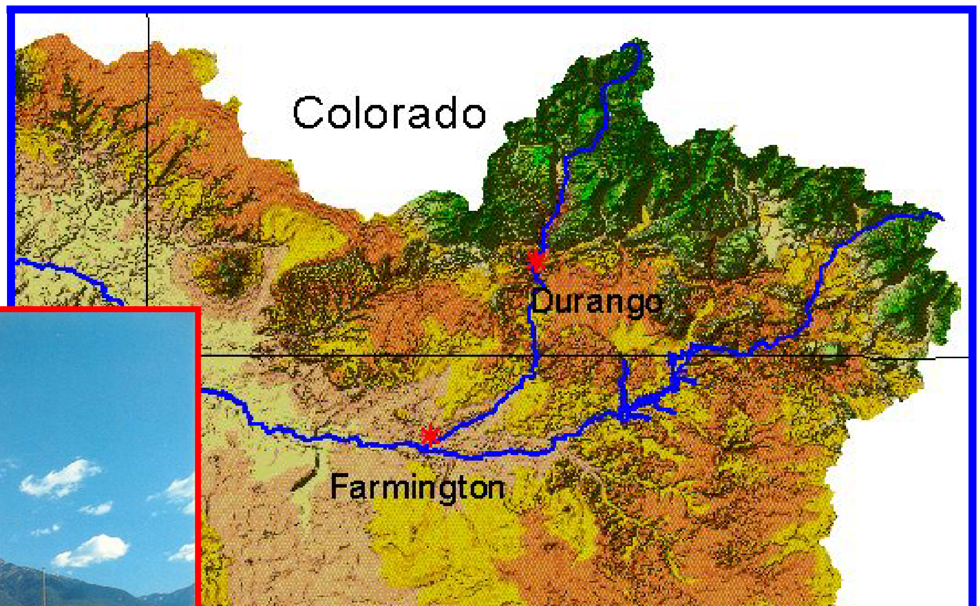
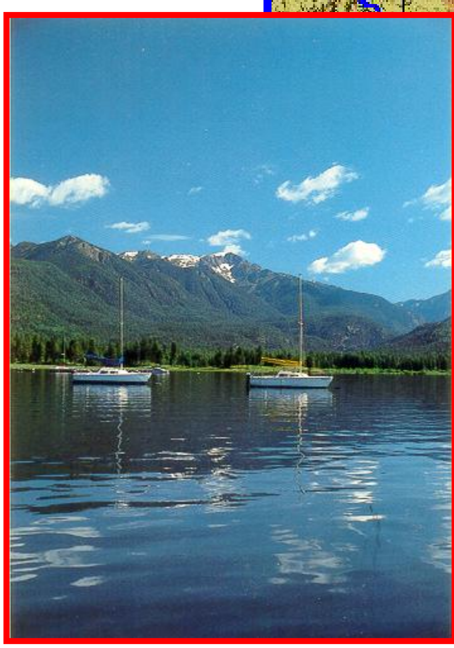
San Juan / Dolores River Basin Water Resources Planning Model User's Manual





October 2009

Colorado's Decision Support Systems

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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, 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. The model input files were enhanced during the CRWAS project in 2009 to extend the study period through 2006. 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. Technical memoranda and reports 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
- San Juan/Dolores Basin Historical Crop Consumptive Use Report

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.

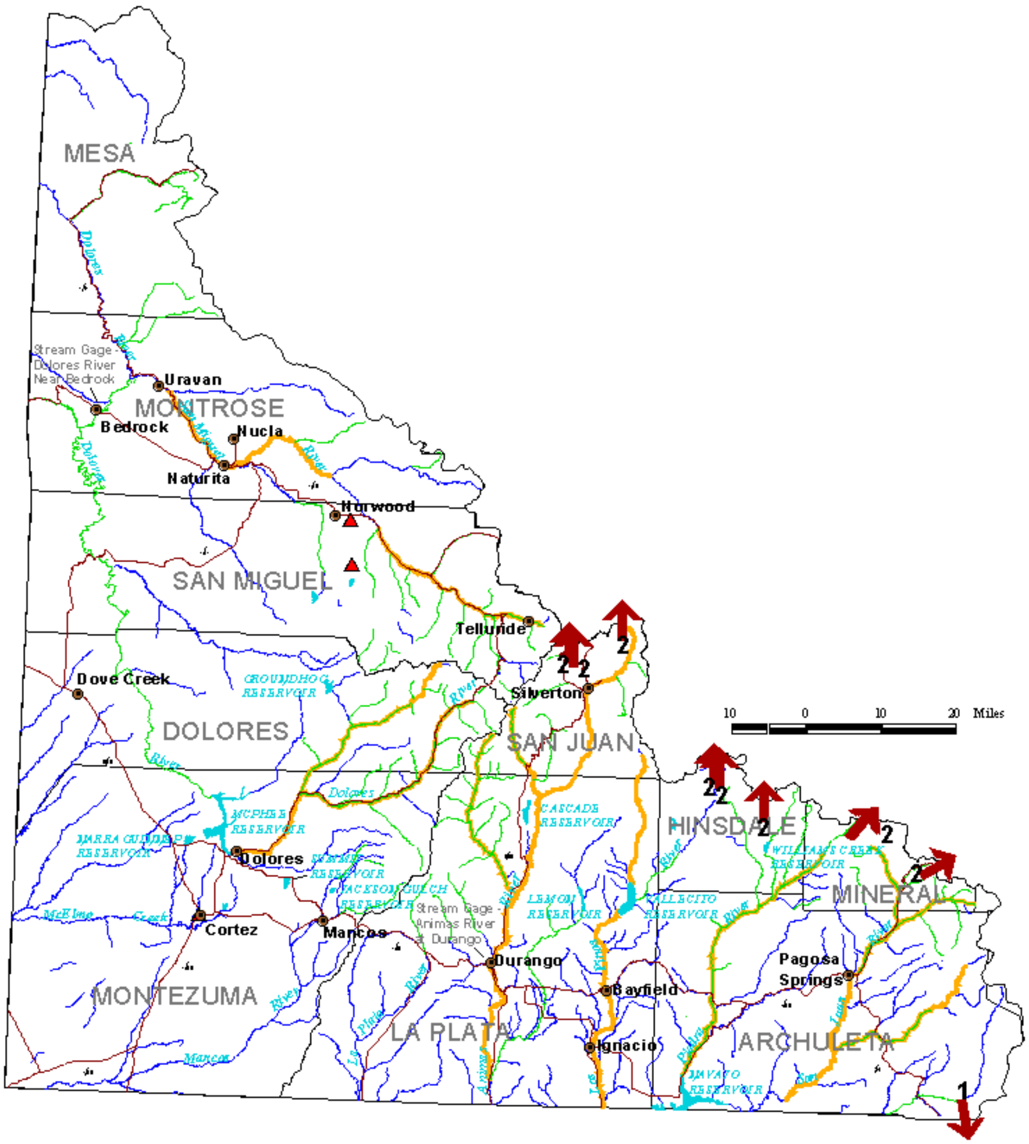
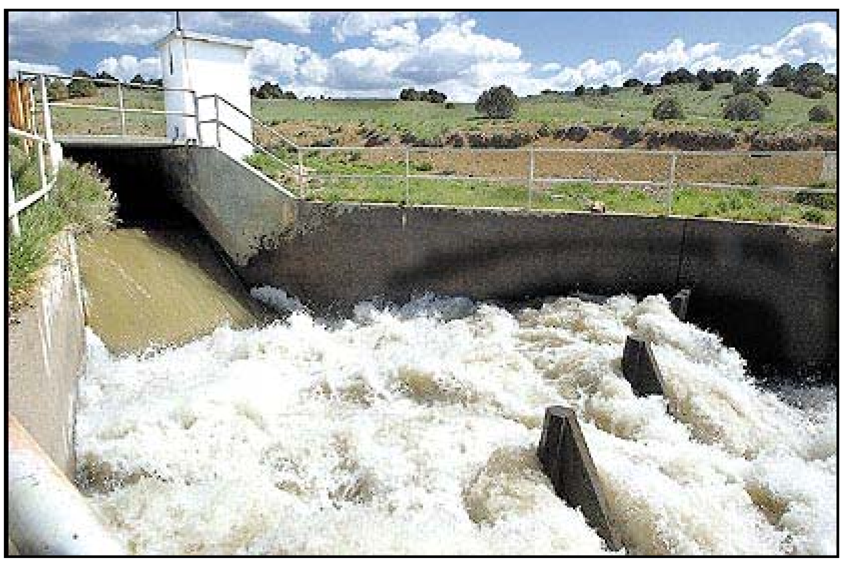


Figure 3.1 – San Juan and Dolores River Basins

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.



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

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 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.

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".

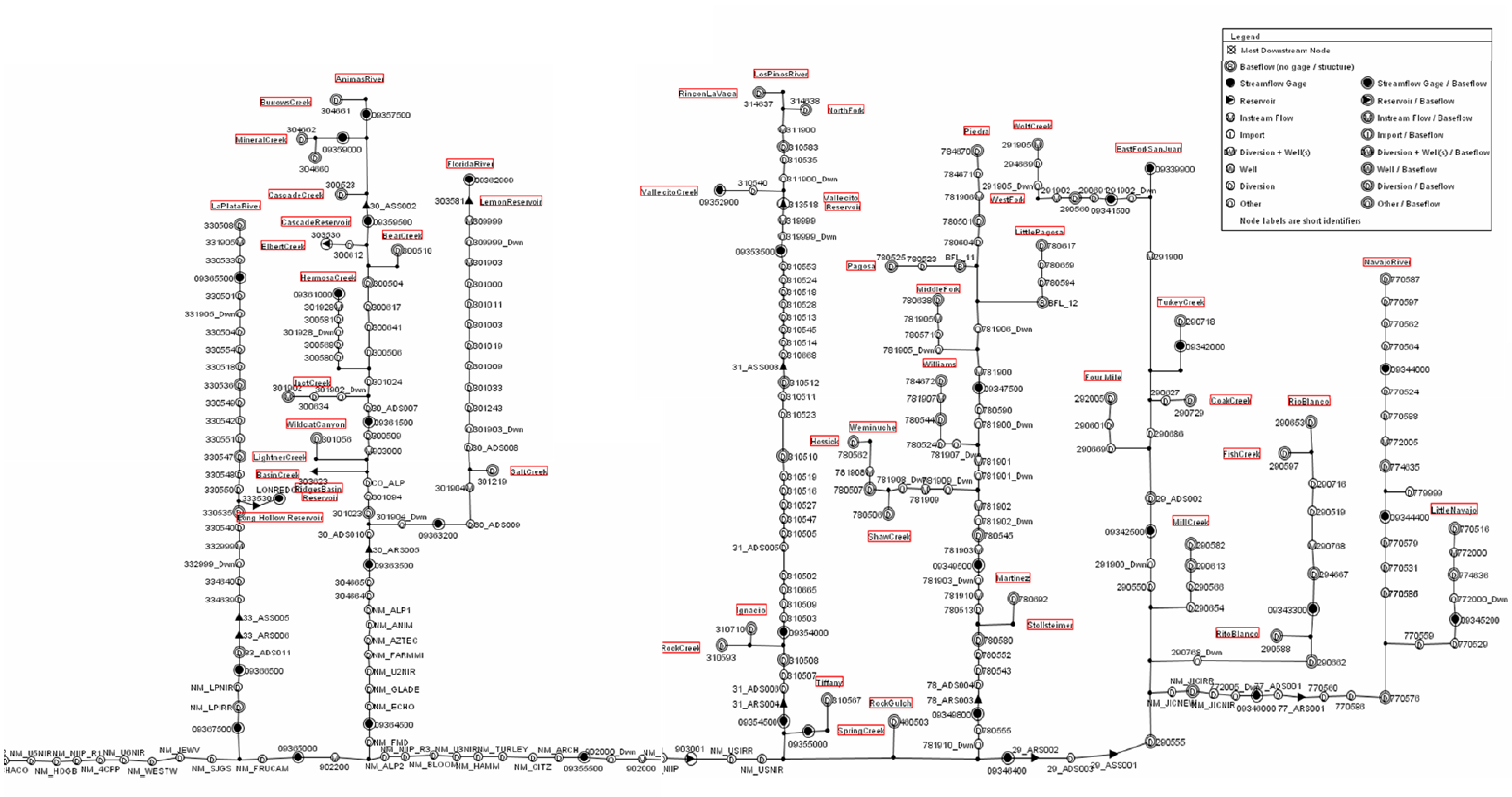


Figure 4.1 Network Diagram – San Juan / Dolores Planning Model from San Juan Headwaters to La Plata River Confluence

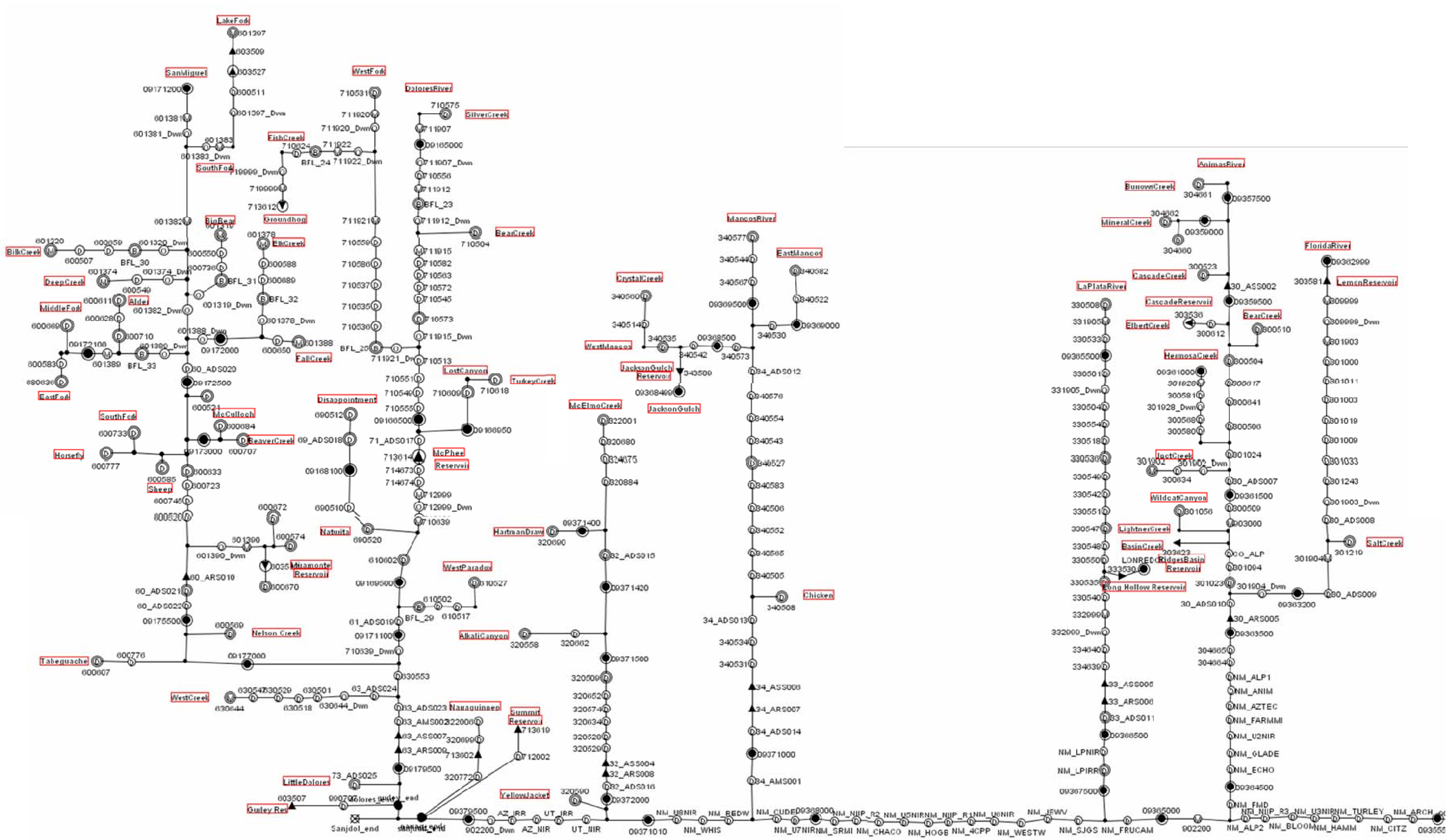


Figure 4.2 Network Diagram – San Juan / Dolores Planning Model from Animas River Confluence to Bluff, plus Dolores and San Miguel Rivers

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.

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.

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

> **Where to find more information**
>
> - Appendix B includes a memo describing the task in which small reservoir and stockponds use was aggregated.

4.2.4. Instream Flow Structures

The model includes 58 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 2005 and operates on USGS water year (October 1 through September 30). The calibration period was 1975 through 2005, 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).

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.

> **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)*

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	1909-2005 Annual Diversion
310665	Spring Creek Ditch	59,833
714674	Main Canal No. 2 (Great Cut)	65,881
714673	Main Canal No. 1 (Dolores Tunnel)	60,192
600633	Highline Canal + Enl	28,728
301011	Florida Farmers Ditch + Florida Canal	33,376
310519	King Ditch	22,251
310547	Robert Morrison Ditch	17,501
300506	Animas Consolidated Ditch	16,844
300617	Reid Ditch	13,816
320772	MVIC U Lateral	62,651
324675	MVIC Dolores Tunnel	55,064

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 25th percentile for that month are characterized as “Dry”, while months at or above the 75th 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.

Where to find more information

- A proof-of-concept effort with respect to the automated data filling process produced the following task memos, which are collected in the CDSS (*Technical Papers)*:

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

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

  -Characterize Streamflow Data (*Appendix E.6)*

  -Verify Diversion Estimates (*Appendix E.7*)

  These memos describe rationale for the data-filling approach, explore availability of basic gage data, explain the streamflow characterization procedure, and provide validation of the methods.
- **StateDMI** documentation describes the Streamflow Characterization Tool, a calculator for categorizing months as Average, Wet, or Dry
- **TSTool** documentation describes how to invoke the automated data filling procedure using those DMI's

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.

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.

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, $\boldsymbol{\eta_{max}}$ be defined as the maximum system efficiency, and let $\mathbf{CU_i}$ 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

$\mathbf{CU_w}$ is water supply limited consumptive use;

$\mathbf{SS_m}$ is the maximum soil moisture reservoir storage;

$\mathbf{SS_i}$ is the initial soil moisture reservoir storage;

$\mathbf{SS_f}$ 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 40 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.

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)

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.

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.

Where to find more information

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

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

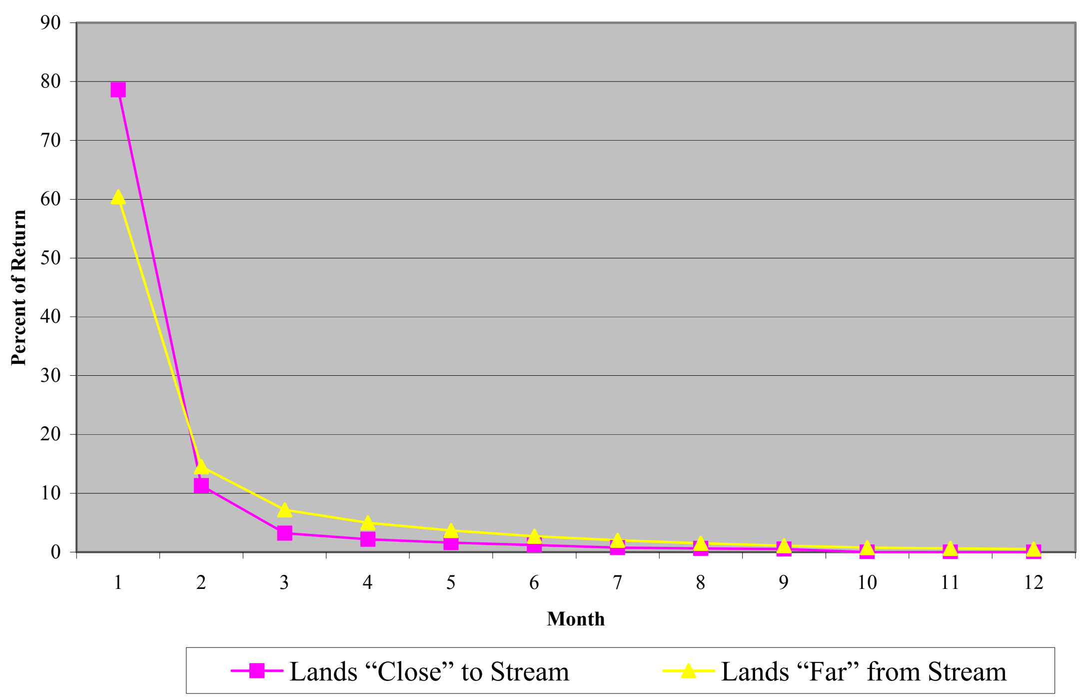


Figure 4.3 Percent of Return in Months After Division

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.

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.

4.7.2. Baseflow Filling

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

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.

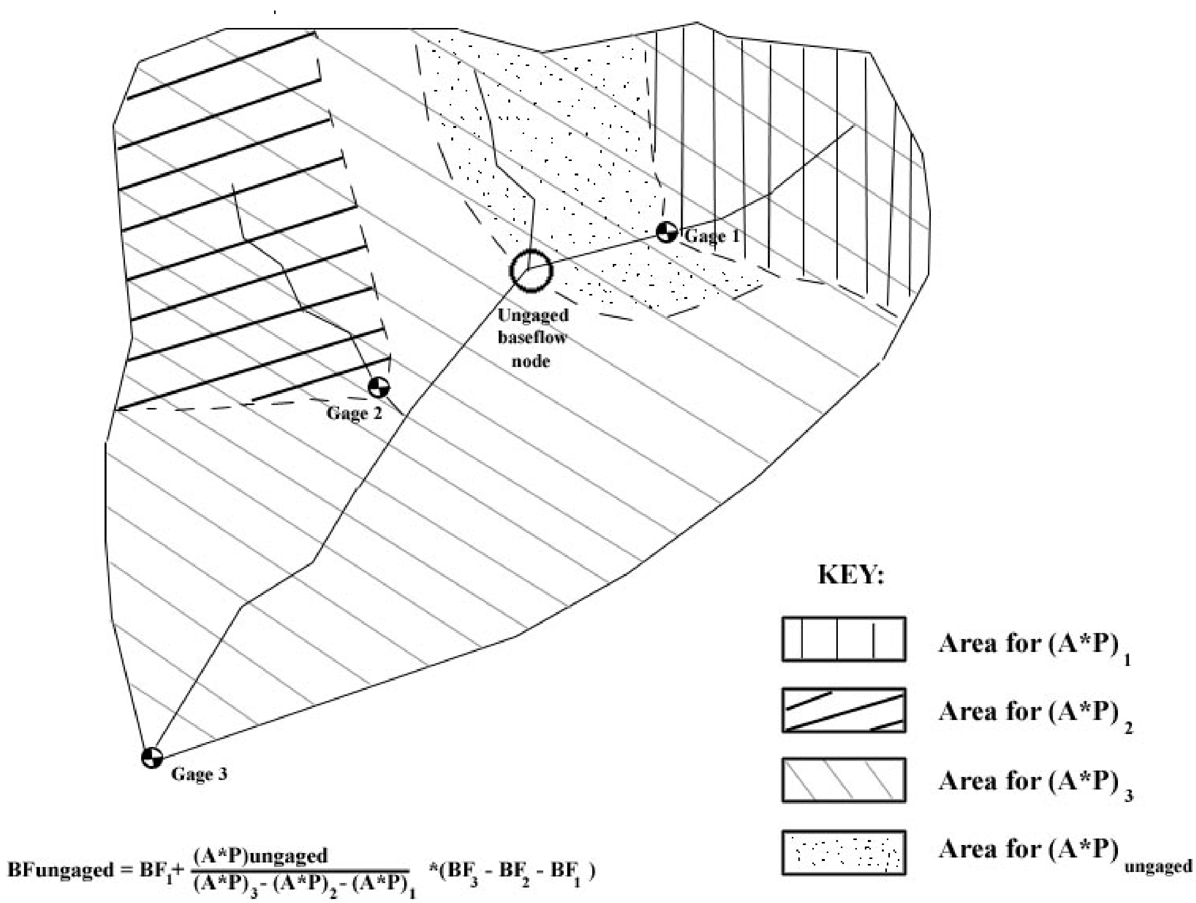


Figure 4.4 Hypothetical Basin Illustration

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.

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.

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 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.

Where to find more information

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

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.

Calculated demands must account for both crop needs and irrigation practices. Monthly calculated demand for 1975 through 2005 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 (54 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 0.54) 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.

Where to find more information

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

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 *sj2009B.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
sj2009.ctl	Control file – specifies execution parameters, such as run title, modeling period, options switches	Section 5.2
sj2009.rin	River network file – lists every model node and specifies connectivity of network	Section 5.3.1
sj2009B.res	Reservoir station file – lists physical reservoir characteristics such as volume, area-capacity table, and some administration parameters	Section 5.6.1
sj2009B.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
sj2009.ris	River station file – lists model nodes, both gaged and ungaged, where hydrologic inflow enters the system	Section 5.3.2
sj2009.ifs	Instream flow station file – lists instream flow reaches	Section 5.7.1
sj2009.ifr	Instream flow right file – gives decreed amount and administration number of instream flow rights associated with instream flow reaches	Section 5.7.3
sj2009.rer	Reservoir rights file – lists storage rights for all reservoirs	Section 5.6.5

File Name	Description	Reference
sj2009.ddr	Direct diversion rights file – lists water rights for direct diversion	Section 5.4.5
sj2009B.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
sj2009.eva	Evaporation file – gives monthly rates for net evaporation from free water surface	Section 5.6.2
sj2009x.xbm	Baseflow data file – time series of undepleted flows at all nodes listed in *sj2009.ris*	Section 5.3.5
sj2009B.ddm	Monthly demand file – monthly time series of headgate demands for each direct diversion structure	Section 5.4.4
sj2009.ifa	Instream flow demand file – gives the decreed monthly instream flow rates	Section 5.7.2
sj2009.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
sj2009B.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
sj2009.ipy	CU Irrigation Parameter Yearly file – maximum efficiency and irrigated acreage by year and by structure, for variable efficiency structures	Section 5.5.2
sj2009B.iwr	Irrigation Water Requirement file – monthly time series of crop water requirement by structure, for variable efficiency structures	Section 5.5.3
sj2009.str	StateCU Structure file – soil moisture capacity by structure, for variable efficiency structures	Section 5.5.1
sj2009.eom	Reservoir End of month contents file – Monthly time series of historical reservoir contents	Section 5.6.3
sj2009.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
sj2009.rih	Historical streamflow file – Monthly time series of streamflows at modeled gages	Section 5.3.4
sj2009.ddh	Historical Diversions – Monthly time series of historical diversions	Section 5.4.3
sj2009.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 sj2009.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 sj2009.xbf. The response file for the third step, in which StateMod distributes baseflow to ungaged points, is named sj2009x.rsp. The only difference between the first-step response file sj2009.rsp and third-step response file sj2009x.rsp is that the sj2009.xbf file replaces the historical gage file sj2009.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 (sj2009.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	331
Instream Flow	58
Reservoirs	32
Stream Gages	60
Total	481

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 60 gages in the model and 124 ungaged baseflow locations, for a total of 184 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

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.

5.3.4 Historical Streamflow File (*.rih)

Created by **TSTool**, the historical streamflow file contains historical gage records for 1909-2005, 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 (1975-2005). 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.

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, *sj2009.sum* and *sj2009.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.

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 – 1996 1999 – 2003	64,419
09341500	West Fork San Juan River near Pagosa Springs	1936 – 1960 1985 – 1987	118,617
09342000	Turkey Creek near Pagosa Springs	1938 – 1949	27,408
09342500	San Juan River at Pagosa Springs	1936 – 2008	268,771
09343000	Rio Blanco near Pagosa Springs	1936 – 1971	61,489
09343300	Rio Blanco below Blanco Diversion Dam near Pagosa Springs	1972 – 2008	32,380

Gage ID	Gage Name	Period of Record	Historical Flow (acre-feet/year)
09344000	Navajo River at Banded Peak Ranch near Chromo	1937 – 2008	78,564
09344400	Navajo River below Oso Diversion Dam nr Chromo	1972 – 2008	46,878
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 – 2008	441,858
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 – 2008	288,453
09352900	Vallecito Creek near Bayfield	1963 – 2008	105,728
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 – 2008	170,598
09355000	Spring Creek at La Boca	1952 – 2008	22,764
09355500	San Juan River near Archuleta	1956 – 2008	816,970
09357500	Animas River at Howardsville	1936 – 2008	75,829
09359000	Mineral Creek near Silverton	1937 – 1949	76,835
09359500	Animas River at Tall Timber Resort above Tacoma	1946 – 1956	386,231
09361000	Hermosa Creek near Hermosa	1921 – 1928 1941 – 1982	97,070
09361500	Animas River at Durango	1913 – 2008	593,993
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 2004 – 2008	672,388
09364500	Animas River at Farmington, NM	1914 – 2008	625,350
09365000	San Juan River at Farmington, NM	1931 – 2008	1,470,537
09365500	La Plata River at Hesperus	1918 – 2008	31,690
LONREDCO	Long Hollow at the Mouth near Red Mesa	1988 – 2008	5,017
09366500	La Plata River at CO-NM State Line	1921 – 2008	25,106
09367500	La Plata River near Farmington, NM	1939 – 2002	20,542
09368000	San Juan at Shiprock	1935 – 2008	1,478,516
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 – 2008	35,940
09371010	San Juan River at Four Corners	1978 – 2008	1,506,522
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 1982 – 1993	40,644
09372000	McElmo Creek near CO-UT State Line	1952 – 2008	36,660
09379500	San Juan River near Bluff	1928 – 2008	1,612,716

Gage ID	Gage Name	Period of Record	Historical Flow (acre-feet/year)
09165000	Dolores River below Rico	1952 – 2008	96,742
09166500	Dolores River at Dolores	1911 – 1912 1922 – 2008	309,193
09166950	Lost Canyon Creek near Dolores	1985 – 2008	14,490
09168100	Disappointment Creek near Dove Creek	1958 – 1986	15,345
09169500	Dolores River at Bedrock	1918 – 1922 1972 – 2008	266,760
09171100	Dolores River near Bedrock	1972 – 2008	265,074
09171200	San Miguel River near Telluride	1960 – 1965	45,840
09172000	Fall Creek near Fall Creek	1942 – 1959	17,842
09172100	Leopard Creek at Noel	1956 – 1963	1,988
09172500	San Miguel River near Placerville	1911 – 1912 1931 – 1934 1943 – 2008	170,441
09173000	Beaver Creek near Norwood	1942 –1967 1976 – 1981	11,377
09175500	San Miguel River at Naturita	1918 – 1929 1941 – 1981	238,641
09177000	San Miguel River at Uravan	1955 – 1962 1974 – 1994 1997 – 2008	264,055
09179500	Dolores River at Gateway	1937 – 1954	707,745

Table 5.3
Baseflow Comparison
1975-2005 Average (acre-feet/yr)

Gage ID	Gage Name	Baseflow	Historical	Difference
09342500	San Juan River at Pagosa Springs	304,883	287,579	17,304
09343300	Rio Blanco bl Blanco Div Dam nr Pagosa	74,060	33,980	40,080
09344000	Navajo Riv at Banded Pk Ranch nr Chromo	84,634	84,024	610
09344400	Navajo River bl Oso Div Dam nr Chromo	95,300	47,760	47,540
09346400	San Juan River near Carracas	567,939	451,442	116,497
09349800	Piedra River near Arboles	321,333	308,528	12,805
09352900	Vallecito Creek near Bayfield	107,015	107,015	0
09354500	Los Pinos River at La Boca	335,736	189,953	145,784
09355000	Spring Creek at La Boca	15,751	23,830	-8,079
09355500	San Juan River near Archuleta, NM	1,243,962	831,223	412,739
09357500	Animas River near Howardsville	77,487	77,348	139
09364500	Animas River at Farmington,NM	743,325	639,319	104,006
09365000	San Juan River at Farmington,NM	1,985,414	1,439,558	545,856
09365500	La Plata River at Hesperus	34,231	31,393	2,838
09366500	La Plata River at Colorado-NM Stateline	46,092	27,450	18,642
09368000	La Plata River at Shiprock, NM	2,021,154	1,412,034	609,120
09371000	Mancos River near Towaoc	58,064	38,873	19,191
09372000	McElmo Creek near Colorado-UT Stateline	35,831	38,909	-3,079
09379500	San Juan River near Bluff	2,111,365	1,539,296	572,069
09166500	Dolores River at Dolores	321,141	317,346	3,795
09169500	Dolores River at Bedrock	453,337	263,674	189,663
09171100	Dolores River near Bedrock	468,336	272,896	195,440

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 1993, 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 sj2009.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 sj2009.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
1975-2005

#	Model ID #	Name	Cap (cfs)	1993 Irrig. Acres	Average System Efficiency (percent)	Average Annual Demand (af)
1	290519 [8)]	BEIGHLEY NO 1_DIVSYS	34	234	45	1,716
2	290550	C H LOUCKS DITCH	130	29	2	5,018
3	290555	CARR DITCH	12	274	29	1,733
4	290560	CHAPSON AND HOWE DITCH	28	568	48	3,001
5	290566	COLTON AND MONTROY DITCH	15	220	39	1,669
6	290582	DOWELL DITCH	8	38	29	536

#	Model ID #	Name	Cap (cfs)	1993 Irrig. Acres	Average System Efficiency (percent)	Average Annual Demand (af)
7	290588	ECHO DITCH	28	1,182	60	4,384
8	290597	FISH CREEK DITCH	14	44	16	1,128
9	290601 [9)]	FOUR-MILE_DIVSYS	41	2,792	60	10,618
10	290613 [1)]	HALLETT DITCH	5	49	12	0
11	290627	J M ROSS AND STURGILL D	10	259	60	953
12	290653	LONG HORN AND MEE DITCH	14	262	60	972
13	290654	LONG MEADOW DITCH	6	26	38	297
14	290662	MARTINEZ AND MARTINEZ D	8	42	29	560
15	290669	MESA DITCH	29	674	60	2,462
16	290686	PARK DITCH	68	1,009	12	20,347
17	290691	PHILLIPPS DITCH	4	73	54	387
18	290716	SISSON-STEPHENS DITCH	10	208	53	1,015
19	290718	SNOWBALL DITCH	39	969	39	6,280
20	290729	STURGILL DITCH	6	63	47	433
21	292005	DUTTON DITCH	23	883	60	3,560
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	109	1,594	42	9,517
25	29_ADS003	29_ADS003_SJuanR@Carracs	126	1,480	37	22,772
26	300504	AMBOLD-WALLACE DITCH	13	112	11	2,509
27	300506	ANIMAS CONSOLIDATED D	97	1,899	13	36,647
28	300509 [6)]	ANIMAS DIVERSION CANAL	280	0	0	0
29	300510	BEAR CREEK DITCH	13	106	26	1,462
30	300523 [2)]	CASCADE CANAL	400	0	0	0
31	300568	HERMOSA COMPANY DITCH	20	347	19	5,149
32	300580	JOHN THOMAS DITCH	11	44	4	2,909
33	300581	J P LAMB DITCH	7	0	13	0
34	300612 [3)]	POWER CANAL NO 1	250	0	0	25,283
35	300617	REID DITCH	93	1,439	19	25,035
36	300634	SITES DITCH	8	68	14	1,464
37	300641	SULLIVAN-WALLACE DITCH	11	125	11	3,383
38	301000 [3)]	DURANGO CITY PIPELINE	15	0	36	3,788
39	301003	HARRIS-PATTERSON DITCH	4	143	50	748
40	301009	MCCLUER AND MURRAY DITCH	7	153	45	842
41	301011 [10)]	Florida_Farmers/Florida_	296	18,042	60	46,468
42	301019	PIONEER DITCH	15	415	50	1,760
43	301023	ANIMAS DITCH	56	1,233	17	17,084
44	301024 [3)]	ANIMAS PMP STA & FOR MN	22	0	36	5,621
45	301033	BANKS-TYNER DITCH	6	291	58	887
46	301056 [1)]	BODO PINE RIDGE DITCH	10	121	51	0
47	301094	EAST MESA DITCH	26	1,497	44	6,958
48	301219	SITES-KERN DITCH	20	780	60	3,230
49	301243	TYNER EAST SIDE DITCH	4	134	30	910
50	304660 [4)]	CARBON LAKE DITCH	999	0	100	284
51	304661 [4)]	MINERAL POINT DITCH	11	0	100	162

#	Model ID #	Name	Cap (cfs)	1993 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	999	0	40	4,914
54	304665 [4)]	TWIN ROCK DITCH	23	20	40	4,414
55	30_ADS007	30_ADS007_AnimasR@Durang	87	1,348	27	12,075
56	30_ADS008	30_ADS008_FloridaRabvSal	46	2,037	59	8,681
57	30_ADS009	30_ADS009_FloridaR@Bonda	38	936	38	4,996
58	30_ADS010	30_ADS010_AnimasR@StLine	62	1,046	17	21,565
59	30_ALP [3)]	WD 30 ALP Demands	280	0	0	0
60	310502	CEANABOO DITCH	20	883	55	4,295
61	310503	COMMISSIONER DITCH	14	528	36	3,173
62	310505 [11)]	DR MORRISON_DIVSYS	129	2,869	40	20,949
63	310507	LA BOCA DITCH	14	466	30	3,464
64	310508	SEVERO DITCH	23	377	28	3,048
65	310509	SPRING CREEK DITCH	75	3,233	43	15,546
66	310510	BEAN DITCH	4	155	40	1,081
67	310511	THOMPSON-EPPERSON DITCH	48	2,218	55	10,713
68	310512	LOS PINOS IRG DITCH	12	356	26	3,717
69	310513	WOMMER IRRIGATION DITCH	8	237	26	2,545
70	310514	BEAR CR AND PINE R DITCH	14	488	41	3,591
71	310516	HIGBEE IRRIGATION DITCH	3	22	24	330
72	310518	MYERS AND ASHER DITCH	3	103	42	797
73	310519	KING DITCH	106	4,920	48	28,582
74	310523 [12)]	SCHRODER IRG_DIVSYS	71	3,506	54	17,704
75	310524	FARRELL DITCH	5	131	44	1,031
76	310527	ISLAND DITCH	2	20	44	110
77	310528	BENNETT-MYERS IRR DITCH	5	130	26	1,413
78	310535	KIRKPATRICK DITCH	7	214	60	983
79	310540	MCLOYD DITCH	8	103	24	1,386
80	310545	CATLIN DITCH	1	117	60	189
81	310547	ROBERT MORRISON DITCH	108	6,539	54	29,252
82	310553	MCBRIDE DITCH	1	29	46	225
83	310567 [1)]	CAMPBELL DITCH	5	60	29	0
84	310583	PORTER DITCH	48	43	31	714
85	310593	SEMLER DITCH E AND E	5	82	55	454
86	310665	SPRING CREEK DITCH	299	15,319	29	83,305
87	310668	SULLIVAN DITCH	11	399	55	2,006
88	310710	IGNACIO CREEK DITCH	6	157	46	1,060
89	314637 [4)]	WEMINUCHE PASS DITCH	40	0	100	1,397
90	314638 [4)]	PINE R WEMINUCHE PASS D	18	0	100	474
91	31_ADS005	31_ADS005_LPinosR@DryCrk	35	1,383	52	6,586
92	31_ADS006	31_ADS006_LPinosR@StLine	73	1,728	35	16,044
93	320509	BLACK DIKE DITCH	13	61	16	1,233
94	320528	COTTONWOOD DITCH NO 1	15	148	12	3,224
95	320529	COTTONWOOD DITCH NO 2	14	114	9	3,482
96	320558	EATON DITCH	9	116	22	1,683

#	Model ID #	Name	Cap (cfs)	1993 Irrig. Acres	Average System Efficiency (percent)	Average Annual Demand (af)
97	320574	HAMBELTON DITCH	16	187	13	4,712
98	320590	ISMAY DITCH	11	60	17	1,074
99	320634	MURRAY-ZWICKER-TOZER D	8	59	6	2,140
100	320652	ROCK CREEK DITCH	38	488	9	11,316
101	320662	SCHALLES DITCH	6	80	20	1,186
102	320680 3)	TOWN OF CORTEZ	999	0	36	2,869
103	320690	WILSON DITCH	30	556	45	3,185
104	320699 2)	NARRAGUINNEP RES INLET	999	0	0	0
105	320772	MVI_U_lateral	999	13,712	40	77,608
106	320884	TOWAOC CANAL	135	6,690	41	26,938
107	322001 3)	DOLORES WATER DIVR HGT	999	0	36	832
108	322006	DOVE CREEK CANAL	999	28,651	60	81,170
109	324675	Dolores_Tunnel	999	18,706	47	76,727
110	32_ADS015	32_ADS015_McELmCkabvAlka	74	1,354	40	8,404
111	32_ADS016	32_ADS016_McElmoCrkNrStL	72	1,481	41	7,713
112	330501	LA PLATA IRG DITCH	8	103	15	1,969
113	330504	HAY GULCH DITCH	19	1,513	50	7,507
114	330508	LA PLATA R & CHERRY CR D	41	1,922	60	6,965
115	330518	AMMONS DITCH	6	391	60	1,394
116	330533	PINE RIDGE DITCH	28	441	51	2,766
117	330535	SOONER VALLEY DITCH	12	280	37	1,233
118	330536	H H DITCH	85	4,467	54	16,220
119	330540	ENTERPRISE ENLARGEMENT D	5	155	42	734
120	330542	SLADE DITCH	37	2,850	54	10,014
121	330547	JOSEPH FREED DITCH	31	1,750	54	6,450
122	330548	REVIVAL DITCH	11	457	55	1,531
123	330549	TREANOR DITCH	67	2,549	55	9,443
124	330550	WARREN-VOSBURGH DITCH	13	765	58	2,474
125	330551	TOWNSITE DITCH	16	475	55	2,032
126	330554	BIG STICK DITCH	40	1,677	56	6,496
127	334639 4)	ENTERPRISE ENLARGEMENT D	999	0	40	655
128	334640 4)	PIONEER DITCH	999	0	40	954
129	33_ADS011	33_ADS011_LaPlataRiver	49	1,510	55	6,229
130	340505	BEAVER DITCH	14	238	47	1,759
131	340506	BOSS DITCH	999	176	50	1,188
132	340508	CARPENTER AND MITCHELL D	11	367	54	1,754
133	340514	CRYSTAL CREEK DITCH	9	332	52	1,769
134	340522	EAST MANCOS HIGHLINE D.	9	196	56	963
135	340527	FRANK DITCH	4	40	21	713
136	340530	GILES DITCH	10	164	40	1,411
137	340531	GLASGOW & BREWER DITCH	7	397	50	1,571
138	340534	HENRY BOLEN DITCH	15	478	51	2,920
139	340535 2)	JACKSON GULCH INLET CNL	524	0	0	0
140	340542	LEE AND BURKE DITCH	8	281	54	1,463
141	340543	LEE DITCH	12	330	54	1,563

#	Model ID #	Name	Cap (cfs)	1993 Irrig. Acres	Average System Efficiency (percent)	Average Annual Demand (af)
142	340544	LONG PARK DITCH	11	338	53	1,670
143	340552	NO 6 DITCH	7	344	53	1,684
144	340554	RATLIFF AND ROOT DITCH	38	1,806	58	8,196
145	340560	RUSH RESERVOIR DITCH	895	846	48	3,461
146	340565	SHEEK DITCH	14	598	53	2,986
147	340567	SMOUSE DITCH	3	34	49	224
148	340573 [3)]	TOWN OF MANCOS DITCH	4	0	36	775
149	340576	WEBBER DITCH	52	1,700	54	8,280
150	340577	WEBER RESERVOIR INLET D	10	116	44	1,093
151	340582 [13)]	WILLIAMS DITCH_DIVSYS	7	199	60	823
152	340583	WILLIS DITCH	5	185	52	1,103
153	34_ADS012	34_ADS012_ManRabvWMancos	11826	949	60	4,220
154	34_ADS013	34_ADS013_ManRabvChicken	161	393	57	1,778
155	34_ADS014	34_ADS014_MancosRNrStLin	1087	1,113	56	27,331
156	34_AMS001	34_MUNICIPAL	1	0	100	1,080
157	460503 [1)]	BRIGGS DITCH	12	19	29	0
158	600507	ALEXANDER DITCH	15	307	60	1,146
159	600511 [3)]	AMES ILIUM HYDRO PROJ	83	0	0	10,911
160	600520	B C D DITCH	6	33	8	970
161	600521	BEAVER MESA DITCH	26	973	60	3,645
162	600549	CARR WADDLE DITCH	8	287	60	1,029
163	600550	CARRIERE DITCH	19	378	60	1,556
164	600569	CRAVER DITCH	13	123	43	1,034
165	600574	DENISON DITCH	8	136	56	608
166	600583	EAGLE DITCH	16	415	60	1,469
167	600585	EASTON DITCH	13	460	55	1,992
168	600588	ELK CREEK DITCH	13	85	16	1,077
169	600607	GLENCOE DITCH	17	560	58	2,010
170	600611	GOLD RUN DITCH	7	165	52	895
171	600628	HASTINGS DITCH	5	94	43	623
172	600633	HIGHLINE CANAL	145	4,051	31	37,616
173	600650	J & M HUGHES DITCH	40	3,446	60	10,721
174	600659	KINLEY DITCH	5	79	44	550
175	600669	LEOPARD CREEK DITCH	8	260	60	1,066
176	600670	LILYLANDS CANAL	122	2,153	58	7,766
177	600672	LONE CONE DITCH	188	453	38	4,745
178	600684	MCCOLLOCH SCOTT DITCH	13	71	31	658
179	600689	MIDDLE ELK CREEK DITCH	20	75	15	970
180	600707 [2)]	NATURITA CANAL	1051	0	0	18,560
181	600710	NEILSON DITCH	7	73	60	300
182	600723 [3)]	NUCLA POWER PLANT DITCH	61	0	0	1,452
183	600733 [2)]	PAXTON DITCH	27	0	0	424
184	600736	PLEASANT VALLEY DITCH	20	577	53	2,486
185	600745	REED CHATFIELD DITCH	7	34	10	901
186	600776	TEMPLETON DITCH	6	20	11	599

#	Model ID #	Name	Cap (cfs)	1993 Irrig. Acres	Average System Efficiency (percent)	Average Annual Demand (af)
187	600777	THEO NETHERLY DITCH NO1	4	45	37	314
188	60_ADS020	60_ADS020_SMiguelNrPlacr	97	2,106	43	15,420
189	60_ADS021	60_ADS021_SMiguelabvWNat	20	1,097	54	4,823
190	60_ADS022	60_ADS022_SMiguel@Naturi	122	1,912	43	12,083
191	610502	GALLOWAY DIVSYS	13	398	41	1,815
192	610517	SOUTH MIDWAY DITCH	20	382	42	2,079
193	610527	RAY DITCH	25	1,095	44	3,956
194	610602 1)	A E L R P & PL	8	0	41	0
195	61_ADS019	61_ADS019_DoloresRNrBedr	52	1,529	34	7,952
196	630501	BARTHOLOMEW AND HATCH D	9	109	15	2,541
197	630518	CLIFF RANCH DITCH	7	97	21	1,836
198	630529	HARMS AND HAZEL DITCH	8	78	32	1,045
199	630547	NOLAN DITCH	8	82	52	606
200	630553	RED CROSS DITCH	10	109	60	594
201	63_ADS023	63_ADS023_DoloresR@Gatew	97	1,079	49	7,925
202	63_ADS024	63_ADS024_WestCreek	332	1,310	38	13,104
203	63_AMS002	63_MUNICIPAL	2	0	100	1,296
204	680636 4)	LEOPARD CREEK DITCH	24	416	100	1,271
205	690510	HORSESHOE DITCH	15	671	48	2,500
206	690512	KNIGHT-EMBLING DITCH	7	340	60	1,350
207	690520	PINE ARROYA DITCH	11	278	49	1,234
208	69_ADS018	69_ADS018_Disappointment	94	1,543	55	6,822
209	710504	BEAR CREEK DITCH	10	38	36	585
210	710513	BURCH AND LONGWILL DITCH	9	126	31	919
211	710531	EAST EDER DITCH	4	47	40	373
212	710535	GARBARINO NO 1 DITCH	4	24	40	203
213	710536	GARBARINO NO 2 DITCH	3	38	52	213
214	710537	GARBARINO NO 3 DITCH	2	23	37	213
215	710545	GOULD & MORIARITY DITCH	6	110	38	914
216	710549	ILLINOIS DITCH	8	151	27	1,375
217	710551	ITALIAN DITCH	4	57	55	294
218	710555	KEYSTONE DITCH	9	69	30	819
219	710556	KING NO 1 DITCH	2	64	60	243
220	710559	KOENIG DITCH	4	66	50	415
221	710563	LINDSTROM DITCH	6	43	35	505
222	710572	MONUMENT ROCK DITCH	8	89	49	569
223	710573	MORIARITY DITCH	7	166	53	870
224	710575 3)	ORIGINAL RICO FLUME	1	0	36	283
225	710582	QUARRY NO 1 DITCH	7	38	22	657
226	710586	RIEVA DITCH	5	29	37	335
227	710609 4)	SUMMIT DITCH	135	0	0	0
228	710618 4)	TURKEY CREEK DITCH	90	0	0	0
229	710624	WEST EDER DITCH	7	167	60	667
230	712002	SUMMIT RES OUTLET	999	4,023	53	18,749
231	714673 2)	MAIN CANAL NO 1	802	5,000	0	0

#	Model ID #	Name	Cap (cfs)	1993 Irrig. Acres	Average System Efficiency (percent)	Average Annual Demand (af)
232	714674 [2)]	MAIN CANAL NO 2	999	5,000	0	0
233	71_ADS017	71_ADS017_DoloRabvMcPhee	221	1,762	58	7,606
234	73_ADS025	73_ADS025_LittleDoloresR	139	3,070	54	16,357
235	770516	CONFAR AND RUSSELL DITCH	7	44	47	344
236	770524	EAKLOR DITCH	34	377	47	2,239
237	770529	ELMER DITCH NO 1	15	335	57	1,635
238	770531	ENTERPRISE DITCH	31	296	34	2,949
239	770536	FITZHUGH DITCH	9	157	54	821
240	770559	MIDLAND DITCH	19	159	54	935
241	770560	MONTOYA DITCH	5	6	5	381
242	770562	NAVAJO MEADOW DITCH	16	20	21	556
243	770564	NAVAJO RIVER DITCH	16	34	23	673
244	770576	SHAHAN IRRIGATION DITCH	8	18	16	389
245	770579	SOUTH SIDE DITCH	21	55	11	2,172
246	770585	UNDERWOOD DITCH	9	60	35	399
247	770586	UNDERWOOD DITCH NO 2	8	140	60	587
248	770587	UPPER CAMP DITCH	15	29	12	1,032
249	770588	UPPER NAVAJO DITCH	7	35	35	450
250	770597	NEW BOND HOUSE D(NAVAJO)	35	20	3	1,368
251	774635 [4)]	USBR_NAVAJO_DIVERSION	950	0	100	0
252	774636 [4)]	USBR_LITTLE_NAVAJO_DIVR	670	0	100	0
253	779999 [4)]	SanJ_Chama_Summary_Node	950	0	100	168,177
254	77_ADS001	77_ADS001_NavajoRiver	160	1,136	43	7,190
255	780501	ABRAHAM DAVIS DITCH	18	407	52	2,084
256	780506 [1)]	BARNES DITCH	11	2	58	0
257	780507	BARNES-MEUSER AND SHAW D	23	1,458	58	5,367
258	780513	BUCKSKIN-NAILOR DITCH	22	193	10	3,149
259	780523 [1)]	CARL AND WEBB DITCH	7	75	16	0
260	780524 [1)]	CIMARRON DITCH	5	232	31	0
261	780525 [1)]	CLAYTON-REED DITCH	10	10	9	0
262	780543	EUGENIO GALLEGOS DITCH	5	53	13	498
263	780544	F S MOCKLER DIVSYS	15	334	31	2,185
264	780545	FARROW AND PETERSON D	17	63	3	3,893
265	780552	GALLEGOS HOME DITCH	6	39	15	861
266	780555	GEORGE S MCDONALD DITCH	6	80	37	511
267	780562	HOSSACK CREEK DITCH	14	158	51	895
268	780571	BESS GIRL DITCH	10	451	44	1,773
269	780580	M E AND M DITCH	12	166	30	1,223
270	780590 [1)]	NICKLES BROTHERS DITCH	9	29	9	0
271	780594 [1)]	PAGOSA DITCH	3	28	16	0
272	780604	PIEDRA FALLS DITCH	26	929	16	7,347
273	780617	STEVENS&CLAYTON DITCH	16	331	9	7,205
274	780638	TONER AND STEVENS DITCH	11	337	50	1,715
275	780659 [1)]	LITTLE PAGOSA CREEK DIVR	26	21	16	0
276	780692 [3)]	FAIRFIELD MUN. WATER SYS	999	0	36	646

#	Model ID #	Name	Cap (cfs)	1993 Irrig. Acres	Average System Efficiency (percent)	Average Annual Demand (af)
277	784670 [4)]	DON LAFONT DITCH NO 1	4	0	100	85
278	784671 [4)]	DON LAFONT DITCH NO 2	6	0	100	235
279	784672 [4)]	WILLIAMS CR SQ PASS DIVR	10	0	100	155
280	78_ADS004	78_ADS004_PiedraRiver	164	2,076	53	16,733
281	990707	GURLEY_IRRIG	1051	12,412	49	47,160
282	AZ_IRR [4)]	AZ_IR	9999	0	100	0
283	AZ_NIR [3)]	AZ_NIR	9999	0	100	0
284	CO_ALP [5)]	CO_ALP_Demands	999	0	50	0
285	NM_4CPP [3)]	FourCornersPP	99	0	83	46,987
286	NM_ABVARCH	AboveArchuleta	5	0	21	0
287	NM_ALP1 [5)]	NM_ALP_Animas_Demand	999	0	50	0
288	NM_ALP2 [5)]	NM_ALP_SanJuan_Demand	999	0	50	0
289	NM_ANIM	NM_AnimasIrr	378	0	20	117,118
290	NM_ARCH	ArchuletaDitch	1	0	22	360
291	NM_AZTEC [3)]	AztecMI	9999	0	50	5,014
292	NM_BLOOM [3)]	BloomfieldMI	90	0	50	5,001
293	NM_CHACO	ChacoIrr	132	0	40	27,921
294	NM_CITZ	CitizenDitch	105	0	21	33,954
295	NM_CUDEI	CudeiCanal	11	0	0	0
296	NM_CUDEIh	CudeiCanal Historical	11	0	28	2,727
297	NM_ECHO	EchoDitch	33	0	20	8,039
298	NM_FARMMI [3)]	FarmingtoNM_I	9999	0	50	10,030
299	NM_FMD	FarmersMutual	99	0	23	32,308
300	NM_FRUCAM	FruitlandAndCambridge	87	0	21	28,614
301	NM_GLADE	FarmingtonGlade	18	0	20	1,837
302	NM_HAMM	Hammond	98	0	30	33,802
303	NM_HOGB	Hogback	137	0	18	47,207
304	NM_JEWV	JewettValley	32	0	23	10,487
305	NM_JICIRR	JicarillaIrri	40	0	35	4,981
306	NM_JICNEW	JicarillaNew	99999	0	100	0
307	NM_JICNIR [3)]	JicarillaNonIr	9999	0	90	379
308	NM_LPIRR	LowerLaPlataIrr	113	0	40	28,406
309	NM_LPNIR [3)]	LaPlataNonIr	9999	0	50	2,706
310	NM_NGBAL [3)]	NIIP NonIrr	3325	0	94	33,242
311	NM_NGNIIP [3)]	NIIP NonIrr	465	0	100	4,647
312	NM_NIIP	NIIP	1800	0	80	315,860
313	NM_NIIP_R1 [7)]	NIIP Ojo Return	9999	0	100	0
314	NM_NIIP_R2 [7)]	NIIP Chaco Return	9999	0	100	0
315	NM_NIIP_R3 [7)]	NIIP Gallegos Return	9999	0	100	0
316	NM_REDW	RedWash	8	0	20	0
317	NM_SJGS [3)]	SJPowerPlant	80	0	100	16,200
318	NM_SRMI [3)]	ShiprockMI	9999	0	50	1,445
319	NM_TURLEY	TurleyDitch	6	0	23	1,931
320	NM_U2NIR [3)]	NM_U2NonIr	9999	0	50	1,787
321	NM_U3NIR [3)]	NM_U3NonIr	9999	0	50	1,653

#	Model ID #	Name	Cap (cfs)	1993 Irrig. Acres	Average System Efficiency (percent)	Average Annual Demand (af)
322	NM_U5NIR [3)]	NM_U5NonIr	9999	0	50	0
323	NM_U6NIR [3)]	NM_U6NonIr	9999	0	50	650
324	NM_U7NIR [3)]	NM_U7NonIr	9999	0	50	398
325	NM_U8NIR [3)]	NM_U8NonIr	9999	0	60	0
326	NM_USIRR [3)]	USNavajoIrr	42	0	40	3,707
327	NM_USNIR [3)]	USNavajoNonIr	9999	0	50	1,076
328	NM_WESTW	Westwater	2	0	40	311
329	NM_WHIS	WhiskeyCreek	2	0	40	890
330	UT_IRR [4)]	UT_IRR	9999	0	100	5,771
331	UT_NIR [3)]	UT_NIR	9999	0	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.

Where to find more information

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

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 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 sj2009.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.

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)*

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 2005) but capped at 0.54.

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 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 2005 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 2005 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 created 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. It is recommended for future updates that the StateDMI commands be run initially without the “set” commands. This allows the modeler to view any changes to water rights (transfers, conditional to absolute, abandonment, etc.) reflected in updated versions of HydroBase and modify the “set” commands as necessary.

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 x 1 + 4 x 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 54 percent for Colorado structures with the exception of MVIC/Dolores Project structures. Maximum system efficiency for Towaoc Canal (320884) is set to 72 percent and Dove Creek Canal (322006) is set to 63 percent to reflect the percent of acreage irrigated with sprinklers. 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 was generated by StateCU for the period 1975 through 2005, then extended back to 1909 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. A standard elevation adjustment was applied to TR-21 crop coefficients. 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 structure was set to the acreage defined in 1993 for the entire study period. The irrigation water requirement file contains the time series of monthly irrigation water requirements for structures whose efficiency varied 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
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, in feet, 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).
- An instream flow nodes was used to represent the recreational instream diversion right associated with the Durango Boating Park (301691).

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	290768b	Rioblanco_isf	29.00
3	291900	SAN JUAN RIVER MIN FLOW	50.00
4	291902	WEST FK SAN JUAN R MIN F	25.00
5	291905	WOLF CREEK MIN FLOW	11.00
6	29_bypass	Rioblanco_bypass	40.00
7	301691	Durango Boating Park	1400.00
8	301902	JUNCTION CREEK	15.00
9	301903	FLORIDA RIVER	14.00
10	301904	FLORIDA RIVER	20.00
11	301928	HERMOSA CR(LOWER REACH)	37.00
12	309999	Lemon_Res_Rel_USA	4.00
13	30_bypass	RidgesBasin_Min_Bypass	225.00
14	311900	LOS PINOS RIVER	32.00
15	319999	Vallecito_Res_Winter	0.00
16	331905	LA PLATA RIVER	9.00
17	332999	LaPlata_Compact_ISF	100.00
18	601319	BIG BEAR CREEK	2.00
19	601320	BILK CREEK	3.00
20	601374	DEEP CREEK	4.00

#	ID	Name	Decree (cfs)
21	601378	ELK CREEK	2.50
22	601381	SAN MIGUEL RIVER	6.50
23	601382	SAN MIGUEL RIVER	20.00
24	601383	SOUTH FK SAN MIGUEL R	9.00
25	601388	FALL CREEK	5.00
26	601389	LEOPARD CREEK	2.50
27	601390	NATURITA CREEK	3.00
28	601397	LAKE FK SAN MIGUEL RIV	2.50
29	601788	BEAVER CREEK	5.00
30	601789	SALTADO CREEK	2.00
31	601950	SAN MIGUEL RIVER	93.00
32	630644	WEST CREEK	6.00
33	710639	DOLORES MINIMUM FLOW	78.00
34	711907	DOLORES RIVER	20.00
35	711912	DOLORES RIVER	35.00
36	711915	DOLORES RIVER	50.00
37	711920	WEST FORK DOLORES RIVER	10.00
38	711921	WEST FORK DOLORES RIVER	17.00
39	711922	FISH CREEK	3.00
40	712999	McPhee_ISF_Fish&Wild	70.00
41	719999	GroundHog/McPhee_Ex	0.00
42	772000	Little_Navajo-Chama_B	27.00
43	772005	NAVAJO RIVER MIN FLOW	92.00
44	772005b	Navajo_isf	55.00
45	7_bypass	Navajo_bypass	88.00
46	781900	PIEDRA RIVER MIN FLOW	30.00
47	781901	PIEDRA RIVER MIN FLOW	44.00
48	781902	PIEDRA RIVER MIN FLOW	53.00
49	781903	PIEDRA RIVER MIN FLOW	70.00
50	781905	MID FK PIEDRA R MIN FLOW	11.00
51	781906	EAST FK PIEDRA R MIN FL	10.00
52	781907	WILLIAMS CREEK MIN FLOW	14.00
53	781908	WEMINUCHE CR MIN FLOW	9.00
54	781909	WEMINUCHE CR MIN FLOW	18.00
55	781910	PIEDRA RIVER MIN FLOW	70.00
56	902000	Navajo_Res_Min_Rel	250.00
57	902200	Navajo_Res_Animas_Min_Re	500.00
58	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

Where to find more information

- StateMod documentation describes the different types of operating rights that can be specified in this file, and describes the required format for the file.
- The section “San Juan and Dolores River Projects and Special Operations” in the document “San Juan and Dolores River Basin Information” describes each reservoir’s typical operations.

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 Summit 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

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

Operating ru

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

Operatin

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 – 2005). 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 2005; 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 2005.

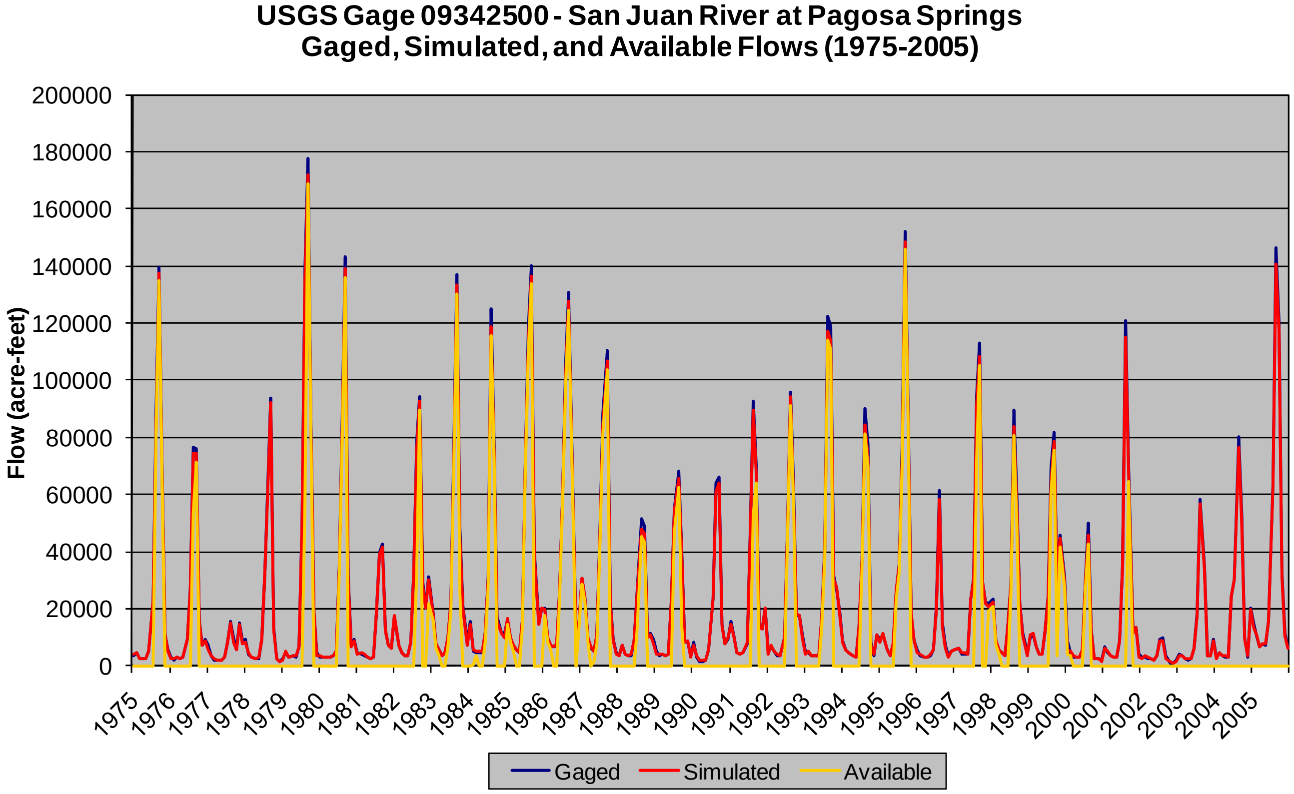
Baseline flows are generally higher than historical flows during the irrigation season on tributaries with significant storage and on tributary gages upstream of senior diverters. This is, in part, due to increased reservoir releases and bypassed flow required to meet the higher Baseline demands. In 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 2005 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 (1909-2005)

Gage ID	Gage Name	Simulated Flow (af)	Simulated Available Flow (af)
09339900	East Fork San Juan River above Sand Creek	66,547	40,002
09341500	West Fork San Juan River near Pagosa Springs	118,348	66,702
09342000	Turkey Creek near Pagosa Springs	25,450	16,157
09342500	San Juan River at Pagosa Springs	274,538	152,823
09343300	Rio Blanco bl Blanco Div Dam nr Pagosa Springs	18,968	2,200
09344000	Navajo River at Banded Peak Ranch near Chromo	82,024	11,575
09344400	Navajo River below Oso Diversion Dam nr Chromo	48,834	12,927
09345200	Little Navajo River bl Oso Diversion Dam nr Chromo	4,951	1,732
09346000	Navajo River at Edith	61,257	21,272
09346400	San Juan River near Carracas	418,360	218,020
09347500	Piedra River at Bridge Ranger Sta. nr Pagosa Springs	78,600	41,830
09349500	Piedra River near Piedra	245,248	130,038
09349800	Piedra River near Arboles	290,565	157,944
09352900	Vallecito Creek near Bayfield	108,542	34,934
09353500	Los Pinos River near Bayfield	276,099	67,420
09354000	Los Pinos River at Bayfield	137,748	80,597
09354500	Los Pinos River at La Boca	176,052	93,488
09355000	Spring Creek at La Boca	24,119	7,986
09355500	San Juan River near Archuleta	617,381	407,768
09357500	Animas River at Howardsville	78,116	59,414
09359000	Mineral Creek near Silverton	73,508	54,692
09359500	Animas River above Tacoma	431,400	221,576
09361000	Hermosa Creek near Hermosa	97,773	69,370
09361500	Animas River at Durango	591,740	252,884
09362999	Florida River above Lemon Reservoir (USBR data)	69,028	8,827
09363200	Florida River at Bondad	64,016	43,451
09363500	Animas River near Cedar Hill, NM	697,309	416,801
09364500	Animas River at Farmington, NM	639,973	429,702
09365000	San Juan River at Farmington, NM	1,247,036	728,770
LONREDCO	Long Hollow at the Mouth near Red Mesa	5,683	1,881

Gage ID	Gage Name	Simulated Flow (af)	Simulated Available Flow (af)
09365500	La Plata River at Hesperus	30,320	3,265
09366500	La Plata River at CO-NM State Line	21,435	9,395
09367500	La Plata River near Farmington, NM	21,638	16,631
09368000	San Juan at Shiprock	1,228,201	807,446
09369500	Middle Mancos River near Mancos	5,080	3,754
09369000	East Mancos River near Mancos	7,666	4,149
09368499	Above Jackson Gulch Reservoir (USBR data)	10,985	774
09368500	West Mancos River near Mancos	26,524	6,672
09371000	Mancos River near Towaoc	28,773	26,907
09371010	San Juan River at Four Corners	1,308,210	899,374
09371400	Hartman Draw at Cortez	7,569	6,864
09371420	McElmo Creek above Alkali Canyon near Cortez	19,328	17,781
09371500	McElmo Creek near Cortez	40,152	26,767
09372000	McElmo Creek near CO-UT State Line	43,395	40,981
09379500	San Juan River near Bluff	1,376,051	1,376,051
09165000	Dolores River below Rico	103,662	36,575
09166500	Dolores River at Dolores	325,285	76,556
09166950	Lost Canyon Creek near Dolores	11,098	5,023
09168100	Disappointment Creek near Dove Creek	13,340	9,589
09169500	Dolores River at Bedrock	178,811	135,236
09171100	Dolores River near Bedrock	188,174	144,560
09171200	San Miguel River near Telluride	51,660	38,861
09172000	Fall Creek near Fall Creek	13,138	9,082
09172100	Leopard Creek at Noel	2,566	1,074
09172500	San Miguel River near Placerville	171,934	108,760
09173000	Beaver Creek near Norwood	8,046	5,799
09175500	San Miguel River at Naturita	223,231	216,926
09177000	San Miguel River at Uravan	257,287	249,959
09179500	Dolores River at Gateway	485,765	485,765



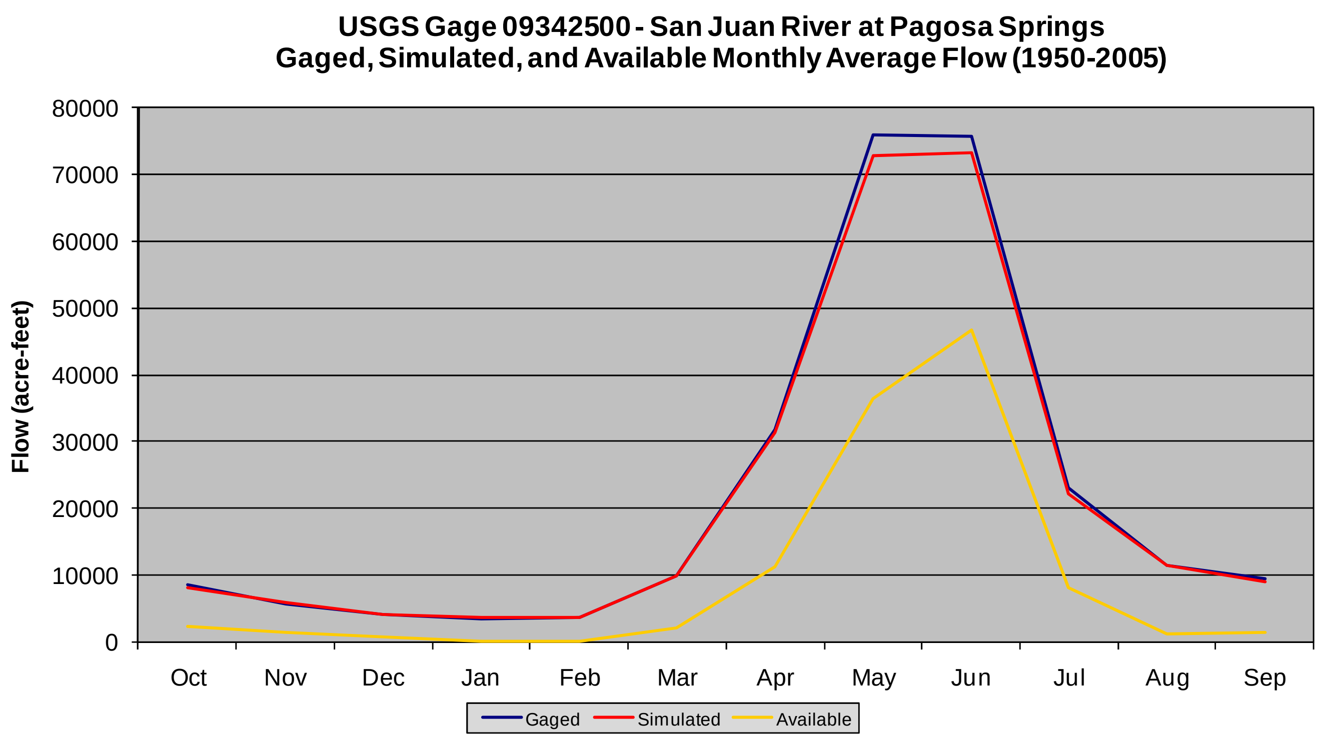
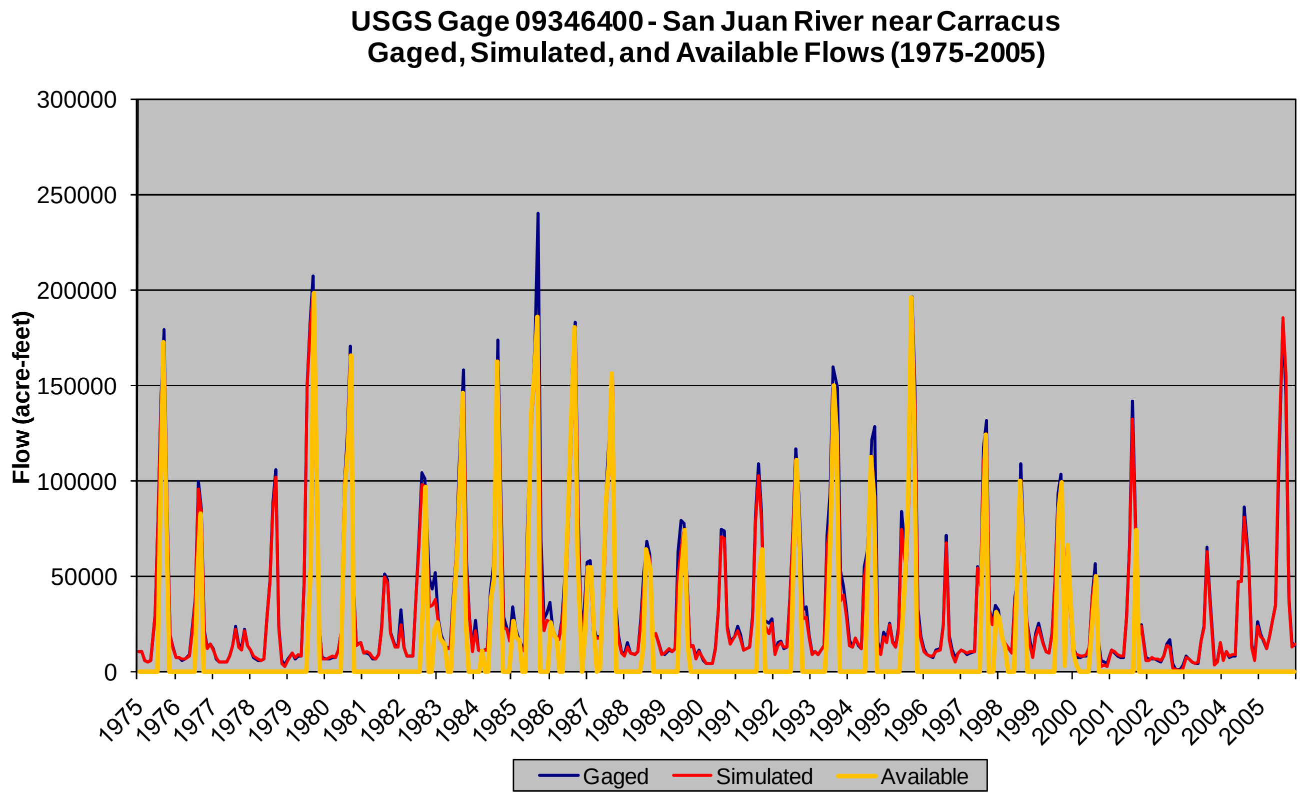


