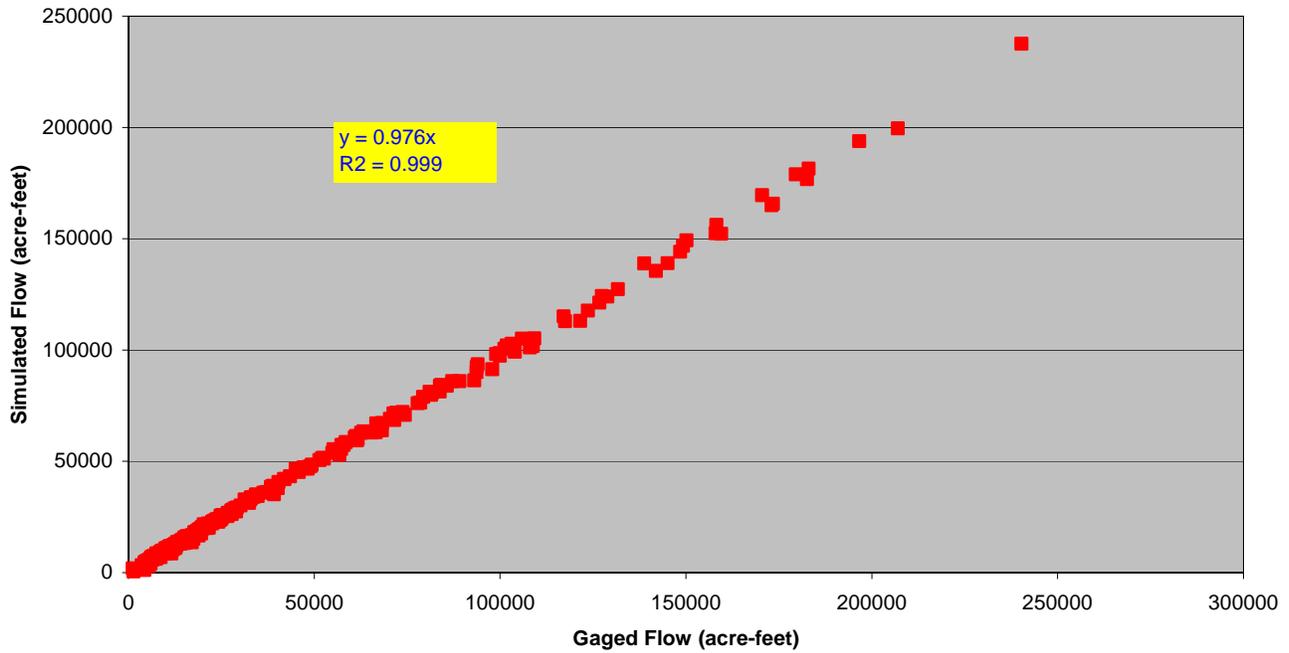


**USGS Gage 09346400 - San Juan River near Carracus**
**Gaged and Simulated Flows (1975-2003)**
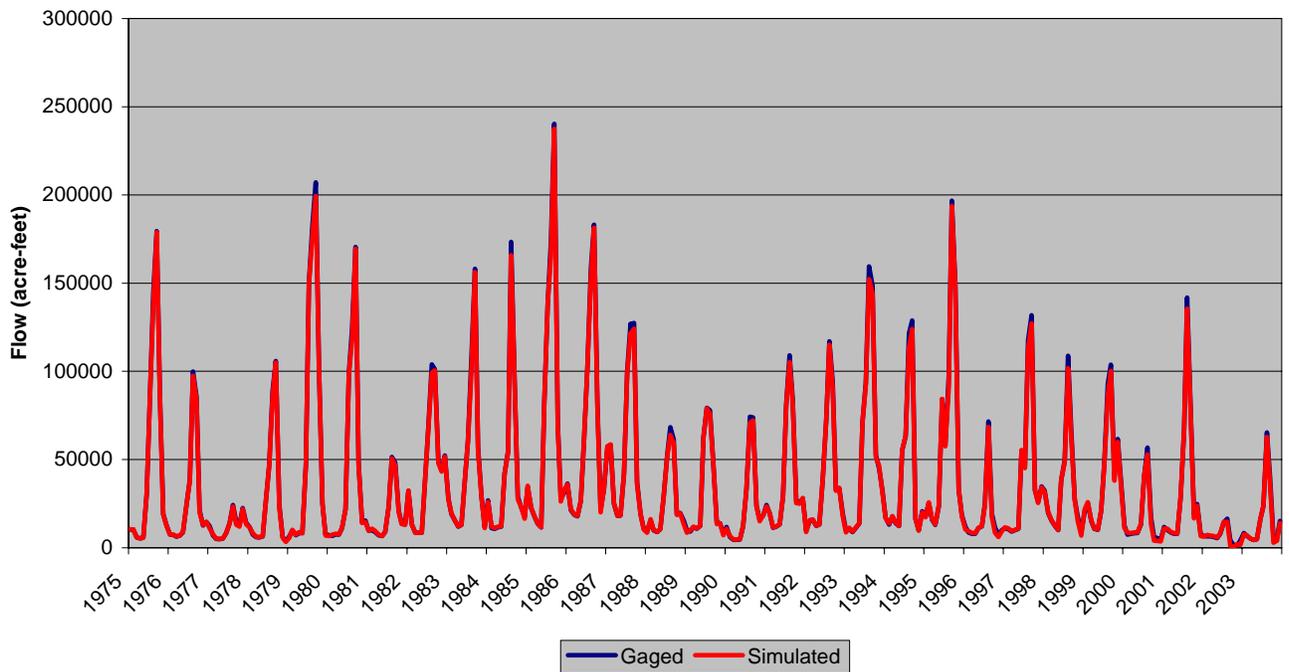
**Figure D.2 Calculated Streamflow Simulation – San Juan River near Carracus**

**USGS Gage 09349800 - Piedra River near Arboles**
**Gaged versus Simulated Flow (1975-2003)**



y = 0.986x
R2 = 0.999
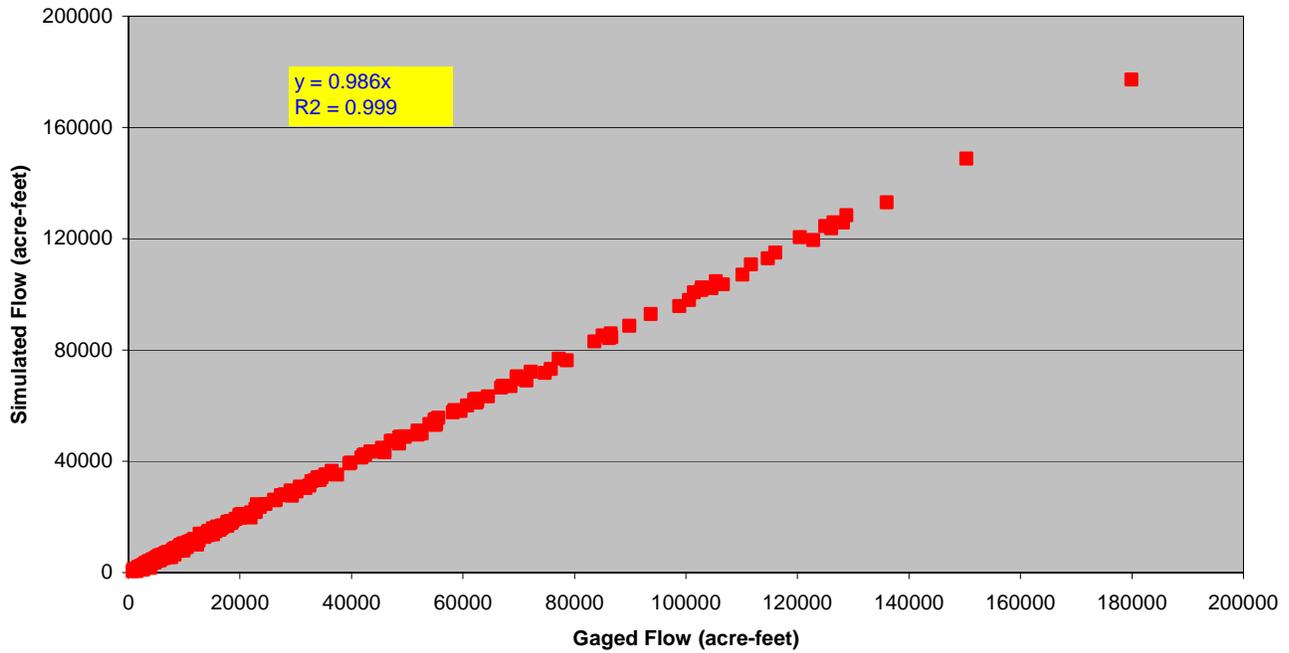
**USGS Gage 09349800 - Piedra River near Arboles**
**Gaged and Simulated Flows (1975-2003)**
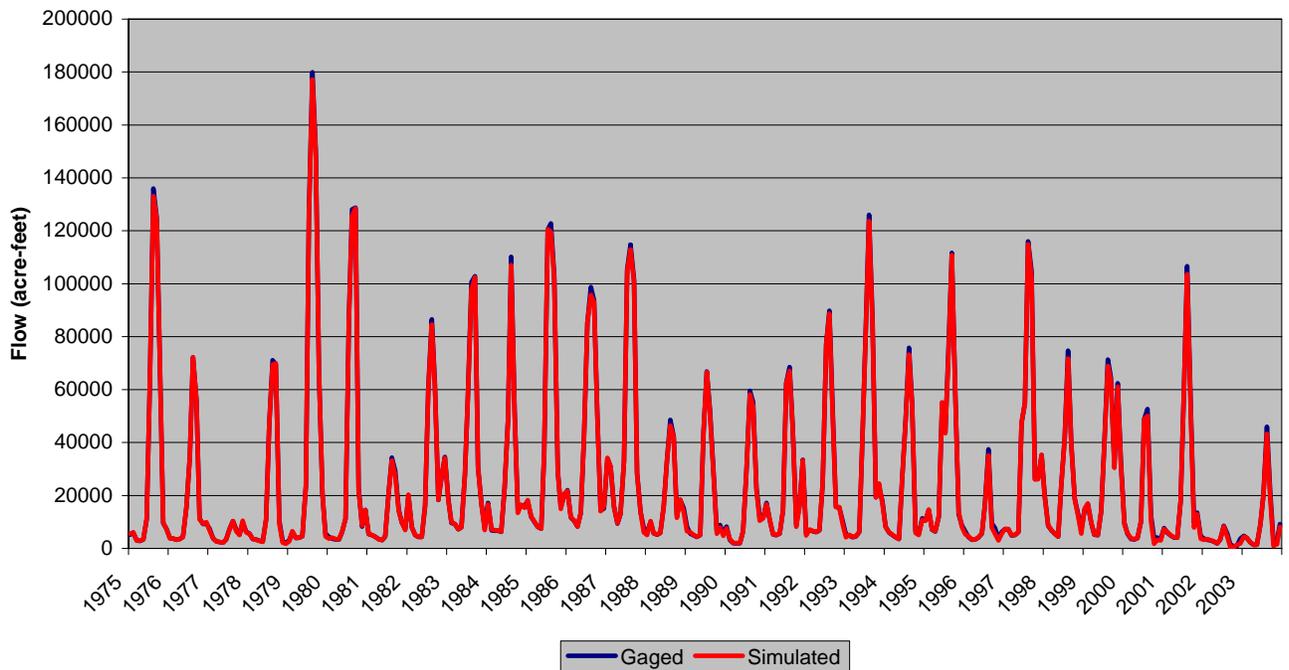


**Figure D.3 Calculated Streamflow Simulation – Piedra River near Arboles**
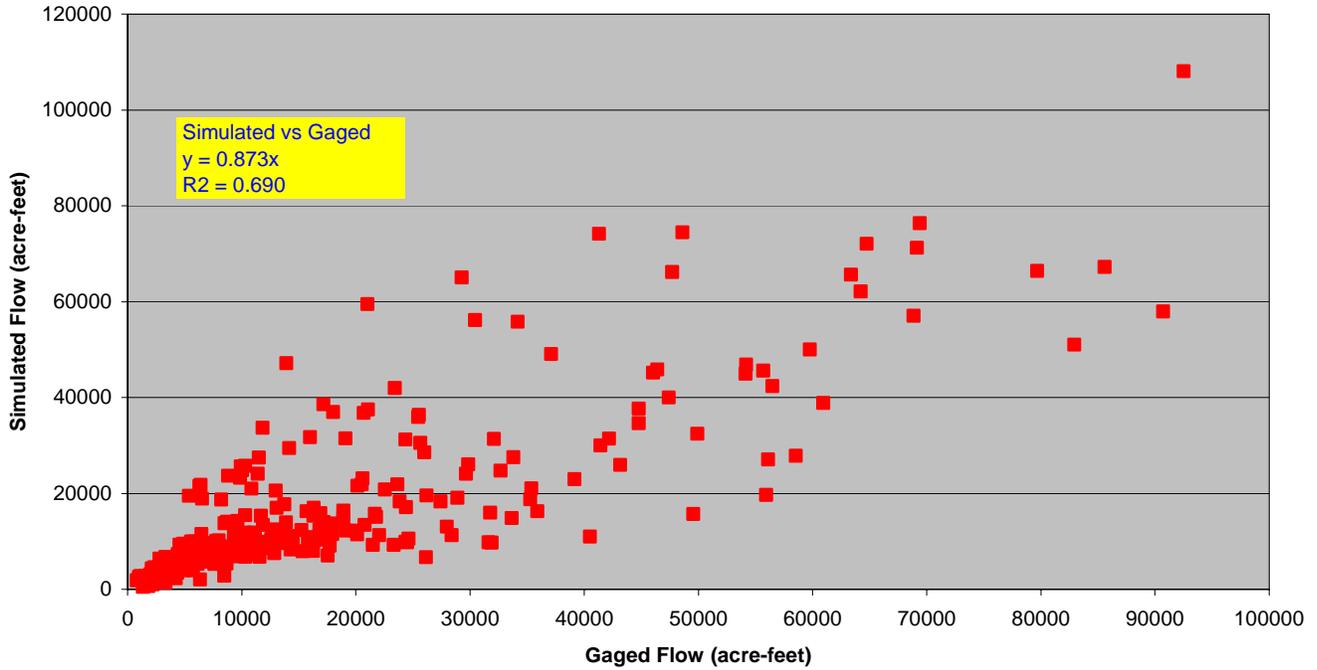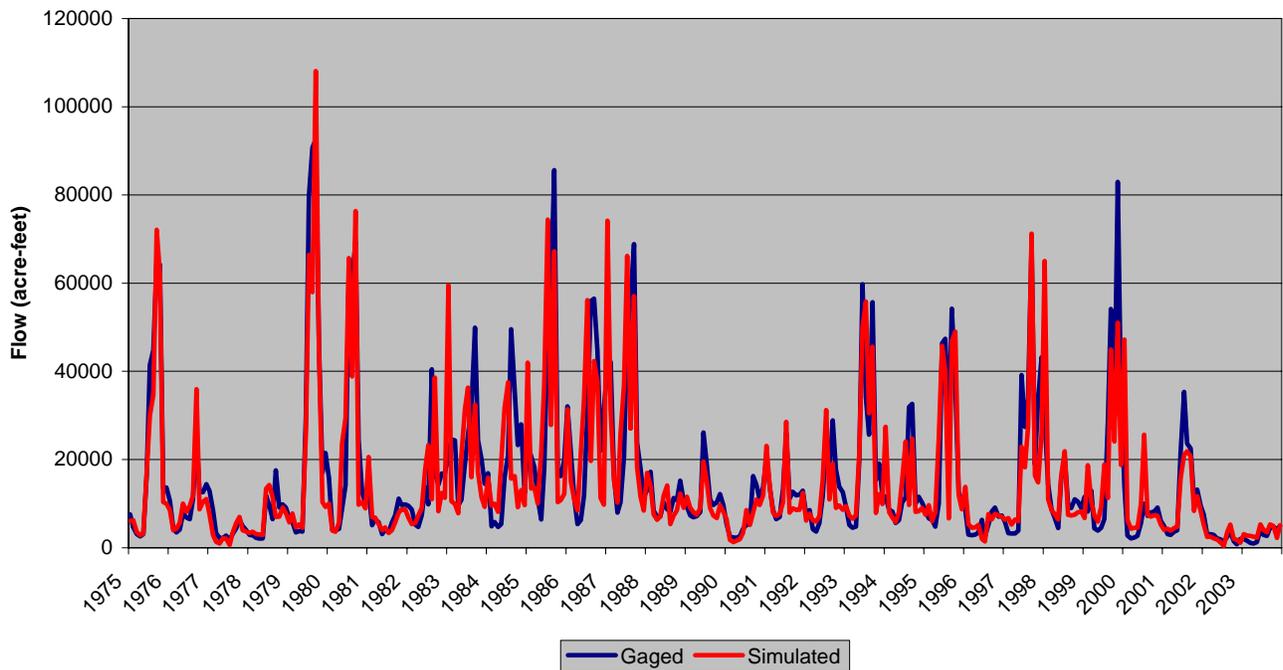
**Figure D.4 Calculated Streamflow Simulation – Los Pinos River at La Boca**

**USGS Gage 09361500 - Animas River at Durango**
**Gaged versus Simulated Flow (1975-2003)**



y = 0.997x
R2 = 0.999
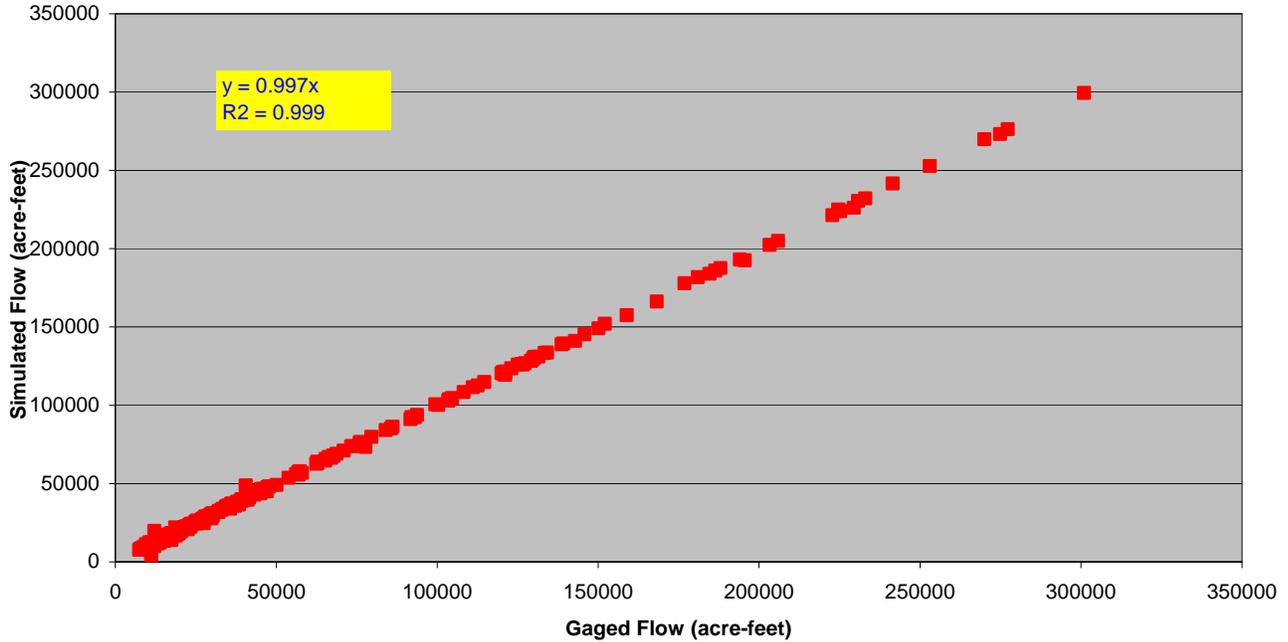
**USGS Gage 09361500 - Animas River at Durango**
**Gaged and Simulated Flows (1975-2003)**
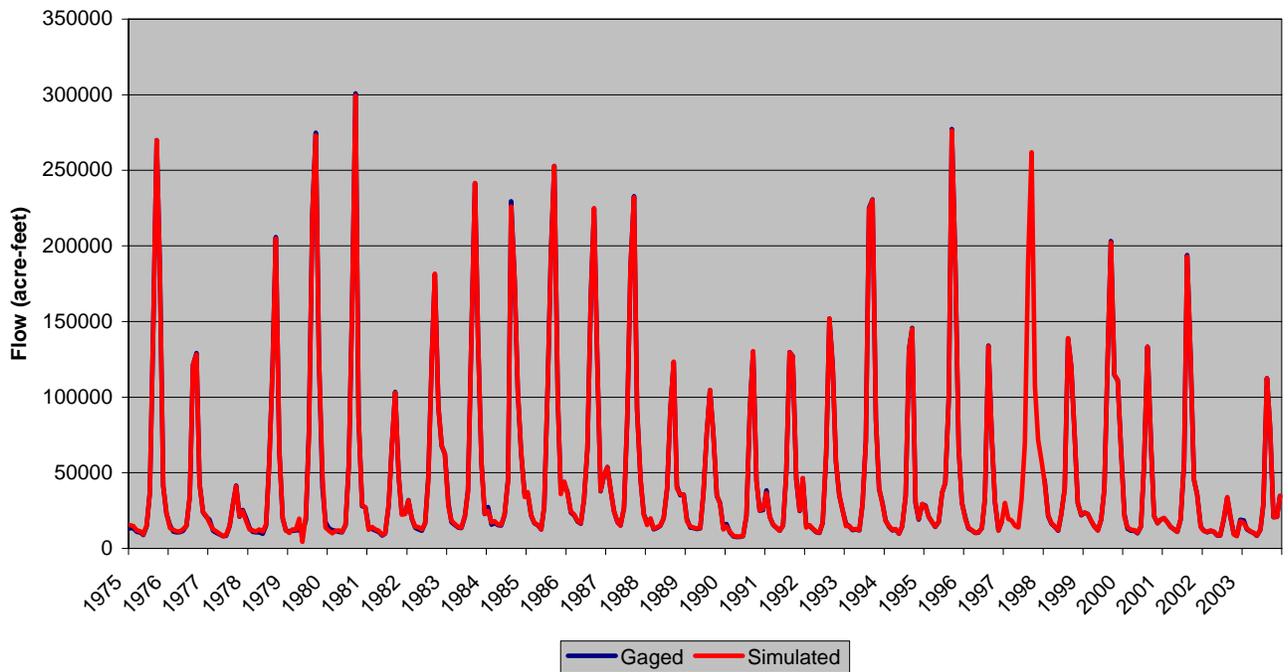


**Figure D.5 Calculated Streamflow Simulation – Animas River at Durango**

**USGS Gage 09366500 - La Plata River at Colorado-New Mexico Stateline**
**Gaged versus Simulated Flow (1975-2003)**



y = 0.845x
R2 = 0.968
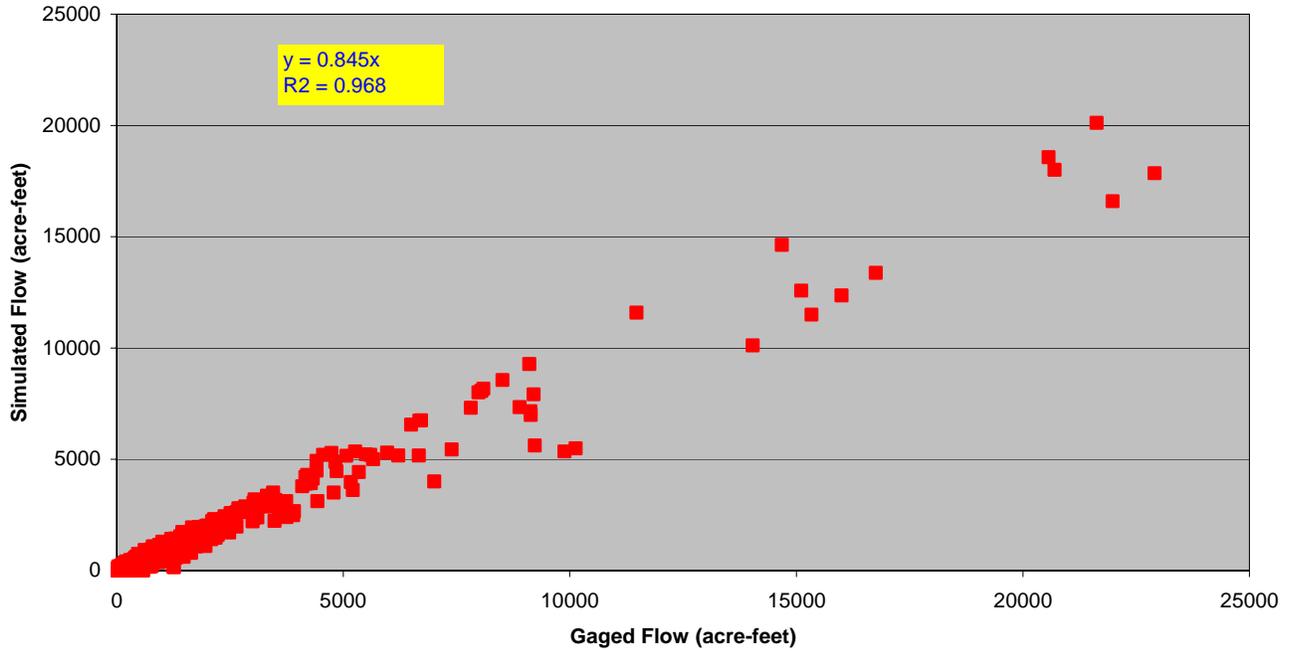
**USGS Gage 09366500 - La Plata River at Colorado-New Mexico Stateline**
**Gaged and Simulated Flows (1975-2003)**
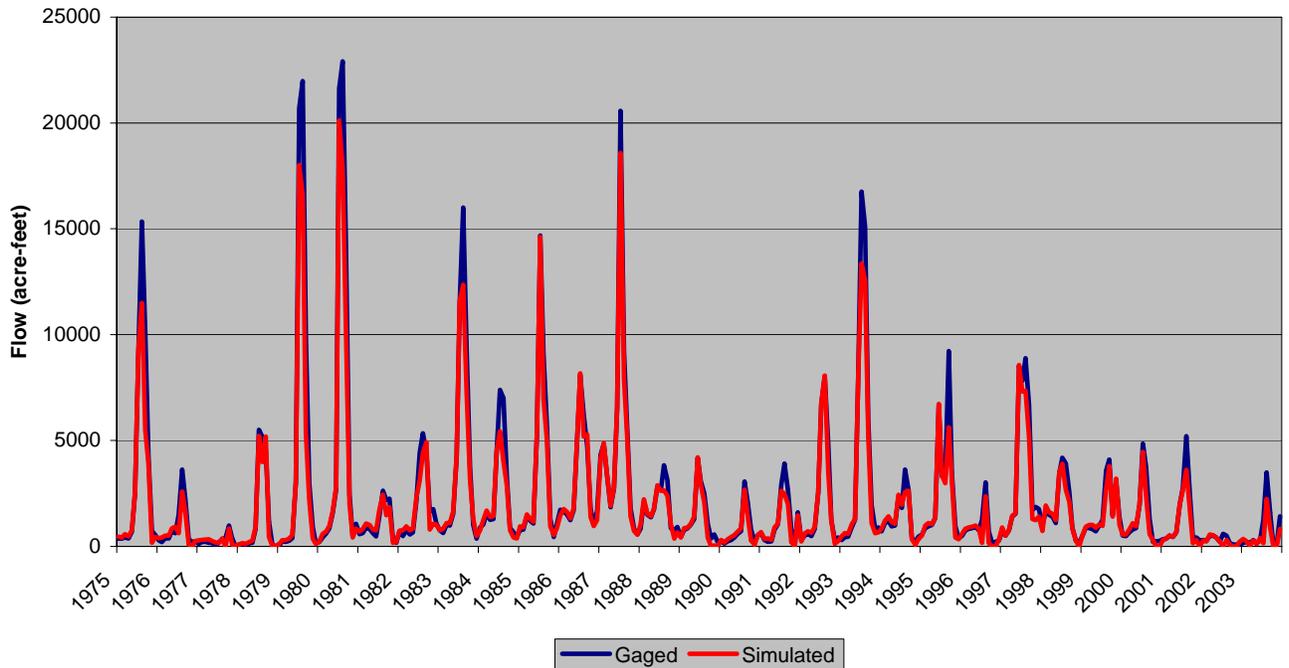


