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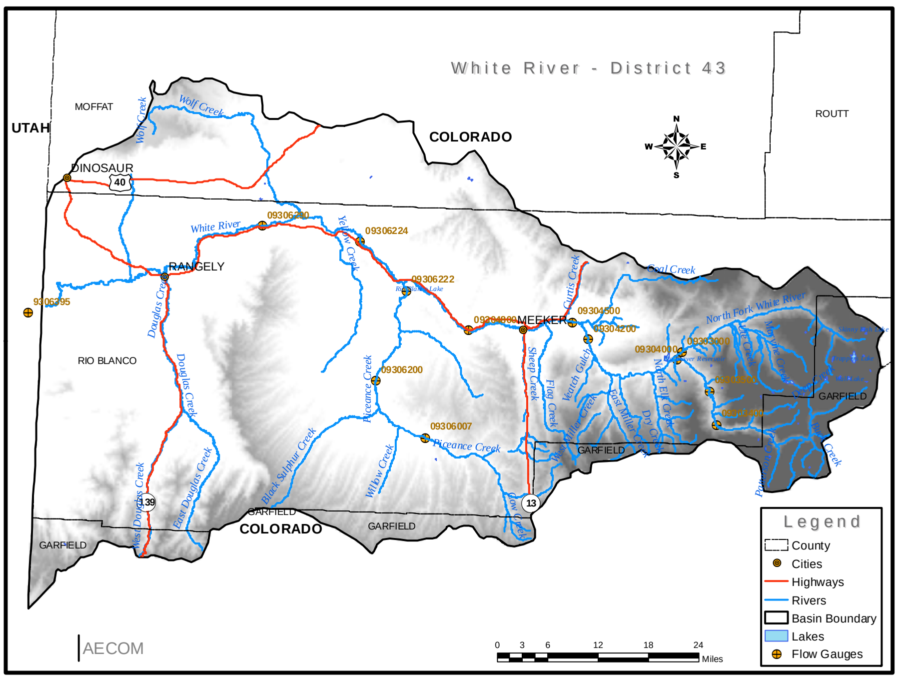
White River Basin
Water Resources Planning Model
User's Manual



October 2009

COLORADO'S DECISION SUPPORT SYSTEMS

COLORADO WATER CONSERVATION BOARD · STATE OF COLORADO · 1876 · 1937

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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 White River Basin Water Resources Planning Model (White River 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 White River 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 White River model was developed as a tool for investigators and decision makers to test impacts and efficacy of proposed structures, operations, or management strategies under complex administrative constraints and highly variable physical water supply. The Baseline data set can serve as the starting point for such analysis, demonstrating condition of the stream absent the proposed change but including current conditions. It is presumed that users will compare the Baseline simulation results to results from a model to which they have added the proposed features, to determine their performance and effects.

1.2 Development of the White River Basin Water Resources Planning Model

The White River model was developed in steps that spanned 1994 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.

One objective of the CDSS endeavor was to represent all potential consumptive use within Colorado, and estimate actual consumptive use under water supply limitations. Thus in Phase IIIa, the previously unmodeled 25 percent use was added to the model as 16 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 White basin model, recently adding the "variable efficiency" method for determining irrigation consumptive use and return flows to the model. The most recent effort also included extending the study period through 2006, and re-evaluating calibration.

1.3 Acknowledgements

CDSS is a project of the Colorado Water Conservation Board (CWCB), with support from the Colorado Division of Water Resources (DWR). The White River model has been developed and enhanced at different stages by Riverside Technology, Inc., Boyle Engineering Corporation, CWCB, and DWR staff.

2 What's In This Document

2.1 Scope of this Manual

This reference manual describes the CDSS White 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 White River development or management scenario
- Is interested in estimated conditions on the White River 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 White River 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. Limited general information is provided on the mechanics of assembling data sets using various CDSS tools.

2.2 Manual Contents

Specifically, the manual is divided into the following sections:

Section 3 White River Basin – describes the physical setting for the model, and 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 White River model, addressing an array of typical modeling issues such as:

- areal 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 White River model.