Figure 6.1 Baseline Results – San Juan River at Pagosa Springs



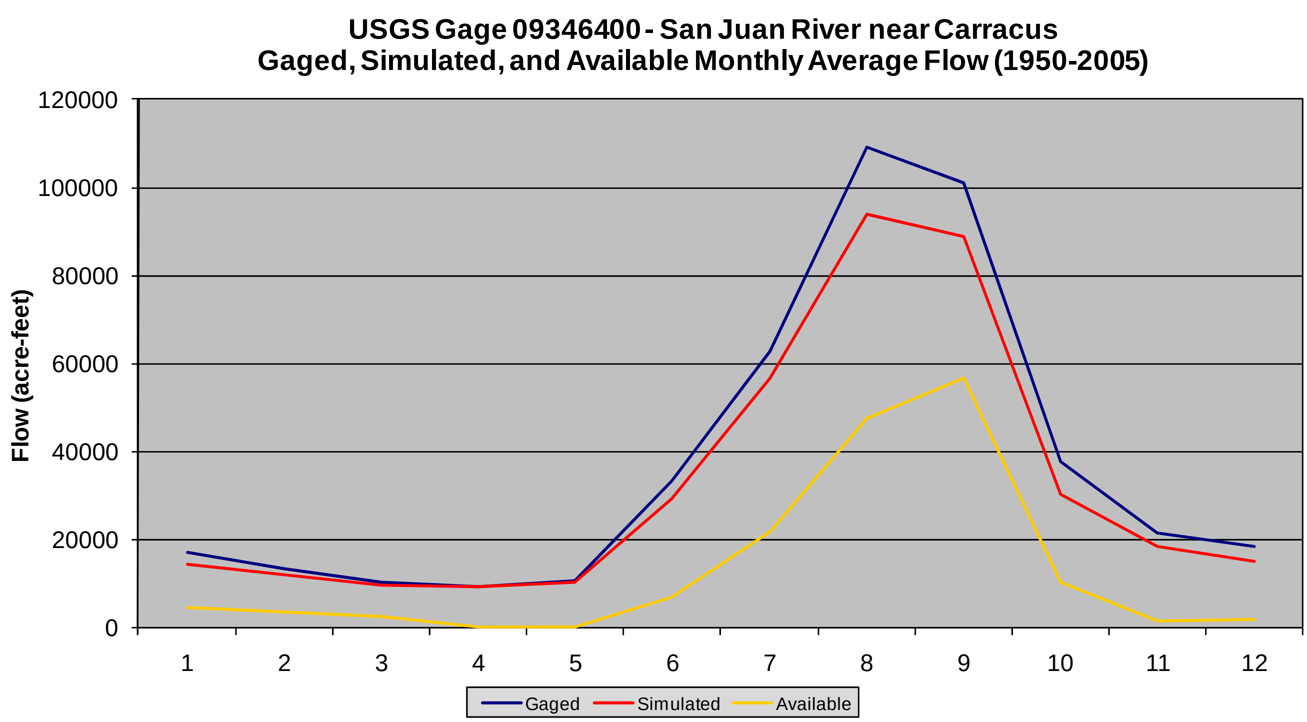
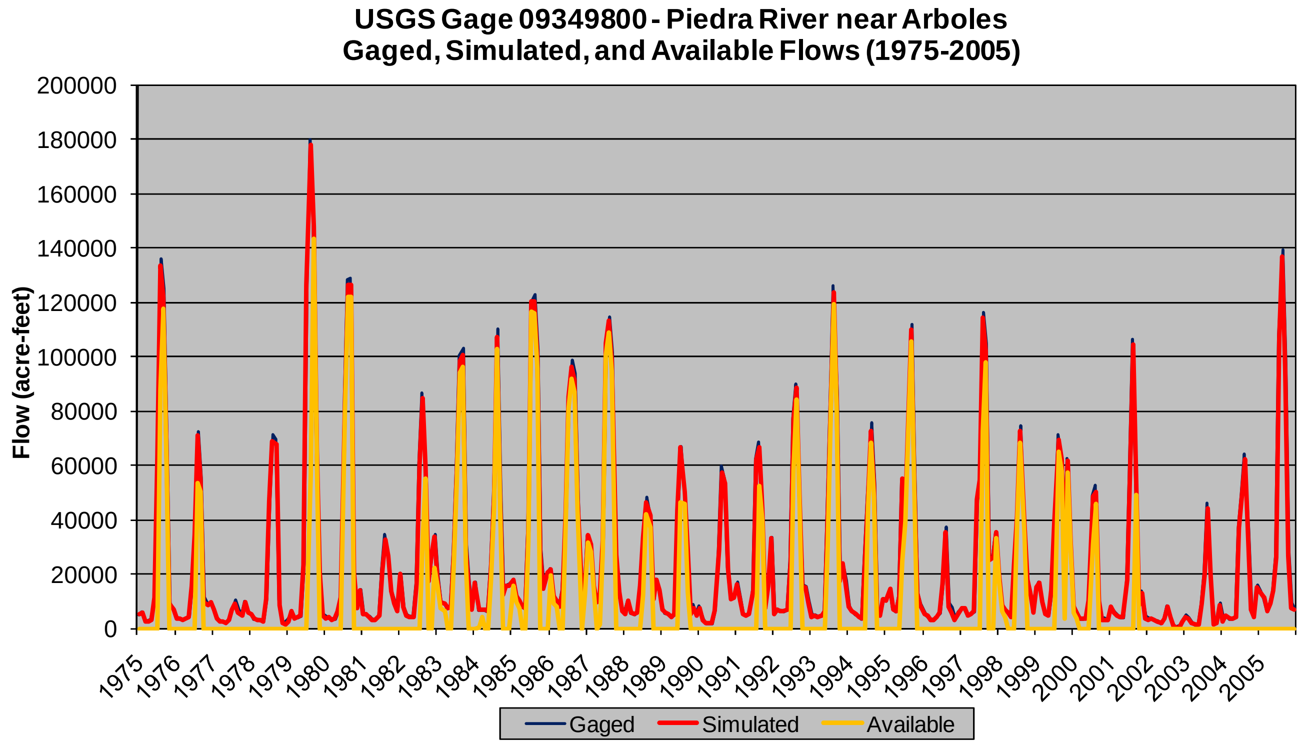


Figure 6.2 Baseline Results – San Juan River near Carracus



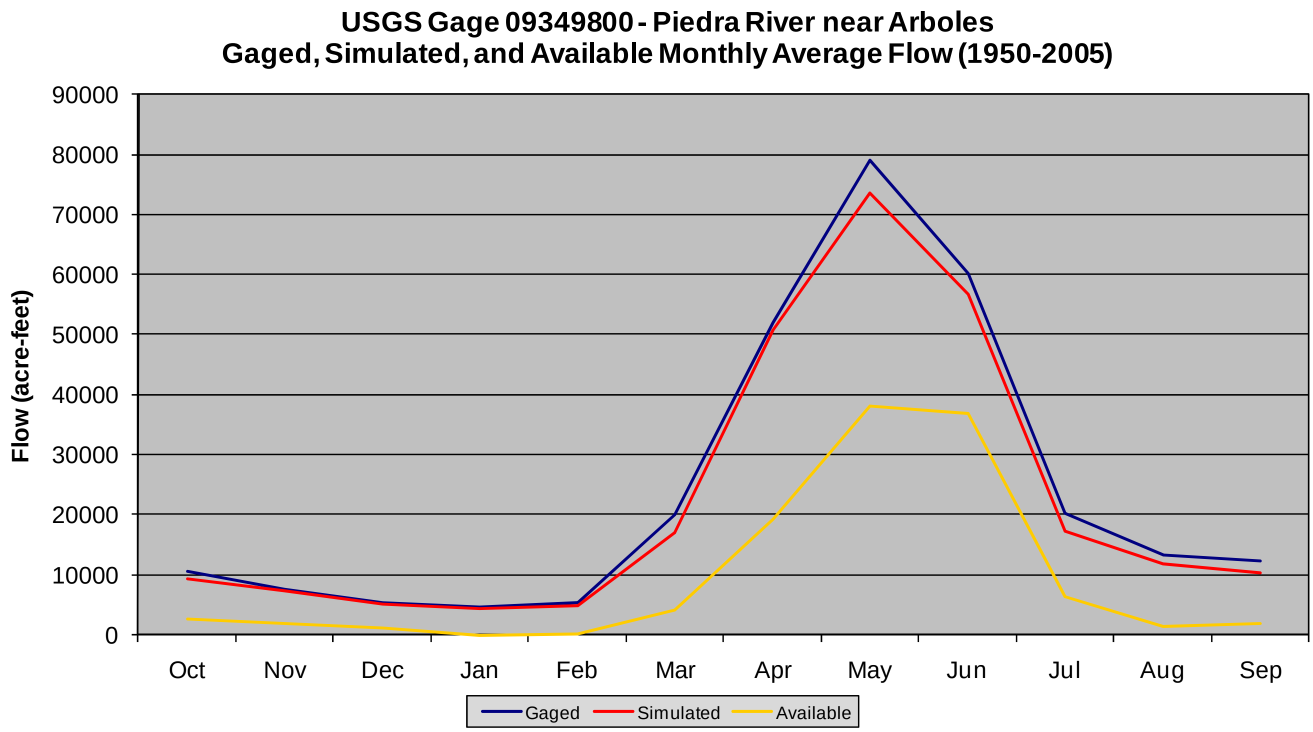
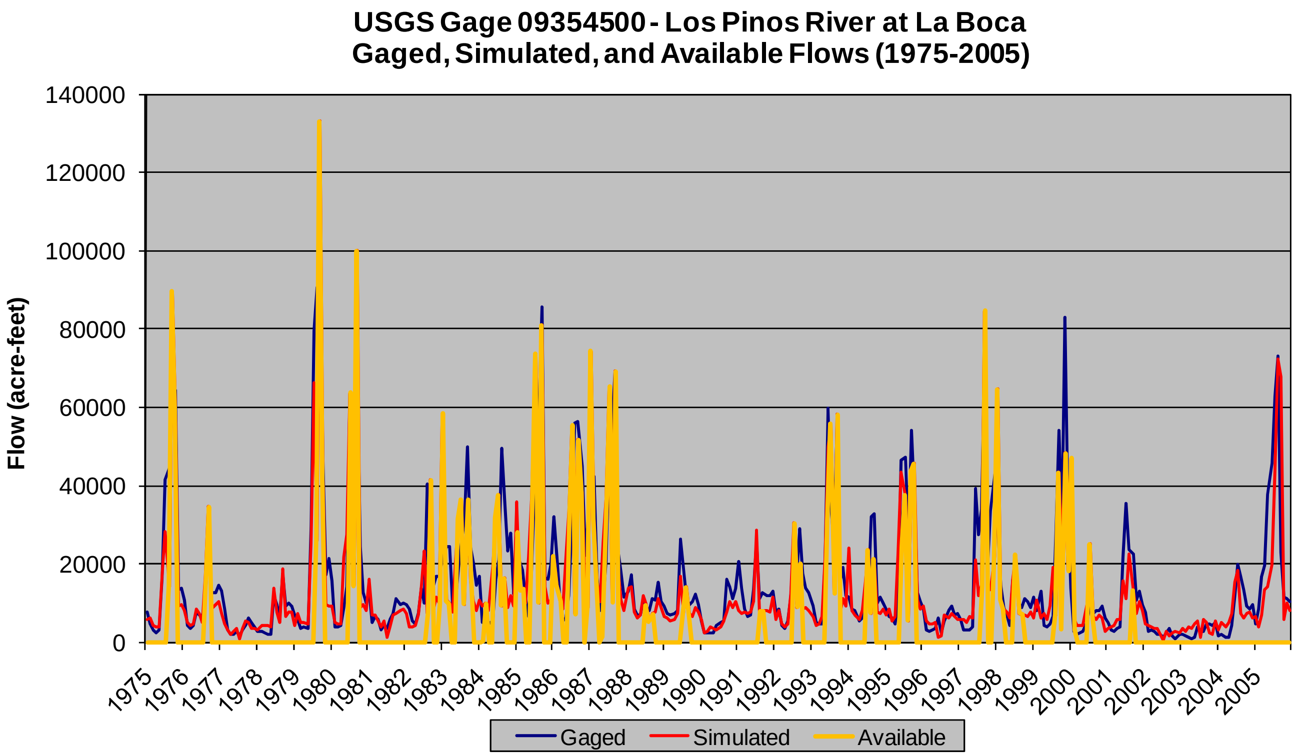


Figure 6.3 Baseline Results – Piedra River near Arboles



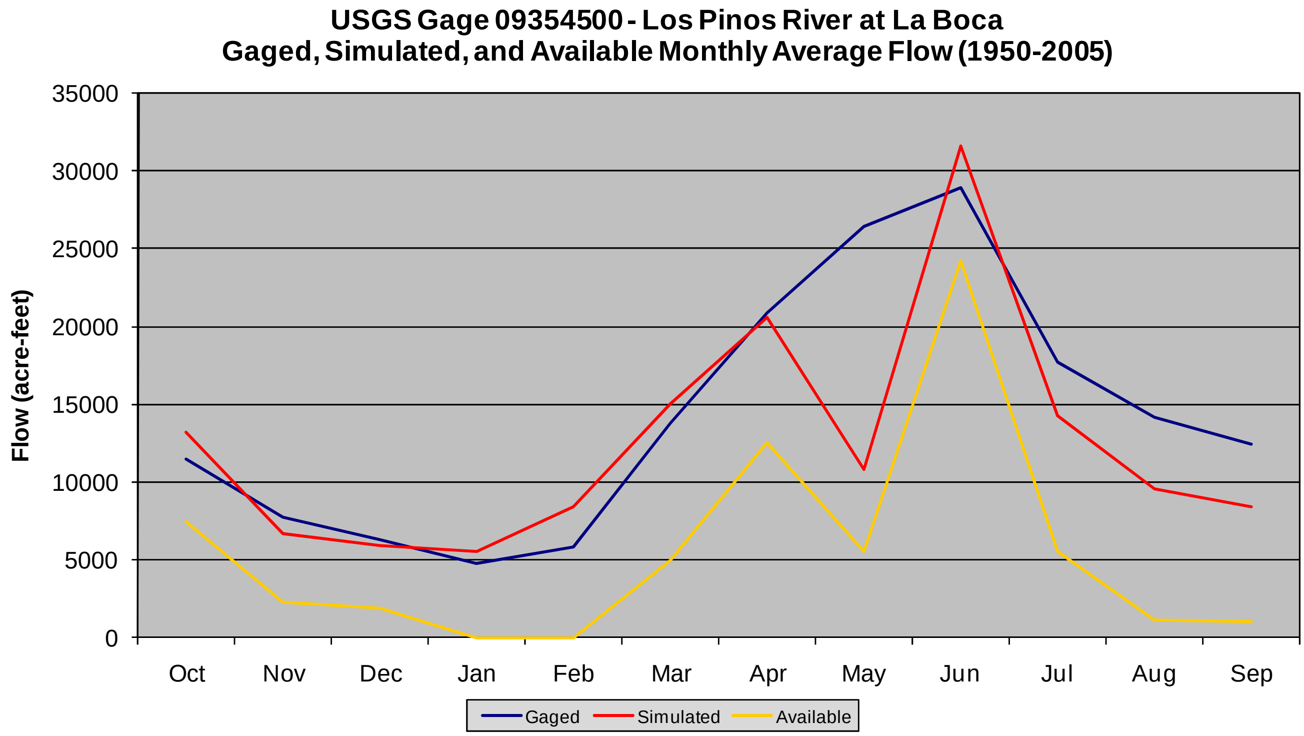
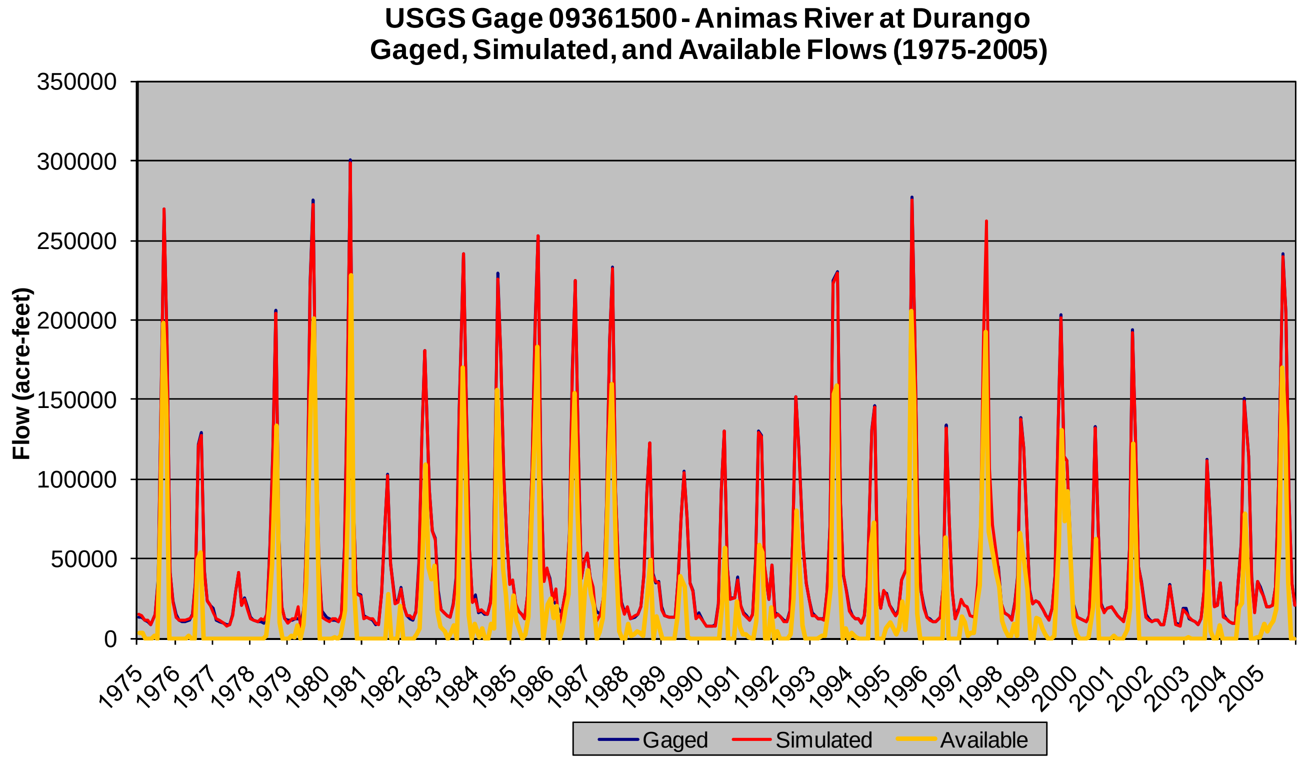


Figure 6.4 Baseline Results – Los Pinos River at La Boca



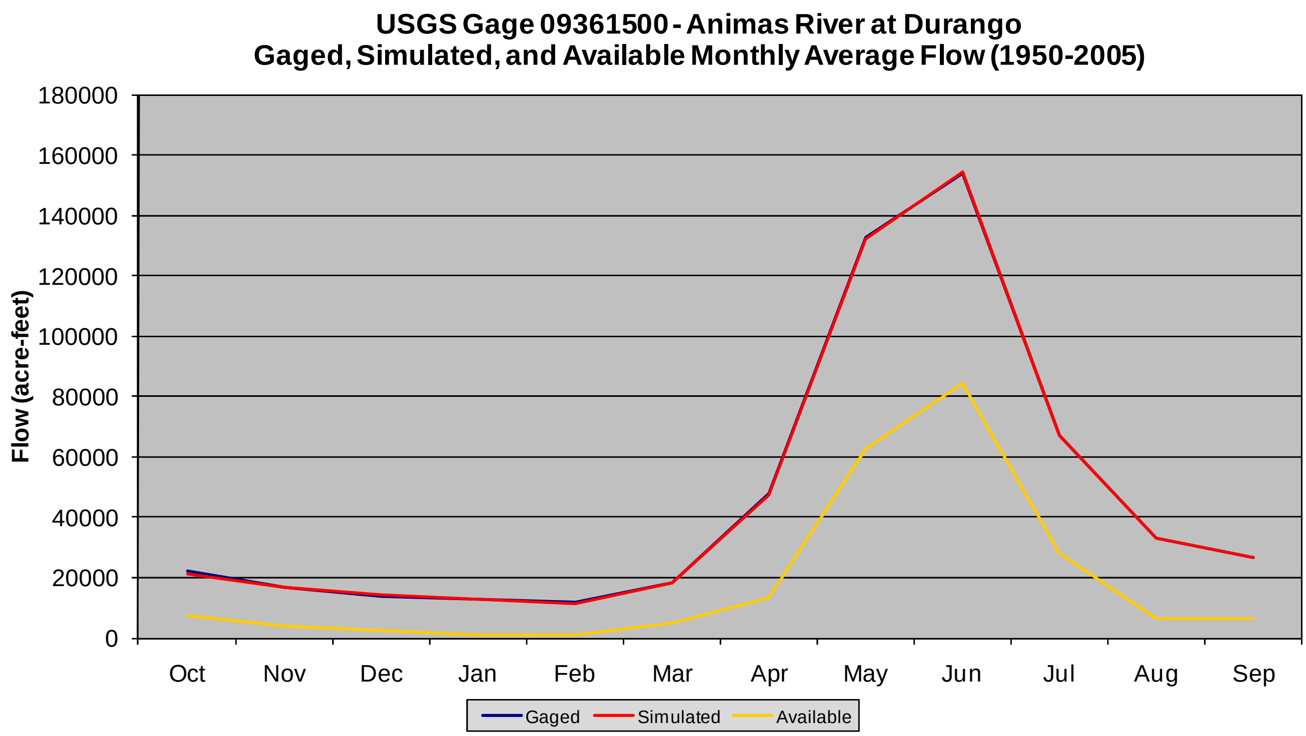
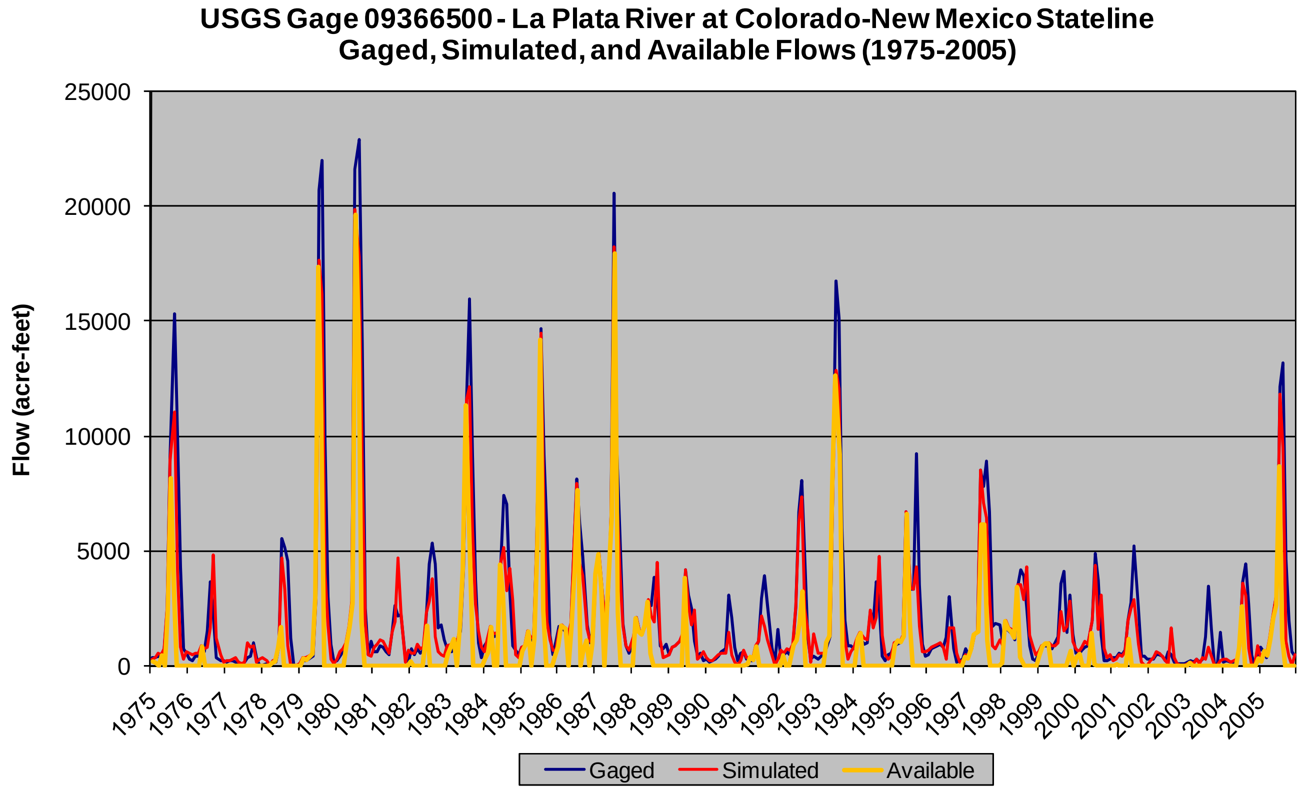


Figure 6.5 Baseline Results – Animas River at Durango



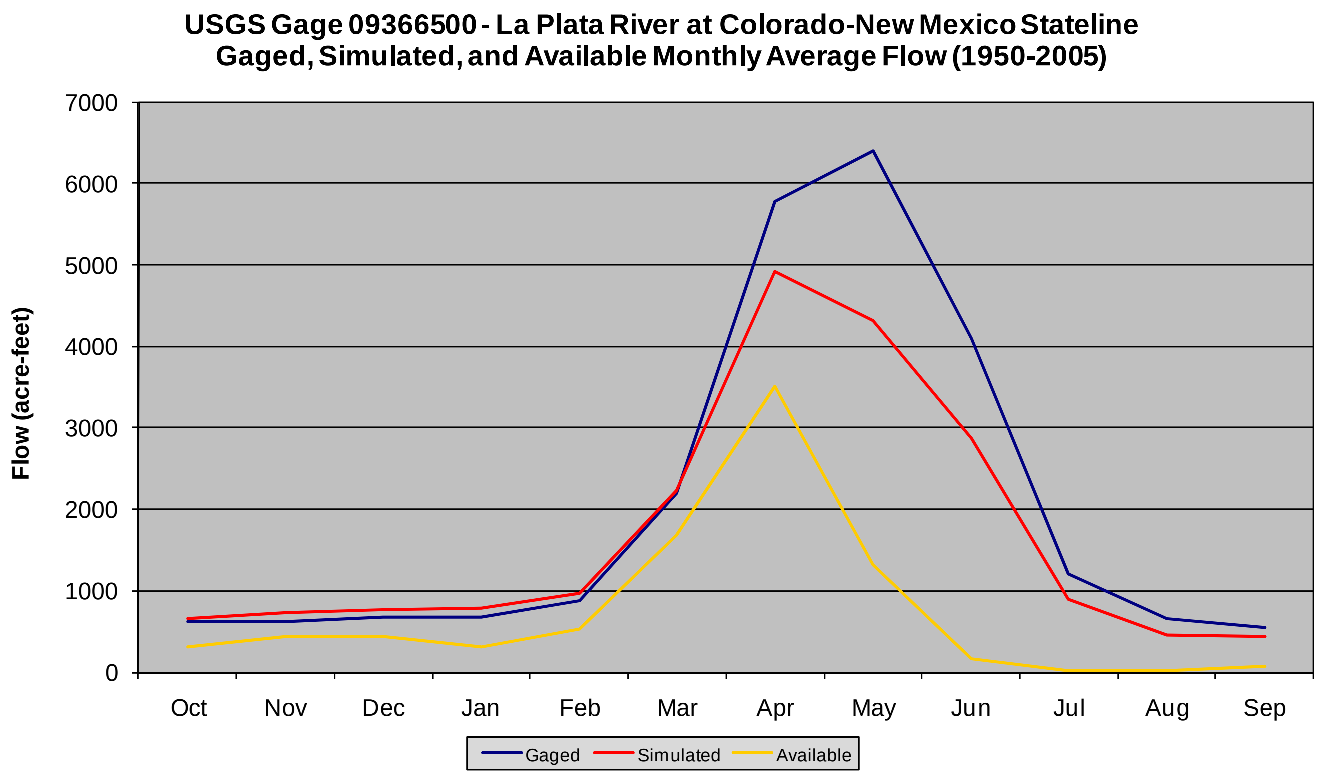
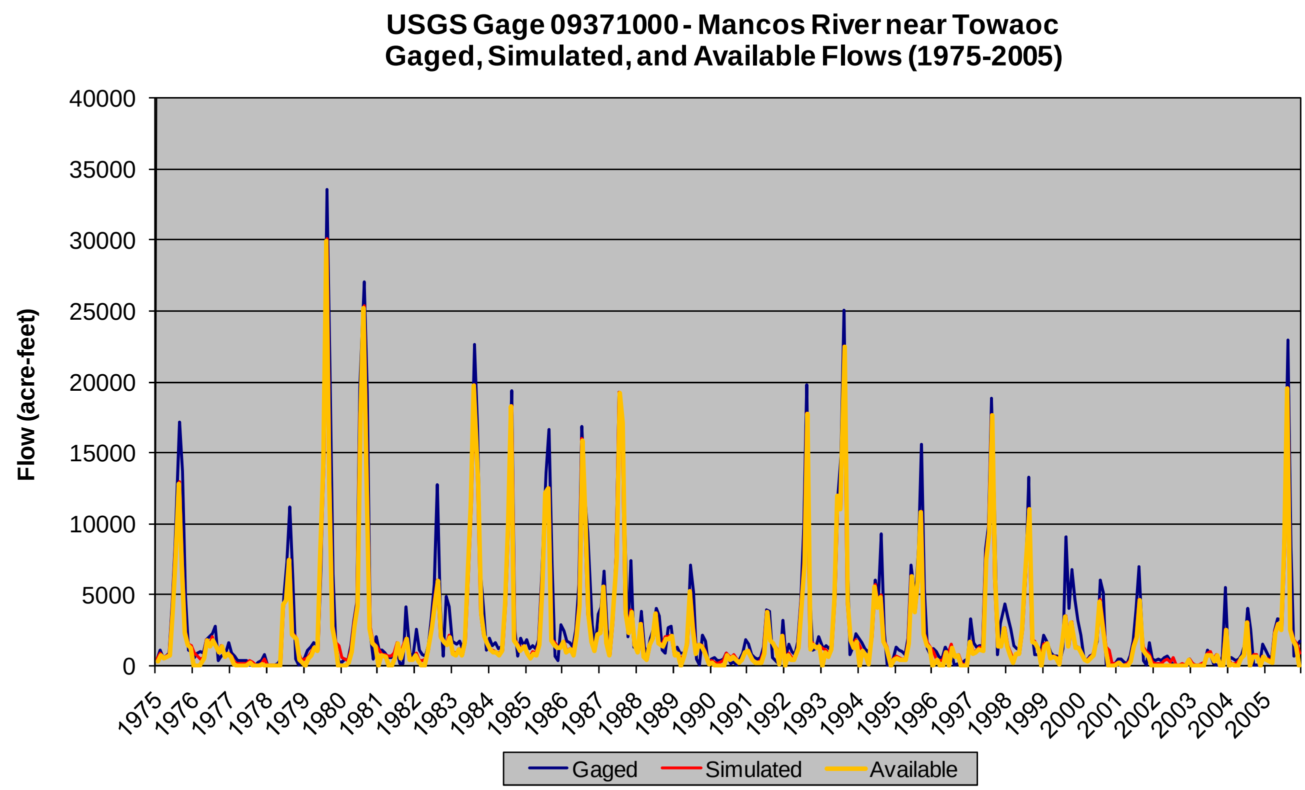


Figure 6.6 Baseline Results – La Plata River at Colorado-New Mexico Stateline



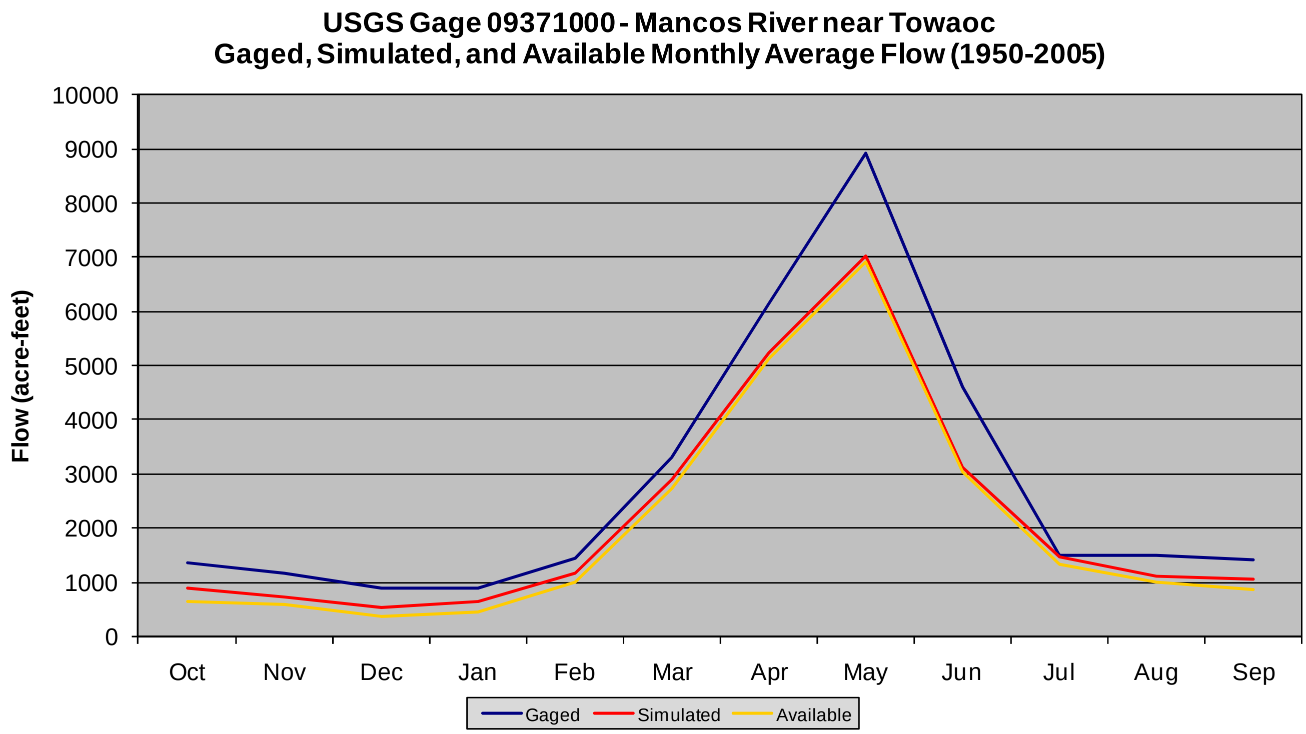
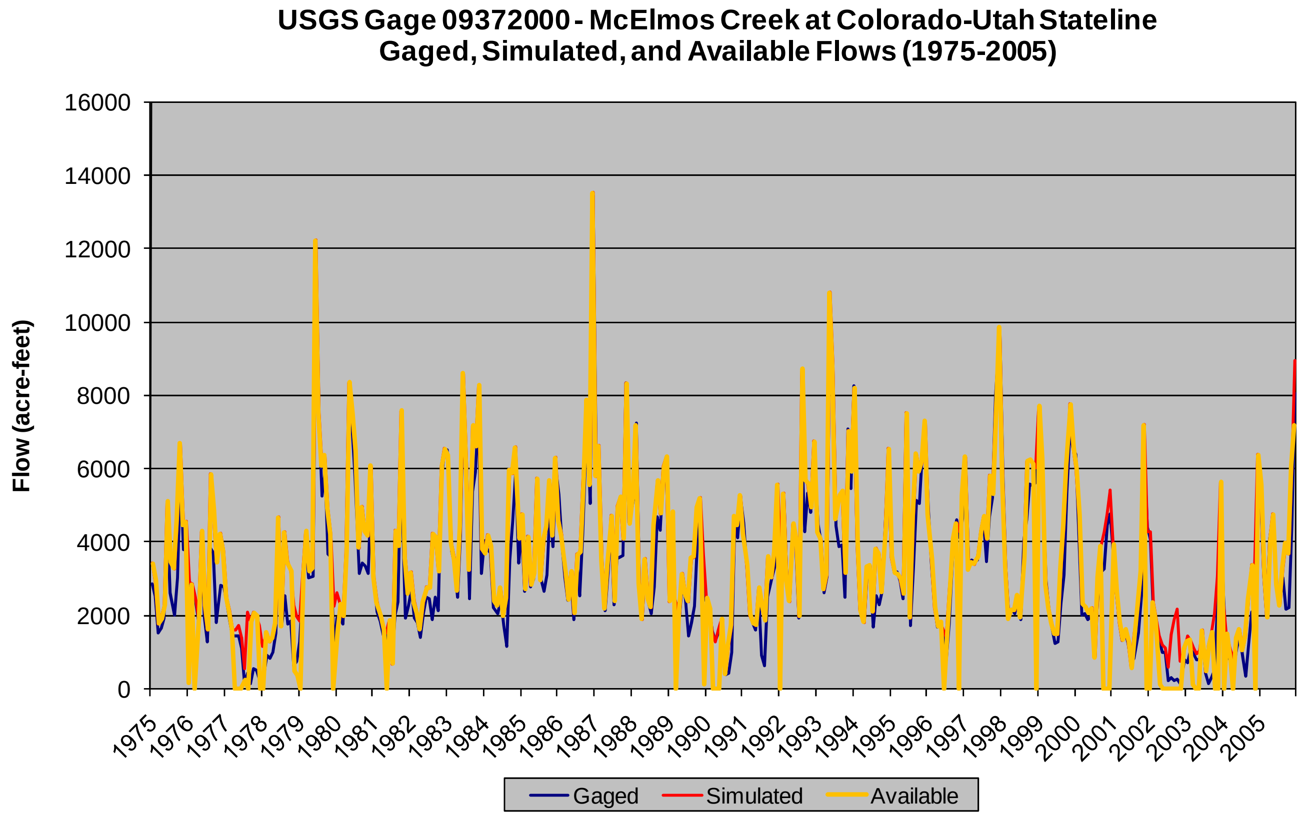


Figure 6.7 Baseline Results – Mancos River near Towaoc



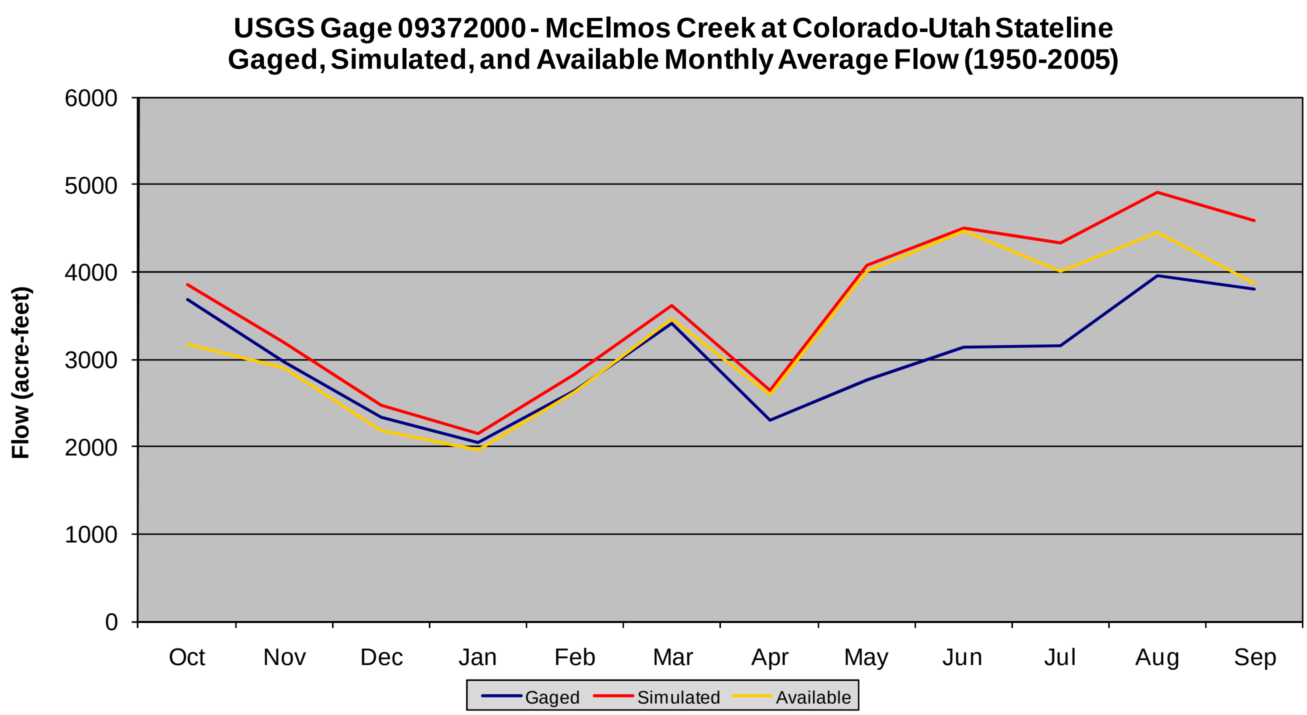
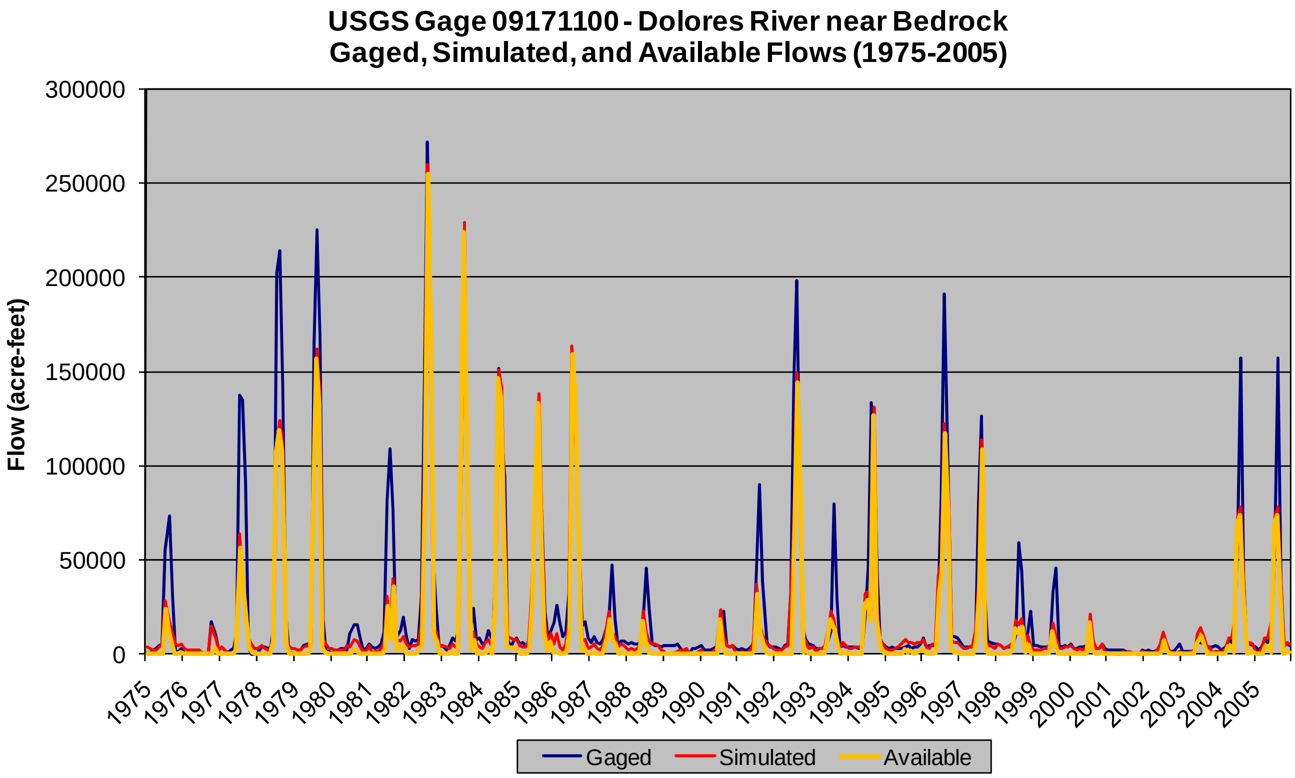


Figure 6.8 Baseline Results – McElmo Creek at Colorado-Utah Stateline



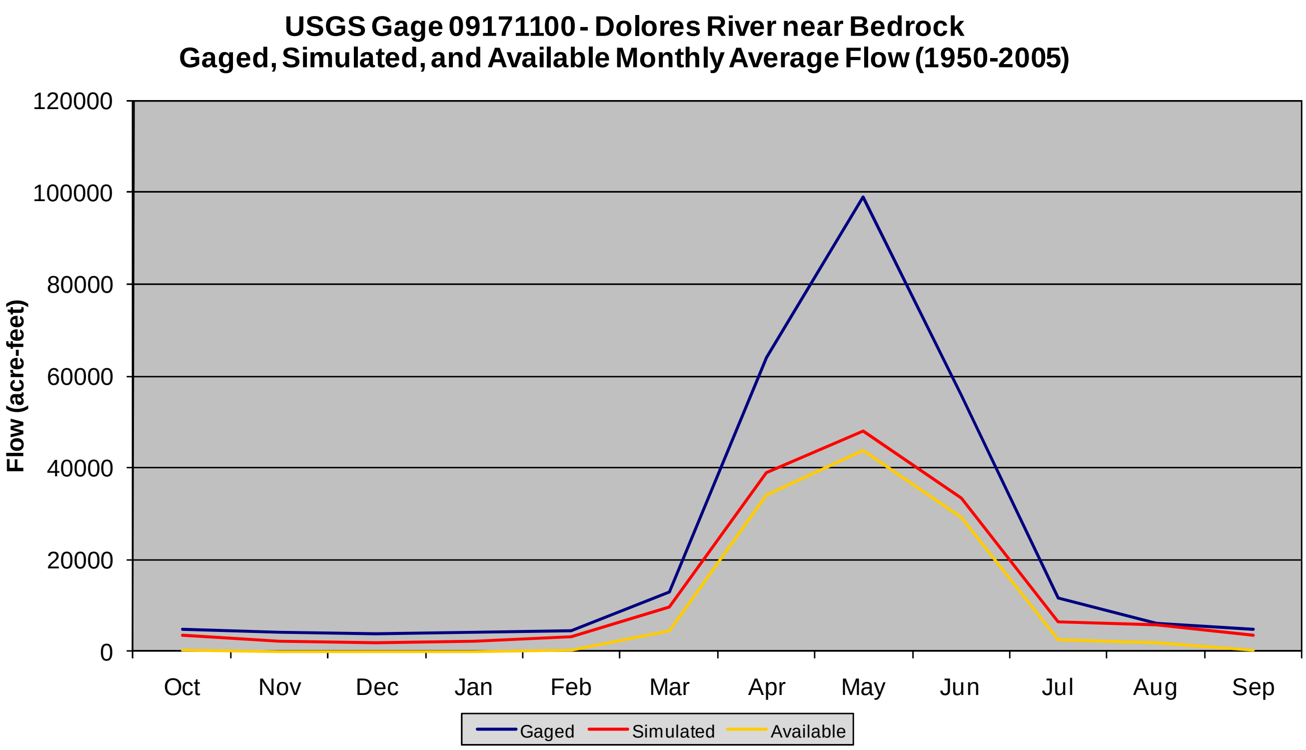
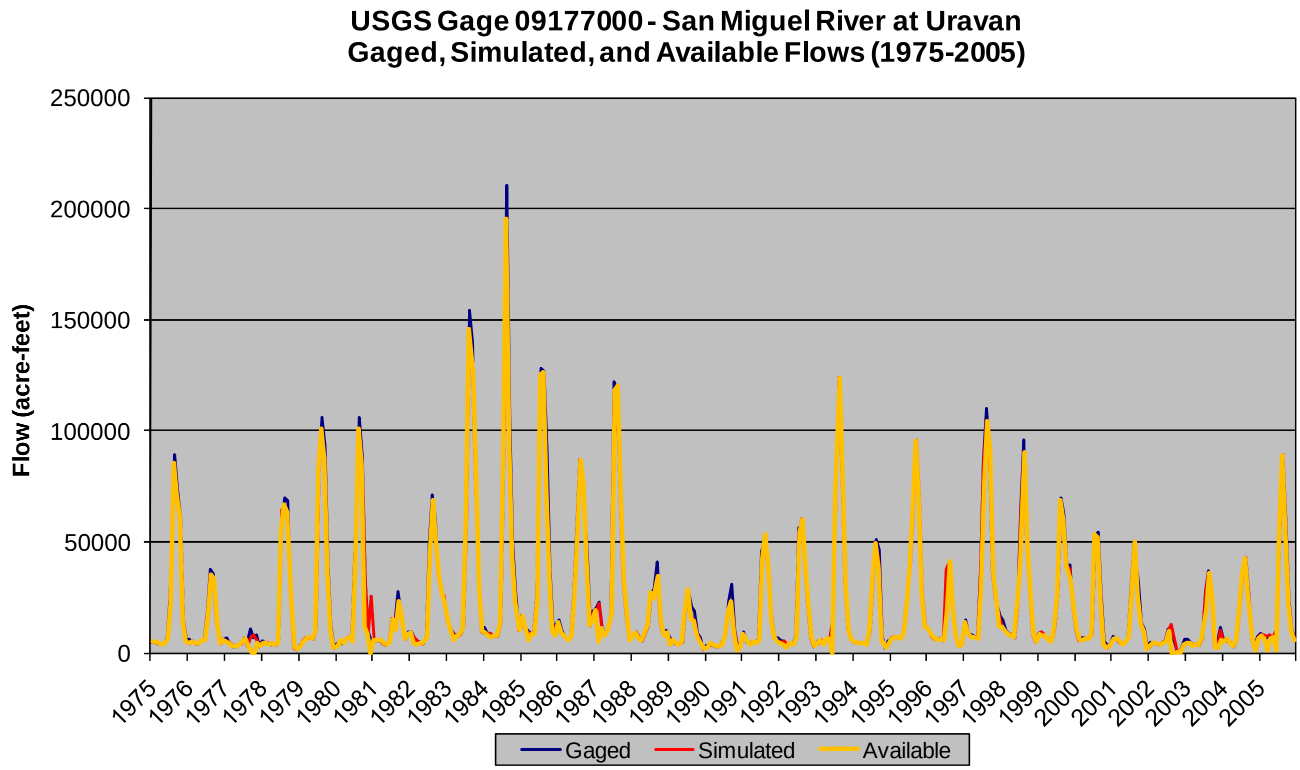


Figure 6.9 Baseline Results – Dolores River near Bedrock



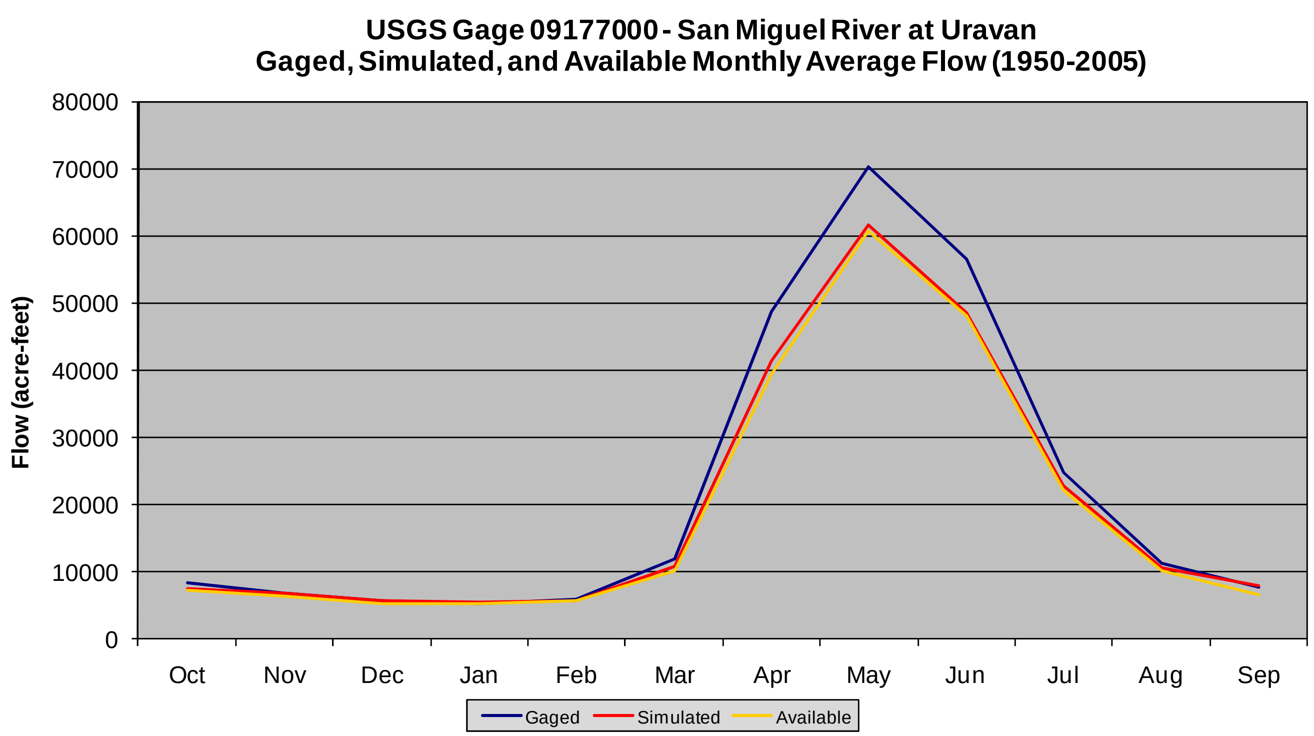


Figure 6.10 Baseline Results – San Miguel River at Uravan

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 2005 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 2005. 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 ▪ Non-irrigation structures – estimated current demand ▪ Demands placed on primary structures of multistructure systems and demands placed at carrier structure headgates	▪ Historical diversions ▪ 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 ▪ 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 ▪ 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 ▪ 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 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 are within 1 percent of 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 2 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 3 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 is around 2 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 (1975-2005). 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:

- Stream water inflow to the basin averages 3.0 million acre-feet per year, and stream water outflow averages 2.1 million acre-feet per year.
- Annual diversions amount to approximately 1.6 million acre-feet on average, indicating that there is extensive re-diversion of return flows in the basin.
- Approximately 772,000 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 1975-2005 (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	94,955	57,197	1,603	153,756	71,411	3,066	102,320	-24,643	2,105	-502	153,756	0	28,968
NOV	68,849	28,104	17	96,970	20,995	672	86,670	-11,384	2,217	-2,200	96,970	0	5,457
DEC	52,698	21,237	0	73,935	16,511	-17	87,170	-29,729	1,088	-1,088	73,935	0	4,227
JAN	58,202	18,362	0	76,564	15,701	215	96,227	-35,579	762	-762	76,564	0	4,212
FEB	80,168	14,985	1	95,153	14,348	894	103,787	-23,876	646	-645	95,153	0	4,793
MAR	176,146	15,962	109	192,217	23,025	2,441	146,217	20,426	1,104	-995	192,217	0	10,747
APR	435,966	32,524	3,418	471,908	79,295	5,428	294,952	88,815	3,850	-432	471,908	0	47,119
MAY	754,009	107,921	8,078	870,009	267,918	8,930	441,181	143,901	6,092	1,986	870,008	1	142,178
JUN	669,434	141,115	7,432	817,981	341,779	12,378	400,126	56,265	3,091	4,341	817,980	1	190,600
JUL	285,757	138,751	5,411	429,920	296,127	11,066	172,676	-55,360	1,760	3,651	429,920	0	155,867
AUG	159,730	128,333	1,825	289,889	241,649	6,040	103,014	-62,641	4,443	-2,618	289,889	0	107,381
SEP	128,531	103,031	1,808	233,370	168,438	5,939	94,831	-37,645	2,778	-970	233,370	0	70,914
TOT	2,964,448	807,522	29,702	3,801,672	1,557,195	57,052	2,129,171	28,549	29,934	-232	3,801,671	1	772,464

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 2005, 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 (1975-2005)
Calibration Run (acre-feet/year)

			Historical -Simulated		
Gage ID	**Historical**	**Simulated**	**Volume**	**Percent**	**Gage Name**
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	287,579	287,698	-119	0%	San Juan River at Pagosa Springs
09343000	*No gage during calibration period*				Rio Blanco near Pagosa Springs
09343300	33,980	34,046	-66	0%	Rio Blanco bl Blanco Div Dam nr Pagosa Sprgs
09344000	84,024	84,025	-1	0%	Navajo River at Banded Peak Ranch nr Chromo
09344400	47,760	47,933	-173	0%	Navajo River bl Oso Diversion Dam nr Chromo
09345200	6,390	6,689	-299	-5%	Little Navajo River bl Oso Div Dam nr Chromo
09346000	67,275	67,696	-421	-1%	Navajo River at Edith
09346400	451,442	451,707	-265	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	308,528	307,836	692	0%	Piedra River near Arboles

Gage ID	Historical	Simulated	Historical -Simulated Volume	Historical -Simulated Percent	Gage Name
09352900	107,015	107,015	0	0%	Vallecito Creek near Bayfield
09353500	299,267	298,085	1,182	0%	Los Pinos River near Bayfield
09354000	*No gage during calibration period*				Los Pinos River at Bayfield
09354500	189,953	190,758	-805	0%	Los Pinos River at La Boca
09355000	23,830	23,855	-25	0%	Spring Creek at La Boca
09355500	831,223	831,668	-445	0%	San Juan River near Archuleta
09357500	77,348	77,348	0	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	589,334	589,545	-211	0%	Animas River at Durango
09362999	73,459	73,459	0	0%	Florida River ab Lemon Reservoir (USBR data)
09363200	58,564	59,667	-1,103	-2%	Florida River at Bondad
09363500	714,323	714,769	-446	0%	Animas River near Cedar Hill, NM
09364500	639,319	641,151	-1,832	0%	Animas River at Farmington, NM
09365000	1,439,558	1,436,913	2,645	0%	San Juan River at Farmington, NM
LONREDCO	5,263	5,079	184	3%	Long Hollow at the Mouth near Red Mesa
9365500	31,393	31,628	-235	-1%	La Plata at Hesperus
09366500	27,450	28,416	-966	-4%	La Plata River at CO-NM State Line
09367500	23,548	27,808	-4,260	-18%	La Plata River near Farmington, NM
09368000	1,412,035	1,406,239	5,796	0%	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	38,873	38,509	364	1%	Mancos River near Towaoc
09371010	1,533,987	1,527,047	6,940	0%	San Juan River at Four Corners
09371400	10,063	10,063	0	0%	Hartman Draw at Cortez
09371420	19,270	19,402	-132	-1%	McElmo Creek above Alkali Canyon nr Cortez
09371500	42,180	42,505	-325	-1%	McElmo Creek near Cortez
09372000	38,909	39,150	-241	-1%	McElmo Creek near CO-UT State Line
09379500	1,539,296	1,533,123	6,173	0%	San Juan River near Bluff
09165000	98,179	98,189	-10	0%	Dolores River below Rico
09166500	317,346	317,817	-471	0%	Dolores River at Dolores
09166950	15,428	12,577	2,851	18%	Lost Canyon Creek near Dolores
09168100	20,926	20,958	-32	0%	Disappointment Creek near Dove Creek
09169500	263,674	263,450	224	0%	Dolores River at Bedrock
09171100	272,896	272,763	133	0%	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	179,783	180,541	-758	0%	San Miguel River near Placerville
09173000	7,212	10,756	-3,544	-49%	Beaver Creek near Norwood
09175500	199,166	203,221	-4,055	-2%	San Miguel River at Naturita
09177000	270,362	271,318	-956	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 2005, by Water District. Table 7.6 (at the end of this section) shows the average annual shortages for water years 1975 through 2005 by structure. On a basin-wide basis, average annual diversions differ from historical diversions by around 2 percent in the calibration run.

Table 7.4
Historical and Simulated Average Annual Diversions by Sub-basin (1975-2005) Calibration Run (acre-feet/year)

Water District - Tributary	Historical	Simulated	Historical minus Simulated	
			Volume	Percent
Water District 29 – San Juan/Blanco Rivers	93,923	93,403	520	1%
Water District 30 – Animas and Florida	240,388	232,186	8,202	3%
Water District 31 – Los Pinos River	212,781	211,910	871	0%
Water District 32 – McElmo Creek	199,382	198,184	1,198	1%
Water District 33 – La Plata River	32,872	30,558	2,314	7%
Water District 43 – Mancos River (Includes Summit Irrigation Use)	47,590	47,878	-288	-1%
Water District 60 – San Miguel River	130,741	127,488	3,253	2%
Water Districts 61,63,69,71,73 Dolores River and Tributaries	230,744	223,361	7,383	3%
Water District 77 – Navajo River	68,418	67,866	552	1%
Water District 78 – Piedra River	33,440	33,169	271	1%
New Mexico, Utah, and Arizona Uses	499,875	491,335	8,540	2%
Basin Total	**1,790,154**	**1,757,338**	**32,816**	**2%**

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.

- 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 approximate 1 percent difference is consistent with the overall basin diversion shortages simulated by the model.

Table 7.5
Average Annual Crop Consumptive Use Comparison (1975-2005)

Comparison	StateCU Results (af/yr)	Calibration Run Results (af/yr)	% Difference
Explicit Structures	297,246	294,584	0.9%
Aggregate Structures	68,090	66,296	2.6%
Basin Total	365,336	360,880	1.2%

Table 7.6
Historical and Simulated Average Annual Diversions (1975-2005)
Calibration Run (acre-feet/year)

WDID	Historical	Simulated	Historical – Simulated Volume	Percent	Name
290519	1,254	1,251	3	0	BEIGHLEY NO 1_DIVSYS
290550	3,909	3,784	125	3	C H LOUCKS DITCH
290555	1,395	1,376	19	1	CARR DITCH
290560	2,153	2,137	16	1	CHAPSON AND HOWE DITCH
290566	1,228	1,205	23	2	COLTON & MONTROY DITCH
290582	401	401	0	0	DOWELL DITCH
290588	2,239	2,239	0	0	ECHO DITCH
290597	895	895	0	0	FISH CREEK DITCH
290601	3,917	3,900	17	0	FOUR-MILE_DIVSYS

WDID	Historical	Simulated	Historical – Simulated Volume	Percent	Name
290613	244	244	0	0	HALLETT DITCH
290627	406	406	0	0	J M ROSS AND STURGILL D
290653	338	336	2	1	LONG HORN AND MEE DITCH
290654	195	195	0	0	LONG MEADOW DITCH
290662	425	417	8	2	MARTINEZ AND MARTINEZ D
290669	1,032	1,017	15	1	MESA DITCH
290686	8,824	8,795	29	0	PARK DITCH
290691	258	257	1	0	PHILLIPPS DITCH
290716	651	651	0	0	SISSON-STEPHENS DITCH
290718	5,204	5,069	135	3	SNOWBALL DITCH
290729	311	310	1	0	STURGILL DITCH
292005	1,066	1,007	59	6	DUTTON DITCH
294667	38,968	38,905	63	0	USBR_BLANCO_R_DIVERSION
294669	212	212	0	0	TREASURE PASS DIVR DITCH
29_ADS002	8,182	8,178	4	0	29_ADS002_SjuanR@PagosaS
29_ADS003	10,216	10,216	0	0	29_ADS003_SjuanR@Carracs
300504	2,082	2,079	3	0	AMBOLD-WALLACE DITCH
300506	25,958	25,926	32	0	ANIMAS CONSOLIDATED D
300509 [1)]	0	0	0	0	ANIMAS DIVERSION CANAL
300510	1,153	1,153	0	0	BEAR CREEK DITCH
300523	31,006	25,578	5,428	18	CASCADE CANAL
300568	4,485	4,432	53	1	HERMOSA COMPANY DITCH
300580	2,523	2,466	57	2	JOHN THOMAS DITCH
300581	2,034	2,023	11	1	J P LAMB DITCH
300612	25,283	25,034	249	1	POWER CANAL NO 1
300617	21,782	21,553	229	1	REID DITCH
300634	1,142	1,142	0	0	SITES DITCH
300641	2,941	2,941	0	0	SULLIVAN-WALLACE DITCH
301000	4,233	4,217	16	0	DURANGO CITY PIPELINE
301003	748	743	5	1	HARRIS-PATTERSON DITCH
301009	842	809	33	4	MCCLUER & MURRAY DITCH
301011	46,468	45,833	635	1	Florida_Farmers/Florida_Canal
301019	1,760	1,686	74	4	PIONEER DITCH
301023	14,867	14,867	0	0	ANIMAS DITCH
301024	0	0	0	0	ANIMAS PMP STA & FOR MN
301033	887	824	63	7	BANKS-TYNER DITCH
301056	296	296	0	0	BODO PINE RIDGE DITCH
301094	6,134	6,134	0	0	EAST MESA DITCH
301219	1,367	1,255	112	8	SITES-KERN DITCH
301243	910	799	111	12	TYNER EAST SIDE DITCH
304660	295	0	295	100	CARBON LAKE DITCH
304661	139	138	1	1	MINERAL POINT DITCH
304662	100	100	0	0	RED MOUNTAIN DITCH
304664	4,785	4,785	0	0	RALSTON DITCH
304665	4,284	3,810	474	11	TWIN ROCK DITCH
30_ADS007	10,958	10,958	0	0	30_ADS007_AnimasR@Durang
30_ADS008	5,671	5,509	162	3	30_ADS008_FloridaRabvSal

WDID	Historical	Simulated	Historical – Simulated Volume	Historical – Simulated Percent	Name
30_ADS009	4,228	4,069	159	4	30_ADS009_FloridaR@Bonda
30_ADS010	11,027	11,027	0	0	30_ADS010_AnimasR@StLine
30_ALP	0	0	0	0	Water District 30 ALP Demands
310502	3,293	3,291	2	0	CEANABOO DITCH
310503	2,819	2,819	0	0	COMMISSIONER DITCH
310505	18,859	18,859	0	0	DR MORRISON_DIVSYS
310507	3,063	3,063	0	0	LA BOCA DITCH
310508	2,627	2,626	1	0	SEVERO DITCH
310509	13,337	13,337	0	0	SPRING CREEK DITCH
310510	949	949	0	0	BEAN DITCH
310511	8,843	8,843	0	0	THOMPSON-EPPERSON DITCH
310512	3,440	3,440	0	0	LOS PINOS IRG DITCH
310513	2,265	2,265	0	0	WOMMER IRRIGATION DITCH
310514	3,147	3,147	0	0	BEAR CR AND PINE R DITCH
310516	252	252	0	0	HIGBEE IRRIGATION DITCH
310518	621	621	0	0	MYERS AND ASHER DITCH
310519	25,254	25,254	0	0	KING DITCH
310523	15,249	15,249	0	0	SCHRODER IRG_DIVSYS
310524	831	831	0	0	FARRELL DITCH
310527	84	84	0	0	ISLAND DITCH
310528	1,229	1,229	0	0	BENNETT-MYERS IRR DITCH
310535	635	631	4	1	KIRKPATRICK DITCH
310540	1,041	1,015	26	2	MCLOYD DITCH
310545	105	104	1	1	CATLIN DITCH
310547	22,926	22,926	0	0	ROBERT MORRISON DITCH
310553	171	171	0	0	MCBRIDE DITCH
310567	322	322	0	0	CAMPBELL DITCH
310583	509	316	193	38	PORTER DITCH
310593	328	328	0	0	SEMLER DITCH E AND E
310665	59,735	59,735	0	0	SPRING CREEK DITCH
310668	1,568	1,568	0	0	SULLIVAN DITCH
310710	854	854	0	0	IGNACIO CREEK DITCH
314637	1,143	954	189	17	WEMINUCHE PASS DITCH
314638	442	351	91	21	PINE R WEMINUCHE PASS D
31_ADS005	5,723	5,375	348	6	31_ADS005_LPinosR@DryCrk
31_ADS006	11,117	11,101	16	0	31_ADS006_LpinosR@StLine
320509	970	967	3	0	BLACK DIKE DITCH
320528	2,700	2,695	5	0	COTTONWOOD DITCH NO 1
320529	2,919	2,915	4	0	COTTONWOOD DITCH NO 2
320558	1,405	1,334	71	5	EATON DITCH
320574	4,085	4,029	56	1	HAMBELTON DITCH
320590	837	828	9	1	ISMAY DITCH
320634	1,904	1,800	104	5	MURRAY-ZWICKER-TOZER D
320652	9,812	9,812	0	0	ROCK CREEK DITCH
320662	952	899	53	6	SCHALLES DITCH
320680	2,952	2,898	54	2	TOWN OF CORTEZ
320690	2,638	2,629	9	0	WILSON DITCH

WDID	Historical	Simulated	Historical – Simulated Volume	Percent	Name
320699 [1)]	0	0	0	0	NARRAGUINNEP RES INLET
320772	67,682	67,682	0	0	MVI_U_lateral
320884	6,416	6,320	96	1	TOWAOC CANAL
322001	673	673	0	0	DOLORES WATER DIVR HGT
322006	20,677	20,184	493	2	DOVE CREEK CANAL
324675	58,973	58,973	0	0	Dolores_Tunnel
32_ADS015	7,225	7,027	198	3	32_ADS015_McELmCkabvAlka
32_ADS016	6,562	6,519	43	1	32_ADS016_McElmoCrkNrStL
330501	1,685	1,454	231	14	LA PLATA IRG DITCH
330504	5,583	4,996	587	11	HAY GULCH DITCH
330508	2,376	2,179	197	8	LA PLATA R & CHERRY CR D
330518	366	329	37	10	AMMONS DITCH
330533	972	892	80	8	PINE RIDGE DITCH
330535	706	645	61	9	SOONER VALLEY DITCH
330536	4,886	4,712	174	4	H H DITCH
330540	478	434	44	9	ENTERPRISE ENLARGEMENT
330542	3,457	3,191	266	8	SLADE DITCH
330547	2,763	2,377	386	14	JOSEPH FREED DITCH
330548	506	460	46	9	REVIVAL DITCH
330549	1,988	1,961	27	1	TREANOR DITCH
330550	753	678	75	10	WARREN-VOSBURGH DITCH
330551	638	620	18	3	TOWNSITE DITCH
330554	2,004	1,924	80	4	BIG STICK DITCH
334639	538	533	5	1	ENTERPRISE ENLARGEMENT
334640	752	752	0	0	PIONEER DITCH
33_ADS011	2,421	2,421	0	0	33_ADS011_LaPlataRiver
340505	1,421	1,406	15	1	BEAVER DITCH
340506	957	951	6	1	BOSS DITCH
340508	758	792	-34	-4	CARPENTER & MITCHELL D
340514	738	737	1	0	CRYSTAL CREEK DITCH
340522	614	604	10	2	EAST MANCOS HIGHLINE D.
340527	586	584	2	0	FRANK DITCH
340530	1,181	1,149	32	3	GILES DITCH
340531	1,113	988	125	11	GLASGOW & BREWER DITCH
340534	2,481	2,466	15	1	HENRY BOLEN DITCH
340535	8,374	6,734	1,640	20	JACKSON GULCH INLET CNL
340542	1,016	1,014	2	0	LEE AND BURKE DITCH
340543	588	587	1	0	LEE DITCH
340544	718	704	14	2	LONG PARK DITCH
340552	1,071	1,066	5	0	NO 6 DITCH
340554	4,395	4,379	16	0	RATLIFF AND ROOT DITCH
340560	1,727	1,708	19	1	RUSH RESERVOIR DITCH
340565	1,762	1,753	9	1	SHEEK DITCH
340567	141	132	9	6	SMOUSE DITCH
340573	727	726	1	0	TOWN OF MANCOS DITCH
340576	5,359	5,338	21	0	WEBBER DITCH
340577	702	654	48	7	WEBER RESERVOIR INLET D