**Figure D.6 Calculated Streamflow Simulation – La Plata River at Colorado-New Mexico Stateline**

**USGS Gage 09371000 - Mancos River near Towaoc**
**Gaged versus Simulated Flow (1975-2003)**

y = 0.878x
R2 = 0.971
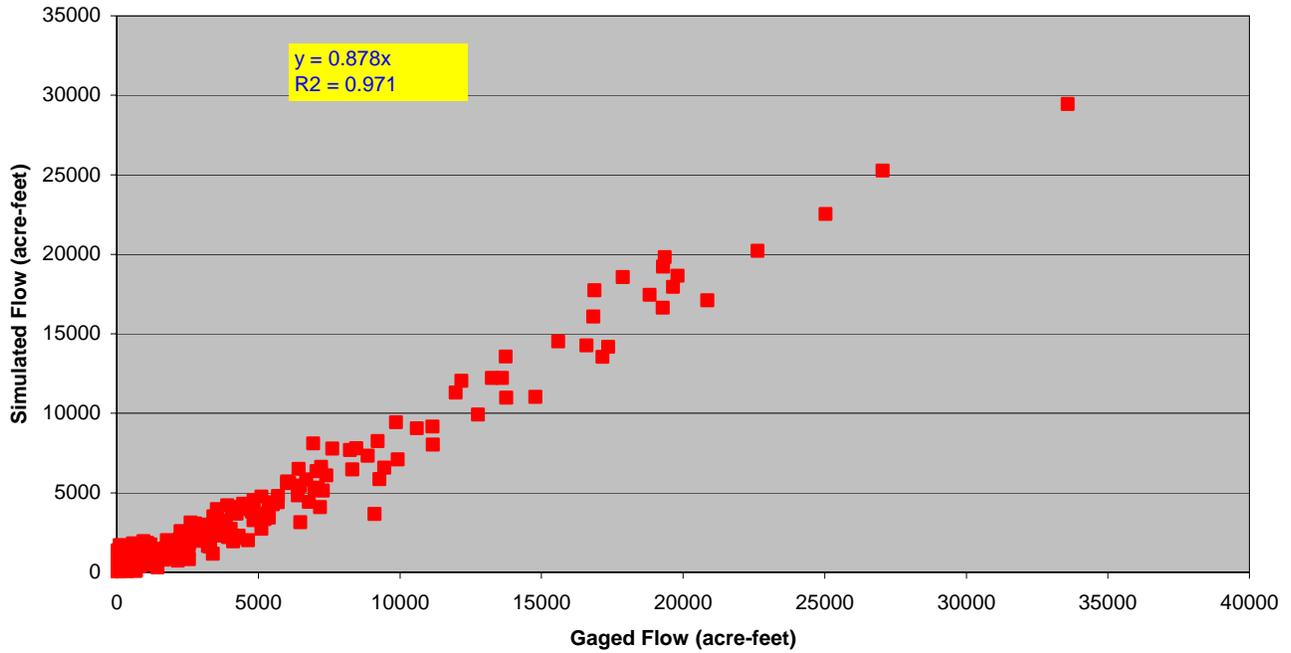


**USGS Gage 09371000 - Mancos River near Towaoc**
**Gaged and Simulated Flows (1975-2003)**
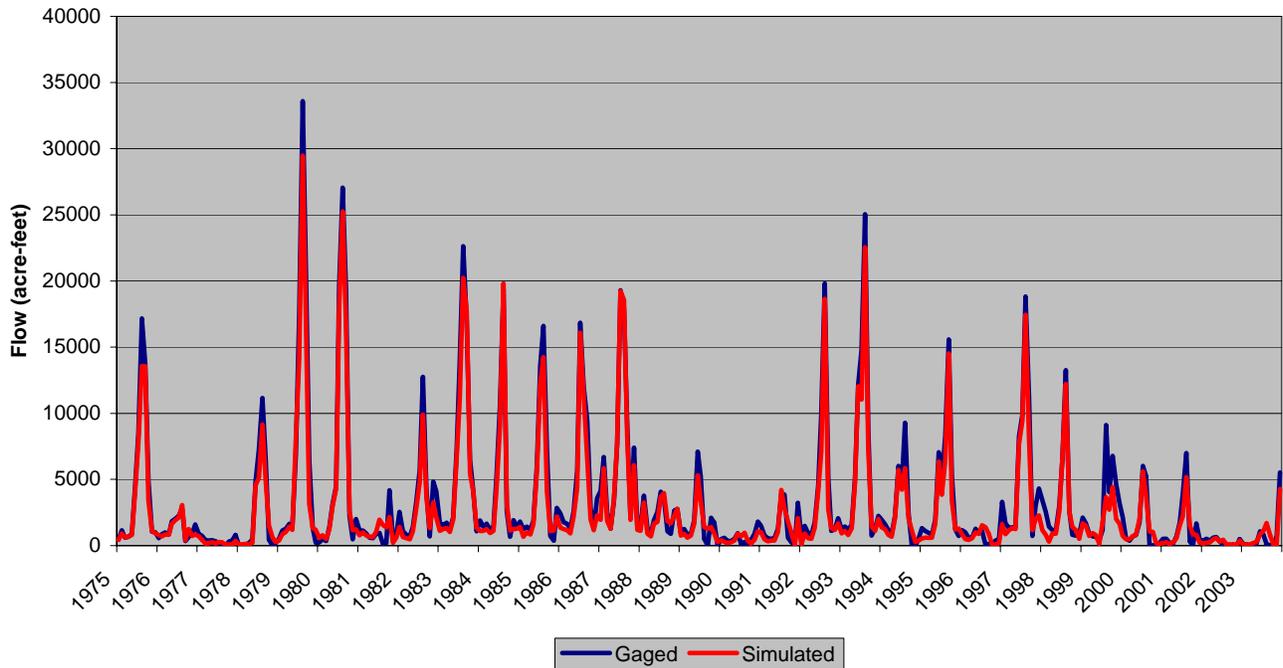
**Figure D.7 Calculated Streamflow Simulation – Mancos River near Towaoc**

USGS Gage 09372000 - McElmo Creek at Colorado-Utah Stateline
Gaged versus Simulated Flow (1975-2003)

y = 0.906x
R2 = 0.947
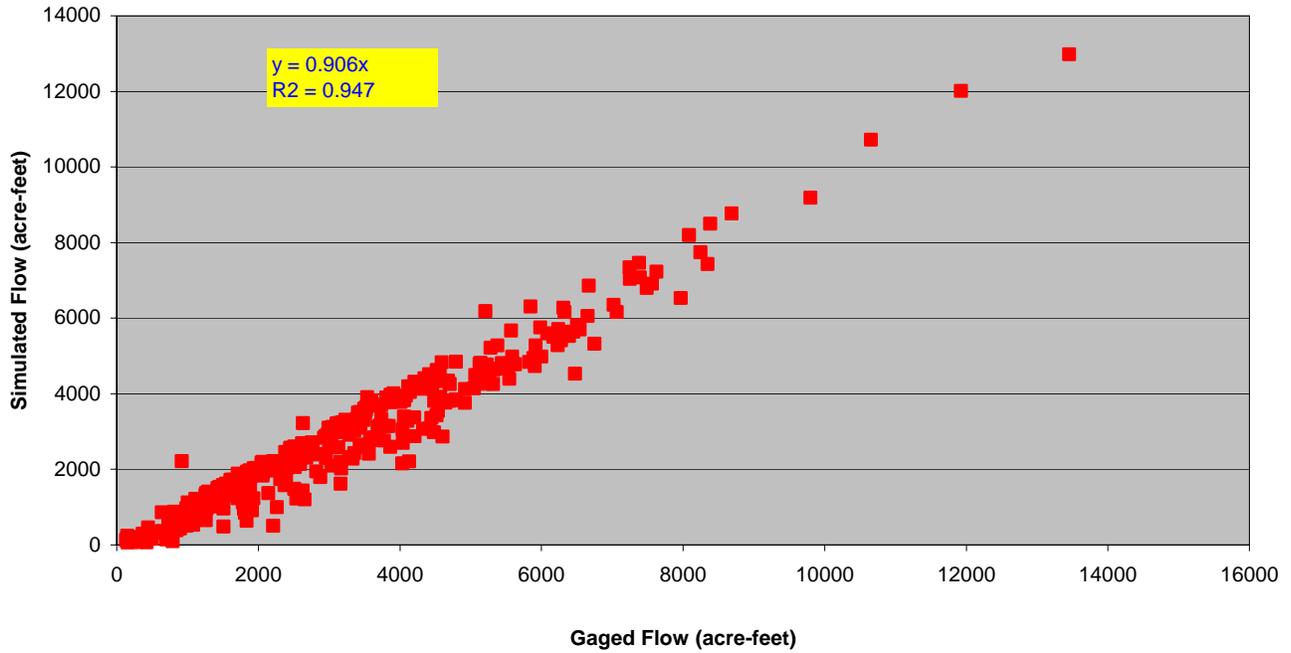


USGS Gage 09372000 - McElmo Creek at Colorado-Utah Stateline
Gaged and Simulated Flows (1975-2002)
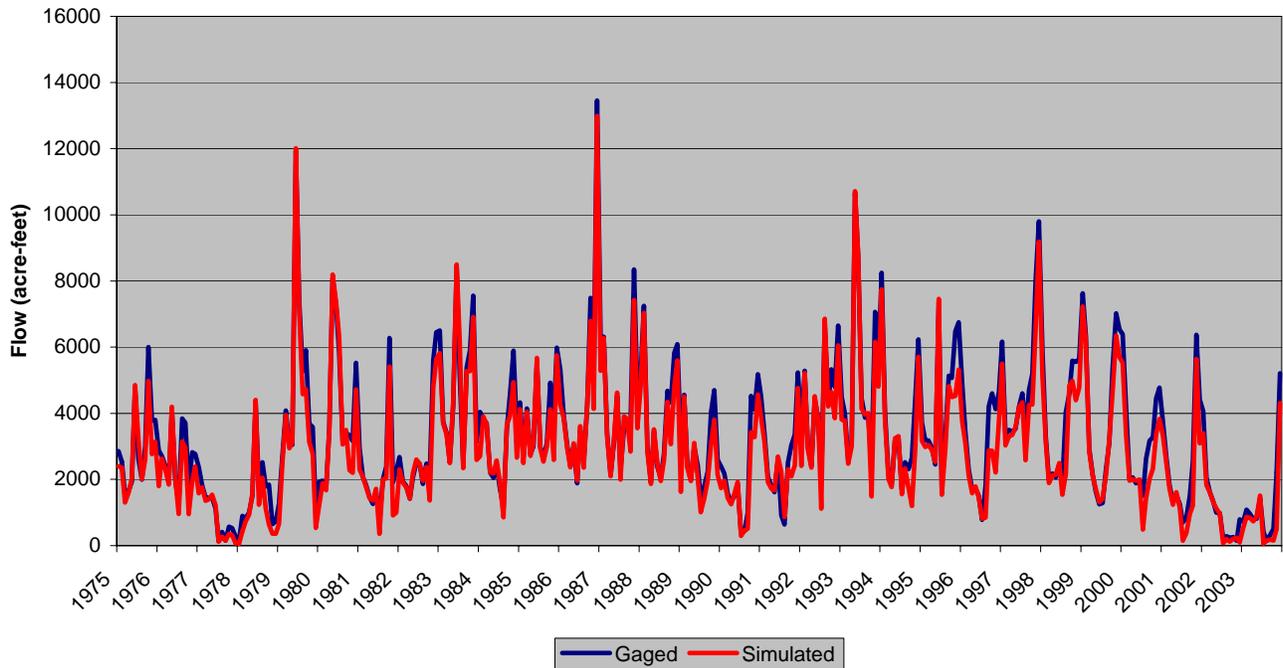
**Figure D.8 Calculated Streamflow Simulation – McElmo Creek at Colorado-Utah Stateline**

USGS Gage 09171100 - Dolores River near Bedrock
Gaged versus Simulated Flow (1975-2003)

y = 0.986x
R2 = 0.973
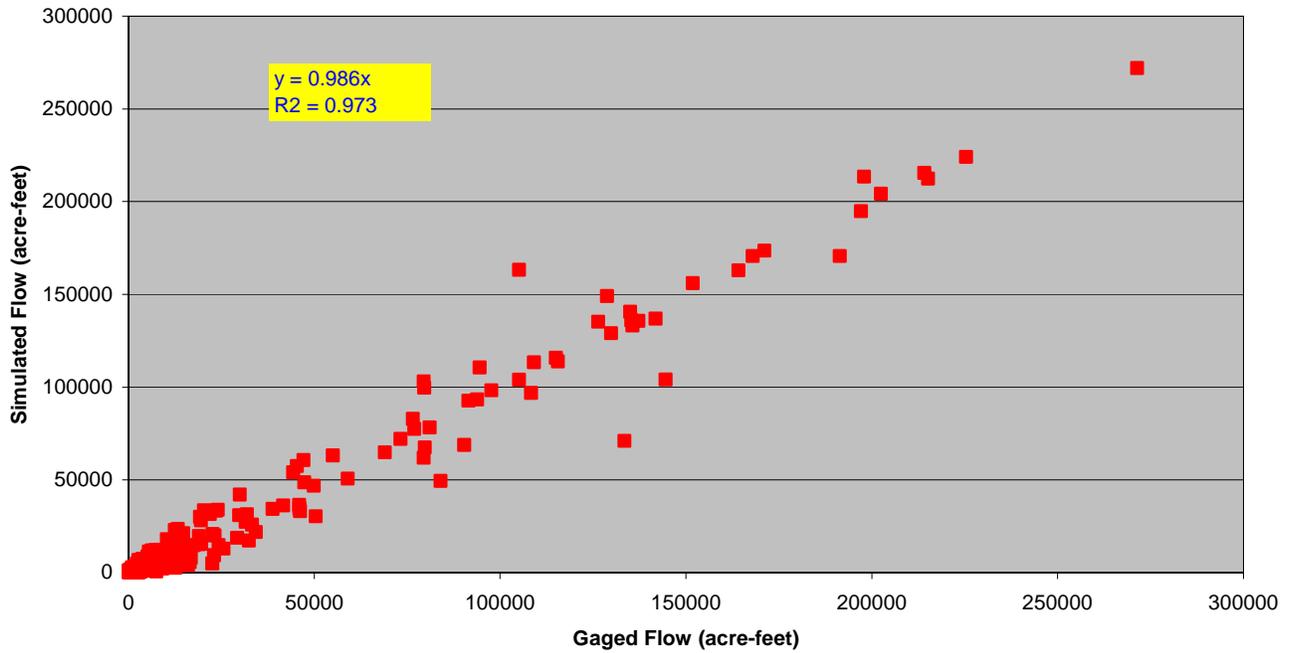
USGS Gage 09171100 - Dolores River near Bedrock
Gaged and Simulated Flows (1975-2003)
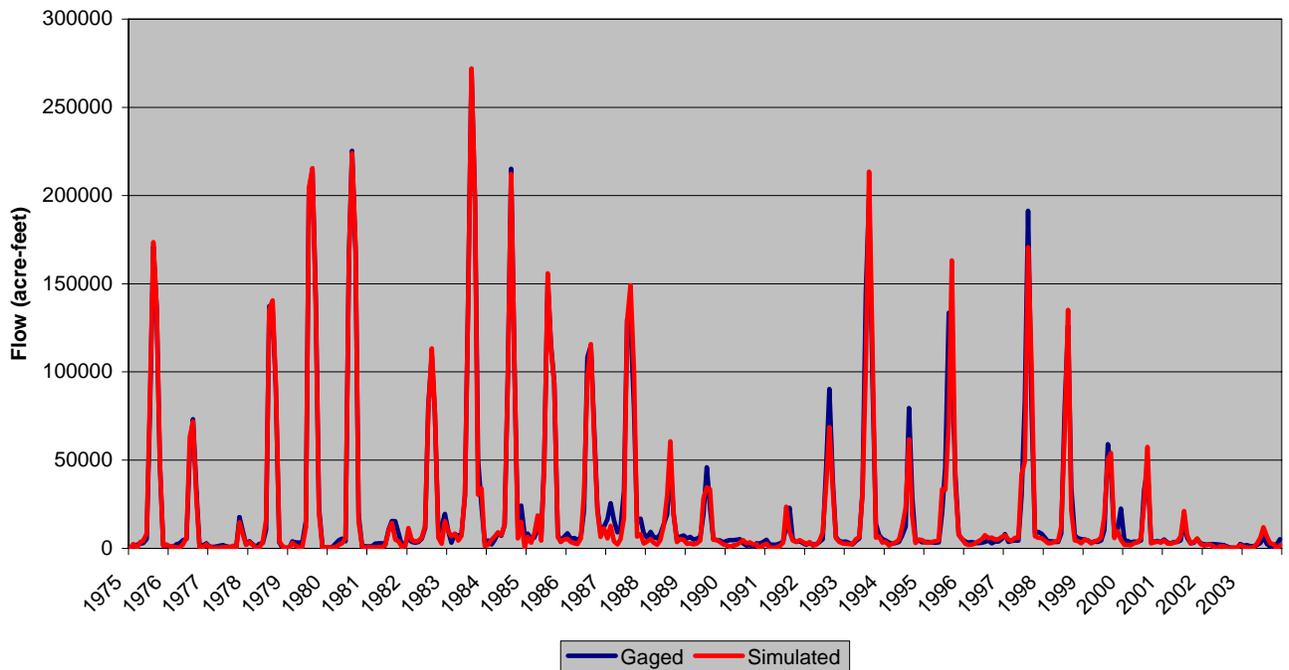
**Figure D.9 Calculated Streamflow Simulation – Dolores River near Bedrock**

**USGS Gage 09177000 - San Miguel River at Uravan**
**Gaged versus Simulated Flow (1975-2003)**

y = 0.942x
R2 = 0.995
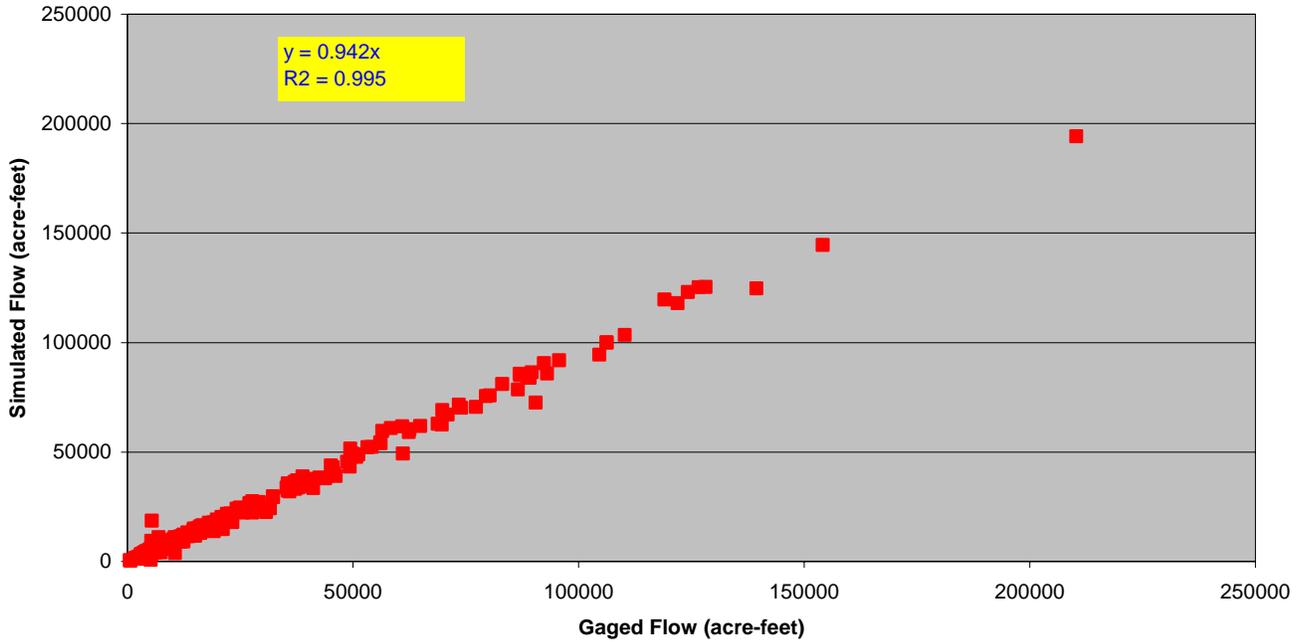
**USGS Gage 09177000 - San Miguel River at Uravan**
**Gaged and Simulated Flows (1975-2003)**
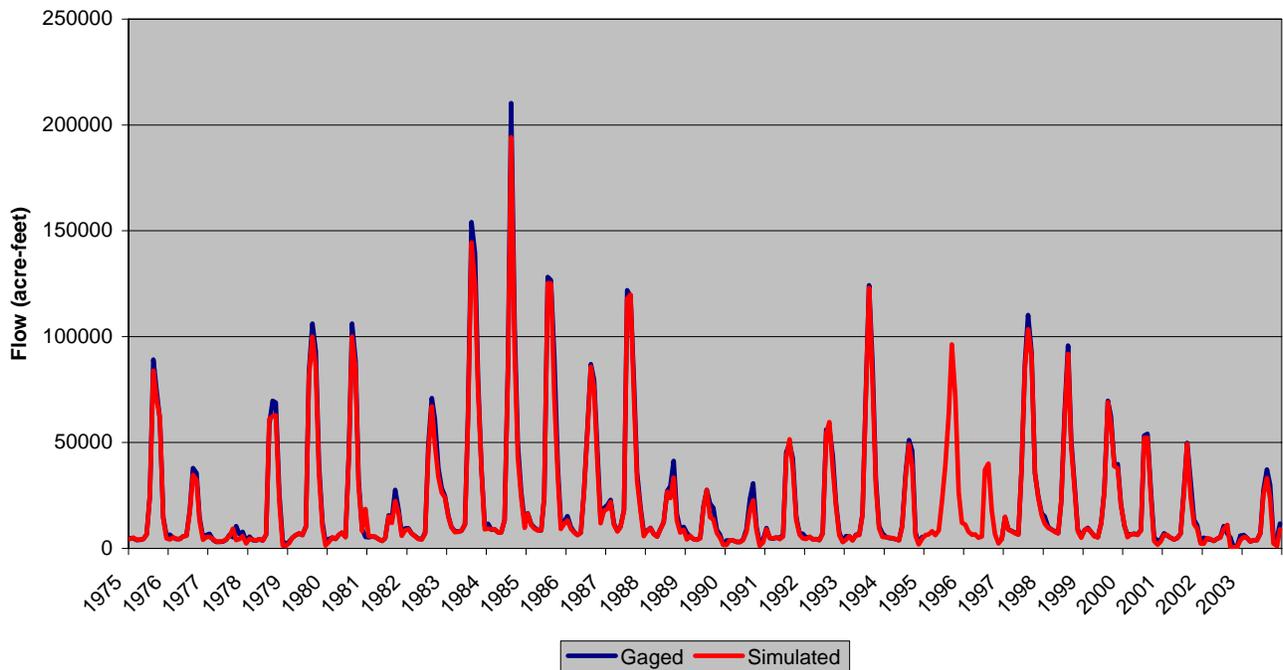
**Figure D.10 Calculated Streamflow Simulation – San Miguel River at Uravan**

**313518 - Vallecito Reservoir**
**Gaged and Simulated EOM Contents (1975-2003)**
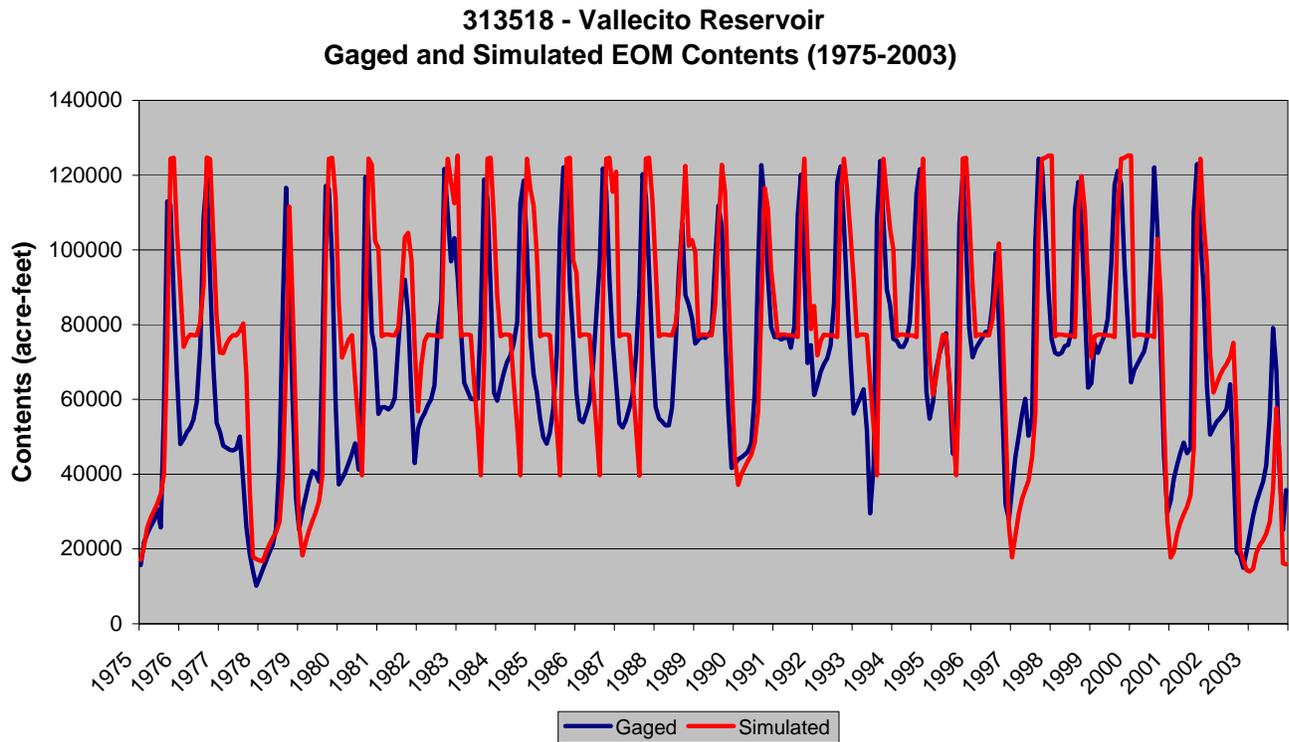
**Figure D.11 Calculated Reservoir Simulation – Vallecito Reservoir**