Section 5 Baseline Data Set – "Baseline data set" refers to the 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 in particular 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 Baseline simulation. It shows the state of the river as the White River 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.

Appendixes A and B – historical technical memoranda specific to the White River 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, and are available at the CDSS website (http://cdss.state.co.us).

Appendix C – compares historical measured data to the monthly "Calculated data set" simulation. The Calculated data set expands on the historical calibration by using irrigation demands based on crop requirements, in lieu of demands based on historical irrigation diversions.

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 White River 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 "White 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.

DMI user documentation – user documentation for **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 DMI's preprocess some of the StateMod input data. For example, **StateDMI** computes coefficients for spatially distributing baseflow gains throughout the model, and aggregates water rights for numerous small structures; **Tstool** preprocesses time series input, and displays time series results. 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 White River model user's understanding of results. Users who are modifying input files should consult Section 4 Input Description to determine how to format files. To analyze model results in detail, he or she should review Section 5 Output Description, which describes the wide variety of reports available to the user.

StateCU documentation – StateCU is the CDSS irrigation consumptive use analysis tool. It is used to generate structure-specific time series of irrigation water requirement, an input to StateMod. A model change that involves modified irrigated acreage or crop-type would require re-execution of StateCU.

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

- Phase IIIb Task Memorandum 10.1 – Data Extension Feasibility
- Phase IIIb Task Memorandum 10.2 – Evaluate Extension of Historical Data
- Phase IIIb Task Memorandum 11.5 – Characterize Streamflow Data
- Phase IIIb Task Memorandum 11.7 – Verify Diversion Estimates
- Phase IIIb Task Memorandum 11.10 – Fill Missing Baseflow data (include Mixed Station Model user instruction)
- 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
- Variable Efficiency Evaluation Task Memorandum 1.5 – Compare StateMod Variable Efficiency and Soil Moisture Accounting Calculated Model Results to Previous CDSS Model Results and Historical Measurements
- CDSS Memorandum "Colorado River Basin Representative Irrigation Return Flow Patterns"
- SPDSS Task 59.1 Memorandum – Develop Locally Calibrated Blarney-Griddle Crop Coefficients

3 The White River Basin

The White River basin lies between the Colorado River and Yampa River basins, in northwest Colorado. The White River is tributary to the Green River, but does not reach the Green until it has traveled into Utah. The basin within Colorado is approximately 3,750 square miles, and encompasses nearly all of Rio Blanco County as well as the southwestern fringe of Moffat County to the north, and portions of Garfield County to the south and east. **Figure 1** is a map of the basin.

3.1 Physical Geography

The North and South Forks of the White River both begin in the highlands of the Flat Tops formation at about 11,000 feet. They flow generally west, meeting near Buford shortly outside the White River National Forest. The Flat Tops are a remnant of the White River Uplift, formed over 50 million years ago, and glaciated during the Pleistocene and possibly early Holocene. As a result, the landscape in the upper White River is characterized by many glacial lakes and U-shaped valleys. The uplift is bounded on the west by the Grand Hogback, a north-south trending, nearly vertical upturn of Mesa Verde sandstones and shales. This feature forms the east boundary of the Piceance Creek basin, a major tributary of the White River that drains the Roan Plateau to the south, flowing north and entering the White River between Meeker and Rangely. At Rangely, the White River is on the edge of the Colorado Plateau physiographic province. Here the terrain is typical of that province, with impressive mesas, cliffs, and rims. The White River enters Utah about 20 miles west of Rangely.

Climate in the White River basin is similar to other western Colorado basins, varying with elevation. Average annual rainfall varies from over 40 inches in the Flat Tops to approximately 10 inches at Rangely. Temperatures vary inversely with elevation and variations in the growing season follow a similar trend. Winter brings snow and cold temperatures at the higher elevations but mild, sunny days in the west.