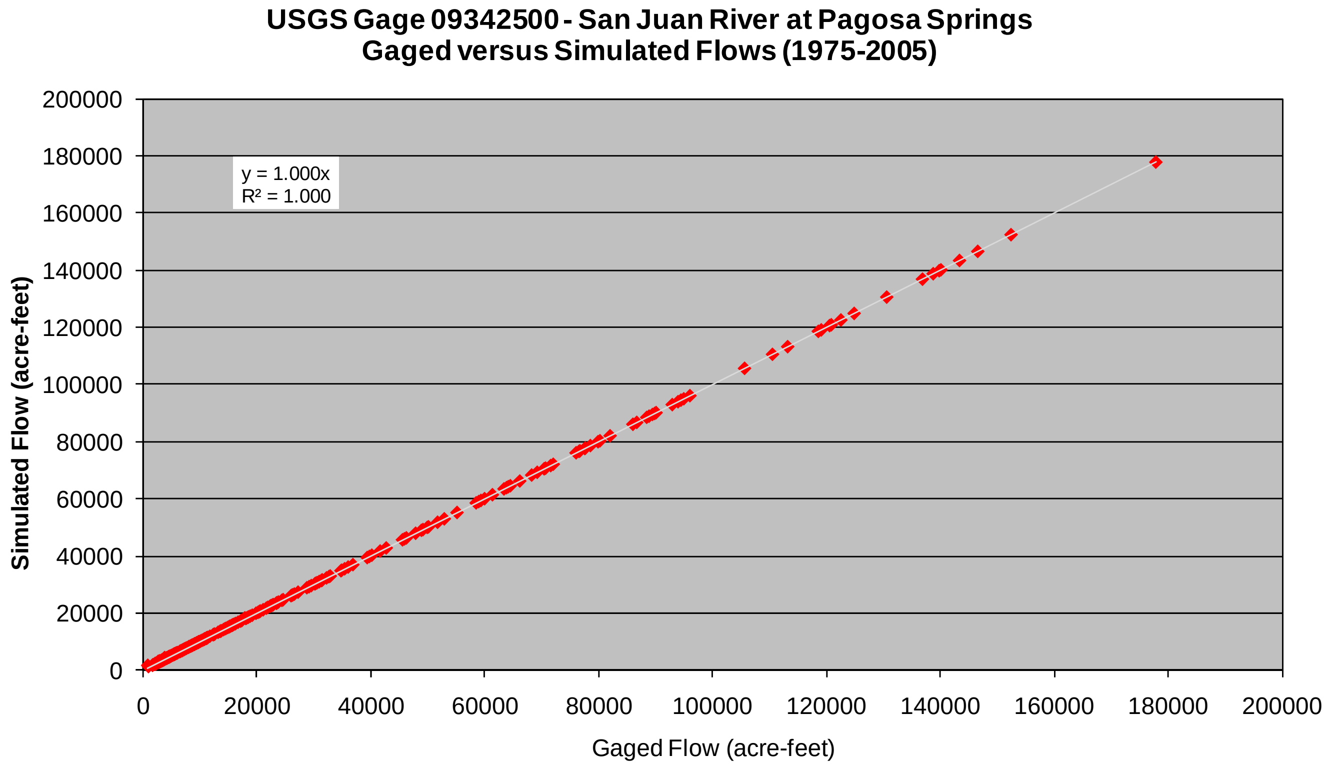
WDID	Historical	Simulated	Historical – Simulated Volume	Percent	Name
340582	260	259	1	0	WILLIAMS DITCH_DIVSYS
340583	812	805	7	1	WILLIS DITCH
34_ADS012	1,556	1,550	6	0	34_ADS012_ManRabvWMancos
34_ADS013	847	835	12	1	34_ADS013_ManRabvChicken
34_ADS014	3,178	3,147	31	1	34_ADS014_MancosRNrStLin
34_AMS001	1,080	1,057	23	2	34_MUNICIPAL
460503	2,116	2,114	2	0	BRIGGS DITCH
600507	306	295	11	4	ALEXANDER DITCH
600511	10,911	10,882	29	0	AMES ILIUM HYDRO PROJ
600520	799	799	0	0	B C D DITCH
600521	1,078	979	99	9	BEAVER MESA DITCH
600549	167	167	0	0	CARR WADDLE DITCH
600550	762	700	62	8	CARRIERE DITCH
600569	719	715	4	1	CRAVER DITCH
600574	404	399	5	1	DENISON DITCH
600583	508	251	257	51	EAGLE DITCH
600585	340	340	0	0	EASTON DITCH
600588	812	800	12	1	ELK CREEK DITCH
600607	363	354	9	2	GLENCOE DITCH
600611	652	649	3	0	GOLD RUN DITCH
600628	478	371	107	22	HASTINGS DITCH
600633	33,070	32,709	361	1	HIGHLINE CANAL
600650	1,638	1,555	83	5	J & M HUGHES DITCH
600659	373	357	16	4	KINLEY DITCH
600669	496	235	261	53	LEOPARD CREEK DITCH
600670	3,115	2,967	148	5	LILYLANDS CANAL
600672	3,473	3,101	372	11	LONE CONE DITCH
600684	518	493	25	5	MCCOLLOCH SCOTT DITCH
600689	724	706	18	2	MIDDLE ELK CREEK DITCH
600707	18,560	18,386	174	1	NATURITA CANAL
600710	166	166	0	0	NEILSON DITCH
600723	1,452	1,452	0	0	NUCLA POWER PLANT DITCH
600733	424	407	17	4	PAXTON DITCH
600736	1,659	1,642	17	1	PLEASANT VALLEY DITCH
600745	715	706	9	1	REED CHATFIELD DITCH
600776	437	436	1	0	TEMPLETON DITCH
600777	225	225	0	0	THEO NETHERLY DITCH NO1
60_ADS020	13,309	13,255	54	0	60_ADS020_SmiguelNrPlacr
60_ADS021	1,512	1,505	7	0	60_ADS021_SmiguelabvWNat
60_ADS022	10,653	10,587	66	1	60_ADS022_Smiguel@Naturi
610502	1,173	1,151	22	2	GALLOWAY DIVSYS
610517	1,381	1,369	12	1	SOUTH MIDWAY DITCH
610527	2,250	2,114	136	6	RAY DITCH
610602	366	341	25	7	A E L R P & PL
61_ADS019	6,763	6,717	46	1	61_ADS019_DoloresRNrBedr
630501	2,200	1,748	452	21	BARTHOLOMEW & HATCH D
630518	1,511	1,189	322	21	CLIFF RANCH DITCH

WDID	Historical	Simulated	Historical – Simulated Volume	Percent	Name
630529	857	656	201	23	HARMS AND HAZEL DITCH
630547	407	327	80	20	NOLAN DITCH
630553	340	333	7	2	RED CROSS DITCH
63_ADS023	6,312	6,251	61	1	63_ADS023_DoloresR@Gatew
63_ADS024	11,257	10,833	424	4	63_ADS024_WestCreek
63_AMS002	1,296	1,273	23	2	63_MUNICIPAL
680636	1,271	968	303	24	LEOPARD CREEK DITCH
690510	1,410	1,369	41	3	HORSESHOE DITCH
690512	570	510	60	11	KNIGHT-EMBLING DITCH
690520	650	629	21	3	PINE ARROYA DITCH
69_ADS018	2,080	2,039	41	2	69_ADS018_Disappointment
710504	421	242	179	43	BEAR CREEK DITCH
710513	742	694	48	6	BURCH & LONGWILL DITCH
710531	283	117	166	59	EAST EDER DITCH
710535	142	55	87	61	GARBARINO NO 1 DITCH
710536	148	56	92	62	GARBARINO NO 2 DITCH
710537	159	51	108	68	GARBARINO NO 3 DITCH
710545	703	681	22	3	GOULD & MORIARITY DITCH
710549	1,148	1,004	144	13	ILLINOIS DITCH
710551	212	204	8	4	ITALIAN DITCH
710555	601	336	265	44	KEYSTONE DITCH
710556	121	83	38	31	KING NO 1 DITCH
710559	273	117	156	57	KOENIG DITCH
710563	351	124	227	65	LINDSTROM DITCH
710572	403	337	66	16	MONUMENT ROCK DITCH
710573	598	383	215	36	MORIARITY DITCH
710575	50	20	30	60	ORIGINAL RICO FLUME
710582	481	224	257	53	QUARRY NO 1 DITCH
710586	249	115	134	54	RIEVA DITCH
710609	3,428	5,753	-2,325	-68	SUMMIT DITCH
710618	1,278	1,011	267	21	TURKEY CREEK DITCH
710624	267	95	172	64	WEST EDER DITCH
712002	6,454	6,255	199	3	SUMMIT RES OUTLET
714673	69,020	68,341	679	1	MAIN CANAL NO 1
714674	90,068	89,742	326	0	MAIN CANAL NO 2
71_ADS017	6,391	4,949	1,442	23	71_ADS017_DoloRabvMcPhee
73_ADS025	9,358	9,276	82	1	73_ADS025_LittleDoloresR
770516	247	222	25	10	CONFAR & RUSSELL DITCH
770524	1,623	1,623	0	0	EAKLOR DITCH
770529	1,249	1,203	46	4	ELMER DITCH NO 1
770531	2,169	2,169	0	0	ENTERPRISE DITCH
770536	571	571	0	0	FITZHUGH DITCH
770559	700	675	25	4	MIDLAND DITCH
770560	276	275	1	0	MONTOYA DITCH
770562	371	371	0	0	NAVAJO MEADOW DITCH
770564	445	445	0	0	NAVAJO RIVER DITCH
770576	267	267	0	0	SHAHAN IRRIGATION DITCH

WDID	Historical	Simulated	Historical – Simulated Volume	Percent	Name
770579	1,723	1,713	10	1	SOUTH SIDE DITCH
770585	303	303	0	0	UNDERWOOD DITCH
770586	332	330	2	1	UNDERWOOD DITCH NO 2
770587	705	705	0	0	UPPER CAMP DITCH
770588	328	328	0	0	UPPER NAVAJO DITCH
770597	987	977	10	1	NEW BOND HOUSE (NAVAJO)
774635	45,456	45,284	172	0	USBR_NAVAJO_DIVERSION
774636	4,011	3,750	261	7	USBR_LITTLE_NAVAJO_DIVR
779999 1)	0	0	0	0	SanJ_Chama_Summary_Node
77_ADS001	6,655	6,655	0	0	77_ADS001_NavajoRiver
780501	1,454	1,434	20	1	ABRAHAM DAVIS DITCH
780506	662	637	25	4	BARNES DITCH
780507	684	678	6	1	BARNES-MEUSER & SHAW D
780513	2,637	2,626	11	0	BUCKSKIN-NAILOR DITCH
780523	450	443	7	2	CARL AND WEBB DITCH
780524	336	329	7	2	CIMARRON DITCH
780525	1,084	936	148	14	CLAYTON-REED DITCH
780543	360	360	0	0	EUGENIO GALLEGOS DITCH
780544	753	747	6	1	F S MOCKLER DIVSYS
780545	3,184	3,184	0	0	FARROW AND PETERSON D
780552	685	680	5	1	GALLEGOS HOME DITCH
780555	370	370	0	0	GEORGE S MCDONALD DITCH
780562	617	615	2	0	HOSSACK CREEK DITCH
780571	1,432	1,432	0	0	BESS GIRL DITCH
780580	961	955	6	1	M E AND M DITCH
780590	576	574	2	0	NICKLES BROTHERS DITCH
780594	267	267	0	0	PAGOSA DITCH
780604	2,312	2,311	1	0	PIEDRA FALLS DITCH
780617	1,835	1,828	7	0	STEVENS&CLAYTON DITCH
780638	1,375	1,369	6	0	TONER AND STEVENS DITCH
780659	342	341	1	0	LITTLE PAGOSA CREEK DIVR
780692	759	758	1	0	FAIRFIELD MUN. WATER SYS
784670	44	43	1	2	DON LAFONT DITCH NO 1
784671	128	126	2	2	DON LAFONT DITCH NO 2
784672	259	254	5	2	WILLIAMS CR SQ PASS DIVR
78_ADS004	7,758	7,758	0	0	78_ADS004_PiedraRiver
990707	18,652	17,929	723	4	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	29,280	29,280	0	0	FourCornersPP
NM_ABVARCH	46	46	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	84,019	82,686	1,333	2	NM_AnimasIrr
NM_ARCH	287	286	1	0	ArchuletaDitch
NM_AZTEC	5,494	5,236	258	5	AztecMI

WDID	Historical	Simulated	Historical – Simulated Volume	Percent	Name
NM_BLOOM	1,485	1,485	0	0	BloomfieldMI
NM_CHACO	11,580	11,580	0	0	ChacoIrr
NM_CITZ	30,909	30,909	0	0	CitizenDitch
NM_CUDEI	0	0	0	0	CudeiCanal
NM_CUDEIh	2,690	2,690	0	0	CudeiCanal Historical
NM_ECHO	6,369	6,369	0	0	EchoDitch
NM_FARMMI	13,097	13,097	0	0	FarmingtoNM_I
NM_FMD	30,728	30,621	107	0	FarmersMutual
NM_FRUCAM	24,672	24,671	1	0	FruitlandAndCambridge
NM_GLADE	2,292	2,223	69	3	FarmingtonGlade
NM_HAMM	20,830	20,830	0	0	Hammond
NM_HOGB	43,497	43,496	1	0	Hogback
NM_JEWV	10,132	10,131	1	0	JewettValley
NM_JICIRR	155	155	0	0	JicarillaIrri
NM_JICNEW	0	0	0	0	JicarillaNew
NM_JICNIR	199	198	1	1	JicarillaNonIr
NM_LPIRR	17,978	14,123	3,855	21	LowerLaPlataIrr
NM_LPNIR	5,431	2,582	2,849	52	LaPlataNonIr
NM_NGBAL	0	0	0	0	NIIP
NM_NBNIIP	0	0	0	0	NIIP
NM_NIIP	126,955	126,955	0	0	NIIP
NM_NIIP_R1	0	0	0	0	NIIP Ojo Return
NM_NIIP_R2	0	0	0	0	NIIP Chaco Return
NM_NIIP_R3	0	0	0	0	NIIP Gallegos Return
NM_REDW	8	8	0	0	RedWash
NM_SJGS	15,917	15,917	0	0	SJPowerPlant
NM_SRMI	0	0	0	0	ShiprockMI
NM_TURLEY	1,862	1,862	0	0	TurleyDitch
NM_U2NIR	1,832	1,783	49	3	NM_U2NonIr
NM_U3NIR	495	495	0	0	NM_U3NonIr
NM_U5NIR	0	0	0	0	NM_U5NonIr
NM_U6NIR	949	949	0	0	NM_U6NonIr
NM_U7NIR	419	419	0	0	NM_U7NonIr
NM_U8NIR	0	0	0	0	NM_U8NonIr
NM_USIRR	1,736	1,726	10	1	USNavajoIrr
NM_USNIR	716	712	4	1	USNavajoNonIr
NM_WESTW	289	289	0	0	Westwater
NM_WHIS	662	661	1	0	WhiskeyCreek
UT_IRR	6,865	6,865	0	0	UT_IRR
UT_NIR	0	0	0	0	UT_NIR
Basin Total	**1,790,154**	**1,757,300**	**32,854**	**2**	

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



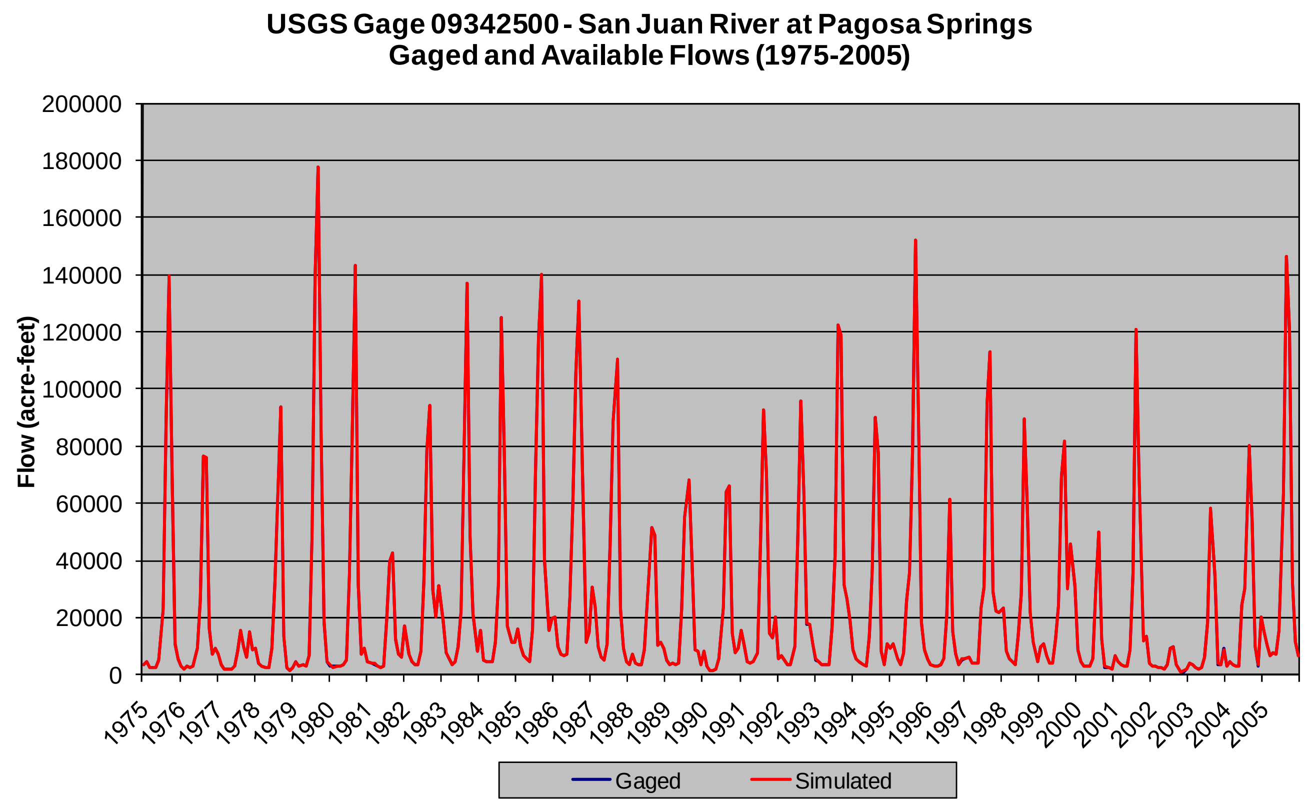
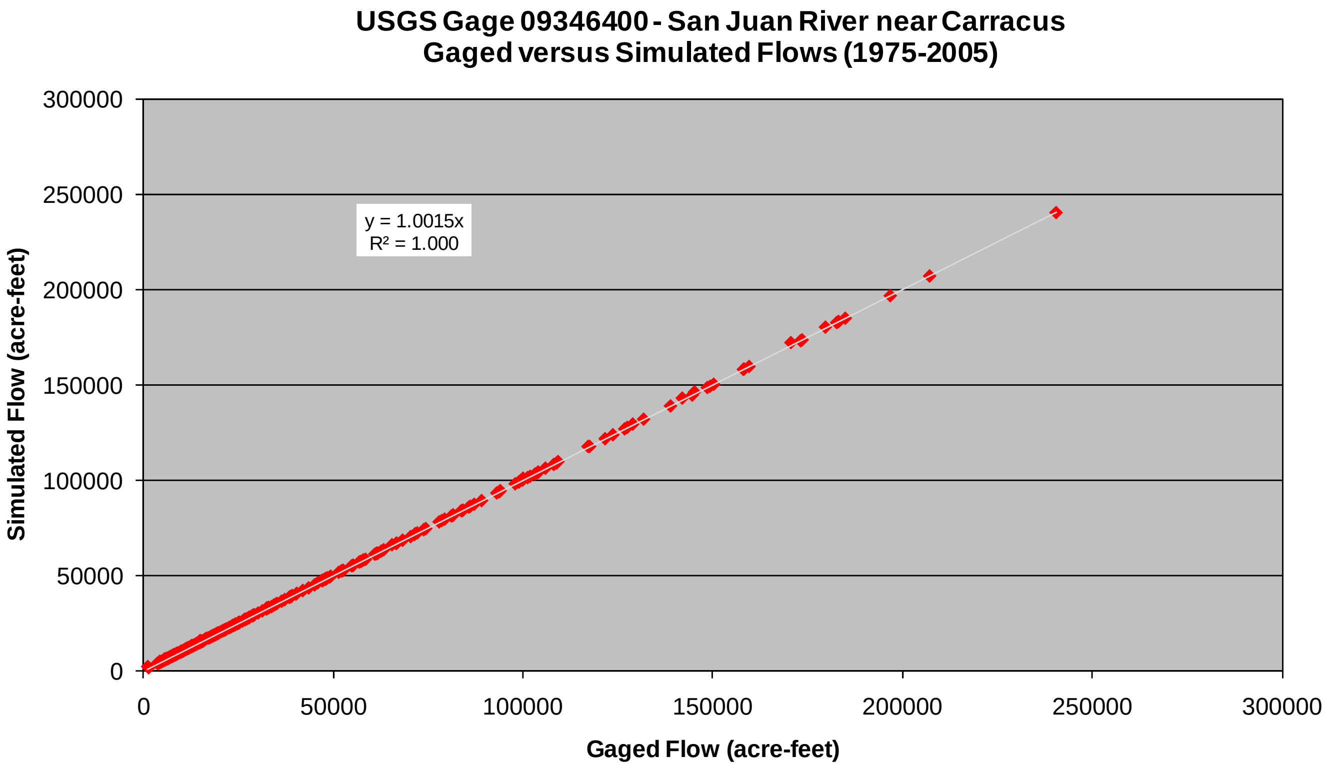


Figure 7.1 Streamflow Calibration – San Juan River at Pagosa Springs



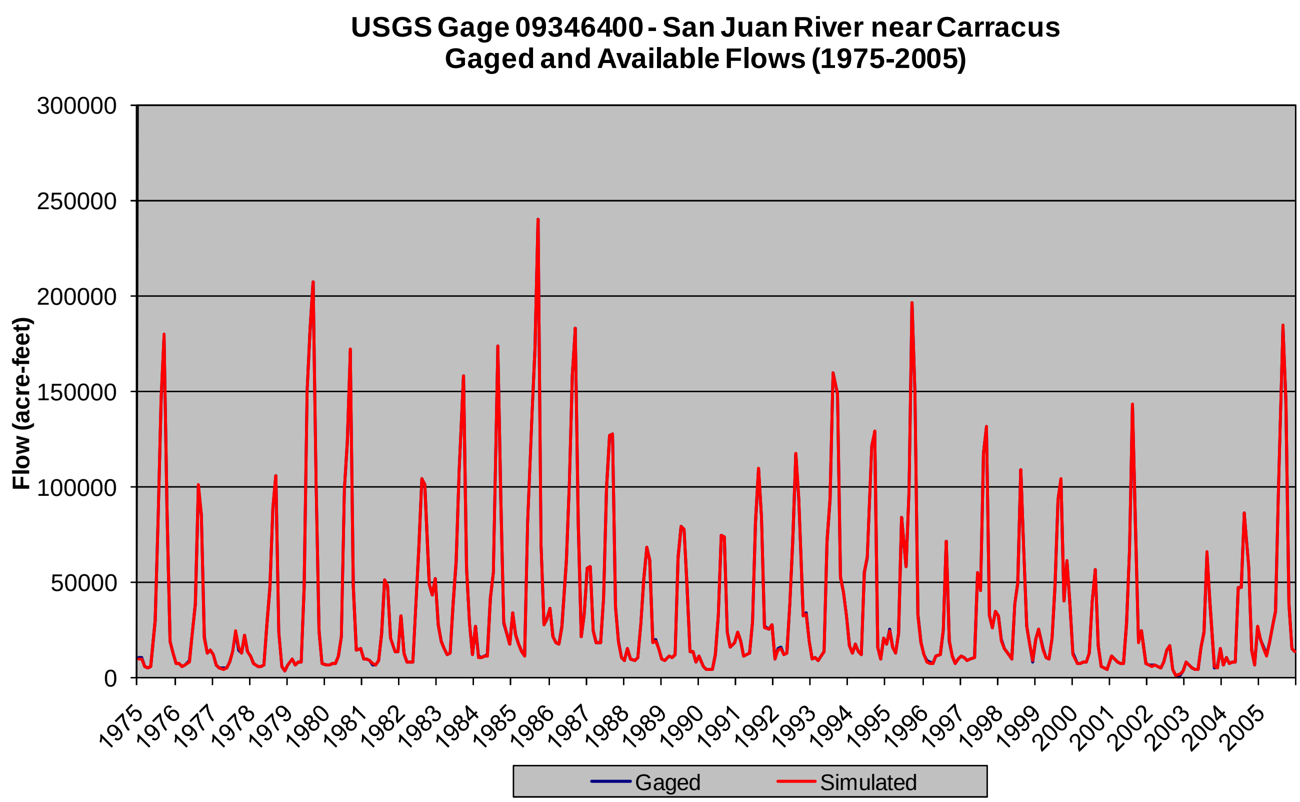
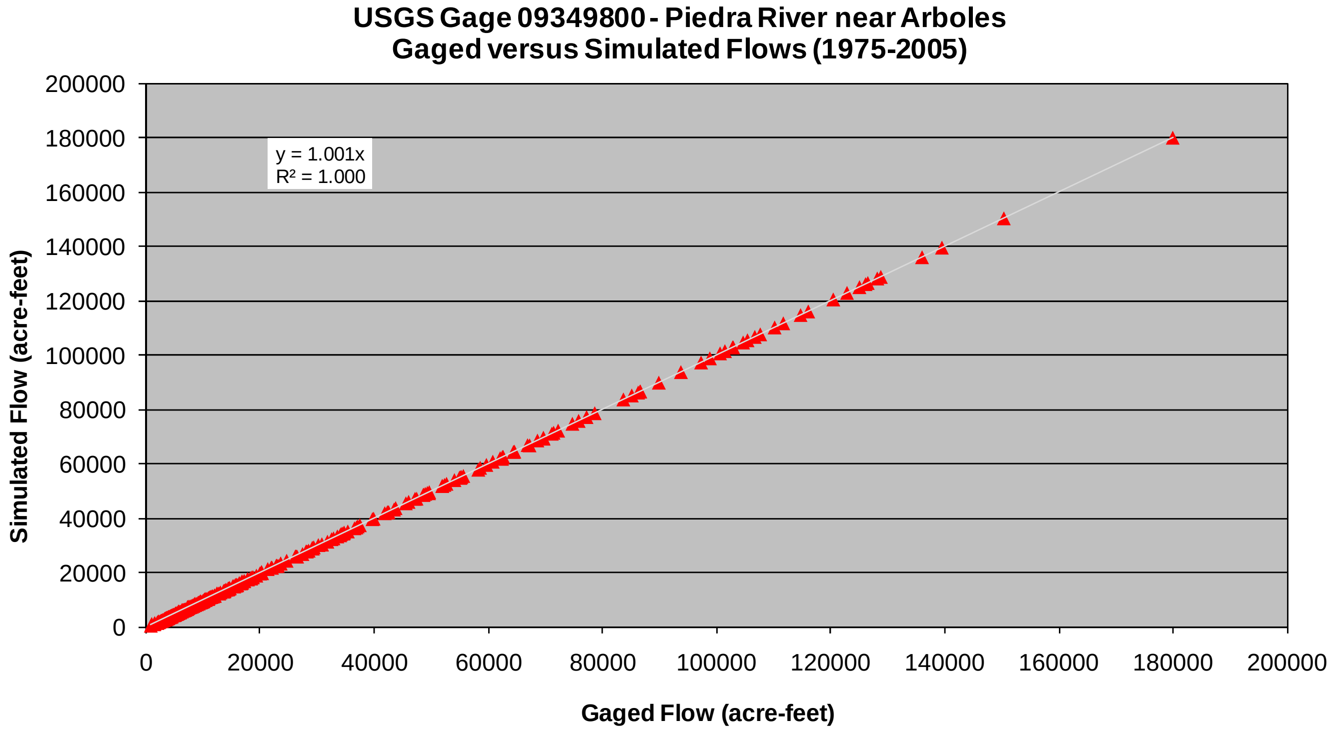


Figure 7.2 Streamflow Calibration – San Juan River near Carracus



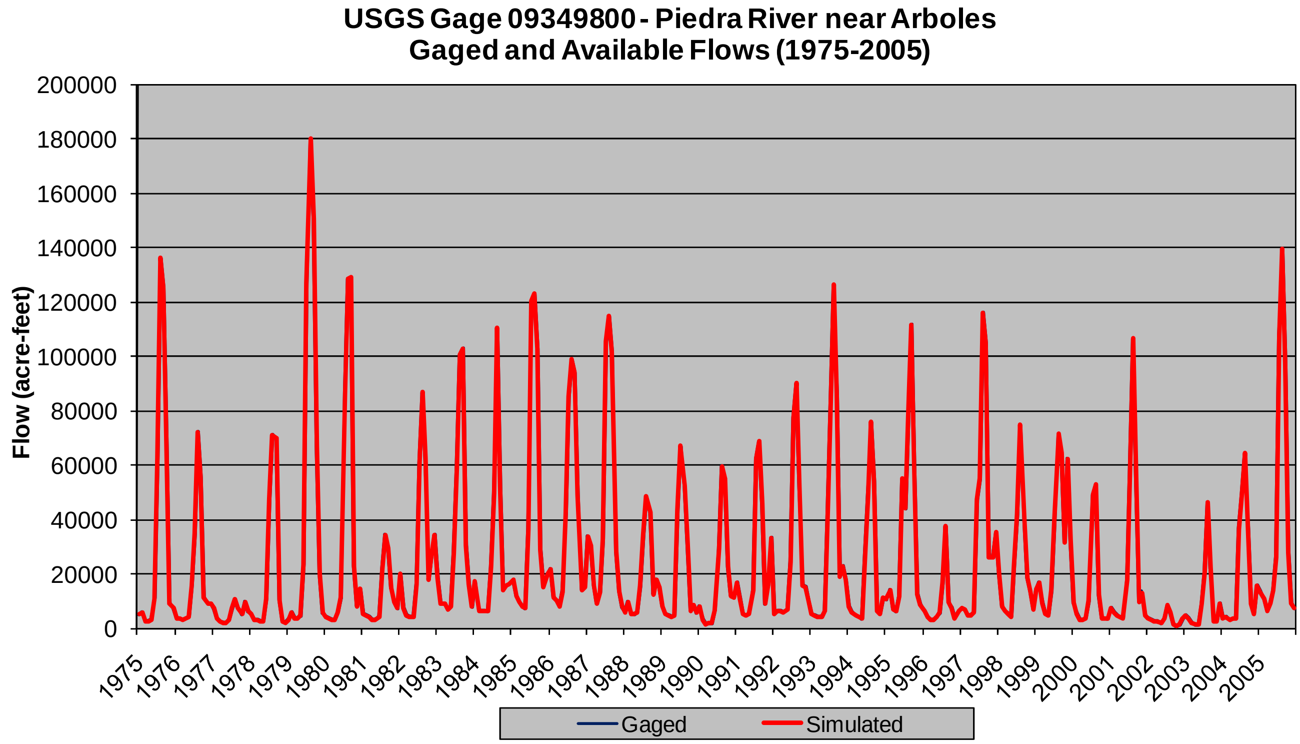
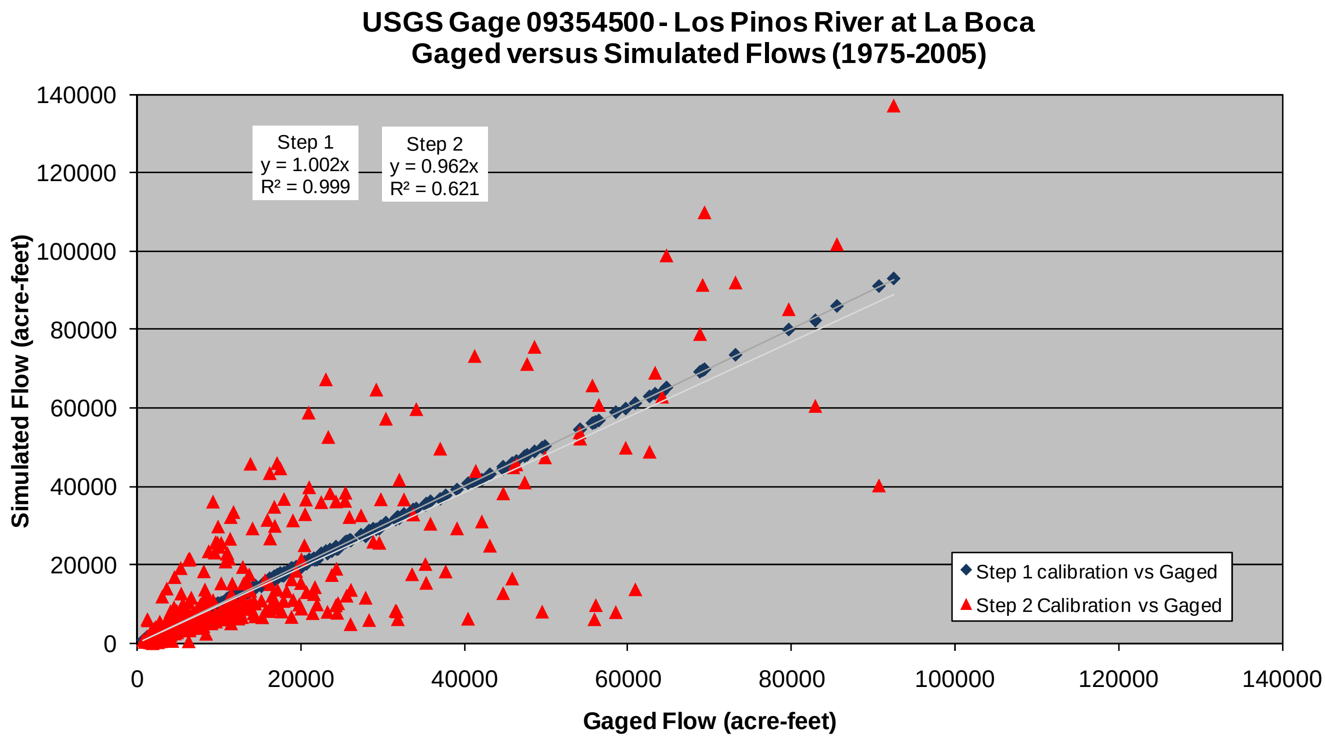


Figure 7.3 Streamflow Calibration – Piedra River near Arboles



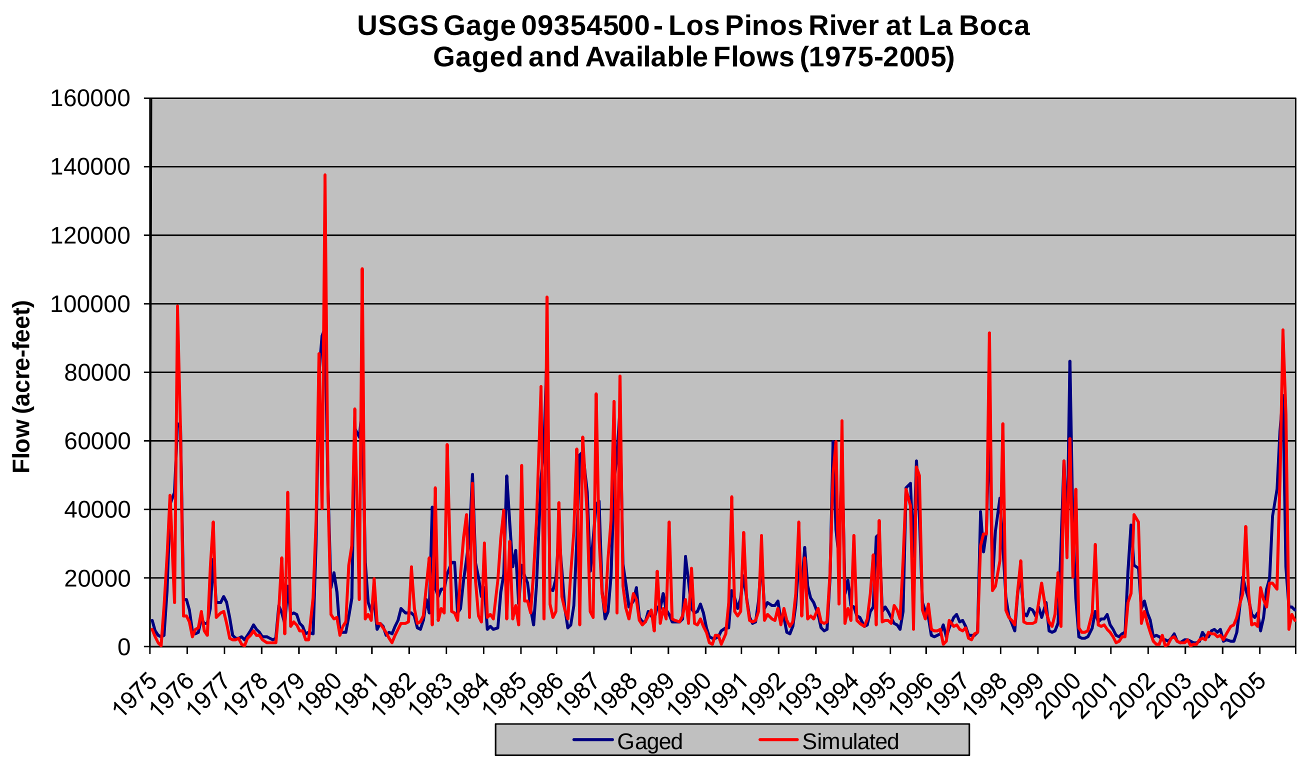
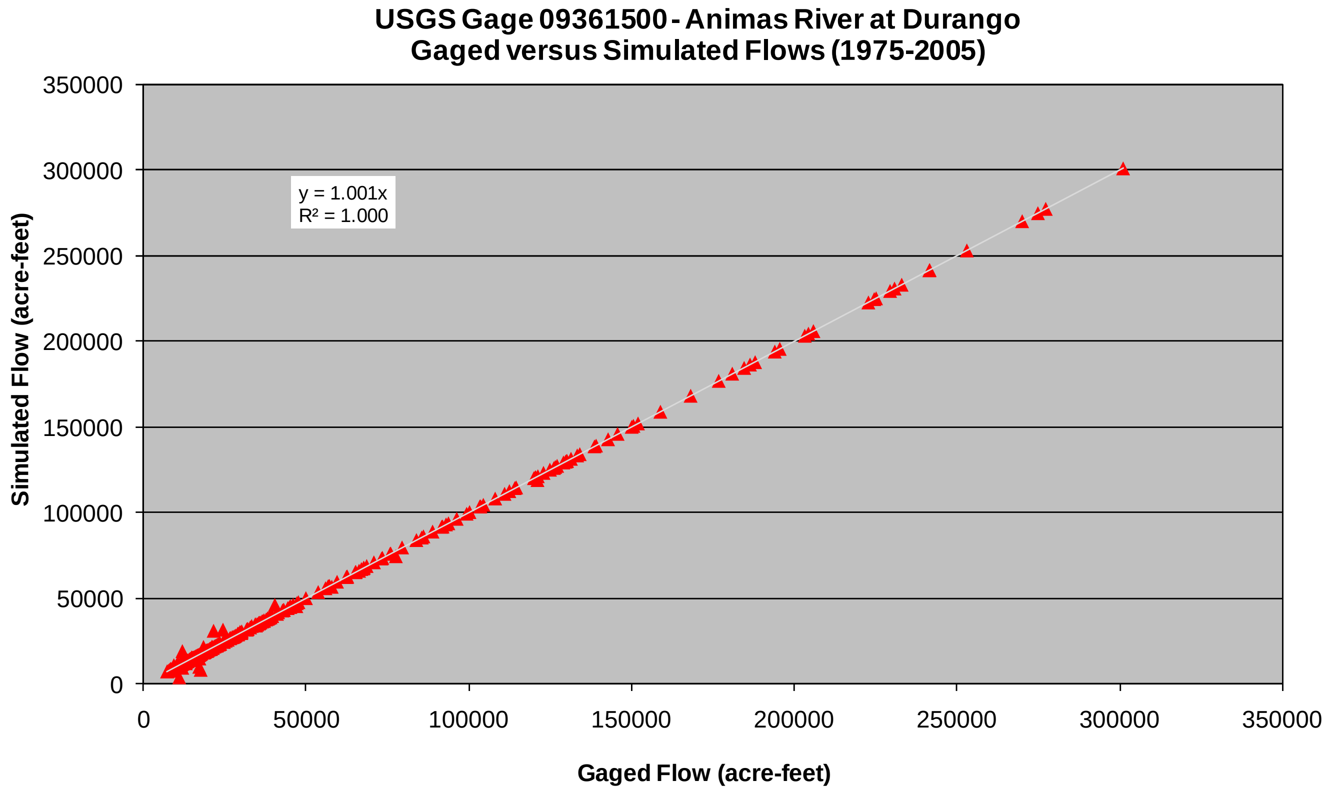


Figure 7.4 Streamflow Calibration – Los Pinos River at La Boca



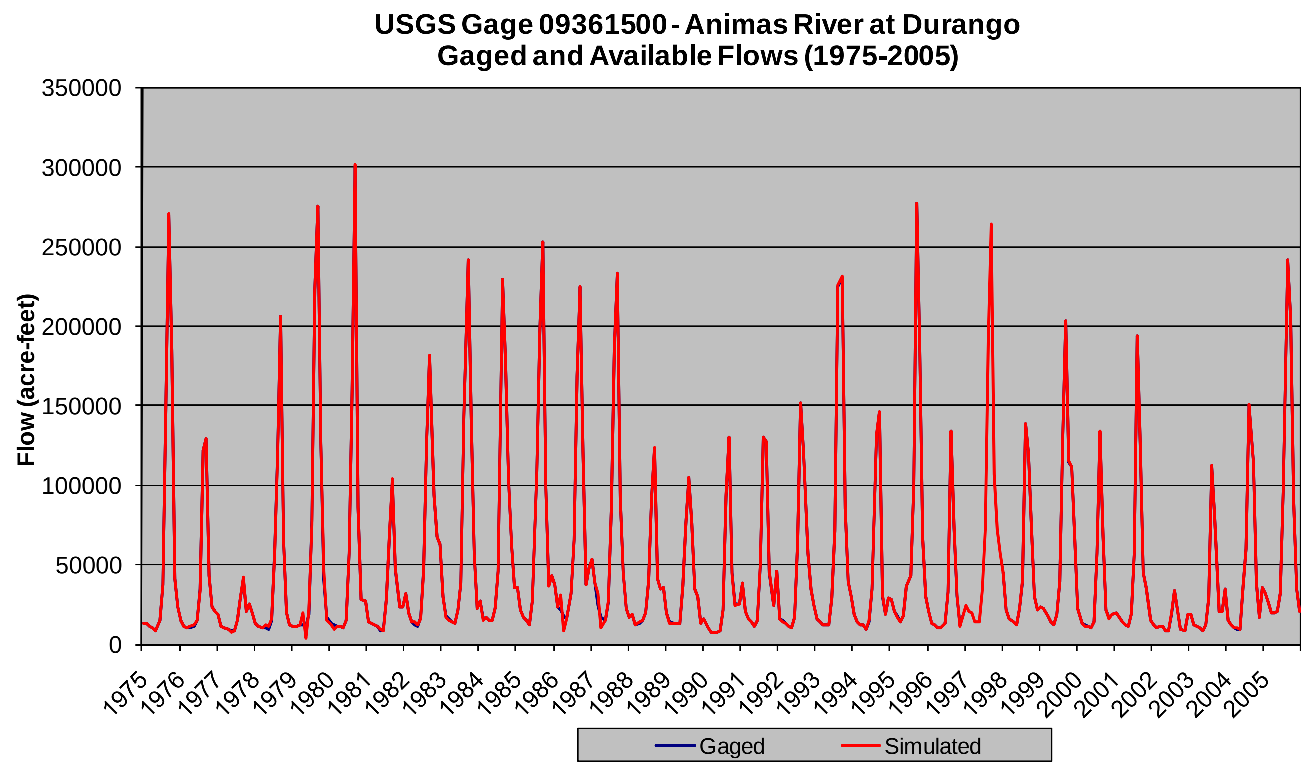
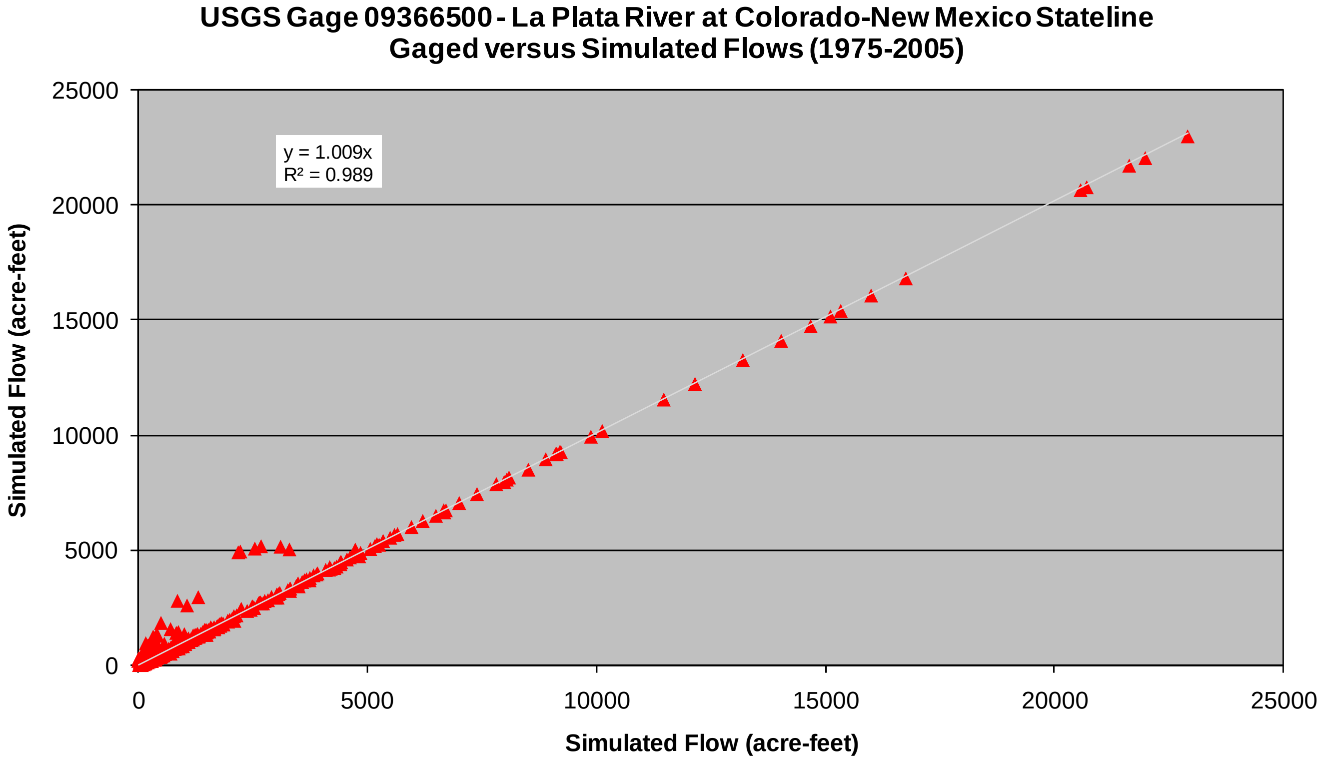


Figure 7.5 Streamflow Calibration – Animas River at Durango



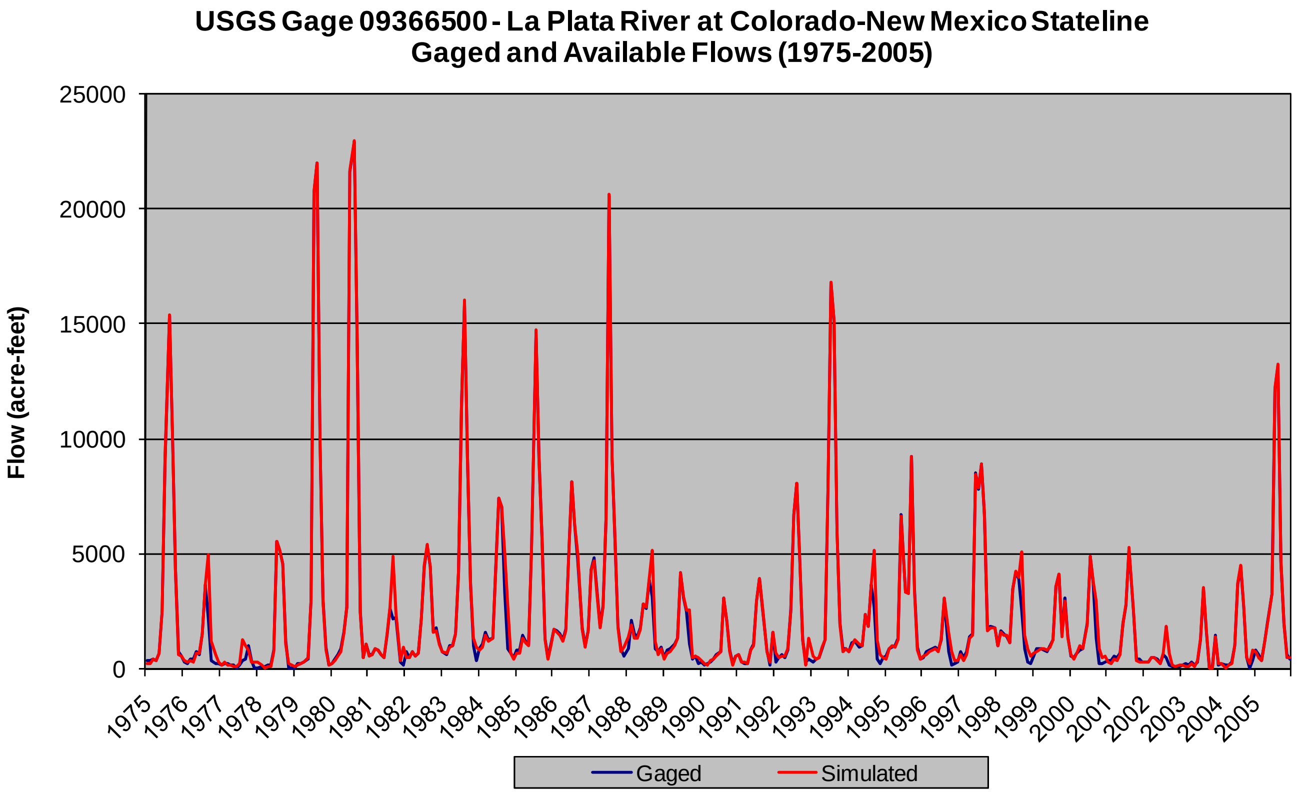
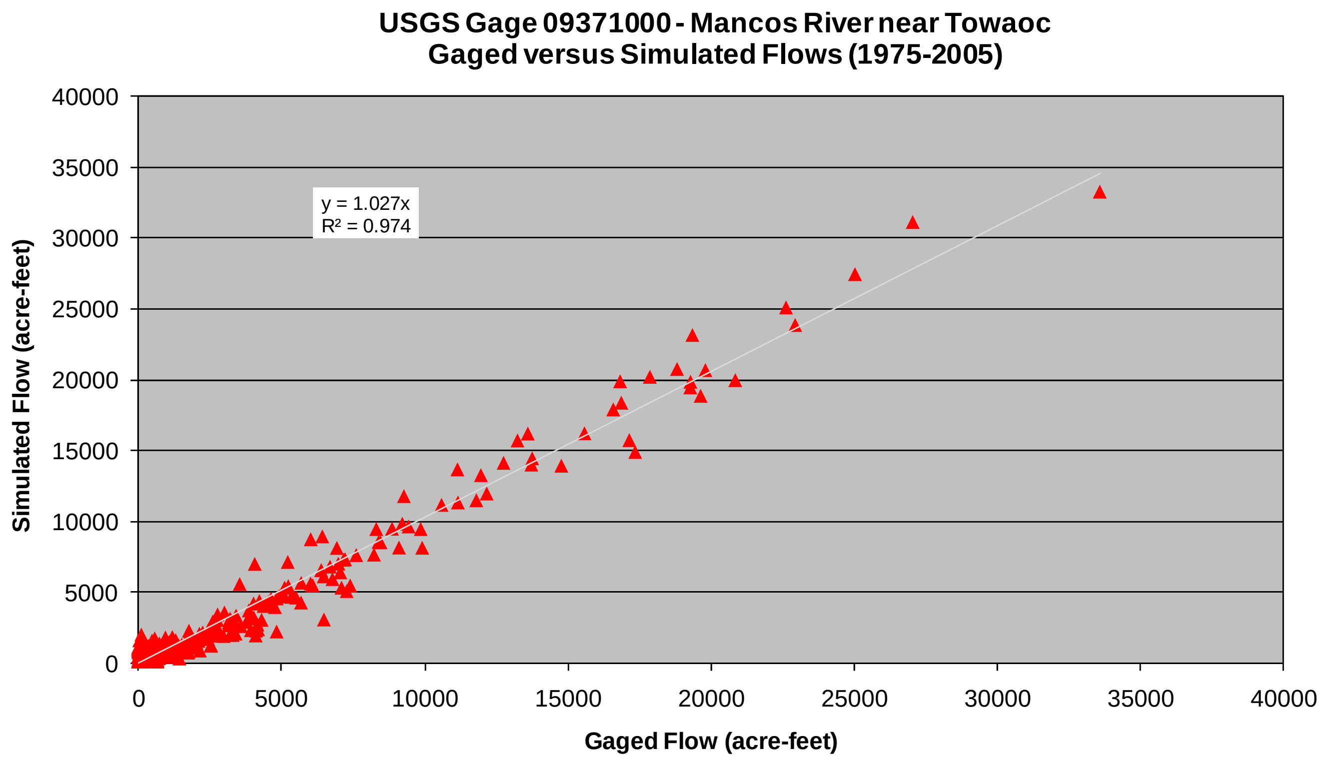


Figure 7.6 Streamflow Calibration – La Plata River at Colorado-New Mexico Stateline



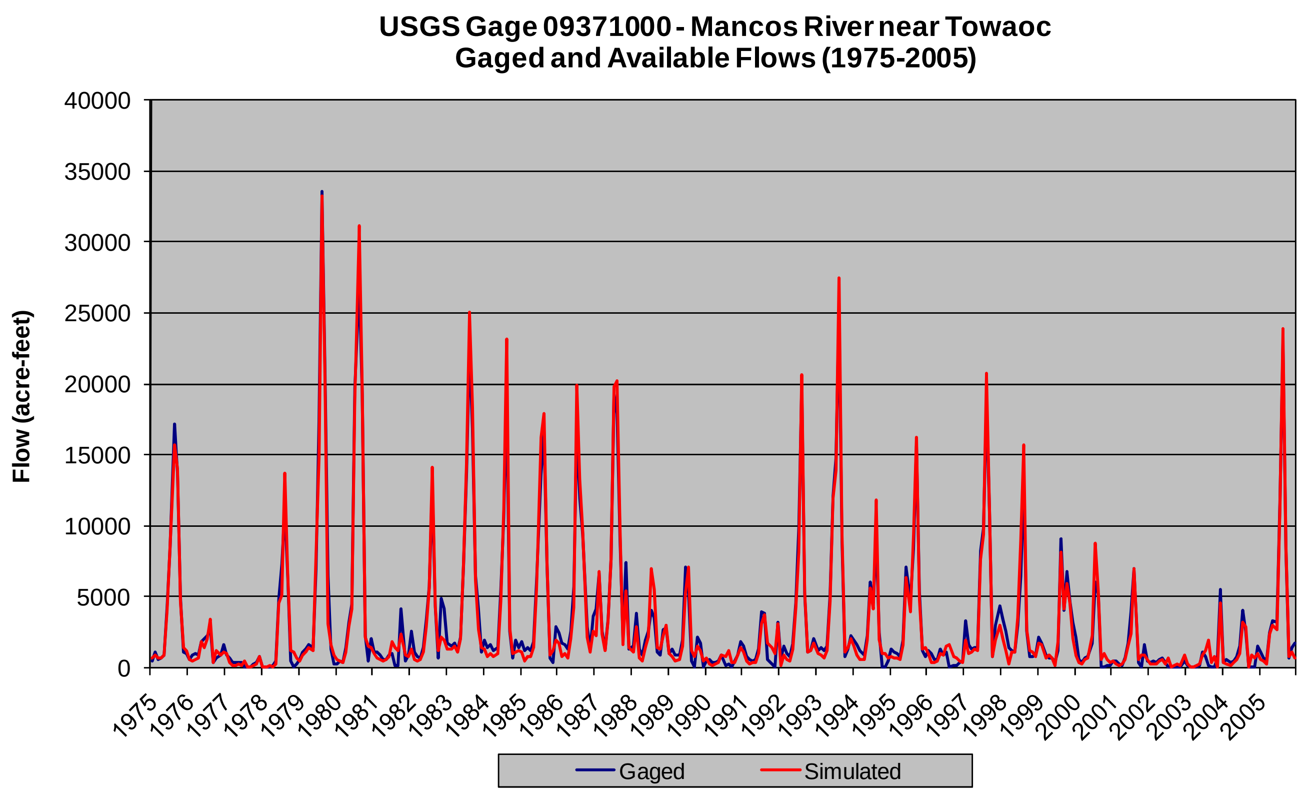
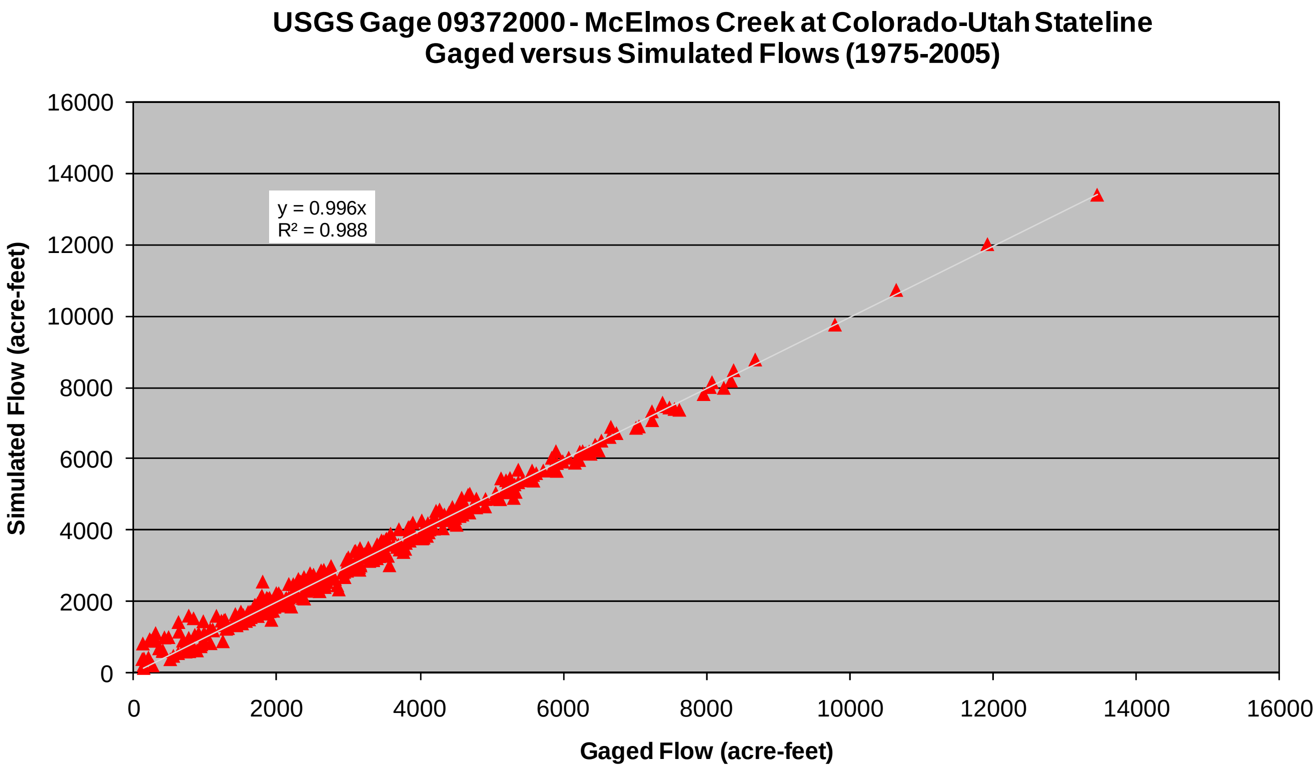


Figure 7.7 Streamflow Calibration – Mancos River near Towaoc



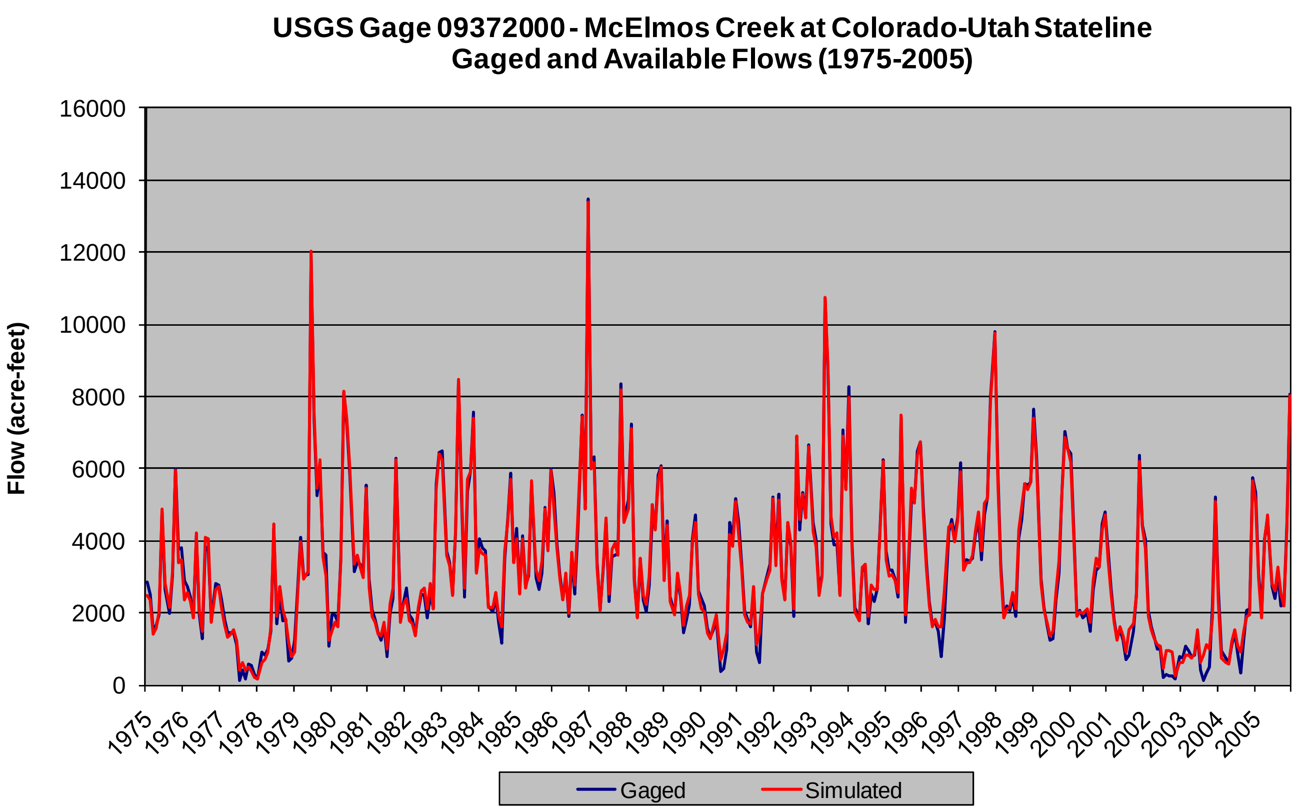
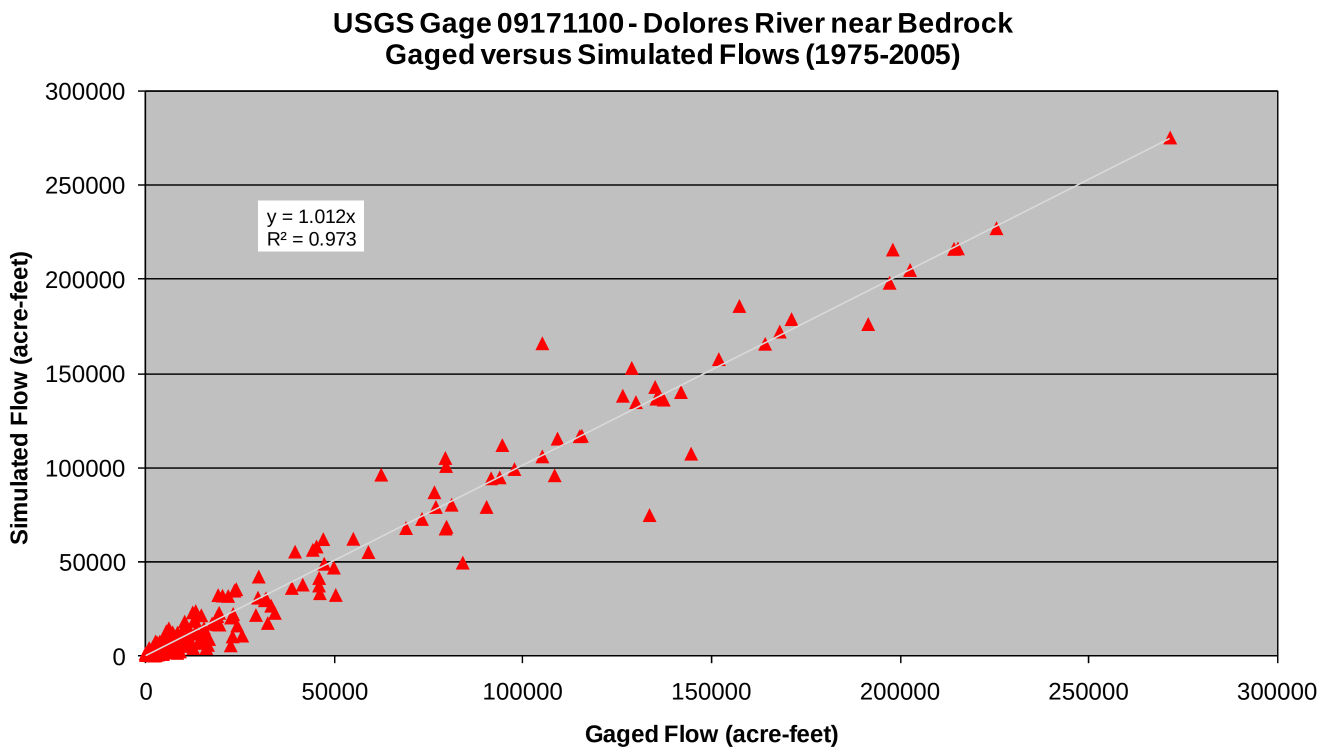


Figure 7.8 Streamflow Calibration – McElmo Creek at Colorado-Utah Stateline



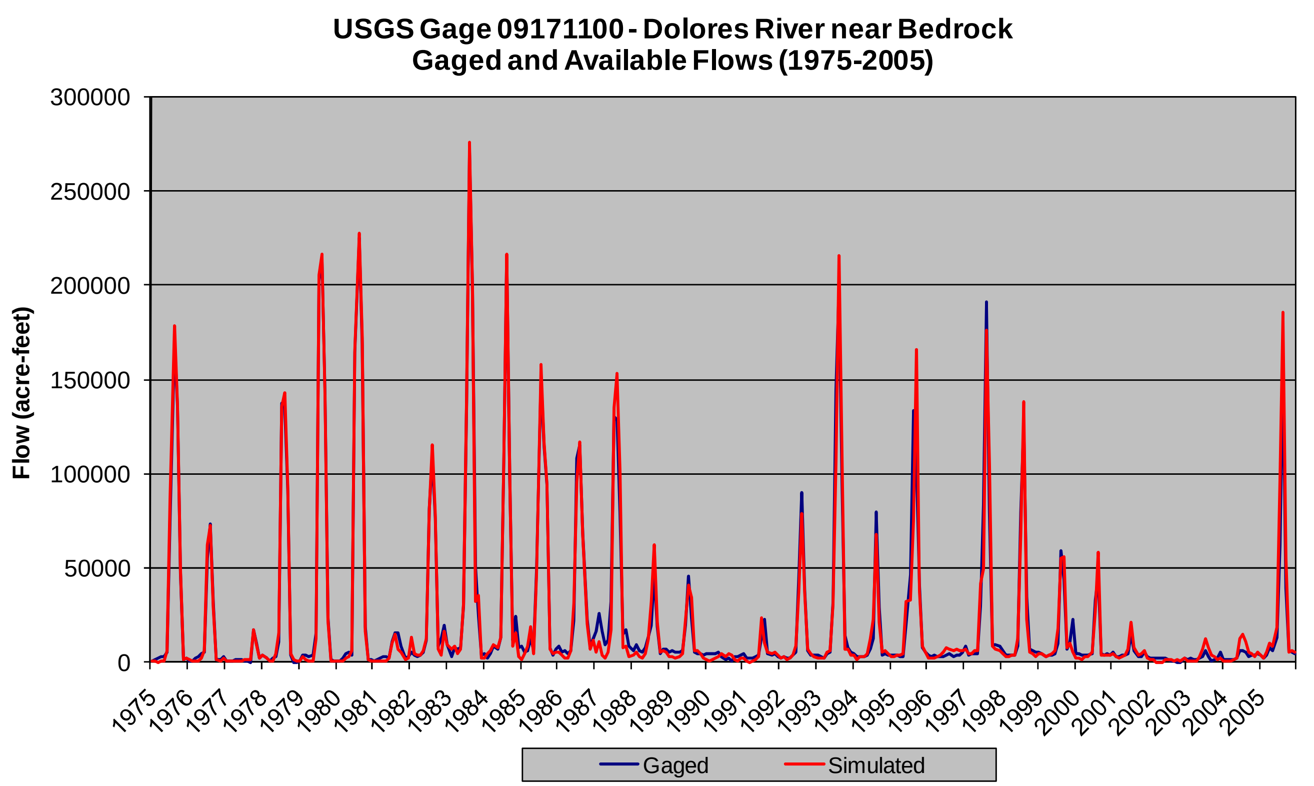
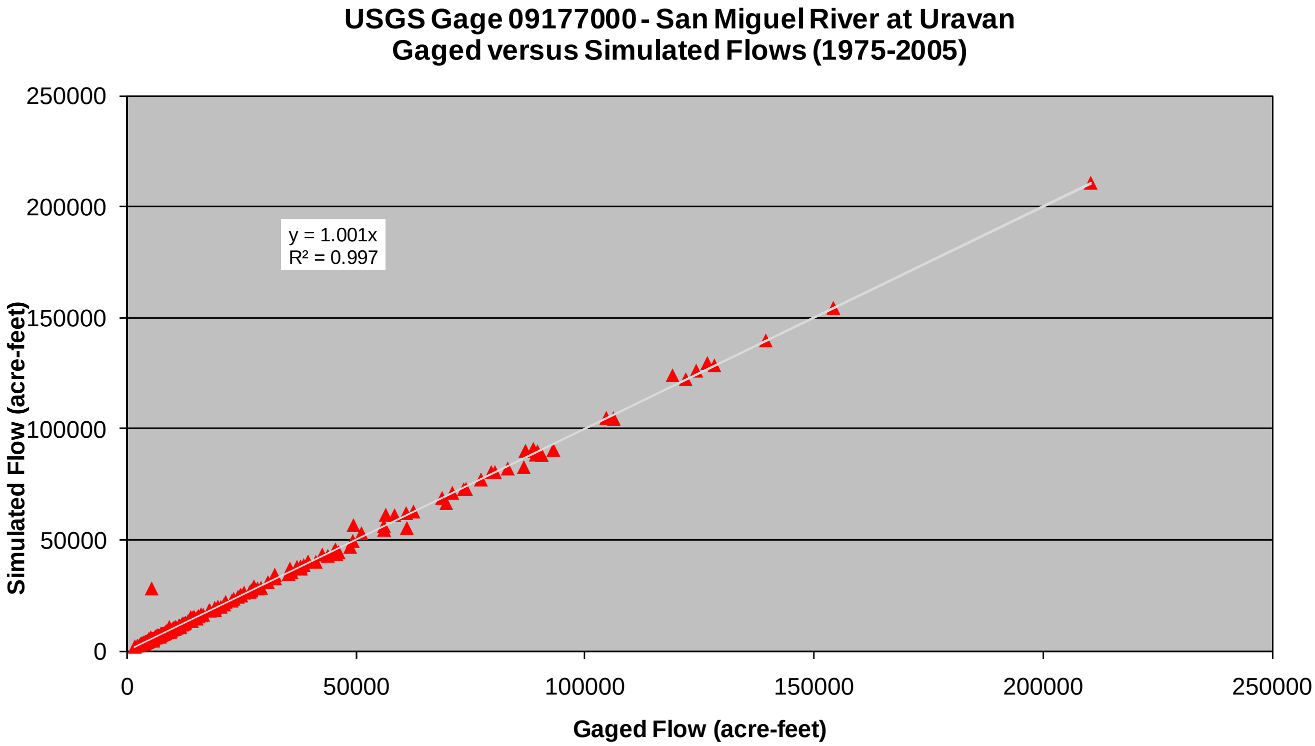