**303581 - Lemon Reservoir**
**Gaged and Simulated EOM Contents (1975-2003)**
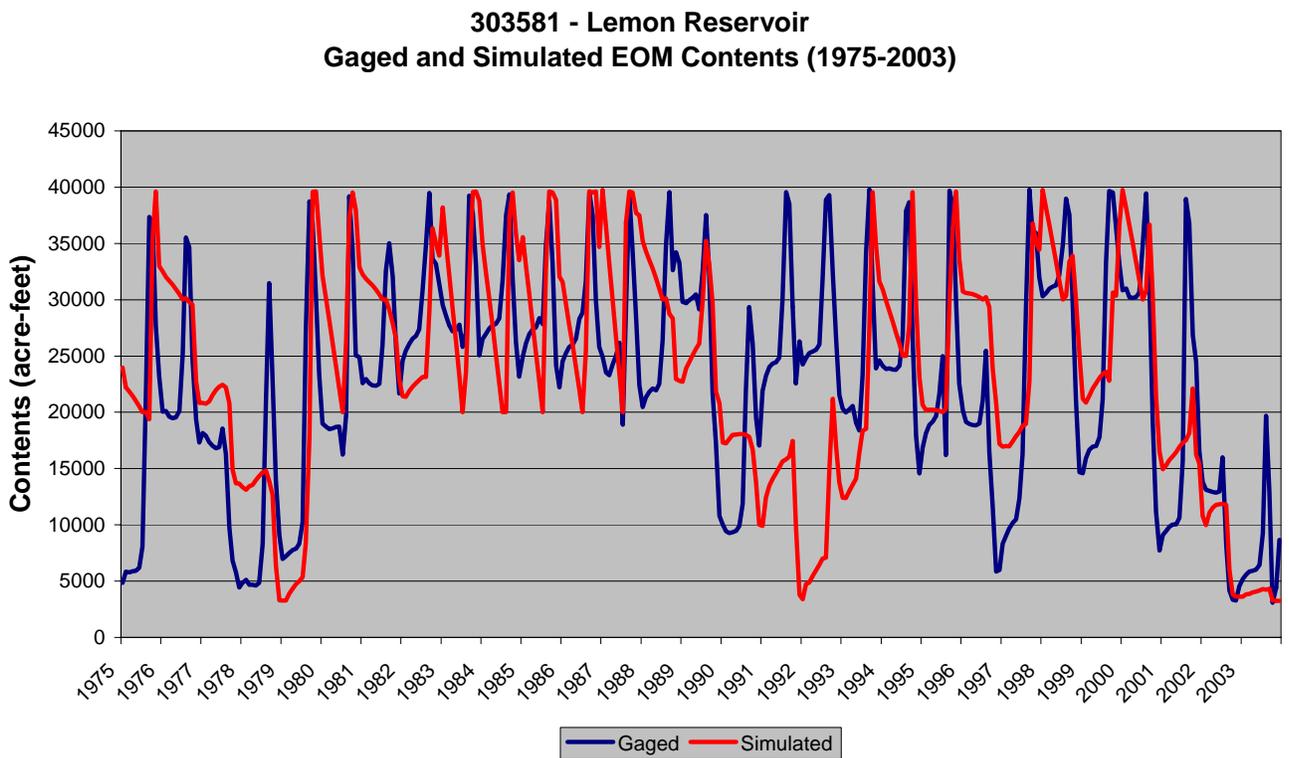
**Figure D.12 Calculated Reservoir Simulation – Lemon Reservoir**

**303536 - Cascade Reservoir**
**Gaged and Simulated EOM Contents (1975-2003)**
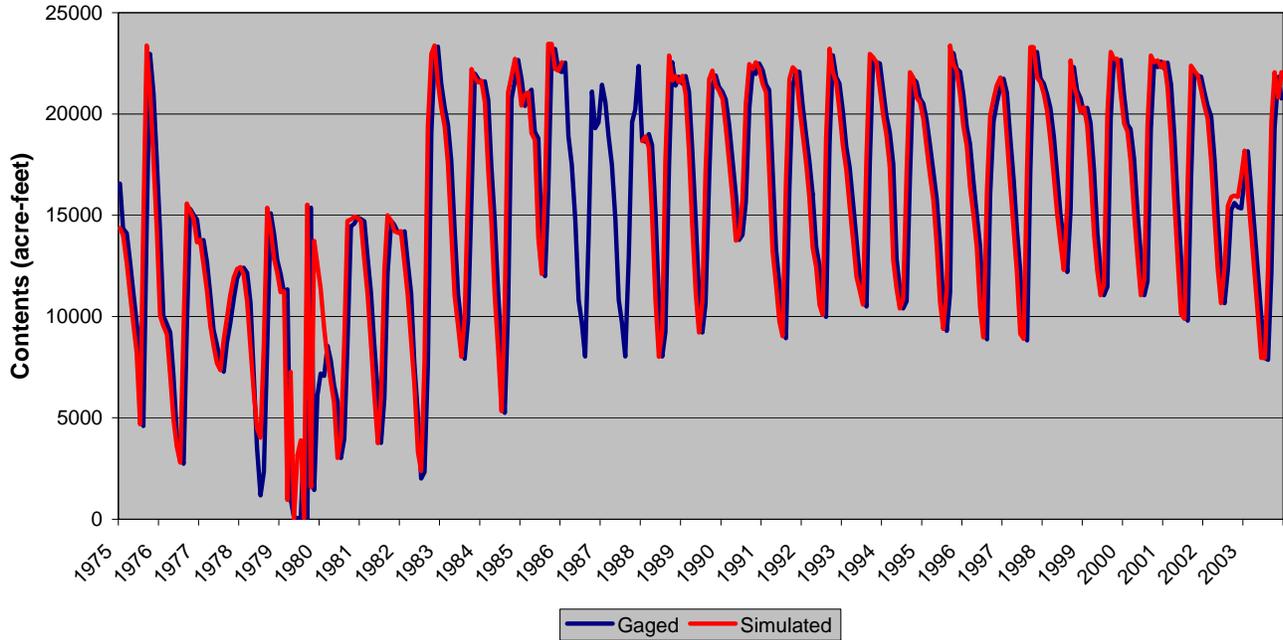


**Figure D.13 Calculated Reservoir Simulation – Cascade Reservoir**

**343589 - Jackson Gulch Reservoir**
**Gaged and Simulated EOM Contents (1975-2003)**
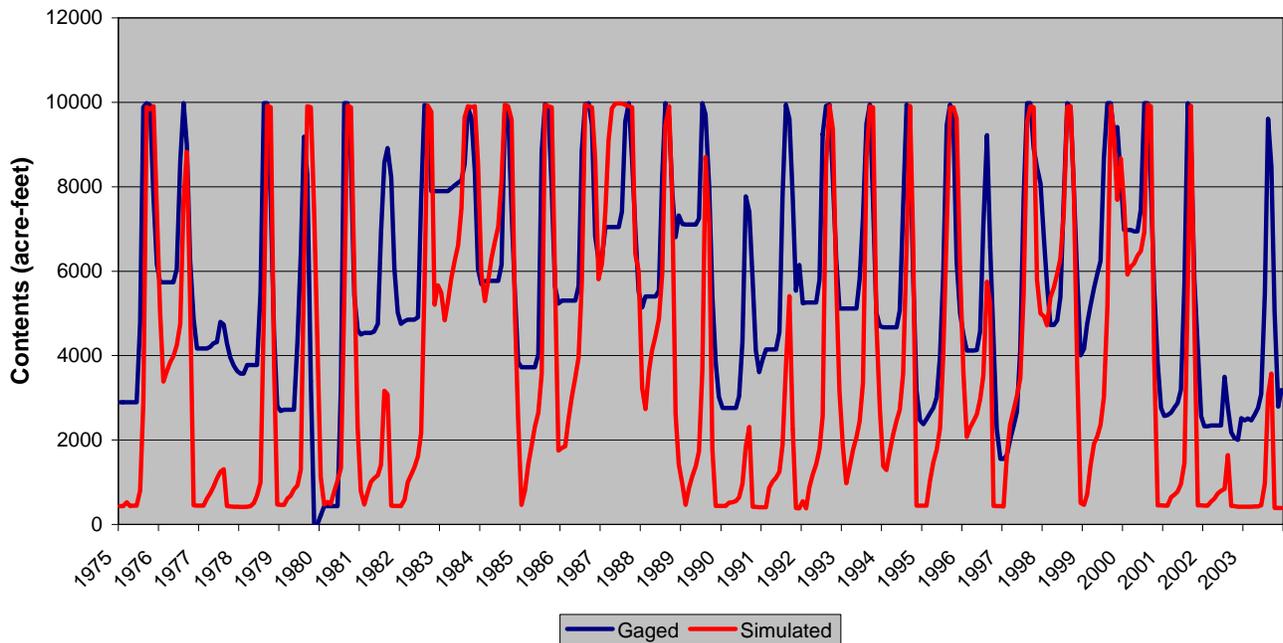


**Figure D.14 Calculated Reservoir Simulation – Jackson Gulch Reservoir**

**713614 - McPhee Reservoir**
**Gaged and Simulated EOM Contents (1975-2003)**
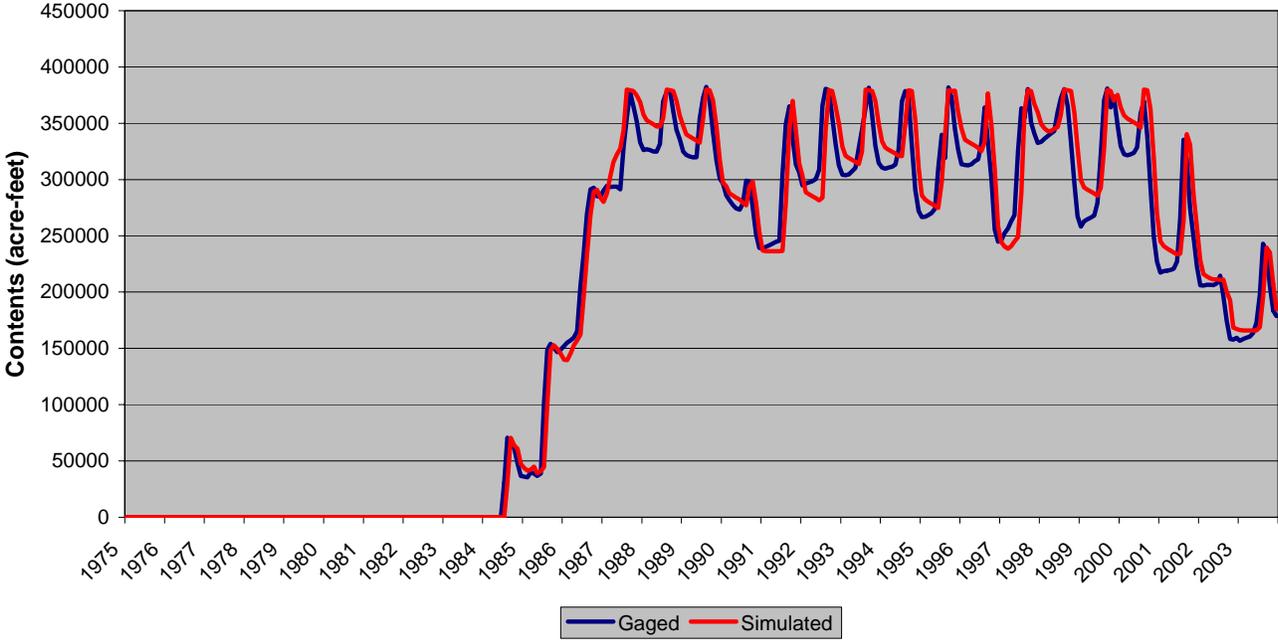
**Figure D.15 Calculated Reservoir Simulation – McPhee Reservoir**

# Appendix E

**Historical Daily Simulation Results**

# Historical Daily Data Set

The "Historical Daily" data set is a data set that was created to run on a daily time-step. The Historical Daily data set simulates the historical demands, infrastructure and projects, and administrative environment. The purpose of the Historical Daily model data set is to capture daily variations in streamflow and call regime. The simulation period for the Historical Daily model is 1975 through 2003. This is the period for which diversion data, and associated irrigation efficiencies, are most complete.

The most difficult part of developing a basin model is understanding the system. By first developing a monthly model, the system operation was investigated without the volume of information ultimately required for a daily model. The Historical Daily model was developed to be able to simulate large and small flow events that occur within a monthly time-step. Therefore, although daily baseflows are used, other terms required for daily analysis, such as diversion demands and reservoir targets, are developed using a simplified approach.

Daily baseflows are estimated using StateMod's Daily Pattern approach. StateMod calculates each day's baseflow by disaggregating monthly baseflows using the daily pattern of flow at selected historical gages. These "pattern gages" are representative of baseflows in subbasins throughout the San Juan and Dolores River basins. The selection and use of pattern gages is discussed in Section 8 Daily Baseline Results.

## Historical Daily Data Set Calibration Efforts

The Historical Daily data set uses existing input from the Historical Calibration data set, with pattern gages used in the Daily Baseline data set. No additional calibration efforts were considered necessary for the Historical Daily San Juan Model.

## Historical Daily Simulation Results

Simulation of the Historical Daily San Juan Model is considered good, with most streamflow gages deviating less than one percent from historical values on an average annual basis. The basinwide shortage in Colorado, determined to be simulated diversions divided by historical demand, is less than 3 percent per year, on average. Simulated reservoir contents are representative of historical values.

### Water Balance Results

Table E.1 summarizes the water balance for the Historical Daily San Juan Model, for the calibration period (1975-2003). Note that this is not an indication of use only in Colorado; New Mexico's use is also included. Following are observations based on the summary table:

- Surface water inflow to the basin averages 2.96 million acre-feet per year, and stream outflow averages 2.17 million acre-feet per year.

- Annual diversions amount to approximately 1.37 million acre-feet on average.

- Approximately 741,000 acre-feet per year is consumed in the Historical Daily simulation. Note that this value is representative of the basin-wide consumptive use and losses, and includes crop consumptive use, municipal and industrial consumptive use, reservoir evaporation, and 100 percent of exports from the basin.

- The column labeled "Inflow – Outflow" represents the net result of gain (inflow, return flows, and negative change in reservoir and soil moisture contents) less outflow terms (diversions, outflow, evaporation, and positive changes in storage). The small values are due to rounding on a daily basis, and indicate that the model correctly conserves mass.

**Table E.1**
**Average Annual Water Balance for Historical Daily Simulation 1975–2003 (af/yr)**

| Month | Stream Inflow | Return | From Soil Moisture | Total Inflow | Diversions | Resvr Evap | Stream Outflow | Resvr Change | To Soil Moisture | Soil Moisture Change | Total Outflow | Inflow - Outflow | CU |
|-------|---------|--------|-------|---------|-----------|--------|---------|---------|--------|---------|---------|--------|--------|
| OCT | 99,894 | 49,089 | 1,574 | 150,557 | 68,297 | 2,531 | 100,063 | -21,887 | 2,261 | -687 | 150,578 | -21 | 28,423 |
| NOV | 72,326 | 24,011 | 17 | 96,355 | 22,067 | 487 | 71,406 | 2,383 | 2,108 | -2,091 | 96,360 | -5 | 5,837 |
| DEC | 55,480 | 19,220 | 0 | 74,700 | 17,521 | -77 | 66,996 | -9,749 | 1,079 | -1,079 | 74,692 | 8 | 4,657 |
| JAN | 59,487 | 16,824 | 0 | 76,311 | 16,670 | 157 | 70,241 | -10,767 | 786 | -786 | 76,301 | 10 | 4,698 |
| FEB | 79,505 | 13,539 | 1 | 93,045 | 15,328 | 746 | 87,444 | -10,470 | 693 | -691 | 93,050 | -5 | 5,127 |
| MAR | 165,409 | 14,329 | 72 | 179,809 | 22,203 | 2,040 | 144,659 | 10,838 | 1,196 | -1,124 | 179,811 | -2 | 10,372 |
| APR | 423,710 | 23,900 | 2,939 | 450,549 | 70,440 | 4,516 | 319,082 | 53,580 | 4,320 | -1,381 | 450,557 | -8 | 44,947 |
| MAY | 734,308 | 74,879 | 6,275 | 815,461 | 226,753 | 7,268 | 488,082 | 87,088 | 7,445 | -1,171 | 815,466 | -4 | 135,080 |
| JUN | 688,658 | 106,672 | 5,626 | 800,955 | 300,323 | 10,033 | 454,679 | 30,298 | 3,649 | 1,976 | 800,959 | -4 | 183,292 |
| JUL | 286,095 | 107,131 | 3,492 | 396,718 | 259,154 | 9,038 | 175,996 | -50,958 | 2,766 | 726 | 396,722 | -4 | 148,454 |
| AUG | 160,466 | 99,952 | 1,310 | 261,728 | 210,085 | 4,943 | 99,341 | -53,937 | 5,426 | -4,116 | 261,742 | -14 | 101,684 |
| SEP | 135,447 | 79,062 | 1,888 | 216,398 | 145,950 | 4,829 | 93,680 | -29,938 | 2,975 | -1,087 | 216,409 | -11 | 68,744 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| AVG | 2,960,785 | 628,607 | 23,193 | 3,612,586 | 1,374,791 | 46,510 | 2,171,669 | -3,519 | 34,704 | -11,510 | 3,612,646 | -60 | 741,315 |

*Note:* Consumptive Use (CU) = Diversion (Divert) * Efficiency + Reservoir Evaporation (Evap)

## Streamflow Results

Table E.2 summarizes the average annual streamflow for water years 1975 through 2003, as estimated in the Historical Daily simulation. It also shows average annual values of actual gage records for comparison. Both numbers are based only on years for which gage data are complete. Calibration based on streamflow simulation is generally very good in terms of both annual volume and monthly pattern. In general, the daily simulation produces better streamflow calibration on the larger tributaries, and slightly poorer calibration on the smaller tributaries. The La Plata Compact requires more water to be delivered to New Mexico based on daily streamflows, resulting in greater than historic flows at the La Plata River at the Colorado-New Mexico State Line gage, and less return flows to Long Hollow.

Temporal variability of the Historical Daily simulated flows are illustrated in Figures E.1 through E.39 for three selected years for each of the daily pattern gages and for five additional downstream gages; San Juan River at Pagosa Springs, Piedra River near Arboles, Los Pinos River at La Boca, McElmo Creek near the Colorado-Utah Stateline, and Dolores River at Bedrock. The selected years represent wet (1995), average (1982), and dry (1977) years in the San Juan and Dolores basins. The historical gaged streamflow is shown on these graphs for comparison. As shown, daily simulated streamflow represents the daily large and small flow events that occur within a monthly time-step.

As with the Historical Monthly calibration, streamflow simulation on the Los Pinos River below Vallecito Reservoir accurately reflects annual volume, but the monthly patterns vary from gaged. Again, it appears that the rule curve provided by the USBR is used only as a guideline, and decisions based on other factors drive actual operations.

Simulated daily flows at the Dolores River at Bedrock for both the representative wet and dry years reflect variation in timing of flows compared to historical, although annual volume is similar. This may indicate that the model operating rules and criteria for Groundhog, McPhee, and Narraguinnep reservoirs represent "normal" operations for average year flows, and that historical operations vary, as necessary, to account for wet and dry periods.

**Table E.2**
**Historical and Simulated Average Annual Streamflow Volumes (1975-2003)**
**Historical Daily Simulation (acre-feet/year)**

| Gage ID | Historical | Simulated | Historical -Simulated | | Gage Name |
| | | | Volume | Percent | |
|---|---|---|---|---|---|
| 09339900 | 64,983 | 64,983 | 0 | 0% | East Fork San Juan River above Sand Creek |
| 09341500 | 171,819 | 171,770 | 49 | 0% | West Fork San Juan River nr Pagosa Springs |
| 09342000 | *No gage during calibration period* | | | | Turkey Creek near Pagosa Springs |
| 09342500 | 283,880 | 283,624 | 256 | 0% | San Juan River at Pagosa Springs |
| 09343300 | 34,450 | 36,383 | -1,933 | -6% | Rio Blanco bl Blanco Div Dam nr Pagosa Sprgs |
| 09344000 | 83,902 | 83,910 | -8 | 0% | Navajo River at Banded Peak Ranch nr Chromo |
| 09344400 | 48,284 | 50,416 | -2,132 | -4% | Navajo River bl Oso Diversion Dam nr Chromo |
| 09345200 | 6,390 | 6,708 | -318 | -5% | Little Navajo River bl Oso Div Dam nr Chromo |
| 09346000 | 67,275 | 69,469 | -2,194 | -3% | Navajo River at Edith |
| 09346400 | 449,666 | 452,559 | -2,893 | -1% | San Juan River near Carracas |
| 09347500 | *No gage during calibration period* | | | | Piedra River at Bridge Ranger Sta. nr Pagosa Sprgs |
| 09349500 | *No gage during calibration period* | | | | Piedra River near Piedra |
| 09349800 | 305,465 | 304,830 | 635 | 0% | Piedra River near Arboles |
| 09352900 | 106,037 | 106,037 | 0 | 0% | Vallecito Creek near Bayfield |
| 09353500 | 299,267 | 295,969 | 3,298 | 1% | Los Pinos River near Bayfield |
| 09354000 | *No gage during calibration period* | | | | Los Pinos River at Bayfield |
| 09354500 | 188,403 | 186,261 | 2,142 | 1% | Los Pinos River at La Boca |
| 09355000 | 24,124 | 23,922 | 202 | 1% | Spring Creek at La Boca |
| 09355500 | 875,505 | 877,477 | -1,972 | 0% | San Juan River near Archuleta |
| 09357500 | 77,578 | 77,579 | -1 | 0% | Animas River at Howardsville |
| 09359000 | *No gage during calibration period* | | | | Mineral Creek near Silverton |
| 09359500 | *No gage during calibration period* | | | | Animas River above Tacoma |
| 09361000 | 96,957 | 96,957 | 0 | 0% | Hermosa Creek near Hermosa |
| 09361500 | 583,380 | 583,191 | 189 | 0% | Animas River at Durango |
| 09362999 | 73,870 | 73,870 | 0 | 0% | Florida River ab Lemon Reservoir (USBR data) |
| 09363200 | 58,564 | 58,568 | -4 | 0% | Florida River at Bondad |
| 09363500 | 707,576 | 707,029 | 547 | 0% | Animas River near Cedar Hill, NM |
| 09364500 | 644,023 | 645,185 | -1,162 | 0% | Animas River at Farmington, NM |
| 09365000 | 1,489,692 | 1,488,534 | 1,158 | 0% | San Juan River at Farmington, NM |
| LONREDCO | 5,471 | 4,771 | 700 | 13% | Long Hollow at the Mouth near Red Mesa |
| 9365500 | 30,970 | 31,120 | -150 | 0% | La Plata at Hesperus |
| 09366500 | 27,452 | 28,536 | -1,084 | -4% | La Plata River at CO-NM State Line |
| 09367500 | 23,548 | 28,547 | -4,999 | -21% | La Plata River near Farmington, NM |
| 09368000 | 1,510,482 | 1,518,683 | -8,201 | -1% | San Juan at Shiprock |
| 09369500 | *No gage during calibration period* | | | | Middle Mancos River near Mancos |
| 09369000 | *No gage during calibration period* | | | | East Mancos River near Mancos |
| 09368499 | 10,687 | 10,186 | 501 | 5% | Above Jackson Gulch Reservoir (USBR data) |
| 09368500 | *No gage during calibration period* | | | | West Mancos River near Mancos |
| 09371000 | 39,123 | 39,628 | -505 | -1% | Mancos River near Towaoc |
| 09371010 | 1,600,019 | 1,599,827 | 192 | 0% | San Juan River at Four Corners |
| 09371400 | 10,063 | 10,441 | -378 | -4% | Hartman Draw at Cortez |
| 09371420 | 19,270 | 21,015 | -1,745 | -9% | McElmo Creek above Alkali Canyon nr Cortez |
| 09371500 | 42,789 | 42,822 | -33 | 0% | McElmo Creek near Cortez |

| Gage ID | Historical | Simulated | Historical -Simulated | | Gage Name |
| | | | Volume | Percent | |
|---|---|---|---|---|---|
| 09372000 | 39,385 | 38,523 | 862 | 2% | McElmo Creek near CO-UT State Line |
| 09379500 | 1,563,647 | 1,560,901 | 2,746 | 0% | San Juan River near Bluff |
| 09165000 | 97,155 | 97,160 | -5 | 0% | Dolores River below Rico |
| 09166500 | 317,356 | 317,745 | -389 | 0% | Dolores River at Dolores |
| 09166950 | 15,240 | 12,115 | 3,125 | 21% | Lost Canyon Creek near Dolores |
| 09168100 | 20,926 | 20,944 | -18 | 0% | Disappointment Creek near Dove Creek |
| 09169500 | 270,404 | 266,056 | 4,348 | 2% | Dolores River at Bedrock |
| 09171100 | 279,550 | 274,892 | 4,658 | 2% | Dolores River near Bedrock |
| 09171200 | *No gage during calibration period* | | | | San Miguel River near Telluride |
| 09172000 | *No gage during calibration period* | | | | Fall Creek near Fall Creek |
| 09172100 | *No gage during calibration period* | | | | Leopard Creek at Noel |
| 09172500 | 181,283 | 181,797 | -514 | 0% | San Miguel River near Placerville |
| 09173000 | 7,212 | 8,175 | -963 | -13% | Beaver Creek near Norwood |
| 09175500 | 199,166 | 200,752 | -1,586 | -1% | San Miguel River at Naturita |
| 09177000 | 273,243 | 271,835 | 1,408 | 1% | San Miguel River at Uravan |
| 09179500 | *No gage during calibration period* | | | | Dolores River at Gateway |

## Diversion Results

Table E.3 summarizes the average annual simulated diversions, by tributary or sub-basin in Colorado, compared to historical diversions for water years 1975 through 2003. On a basin-wide basis, average annual diversions differ from historical diversions by about 3 percent in the daily calibration run. The tributaries showing the greatest simulated variance from historical diversions are also the problematic tributaries in the monthly Historical simulation. Basin-wide diversions are shorted by about 2 percent more when simulated using a daily time-step.

**Table E.3**
**Historical and Simulated Average Annual Diversions by Sub-basin (1975-2003)**
**Historical Daily Simulation (acre-feet/year)**

| Tributary or Sub-basin | Historical | Simulated | Historical minus Simulated | |
| --- | --- | --- | --- | --- |
| | | | Volume | Percent |
| Navajo-Blanco Rivers | 109,866 | 105,101 | 4,765 | 4% |
| San Juan | 44,906 | 43,176 | 1,730 | 4% |
| Piedra River | 29,636 | 29,068 | 569 | 2% |
| Los Pinos River | 201,279 | 200,181 | 1,098 | 1% |
| Animas and Florida Rivers | 178,259 | 174,494 | 3,764 | 2% |
| La Plata River | 32,185 | 28,703 | 3,482 | 11% |
| Mancos River (includes MVIC/Dolores Project and Summit Irrigation Use) | 35,449 | 32,580 | 2,869 | 8% |
| McElmo Creek | 204,795 | 197,083 | 7,711 | 4% |
| San Miguel River | 119,088 | 116,941 | 2,147 | 2% |
| Dolores River | 51,624 | 47,526 | 4,098 | 8% |
| **Basin Total** | **1,007,087** | **974,853** | **32,234** | **3%** |

## Reservoir Results

Figures E.40 through E.44 (located at the end of this chapter) present reservoir EOM contents estimated by the Historical Daily model simulation compared to historical observations at selected reservoirs. Simulated reservoir end-of-month contents using a daily time-step are very close to simulations using a monthly time-step. The issues identified in Section 7.4.4 are valid on a daily time-step.

## Consumptive Use Results

Crop consumptive use is estimated by StateMod and reported in the consumptive use summary file (*.xcu) for each diversion structure in the scenario. This file also includes consumptive use for municipal and industrial diversions. The crop consumptive use estimated by StateCU is reported in the water supply-limited summary file (*.wsl) for each agricultural diversion structure in the basin. Therefore, to provide a one-to-one comparison, only structures in the StateCU analysis are included.

Table E.4 shows the comparison of StateCU estimated crop consumptive use compared to StateMod estimate of crop consumptive use for explicit structures, aggregate structures, and basin total. As shown, both explicit and aggregate structure consumptive use match StateCU results very well. Historical diversions are used by StateCU to estimate supply-limited (actual)

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consumptive use. The 3 percent difference is close to the overall basin diversion shortages simulated by the model.