The various elevations in the basin define distinctive vegetation types and coverages. Lacking elevations over 12,500 feet, the White River basin has little land above treeline. At the upper, eastern end of the basin, Englemann spruce and sub-alpine fir are the dominant forest cover. Lodgepole pine, ponderosa pine, and spruce fir mingle with areas of high grasslands at slightly lower elevations. Below 9,000 feet, vegetation transitions to Gambel oak, pinion/juniper, and sagebrush-steppe communities. The western portion of the basin, at an elevation of approximately 5,500 feet, is dominated by sagebrush, grasslands, and salt desert shrublands.

Average annual streamflow in the White River at the Colorado-Utah state line is 596,000 acre-feet, based on operation of a USGS gage at the State Line from 1977 through 1985.

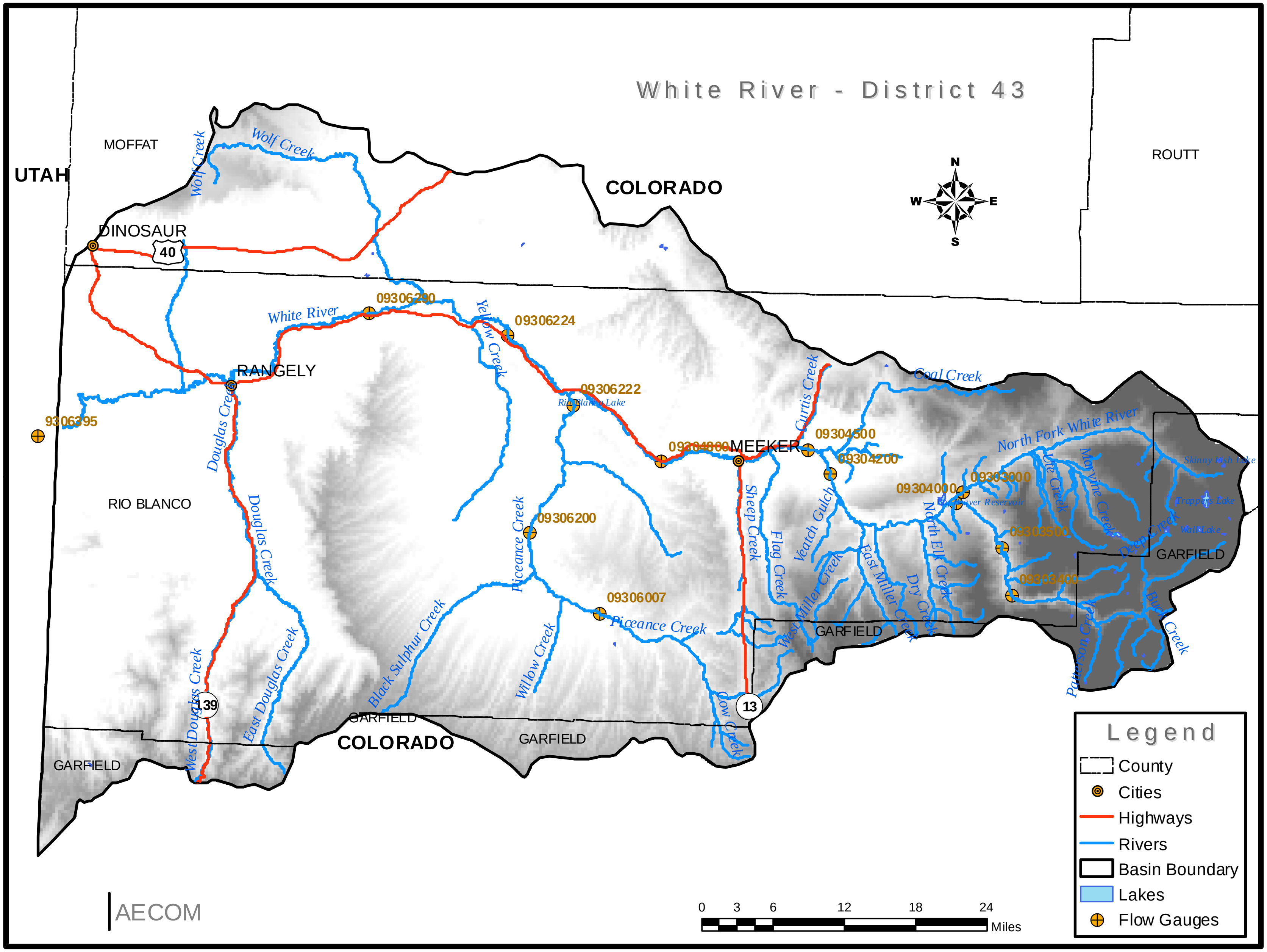
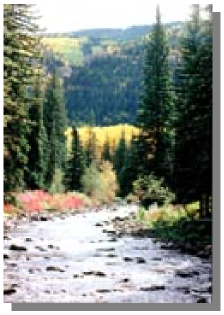