Figure 7.9 Streamflow Calibration – Dolores River near Bedrock



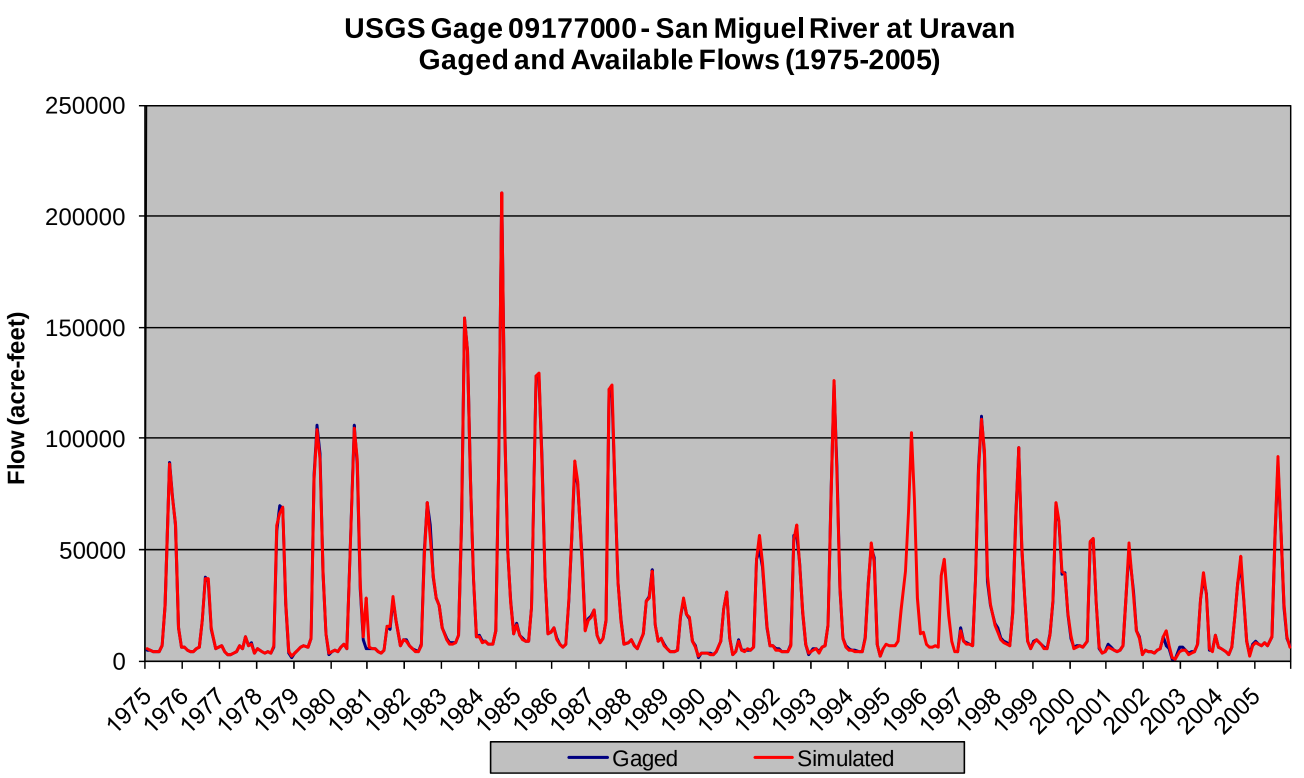


Figure 7.10 Streamflow Calibration – San Miguel River at Uravan

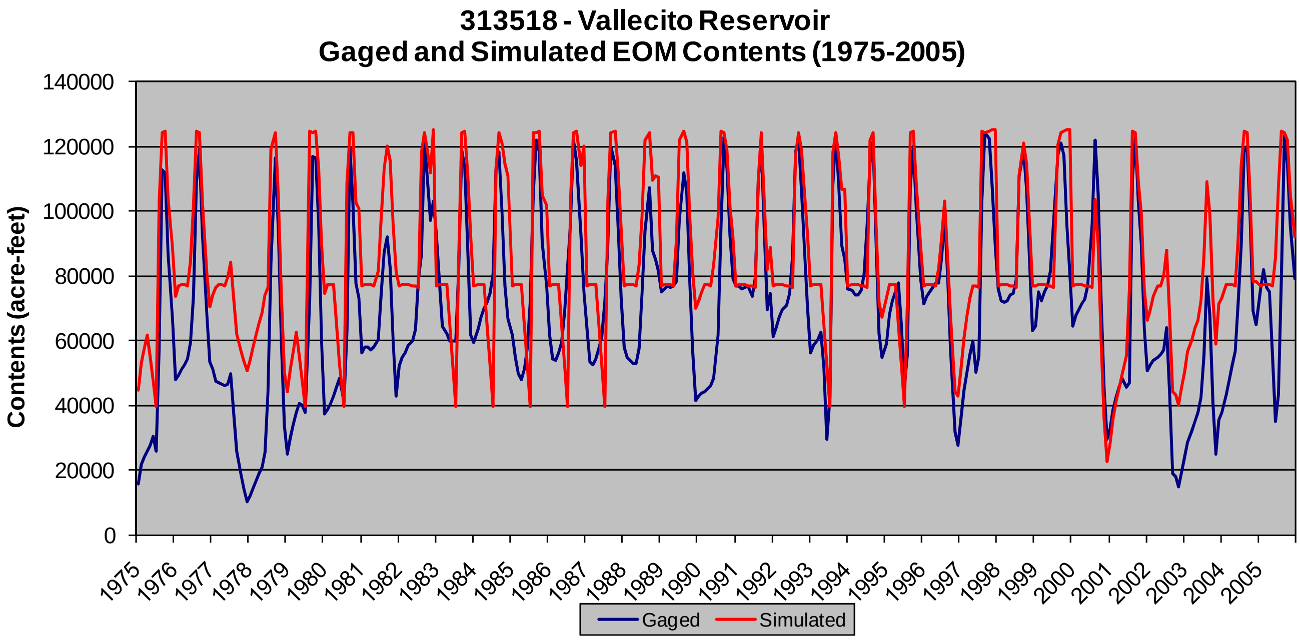


Figure 7.11 Reservoir Calibration – Vallecito Reservoir

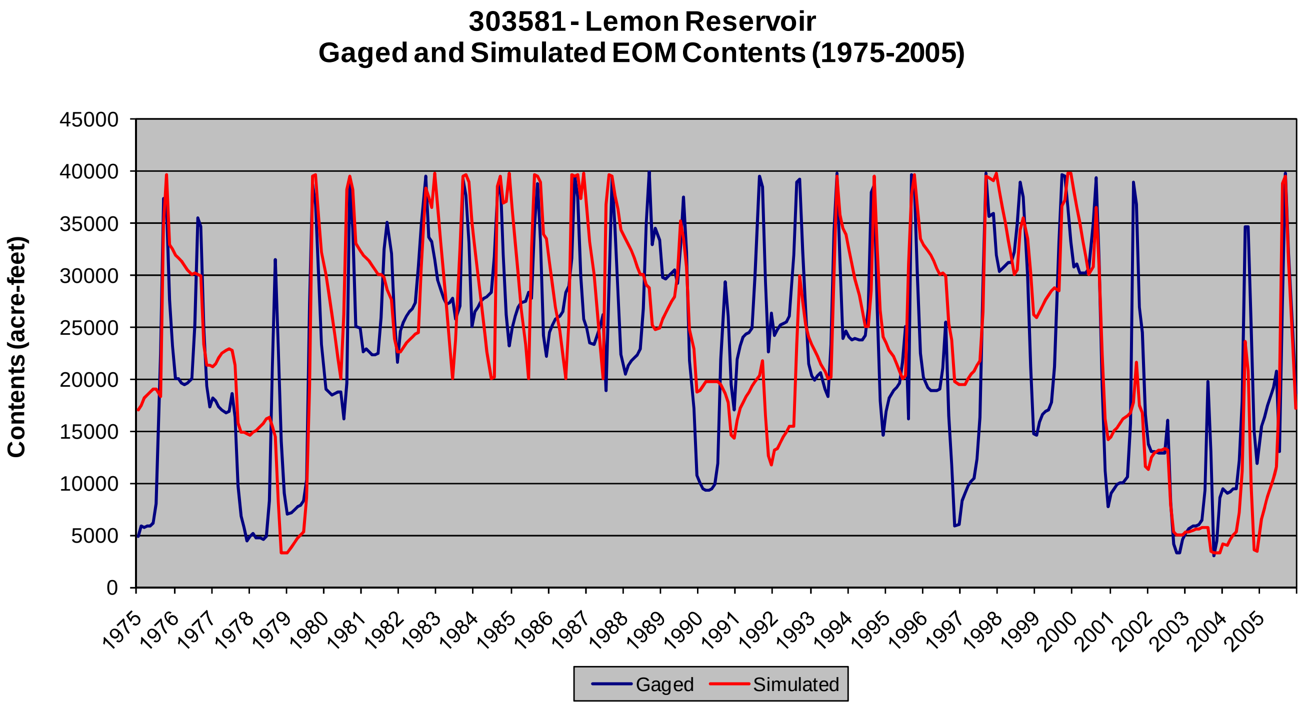


Figure 7.12 Reservoir Calibration – Lemon Reservoir

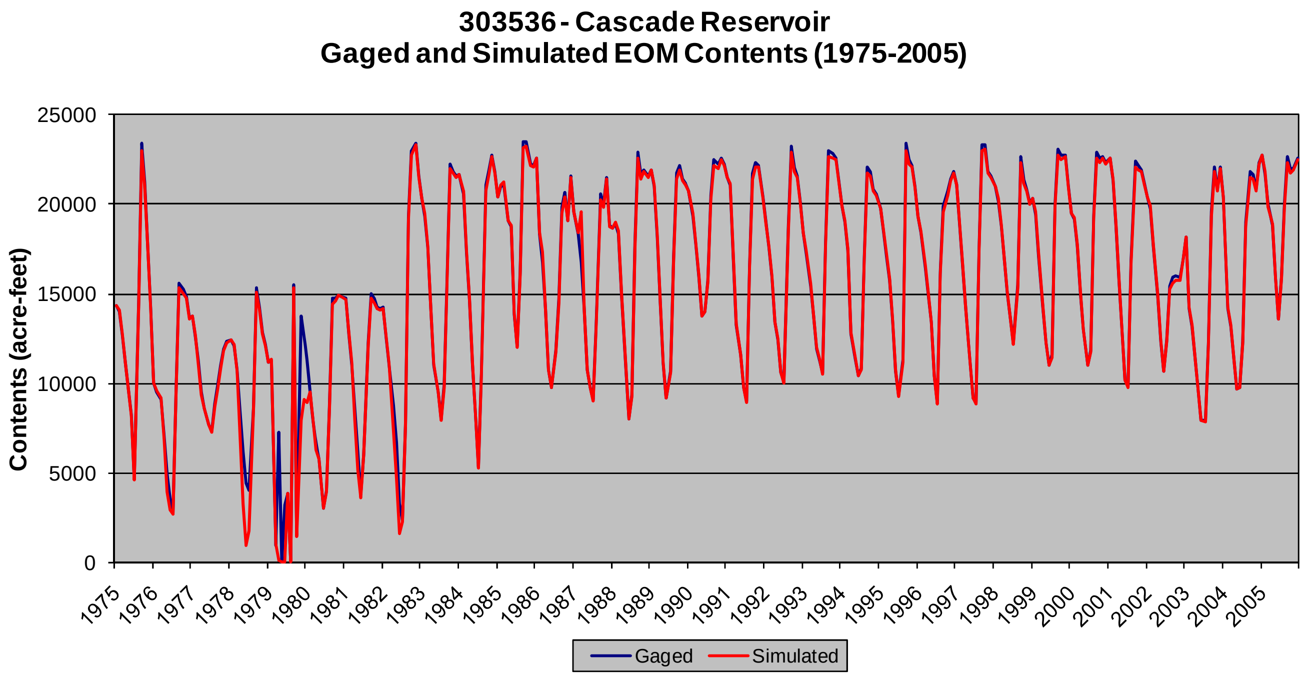


Figure 7.13 Reservoir Calibration – Cascade Reservoir

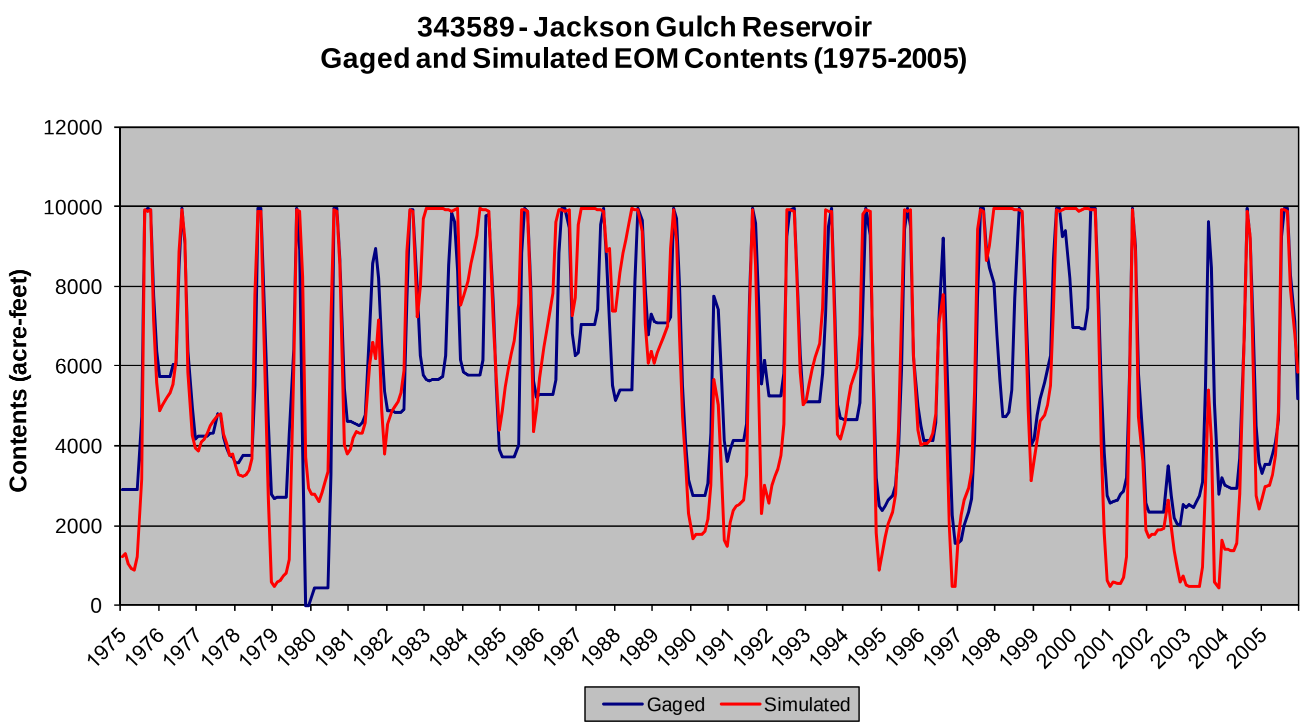


Figure 7.14 Reservoir Calibration – Jackson Gulch Reservoir

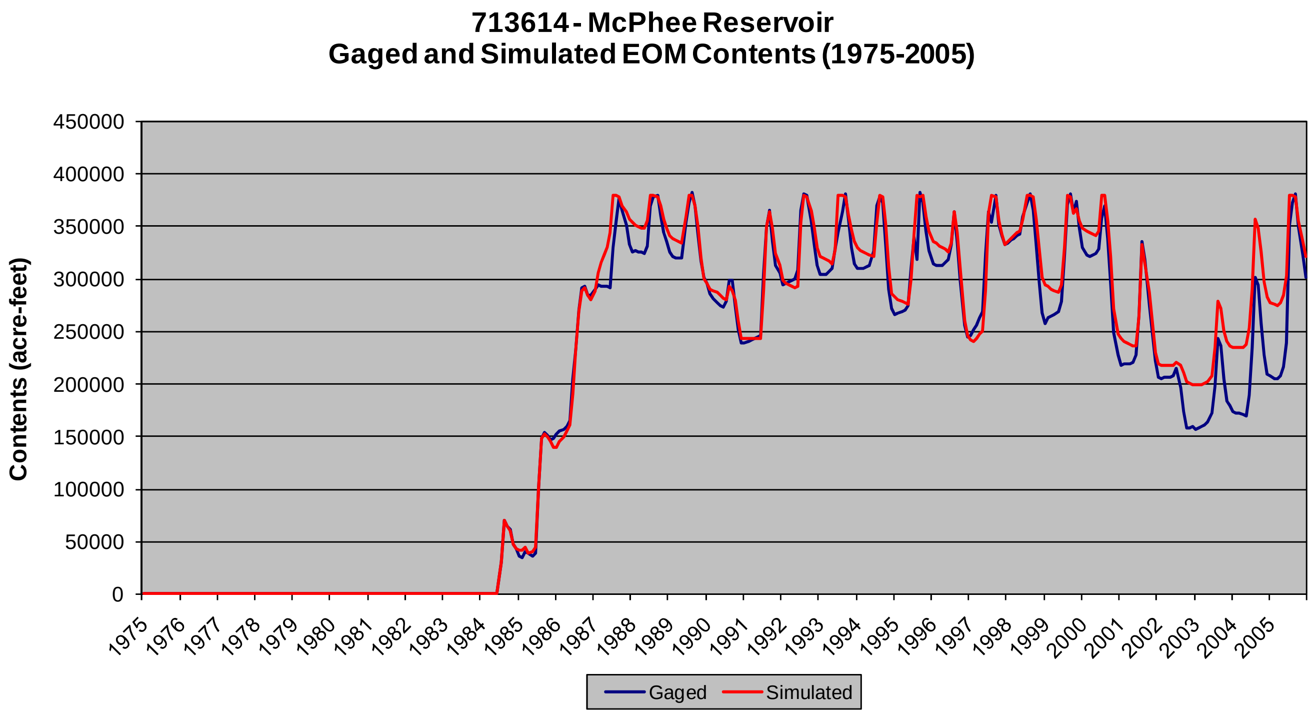


Figure 7.15 Reservoir Calibration – McPhee Reservoir

8. Daily Baseline Results

Note: This section describes a Daily Baseline Data Set that was completed in November 2005. The San Juan Model Historical (calibration), Calculated and Baseline data files were updated in October 2009, and the 2009 calibration and Baseline data sets are described in this user manual. Inconsistencies between the 2008 and 2009 Daily Baseline Data Set are minor, and include:

1) maximum irrigation efficiency set to 0.60 in 2008, and set to 0.54 in 2009
2) differences in IWR for fields below 6,500 ft in elevation, because an elevation adjustment was applied to crop coefficients in the Blaney-Criddle analysis in the 2009 model

The approach described for the Daily Baseline Data Set is accurate, except for the items listed above. Table values in this appendix are expected to be similar to, but not exactly, what would be produced with an updated Daily Baseline Data Set.

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	Section 5.8

File Name	Description	Reference
	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	
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	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.

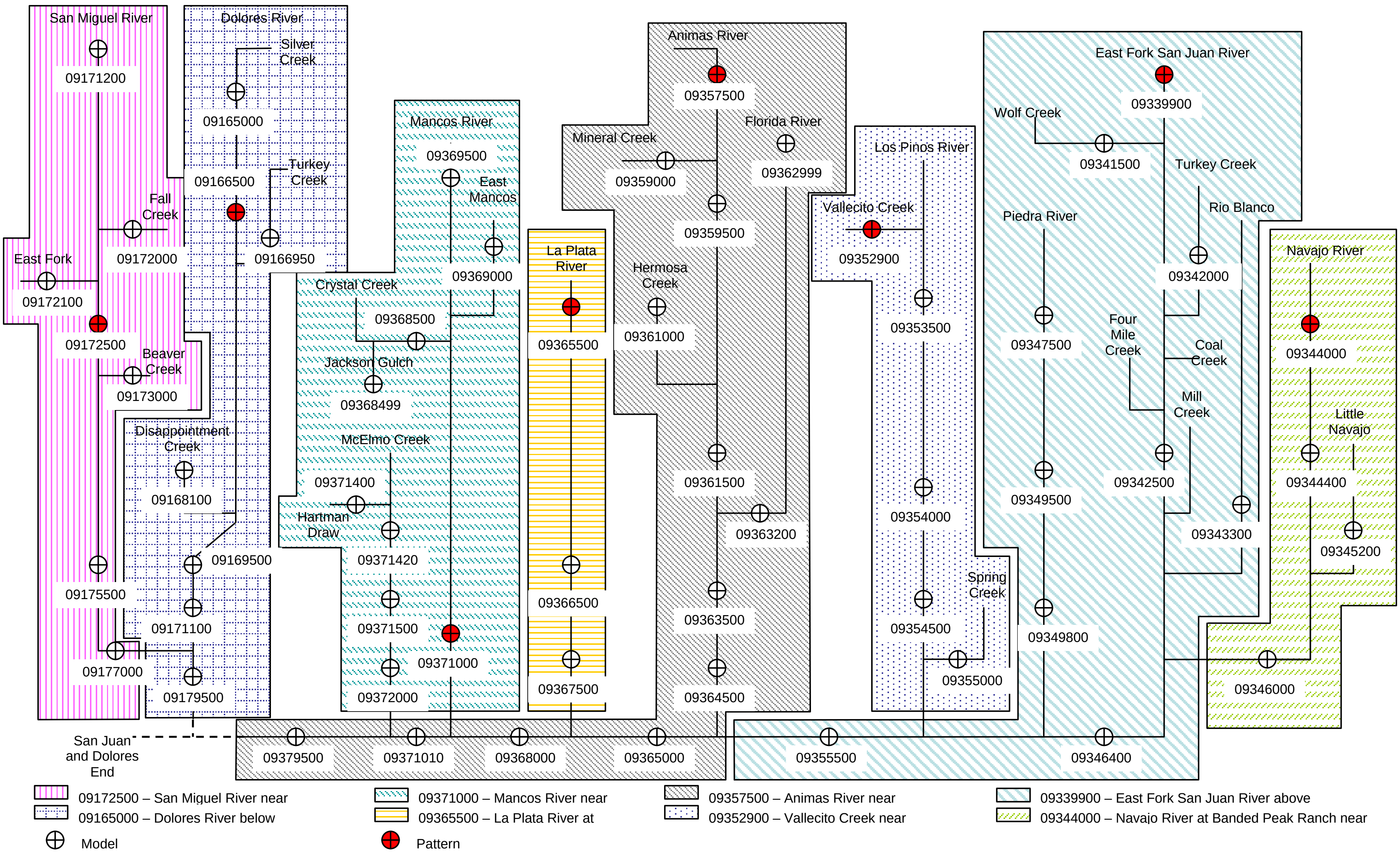


Figure 8.1 – Recommended Application of Daily Pattern Gages

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.

Where to find more information

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

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%

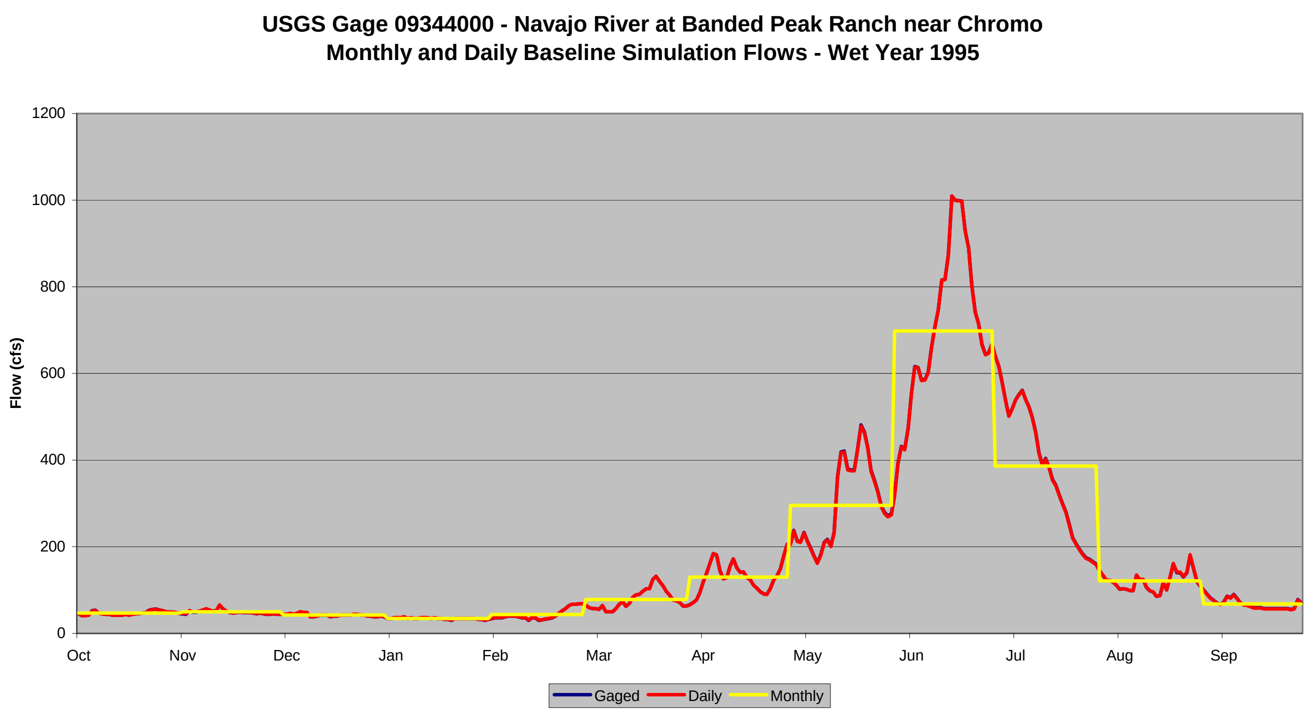


Figure 8.2 Daily Baseline Comparison, Wet Year – Navajo River at Banded Peak Ranch

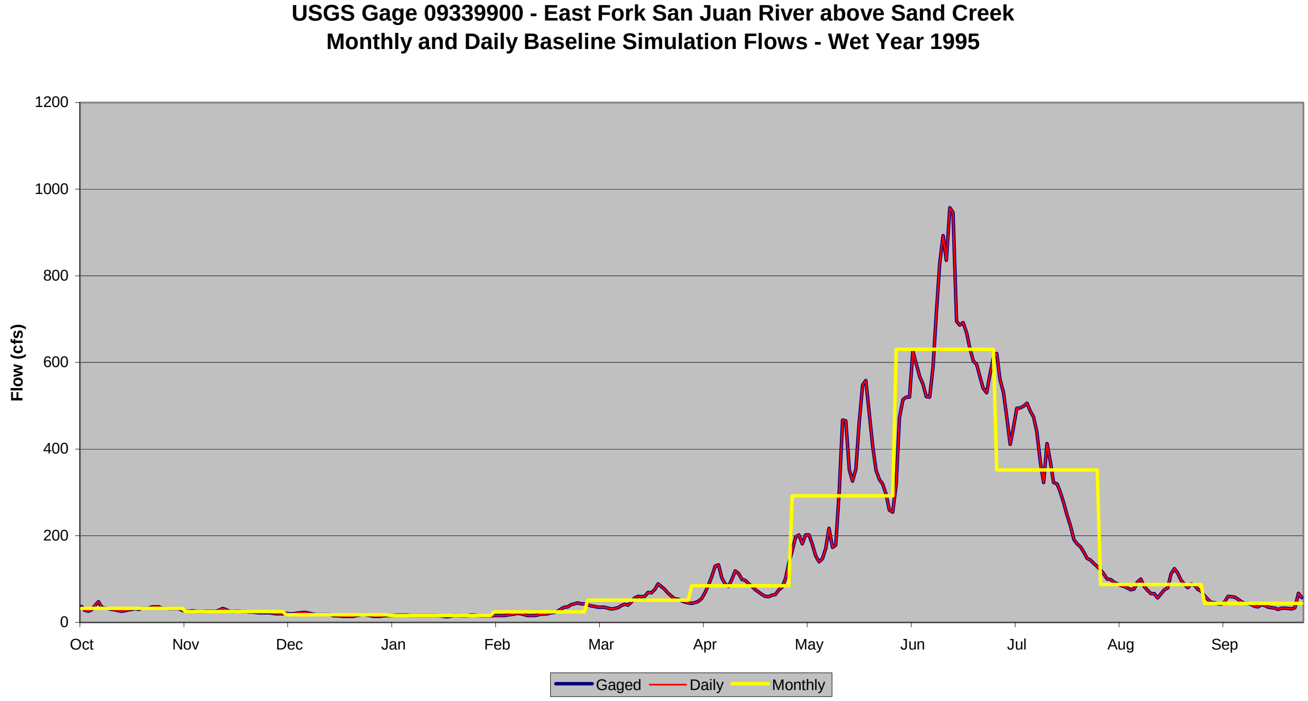


Figure 8.3 Daily Baseline Comparison, Wet Year – East Fork San Juan above Sand Creek

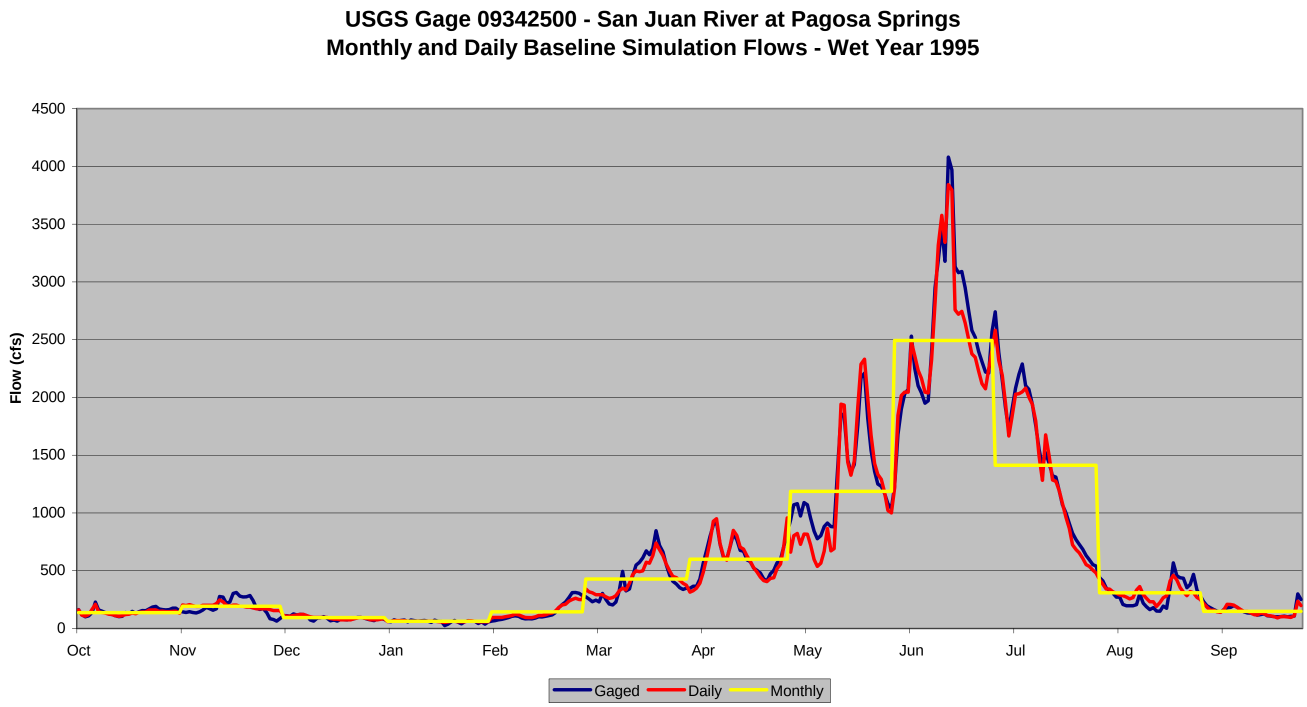


Figure 8.4 Daily Baseline Comparison, Wet Year – San Juan River at Pagosa Springs

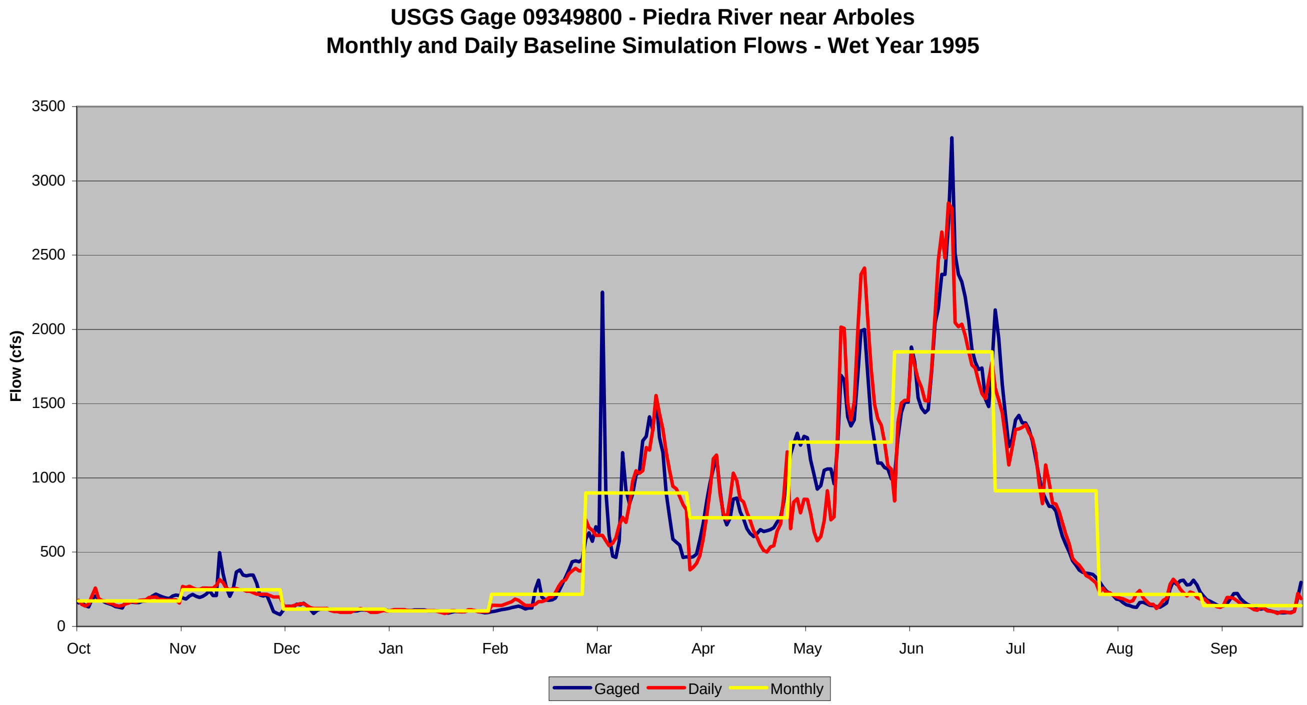


Figure 8.5 Daily Baseline Comparison, Wet Year – Piedra River near Arboles

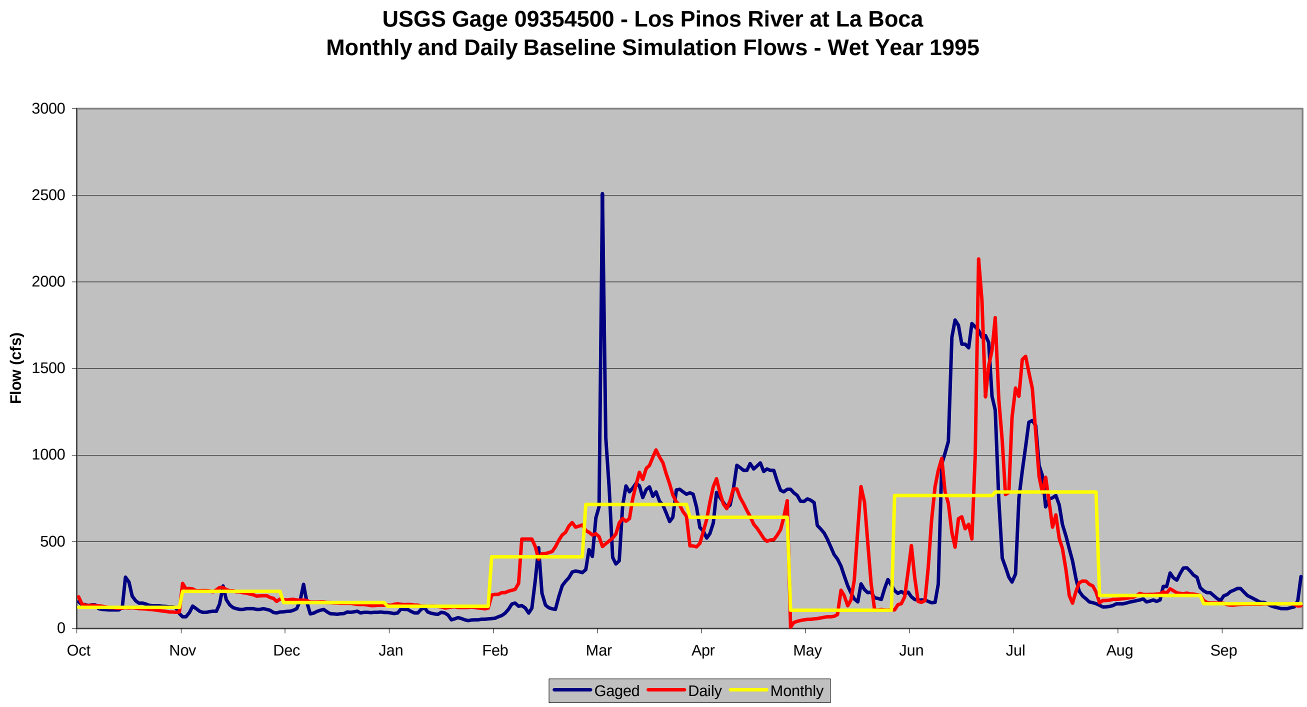


Figure 8.6 Daily Baseline Comparison, Wet Year – Los Pinos River at La Boca

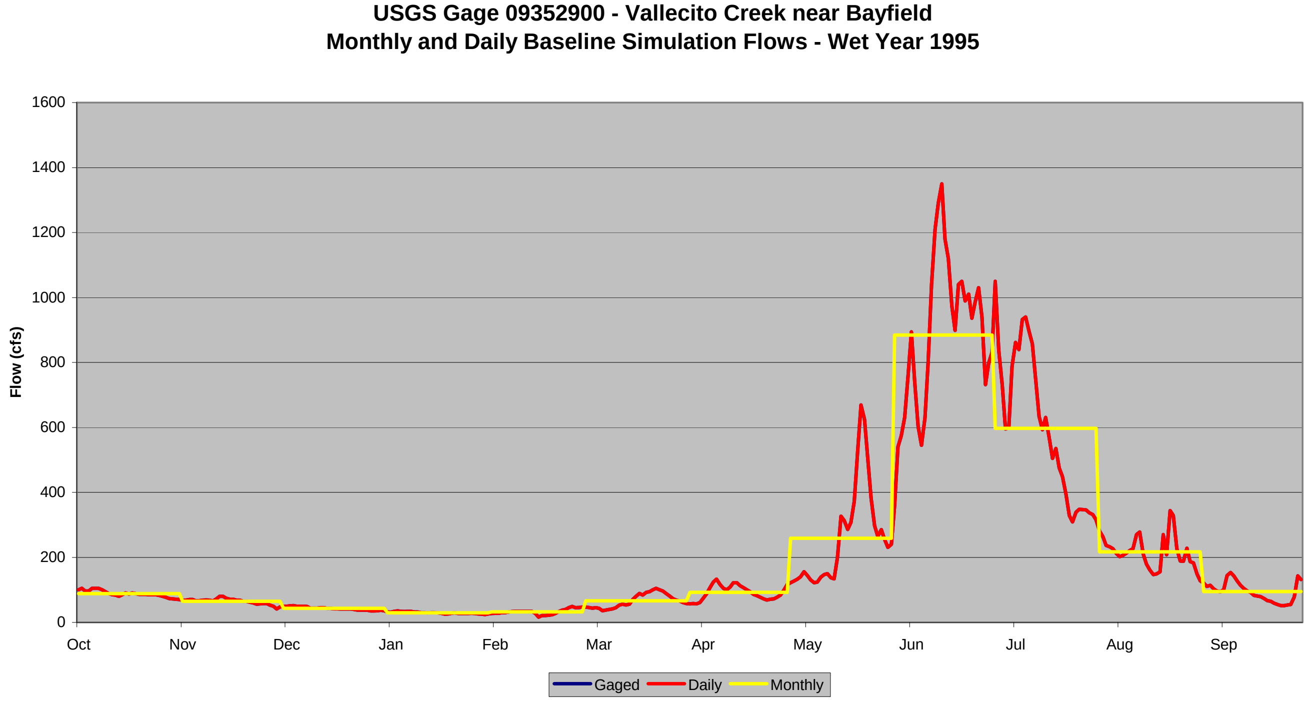


Figure 8.7 Daily Baseline Comparison, Wet Year – Vallecito Creek near Bayfield

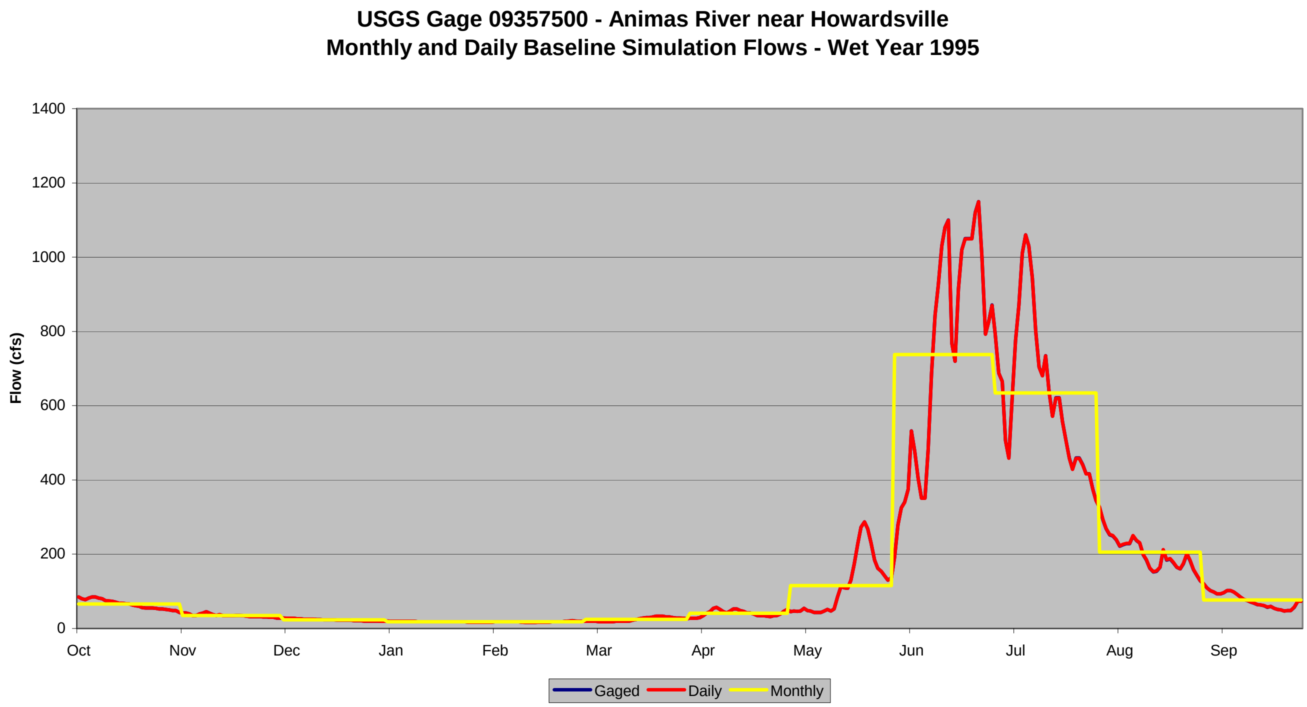


Figure 8.8 Daily Baseline Comparison, Wet Year – Animas River near Howardsville

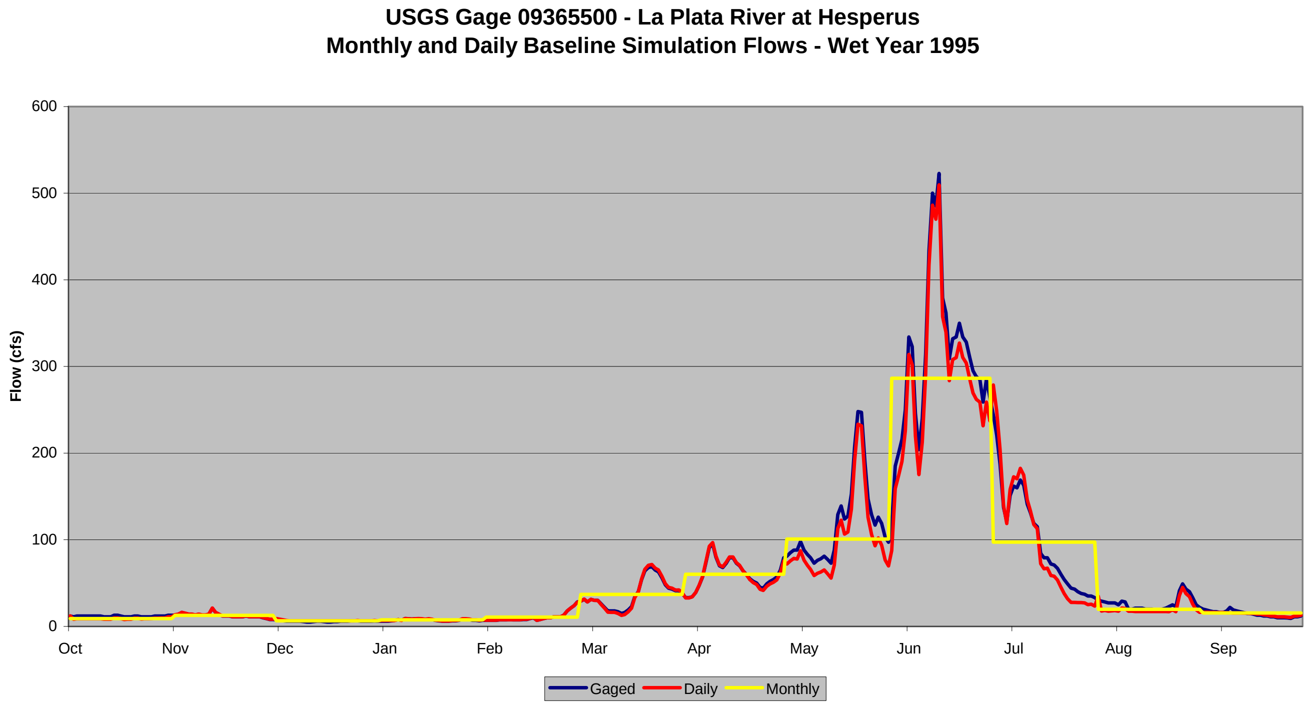


Figure 8.9 Daily Baseline Comparison, Wet Year – La Plata River at Hesperus

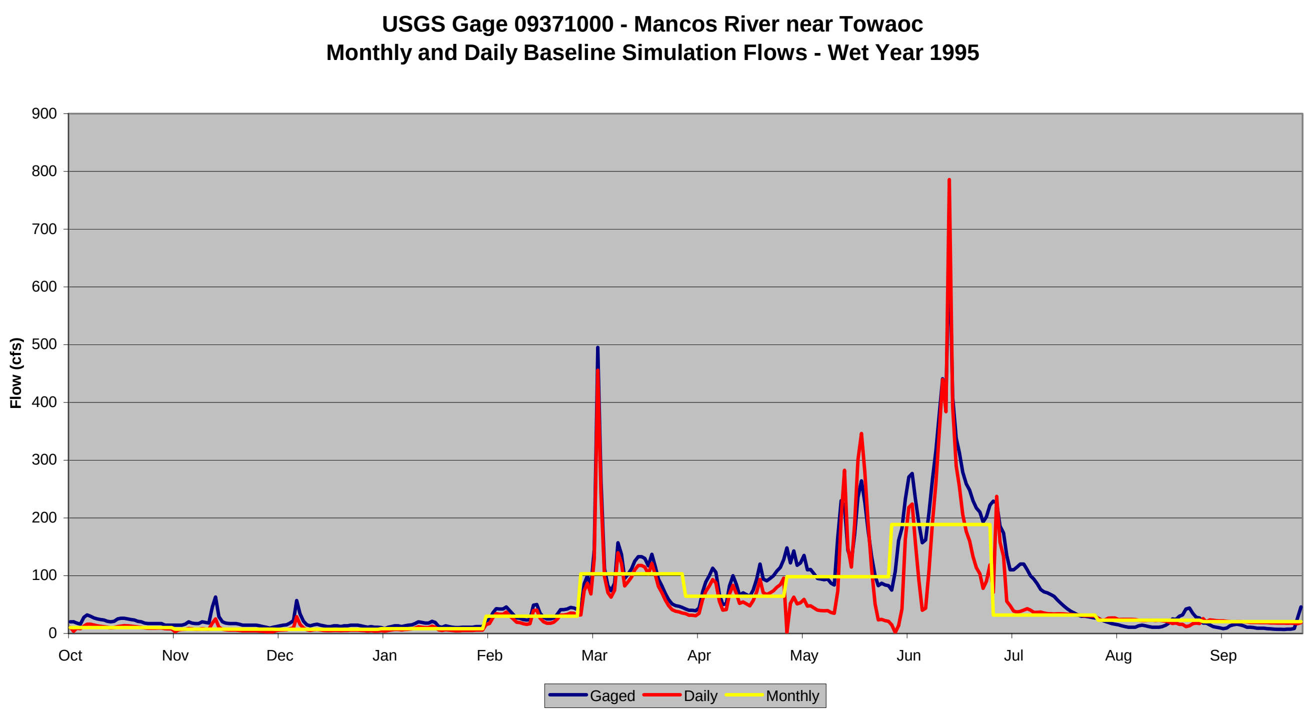


Figure 8.10 Daily Baseline Comparison, Wet Year – Mancos River near Towaoc

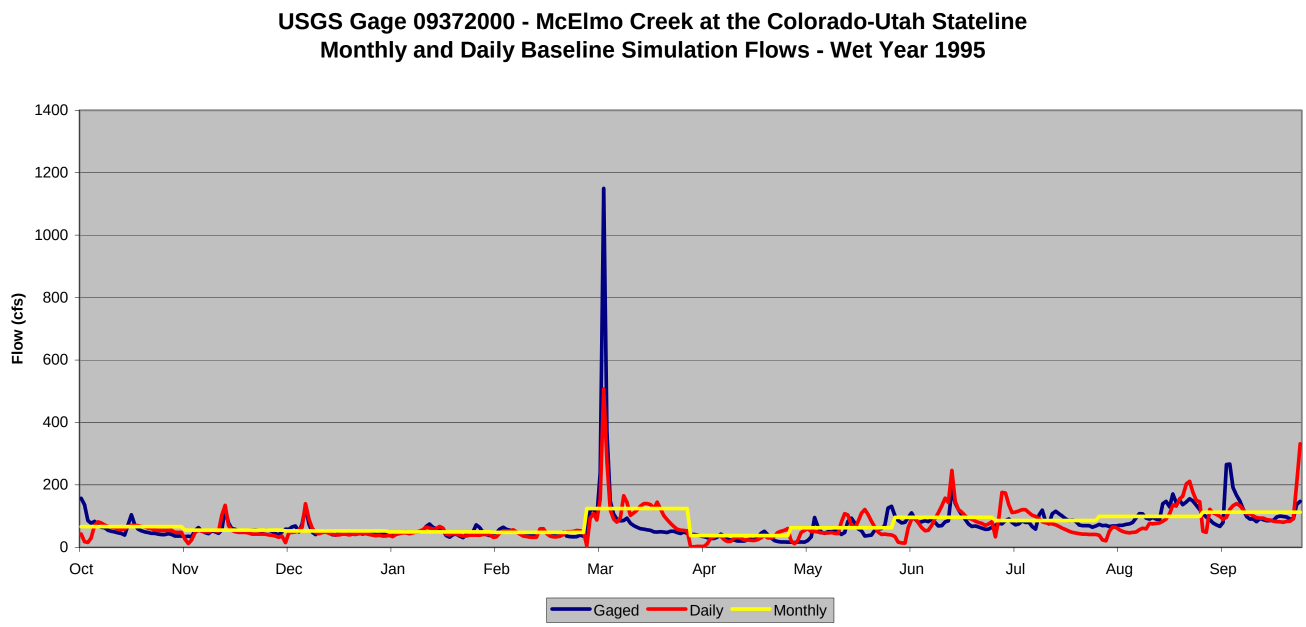


Figure 8.11 Daily Baseline Comparison, Wet Year – McElmo Creek at CO-UT Stateline

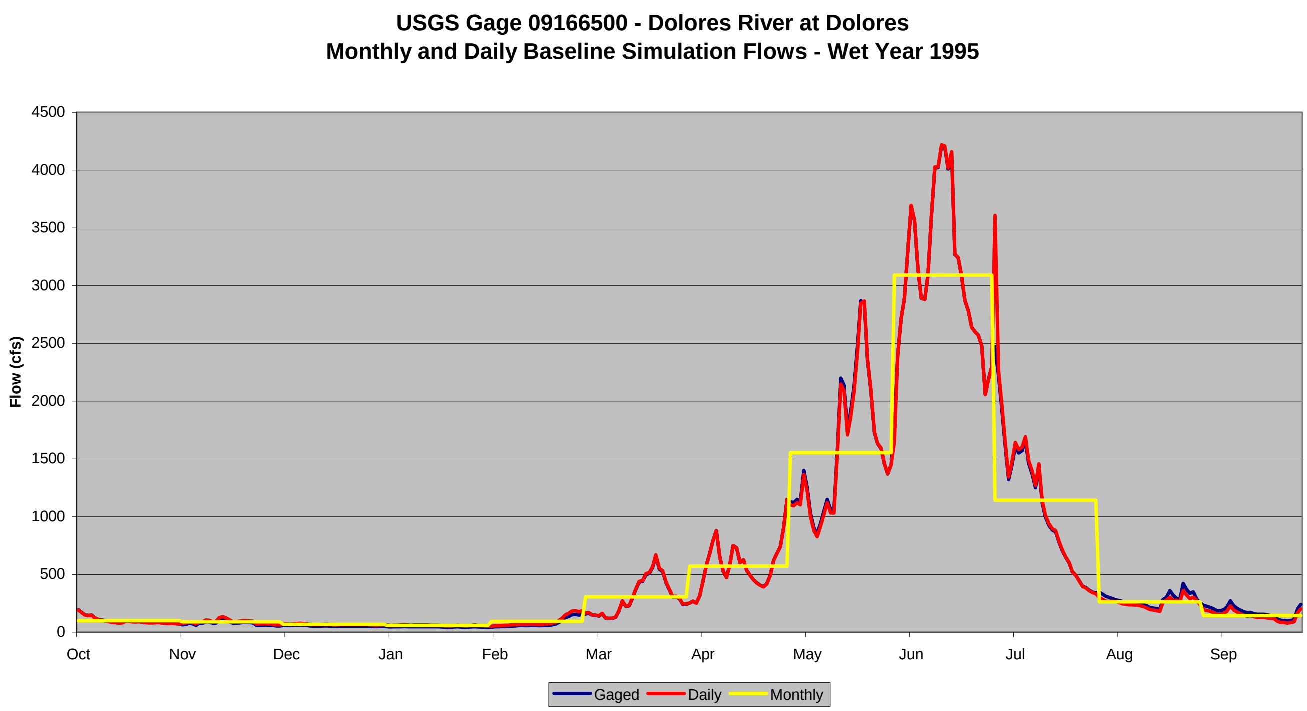


Figure 8.12 Daily Baseline Comparison, Wet Year – Dolores River at Dolores

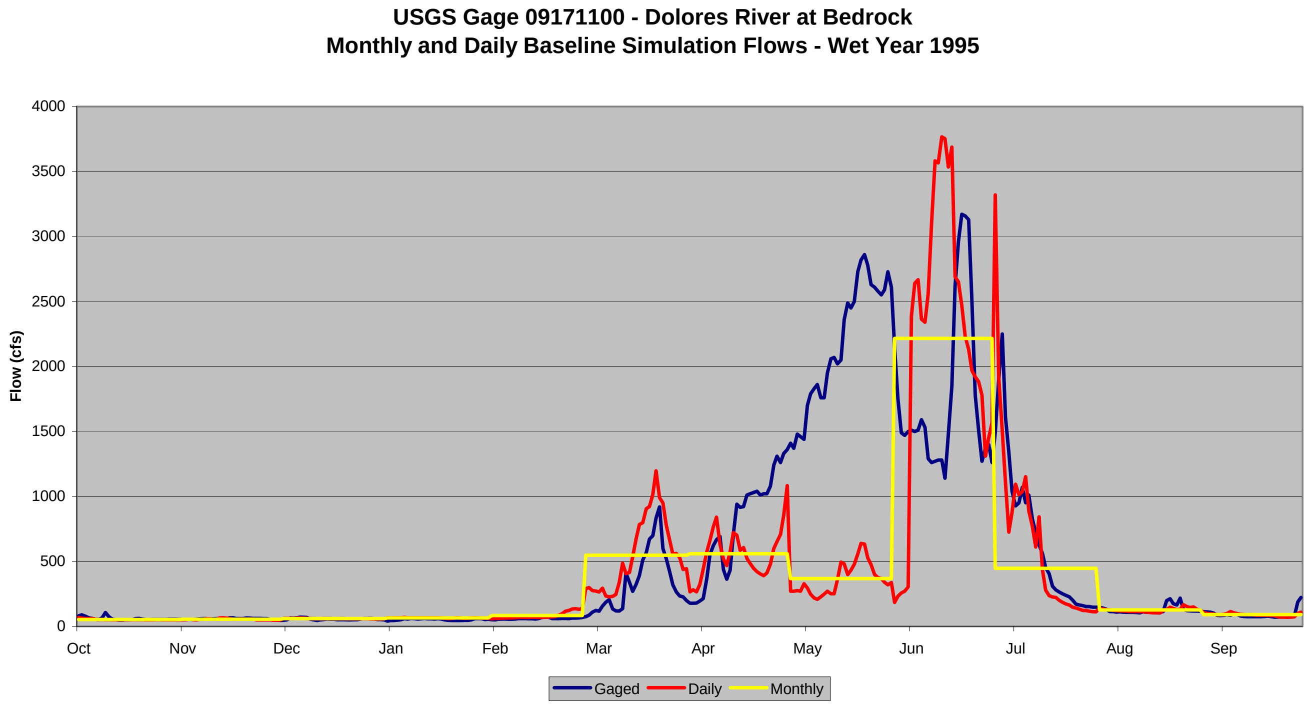


Figure 8.13 Daily Baseline Comparison, Wet Year – Dolores River at Bedrock

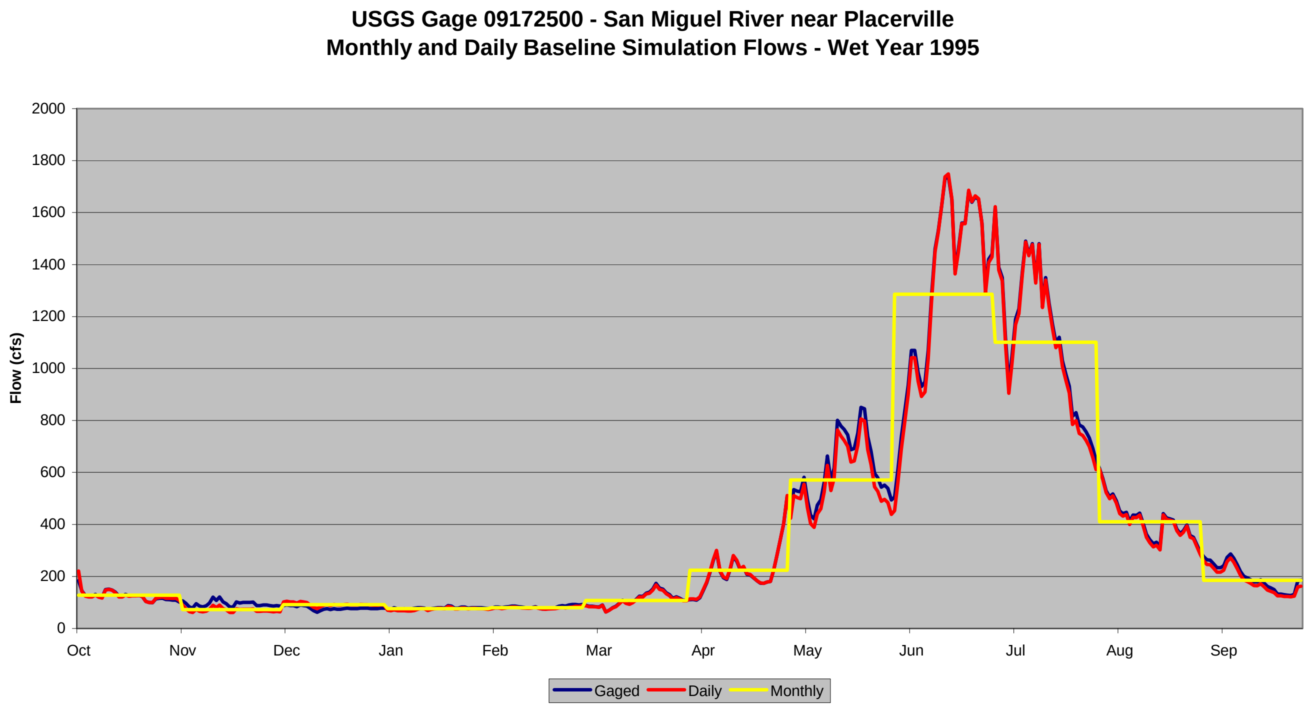


Figure 8.14 Daily Baseline Comparison, Wet Year – San Miguel River near Placerville

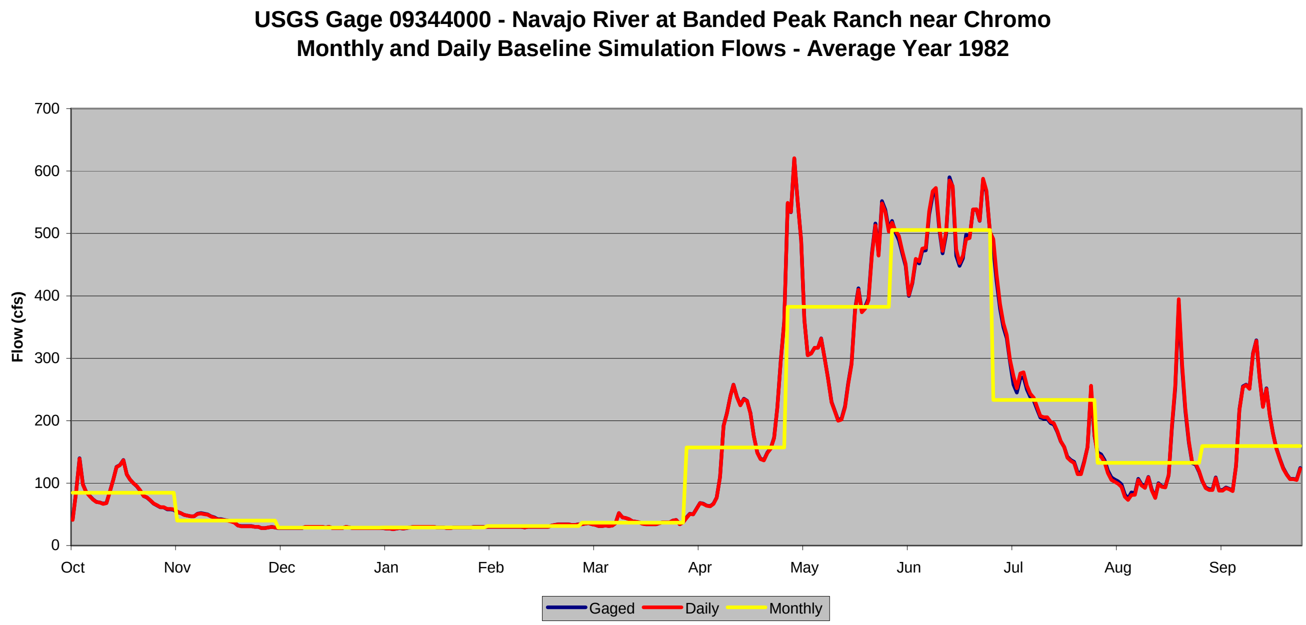


Figure 8.15 Daily Baseline Comparison, Average Year – Navajo River at Banded Peak Ranch

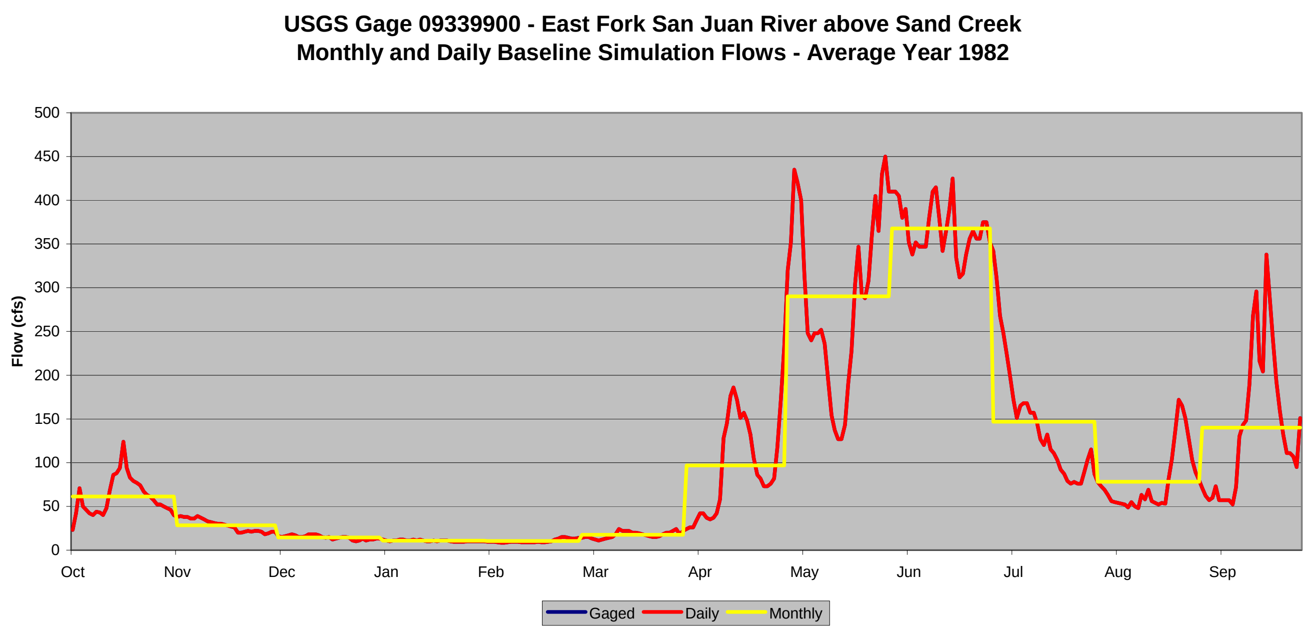


Figure 8.16 Daily Baseline Comparison, Average Year – East Fork San Juan River ab Sand Creek

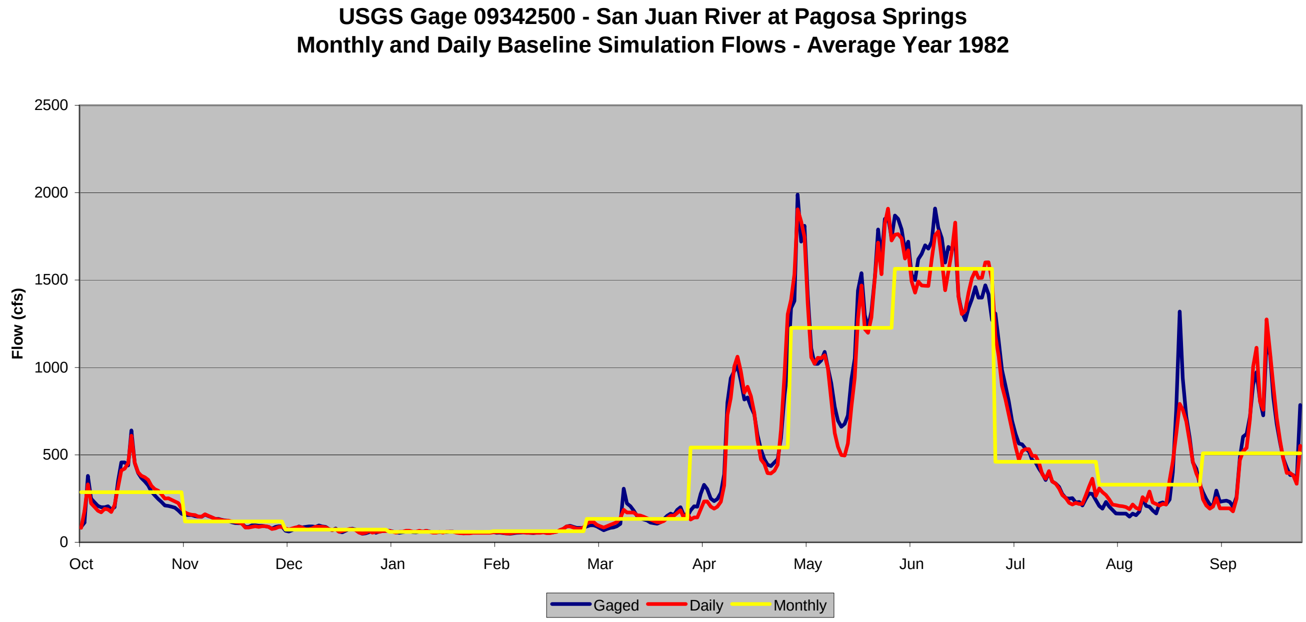


Figure 8.17 Daily Baseline Comparison, Average Year – San Juan River at Pagosa Springs

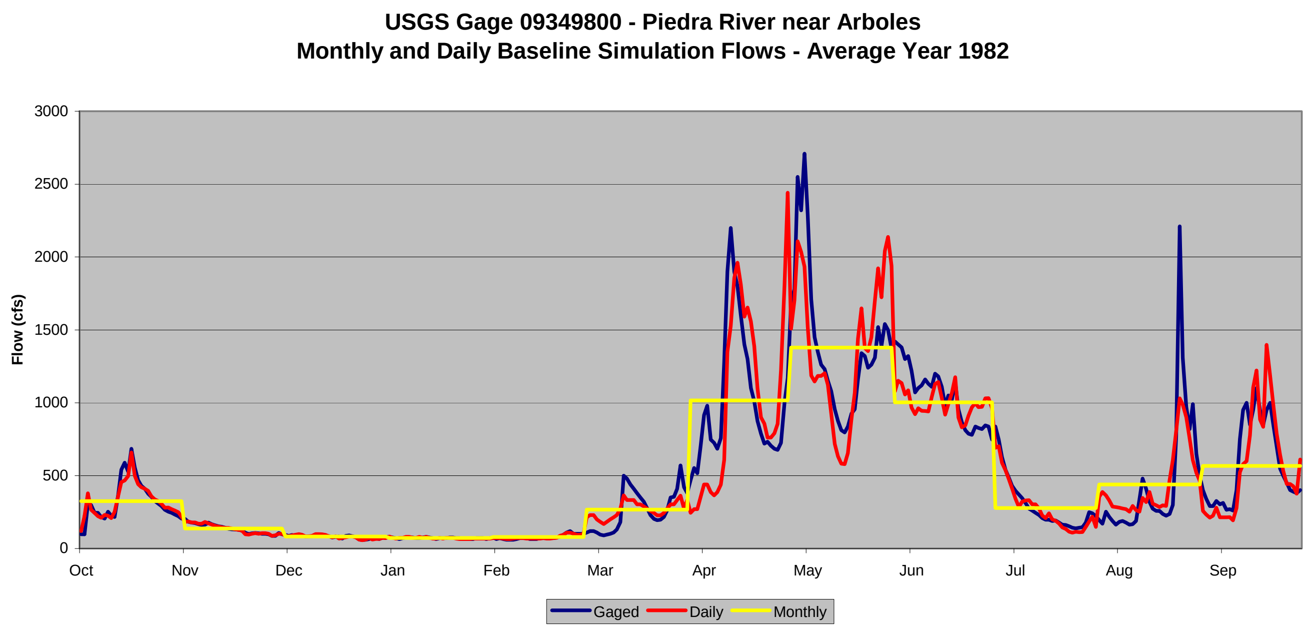


Figure 8.18 Daily Baseline Comparison, Average Year – Piedra River near Arboles

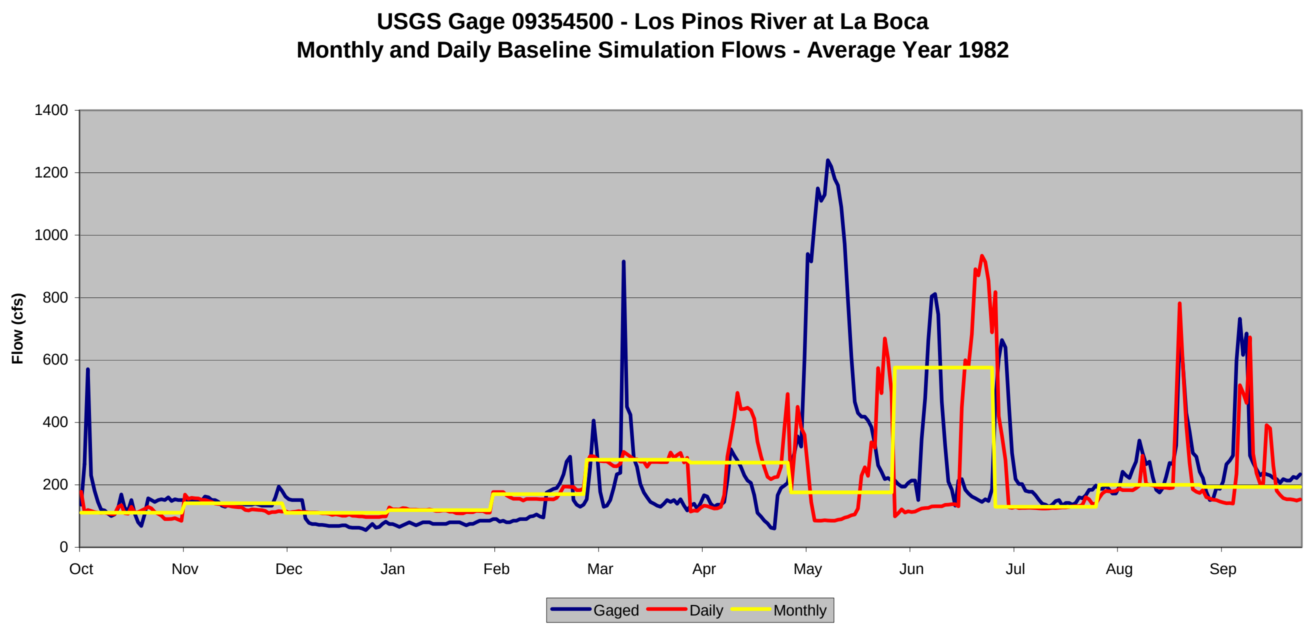


Figure 8.19 Daily Baseline Comparison, Average Year – Los Pinos River at La Boca

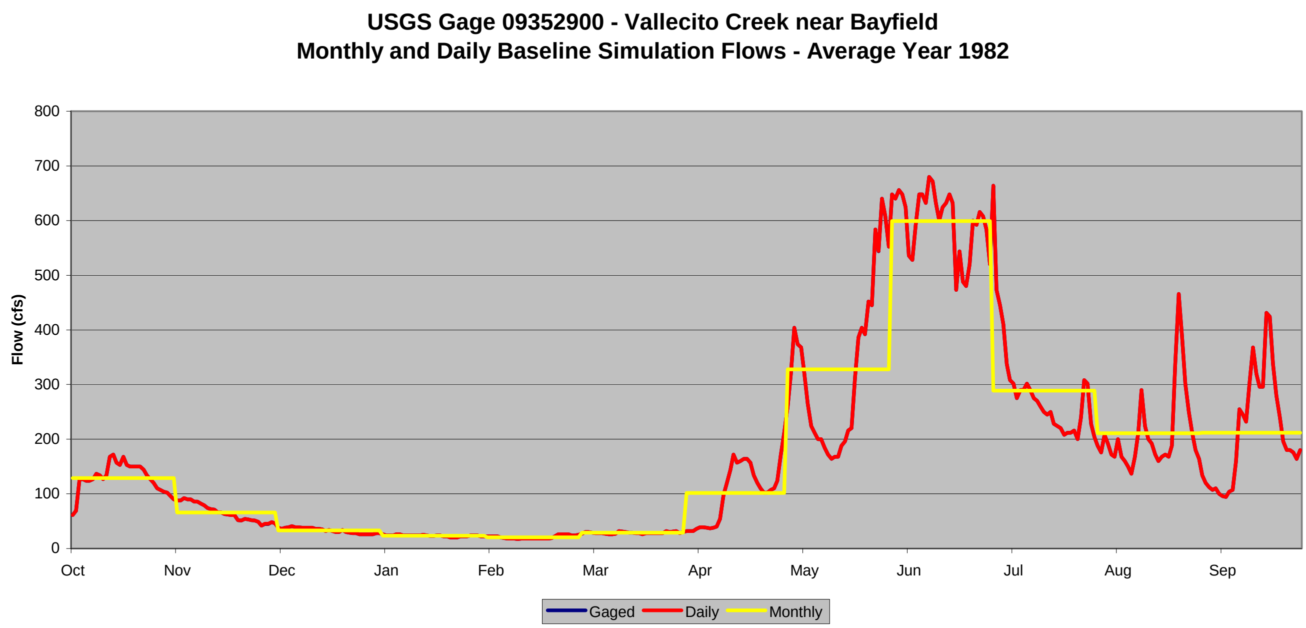


Figure 8.20 Daily Baseline Comparison, Average Year – Vallecito Creek near Bayfield