**Table E.4**
**Average Annual Crop Consumptive Use Comparison (1975-2003)**

| Comparison | StateCU Results (af/yr) | Daily Run Results (af/yr) | % Difference |
|---|---|---|---|
| Explicit Structures | 297,025 | 284,241 | 3% |
| Aggregate Structures | 53,855 | 51,431 | 3% |
| Basin Total | 350,880 | 335,672 | 3% |

**USGS Gage 09344000 - Navajo River at Banded Peak Ranch near Chromo**
**Gaged and Simulated Daily Flows - Wet Year 1995**
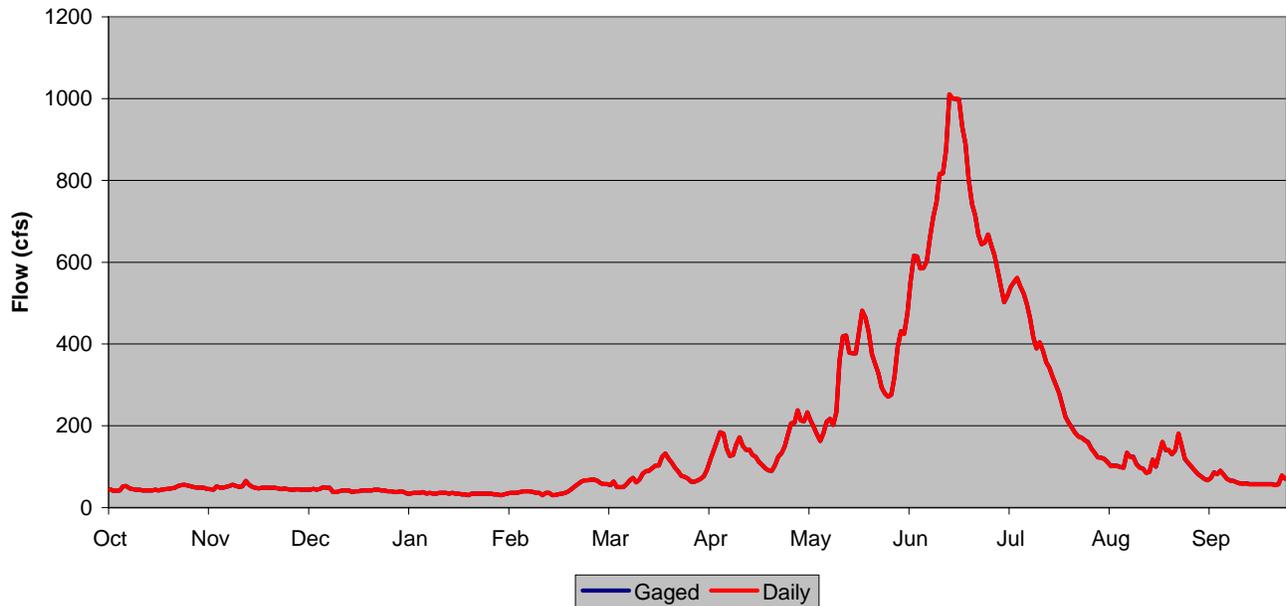


**Figure E.1 Historical Daily Comparison, Wet Year – Navajo River at Banded Peak Ranch**
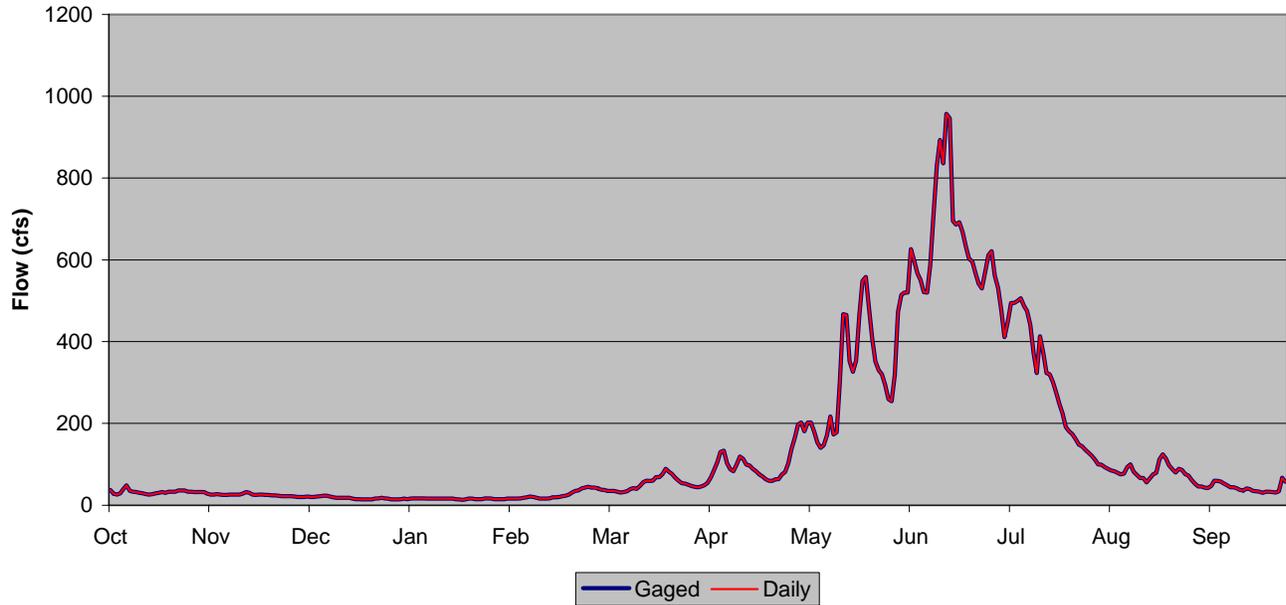
**Figure E.2 Historical Daily Comparison, Wet Year – East Fork San Juan above Sand Creek**
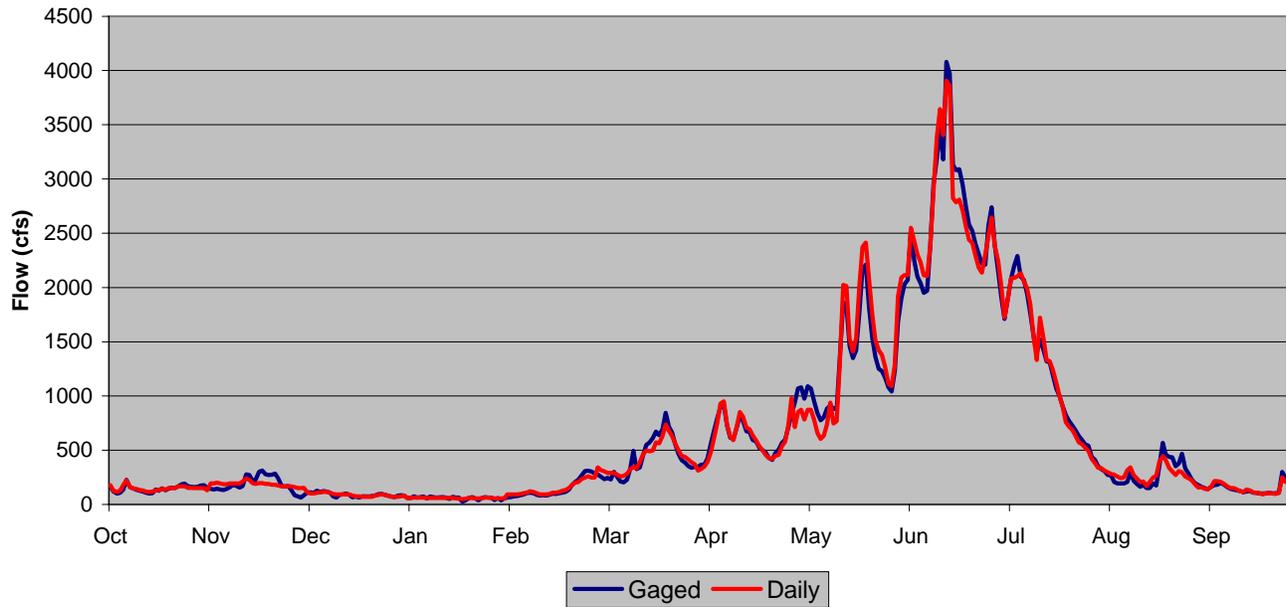


**Figure E.3 Historical Daily Comparison, Wet Year – San Juan River at Pagosa Springs**

**USGS Gage 09349800 - Piedra River near Arboles**
**Gaged and Simulated Daily Flows - Wet Year 1995**
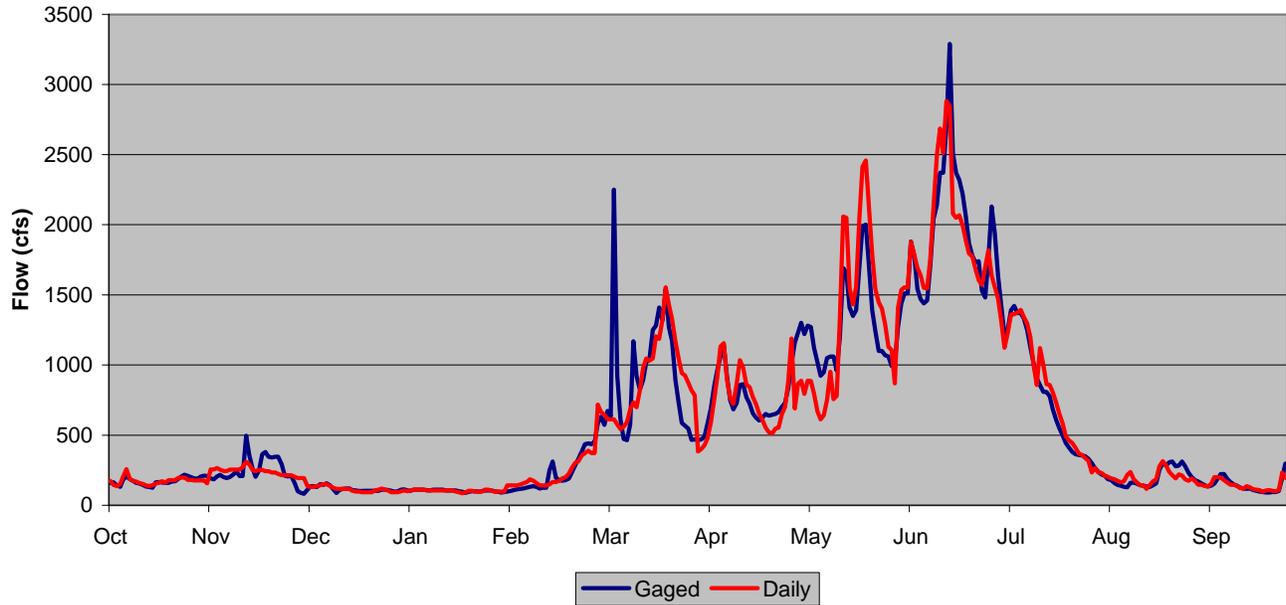


**Figure E.4 Historical Daily Comparison, Wet Year – Piedra River near Arboles**

**USGS Gage 09354500 - Los Pinos River at La Boca**
**Gaged and Simulated Daily Flows - Wet Year 1995**
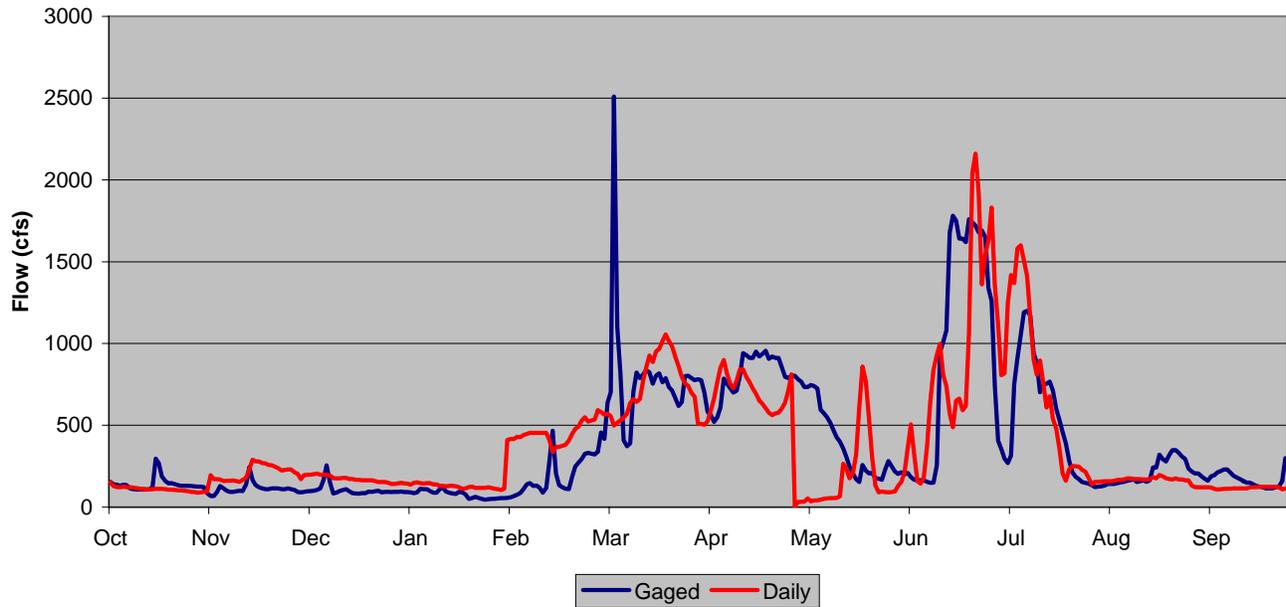


**Figure E.5 Historical Daily Comparison, Wet Year – Los Pinos River at La Boca**

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**USGS Gage 09352900 - Vallecito Creek near Bayfield**
**Gaged and Simulated Daily Flows - Wet Year 1995**
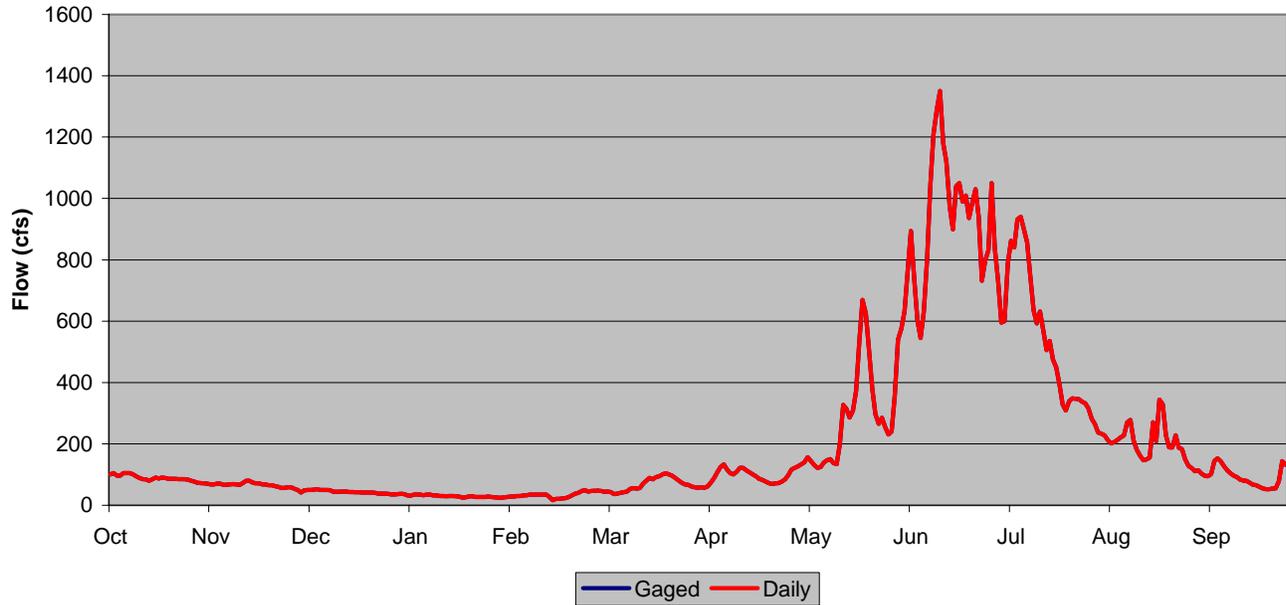
**Figure E.6 Historical Daily Comparison, Wet Year – Vallecito Creek near Bayfield**



**USGS Gage 09357500 - Animas River near Howardsville**
**Gaged and Simulated Daily Flows - Wet Year 1995**
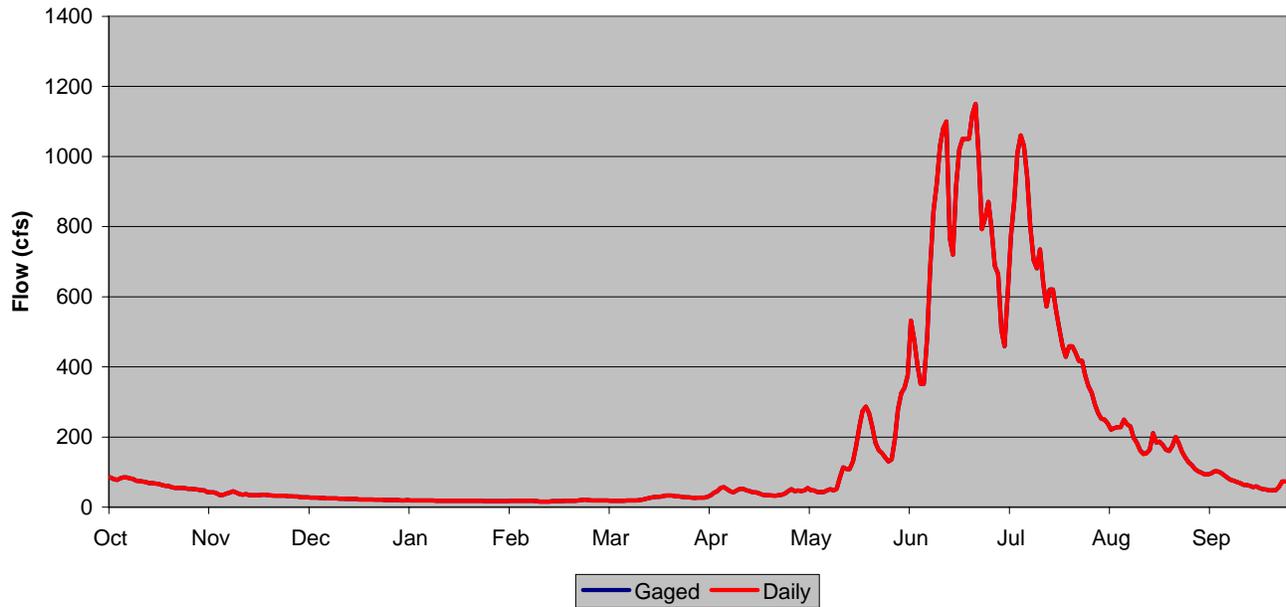
**Figure E.7 Historical Daily Comparison, Wet Year – Animas River near Howardsville**

**USGS Gage 09365500 - La Plata River at Hesperus**
**Gaged and Simulated Daily Flows - Wet Year 1995**
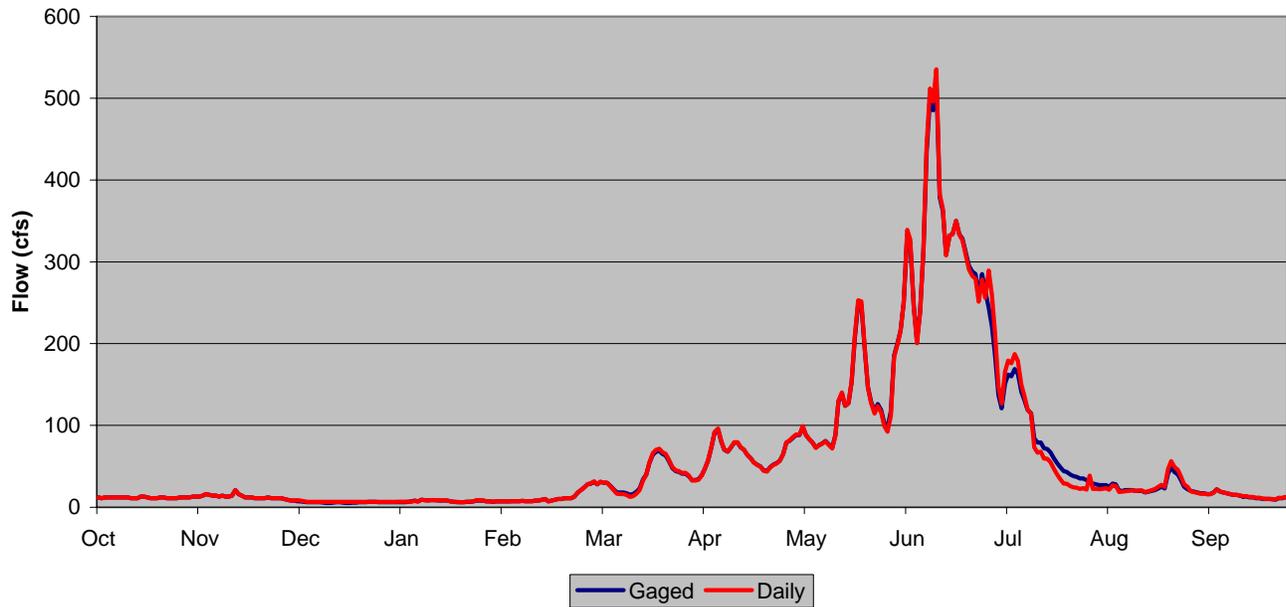


**Figure E.8 Historical Daily Comparison, Wet Year – La Plata River at Hesperus**

**USGS Gage 09371000 - Mancos River near Towaoc**
**Gaged and Simulated Daily Flows - Wet Year 1995**
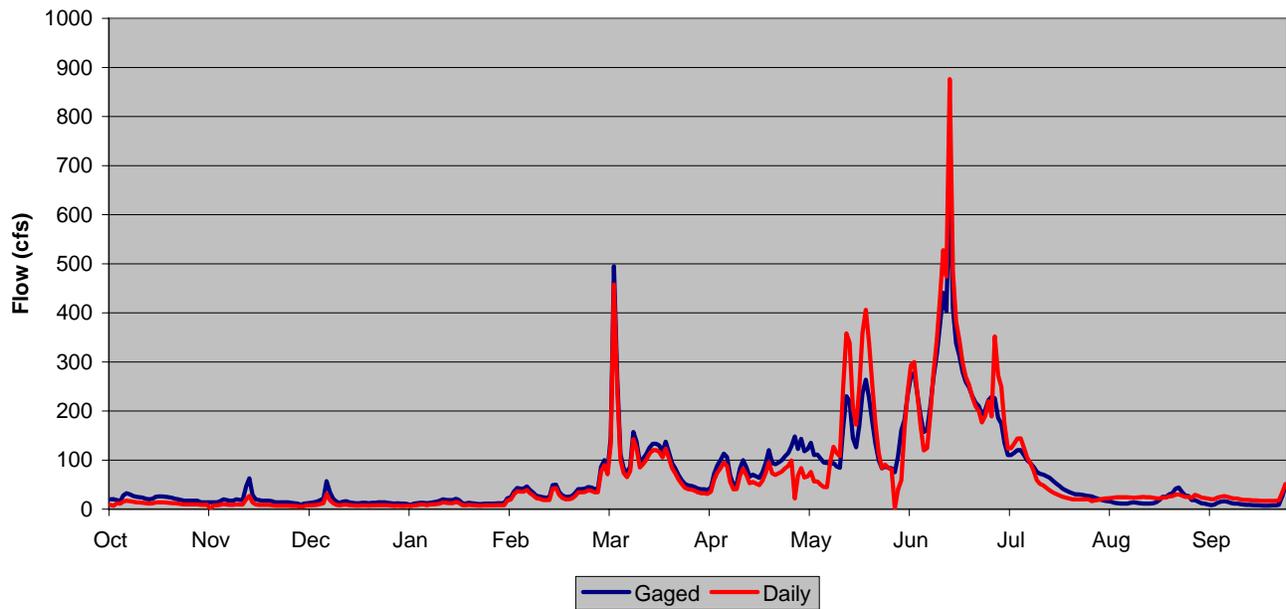


**Figure E.9 Historical Daily Comparison, Wet Year – Mancos River near Towaoc**

**USGS Gage 09372000 - McElmo Creek at the Colorado-Utah State Line**
**Gaged and Simulated Daily Flows - Wet Year 1995**
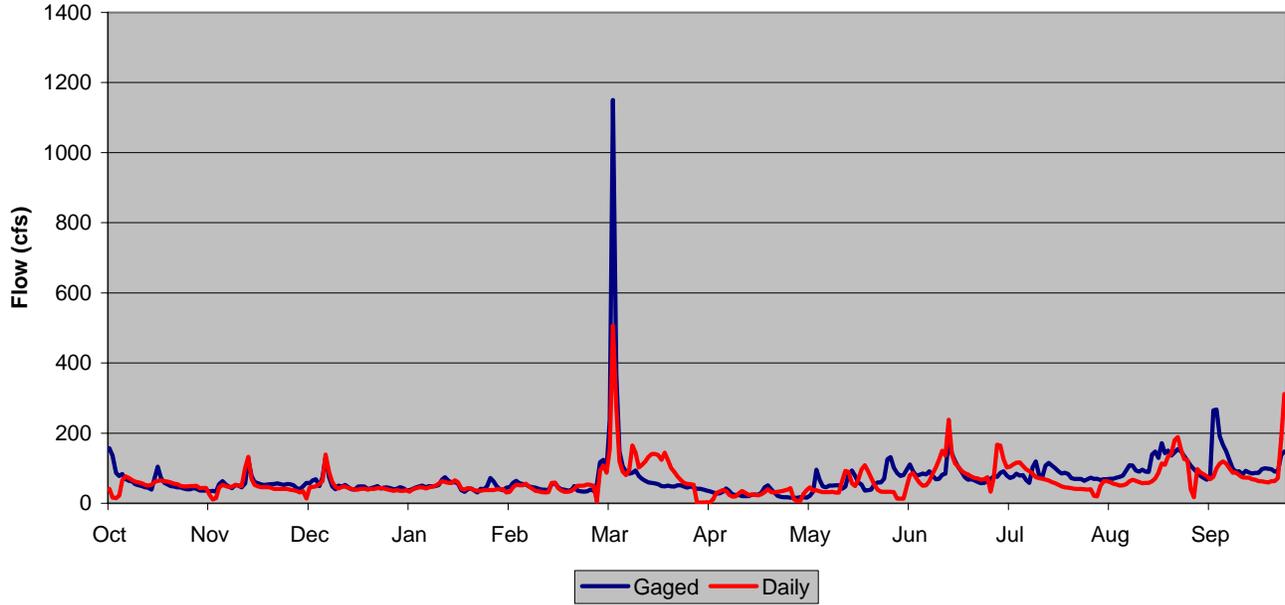


**Figure E.10 Historical Daily Comparison, Wet Year – McElmo Creek at CO-UT State Line**

**USGS Gage 09166500 - Dolores River at Dolores**
**Gaged and Simulated Daily Flows - Wet Year 1995**
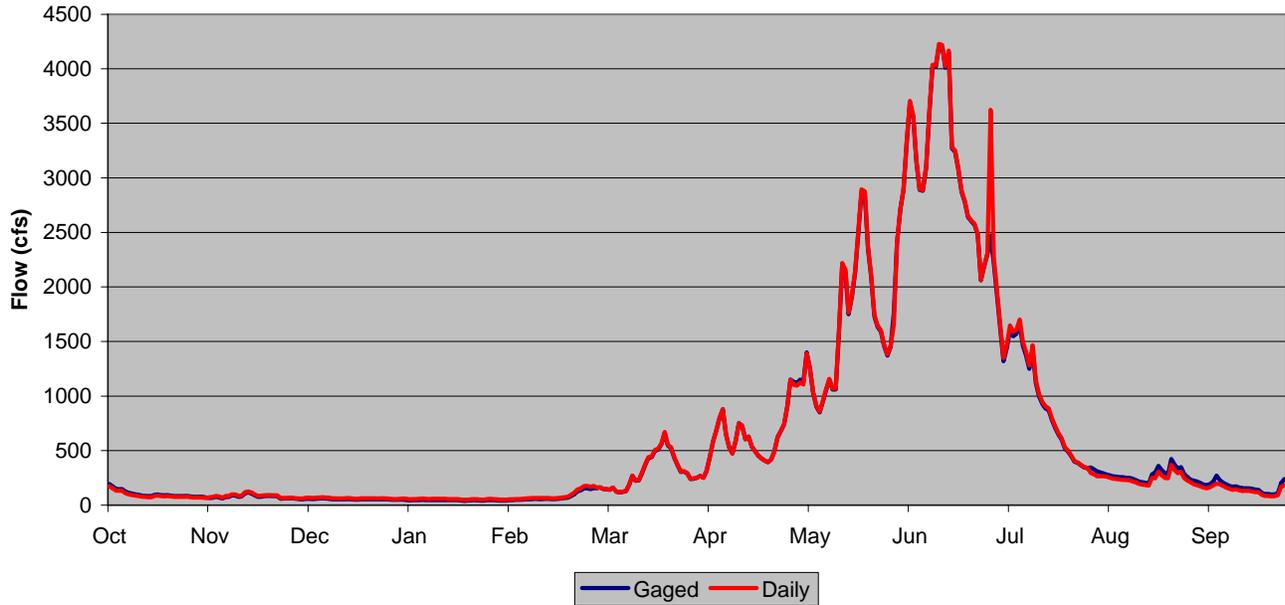