Figure 3.1 – White River Basin

Most of the runoff is attributable to snowmelt from the higher elevation areas. Sub-basins in the White River basin include Big Beaver Creek, Fawn Creek, Hahn Creek, the North, and South Forks of the White River, Piceance Creek, Yellow Creek, and Douglas Creek.

3.2 Human and Economic Factors



Trapper's Lake

Public lands, primarily federally held, comprise the majority of the White River basin. The White River National Forest, including portions of the Flattop Wilderness Area, occupies the eastern headwater area. The central and western basin is nearly all under the Bureau of Land Management; of the White River basin in Rio Blanco County, approximately 60 percent is under BLM management. Private land is located between the National Forest and the BLM holdings, more or less in the vicinity of Meeker; and in narrow bands along the White River from Powell Park, west of Meeker, to the State Line, and along Piceance Creek.

The White River basin is sparsely populated. Several sources place Rio Blanco County's population at about 6,000 in recent years. Meeker and Rangely are the only towns in the county, with populations of 2,400 and 2,200 respectively.

Farming and ranching are predominant economic activities in the eastern half of the basin. Irrigated acreage in the White River basin totals approximately 28,600 acres, of which approximately ninety percent is in pasture grass, and the remaining ten percent is in alfalfa. The greatest concentration of irrigated lands is in the river valley around Meeker. Irrigation is practiced on benches and lands adjacent to the stream, in the privately held corridors described above.

Mining and oil and gas extraction are major economic activities in the basin, particularly in the western portion. Traditional methods of extracting oil and gas have been used in the White River basin since Chevron Oil discovered the Weber Sandstone oil field there in the 1930's. The flagging economy of the day was responsible for low production there until World War II, after which Rangely became first a booming oil camp and then a town. The Roan Creek Plateau and Piceance Creek basin host some of the largest oil shale deposits and coal bed methane reservoirs known. Although oil extraction from oil shale is not practiced on a production scale, many conditional water rights have been filed in this area.

Recreational assets are abundant in the White River basin. Hunting and fishing are primary draws, as this area includes some of Colorado's best elk hunting. The Town of Meeker's website asserts that their population doubles during hunting season, and the Colorado Division of Wildlife estimated that in 1996, out-of-state hunters and anglers brought $9.7 million dollars into Rio Blanco County.

3.3 Water Resources Development

The earliest rights in White River basin are irrigation rights bearing an appropriation date of 1880, and the first general adjudication was done in 1889. Although there is some municipal and industrial use of surface water, the primary use is agricultural. Irrigation is generally practiced by individual farmers or ranchers, and there are a small number of large organized, mutual ditch or irrigation companies, compared with other basins in the state.

The towns of Meeker and Rangely draw drinking water from the White River via alluvial wells. According to the Groundwater Atlas of Colorado, about 1,000 af/yr is pumped from alluvial aquifers, primarily for municipal, domestic, and stock watering purposes.

There are no known exports of water out of the White River basin.