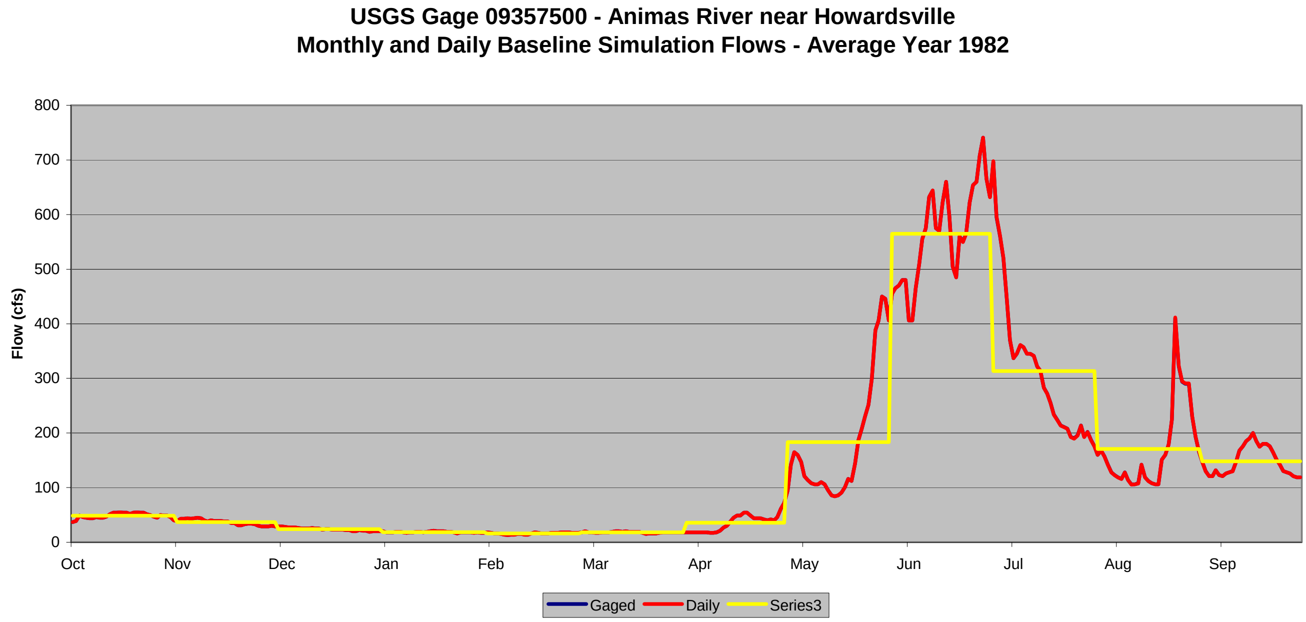


Figure 8.21 Daily Baseline Comparison, Average Year – Animas River near Howardsville

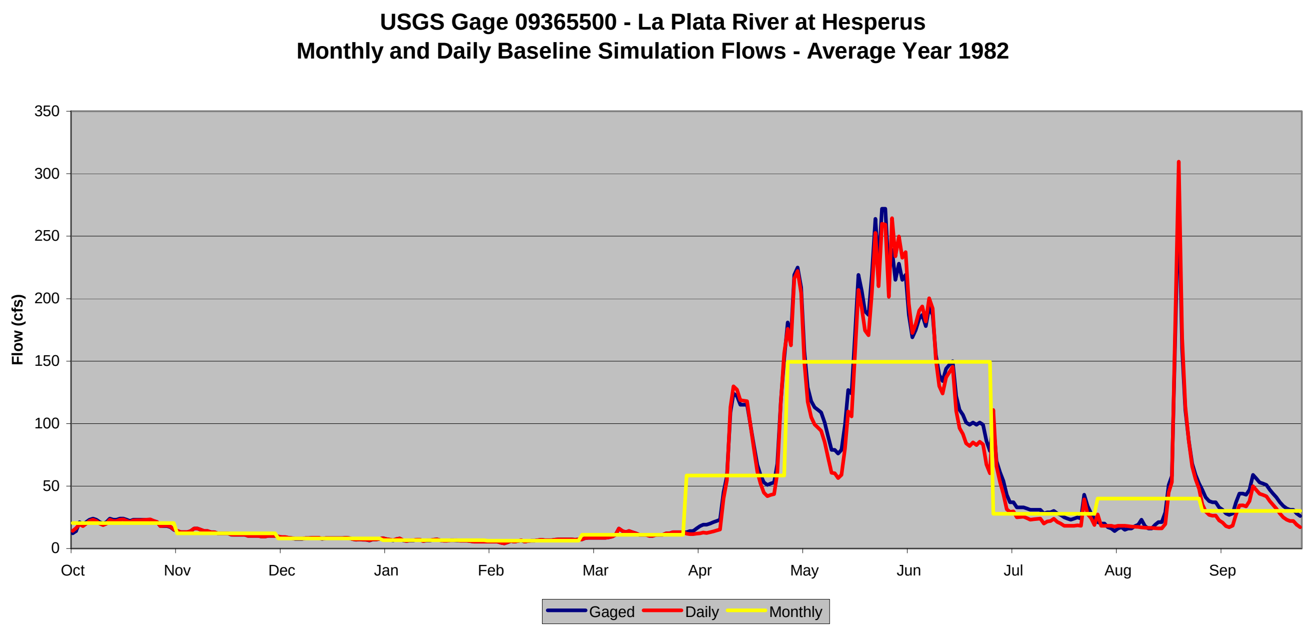


Figure 8.22 Daily Baseline Comparison, Average Year – La Plata River at Hesperus

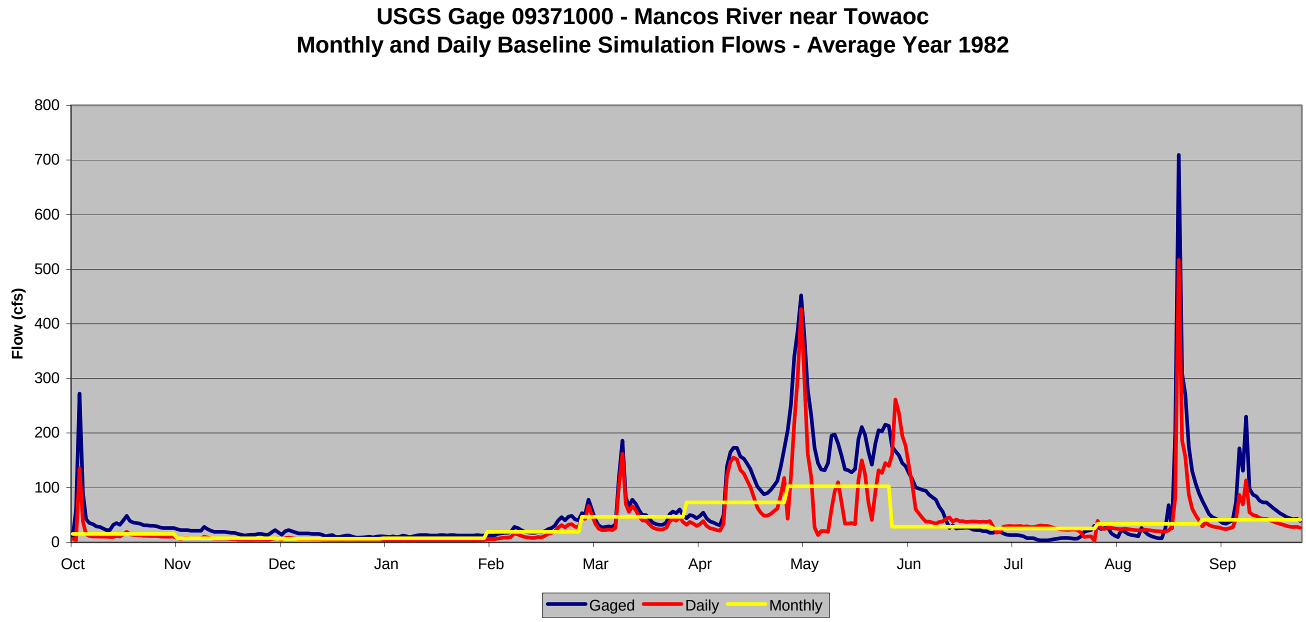


Figure 8.23 Daily Baseline Comparison, Average Year – Mancos River near Towaoc

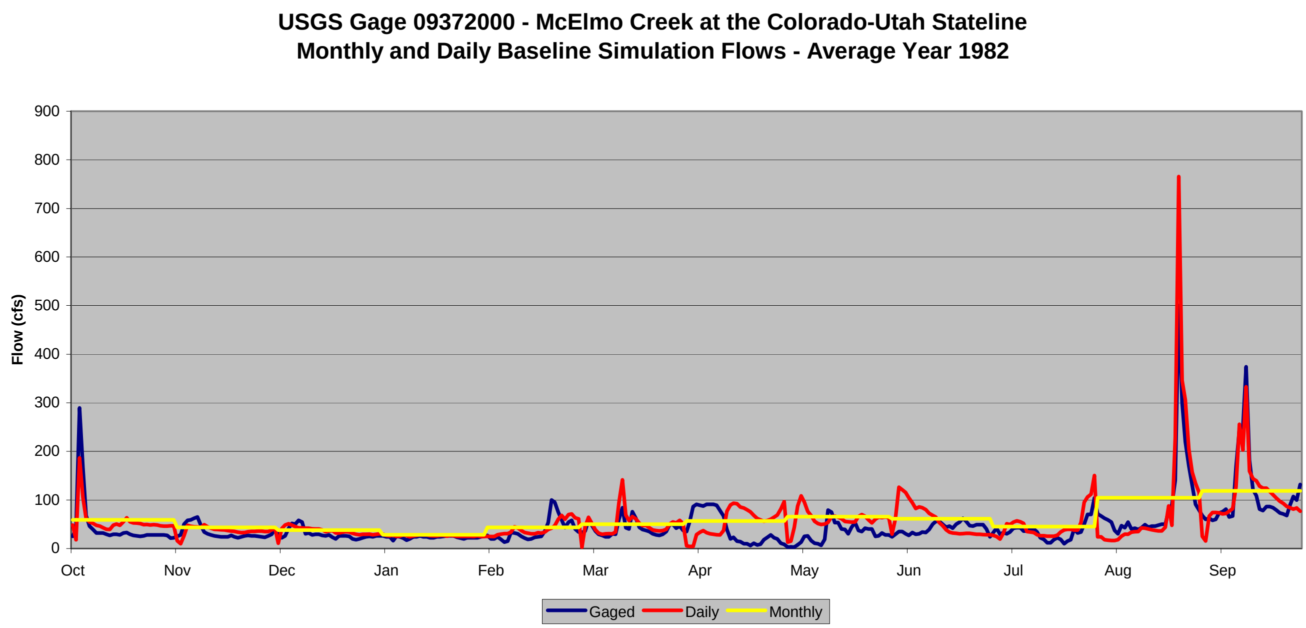


Figure 8.24 Daily Baseline Comparison, Average Year – McElmo Creek at CO-UT Stateline

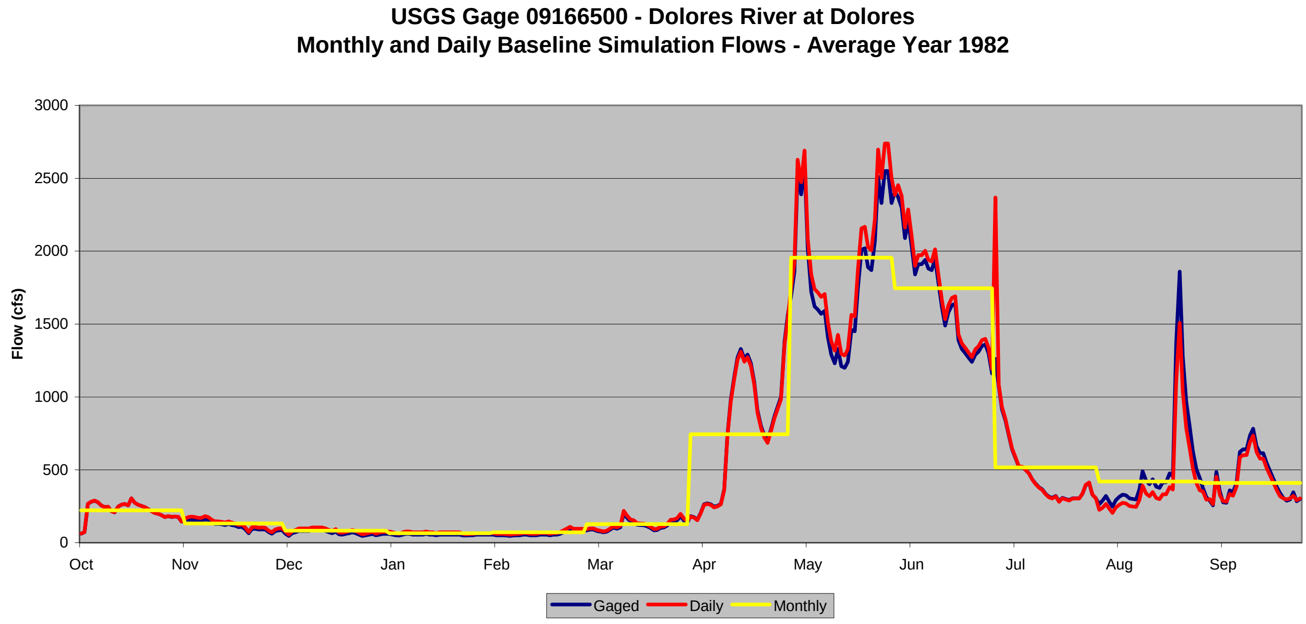


Figure 8.25 Daily Baseline Comparison, Average Year – Dolores River at Dolores

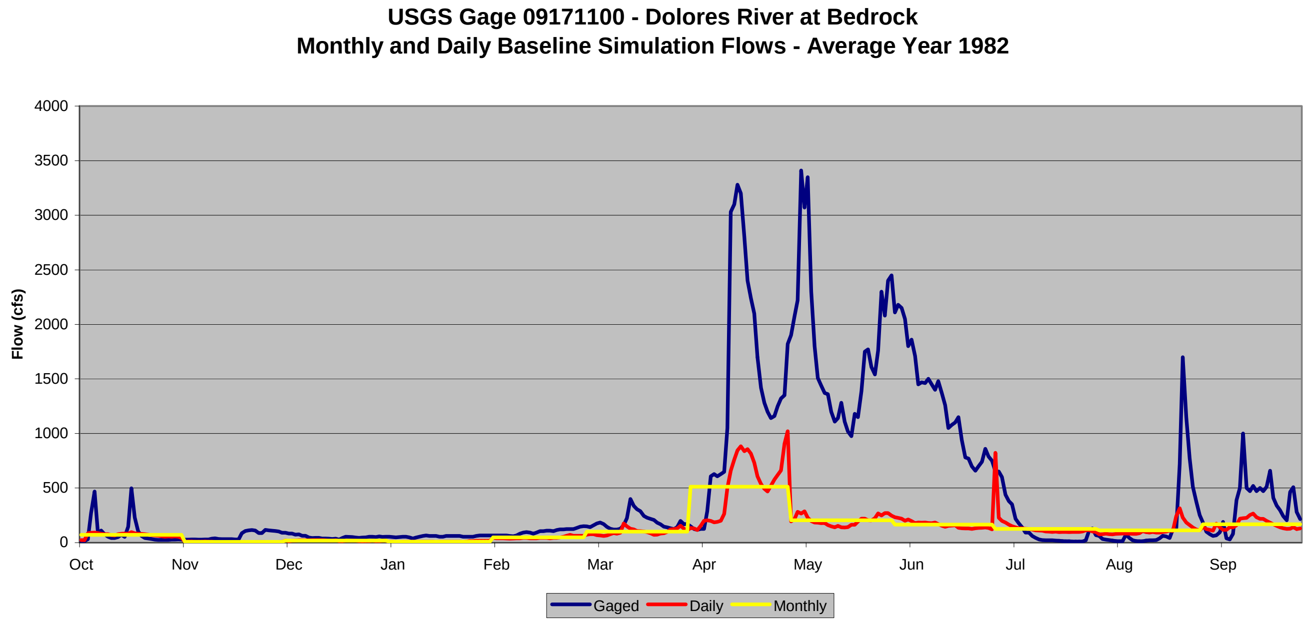


Figure 8.26 Daily Baseline Comparison, Average Year – Dolores River at Bedrock

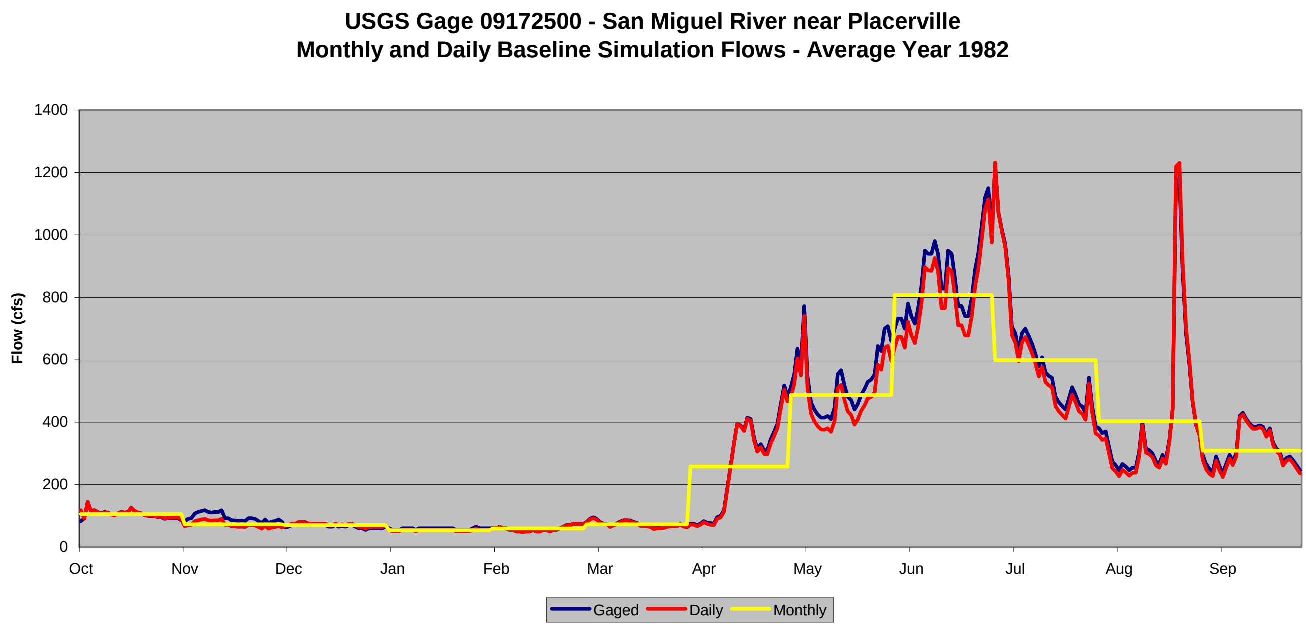


Figure 8.27 Daily Baseline Comparison, Average Year – San Miguel River near Placerville

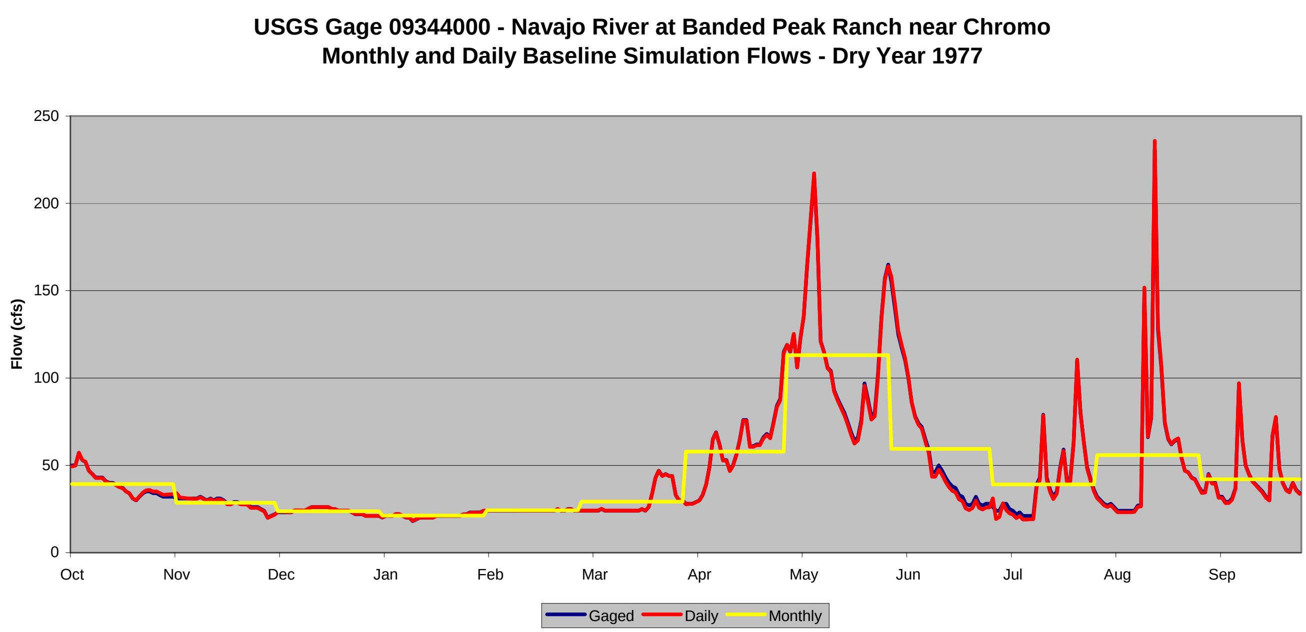


Figure 8.28 Daily Baseline Comparison, Dry Year – Navajo River at Banded Peak Ranch

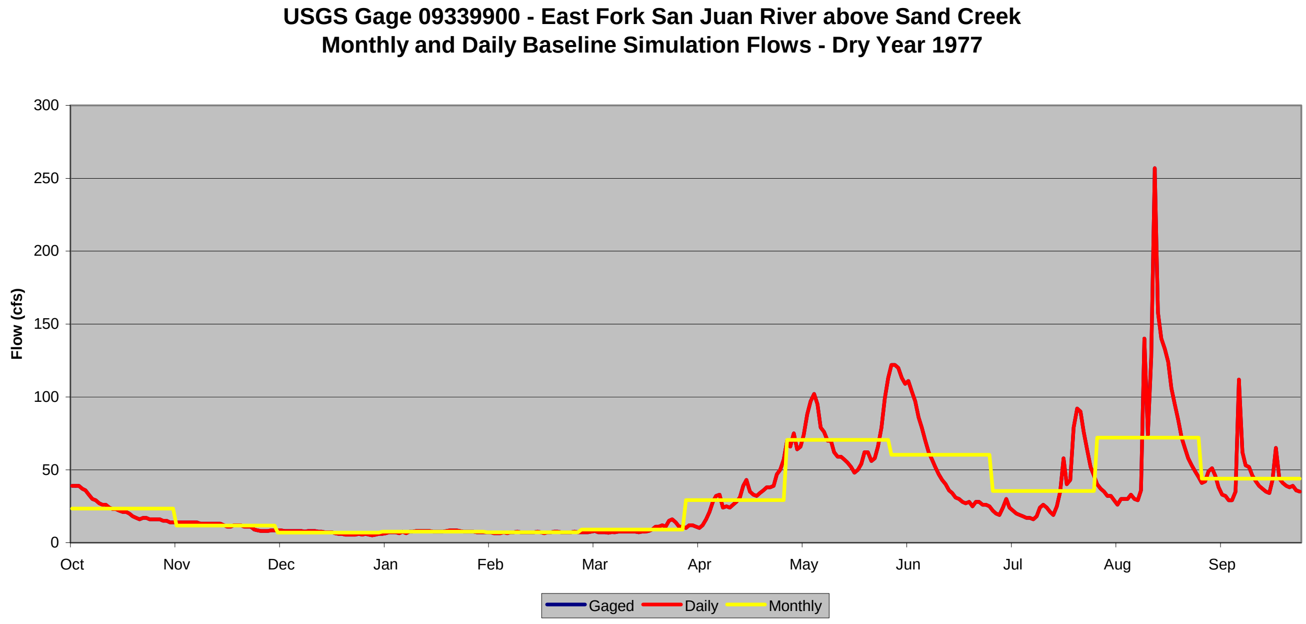


Figure 8.29 Daily Baseline Comparison, Dry Year – East Fork San Juan River above Sand Creek

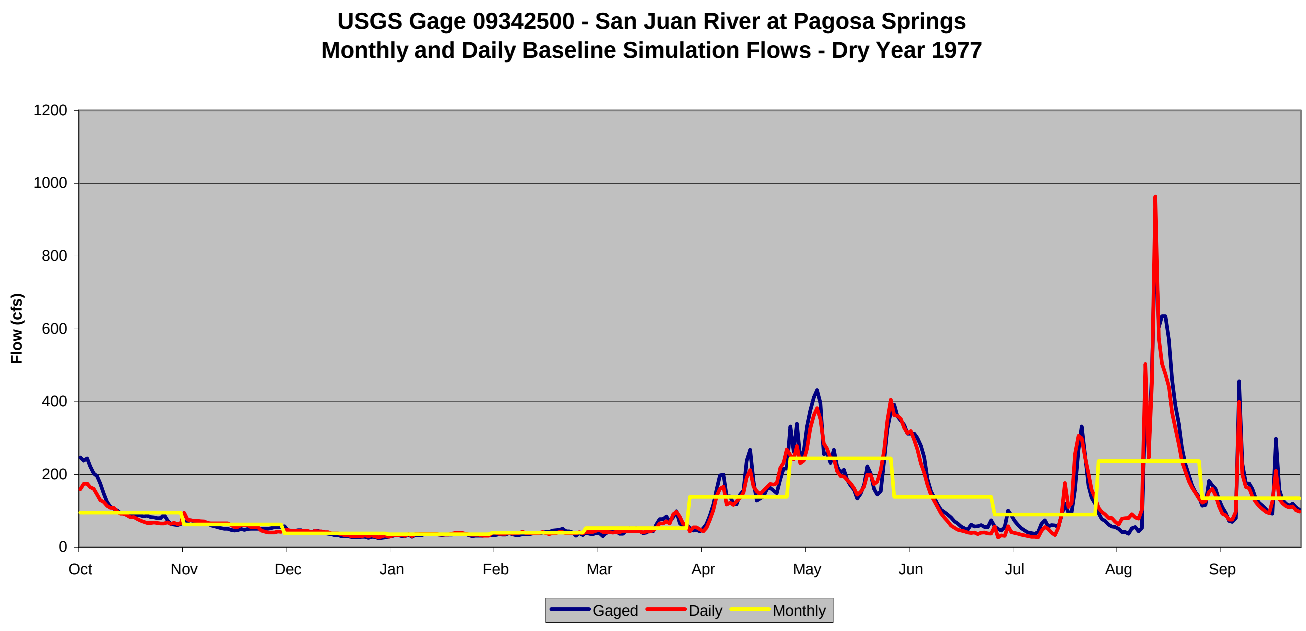


Figure 8.30 Daily Baseline Comparison, Dry Year – San Juan River at Pagosa Springs

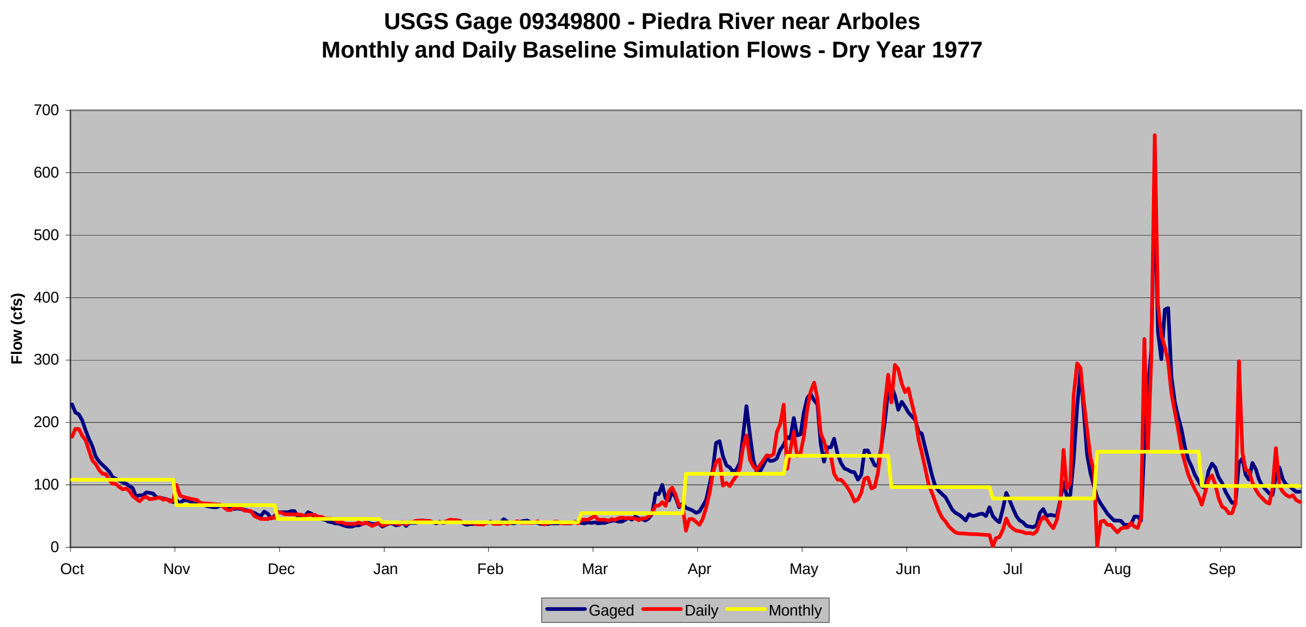


Figure 8.31 Daily Baseline Comparison, Dry Year – Piedra River near Arboles

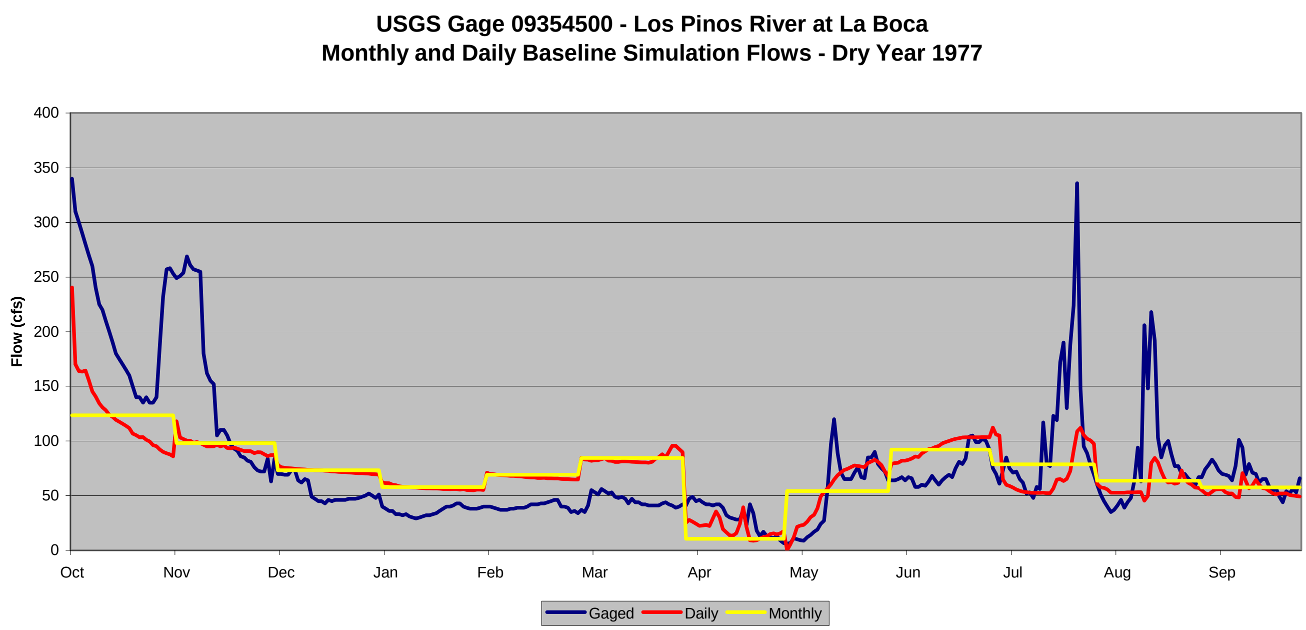


Figure 8.32 Daily Baseline Comparison, Dry Year – Los Pinos River at La Boca

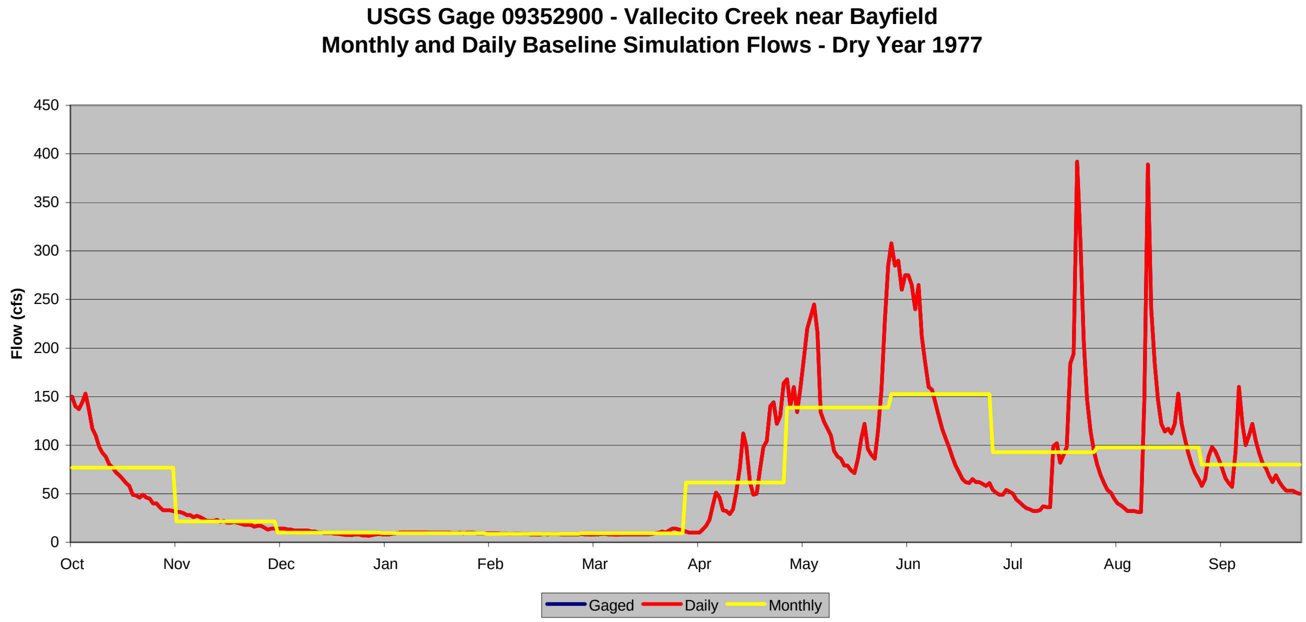


Figure 8.33 Daily Baseline Comparison, Dry Year – Vallecito Creek near Bayfield

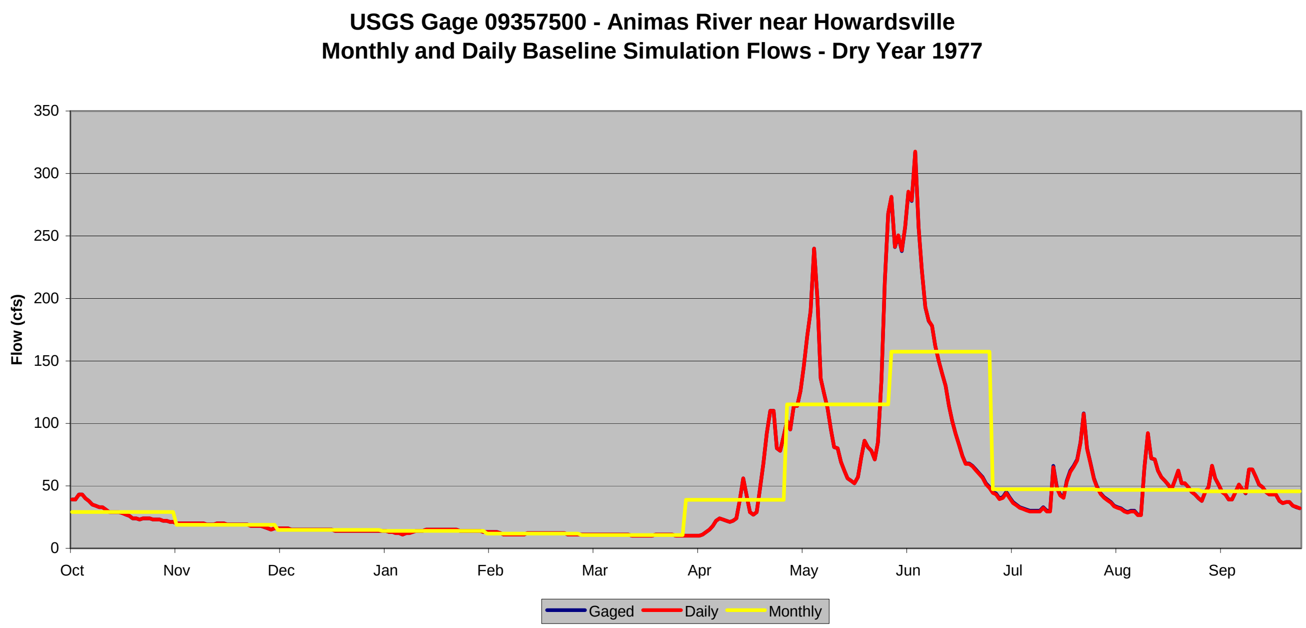


Figure 8.34 Daily Baseline Comparison, Dry Year – Animas River near Howardsville

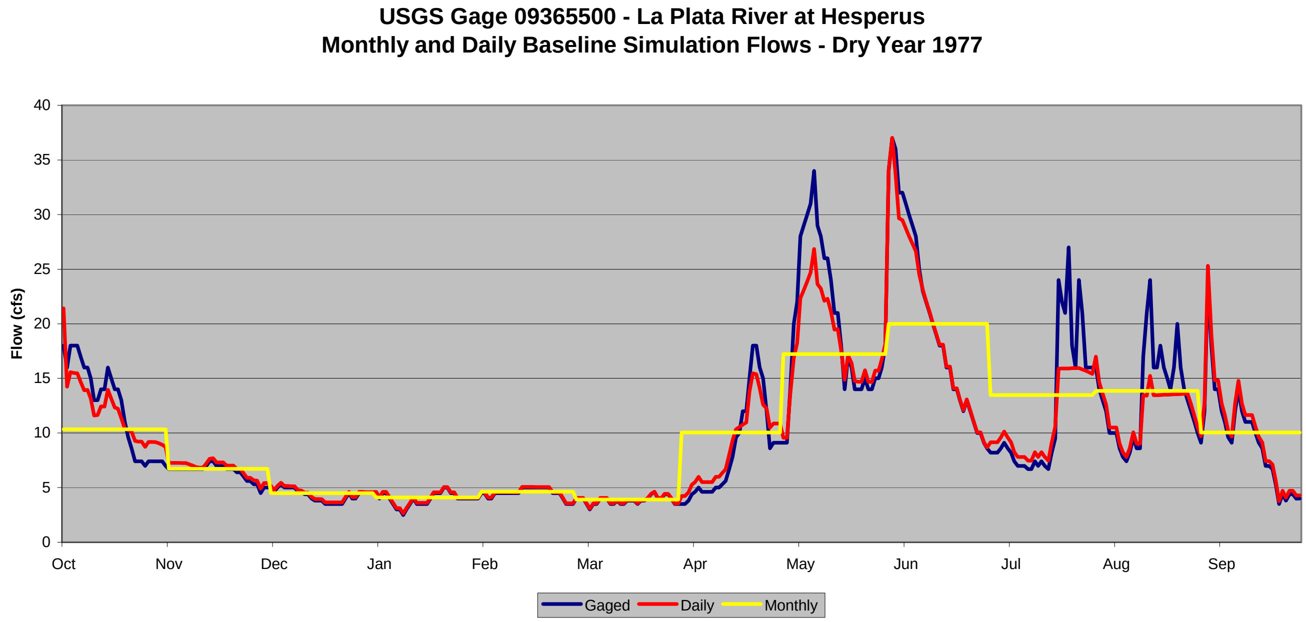


Figure 8.35 Daily Baseline Comparison, Dry Year – La Plata River at Hesperus

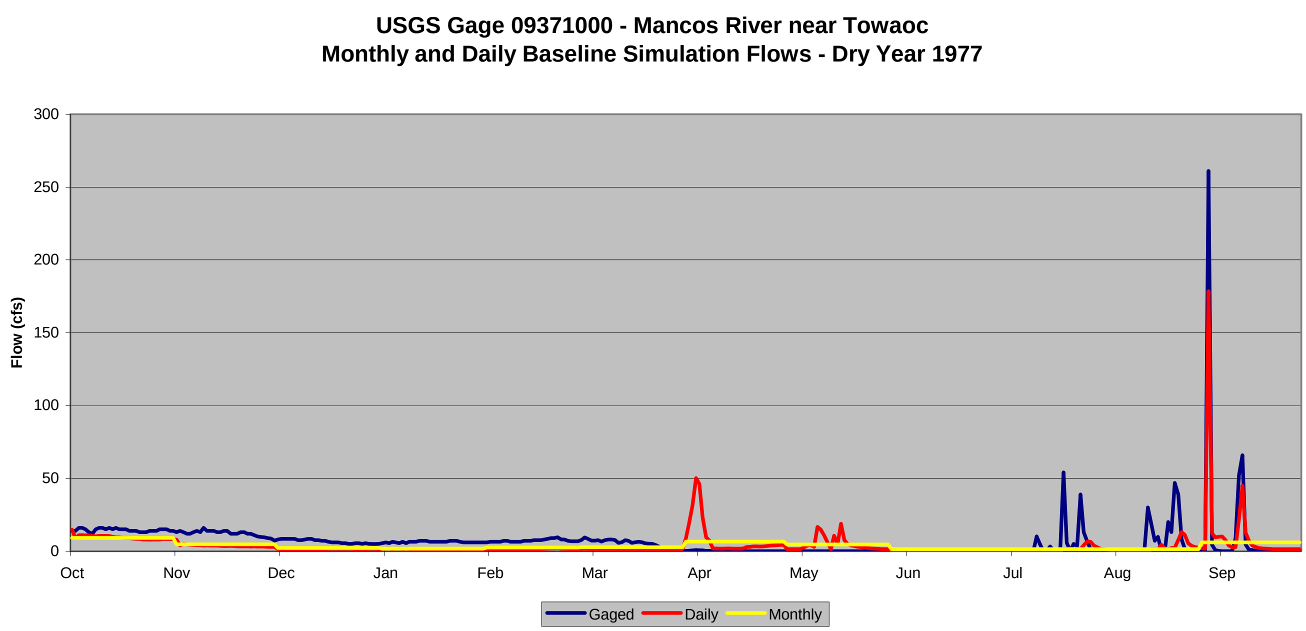


Figure 8.36 Daily Baseline Comparison, Dry Year – Mancos River near Towaoc

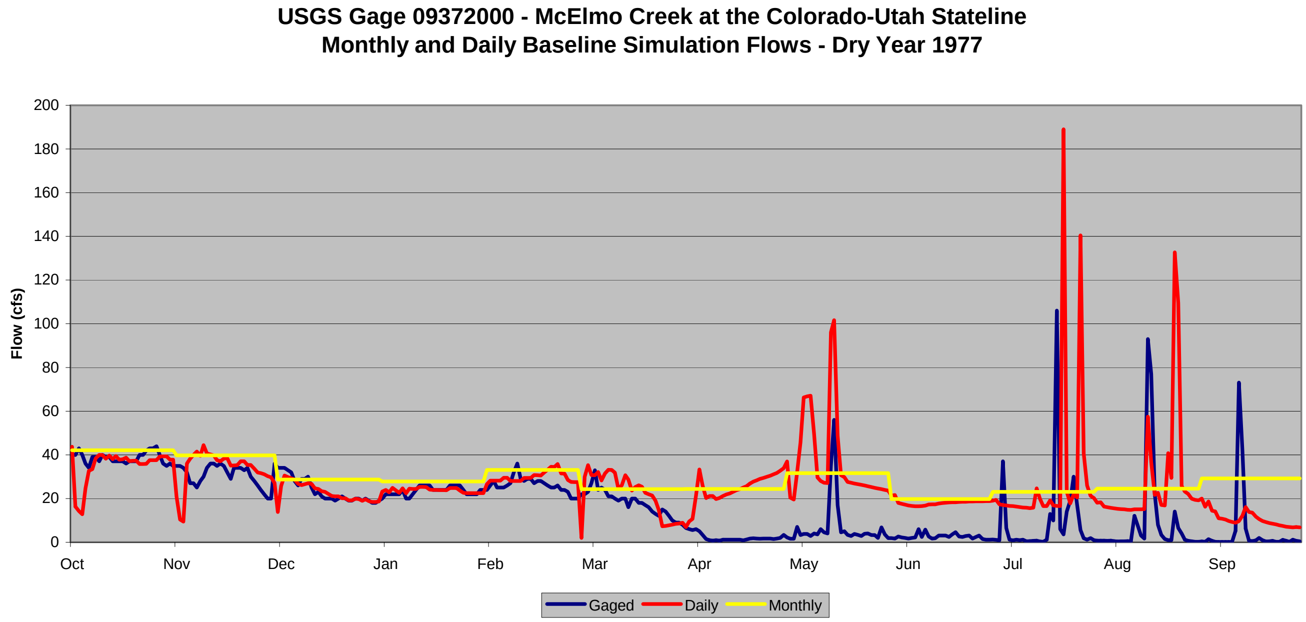


Figure 8.37 Daily Baseline Comparison, Dry Year – McElmo Creek at CO/UT Stateline

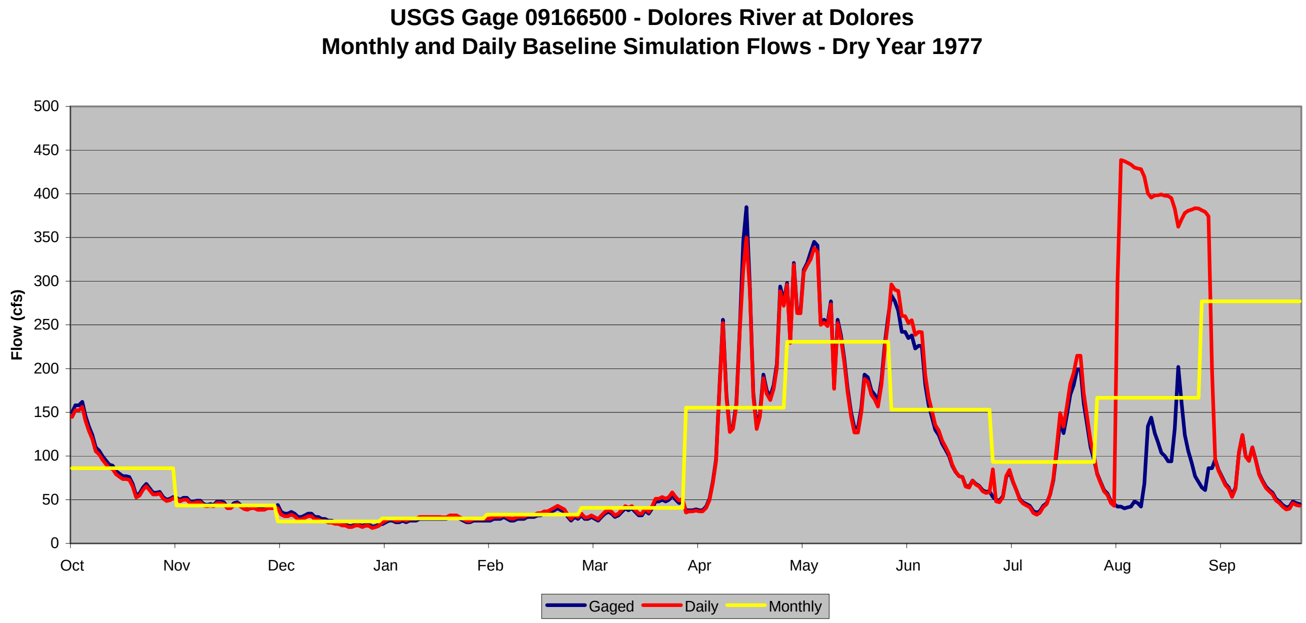


Figure 8.38 Daily Baseline Comparison, Dry Year – Dolores River at Dolores

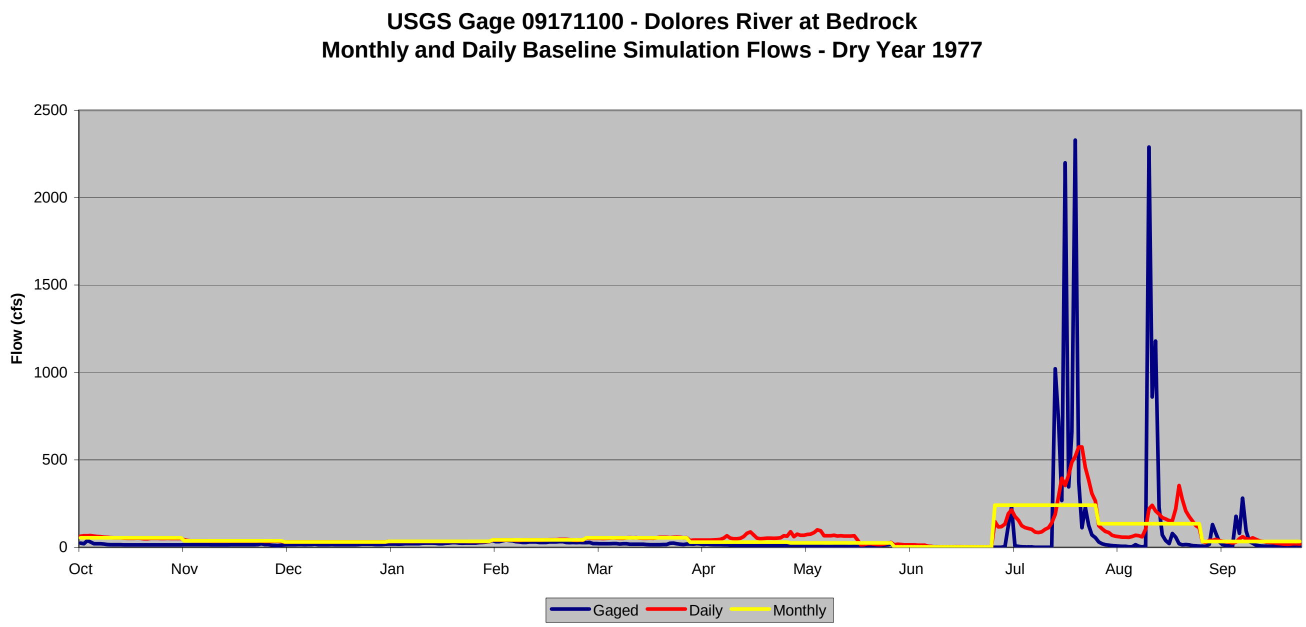


Figure 8.39 Daily Baseline Comparison, Dry Year – Dolores River at Bedrock

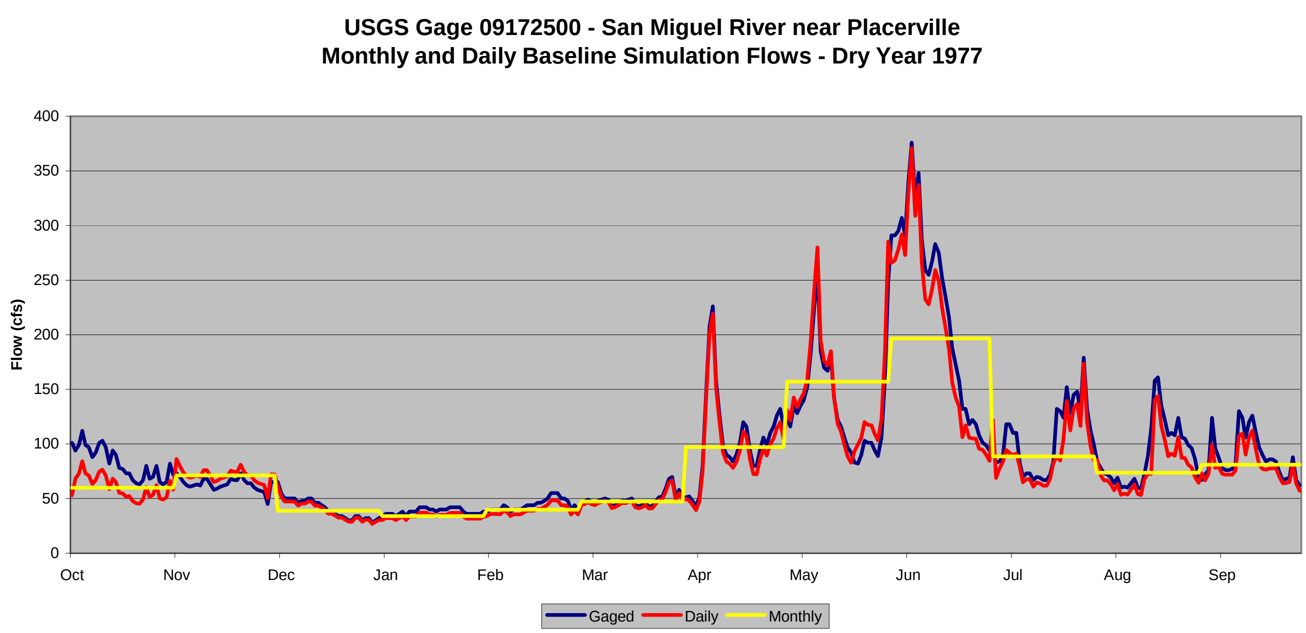


Figure 8.40 Daily Baseline Comparison, Dry Year – San Miguel near Placerville

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.

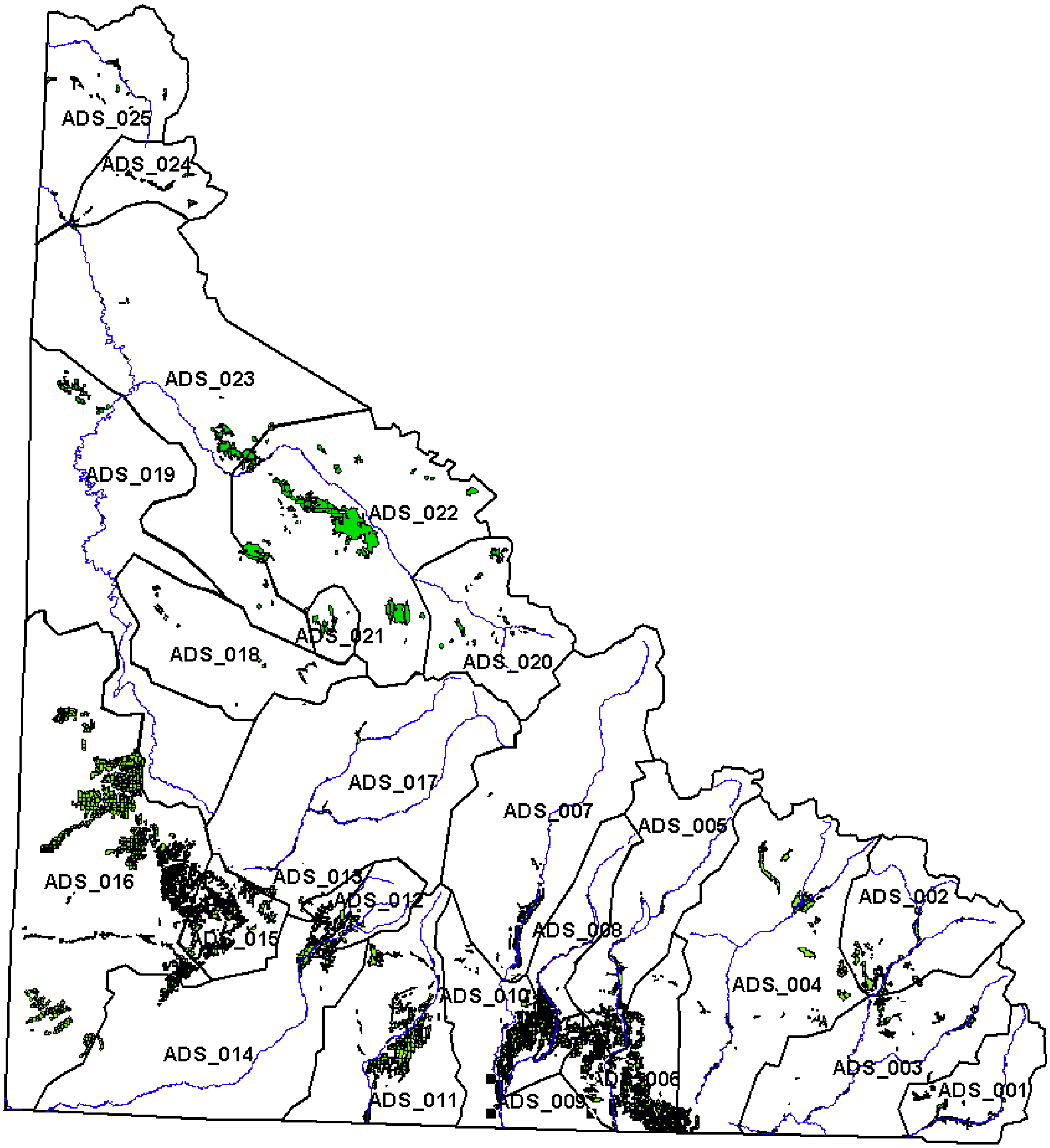


Figure 1 – Aggregate Structure Boundaries

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	18,941	20
	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	11,757	33.3
	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 1968 - 1983
09363500	ANIMAS RIVER NEAR CEDAR HILL, NM	1934 - 1996
09364500	ANIMAS RIVER AT FARMINGTON, NM	1920 - 1925 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 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 1941 - 1943 1951 - 1954 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. 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.

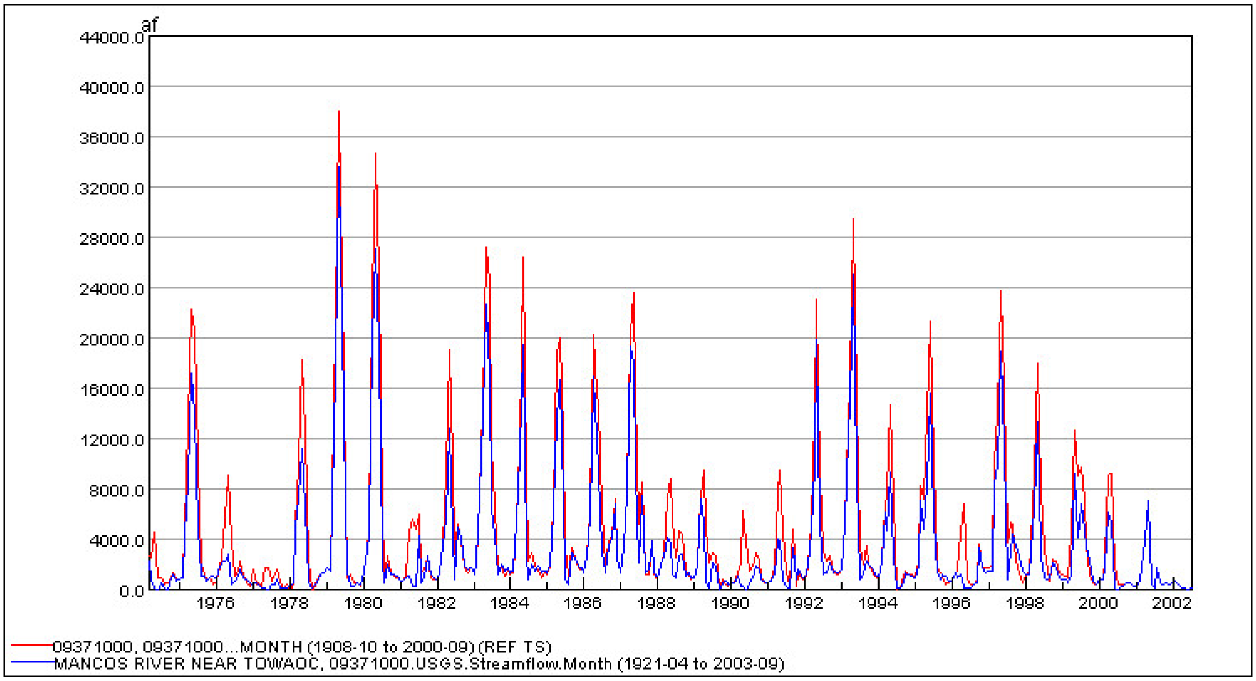


Figure 1 – Comparison of 09371000 StateMod developed baseflows and 09371000 historical flows

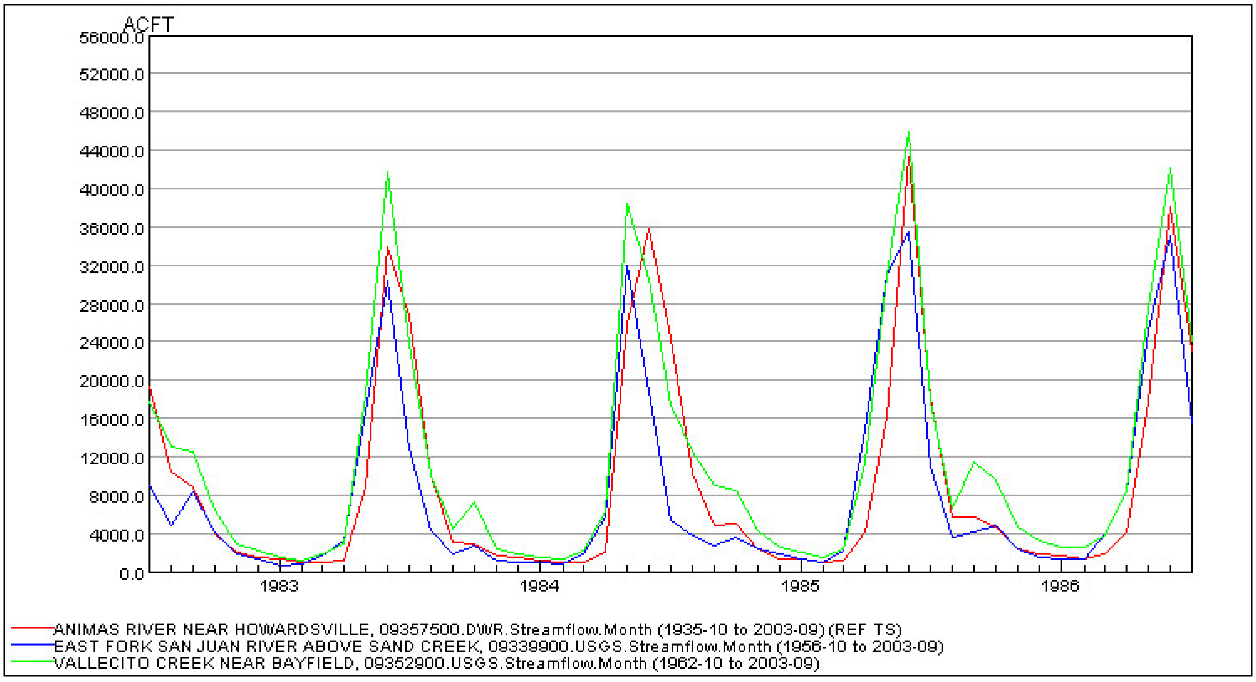


Figure 2 – Comparison of historical flows at gages 09357500, 09339900, and 09352900 for determination of which gage would best represent the mainstem of the San Juan River.

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.