**Figure E.11 Historical Daily Comparison, Wet Year – Dolores River at Dolores**

**USGS Gage 09171100 - Dolores River at Bedrock**
**Gaged and Simulated Daily Flows - Wet Year 1995**
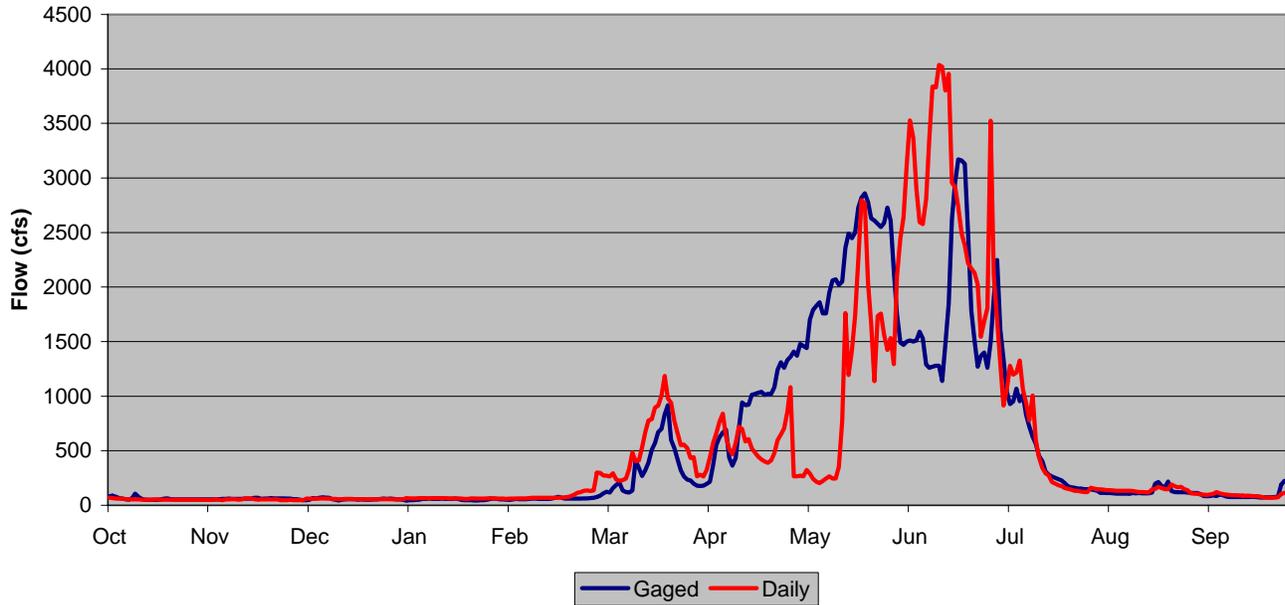


**Figure E.12 Historical Daily Comparison, Wet Year – Dolores River at Bedrock**

**USGS Gage 09172500 - San Miguel River near Placerville**
**Gaged and Simulated Daily Flows - Wet Year 1995**



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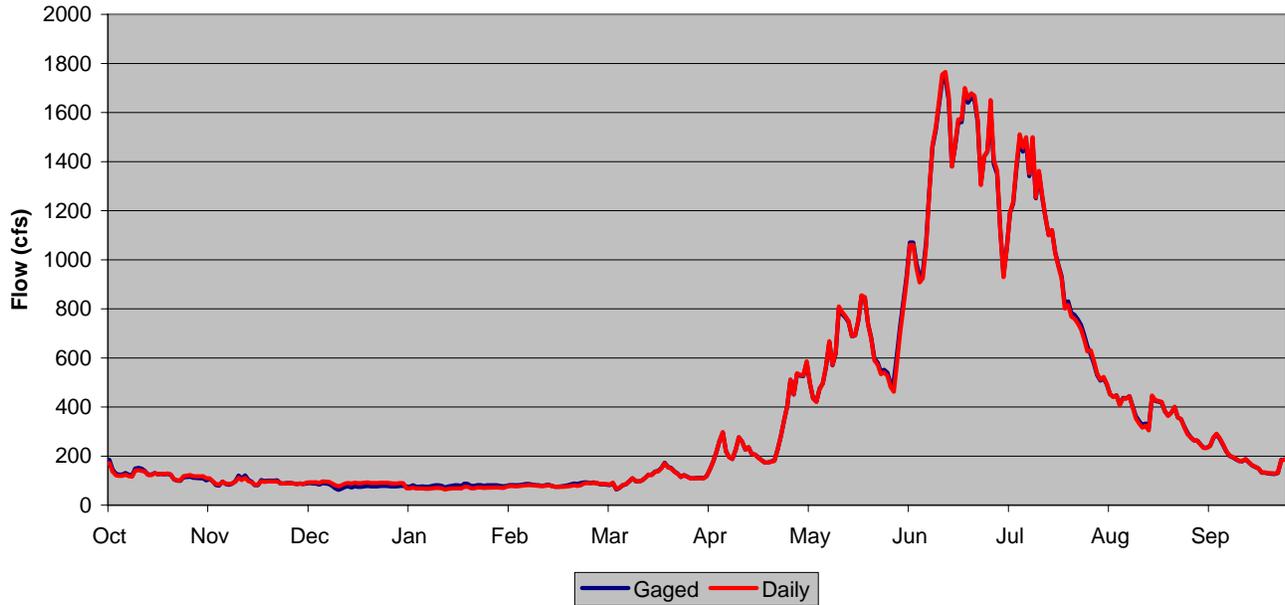
**Figure E.13 Historical Daily Comparison, Wet Year – San Miguel River near Placerville**

**USGS Gage 09344000 - Navajo River at Banded Peak Ranch near Chromo**
**Gaged and Simulated Daily Flows - Average Year 1982**
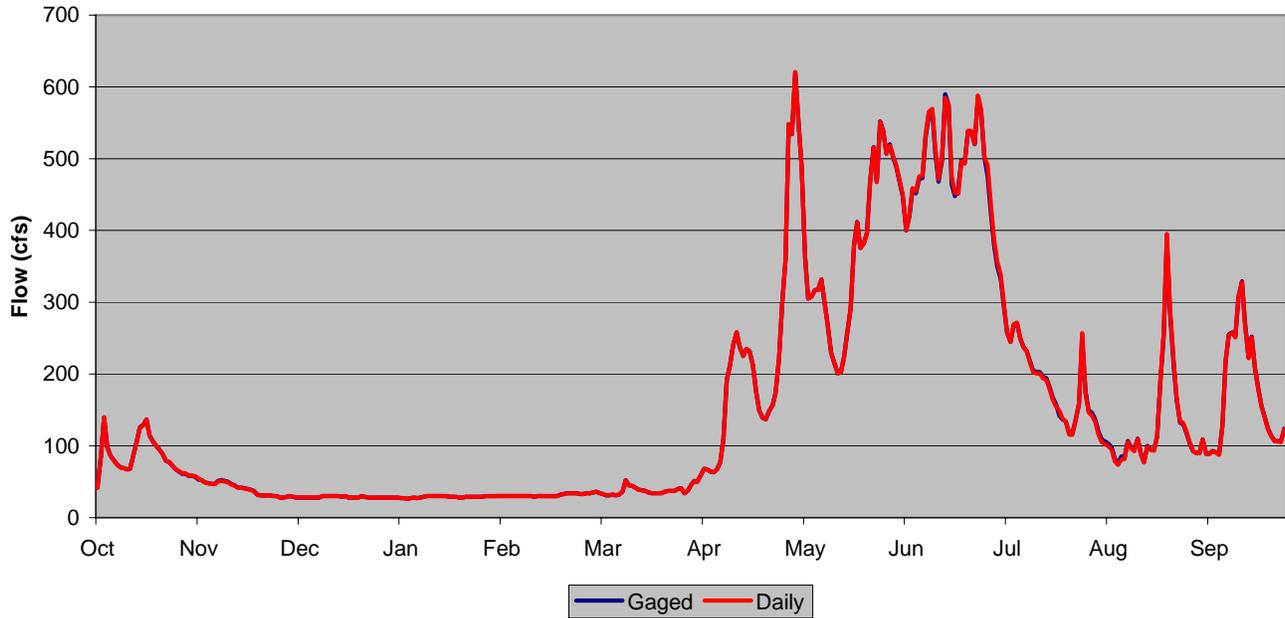


**Figure E.14 Historical Daily Comparison, Average Year – Navajo River at Banded Peak Ranch**

**USGS Gage 09339900 - East Fork San Juan River above Sand Creek**
**Gaged and Simulated Daily Flows - Average Year 1982**
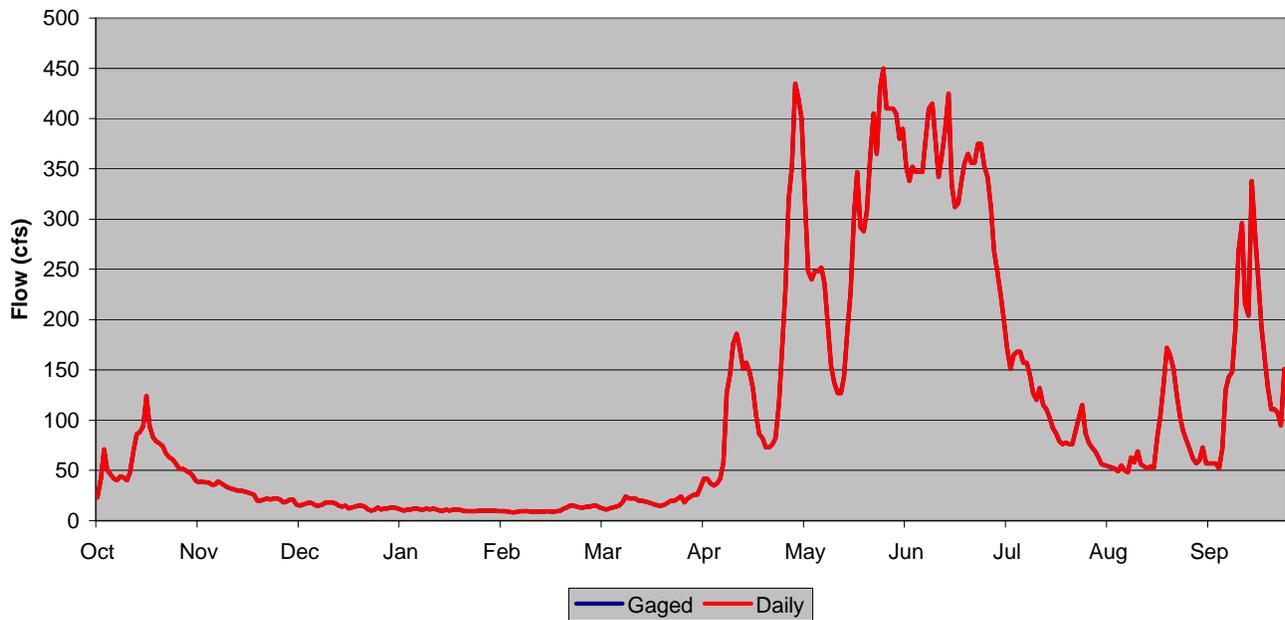


**Figure E.15 Historical Daily Comparison, Average Year – East Fork San Juan River ab Sand Creek**

**USGS Gage 09342500 - San Juan River at Pagosa Springs**
**Gaged and Simulated Daily Flows - Average Year 1982**
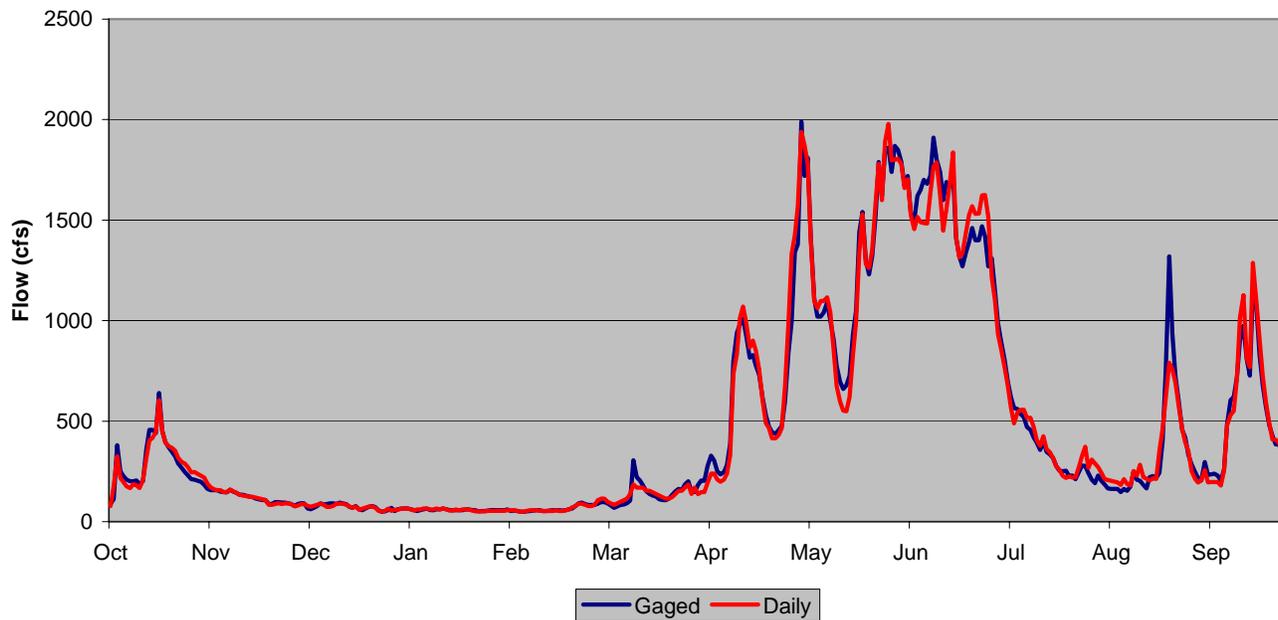


**Figure E.16 Historical Daily Comparison, Average Year – San Juan River at Pagosa Springs**

**USGS Gage 09349800 - Piedra River near Arboles**
**Gaged and Simulated Daily Flows - Average Year 1982**
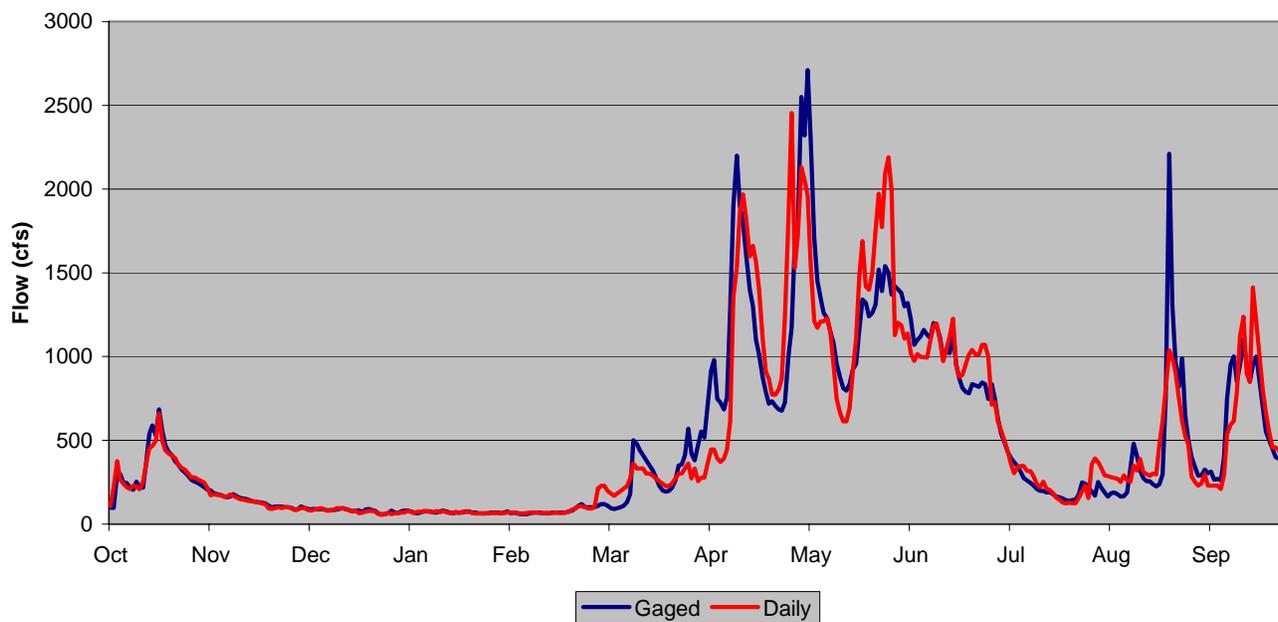


**Figure E.17 Historical Daily Comparison, Average Year – Piedra River near Arboles**
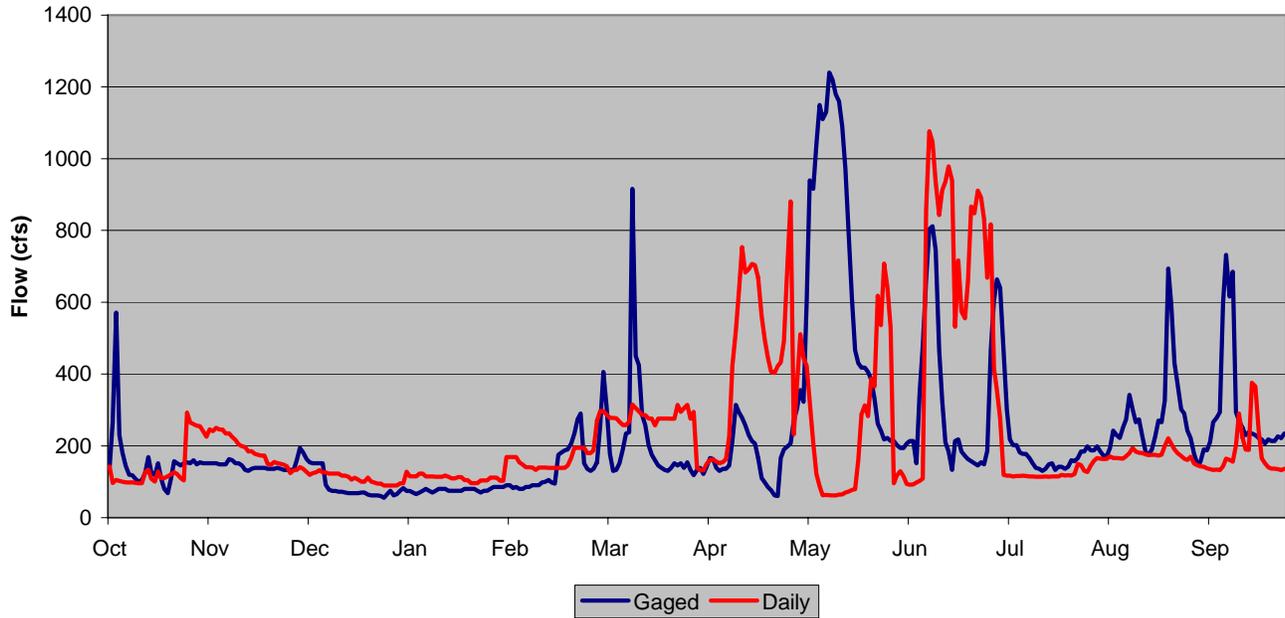
**Figure E.18 Historical Daily Comparison, Average Year – Los Pinos River at La Boca**
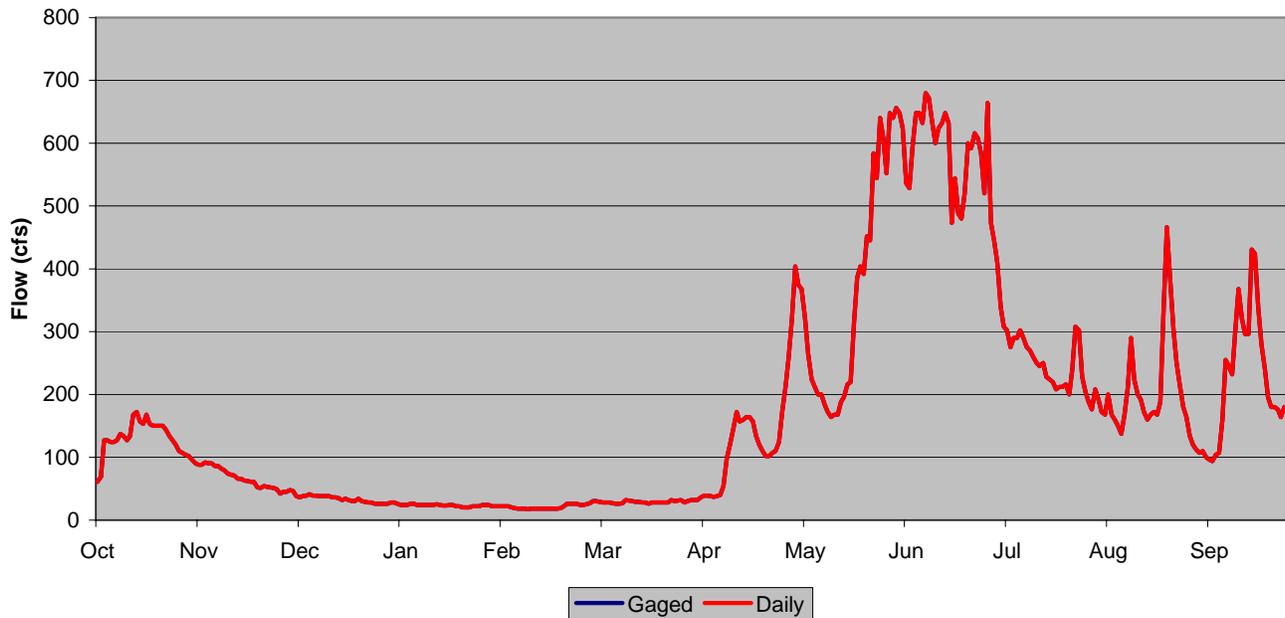


**Figure E.19 Historical Daily Comparison, Average Year – Vallecito Creek near Bayfield**

**USGS Gage 09357500 - Animas River near Howardsville**
**Gaged and Simulated Daily Flows - Average Year 1982**
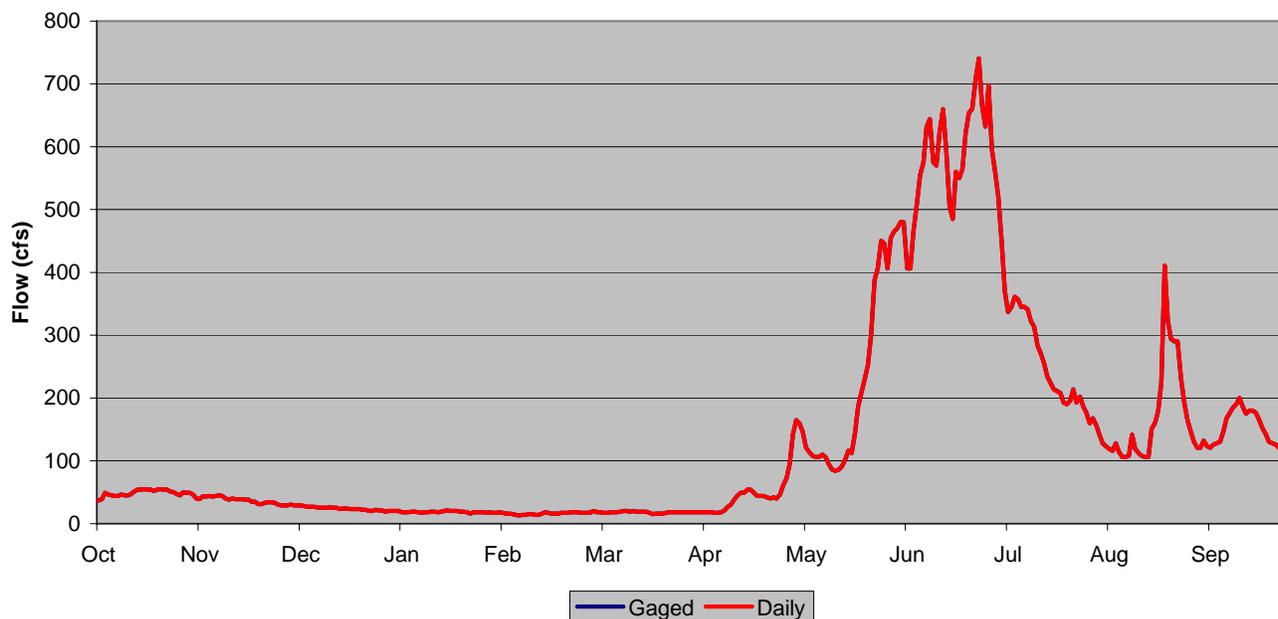


**Figure E.20 Historical Daily Comparison, Average Year – Animas River near Howardsville**

**USGS Gage 09365500 - La Plata River at Hesperus**
**Gaged and Simulated Daily Flows - Average Year 1982**
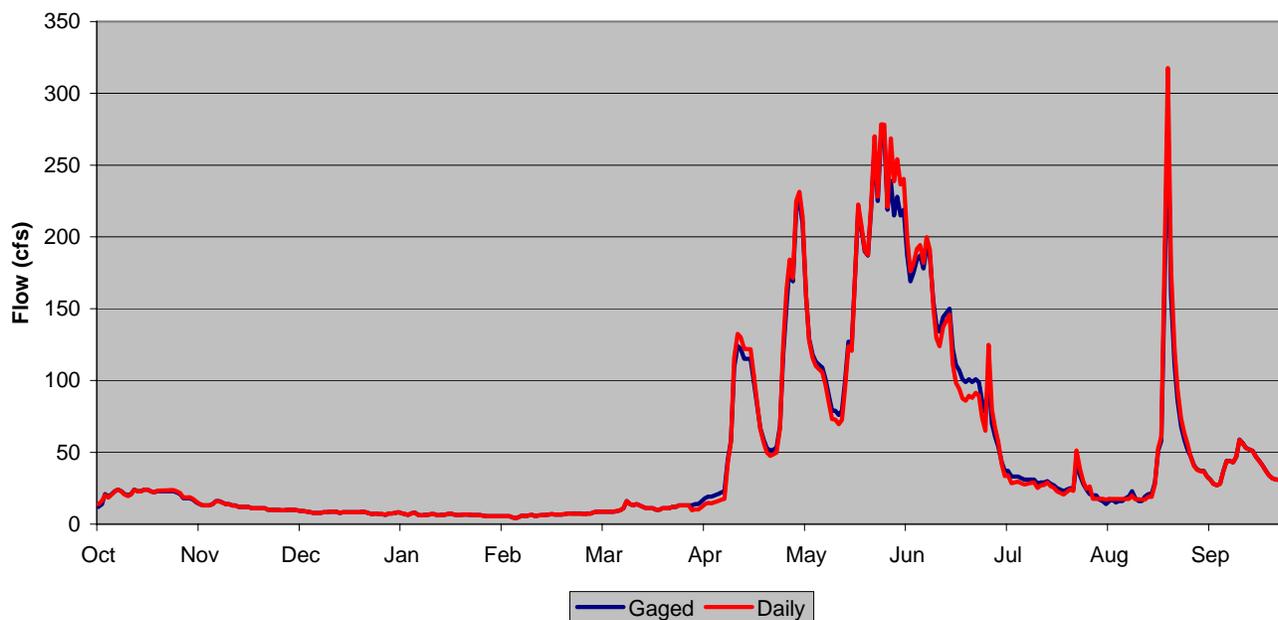