Reservoir storage has not been significantly developed, and in fact, there are no federal storage projects in the basin. The three largest reservoirs in the basin are:

Kenney Reservoir

- Taylor Draw Reservoir (also known as Kenney Reservoir) has a storage volume of 13,800 acre-feet and is used primarily for recreation and hydropower generation. It is located just east of Rangely, was constructed by the Colorado River Water Conservation District, and is now owned and operated by Rio Blanco Water Conservancy District.
- Lake Avery Reservoir (also known as Big Beaver Reservoir) has a storage volume of 7,658 acre-feet and is used primarily for recreation. It is owned and operated by the Colorado Division of Wildlife and is located about 20 miles east of Meeker.
- Rio Blanco Reservoir (also known as Johnnie Johnson Reservoir), has a storage volume of 1,036 acre-feet. It is an off-channel reservoir located about 16 miles west of Meeker.

Industrial use of water in the basin remains minor at this time, amounting to less than 1,000 af/yr, according to estimates made during early CDSS development. The long-range potential for oil shale development in the area remains an open issue, however. Should such development occur the increased demand for water could potentially be high, depending on the technology used, the extent of the project, and the urban development required to accommodate an associated influx of the industrial workers and their families.

3.4 Water Rights Administration

There are few special water rights operations, exchanges, or water user agreements on the mainstream of the White River. The key ditch structures, which are located east of Meeker, include:

- Highland Ditch

- Miller Creek Ditch
- Oak Ridge Park Ditch
- Old Agency Ditch, and
- Lowland Ditch

Historical water rights have been administered in the White River basin on the basis of direct flow priorities where senior direct flow rights will call out junior diverts elsewhere on the river. The senior direct flow rights on the mainstream of the White River between Flat Creek and Miller Creek have only had to callout junior diverters once, in 1977. Piceance Creek, a tributary to the White, is routinely subject to administrative regulation during the irrigation season.

4 Modeling Approach

This section describes the approach taken in modeling the White 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 White River 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 without and with 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.

Moreover, the model was used to estimate the basin’s 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 7.

4.2 Model Coverage and Extent

4.2.1 Network Diagram

Figure 4.1 is the network diagram for the White River model. It includes approximately 140 nodes, beginning at the headwaters of the North and South Forks and extending to the Colorado-Utah state line.