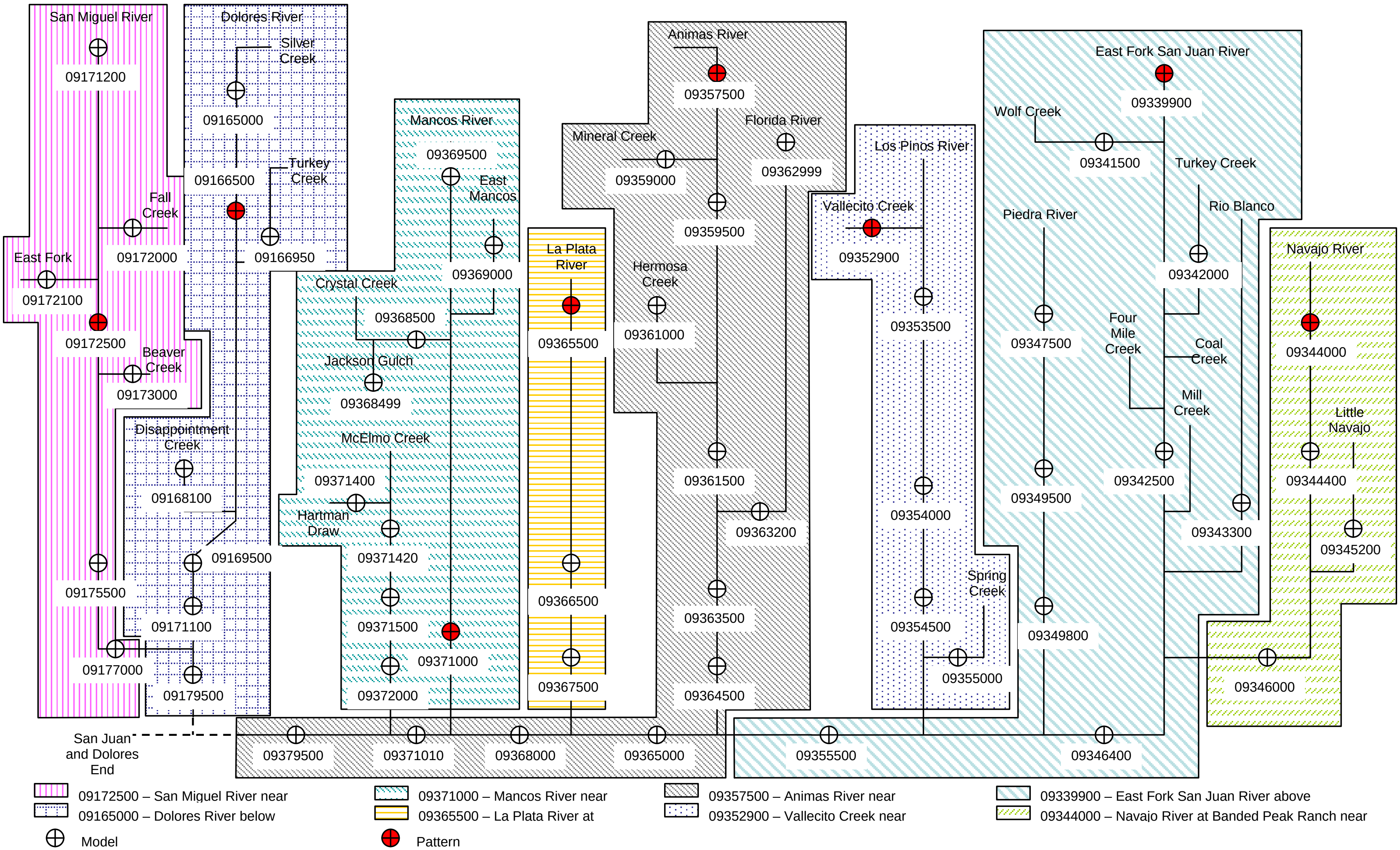
Conclusions

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



Attachment A

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,MonthlyEqua
tions,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,MonthlyEqua
tions,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

Note: This section describes a Calculated Data Set that was completed in November 2005. The San Juan Model Historical (calibration), Calculated and Baseline data files were updated in October 2009, and the 2009 calibration and Baseline data sets are described in this user manual. Inconsistencies between the 2008 and 2009 Calculated Data Set are minor, and include:

1) maximum irrigation efficiency set to 0.60 in 2008, and set to 0.54 in 2009
2) differences in IWR for fields below 6,500 ft in elevation, because an elevation adjustment was applied to crop coefficients in the Blaney-Criddle analysis in the 2009 model

The approach described for the Calculated Data Set is accurate, except for the items listed above. Table values in this appendix are expected to be similar to, but not exactly, what would be produced with an updated 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		Gage Name
			Volume	Percent	
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)

			Historical minus Simulated	
Tributary or Sub-basin	**Historical**	**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 Volume	Historical - Simulated Percent	Name
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 Volume	Percent	Name
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 Volume	Percent	Name
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

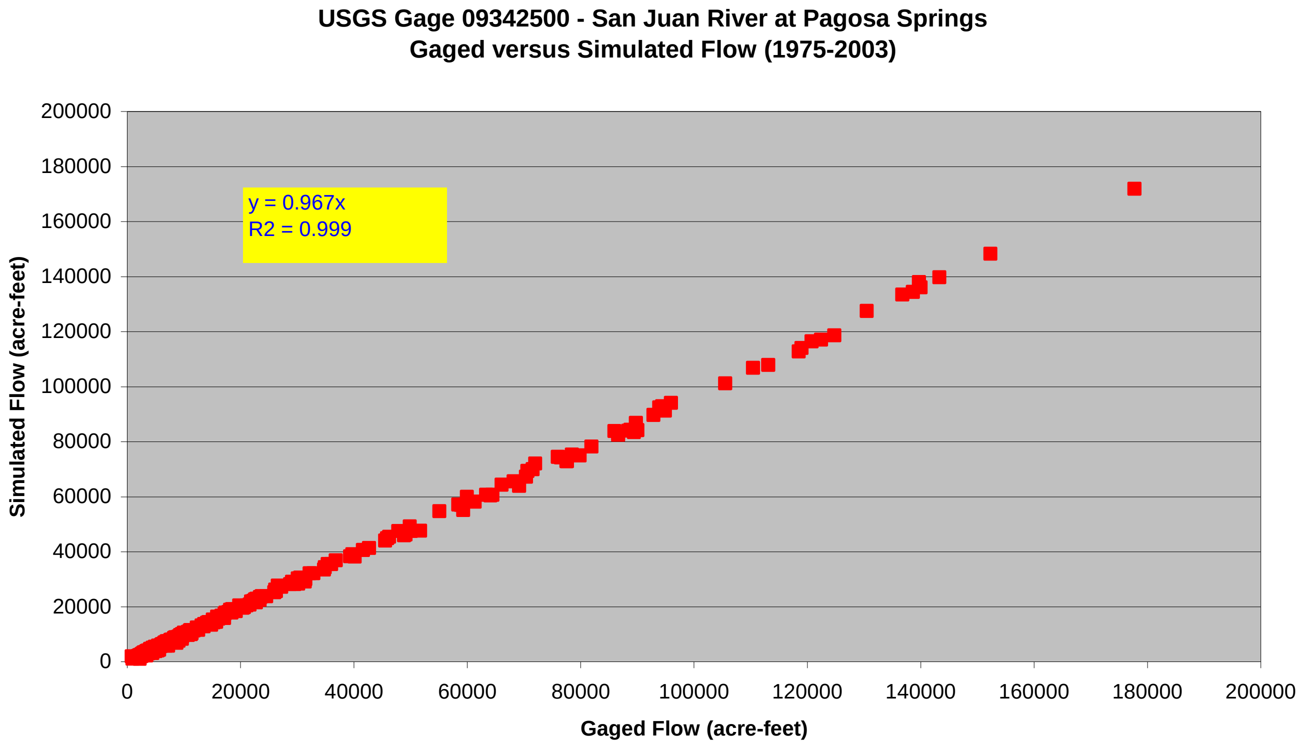
WDID	Historical	Simulated	Historical - Simulated Volume	Percent	Name
600776	451	584	-133	-29%	TEMPLETON DITCH
600777	231	318	-87	-37%	THEO NETHERLY DITCH NO1
60_ADS020	5,043	8,966	-3,923	-78%	60_ADS020_SMiguelNrPlacr
60_ADS021	1,352	4,515	-3,164	-234%	60_ADS021_SMiguelabvWNat
60_ADS022	8,385	10,284	-1,899	-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	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 Volume	Percent	Name
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



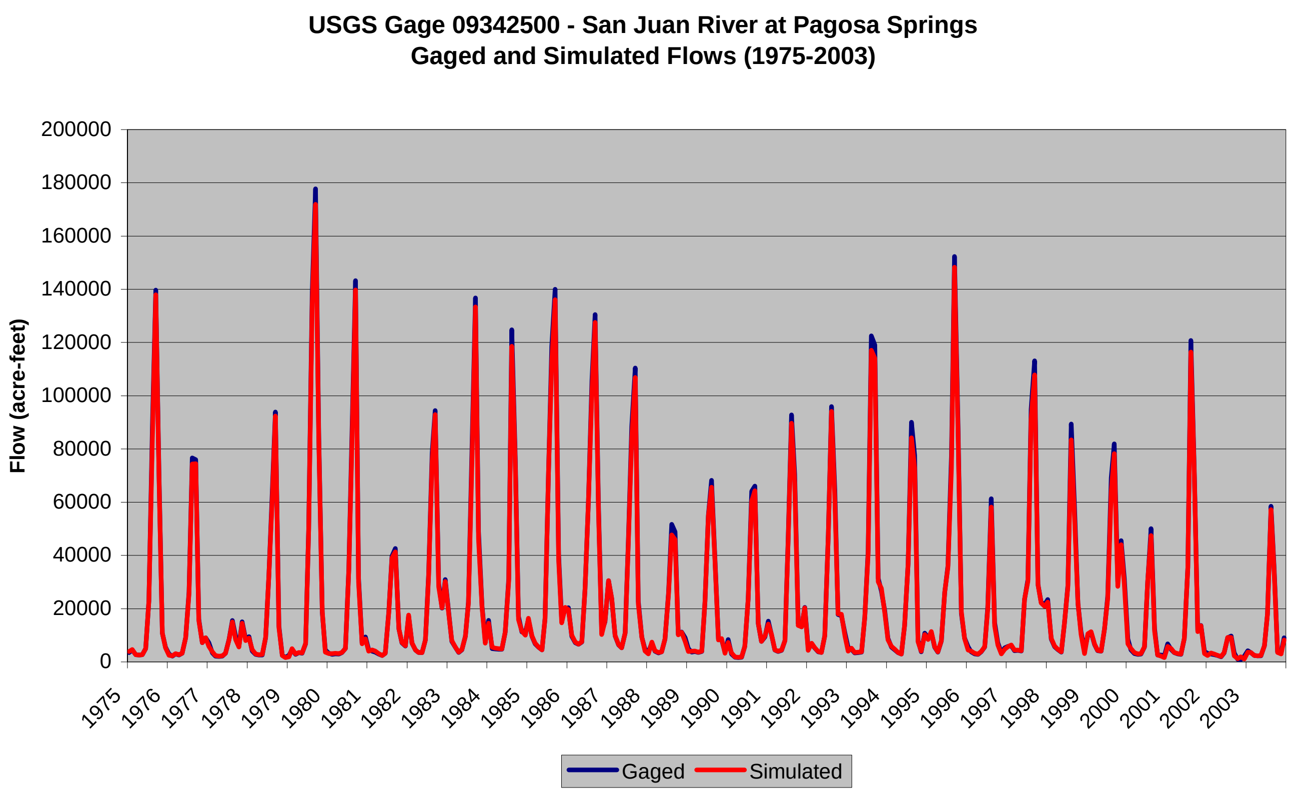
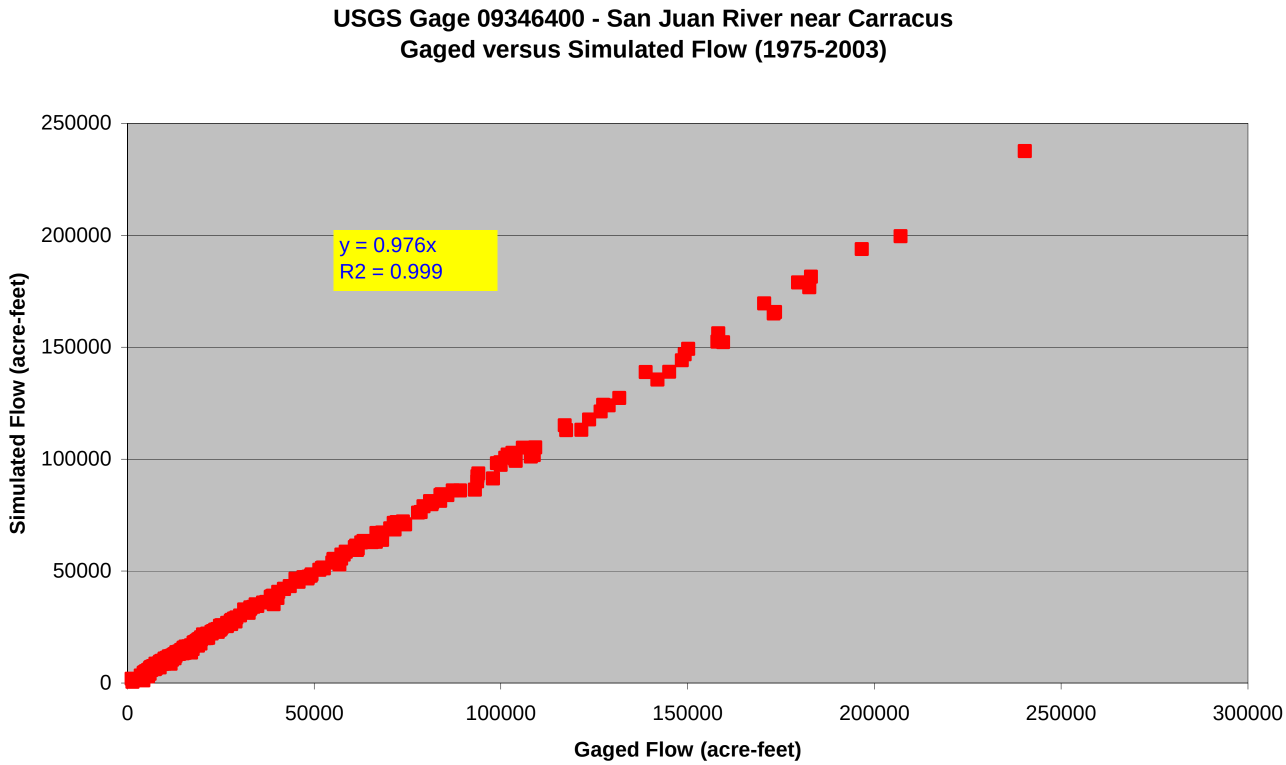


Figure D.1 Calculated Streamflow Simulation – San Juan River at Pagosa Springs



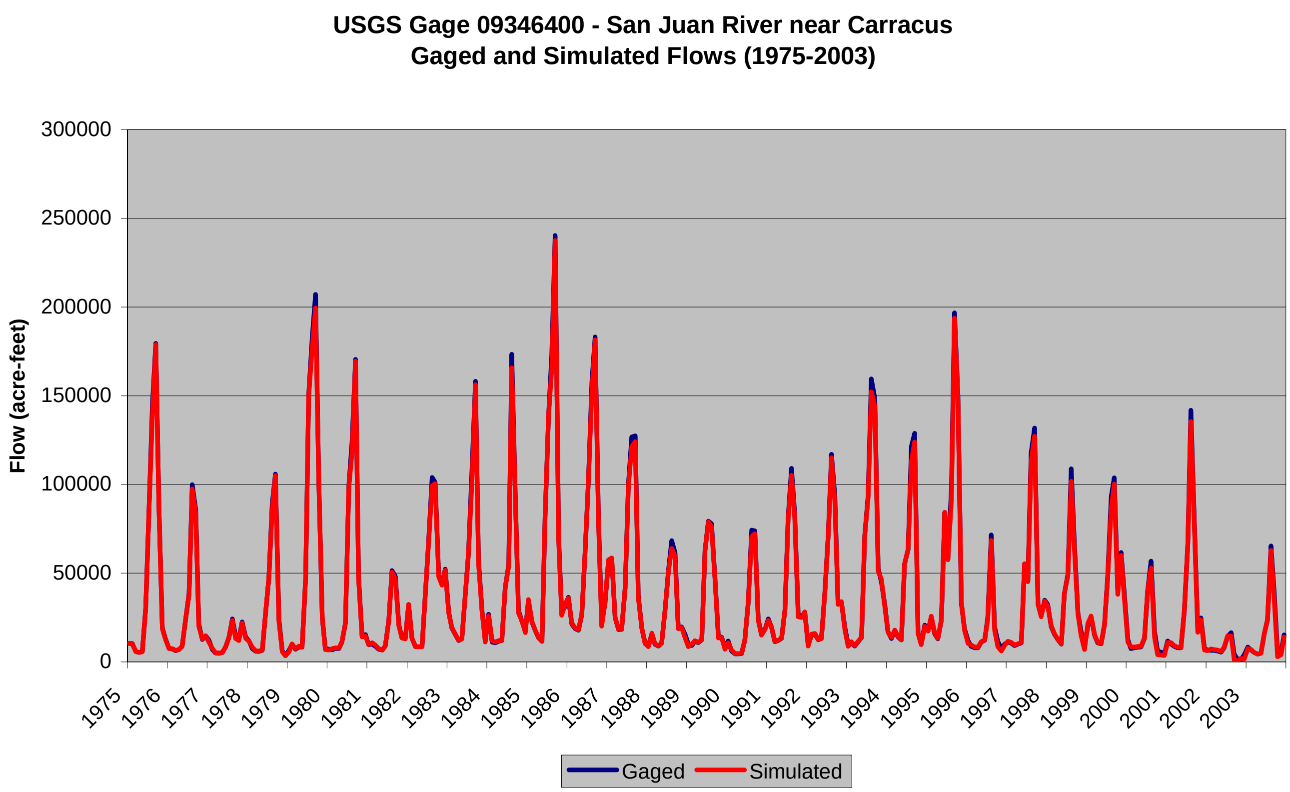
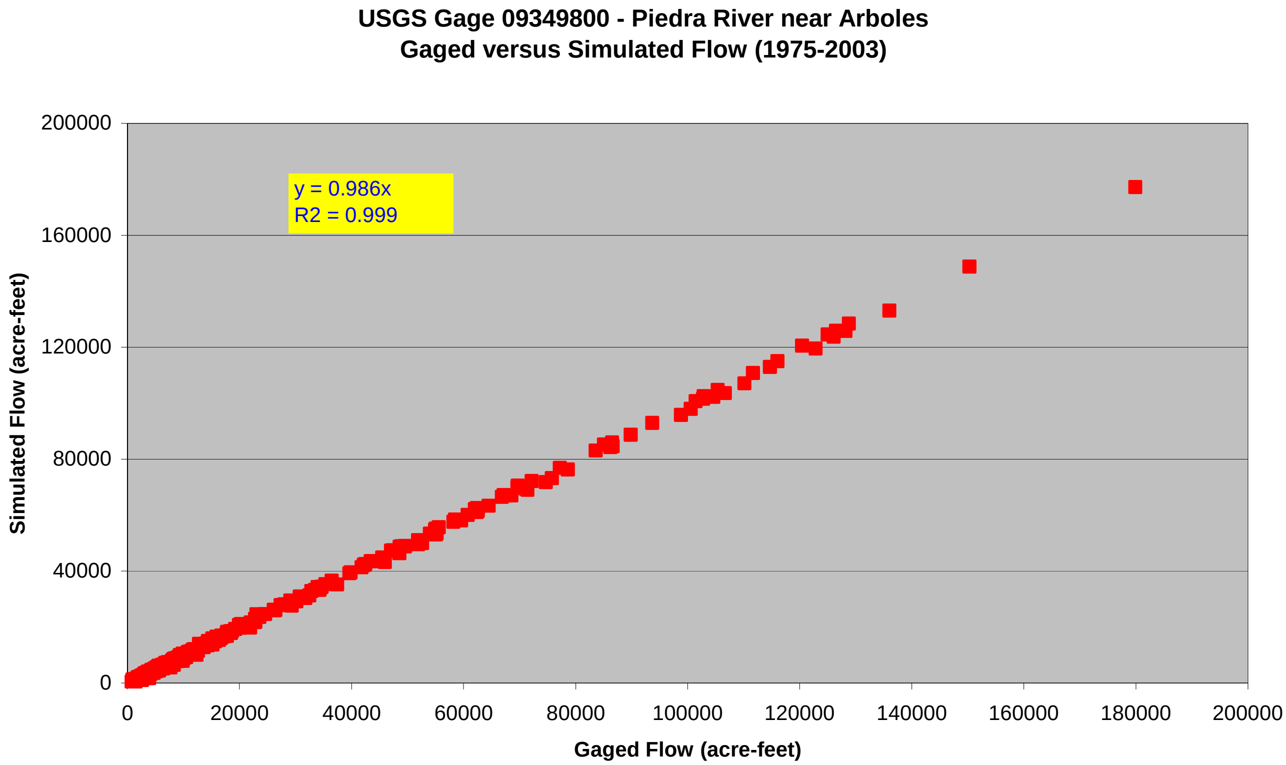


Figure D.2 Calculated Streamflow Simulation – San Juan River near Carracus



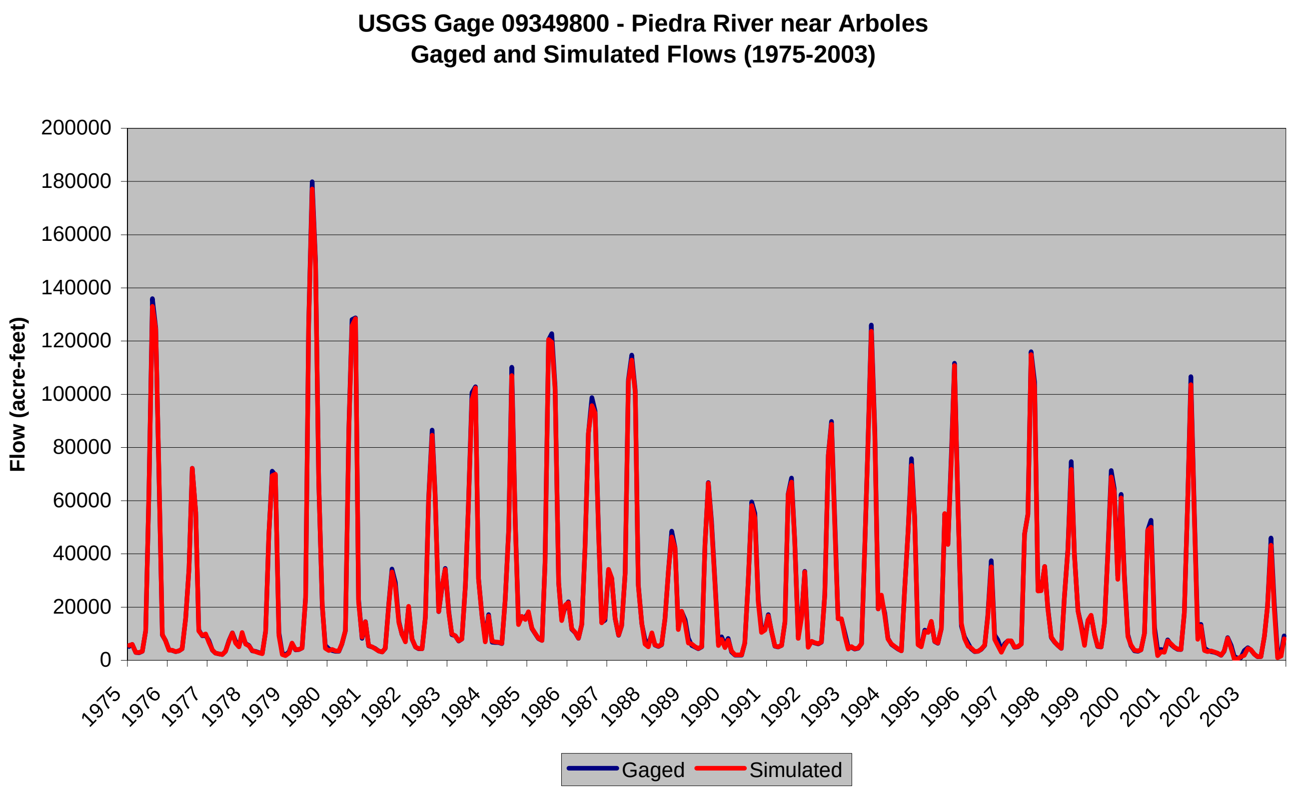
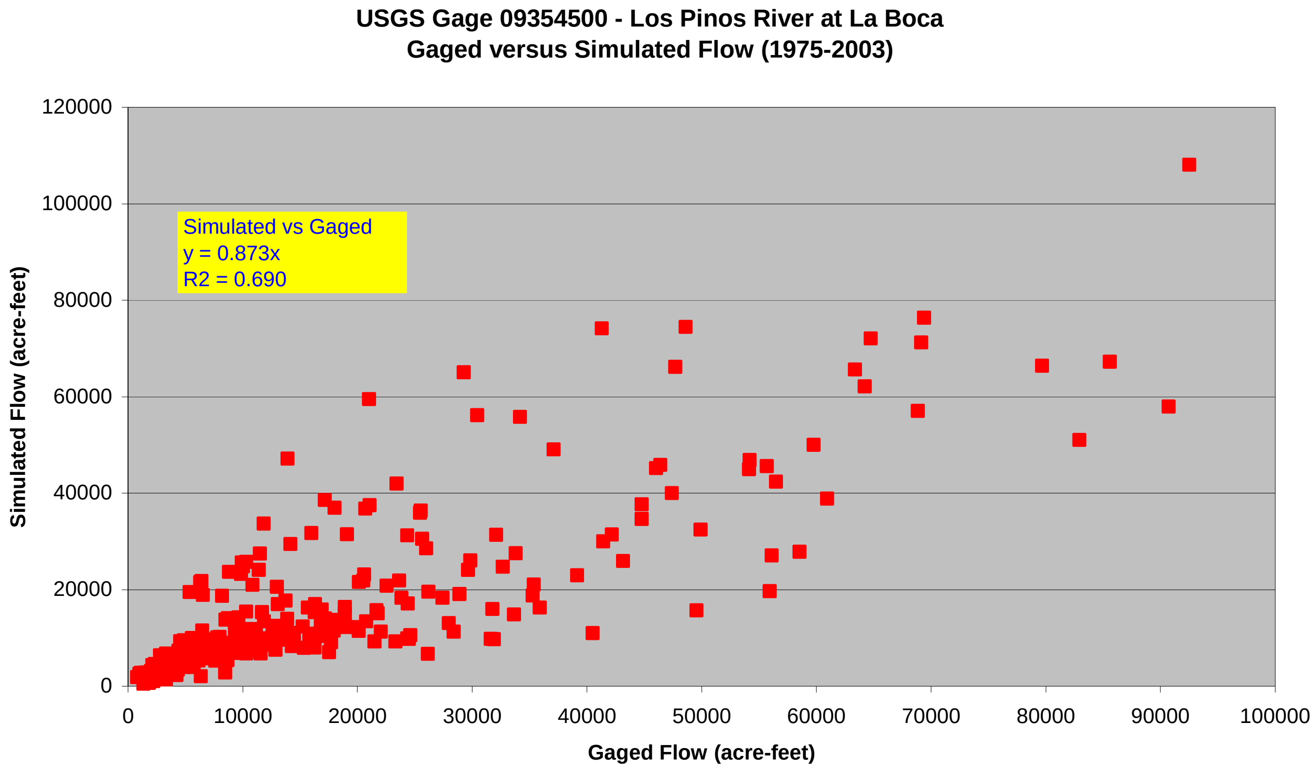


Figure D.3 Calculated Streamflow Simulation – Piedra River near Arboles



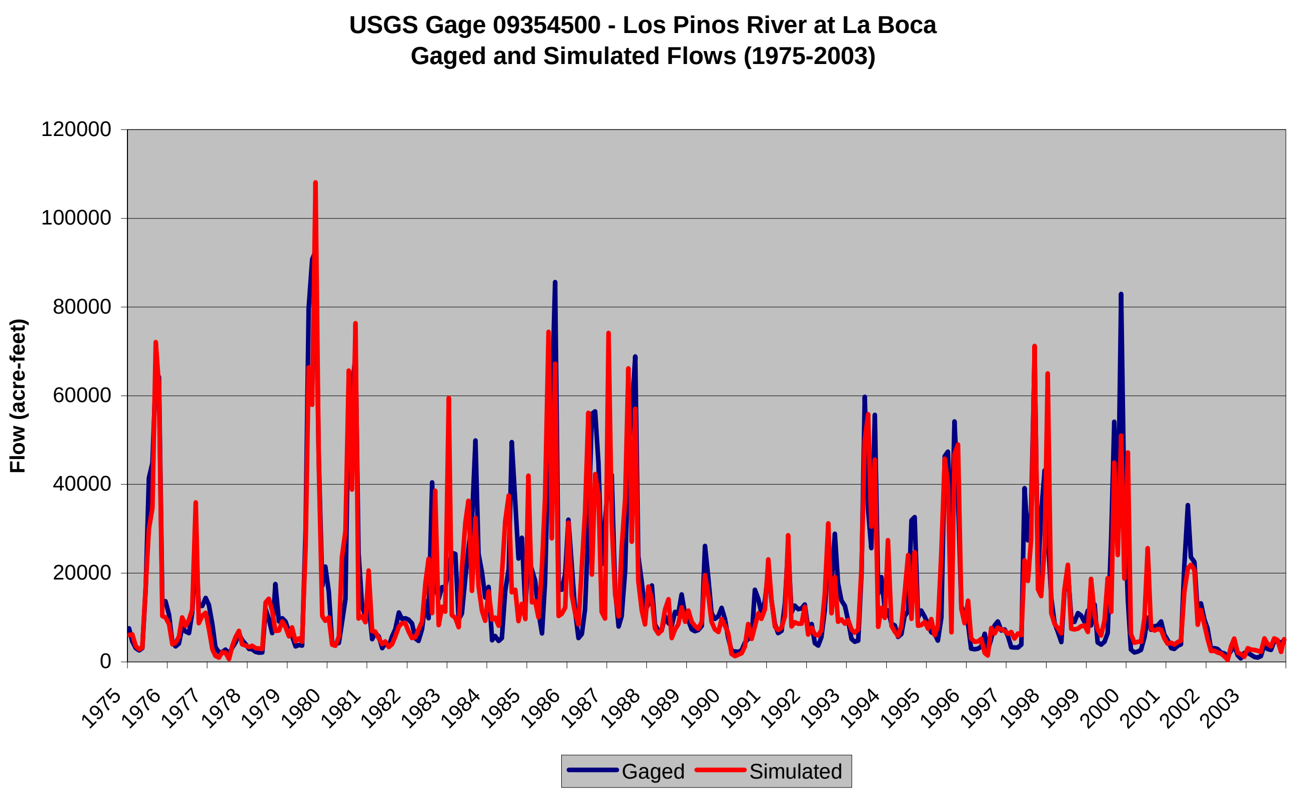
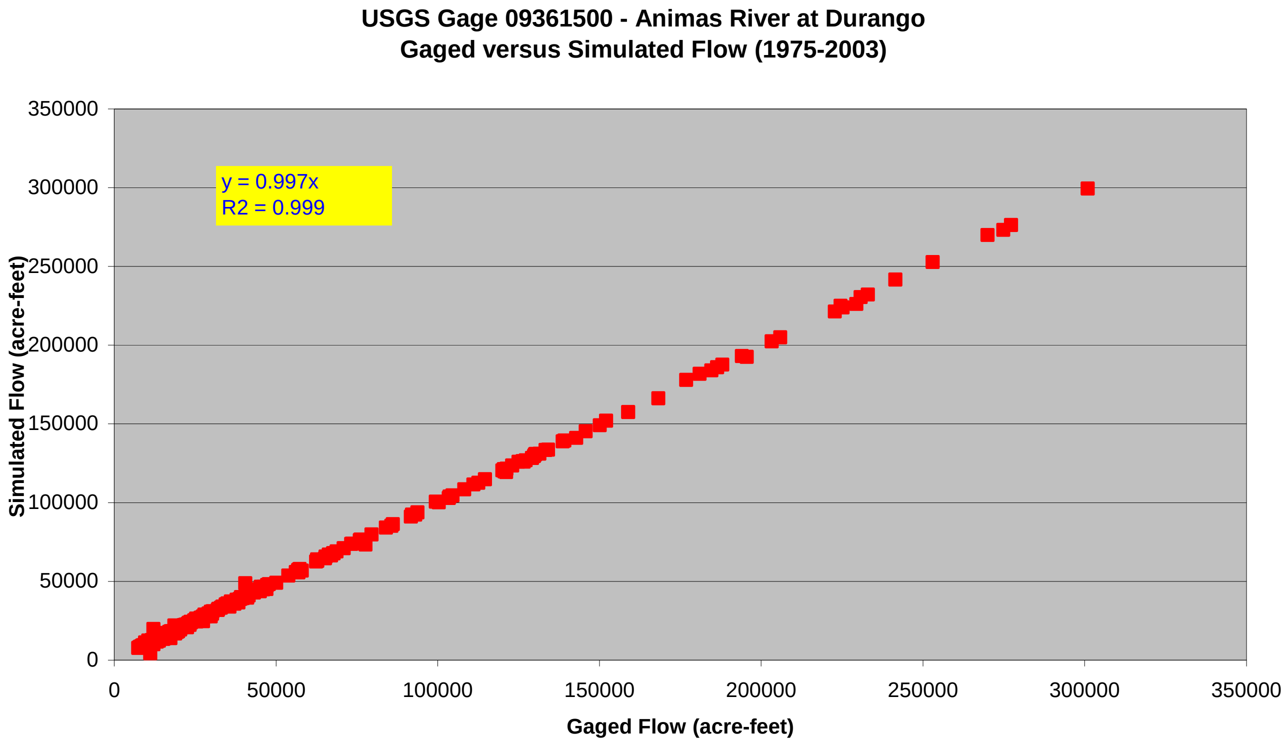


Figure D.4 Calculated Streamflow Simulation – Los Pinos River at La Boca



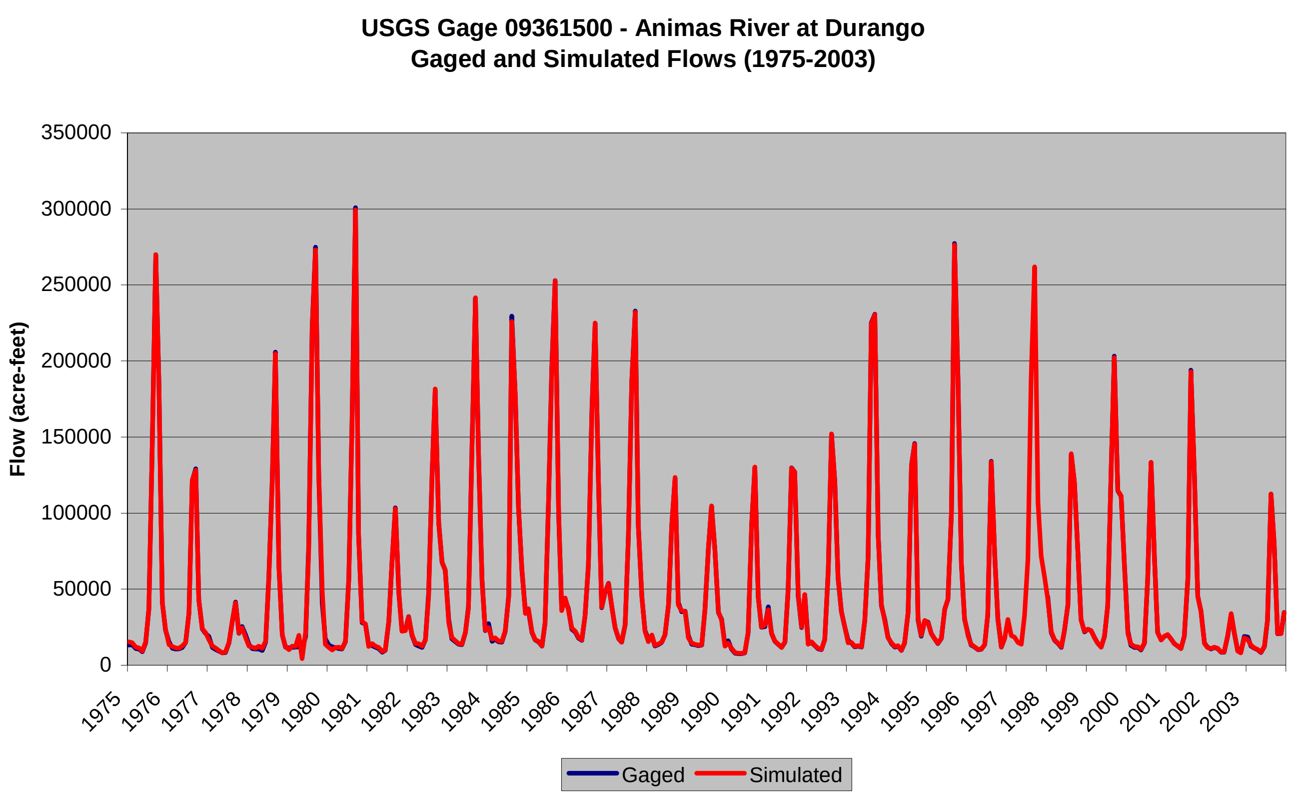
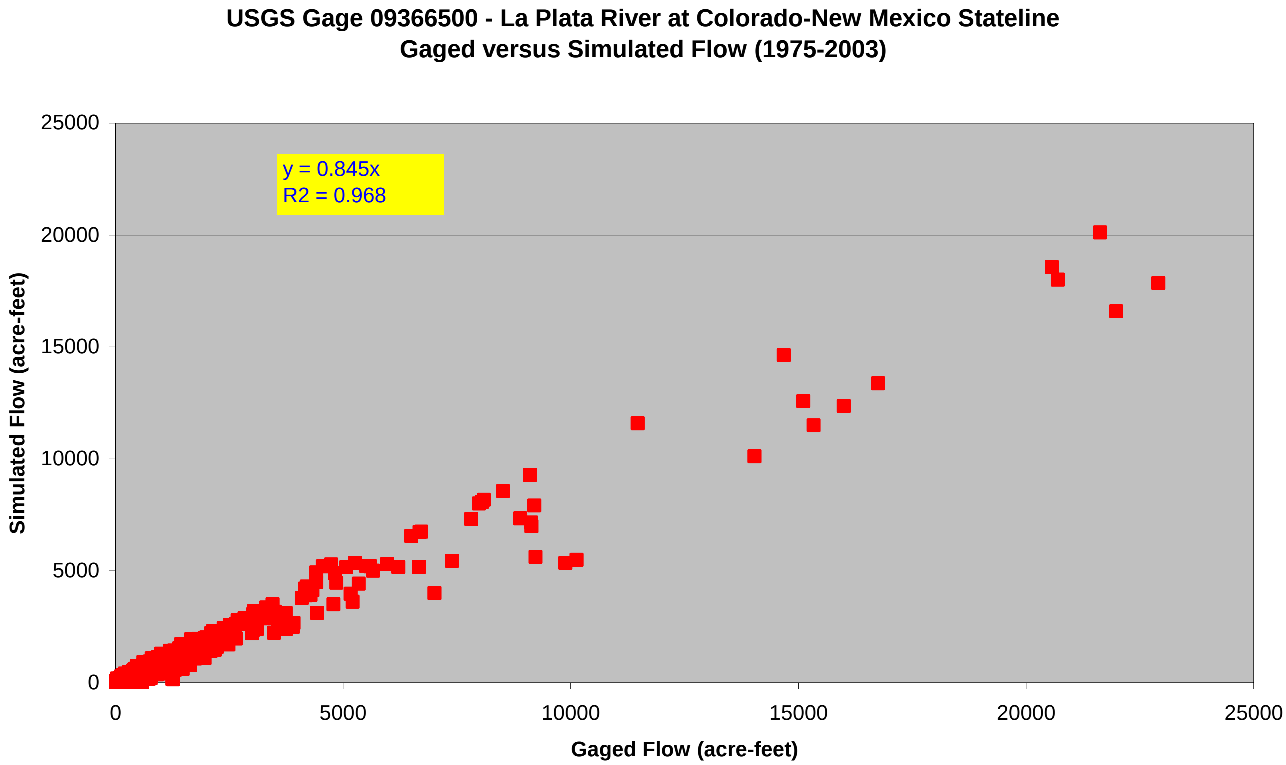


Figure D.5 Calculated Streamflow Simulation – Animas River at Durango



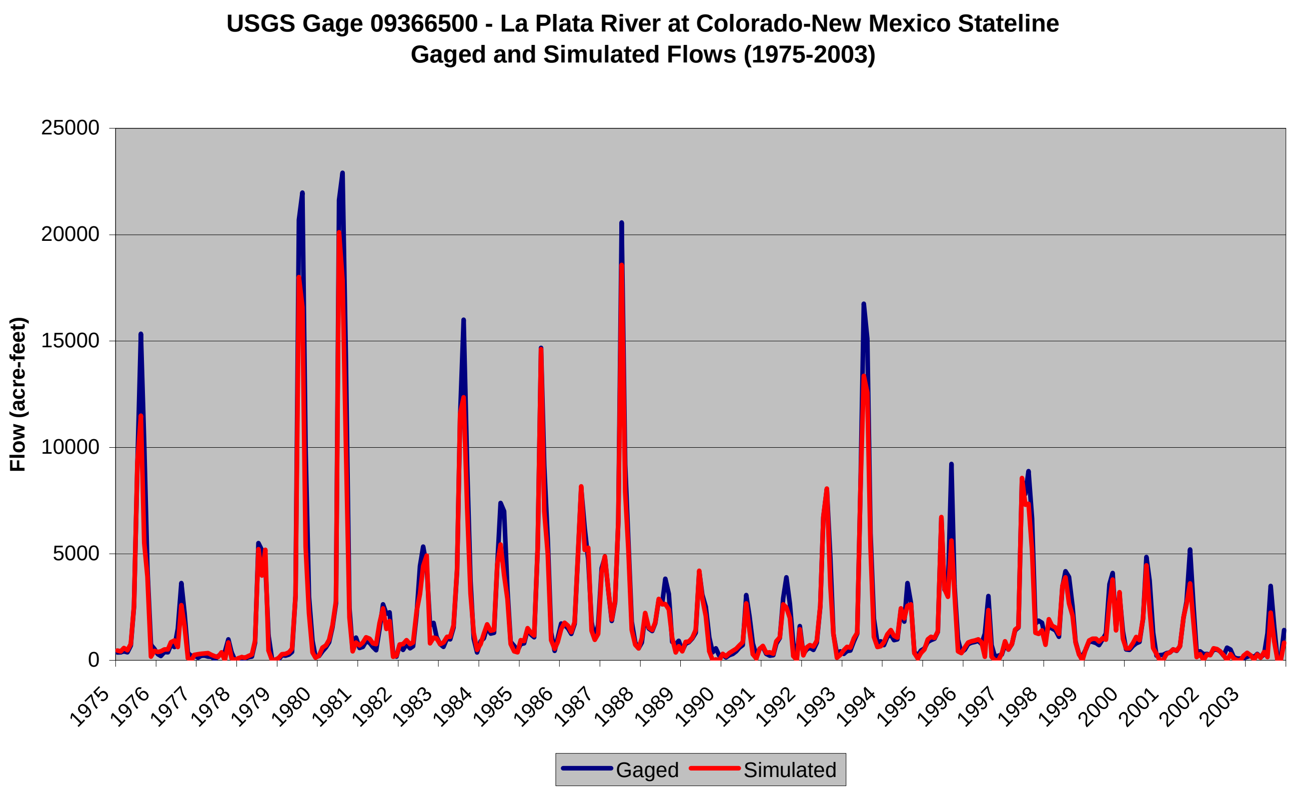
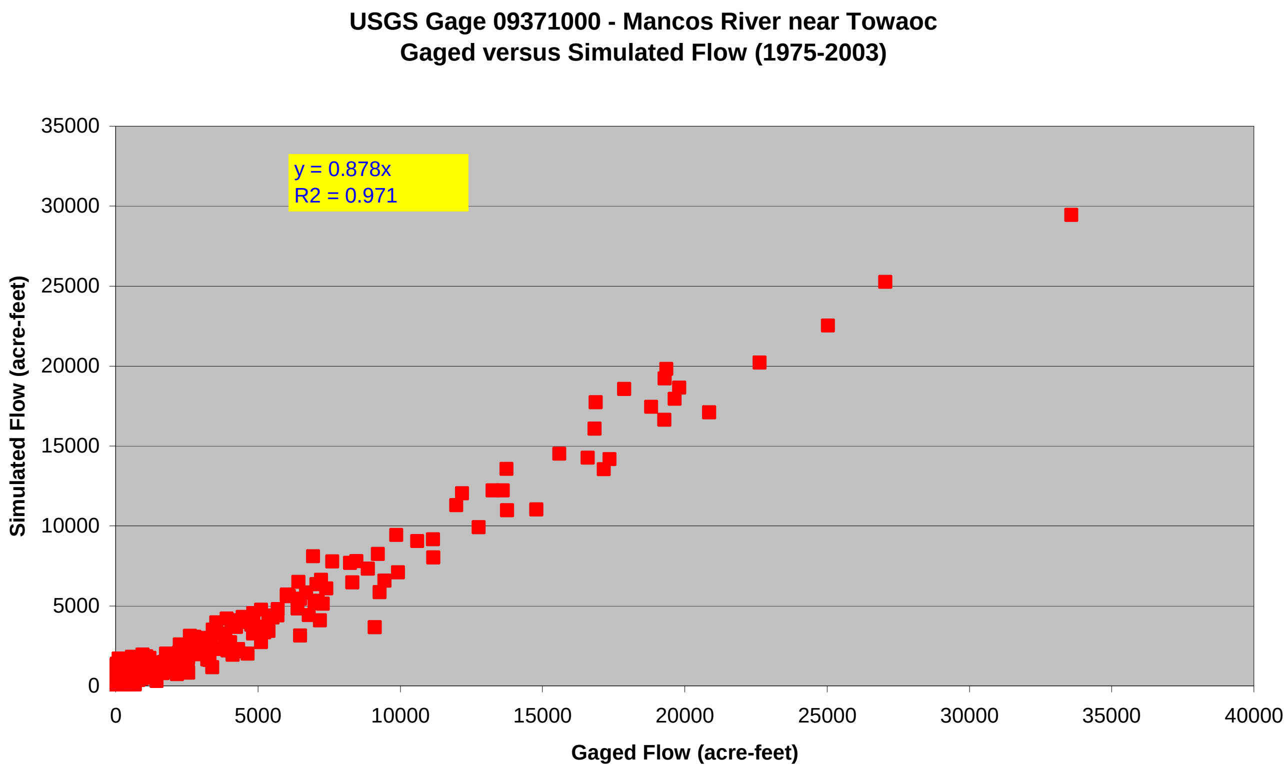


Figure D.6 Calculated Streamflow Simulation – La Plata River at Colorado-New Mexico Stateline



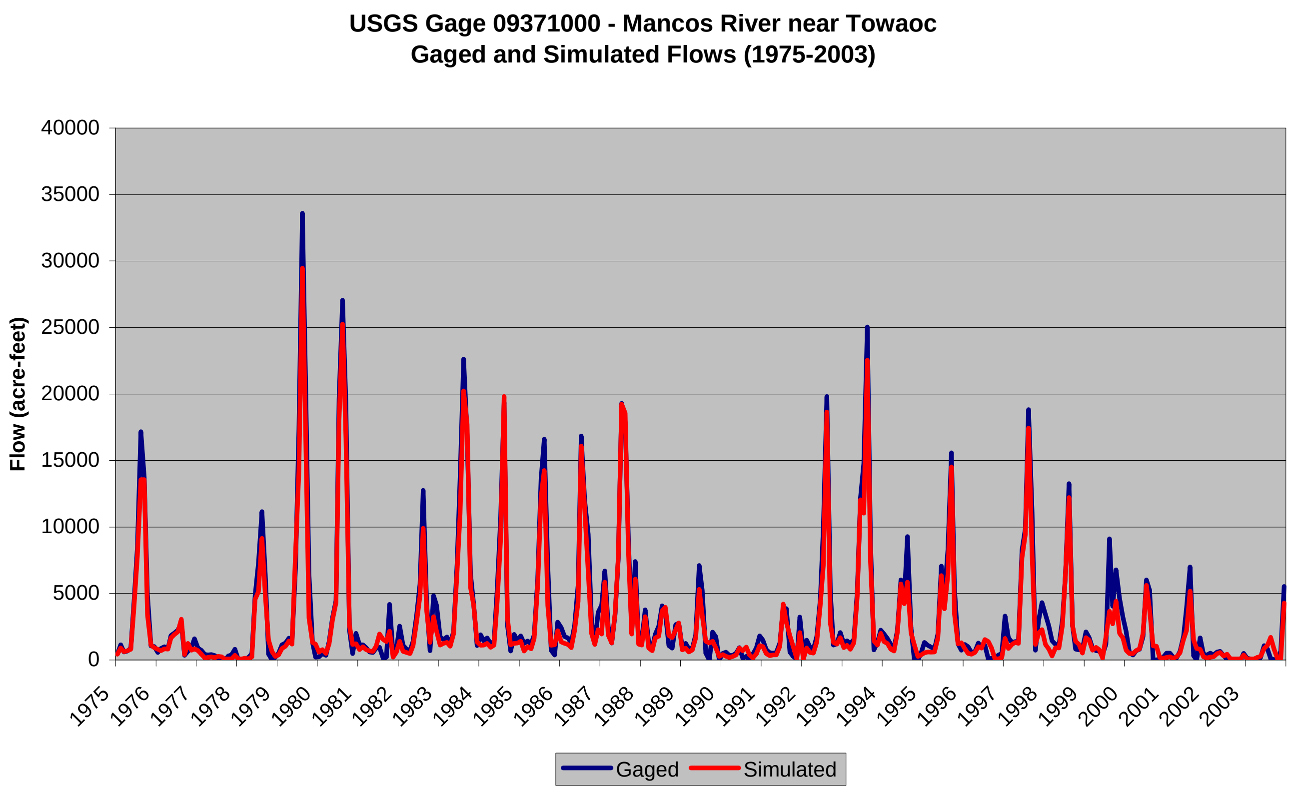
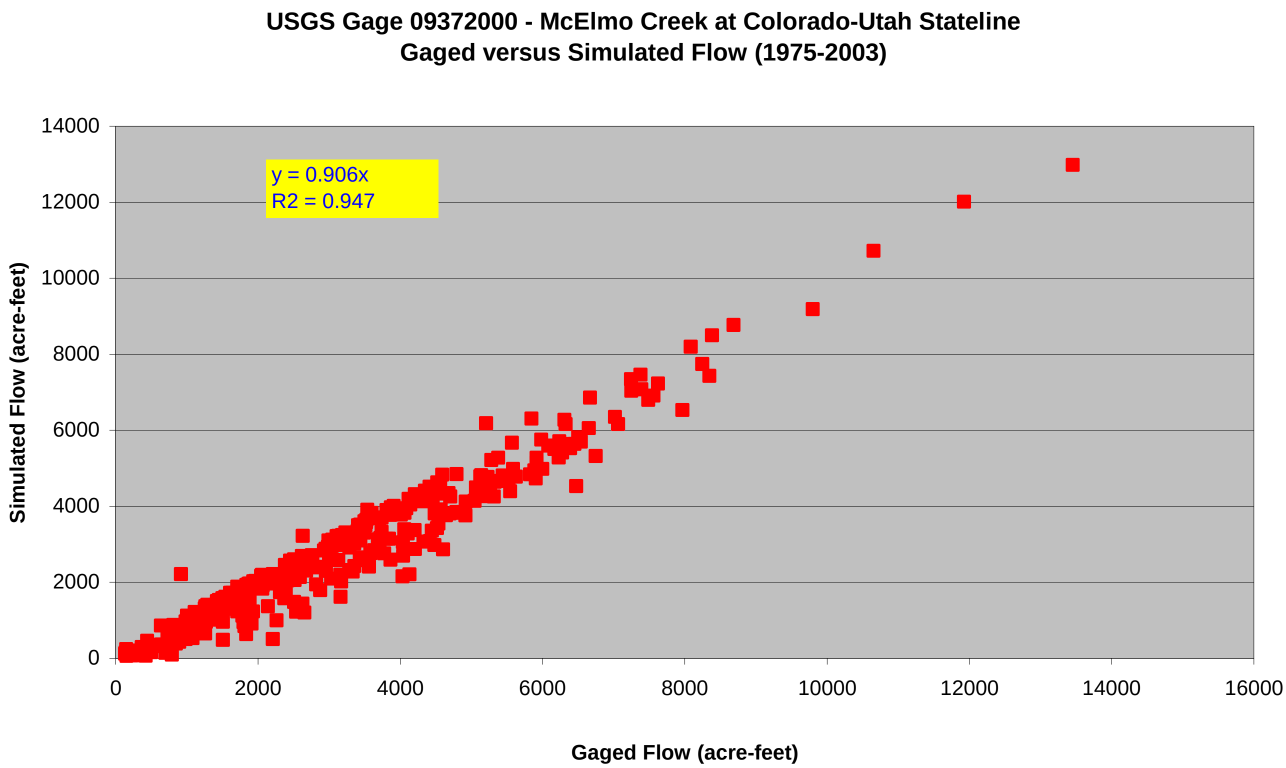


Figure D.7 Calculated Streamflow Simulation – Mancos River near Towaoc



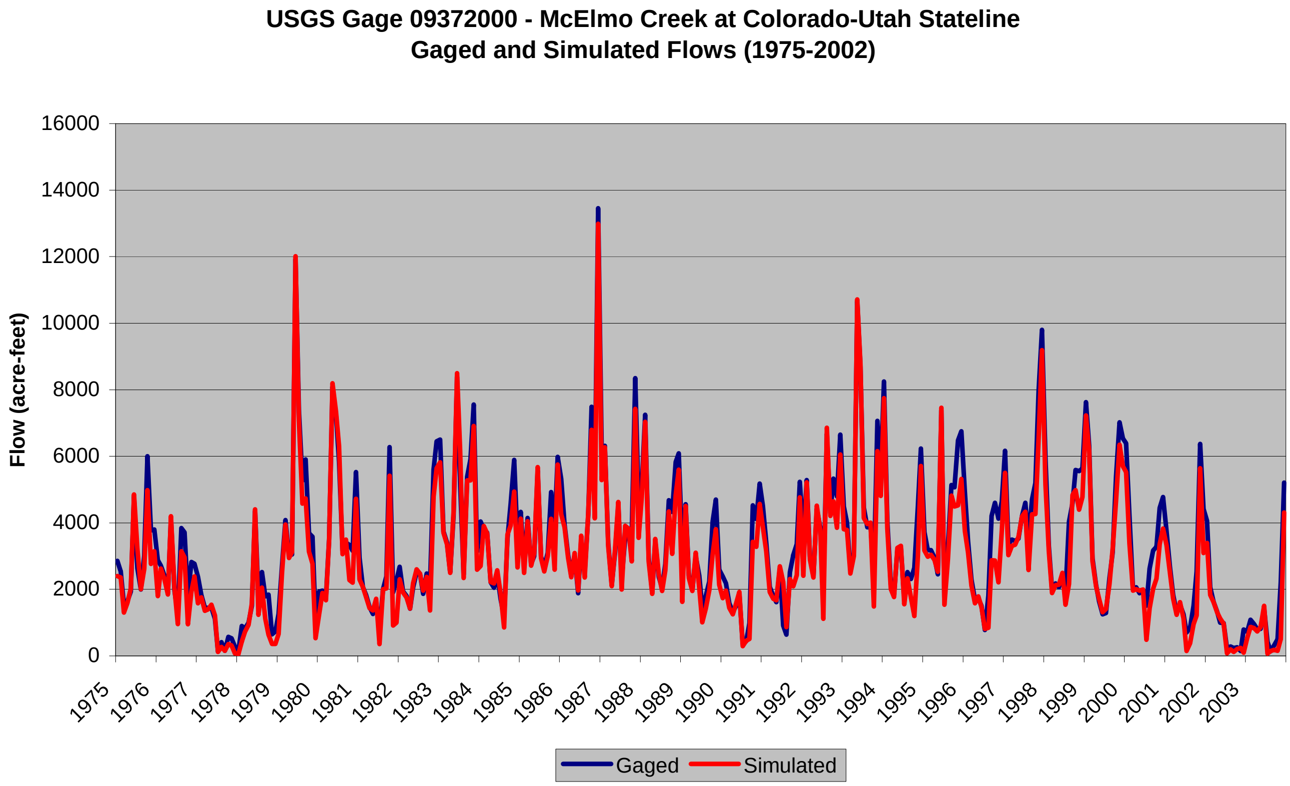
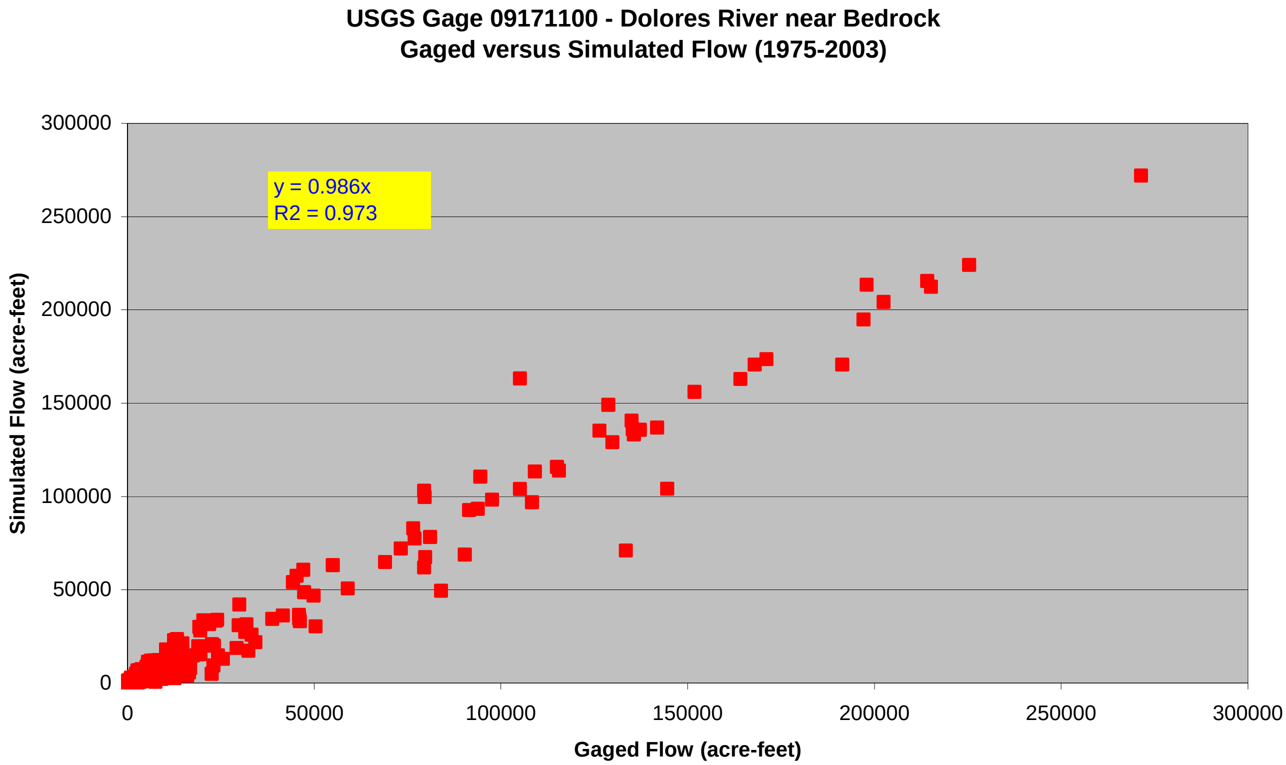


Figure D.8 Calculated Streamflow Simulation – McElmo Creek at Colorado-Utah Stateline



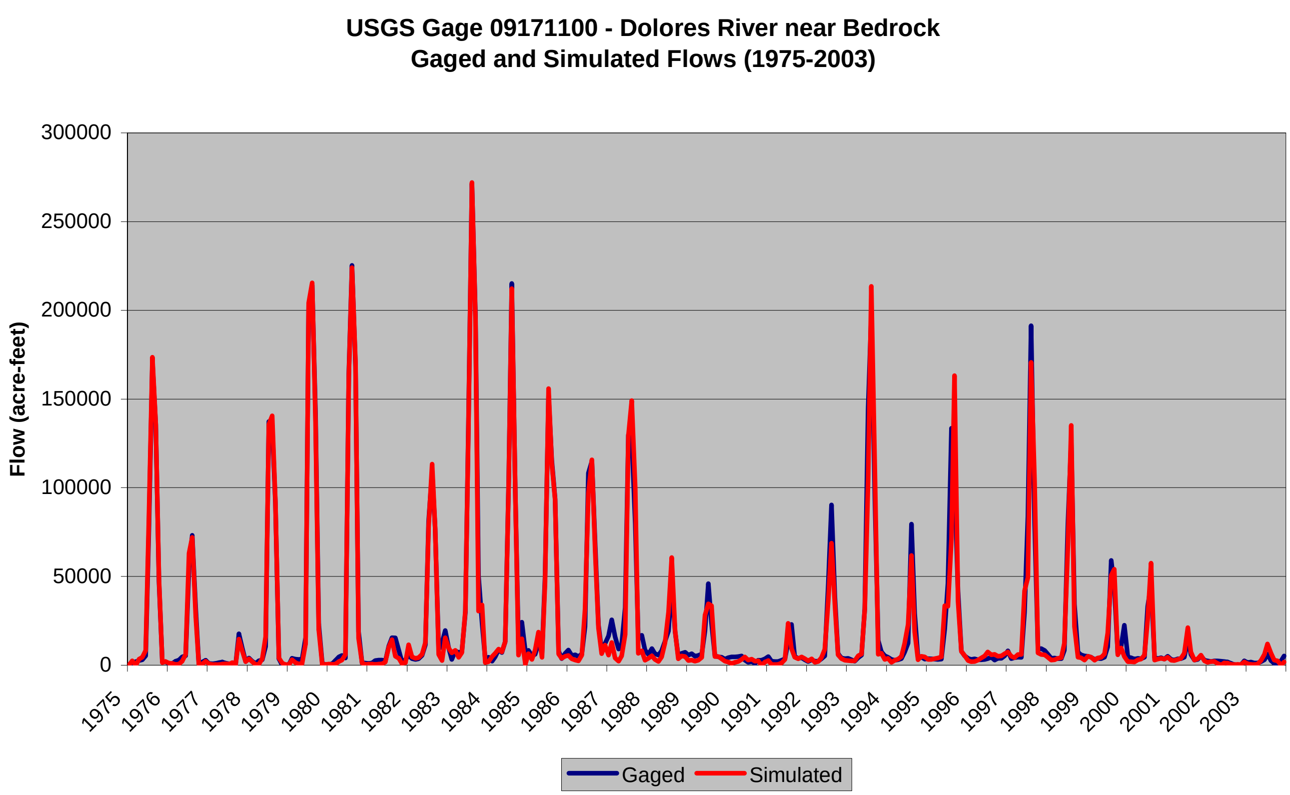
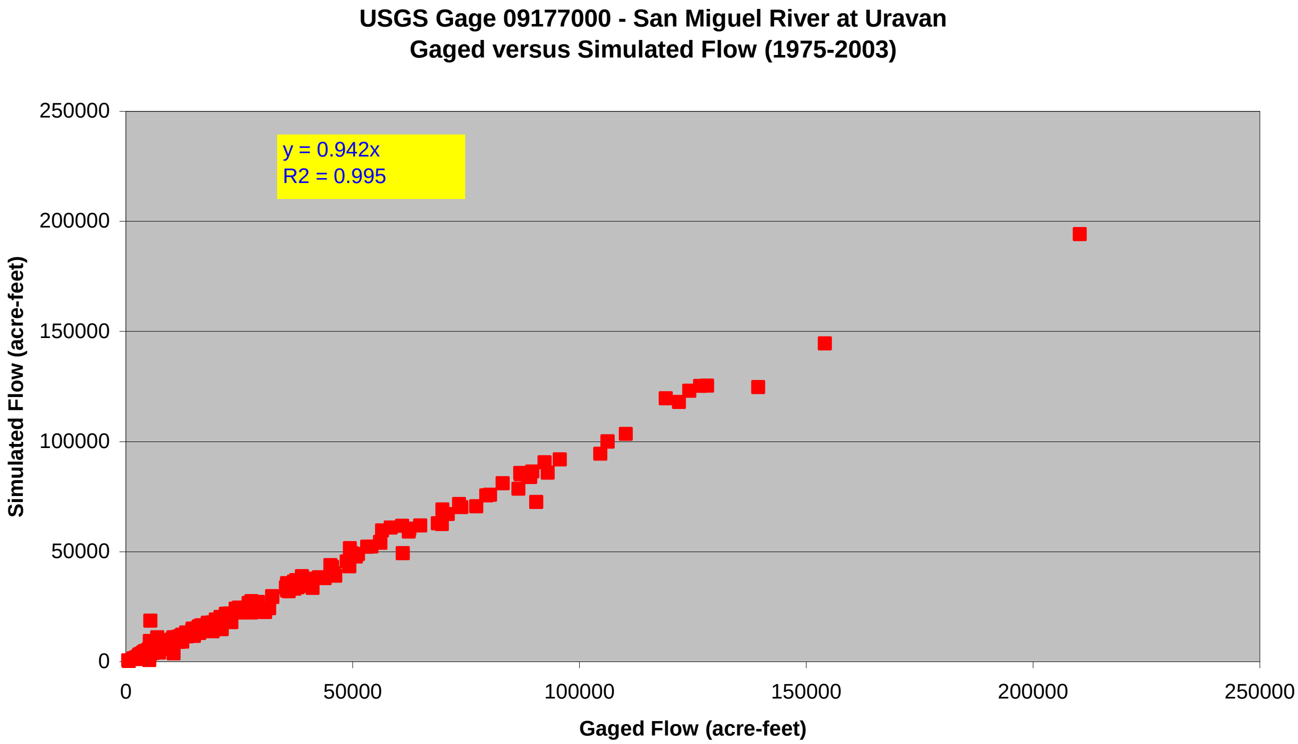


Figure D.9 Calculated Streamflow Simulation – Dolores River near Bedrock



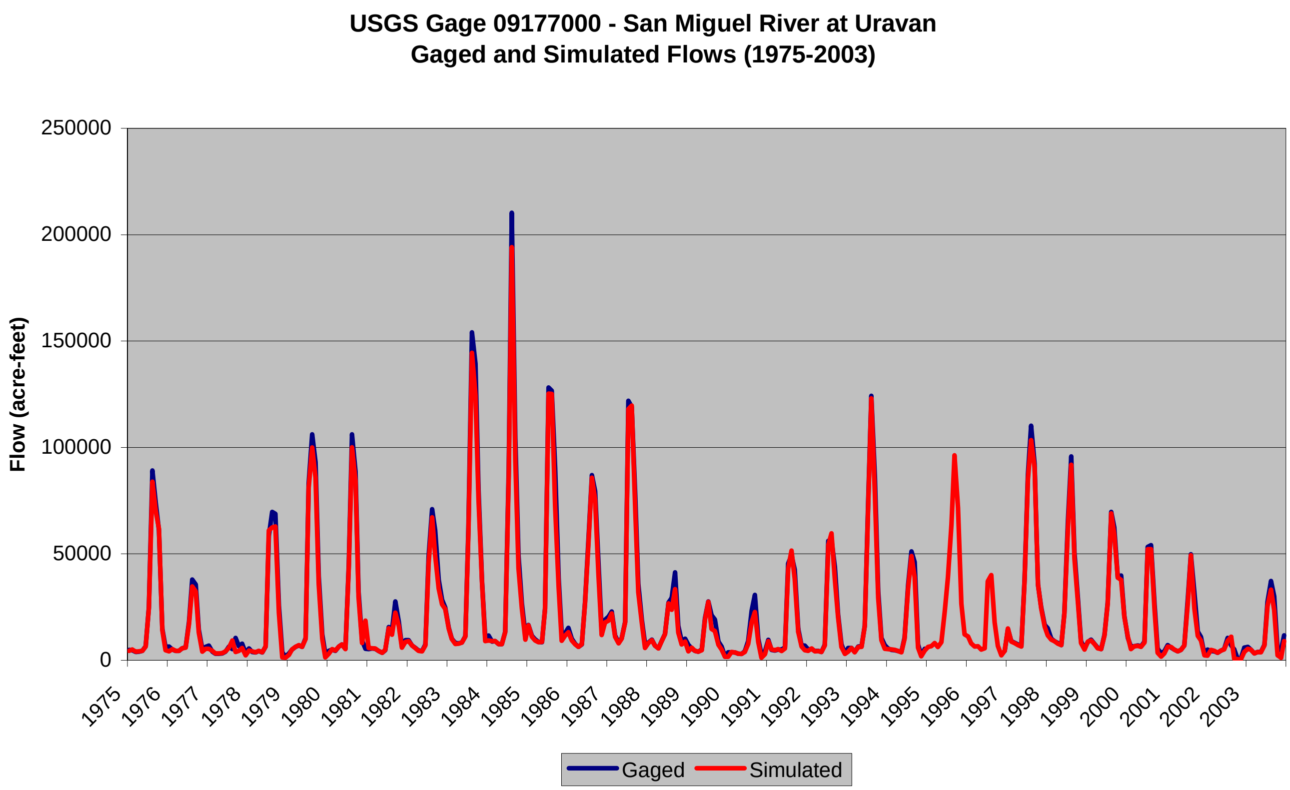


Figure D.10 Calculated Streamflow Simulation – San Miguel River at Uravan

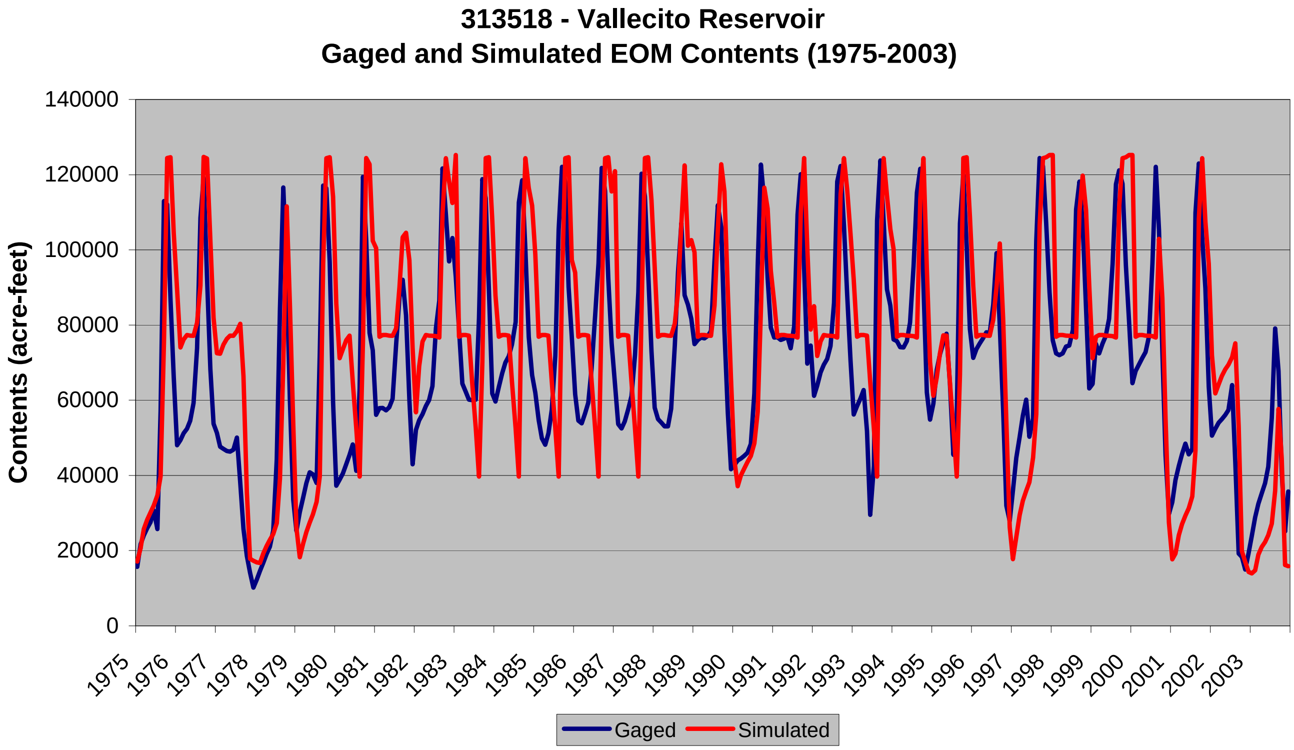


Figure D.11 Calculated Reservoir Simulation – Vallecito Reservoir

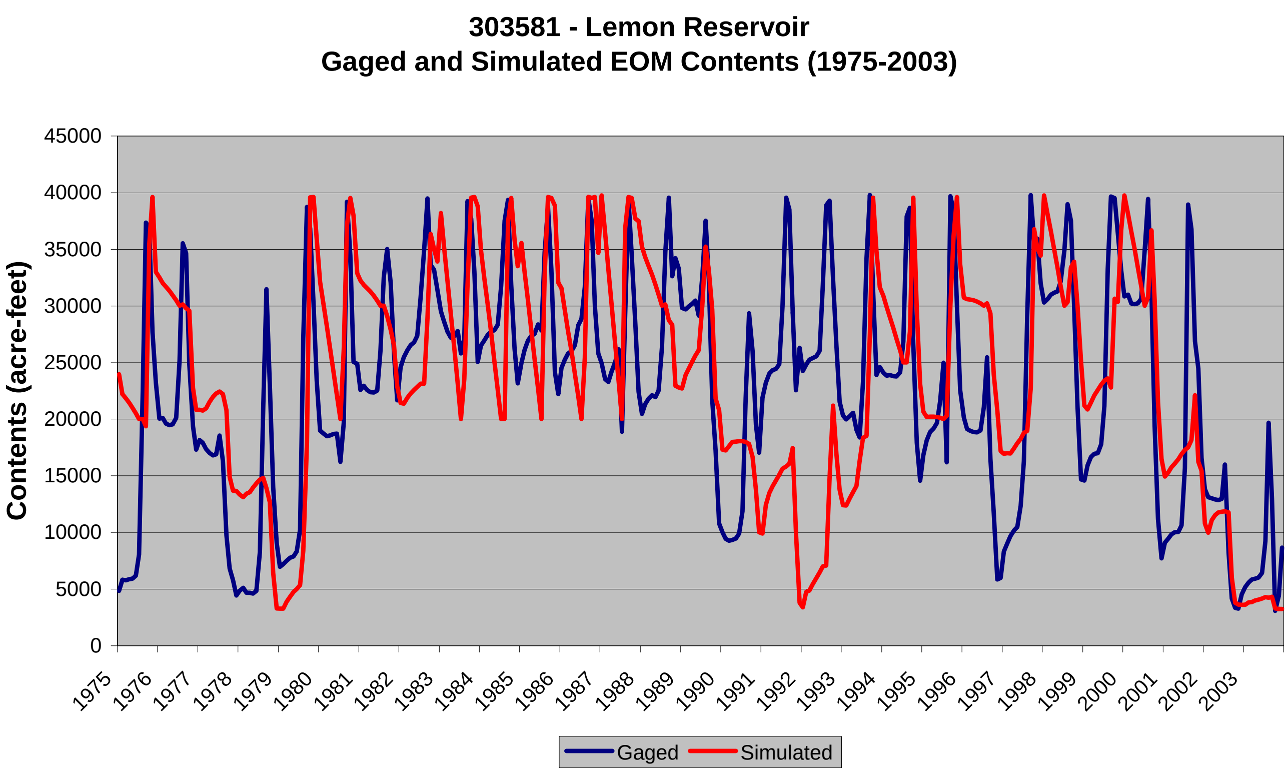


Figure D.12 Calculated Reservoir Simulation – Lemon Reservoir

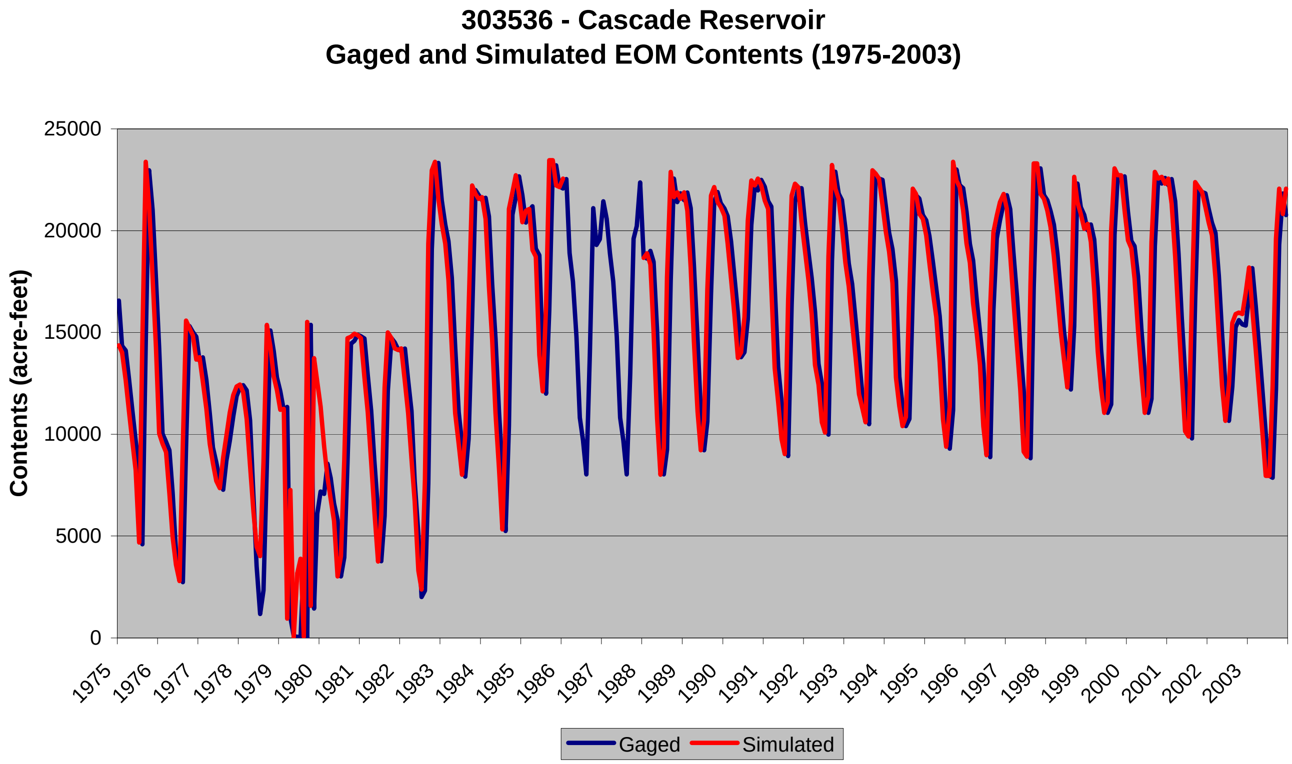


Figure D.13 Calculated Reservoir Simulation – Cascade Reservoir

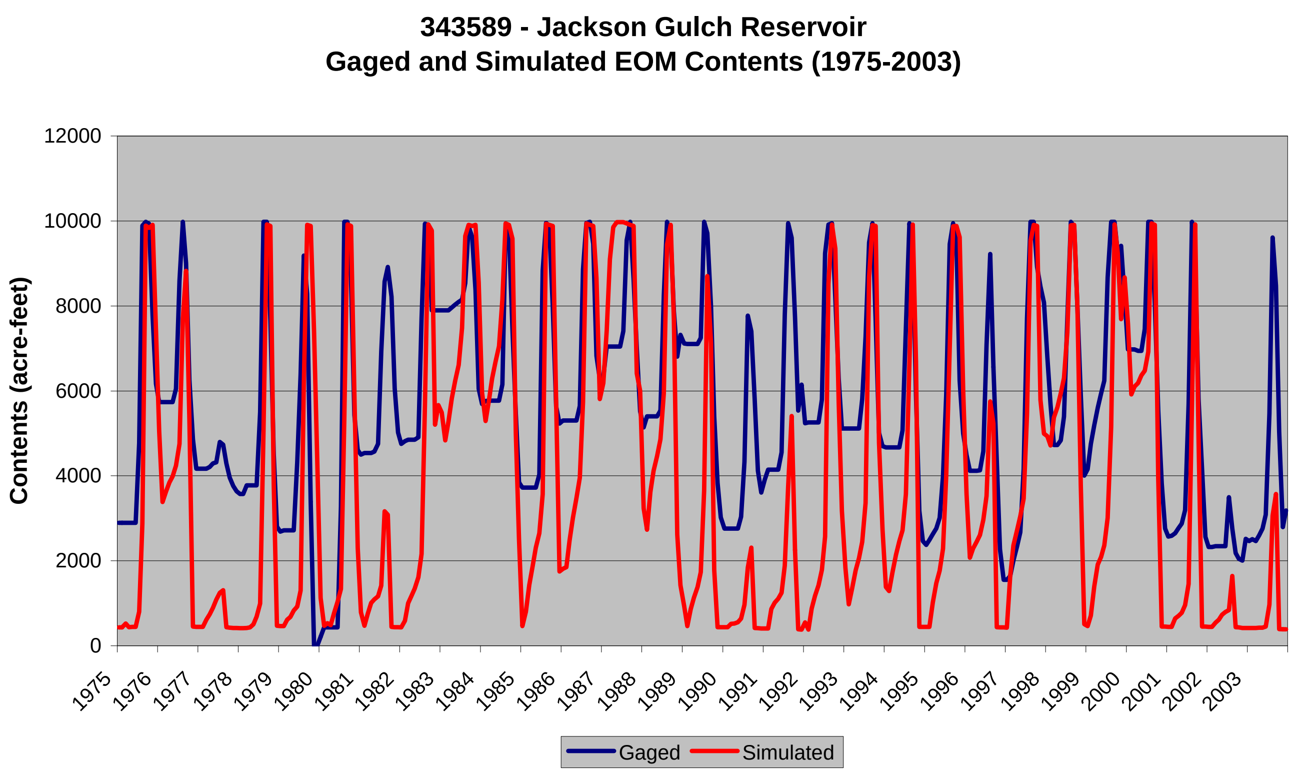


Figure D.14 Calculated Reservoir Simulation – Jackson Gulch Reservoir

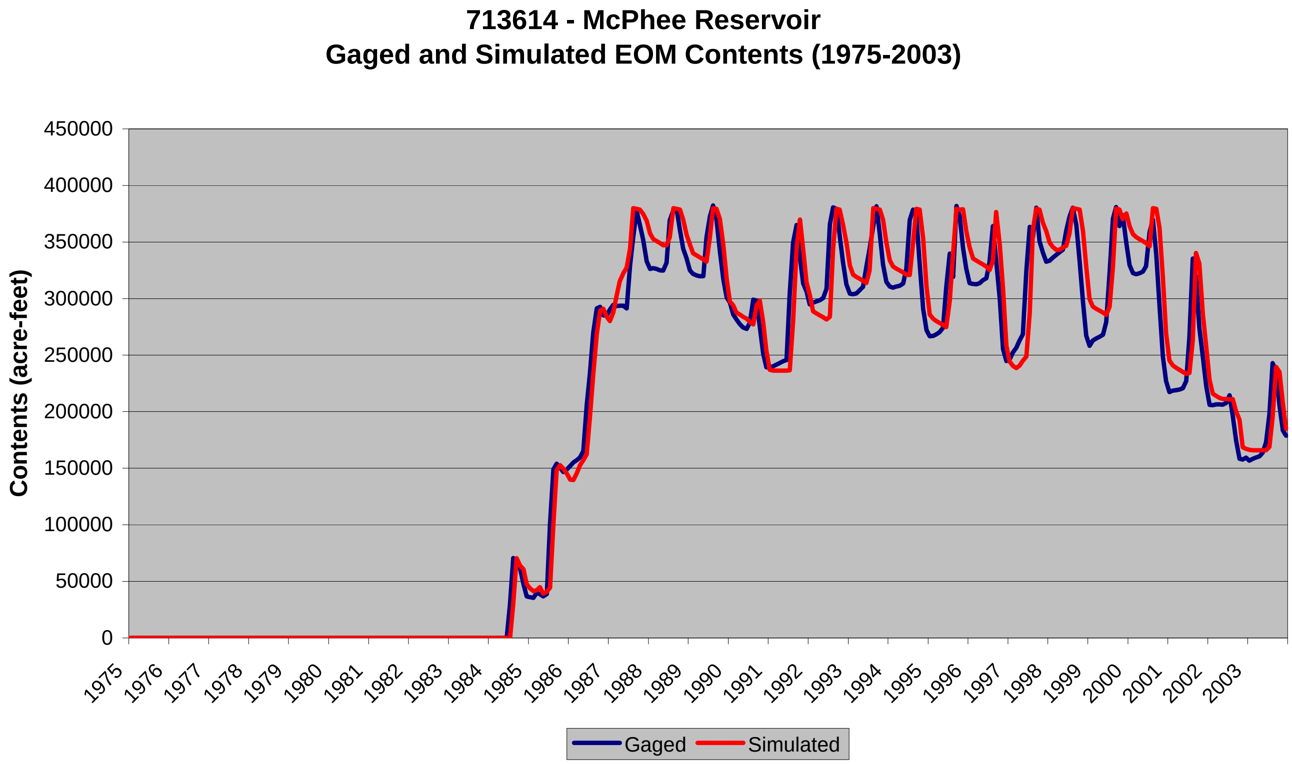


Figure D.15 Calculated Reservoir Simulation – McPhee Reservoir

Appendix E

Historical Daily Simulation Results

Historical Daily Data Set

> *Note*: This section describes a Historical Daily Data Set that was completed in November 2005. The San Juan Model Historical (calibration), Calculated and Baseline data files were updated in October 2009, and the 2009 calibration and Baseline data sets are described in this user manual. Inconsistencies between the 2008 and 2009 Historical Daily Data Set are minor, and include:
>
> 1) maximum irrigation efficiency set to 0.60 in 2008, and set to 0.54 in 2009
> 2) differences in IWR for fields below 6,500 ft in elevation, because an elevation adjustment was applied to crop coefficients in the Blaney-Criddle analysis in the 2009 model
>
> The approach described for the Historical Daily Data Set is accurate, except for the items listed above. Table values in this appendix are expected to be similar to, but not exactly, what would be produced with an updated 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 Volume	Historical -Simulated Percent	Gage Name
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 Volume	Historical -Simulated Percent	Gage Name
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) 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%