**Figure E.21 Historical Daily Comparison, Average Year – La Plata River at Hesperus**

**USGS Gage 09371000 - Mancos River near Towaoc**
**Gaged and Simulated Daily Flows - Average Year 1982**
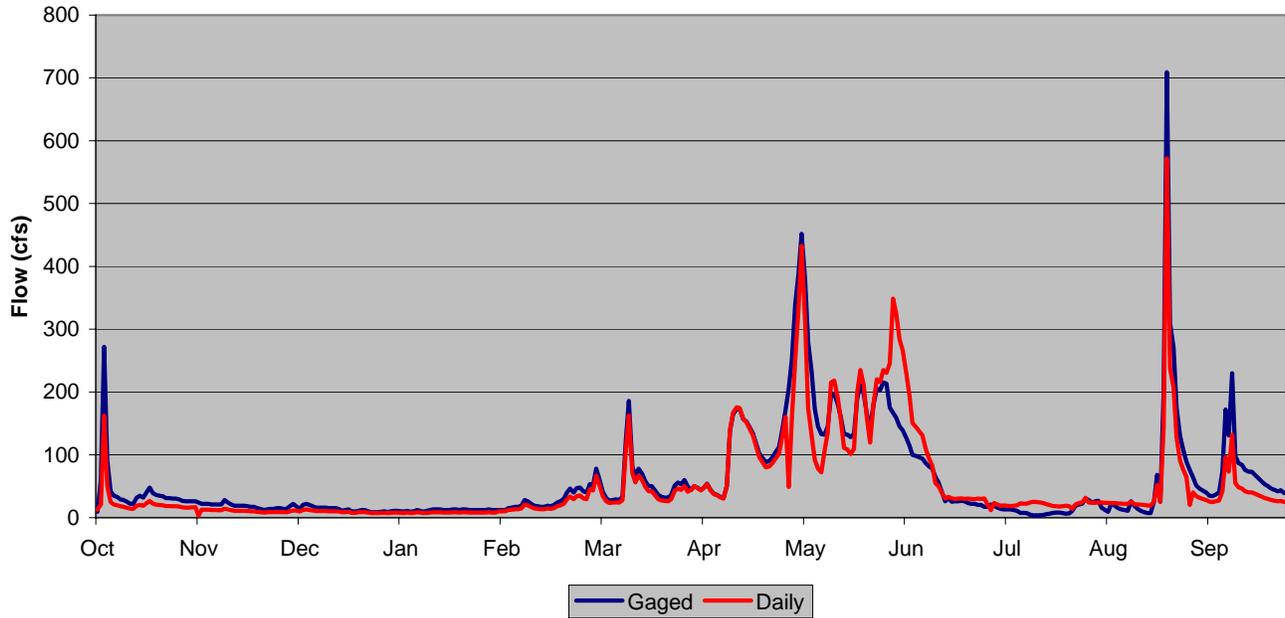
**Figure E.22 Historical Daily Comparison, Average Year – Mancos River near Towaoc**



**USGS Gage 09372000 - McElmo Creek at the Colorado-Utah State Line**
**Gaged and Simulated Daily Flows - Average Year 1982**
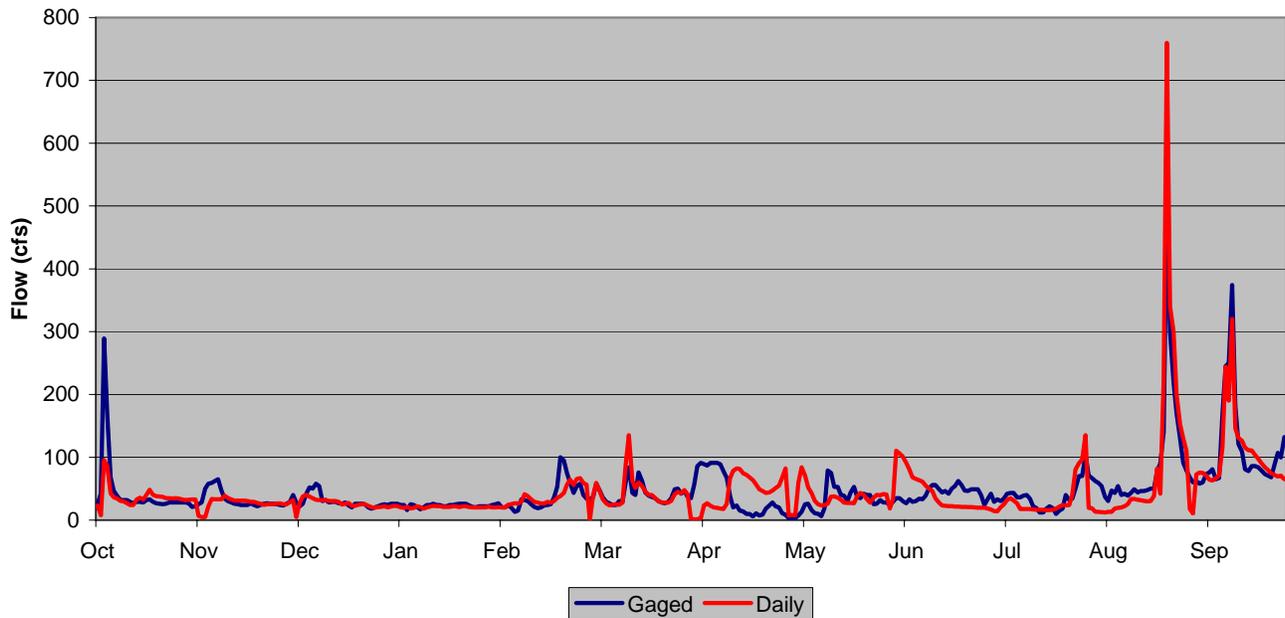
**Figure E.23 Historical Daily Comparison, Average Year – McElmo Creek at CO-UT State Line**

**USGS Gage 09166500 - Dolores River at Dolores**
**Gaged and Simulated Daily Flows - Average Year 1982**
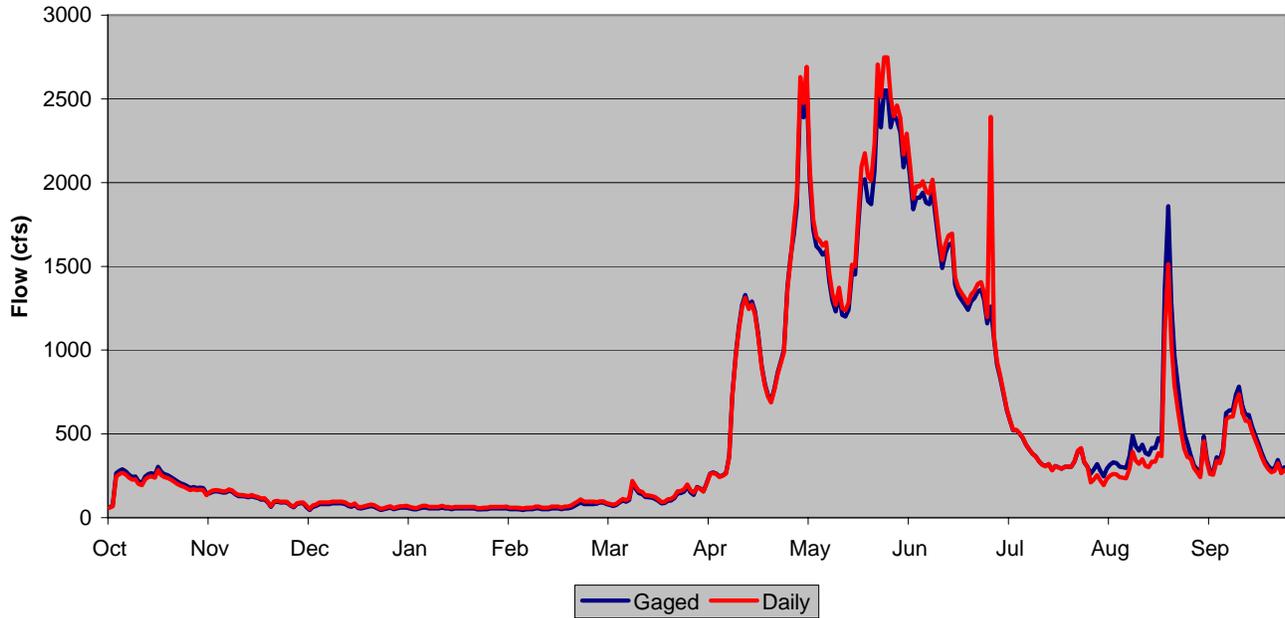
**Figure E.24 Historical Daily Comparison, Average Year – Dolores River at Dolores**



**USGS Gage 09171100 - Dolores River at Bedrock**
**Gaged and Simulated Daily Flows - Average Year 1982**
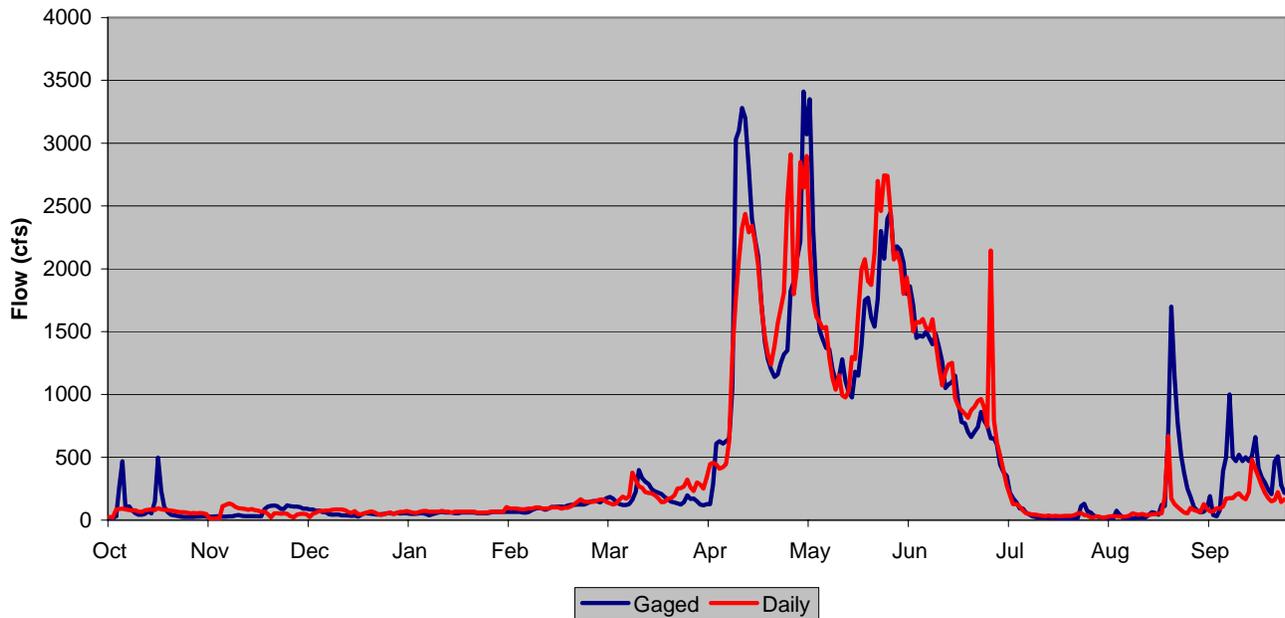
**Figure E.25 Historical Daily Comparison, Average Year – Dolores River at Bedrock**

**USGS Gage 09172500 - San Miguel River near Placerville**
**Gaged and Simulated Daily Flows - Average Year 1982**
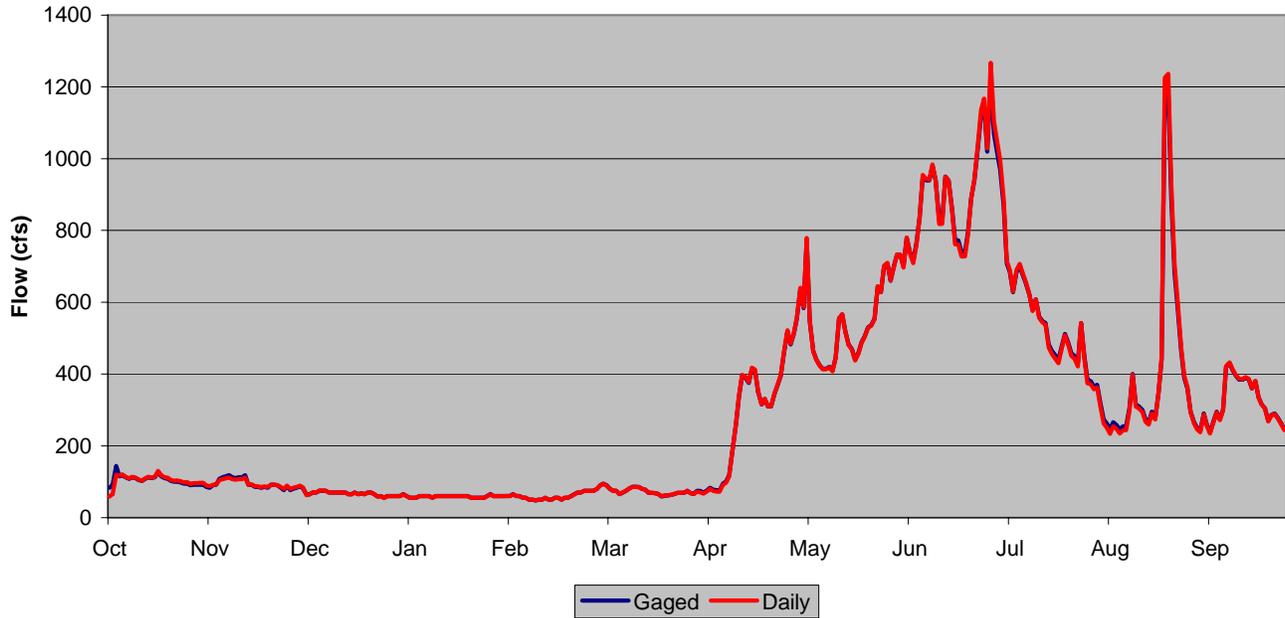


**Figure E.26 Historical Daily Comparison, Average Year – San Miguel River near Placerville**

**USGS Gage 09344000 - Navajo River at Banded Peak Ranch near Chromo**
**Gaged and Simulated Daily Flows - Dry Year 1977**
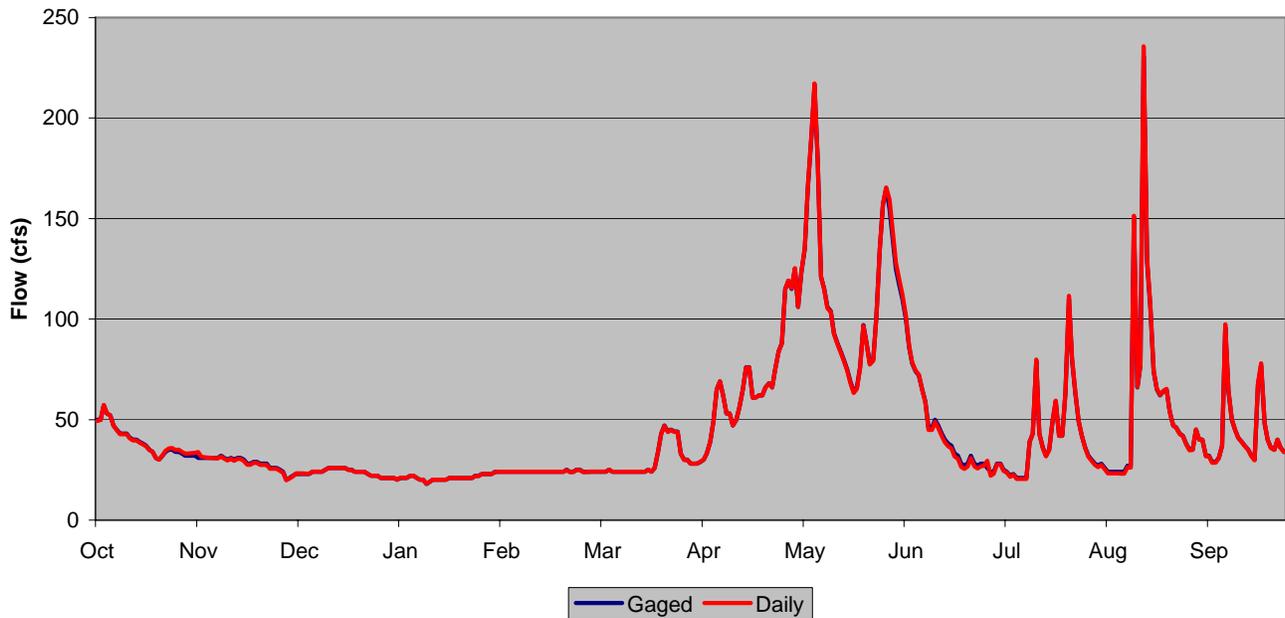


**Figure E.27 Historical Daily Comparison, Dry Year – Navajo River at Banded Peak Ranch**

**USGS Gage 09339900 - East Fork San Juan River above Sand Creek**
**Gaged and Simulated Daily Flows - Dry Year 1977**
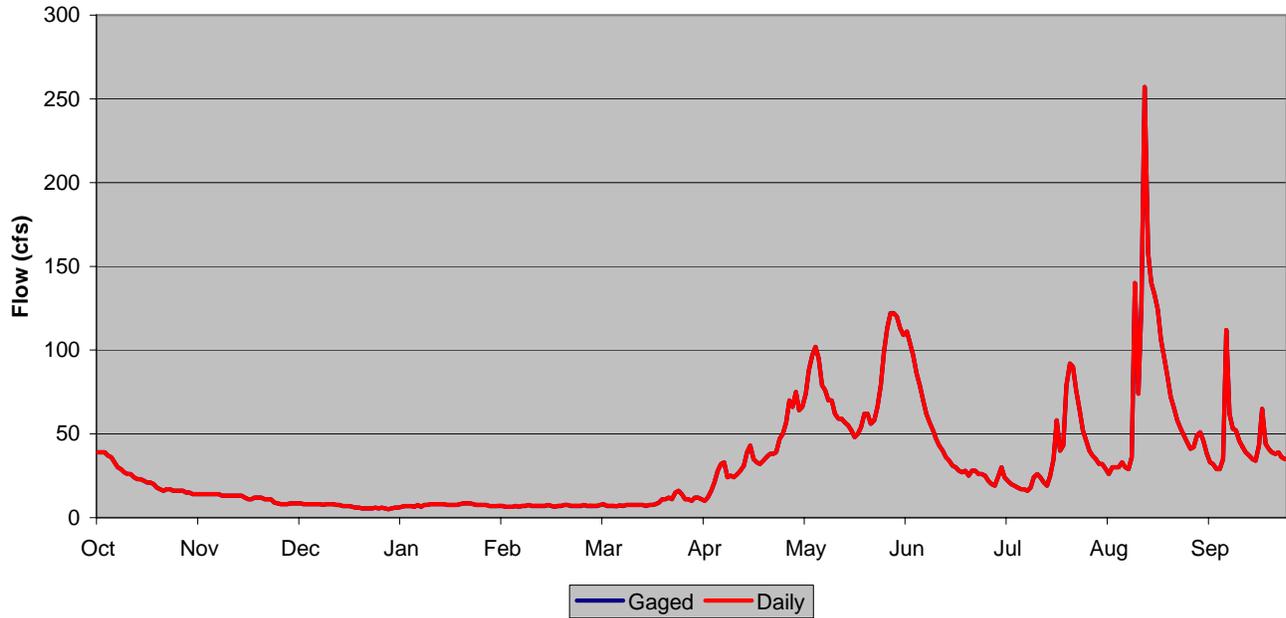


**Figure E.28 Historical Daily Comparison, Dry Year – East Fork San Juan River above Sand Creek**

**USGS Gage 09342500 - San Juan River at Pagosa Springs**
**Gaged and Simulated Daily Flows - Dry Year 1977**
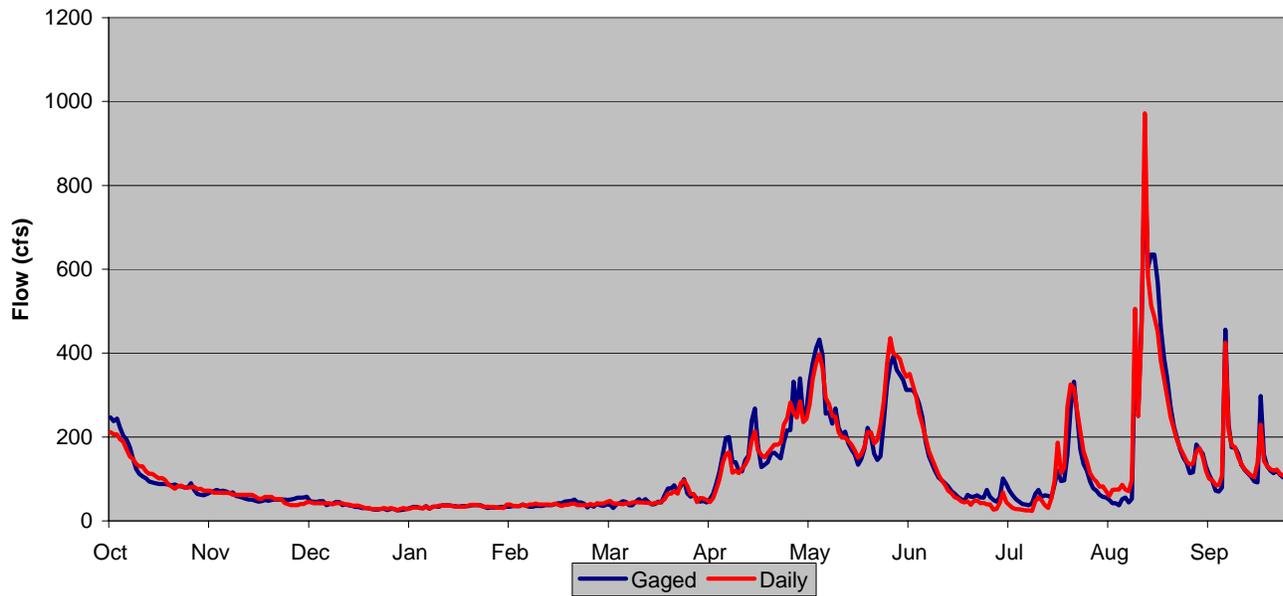


**Figure E.29 Historical Daily Comparison, Dry Year – San Juan River at Pagosa Springs**

**USGS Gage 09349800 - Piedra River near Arboles**
**Gaged and Simulated Daily Flows - Dry Year 1977**
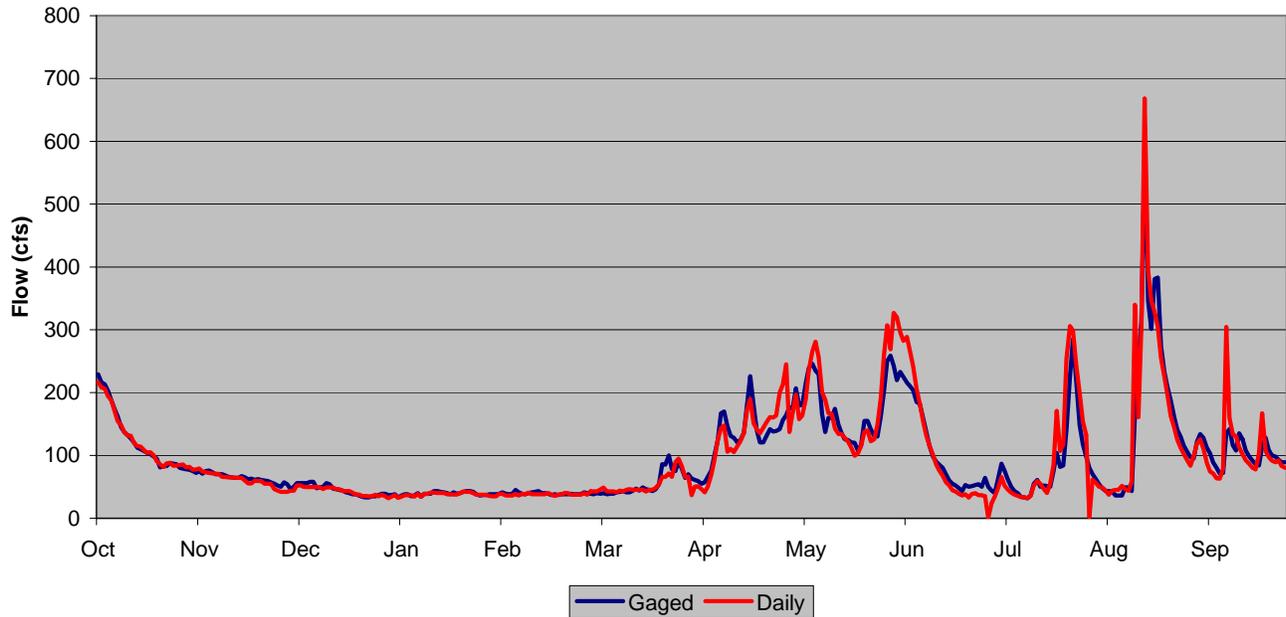


**Figure E.30 Historical Daily Comparison, Dry Year – Piedra River near Arboles**

**USGS Gage 09354500 - Los Pinos River at La Boca**
**Gaged and Simulated Daily Flows - Dry Year 1977**
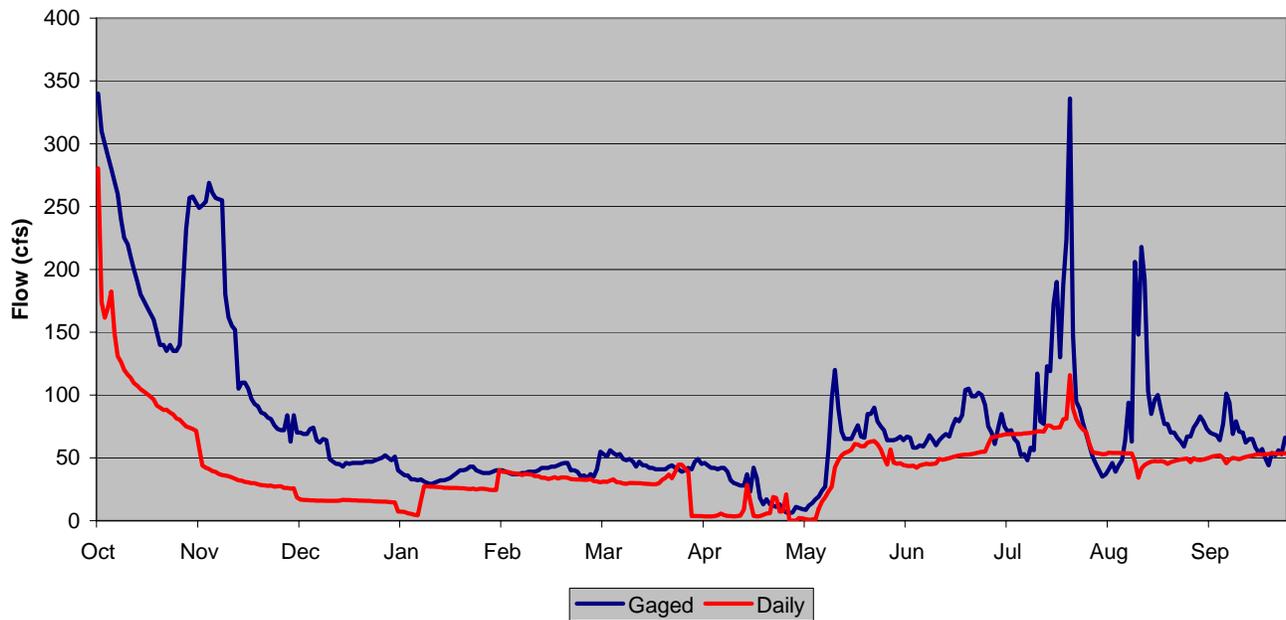