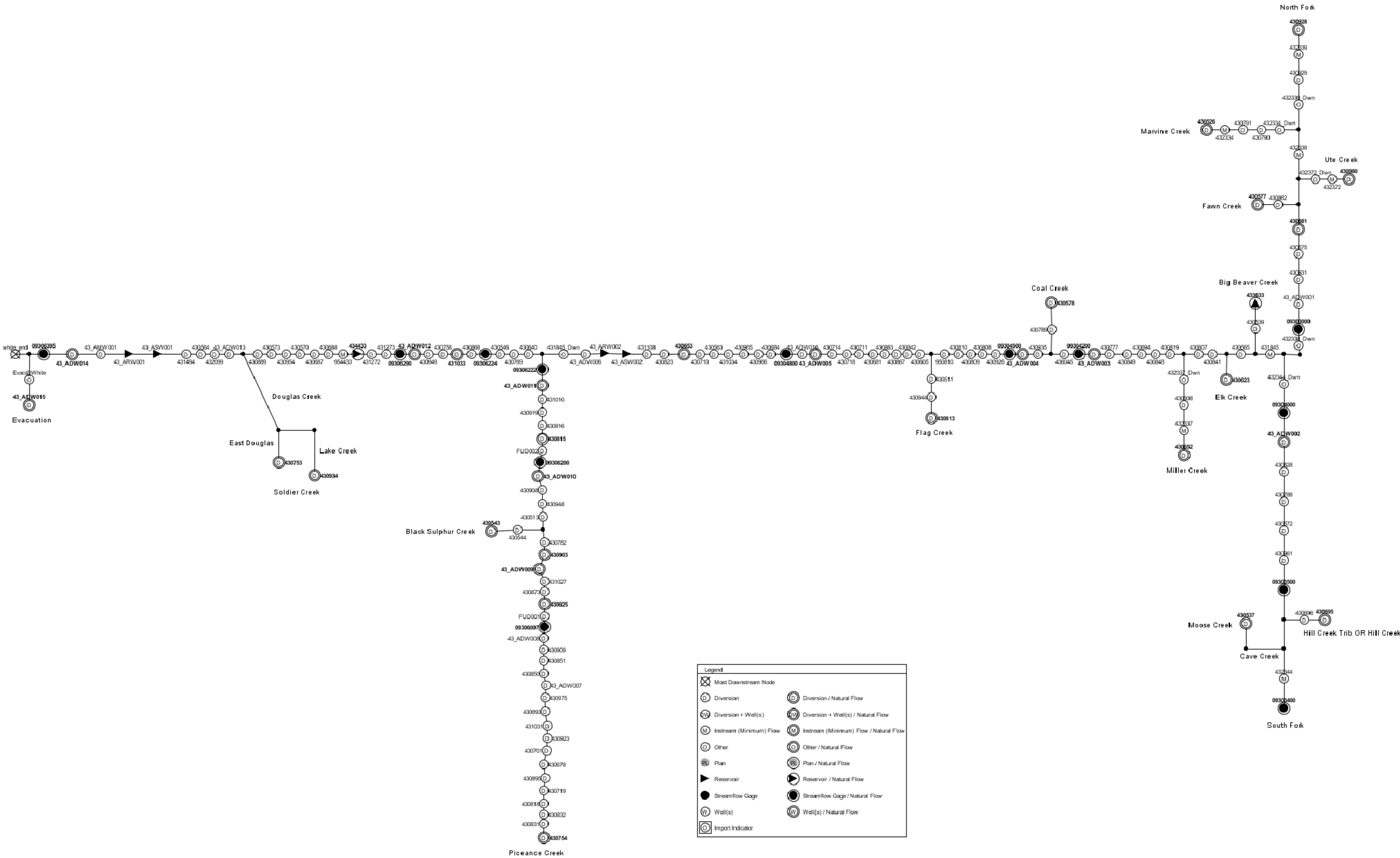


Figure 4.1 - Network Diagram – White River Planning Model

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 basin-wide 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, 4.8 cubic feet per second (cfs) was selected as the cutoff for explicit representation in the White River basin; key diversion structures are those with total absolute water rights equal to or greater than 4.8 cfs. The White River model includes 100 key diversion structures.

Where to find more information

- Section 3 of the CDSS document "White 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 White River Basin Information section "Division 6 Meeting".

4.2.2.2 Aggregation of Irrigation Structures

The use associated with irrigation diversions having total absolute rights less than 4.8 cfs 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, or if on the mainstem, gage location, critical administrative reaches, and instream flow reaches. The aggregations were devised so that each represented no more than 1,000 irrigated acres. In the White River model, 16 aggregated nodes were identified, representing nearly 7,000 acres of irrigated crops. Generally, 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 member 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 memorandum Subtask 2.03 White River Aggregated Irrigation Structures describes the task in which irrigation structures were aggregated. It includes a table showing what diversion structures are included in each aggregation.
- Appendix A memorandum Subtask 2.04 White River Add Aggregated Irrigation Structures to Network describes the task in which aggregated nodes were placed in the model network.

4.2.2.3 Aggregation of Municipal and Industrial Uses

One node in the model represents the combined small diversions for municipal, industrial, and livestock use in the basin. Total non-irrigation consumptive use in the White basin was estimated relatively early in CDSS development, as part of an effort to quantify total consumptive uses and losses in the Colorado River basin. Consumptive use of the key municipal and industrial diversions in the model was subtracted from this White River basin-wide M&I consumption, to derive the basin-wide consumptive use attributable to small M&I users.

The aggregated M&I node in the White River model represents approximately 1,100 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 annual demand is distributed uniformly across the twelve months of the year.