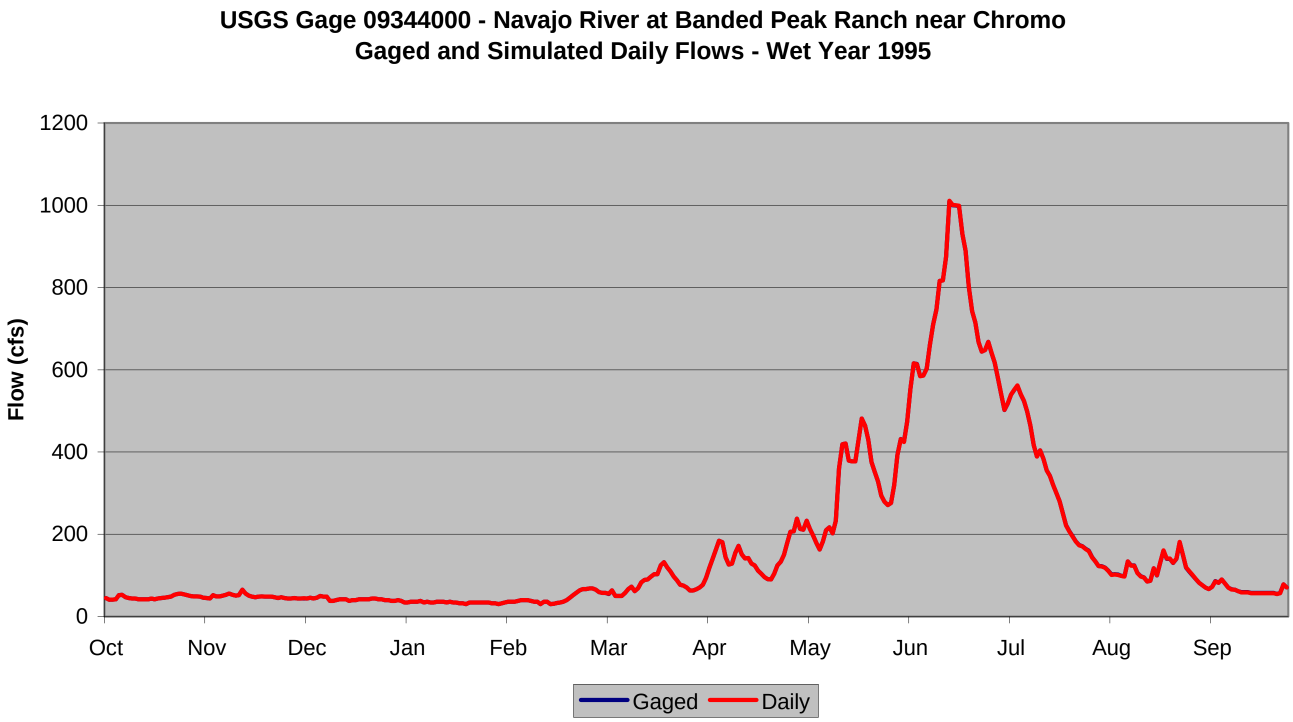


Figure E.1 Historical Daily Comparison, Wet Year – Navajo River at Banded Peak Ranch

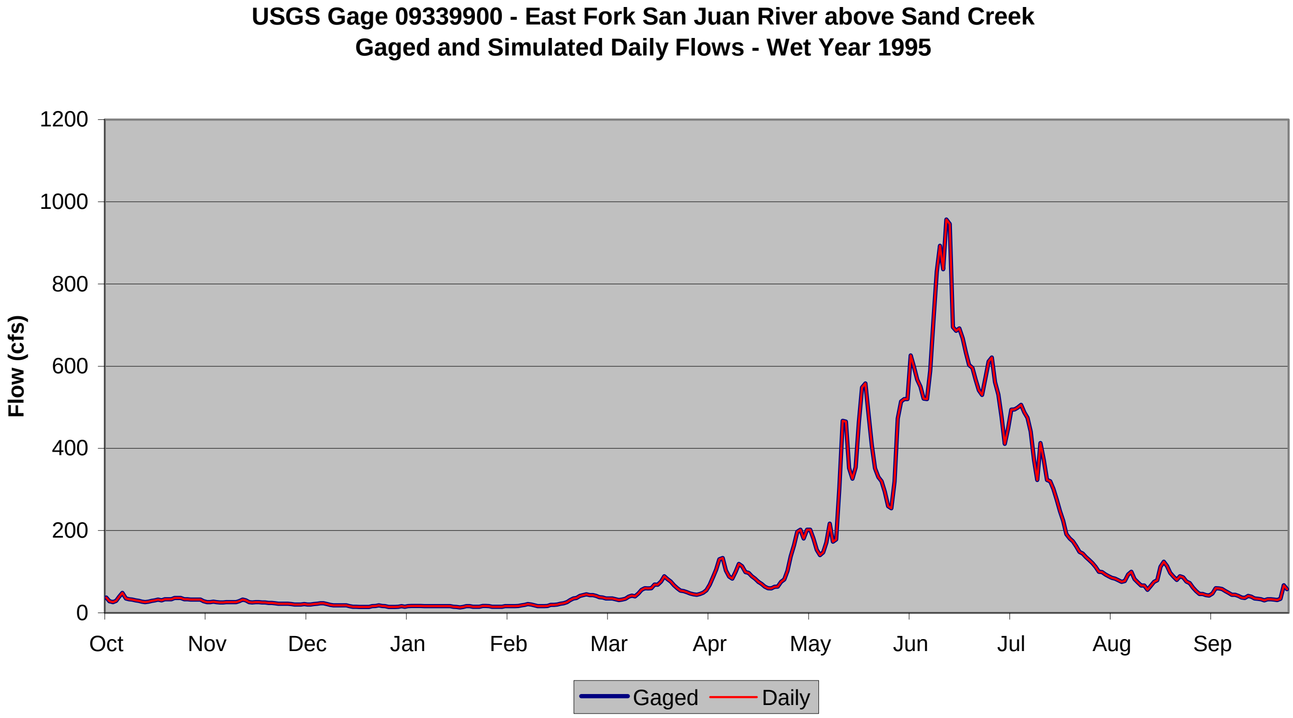


Figure E.2 Historical Daily Comparison, Wet Year – East Fork San Juan above Sand Creek

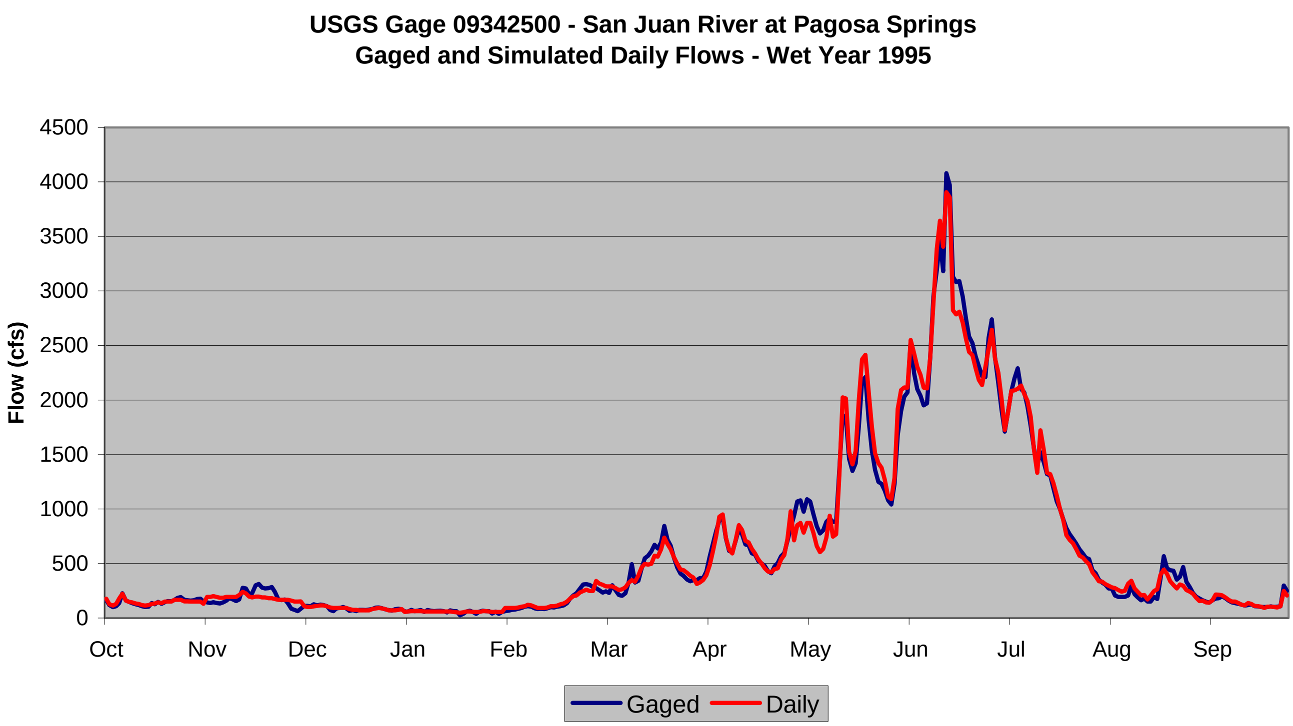


Figure E.3 Historical Daily Comparison, Wet Year – San Juan River at Pagosa Springs

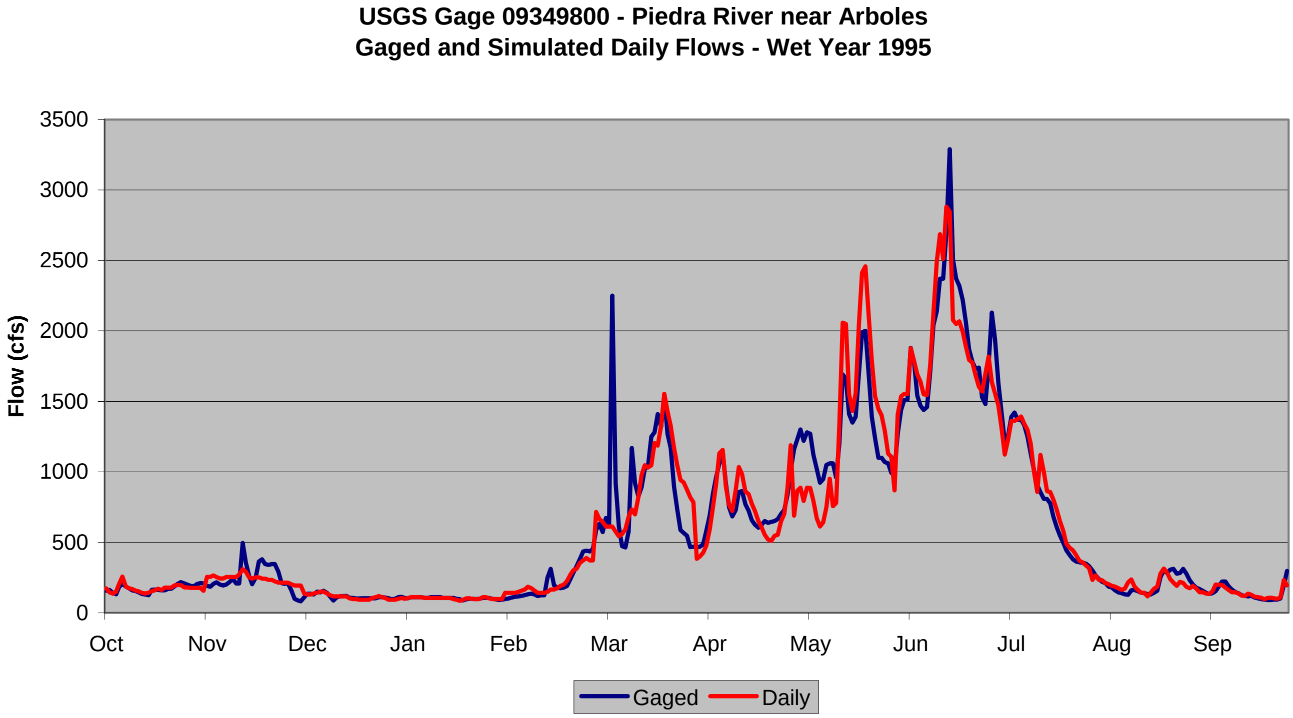


Figure E.4 Historical Daily Comparison, Wet Year – Piedra River near Arboles

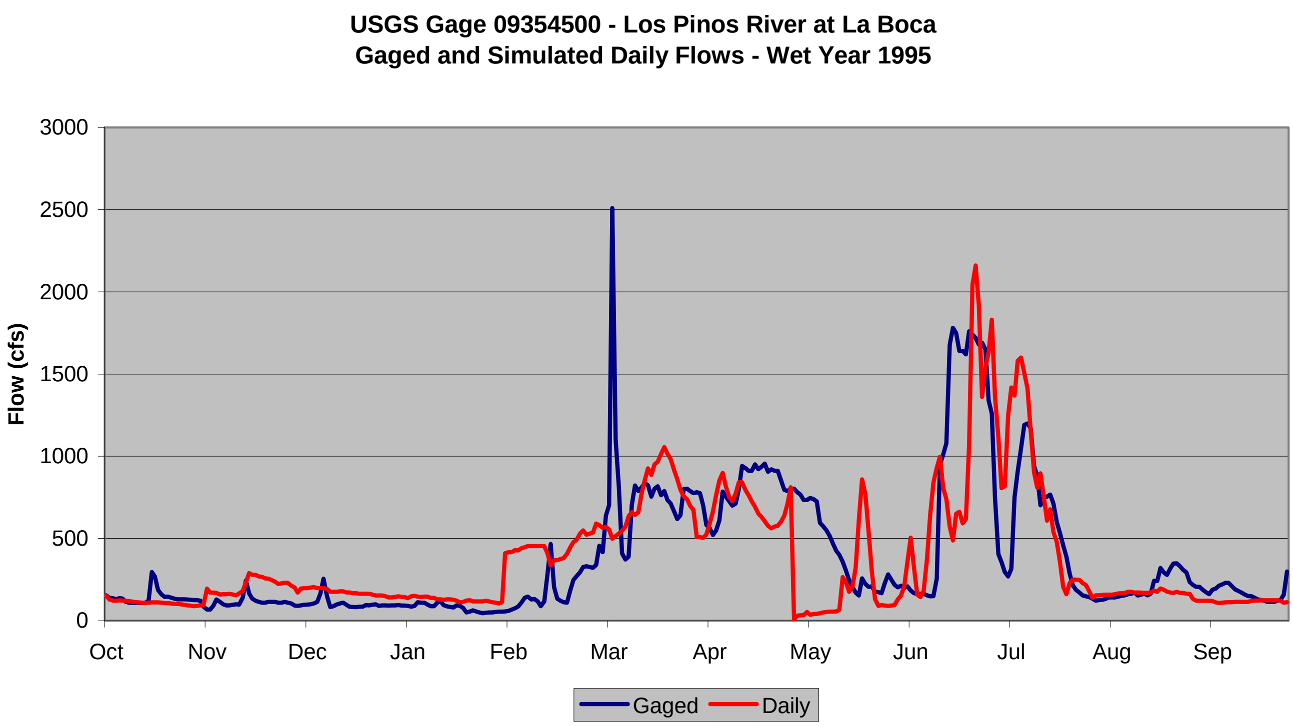


Figure E.5 Historical Daily Comparison, Wet Year – Los Pinos River at La Boca

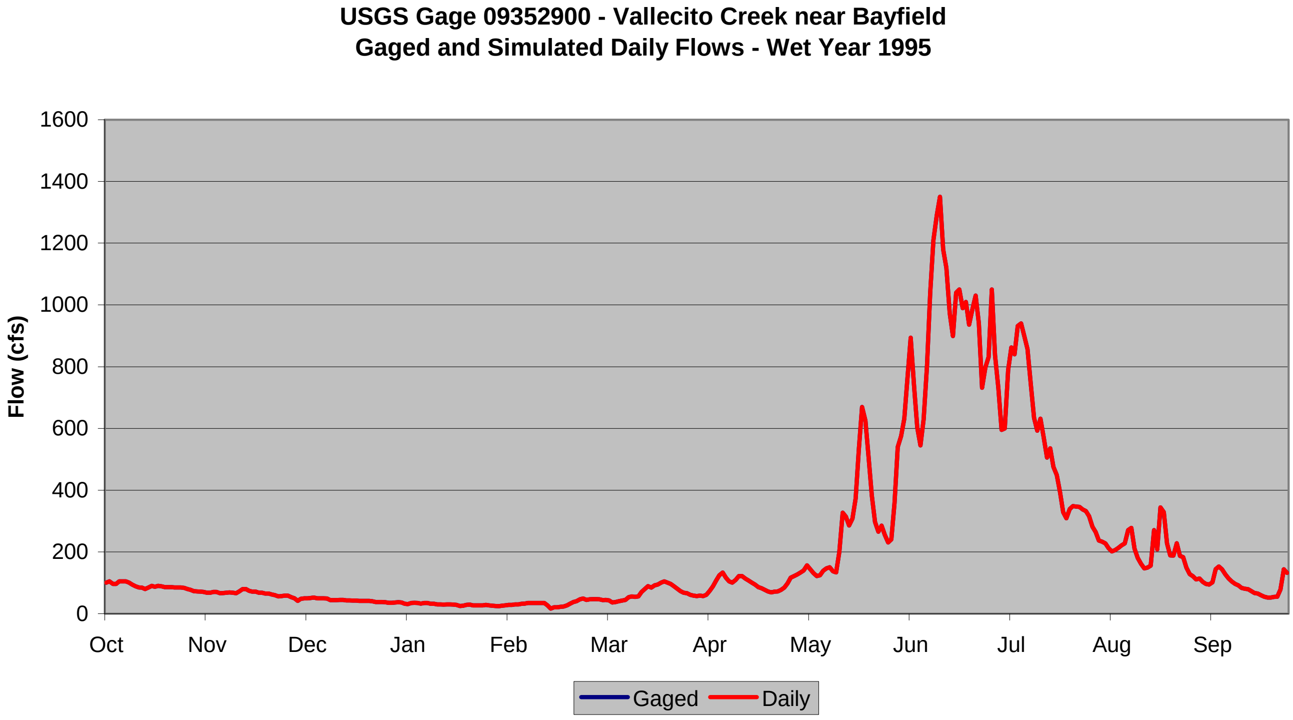


Figure E.6 Historical Daily Comparison, Wet Year – Vallecito Creek near Bayfield

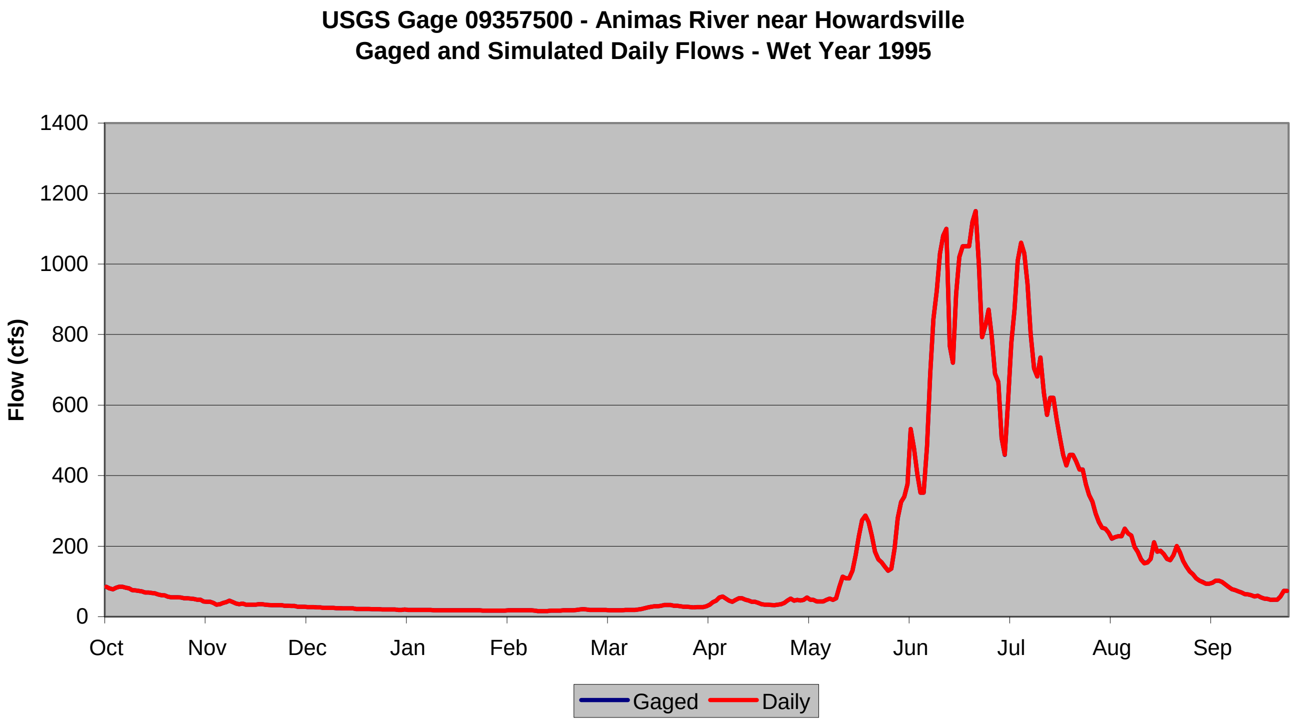


Figure E.7 Historical Daily Comparison, Wet Year – Animas River near Howardsville

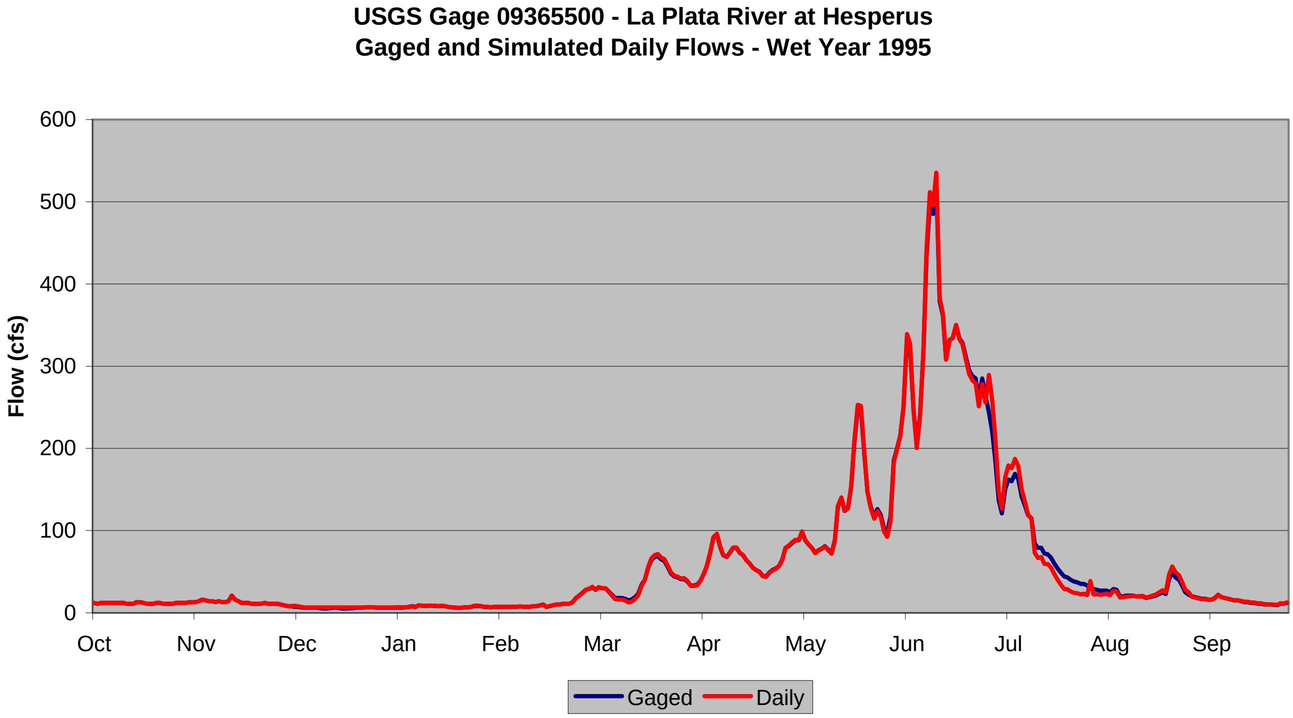


Figure E.8 Historical Daily Comparison, Wet Year – La Plata River at Hesperus

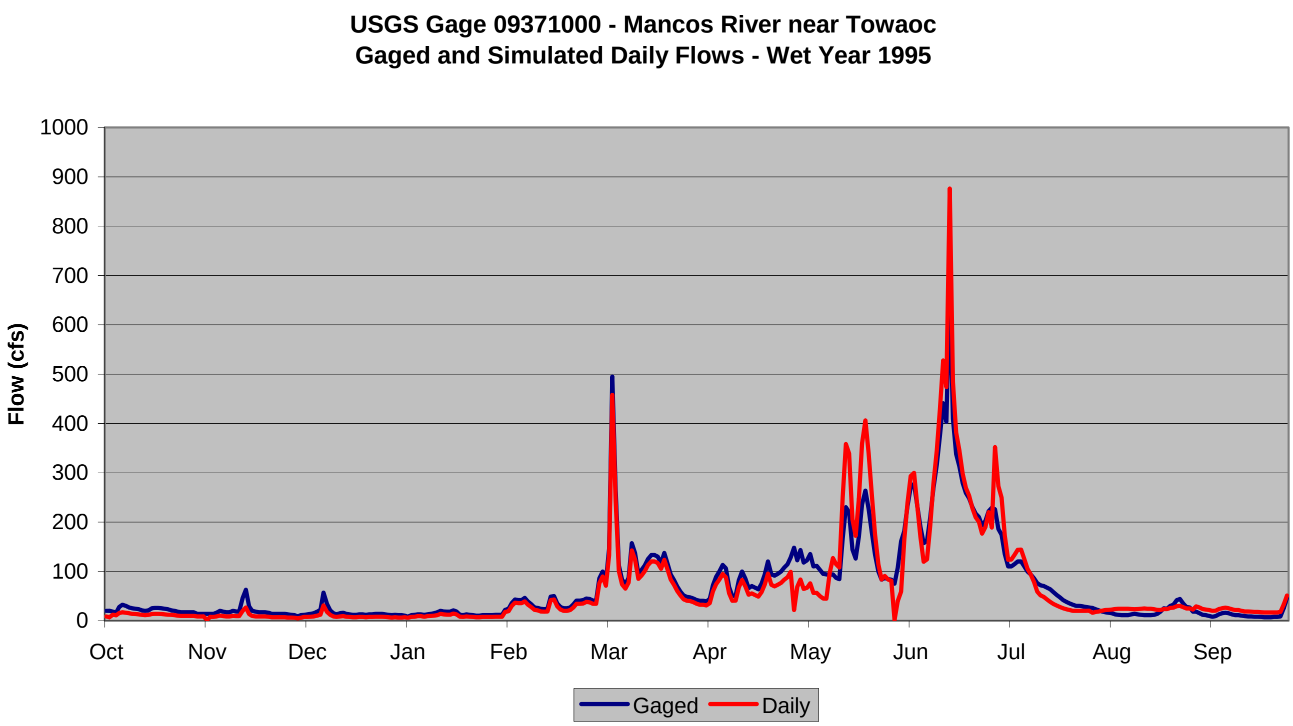


Figure E.9 Historical Daily Comparison, Wet Year – Mancos River near Towaoc

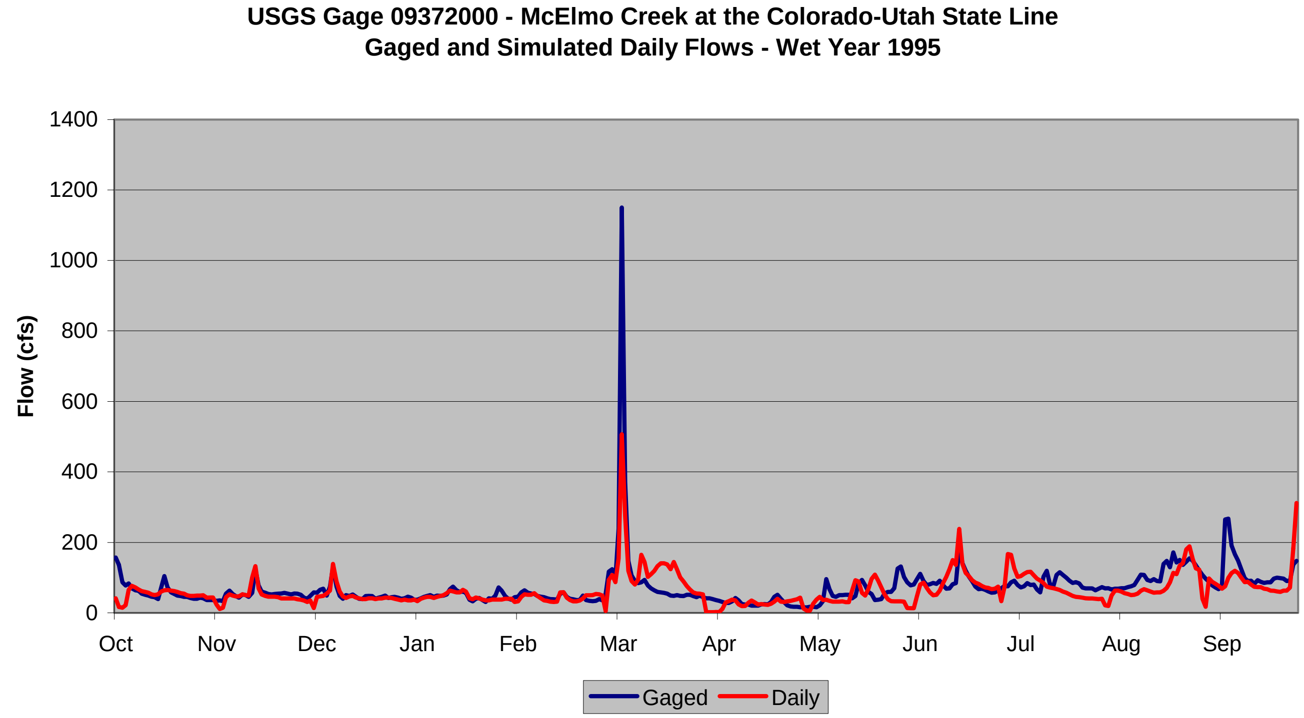


Figure E.10 Historical Daily Comparison, Wet Year – McElmo Creek at CO-UT State Line

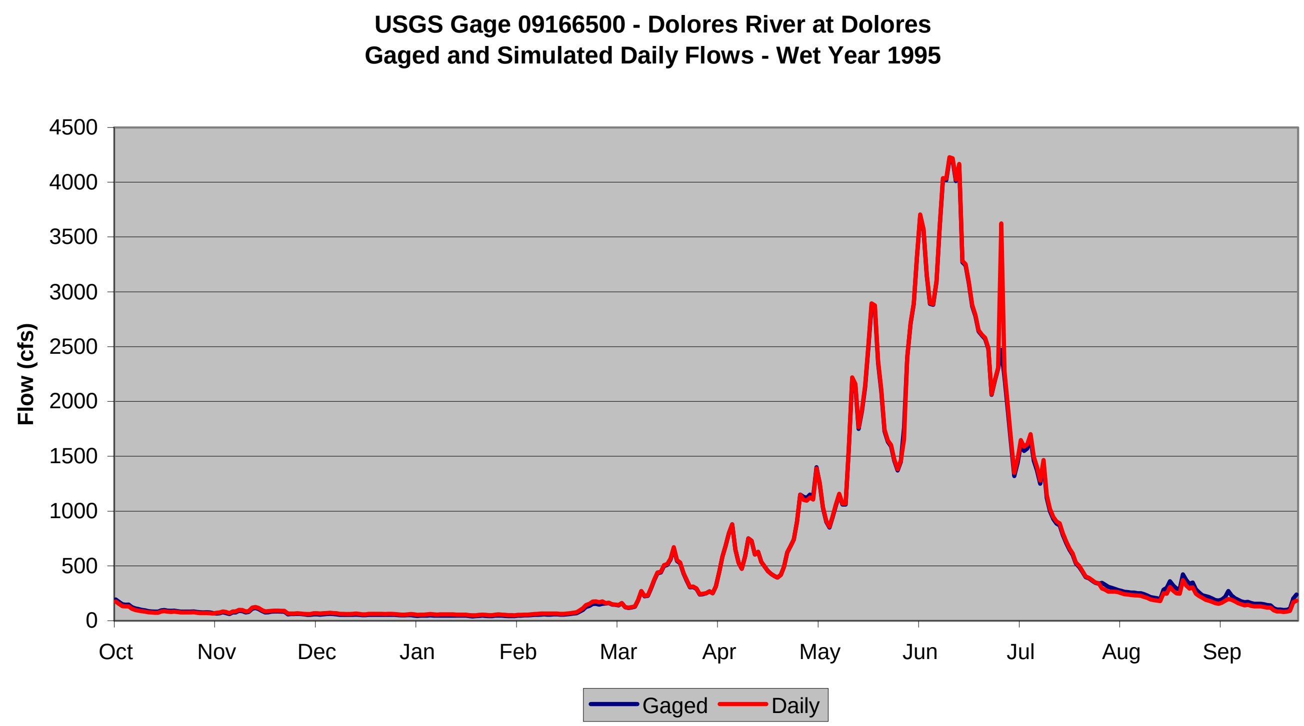


Figure E.11 Historical Daily Comparison, Wet Year – Dolores River at Dolores

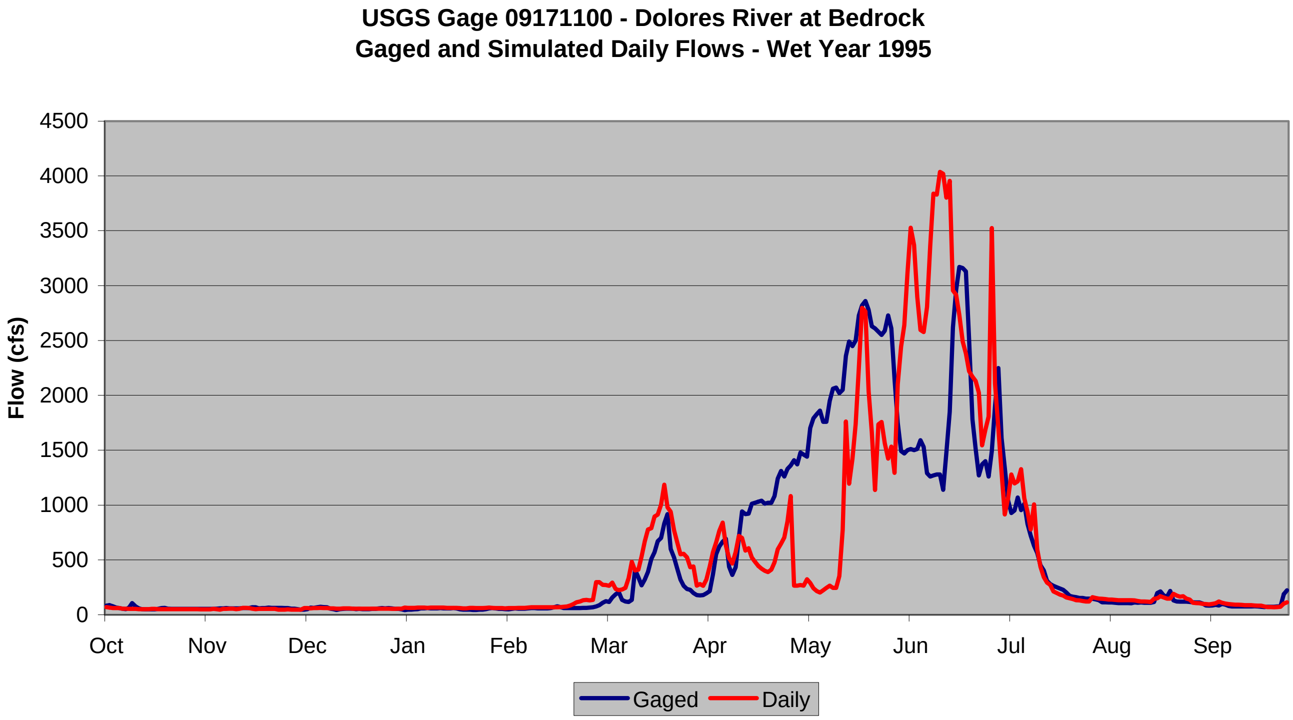


Figure E.12 Historical Daily Comparison, Wet Year – Dolores River at Bedrock

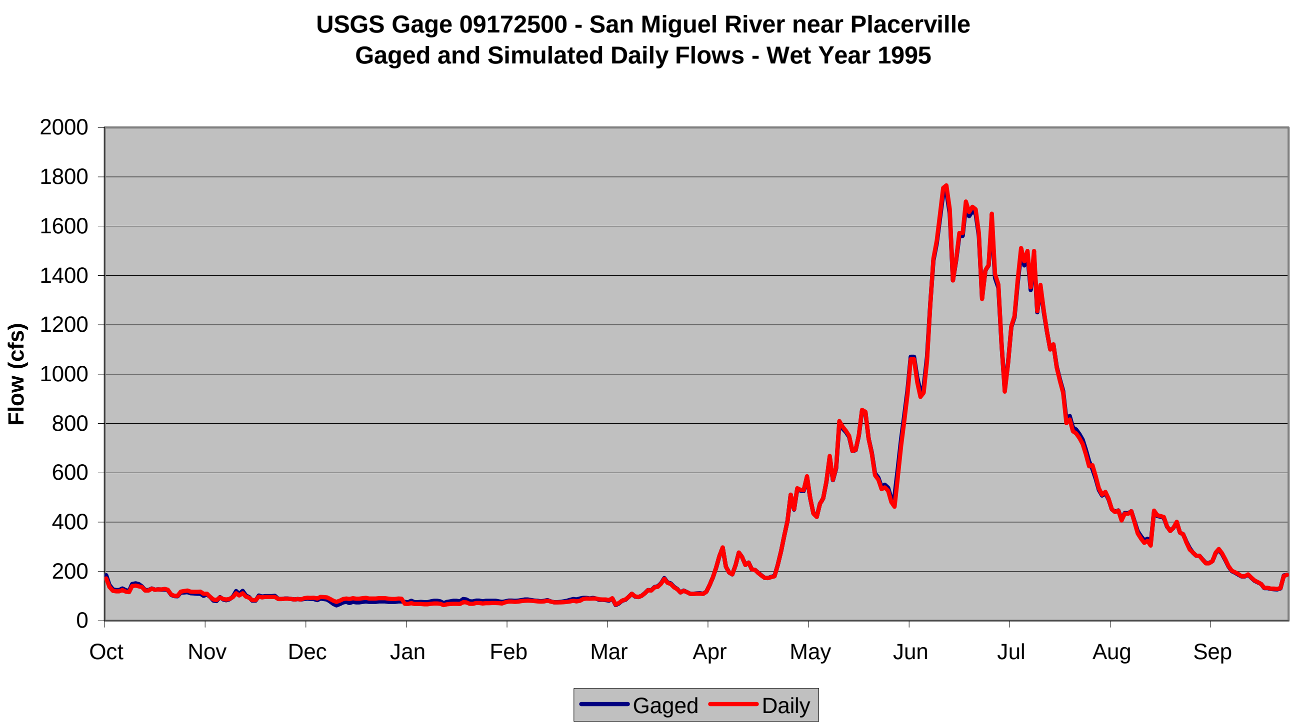


Figure E.13 Historical Daily Comparison, Wet Year – San Miguel River near Placerville

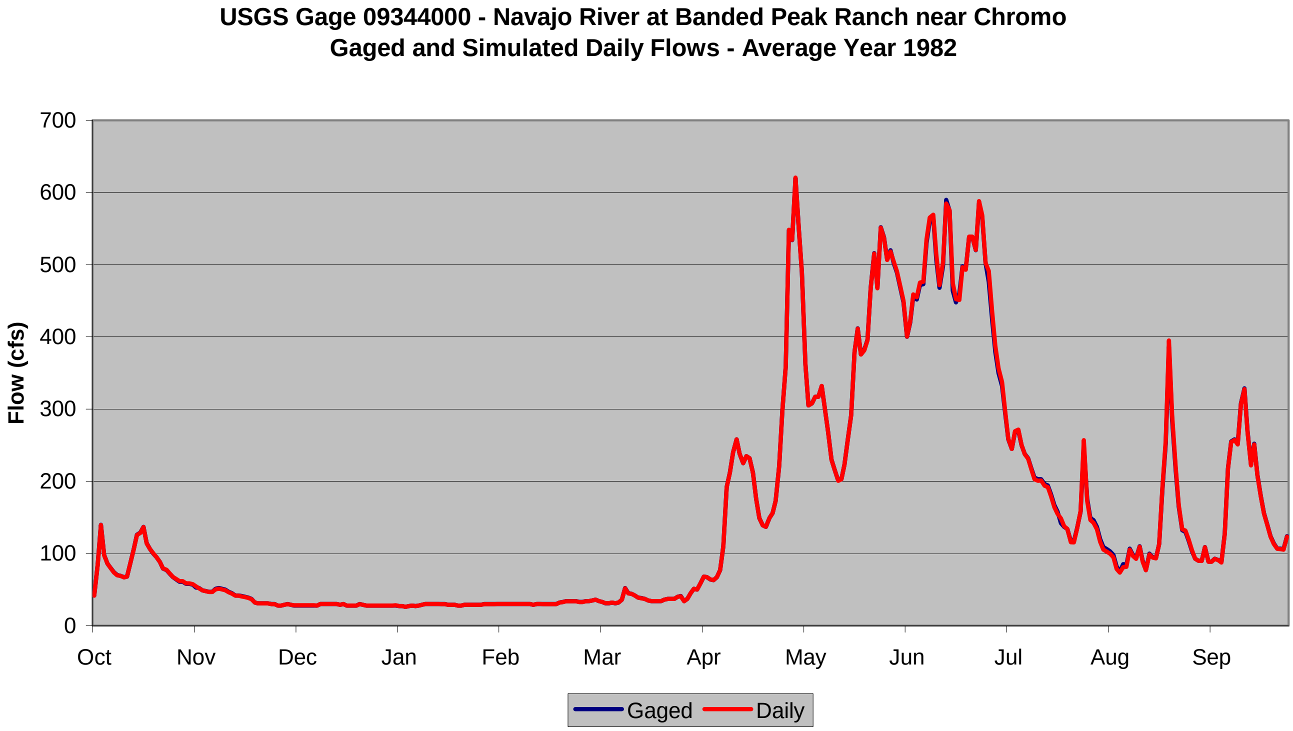


Figure E.14 Historical Daily Comparison, Average Year – Navajo River at Banded Peak Ranch

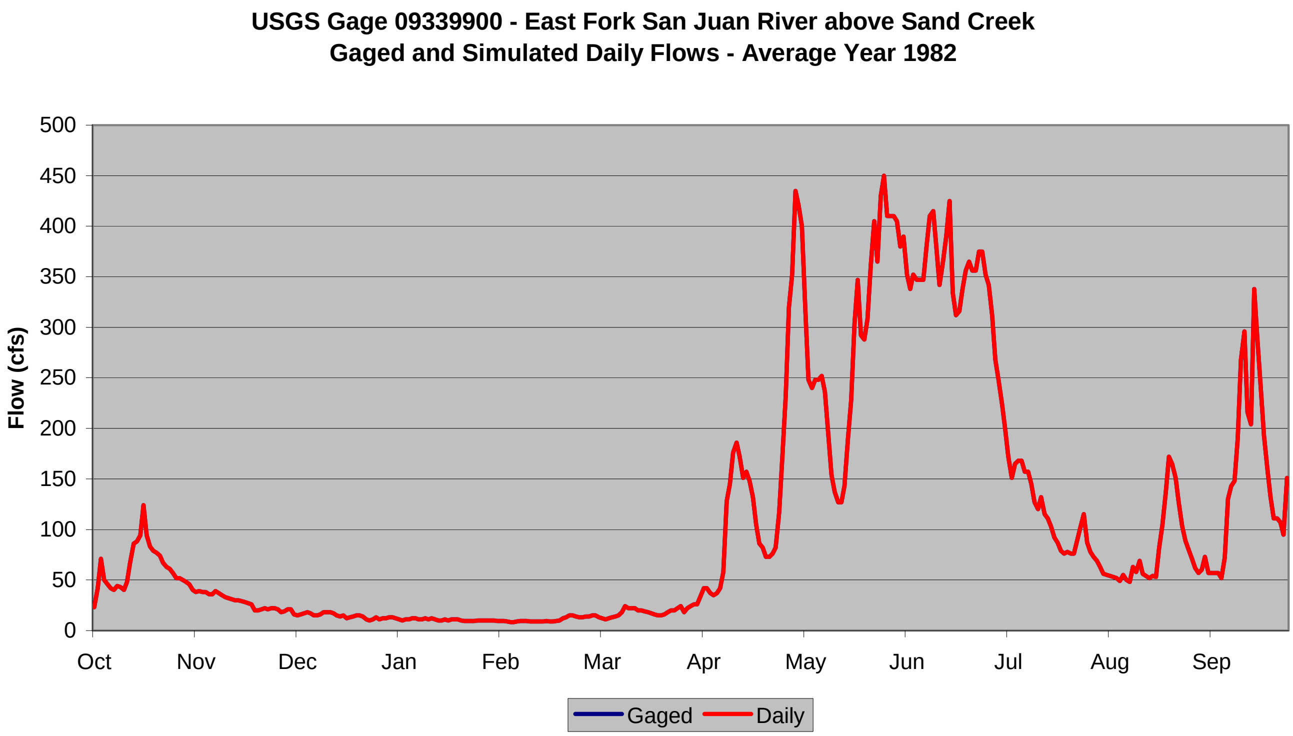


Figure E.15 Historical Daily Comparison, Average Year – East Fork San Juan River ab Sand Creek

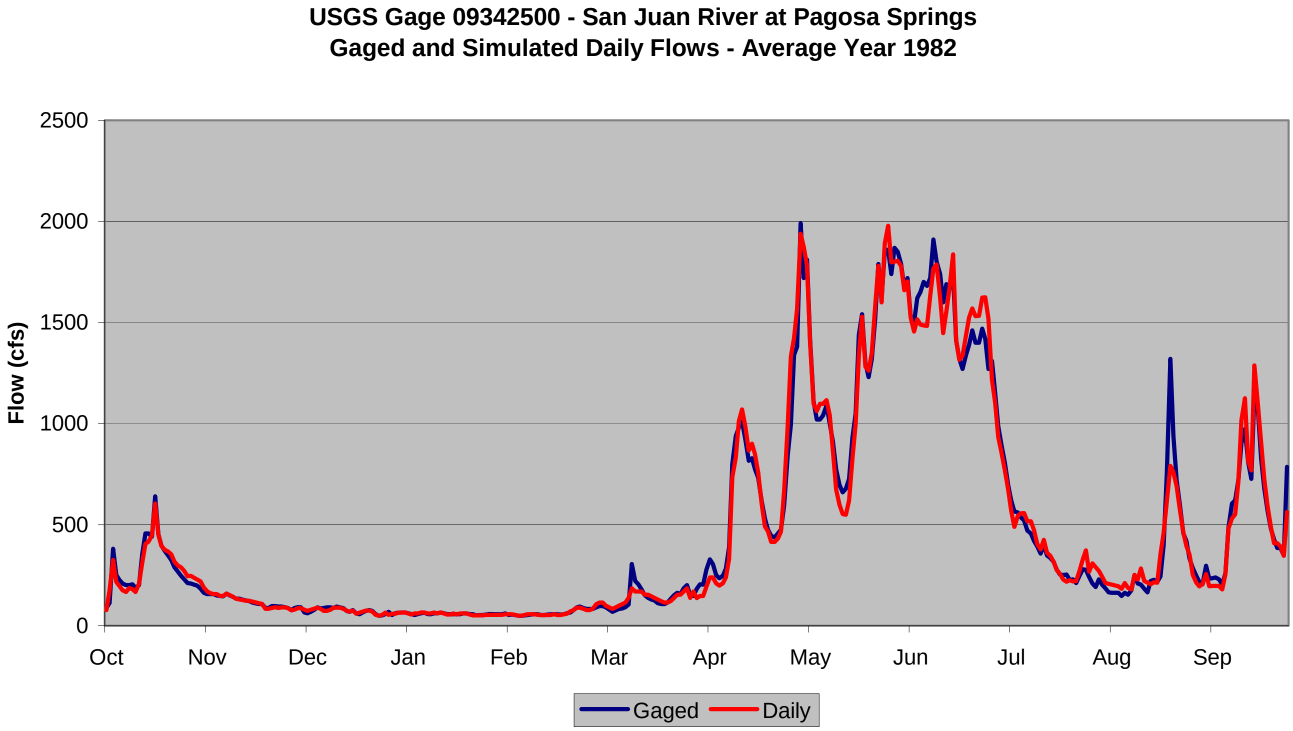


Figure E.16 Historical Daily Comparison, Average Year – San Juan River at Pagosa Springs

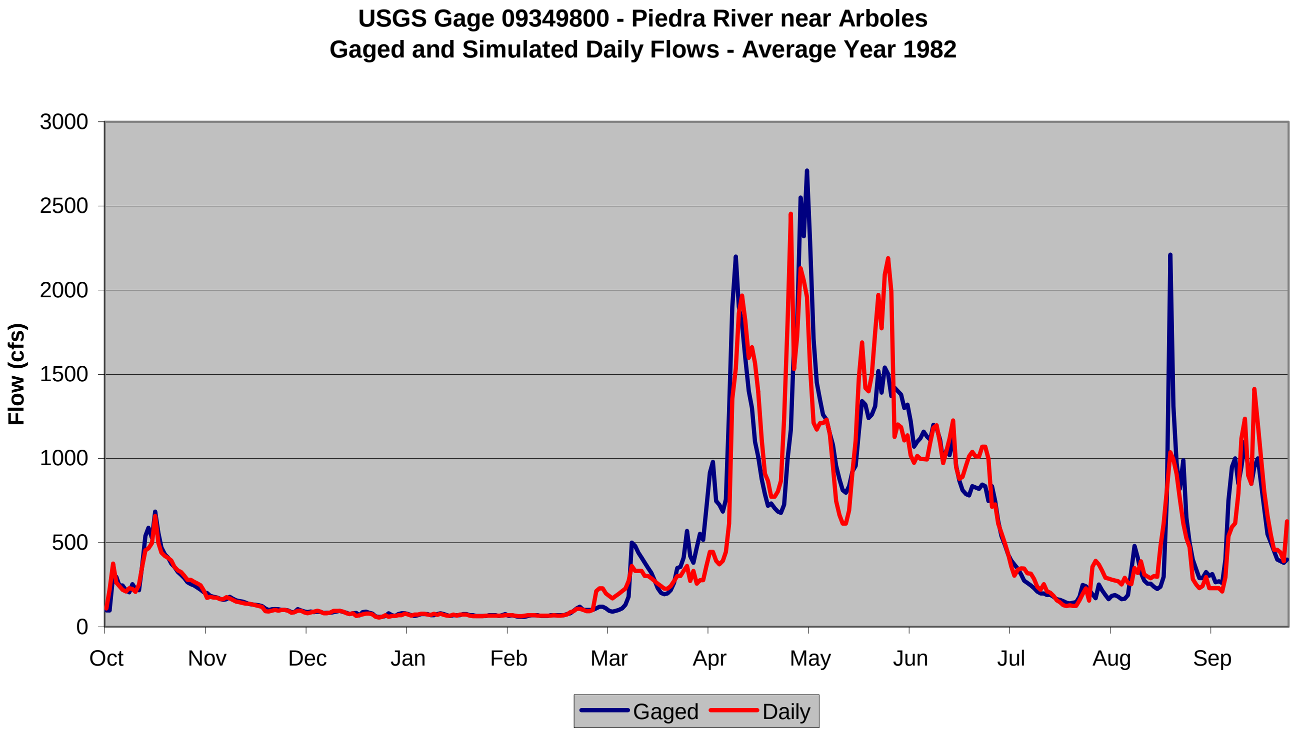


Figure E.17 Historical Daily Comparison, Average Year – Piedra River near Arboles

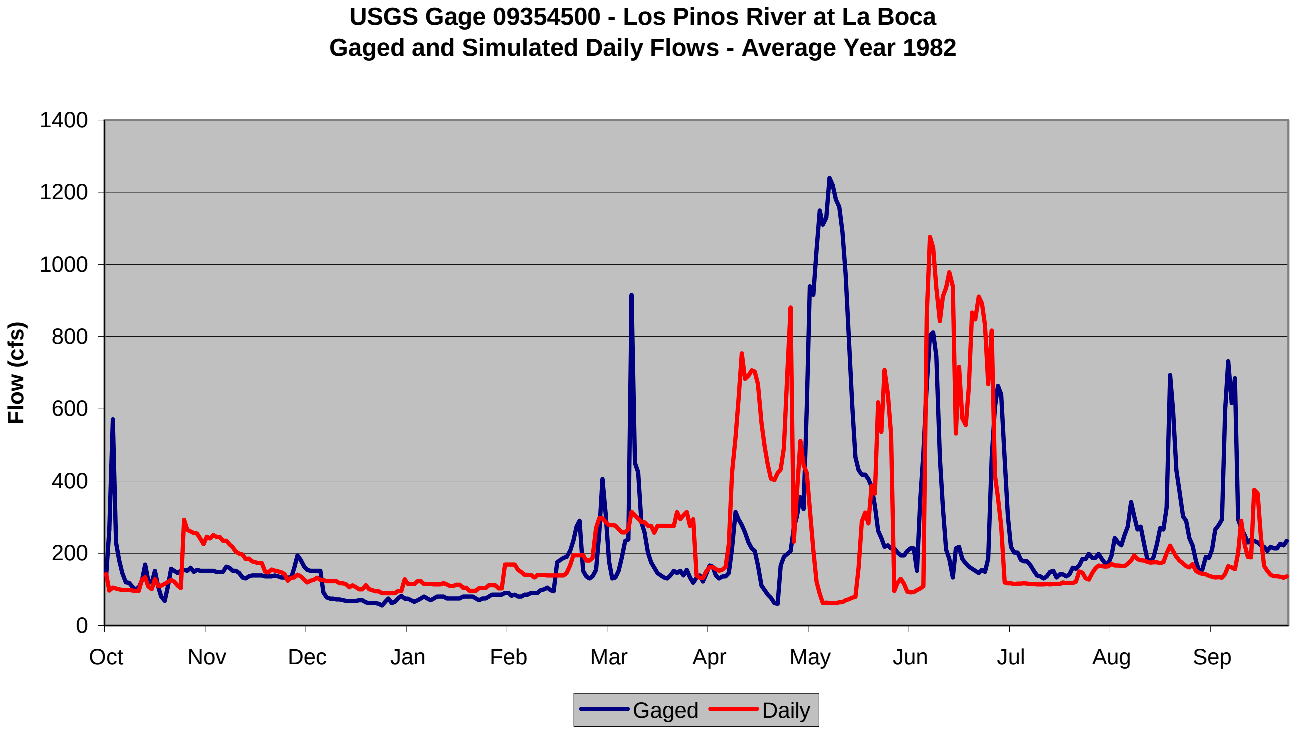


Figure E.18 Historical Daily Comparison, Average Year – Los Pinos River at La Boca

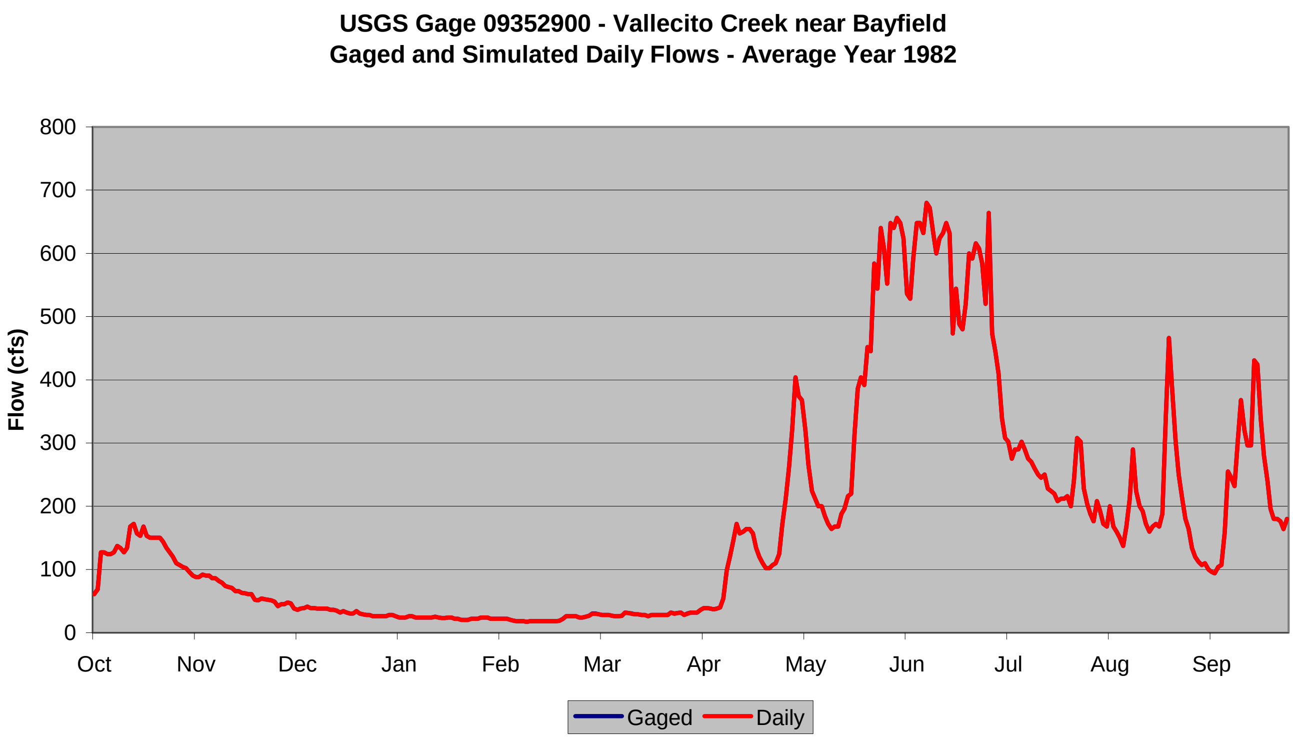


Figure E.19 Historical Daily Comparison, Average Year – Vallecito Creek near Bayfield

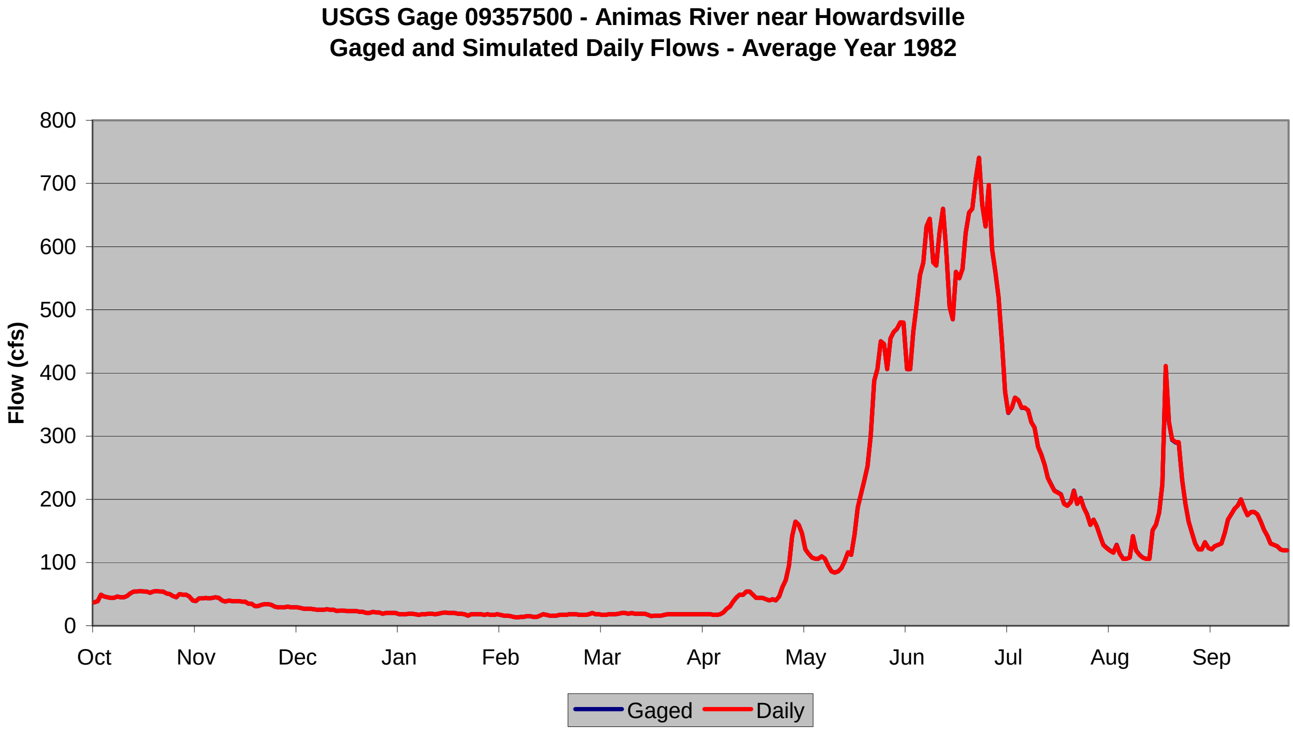


Figure E.20 Historical Daily Comparison, Average Year – Animas River near Howardsville

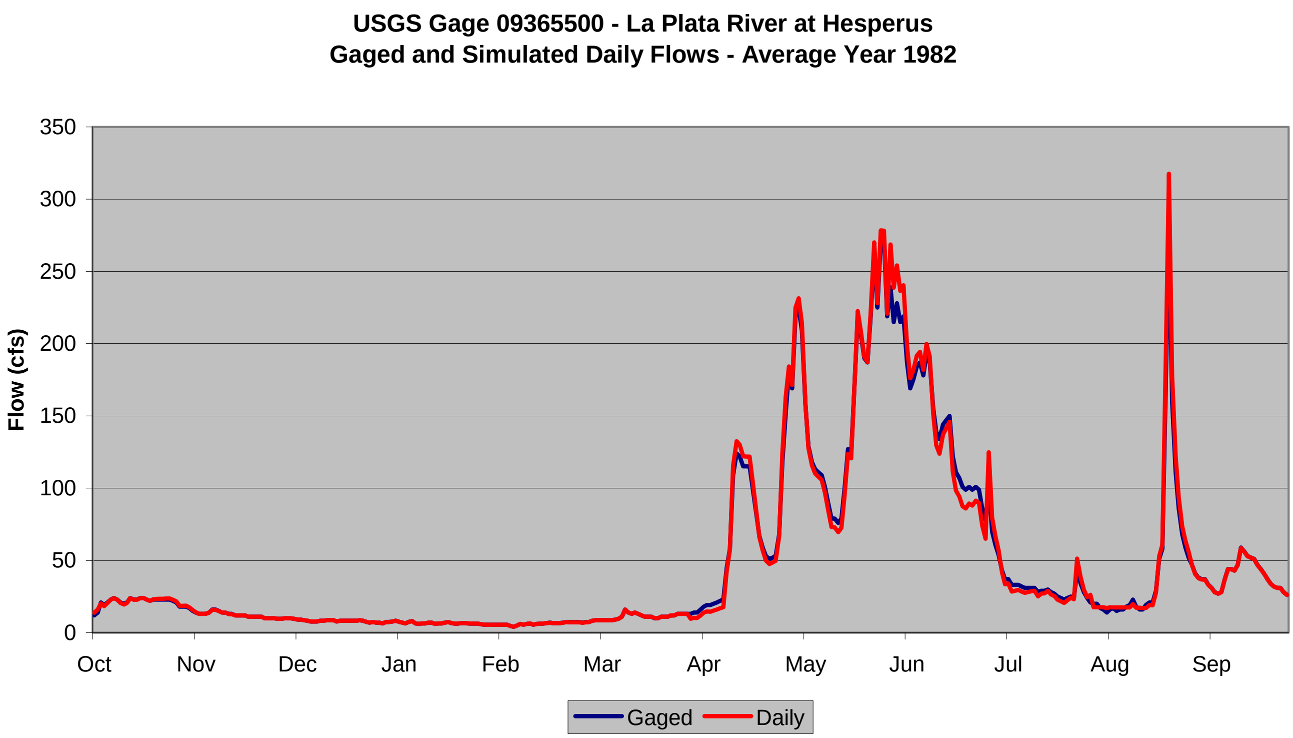


Figure E.21 Historical Daily Comparison, Average Year – La Plata River at Hesperus

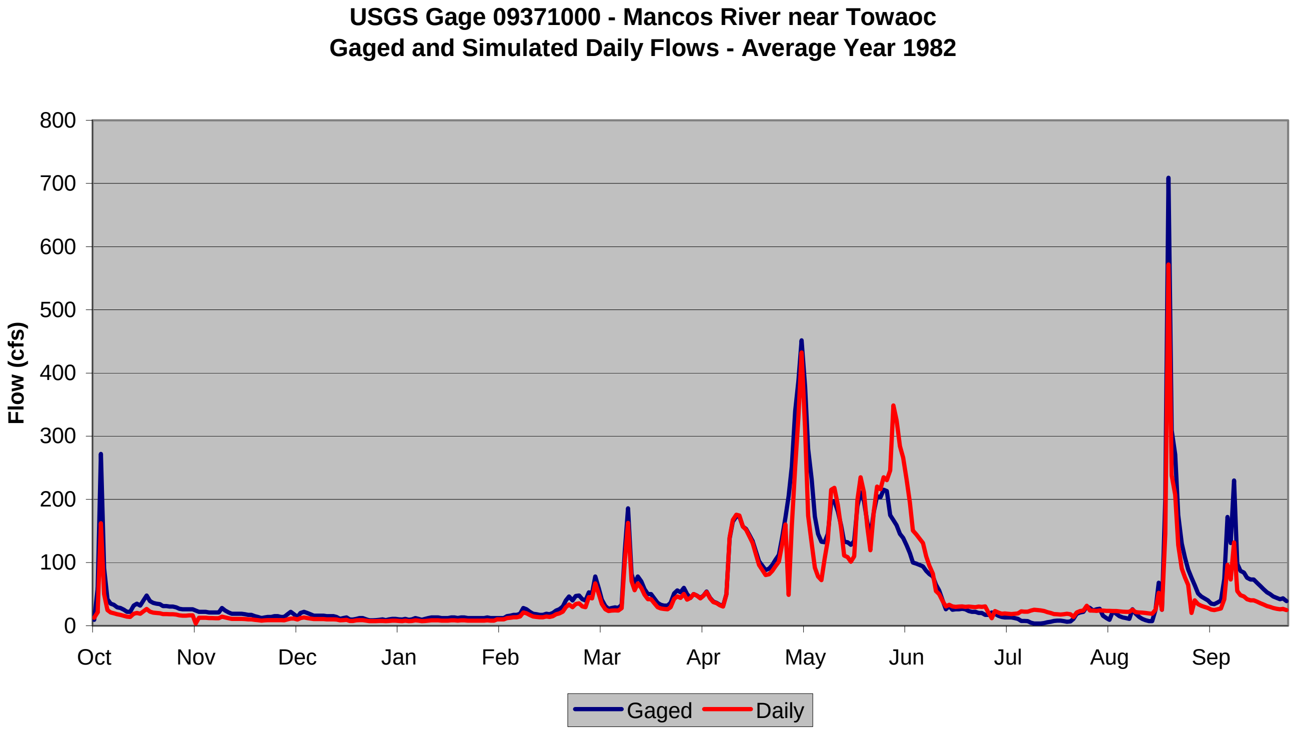


Figure E.22 Historical Daily Comparison, Average Year – Mancos River near Towaoc

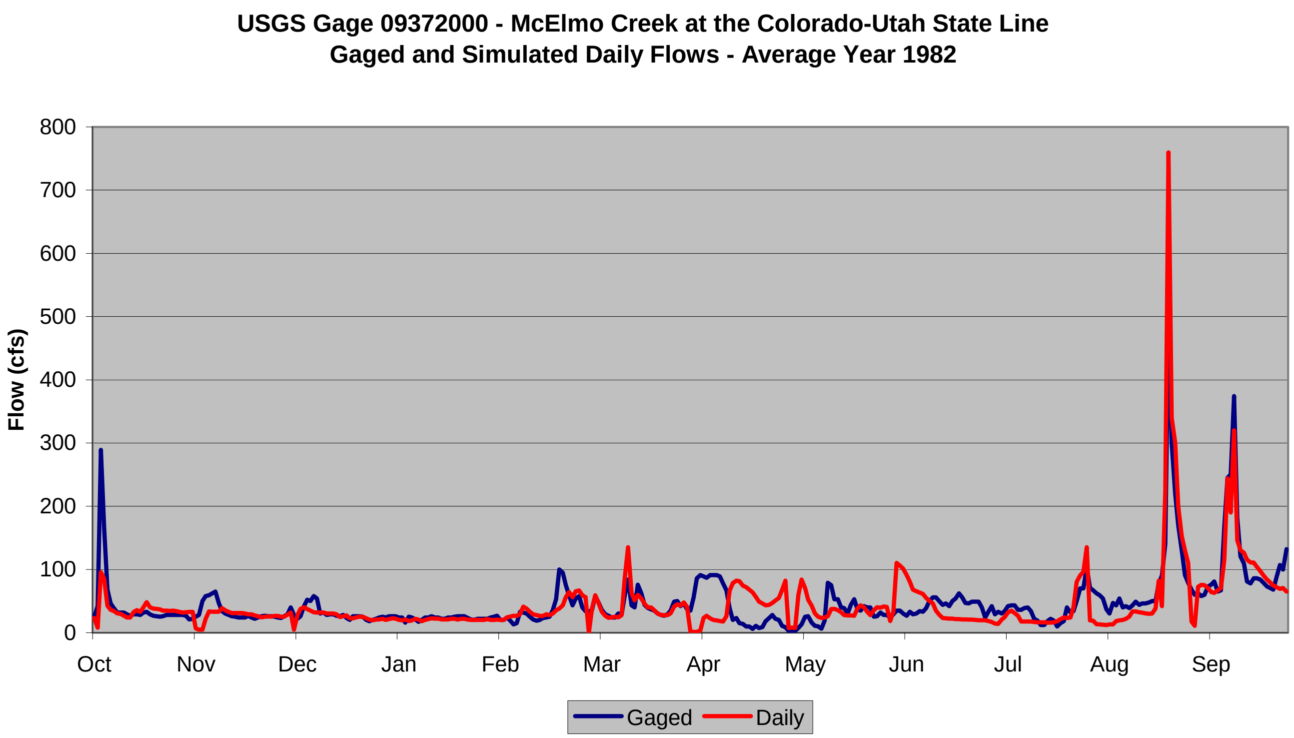


Figure E.23 Historical Daily Comparison, Average Year – McElmo Creek at CO-UT State Line