**Figure E.31 Historical Daily Comparison, Dry Year – Los Pinos River at La Boca**

**USGS Gage 09352900 - Vallecito Creek near Bayfield**
**Gaged and Simulated Daily Flows - Dry Year 1977**
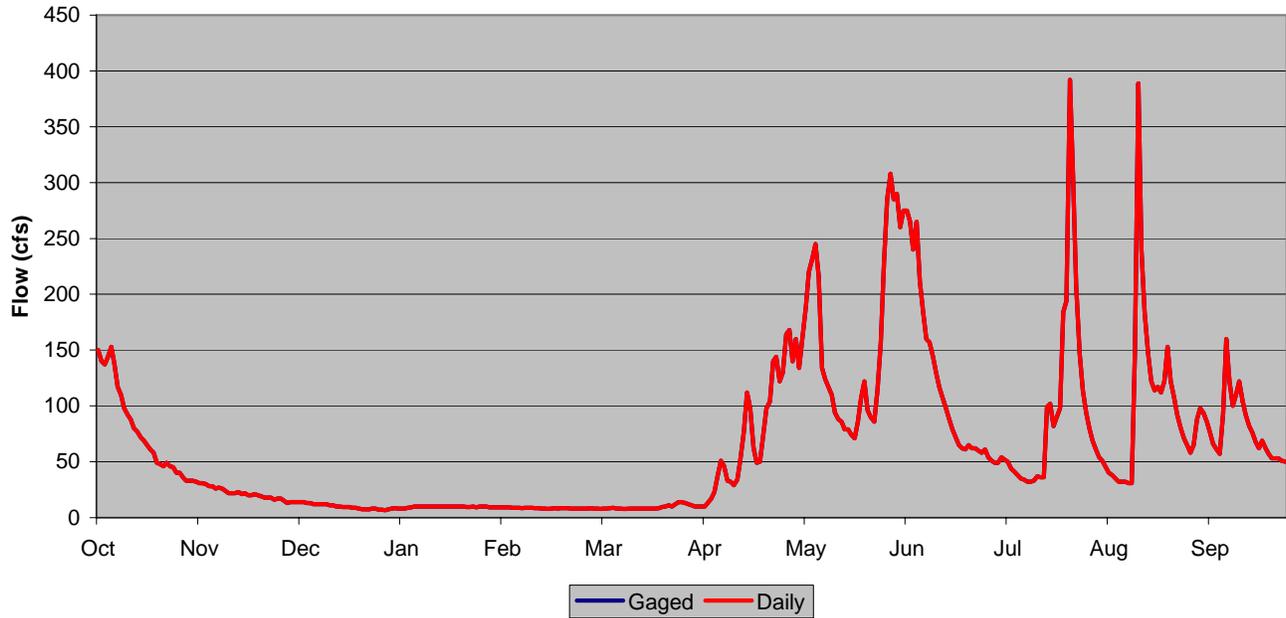


**Figure E.32 Historical Daily Comparison, Dry Year – Vallecito Creek near Bayfield**

**USGS Gage 09357500 - Animas River near Howardsville**
**Gaged and Simulated Daily Flows - Dry Year 1977**
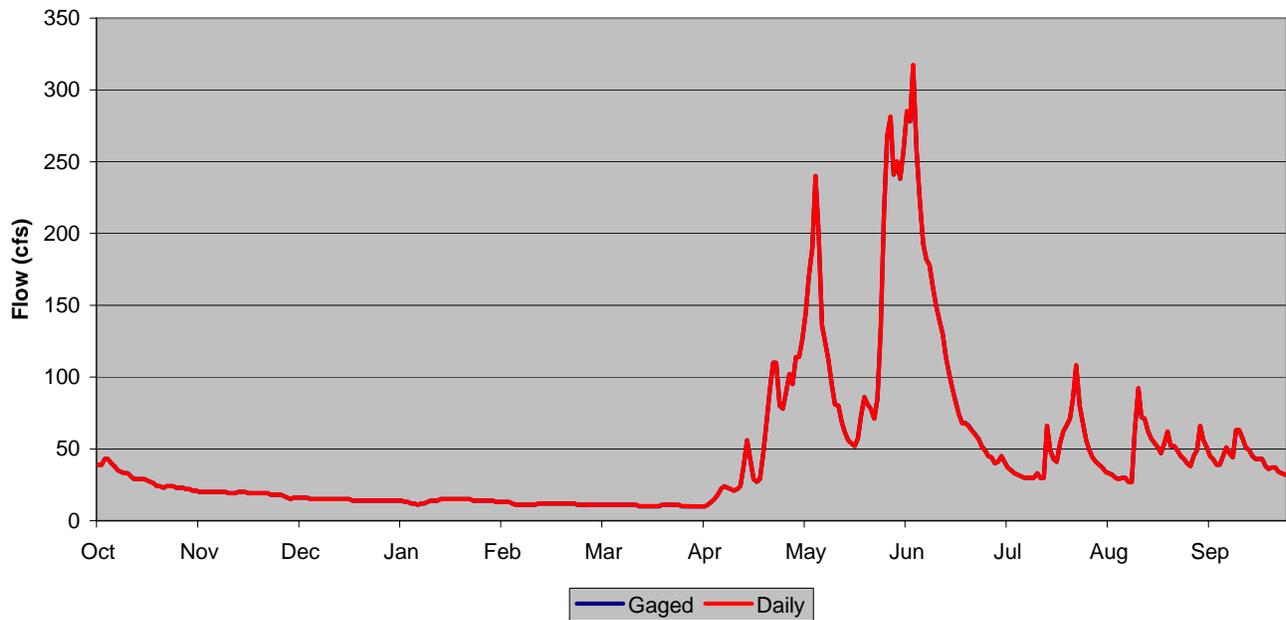


**Figure E.33 Historical Daily Comparison, Dry Year – Animas River near Howardsville**

**USGS Gage 09365500 - La Plata River at Hesperus**
**Gaged and Simulated Daily Flows - Dry Year 1977**
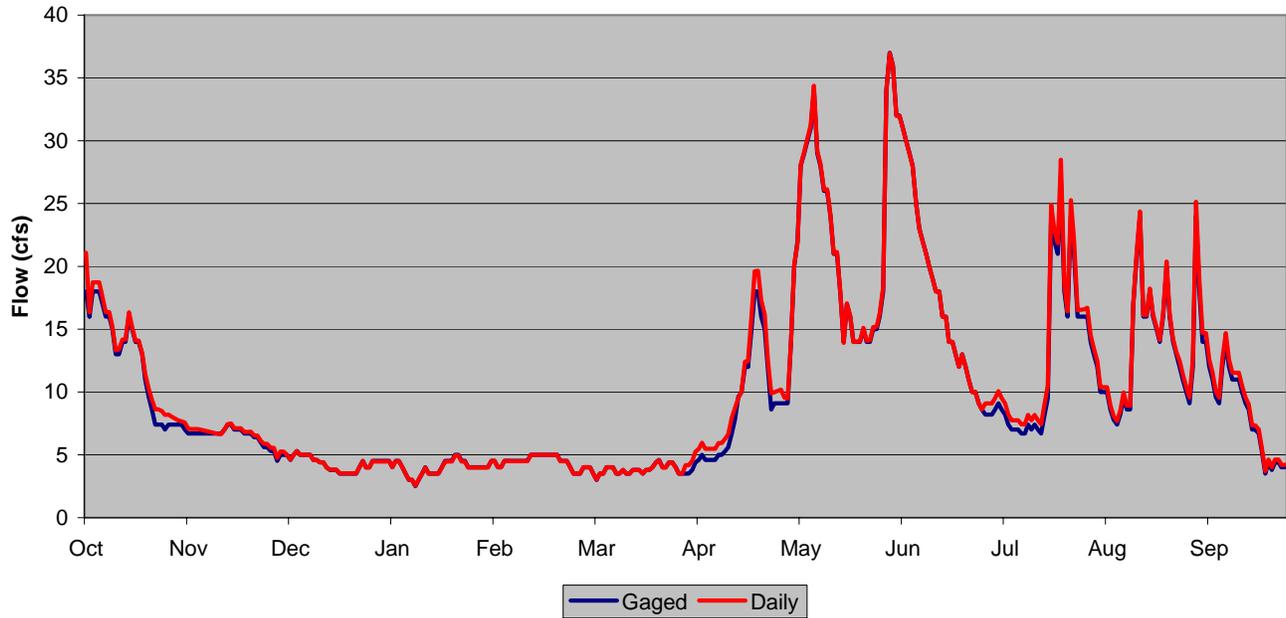


**Figure E.34 Historical Daily Comparison, Dry Year – La Plata River at Hesperus**

**USGS Gage 09371000 - Mancos River near Towaoc**
**Gaged and Simulated Daily Flows - Dry Year 1977**
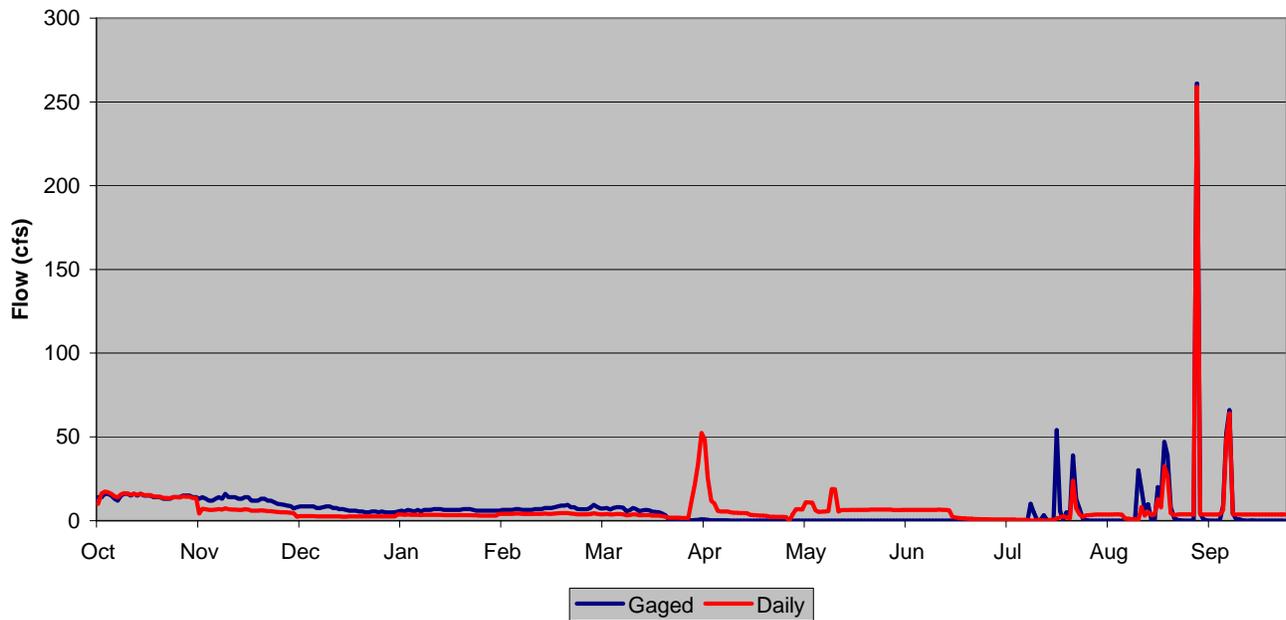


**Figure E.35 Historical Daily Comparison, Dry Year – Mancos River near Towaoc**

**USGS Gage 09372000 - McElmo Creek at the Colorado-Utah State Line**
**Gaged and Simulated Daily Flows - Dry Year 1977**
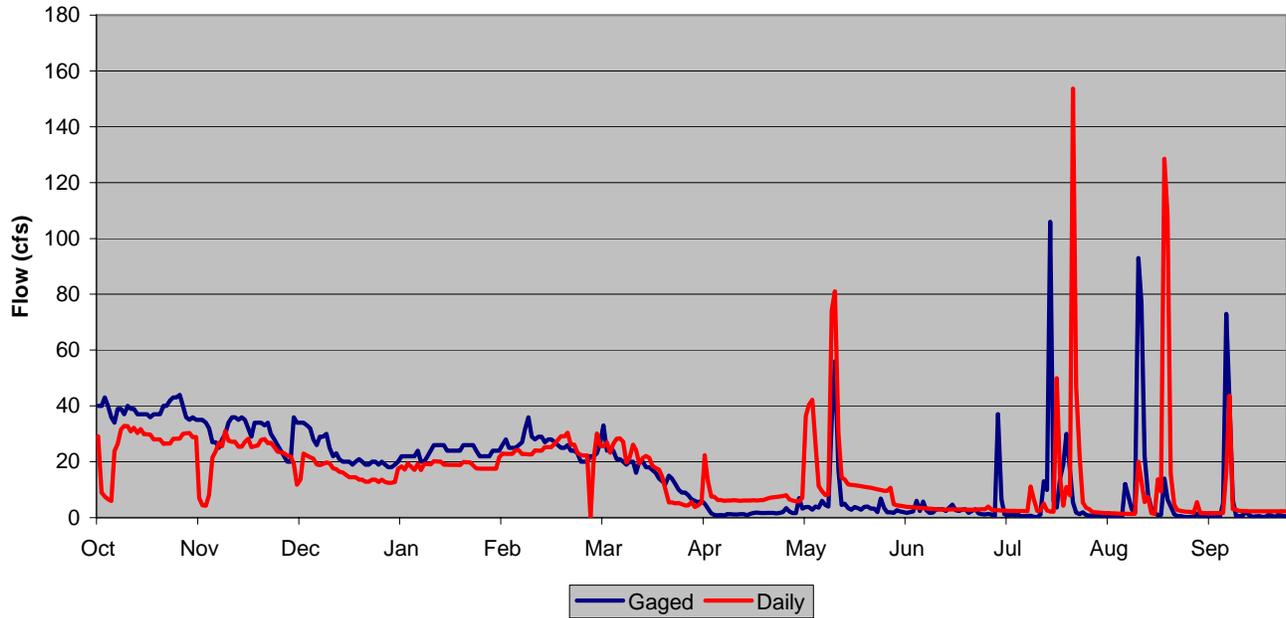


**Figure E.36 Historical Daily Comparison, Dry Year – McElmo Creek at CO/UT State Line**

**USGS Gage 09166500 - Dolores River at Dolores**
**Gaged and Simulated Daily Flows - Dry Year 1977**
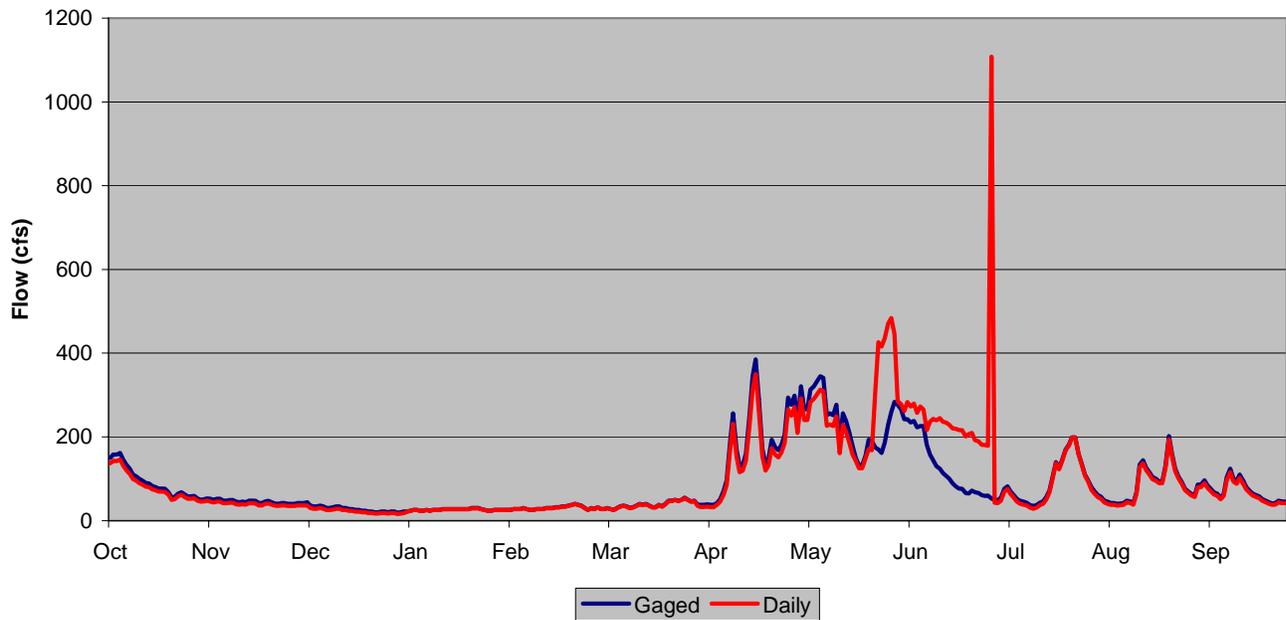


**Figure E.37 Historical Daily Comparison, Dry Year – Dolores River at Dolores**

**USGS Gage 09171100 - Dolores River at Bedrock**
**Gaged and Simulated Daily Flows - Dry Year 1977**
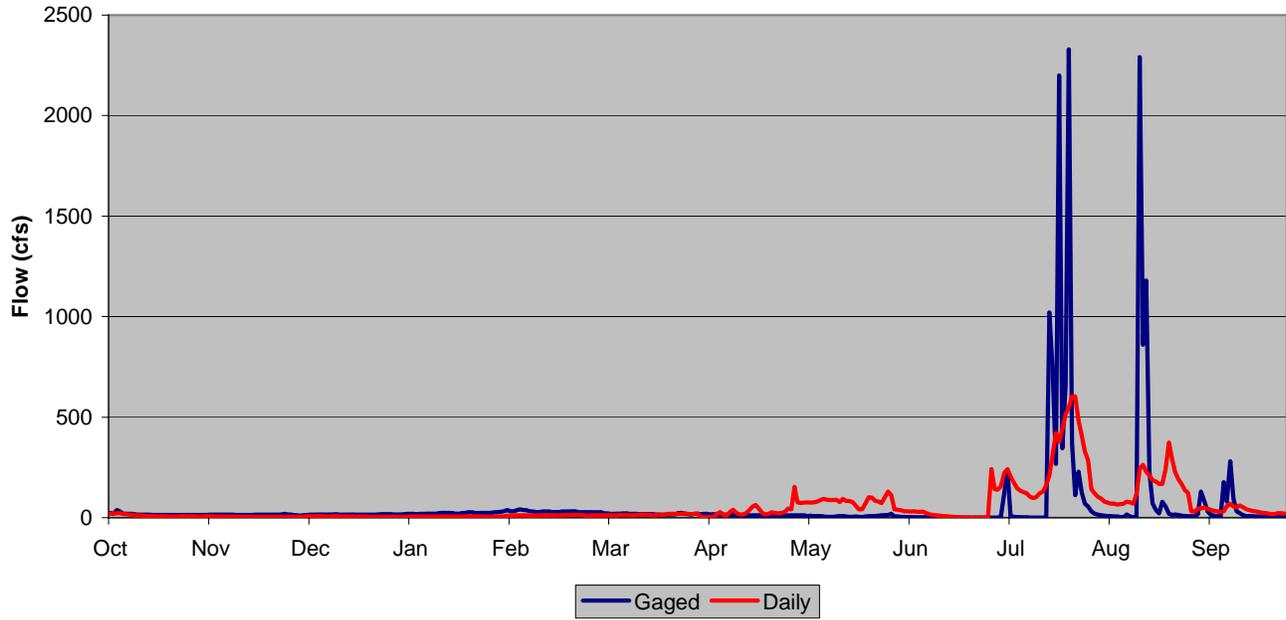


**Figure E.38 Historical Daily Comparison, Dry Year – Dolores River at Bedrock**

**USGS Gage 09172500 - San Miguel River near Placerville**
**Gaged and Simulated Daily Flows - Dry Year 1977**
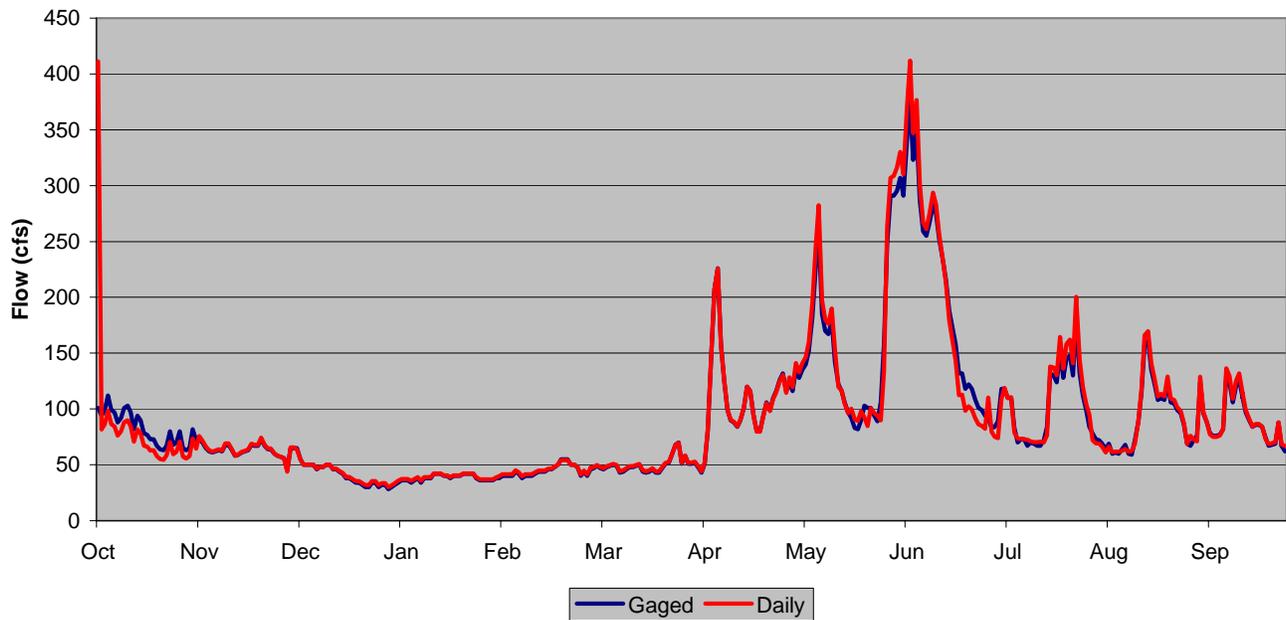


**Figure E.39 Historical Daily Comparison, Dry Year – San Miguel near Placerville**

**313518 - Vallecito Reservoir**
**Gaged and Simulated EOM Contents (1975-2003)**
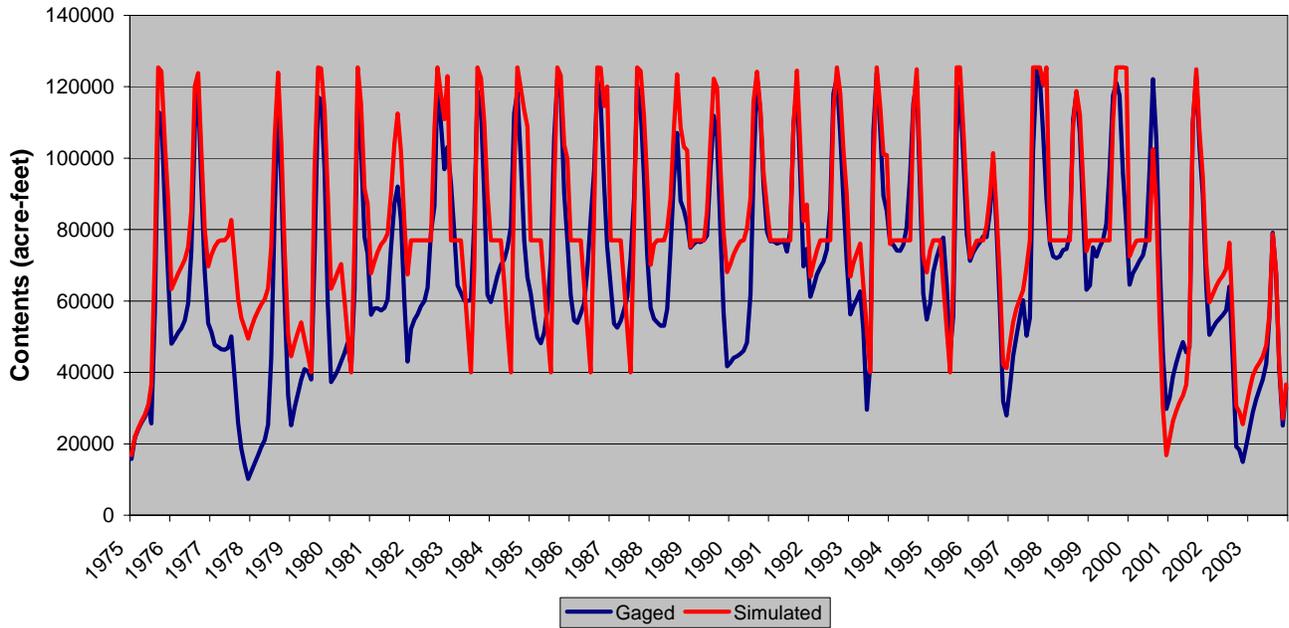