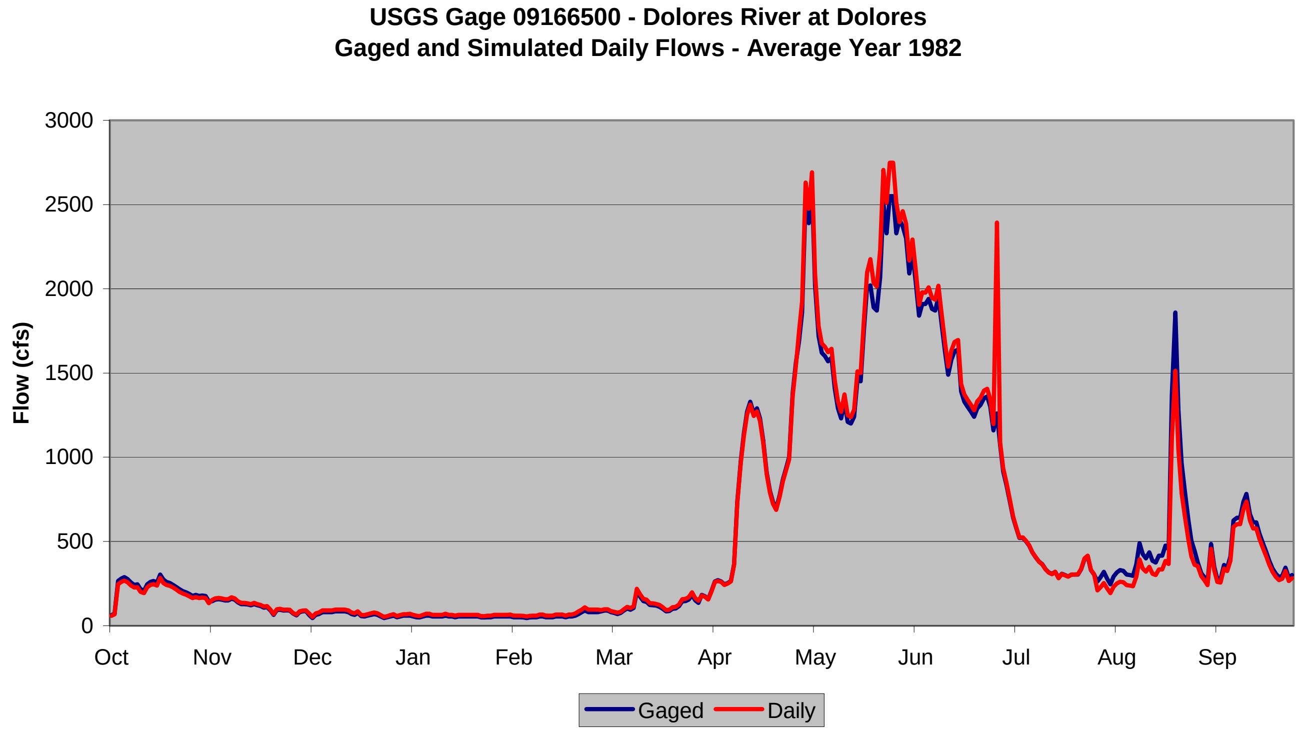


Figure E.24 Historical Daily Comparison, Average Year – Dolores River at Dolores

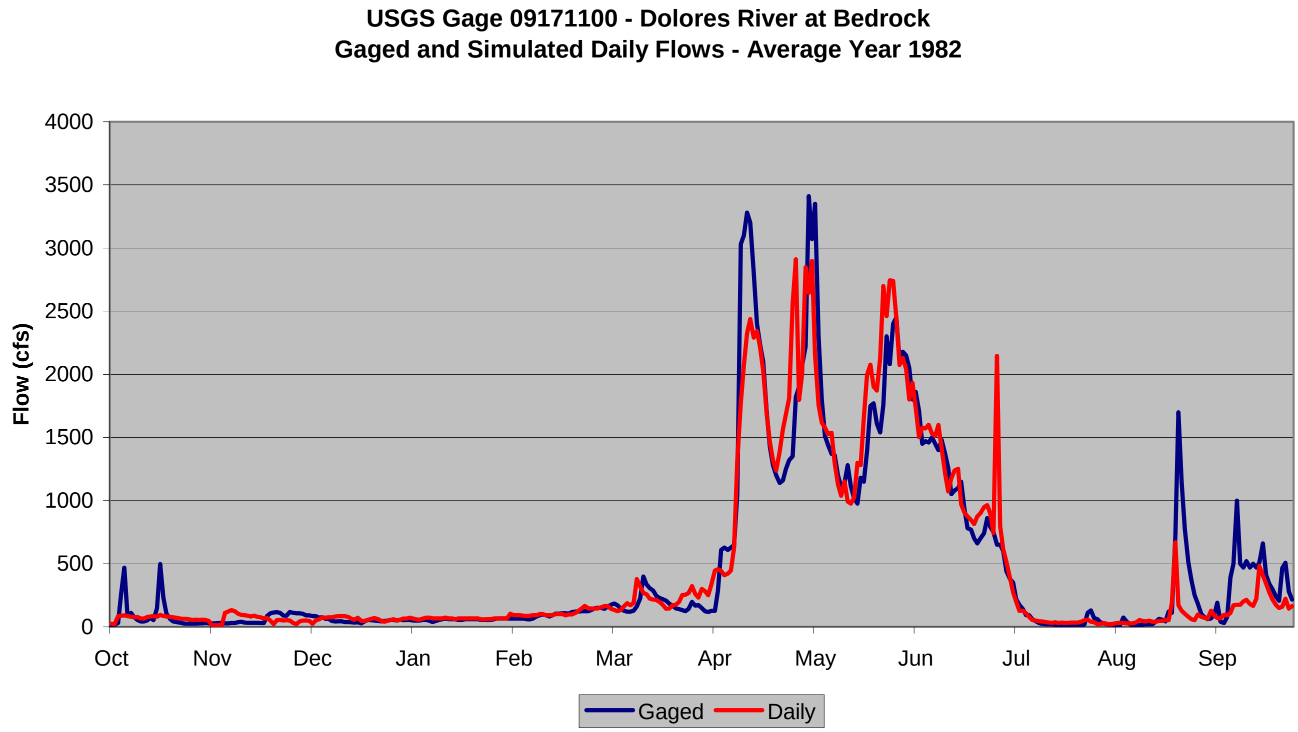


Figure E.25 Historical Daily Comparison, Average Year – Dolores River at Bedrock

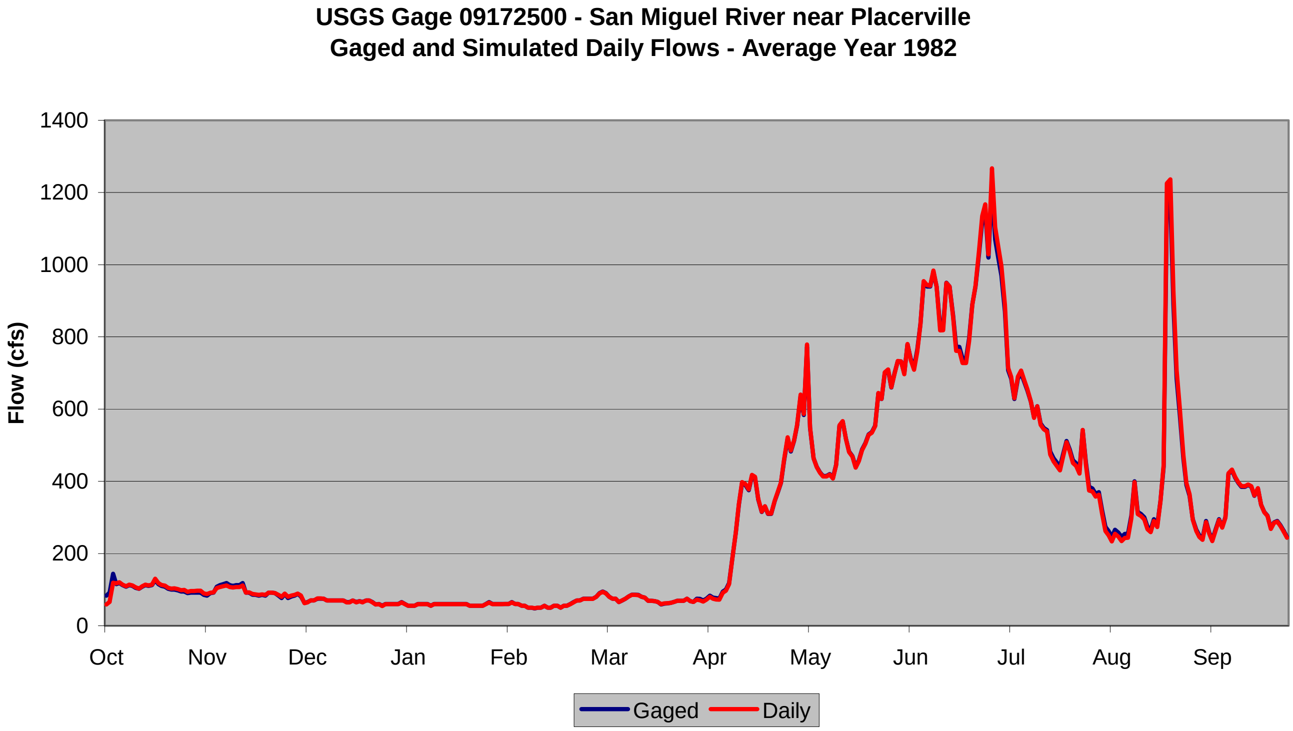


Figure E.26 Historical Daily Comparison, Average Year – San Miguel River near Placerville

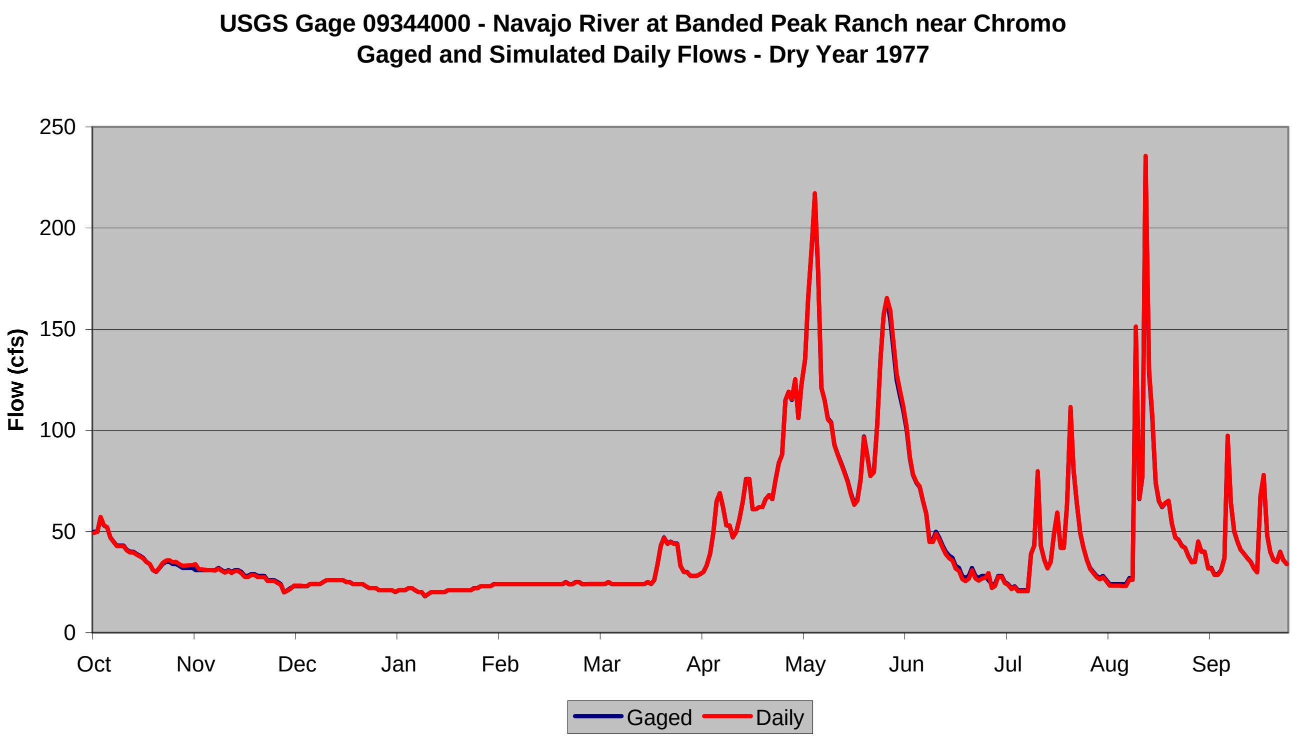


Figure E.27 Historical Daily Comparison, Dry Year – Navajo River at Banded Peak Ranch

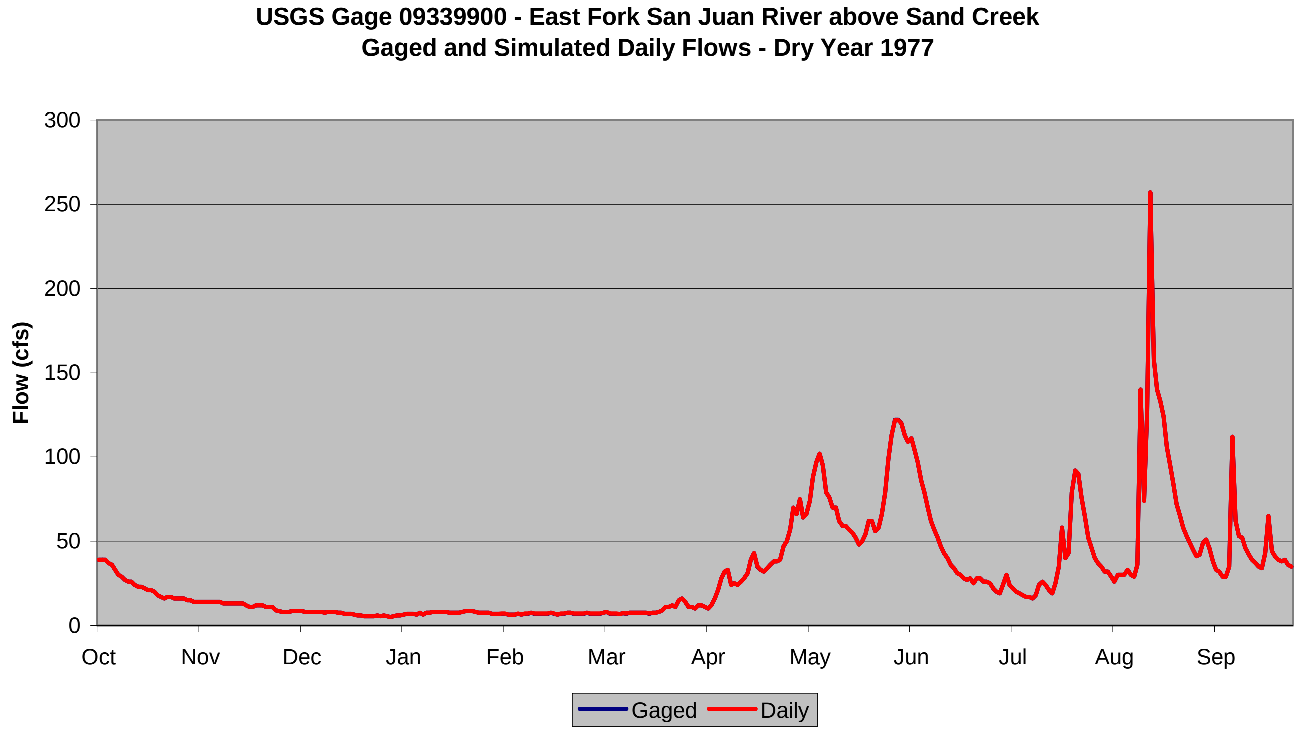


Figure E.28 Historical Daily Comparison, Dry Year – East Fork San Juan River above Sand Creek

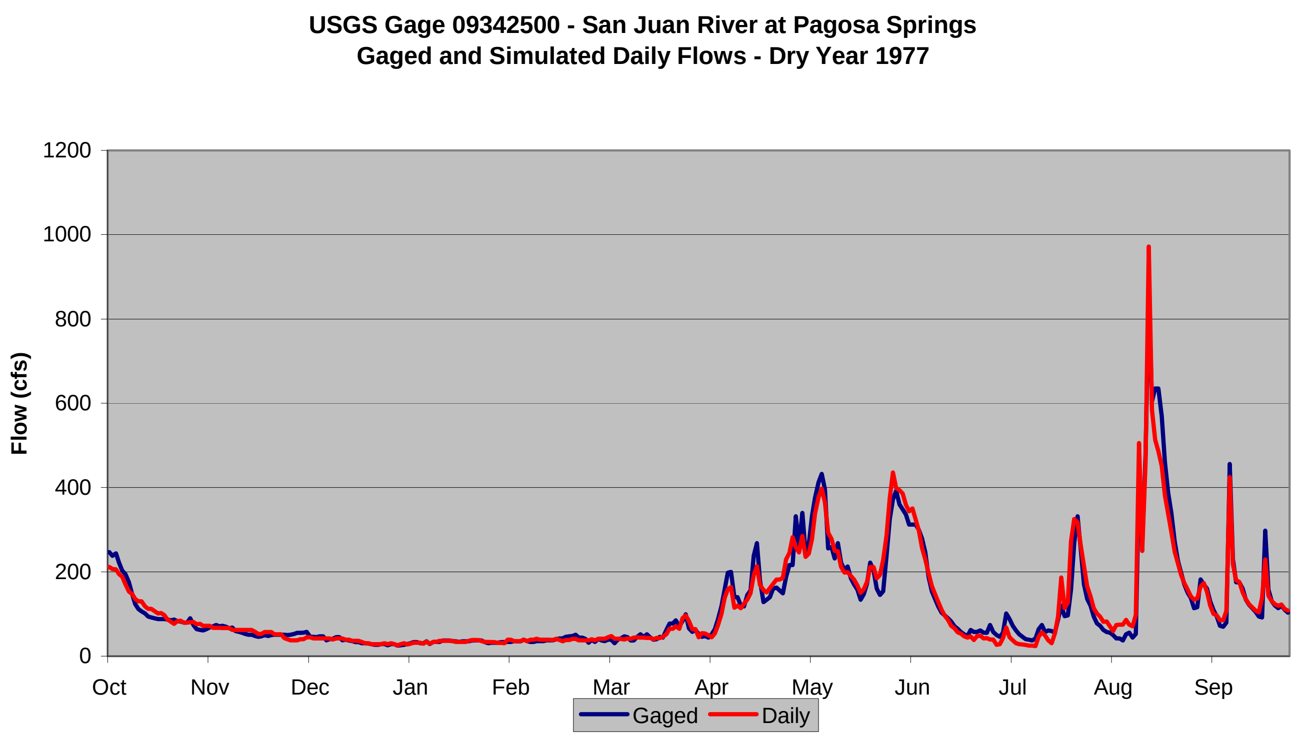


Figure E.29 Historical Daily Comparison, Dry Year – San Juan River at Pagosa Springs

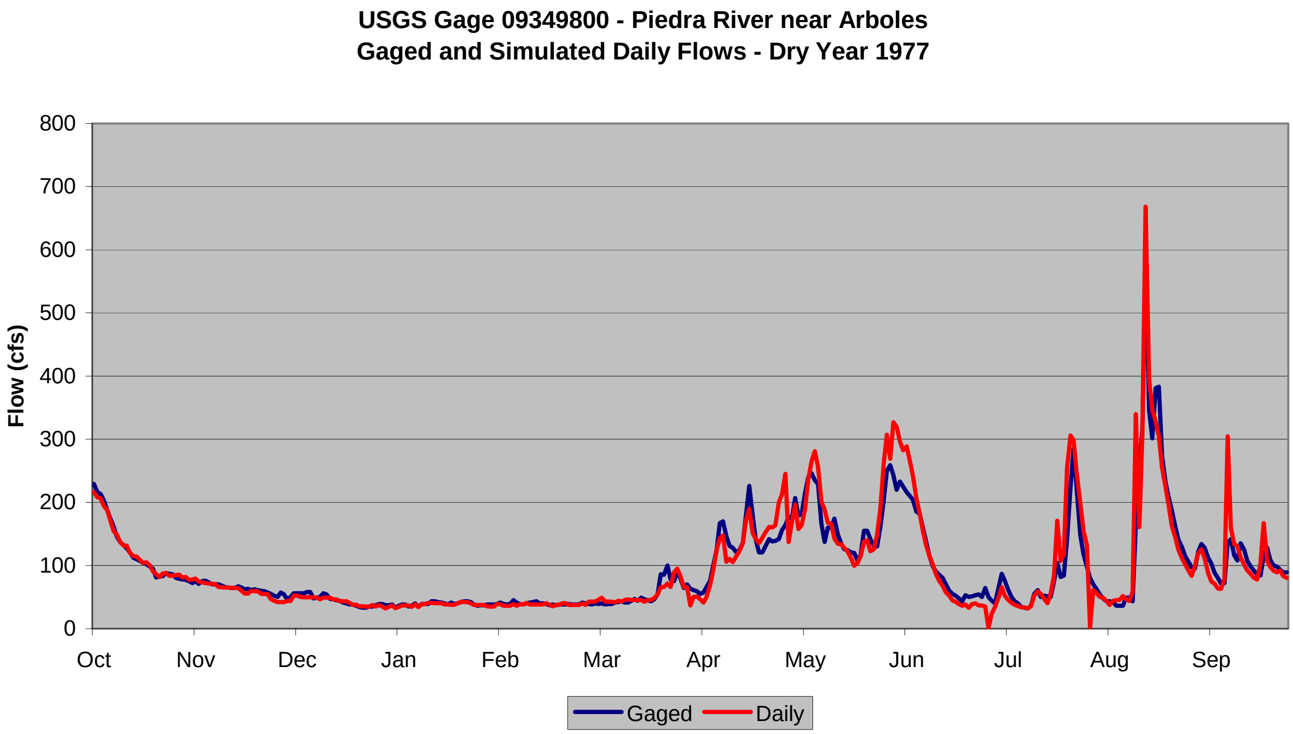


Figure E.30 Historical Daily Comparison, Dry Year – Piedra River near Arboles

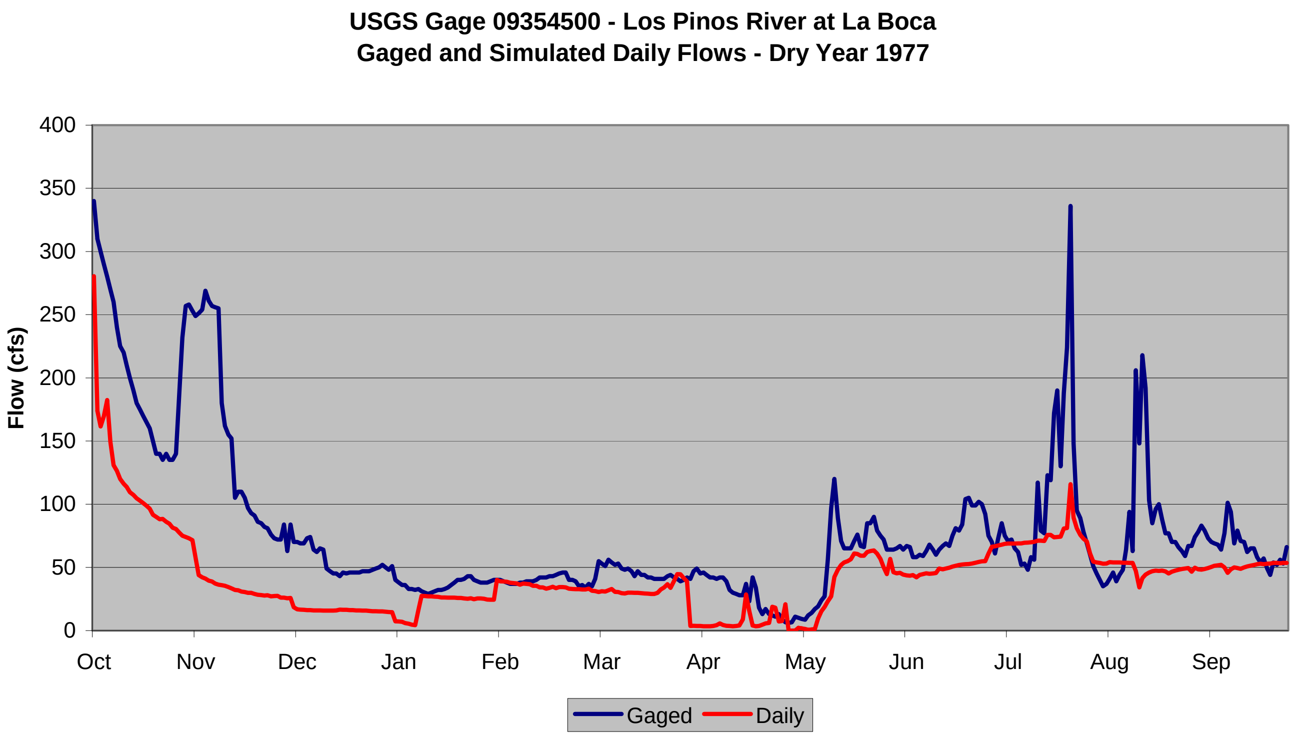


Figure E.31 Historical Daily Comparison, Dry Year – Los Pinos River at La Boca

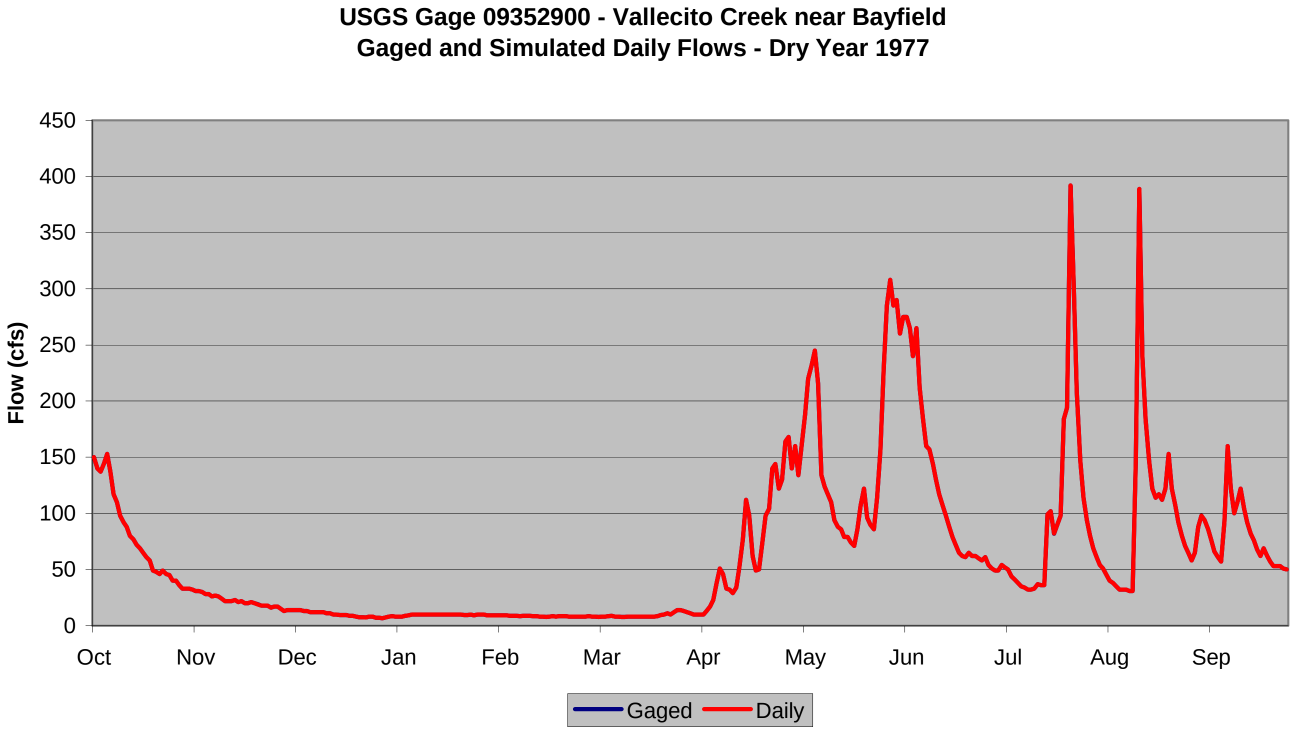


Figure E.32 Historical Daily Comparison, Dry Year – Vallecito Creek near Bayfield

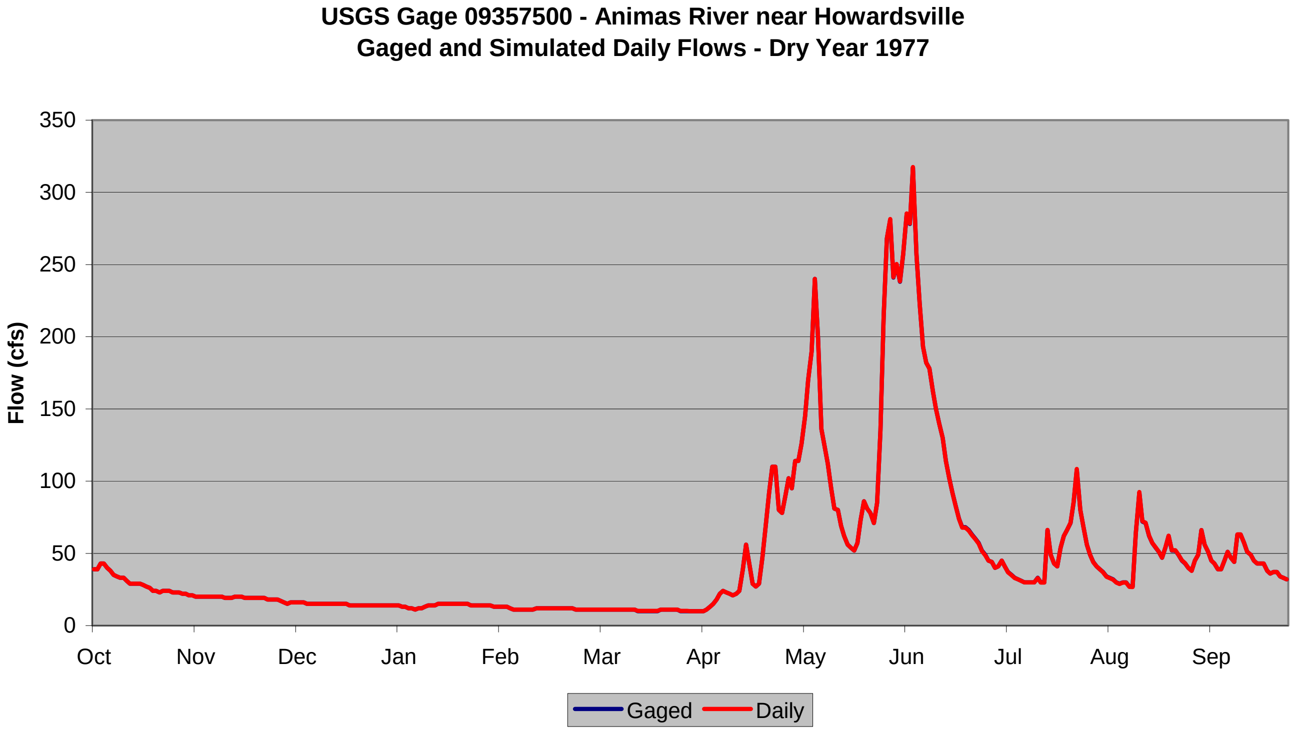


Figure E.33 Historical Daily Comparison, Dry Year – Animas River near Howardsville

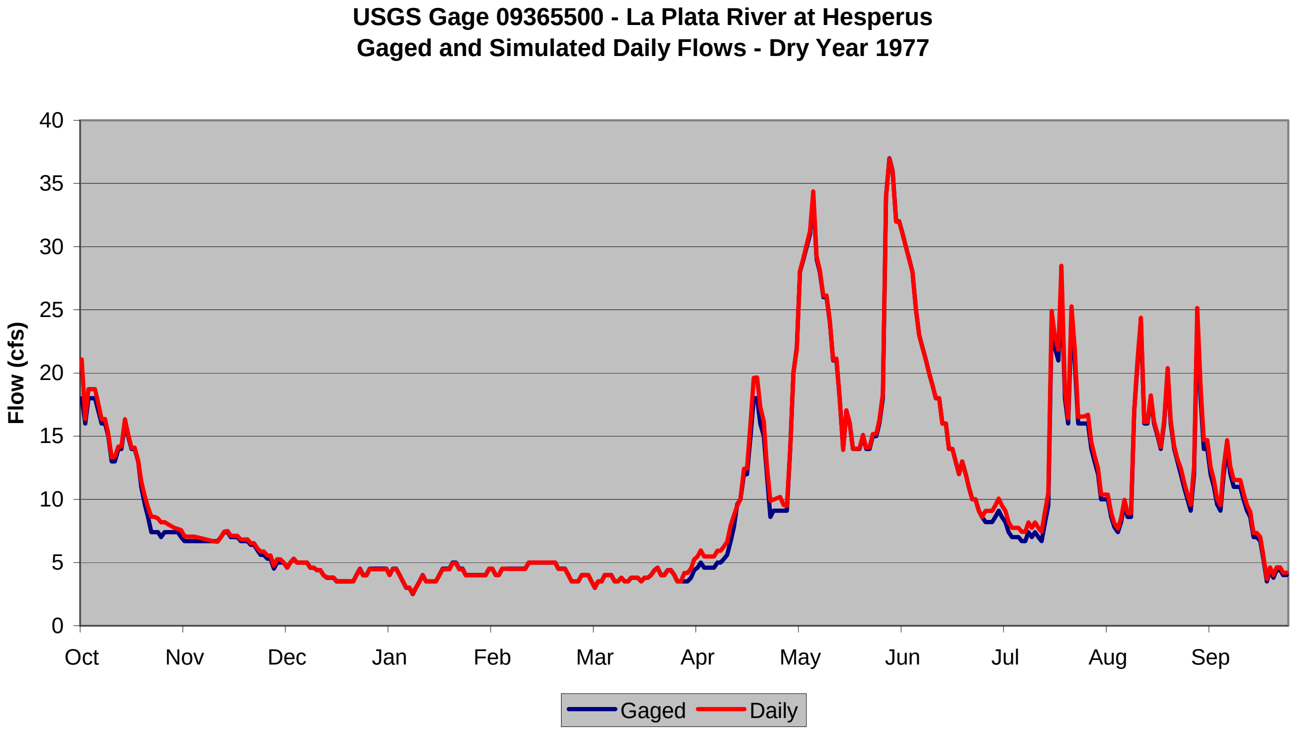


Figure E.34 Historical Daily Comparison, Dry Year – La Plata River at Hesperus

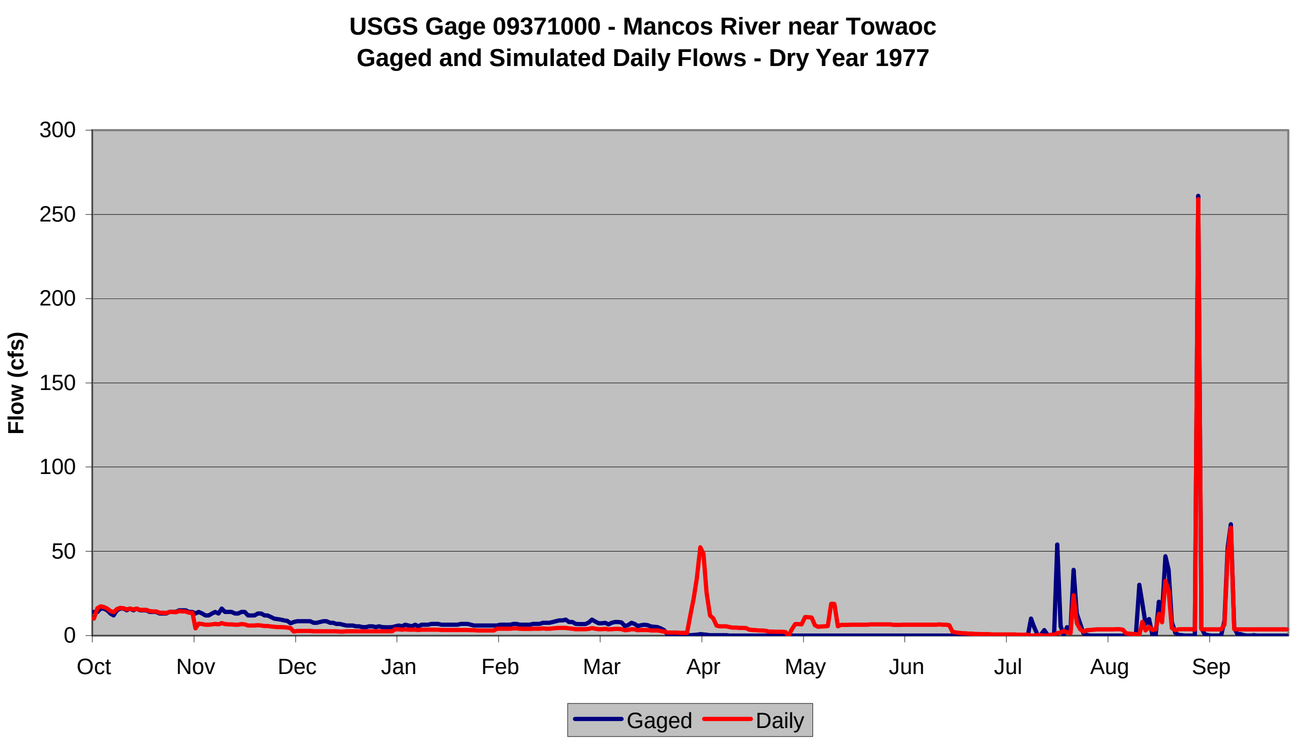


Figure E.35 Historical Daily Comparison, Dry Year – Mancos River near Towaoc

USGS Gage 09372000 - McElmo Creek at the Colorado-Utah State Line
Gaged and Simulated Daily Flows - Dry Year 1977

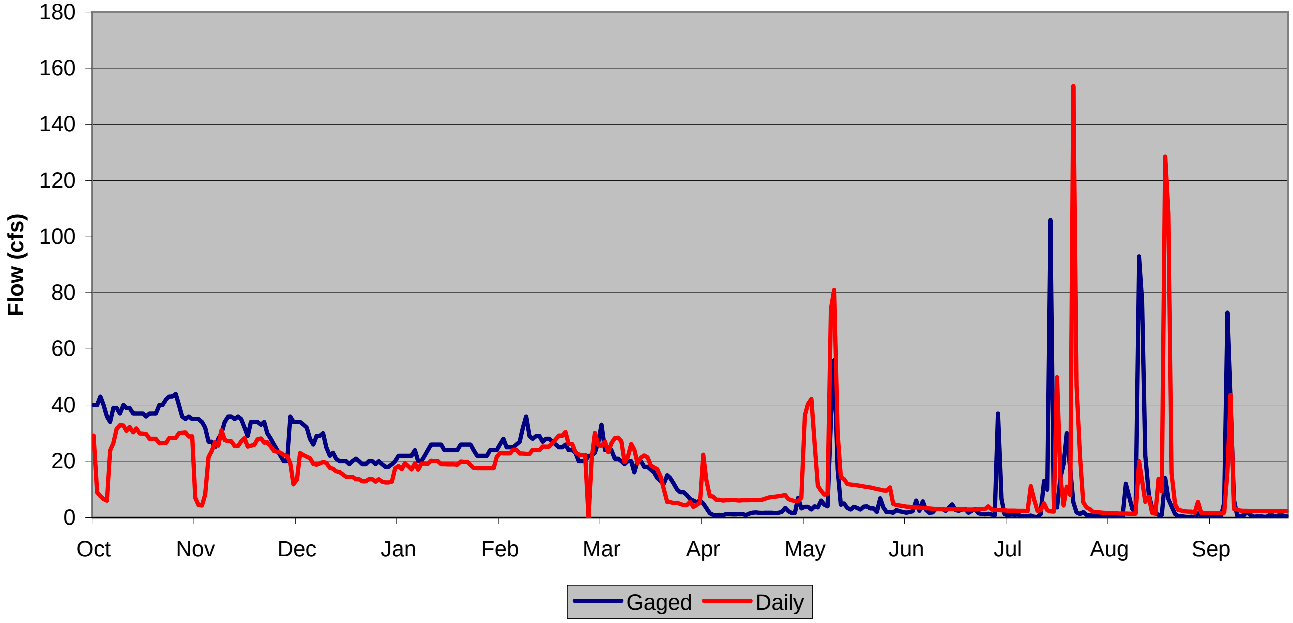


Figure E.36 Historical Daily Comparison, Dry Year – McElmo Creek at CO/UT State Line

USGS Gage 09166500 - Dolores River at Dolores
Gaged and Simulated Daily Flows - Dry Year 1977

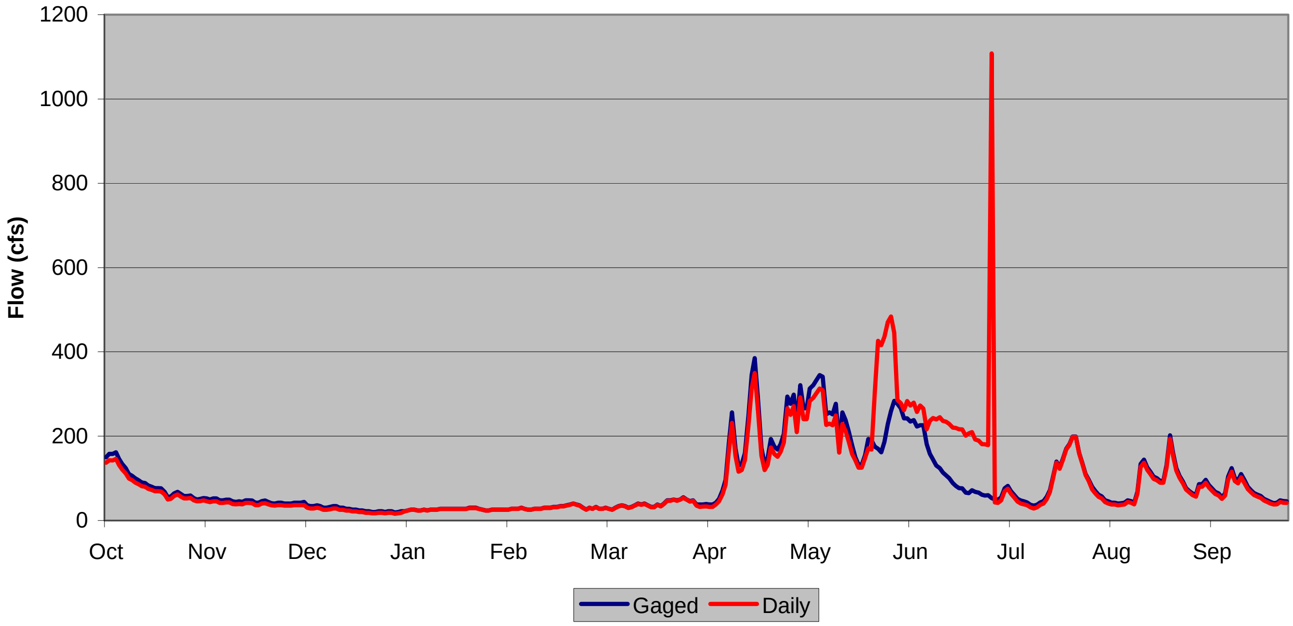


Figure E.37 Historical Daily Comparison, Dry Year – Dolores River at Dolores

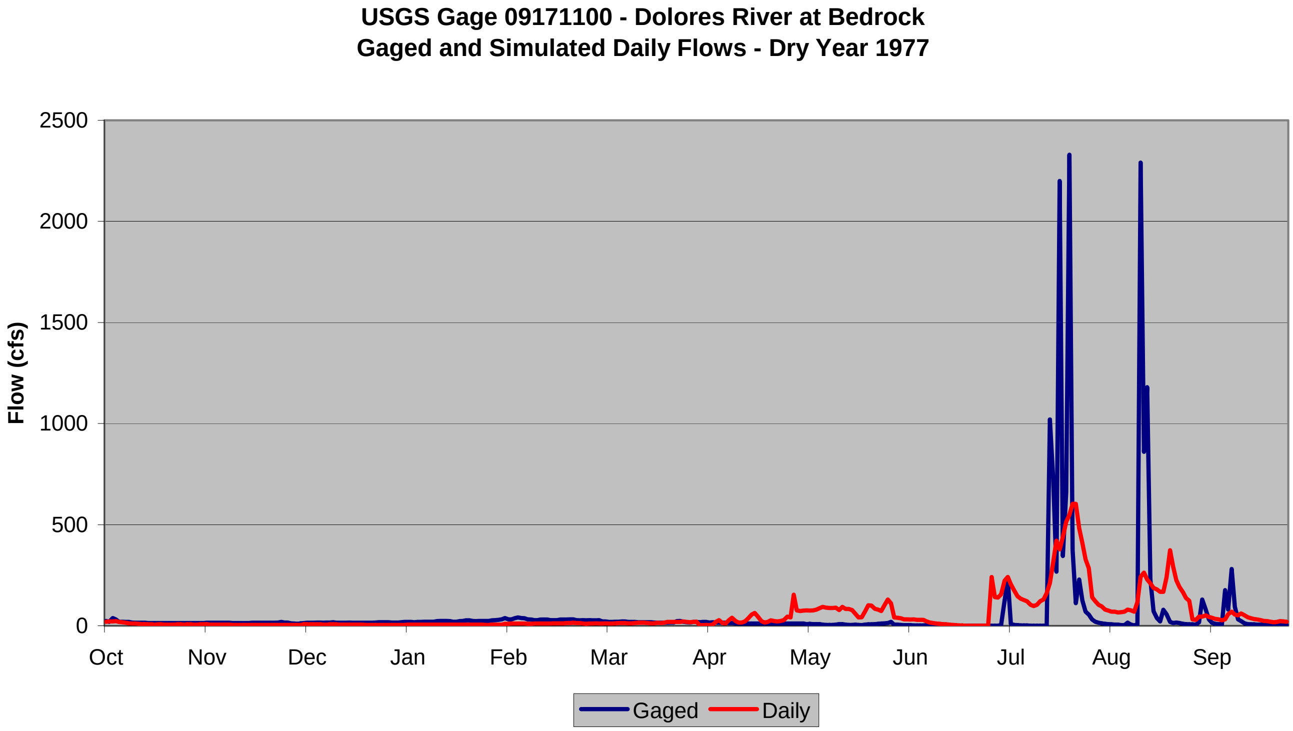


Figure E.38 Historical Daily Comparison, Dry Year – Dolores River at Bedrock

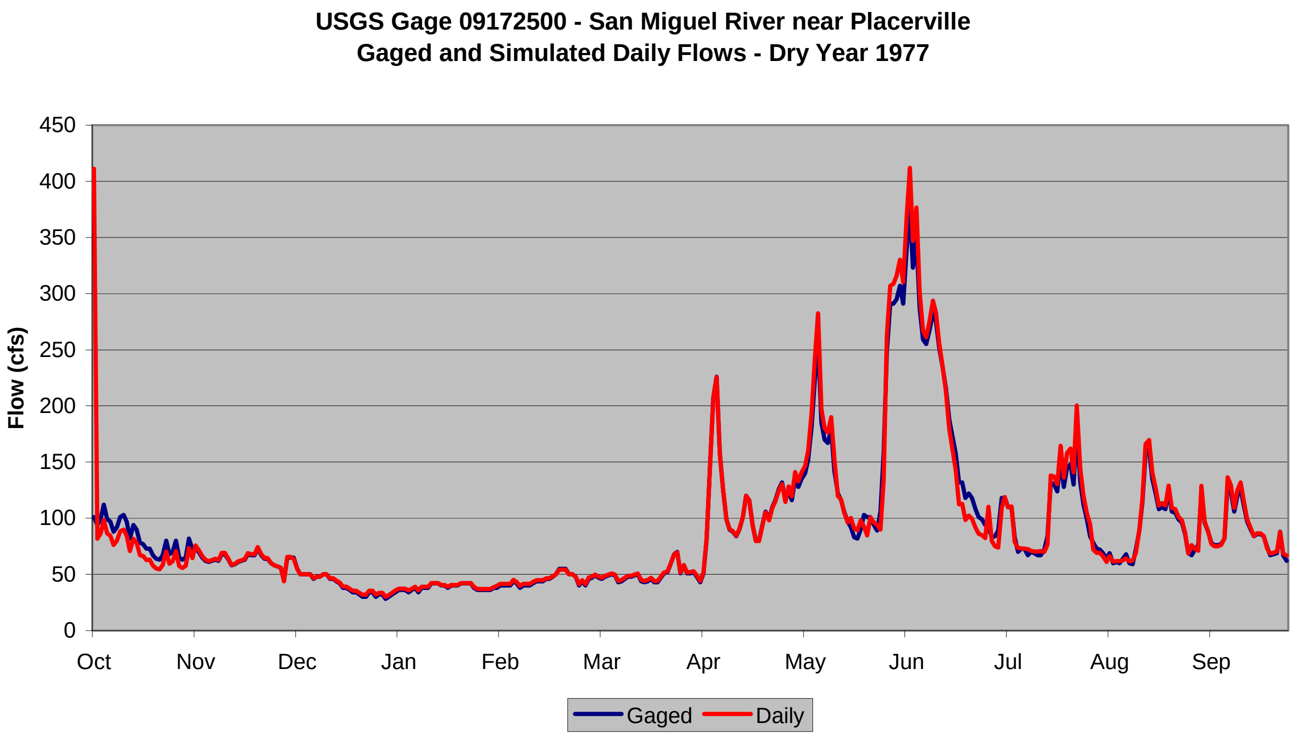


Figure E.39 Historical Daily Comparison, Dry Year – San Miguel near Placerville

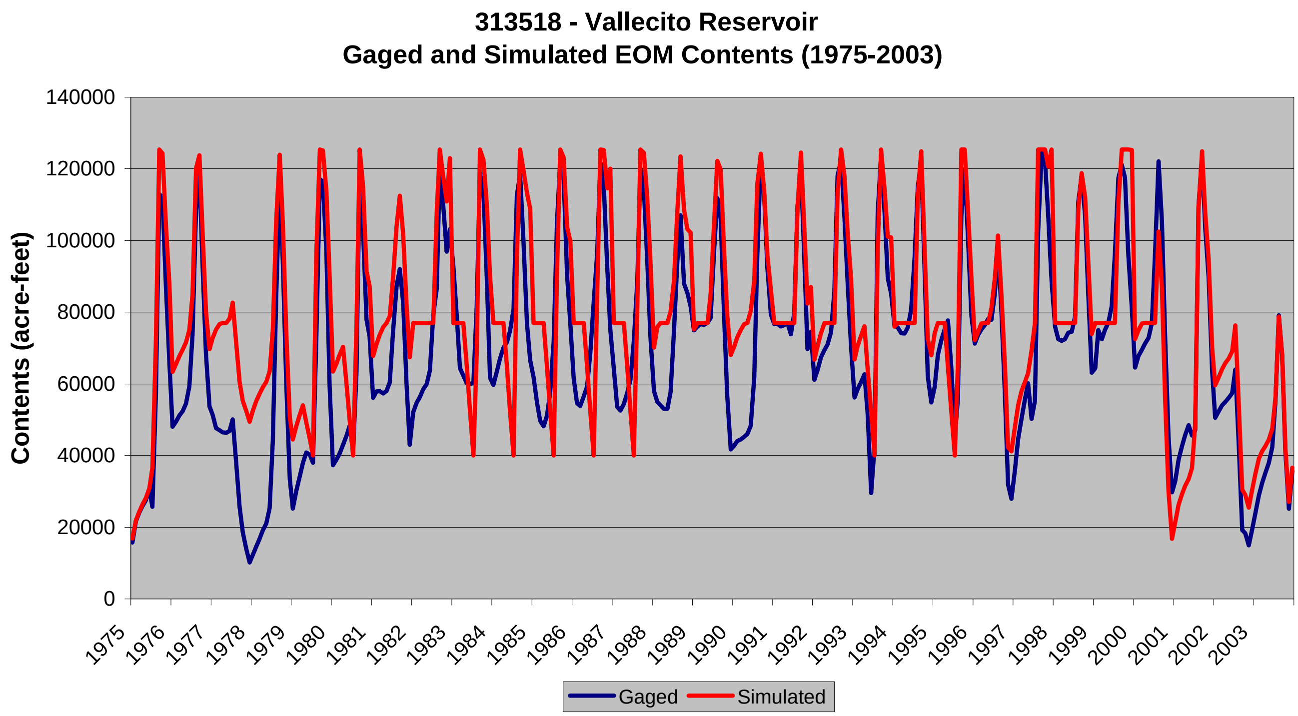


Figure E.40 Historical Daily Reservoir Simulation – Vallecito Reservoir

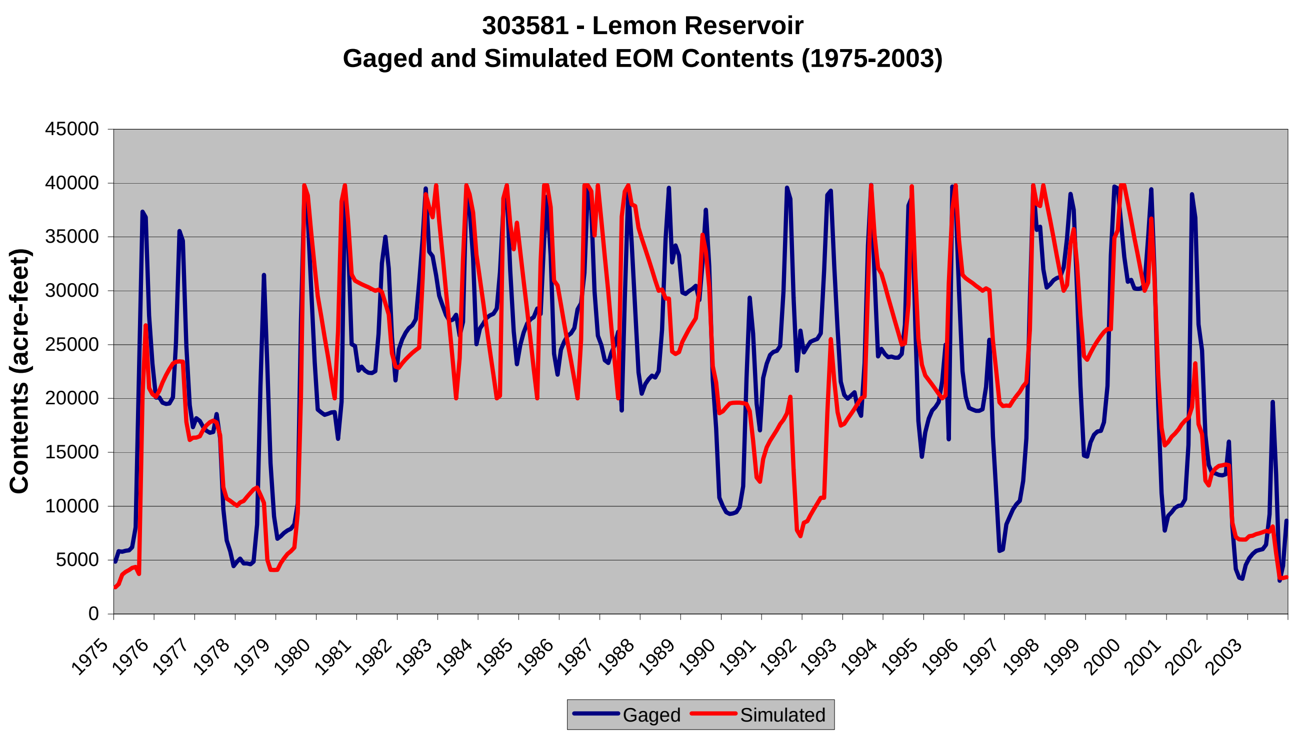


Figure E.41 Historical Daily Reservoir Simulation – Lemon Reservoir

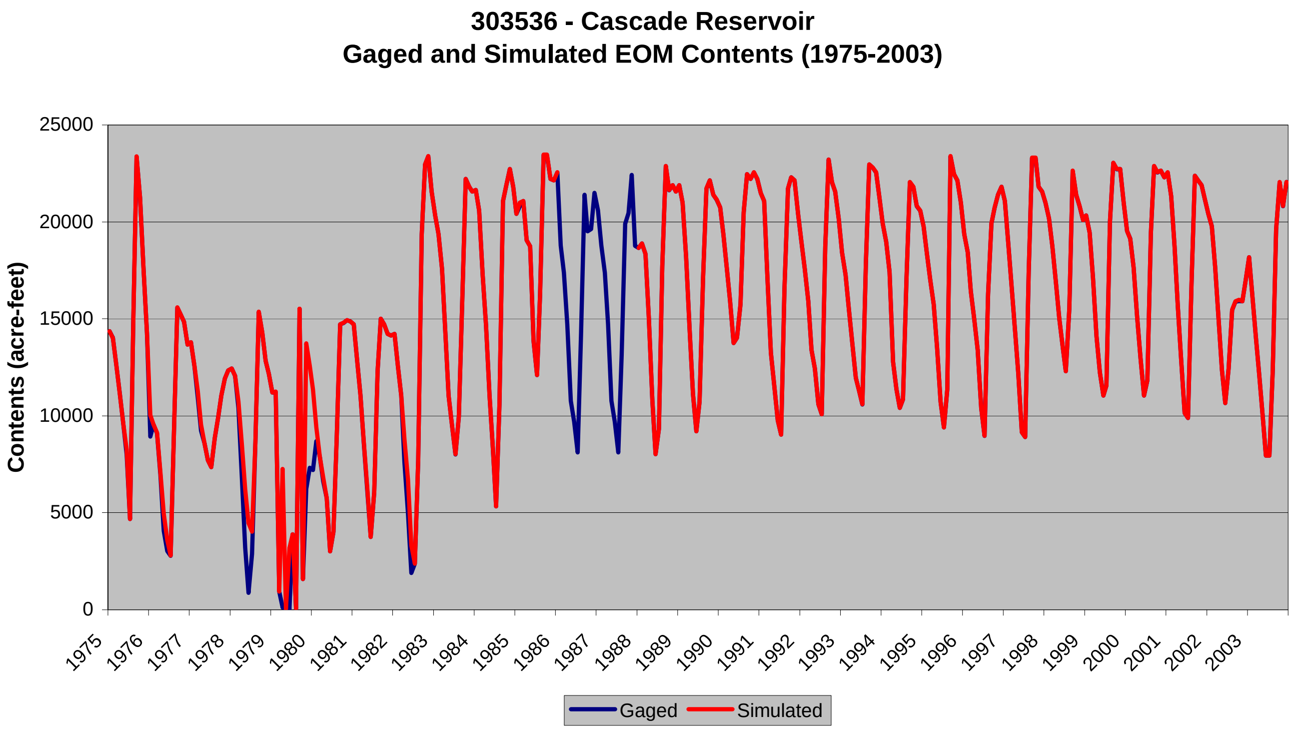


Figure E.42 Historical Daily Reservoir Simulation – Cascade Reservoir

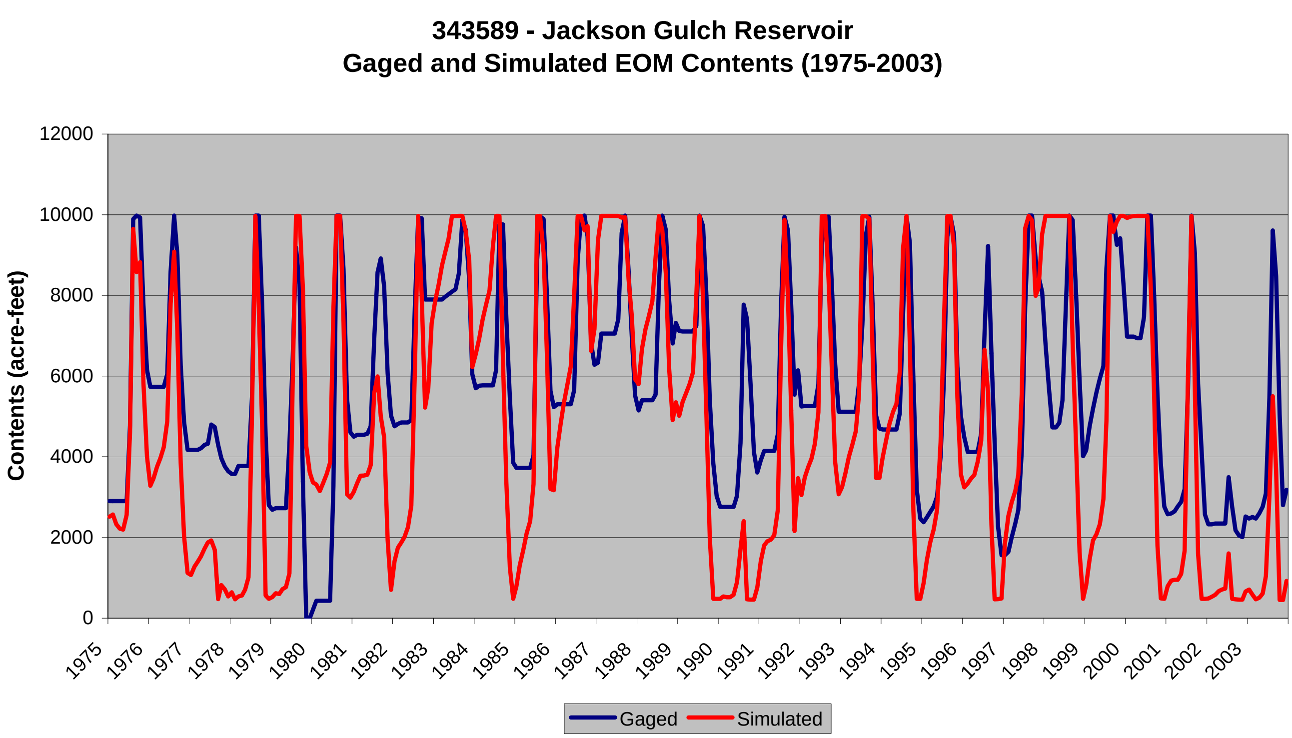


Figure E.43 Historical Daily Reservoir Simulation – Jackson Gulch Reservoir

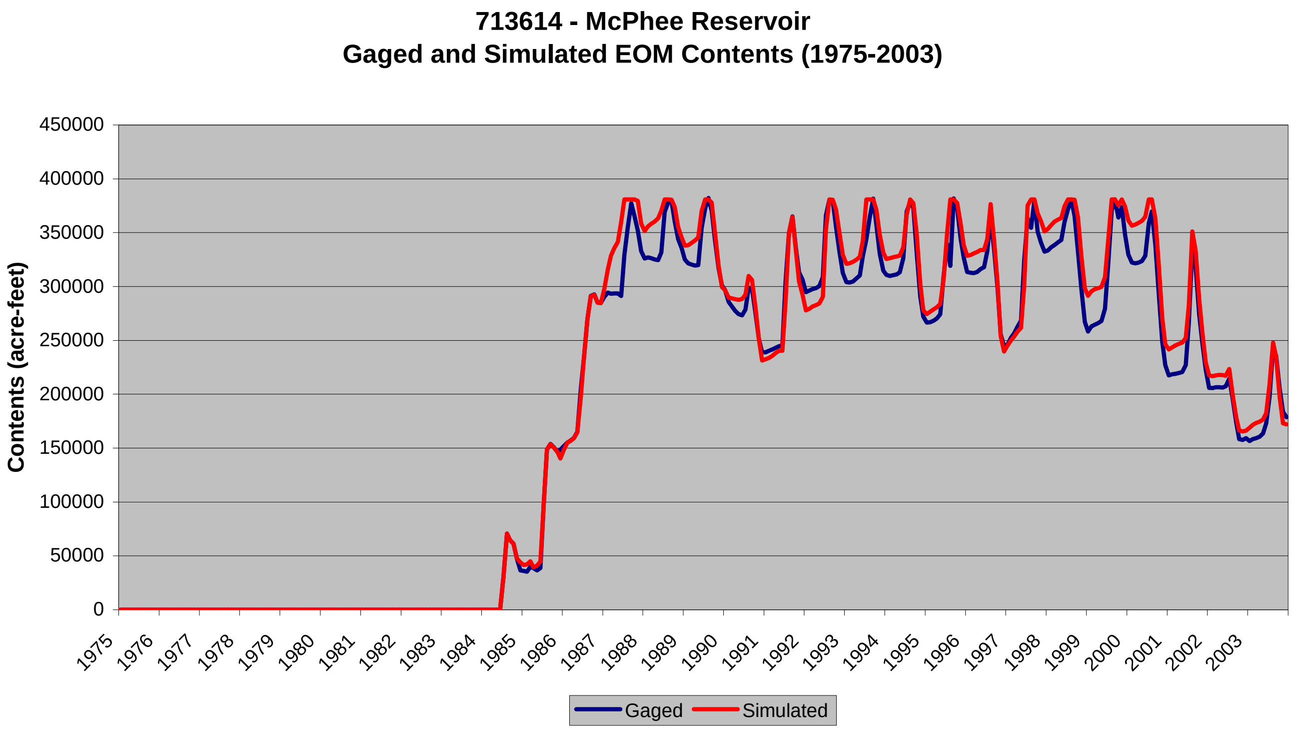


Figure E.44 Historical Daily Reservoir Simulation – McPhee Reservoir

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.

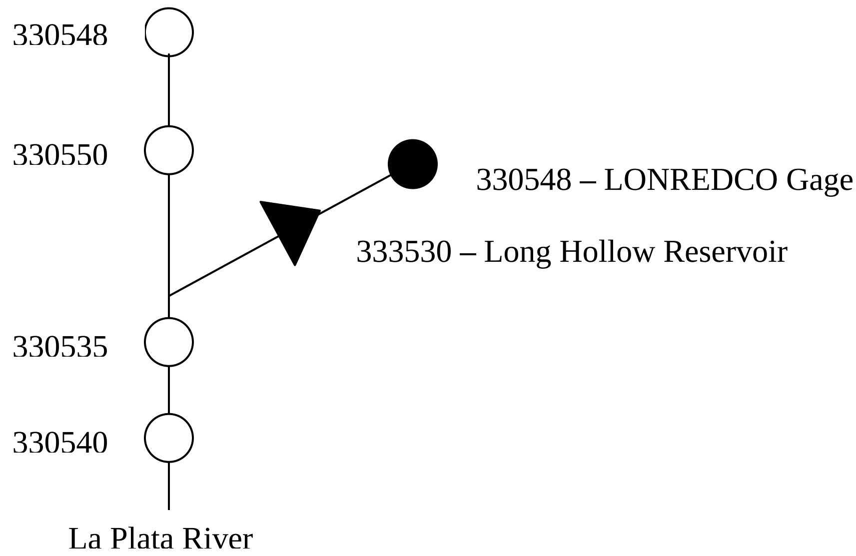
Wright Water Engineers, Inc. (WWE) conducted an engineering investigation into the proposed reservoir and provided information used in the modeling efforts. Information was obtained from the WWE report "Operation Plan for the Proposed Long Hollow Reservoir – Preliminary Draft for Discussion Purposes 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.

<u>Physical Information</u> – 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.



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 %

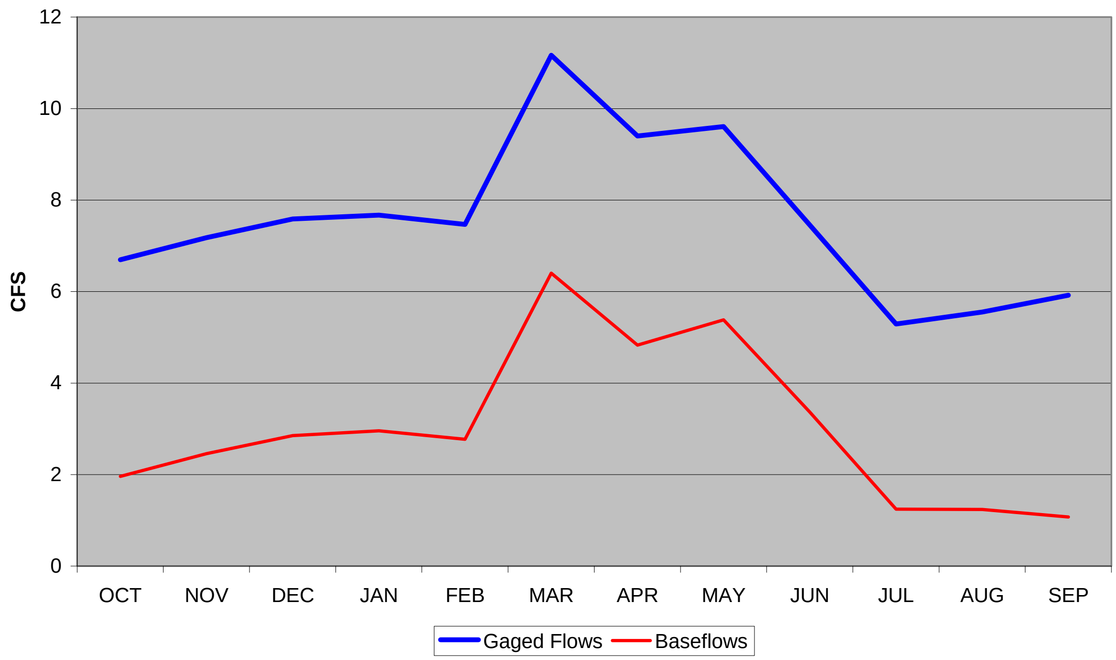
Table 3 shows the return flow pattern used in the model. As with other diversions in the basin, 6 percent of unused water is estimated to be lost from the system due to evaporation and native vegetative use, therefore the return flow delay pattern adds up to 94 percent. Note that the pattern reflects 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



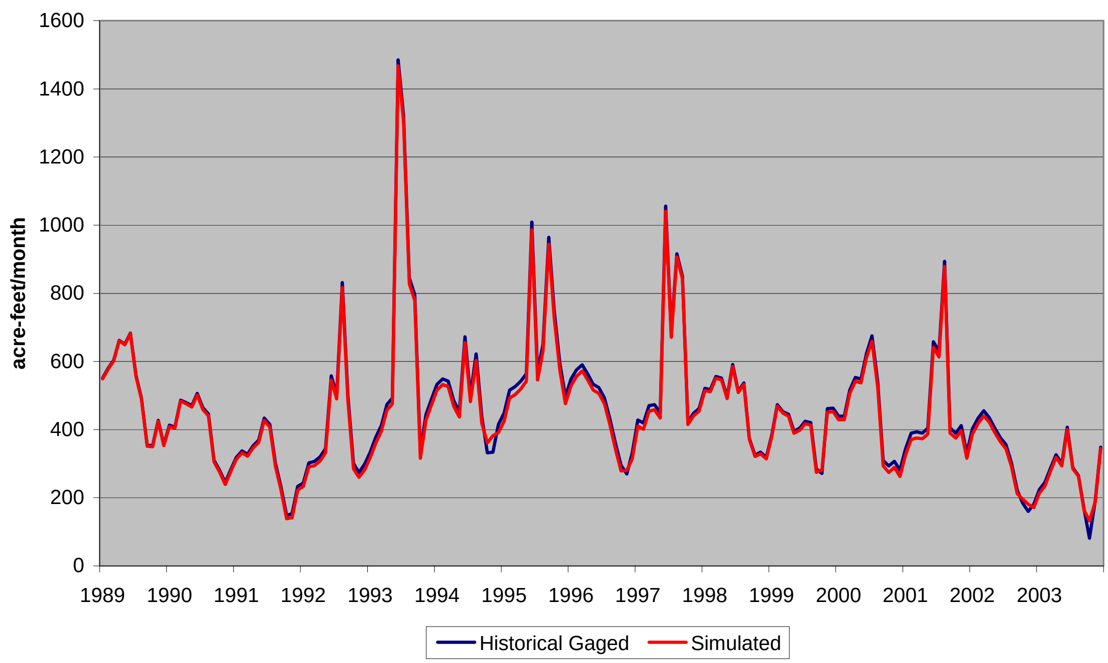
<u>Reservoir Operations</u> – The purpose of Long Hollow Reservoir is to help Colorado meet their La Plata River Compact requirements, thus reducing irrigation restrictions in Colorado and providing more flow for diversions in New Mexico. The La Plata Compact requires defined stateline flows to be met 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



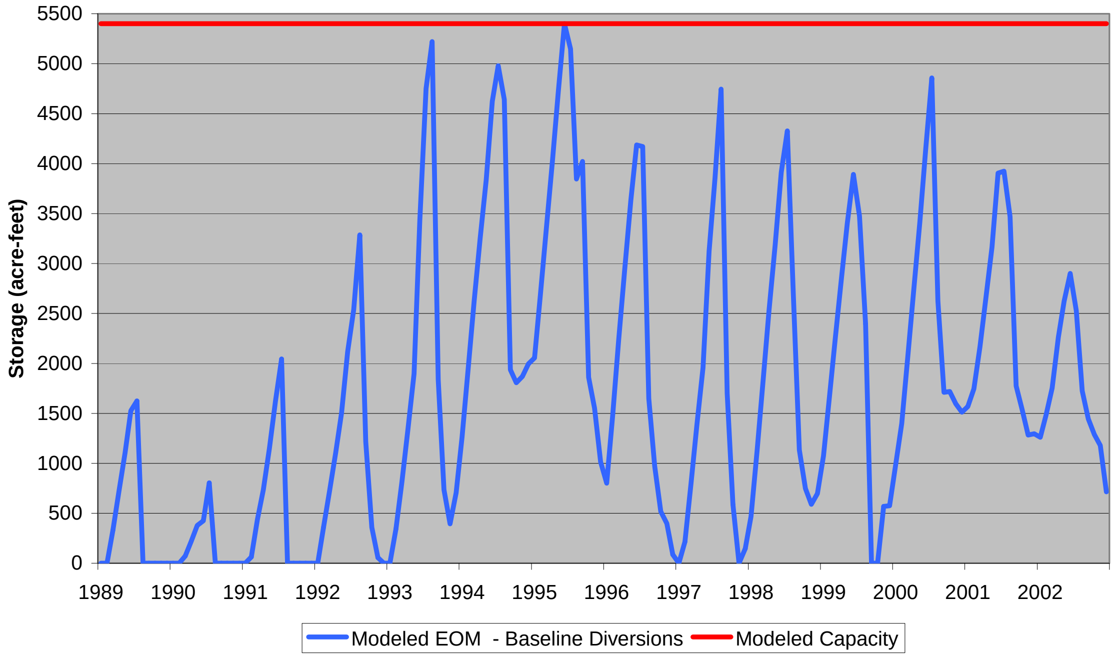
Baseline Irrigation Diversions – Baseline demands represent irrigation water requirements and current irrigated acreage. Because ditches diverting from the La Plata River are generally shorted during the irrigation season, baseline demands are greater than historical diversions for every year. For structures 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.

<u>Compact Deliveries</u> – 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.