**Figure E.40 Historical Daily Reservoir Simulation – Vallecito Reservoir**

**303581 - Lemon Reservoir**
**Gaged and Simulated EOM Contents (1975-2003)**
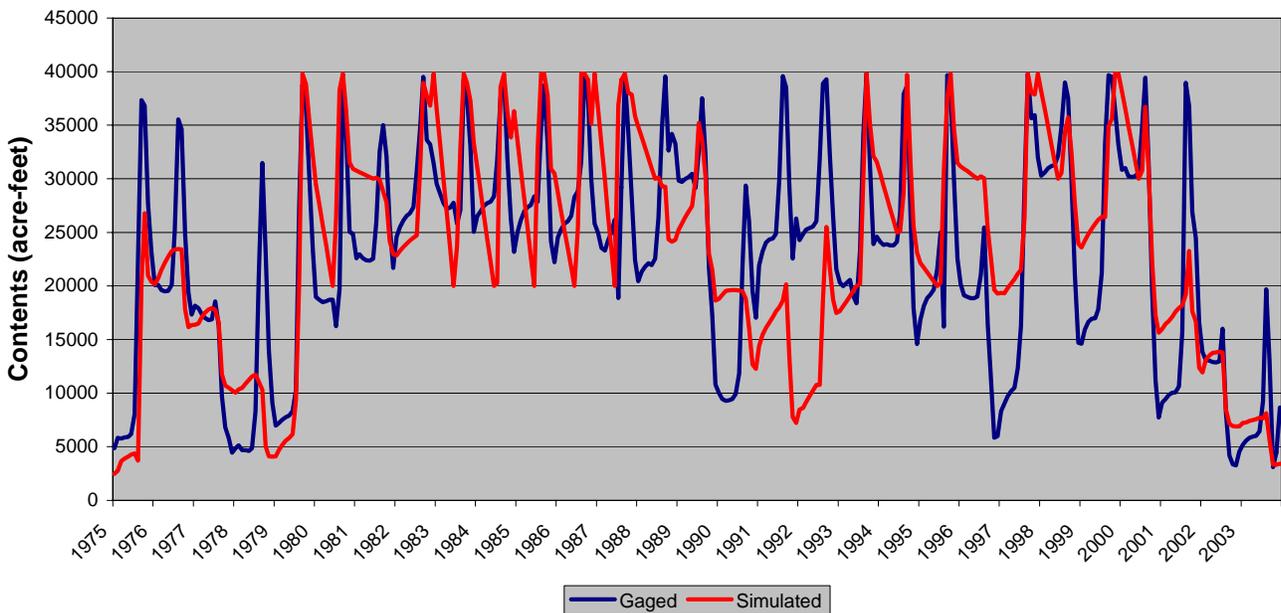


**Figure E.41 Historical Daily Reservoir Simulation – Lemon Reservoir**

**303536 - Cascade Reservoir**
**Gaged and Simulated EOM Contents (1975-2003)**
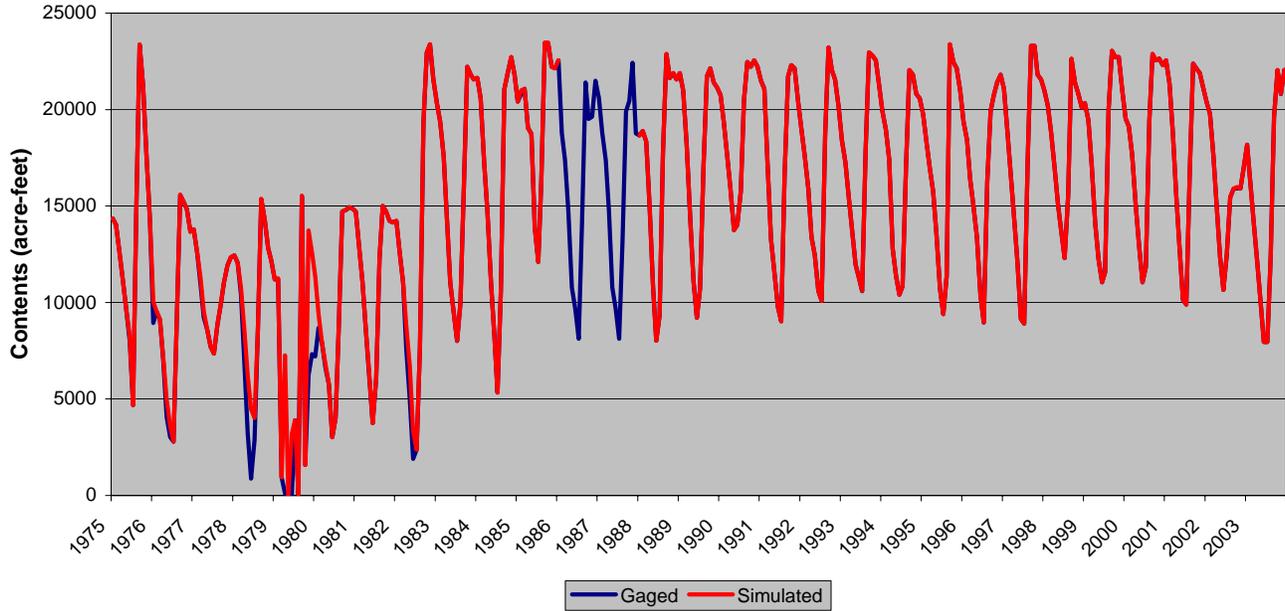


**Figure E.42 Historical Daily Reservoir Simulation – Cascade Reservoir**

**343589 - Jackson Gulch Reservoir**
**Gaged and Simulated EOM Contents (1975-2003)**
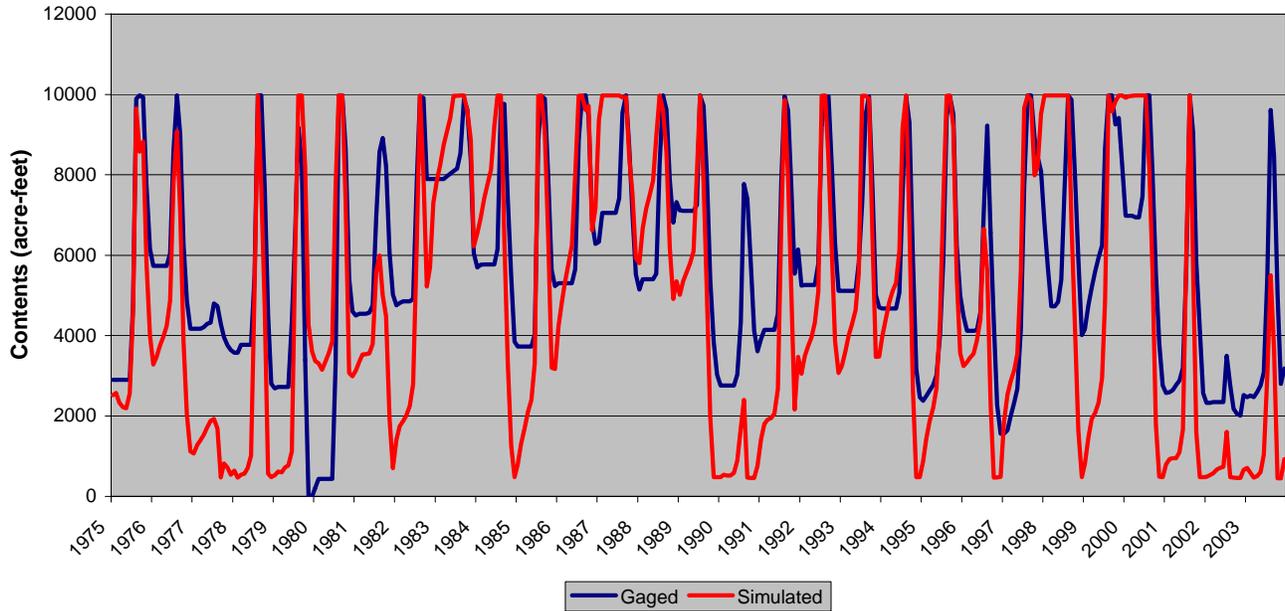


**Figure E.43 Historical Daily Reservoir Simulation – Jackson Gulch Reservoir**

**713614 - McPhee Reservoir**
**Gaged and Simulated EOM Contents (1975-2003)**
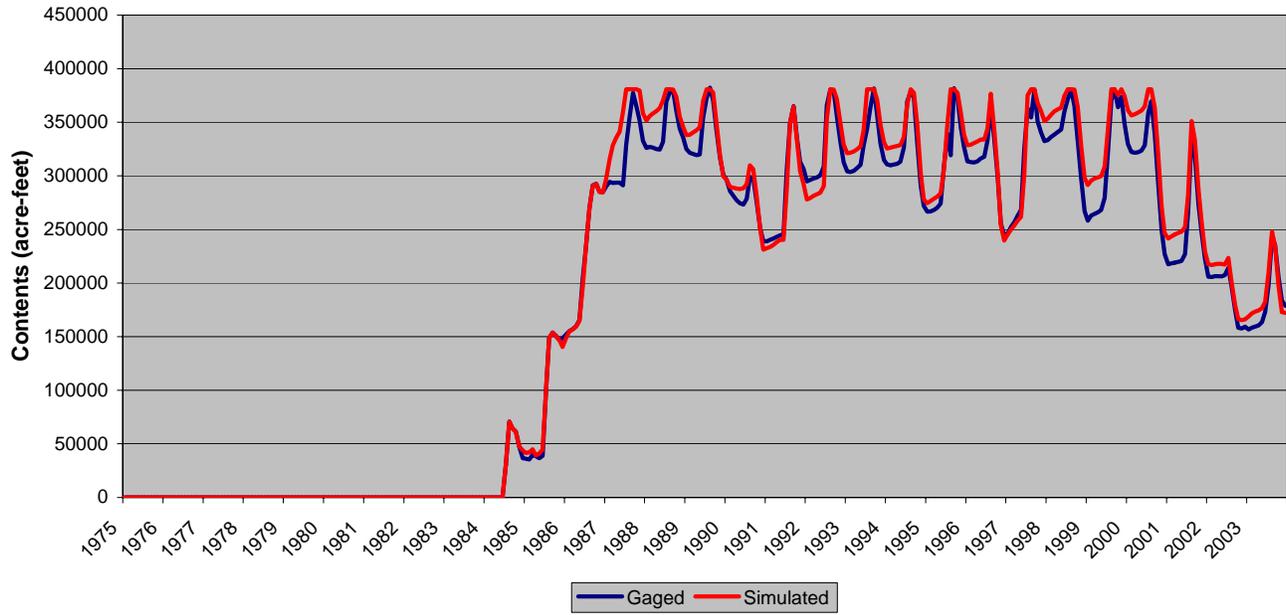


**Figure E.44 Historical Daily Reservoir Simulation – McPhee Reservoir**

# Appendix F

**San Juan Surface Water Model – Long Hollow Reservoir**

# CDSS Memorandum
## Final

**To:**        Ray Alvarado

**From:**     Leonard Rice Engineers, Inc. – Erin Wilson

**Subject:**   San Juan Surface Water Model – Long Hollow Reservoir

**Date:**      October 28, 2005

**Introduction**

This memorandum documents the modeling of the proposed Long Hollow Reservoir inflows and operations for the CDSS San Juan Basin Surface Water Modeling efforts. Long Hollow Reservoir water rights and operations are represented in the Baseline model.

Wright Water Engineers, Inc. (WWE) conducted an engineering investigation into the proposed reservoir and provided information used in the modeling efforts. Information was obtained from the WWE report "Operation Plan for the Proposed Long Hollow Reservoir – Preliminary Draft for Discussion Purposes Only", March 2004, and from phone conversations with Eric Bikis of WWE.

**Approach**

The following provides the approach taken to model Long Hollow Reservoir, including specific information regarding representation in StateMod input files. This section is split into four sections that describe the physical representation, water rights, hydrologic representation, and operational rules.

Physical Information – Physical reservoir parameters are set in the reservoir station file (sj2004.res). Long Hollow Reservoir (ID 333530) is modeled with a capacity of 5,400 acre-feet and a maximum surface area of 160 acres. Monthly evaporation rates representing reservoirs in Water District 33 are used.

LONREDCO streamflow gaging station has measured Long Hollow flows near the reservoir location since October 1988 (water year 1989). The model network is described in the network file (sj2004.net). Long Hollow is included in the model network as a two-node tributary entering the La Plata River upstream of Sooner Valley Ditch (330535). LONREDCO is represented as the baseflow node with Long Hollow Reservoir node just downstream, as shown below.

```
330548        ◯

330550        ◯              ●        330548 – LONREDCO Gage

                         ▼            333530 – Long Hollow Reservoir

330535        ◯

330540        ◯

          La Plata River
```
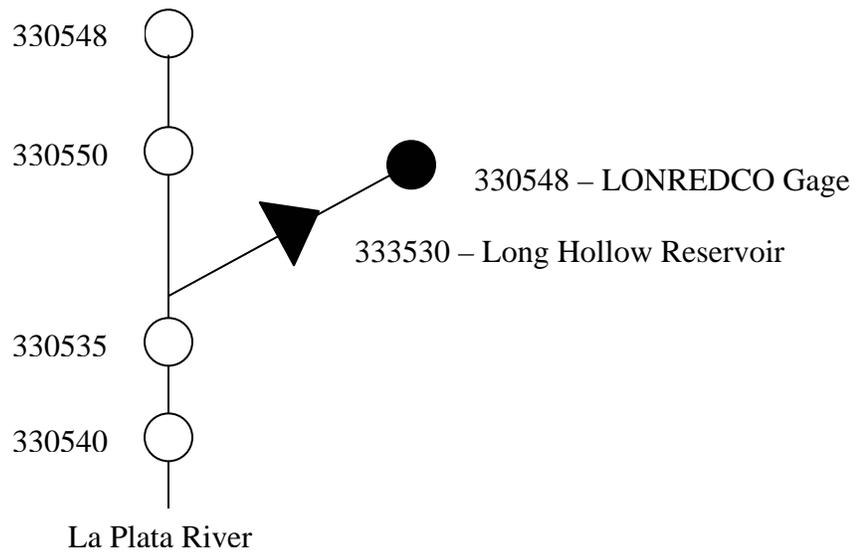
Water Rights – Reservoir storage rights are set in the reservoir rights file (sj2004.rer). Long Hollow Reservoir's two conditional water rights are active for the Baseline model, as shown in Table 1.

**Table 1**
**Conditional Water Rights**

| Conditional Storage (acre-feet) | Prior Adjudication Date | Appropriation Date | Administration Number |
|---|---|---|---|
| 1,200 | 12/31/1979 | 06/01/1973 | 47481.45077 |
| 4,200 | 12/31/1993 | 06/01/1973 | 52595.45077 |

Hydrologic Representation – The LONREDCO gage has measured flows near the reservoir location since October 1988.  According to WWE, these flows are almost entirely delayed ground water return flows from irrigation on Red Mesa.  Therefore, the percentage of upstream ditches that return to Red Mesa and the appropriate return flow delay pattern, are required model inputs. WWE did not include monthly return flow patterns in their analysis; therefore the following procedure was used to represent Long Hollow flows.

1. The CDSS GIS coverage representing the 2000 irrigation year and topography coverage were used to determine the irrigated acreage on Red Mesa, by ditch, that is likely tributary to Long Hollow.  The percentage of each ditch acreage tributary to Long Hollow is required input, set in the diversion station file (sj2004.dds).
2. Average monthly flows over the water years 1989 through 2003 period at the LONDREDCO gage are shown in Figure 1. As shown, there appears to be some runoff in early spring months, with irrigation returns occurring throughout the year.  As noted above, WWE did not include monthly return flow patterns in their analysis, and a ground water analysis was not performed as part of the CDSS efforts.  Instead, several patterns

were used in the baseflow simulation until a reasonable pattern (return pattern "3") was found that resulted in baseflows around 2 cfs in most months, with a short runoff period in early spring (see Figure 1.) Because Long Hollow baseflows are calculated by subtracting return flows from gaged flows, this is consistent with WWE information that LONREDCO measured flows are almost entirely from delayed returns. An attempt to modify return flow percents and the delay pattern to reduce baseflows further resulted in a significant number of negative baseflows.

Return flow delay pattern assignments for each return node are defined in the diversion station file (sj2004.dds). Pattern "3" was assigned to unused diversions returning to Long Hollow. The delay pattern is provided in the delay file (sj2004.dly).

Table 2 shows the percent of non-consumed ditch diversions modeled as returning to Long Hollow.

**Table 2**
**Return Flow Percentages to Long Hollow**

| Irrigating Ditch ID | Ditch Name | Percent Returns to Long Hollow |
|---|---|---|
| 330501 | La Plata Irrigating Ditch | 10 % |
| 330533 | Pine Ridge Diversion System | 40 % |
| 330536 | H H Ditch | 55 % |
| 330542 | Slade Ditch | 65 % |
| 330547 | Joseph Freed Ditch | 20 % |
| 330549 | Treanor Ditch | 80 % |
| 330551 | Townside Ditch | 60 % |

Table 3 shows the return flow pattern used in the model. As with other diversions in the basin, 6 percent of unused water is estimated to be lost from the system due to evaporation and native vegetative use, therefore the return flow delay pattern adds up to 94 percent. Note that the pattern reflects less return flows during the first three months after irrigation, representing travel time through the ground water zone, prior to more steady return flow during the next 33 months.

**Table 3**
**Delay Pattern "3" for Returns to Long Hollow**

| Month (Month 1 represents the month of water diverted from irrigation) | % of Unused Water Returning |
|---|---|
| 1 | 1.3 % |
| 2 | 1.5 % |
| 3 | 1.6 % |
| 4 – 12 | 3.0 % |
| 13 – 14 | 2.7 % |
| 15 – 36 | 2.6 % |

Figure 1 also shows average monthly baseflows estimated at LONREDCO for the 1988 through 2003 period.

**Figure 1**
**Average Monthly Flows at LONREDCO Gage**
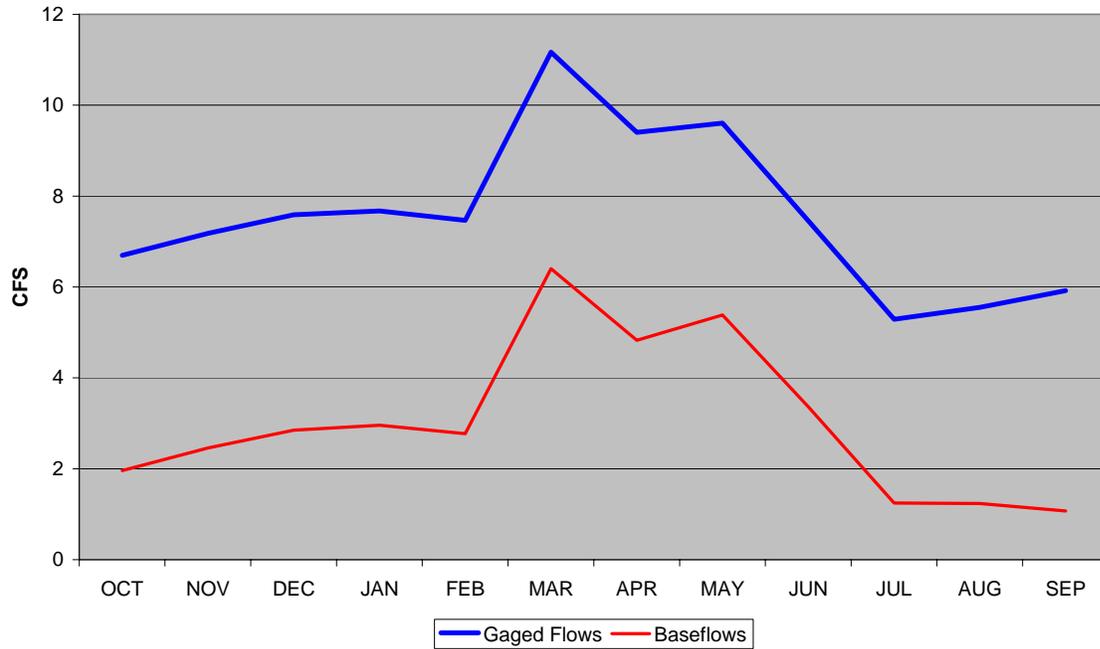


Reservoir Operations – The purpose of Long Hollow Reservoir is to help Colorado meet their La Plata River Compact requirements, thus reducing irrigation restrictions in Colorado and providing more flow for diversions in New Mexico.  The La Plata Compact requires defined stateline flows to be met from the time of peak runoff (represented in the CDSS model as mid-May) through November.  Therefore, subject to downstream non-irrigation use, Long Hollow Reservoir is able to store return flows during the winter months.  The reservoir "demand" set in the baseline reservoir target input file (sj2004B.tar) is capacity, directing StateMod to store as much as possible in priority every month of the study period.

Reservoir and other operation rules are set in the baseline Operating Rules file (sj2004B.opr).  The La Plata Compact is modeled as an "instream flow" demand, calculated each timestep based on streamflow at the La Plata River at Hesperus gage.  The "instream flow" right assigned to the La Plata Compact is the number one right in the model.  Thirteen type 4 operating rules are set to release water from Long Hollow Reservoir to replace increased upstream diversions that are out-of-priority to compact demands.  Two type 3 operating rules are set to release water from Long Hollow directly to increased downstream diversions that are out-of-priority to compact demands.

## Results

Historical Streamflow Representation – As discussed above under the Hydrologic Representation section, baseflows for the Long Hollow are determined by removing return flows from irrigation on Red Mesa.  During the historical model simulation, when Long Hollow Reservoir storage is not active, simulated streamflows in Long Hollow should "calibrate" well with historical streamflows at the LONREDCO gage.  Figure 2 shows this simulated versus historical streamflows.

**Figure 2**
**Gaged verus Simulated Flow at LONREDCO**
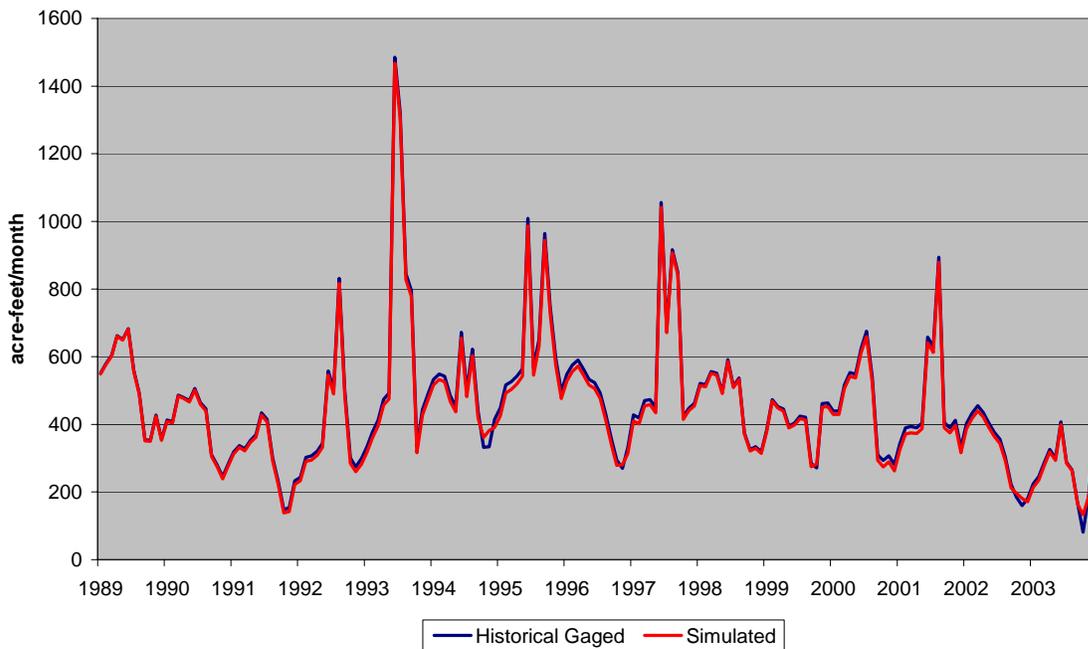


Baseline Irrigation Diversions – Baseline demands represent irrigation water requirements and current irrigated acreage. Because ditches diverting from the La Plata River are generally shorted during the irrigation season, baseline demands are greater than historical diversions for every year.  For structures diverting from the La Plata River in Colorado, the "incremental ditch diversions" that are met from Long Hollow releases in the baseline simulation are shown in the Table 4. Note that in time of excess flows, additional incremental diversions also occur. Those shown in Table 4 only represent increased diversions that must be replaced by Long Hollow to meet compact demands.

**Table 4**
**La Plata Incremental Ditch Diversions met by Long Hollow**

| Water Year | CDSS Incremental Diversion | WWE Incremental Diversion | Difference (CDSS – WWE) |
|---|---|---|---|
| 1989 | 1,828 | 3,727 | -1,899 |
| 1990 | 805 | 1,497 | -692 |
| 1991 | 2,045 | 1,697 | 348 |
| 1992 | 3,342 | 1,614 | 1,728 |
| 1993 | 4,776 | 2,369 | 2,407 |
| 1994 | 2,927 | 3,392 | -465 |
| 1995 | 4,484 | 2,277 | 2,207 |
| 1996 | 4,181 | 5,157 | -976 |
| 1997 | 4,714 | 3,686 | 1,028 |
| 1998 | 3,659 | 3,376 | 283 |
| 1999 | 3,983 | 2,057 | 1,926 |
| 2000 | 3,231 | 3,361 | -130 |
| 2001 | 2,434 | 2,584 | -150 |
| 2002 | 2,356 | 1,464 | 892 |
| Average | 3,198 | 2,733 | 465 |

Baseline Reservoir Operations – Figure 3 shows end-of-month reservoir contents for the period 1988 through 2002. As shown, all water stored in the reservoir during the winter is released in 8 of 14 years to supplement incremental diversions and assure that La Plata Compact obligations are met during the irrigation season. The WWE report estimated that the reservoir would release all water in 10 of the 14 years in the simulation period. Note that this is shown graphically in Figure 9 of the WWE report.

**Figure 3**
**Long Hollow Reservoir End-of-Month Content - Baseline Simulation**
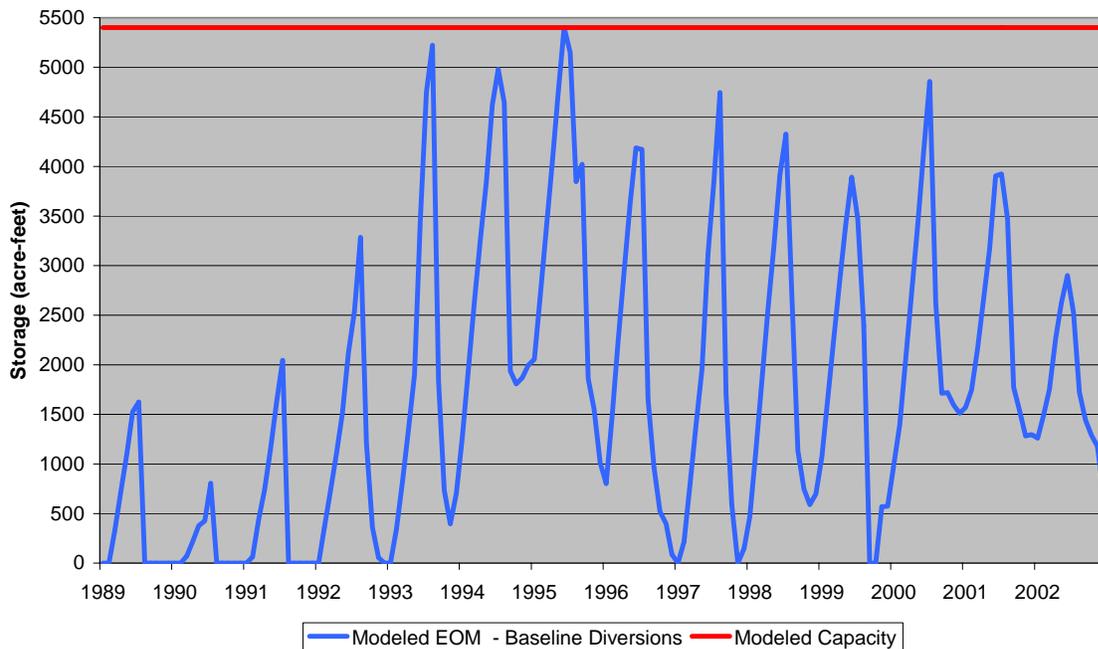


The CDSS simulation shows the reservoir maximum storage of 5,400 acre-feet in only 1 of 14 years of the study period. The WWE report estimated that Long Hollow Reservoir would fill to the 5,400 acre-feet capacity 4 out of the14 years in the study period. WWE estimated that the average annual amount of water stored in Long Hollow would be 3,540 acre-feet. The StateMod baseline simulation estimates the average annual amount of water stored is 3,440 acre-feet for the same period. Therefore, both physical and legal available water for storage is similar in the two estimates, but the StateMod simulation indicates more releases to meet the increased incremental diversions.

The StateMod baseline simulation estimates releases from Long Hollow Reservoir average 3,200 acre-feet per year to meet compact requirements while allowing incremental ditch diversions. As shown in the above table, the WWE analysis estimated an average of 2,700 acre-feet per year of releases therefore, the need to make releases from Long Hollow was less in their study.

Compact Deliveries – Monthly compact demands are completely met during the CDSS baseline simulation.

**Conclusions**

1. The amount of water physically and legally available for storage in Long Hollow is consistent between the StateMod baseline simulation and the WWE report.
2. CDSS baseline demands, based on irrigation water requirements, are significantly higher than historical demands, but still within individual ditch decreed rights. Increase in baseline demands contributes to reservoir contents not matching estimates by WWE. As shown in Table 4, both the quantity of releases to incremental demands and the pattern vary from year to year. WWE only releases for upstream exchanges if La Plata Compact requirements cannot be met by natural streamflows. In the CDSS simulation, when there is an unmet irrigation water requirement and when water is available in Long Hollow, releases are made to replace diversions. This results in reservoir releases from Long Hollow that are 17 percent higher, on average, than releases estimated by WWE.