Where to find more information

- Appendix B memorandum Subtask 2.10 White River Basin Aggregated Municipal and Industrial Use describes the task in which municipal and industrial uses were aggregated.

4.2.3 Reservoirs

4.2.3.1 Key Reservoirs

The two largest reservoirs, Big Beaver (aka Lake Avery) and Kenney Reservoir (aka Taylor Draw Reservoir), are considered key reservoirs and are explicitly modeled. Their physical capacities are 7,658 and 13,800 acre-feet, respectively.

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 four aggregated reservoirs structures. Two structures represent all the adjudicated, absolute storage rights in the database that are otherwise unaccounted for. The basin-wide total storage of these rights amounted to approximately 4,200 acre-feet which were divided evenly between the two aggregations. One is located in the model above Piceance Creek in the middle of the basin, and the second is located near the Colorado-Utah state line gage. Surface area for the reservoirs was developed assuming they are straight-sided pits with a depth of 24.9 feet.

Table 4.1
Aggregated Reservoirs

ID	Name	Capacity (AF)	%
43_ARW001	Agg Res near COLO-UTAH State Line	2,117	50
43_ARW002	Agg Res above Piceance Cr - White River confluence	2,117	50
	Total	4,234	100

The two remaining reservoirs represent stockpond use, as documented in CDSS Task Memo 2.09, "Non-Evapotranspiration (Other Uses) Consumptive Uses and Losses in the White River Basin" (August, 1996). Total estimated storage for District 43 was divided in two and represented at two nodes. As with the decreed reservoir aggregates, one is located in the model in the middle of the basin above Piceance Creek, and the second is located near the state line. The stockponds were modeled as 10-foot deep, straight-sided pits.

Table 4.2
Aggregated Stockponds

ID	Name	Capacity(AF)	%
43_ASW001	Stock Pond near COLO-UTAH State Line	2,388	50
43_ASW002	Stock Pond above Piceance Cr - White River confluence	2,388	50
	Total	4,776	100

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.

Where to find more information

- Appendix B memorandum Subtask 2.11 White River Basin Aggregated Reservoirs and Stock Ponds describes the task in which small reservoir and stock pond use was aggregated.

4.2.4 Instream Flow Structures

The model includes 7 instream flow reaches representing instream flow rights held by CWCB. 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. An additional instream flow structure is included to simulate a bypass requirement below Taylor Draw

Reservoir. The purpose of the bypass is to meet flow needs of Colorado squawfish, as described in the Biological Opinion for the Taylor Draw Project, issued by the U.S. Fish and Wildlife Service in May, 1982.

4.3 Modeling Period

The White River model data set extends from 1909 through 2006. The calibration period was 1975 through 2006, 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, 2002) 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 West Slope planning models.

Where to find more information

- The feasibility study for the data extension is documented in two task memos, which are available on the CDSS website:
  - Task 10.1 - Data Extension Feasibility
  - Task 10.2 - Evaluate Extension of Historical Data

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. Generally, HydroBase data begins in 1975, although for some structures there is additional, earlier historical data. Therefore, CDSS methods and tools had to be developed to automate the estimation process for the remaining structures. This section describes data filling and extension for the White River basin model.

4.4.1 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 a long-term "indicator" gage in the White 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". The streamflow characterization in the White basin is based on the USGS gage White River near Meeker (09304500). 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 between these two cutoffs 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.

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 available on the CDSS website:
  - Task 10.1 - Data Extension Feasibility
  - Task 10.2 - Evaluate Extension of Historical Data
  - Task 11.5 - Characterize Streamflow Data
  - Task 11.7 - Verify Diversion Estimates
- 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

4.4.2 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 used 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.

In reality, the further back in time records are researched, the fewer gage records exist to create baseflow series that can serve as independent variables. In 1909, there were no gages in the White River basin, and there were three or fewer USGS stations in the basin, depending on the year, until the early 1960's. To fill baseflows during these early periods, long-term historical gages outside the White basin were added to the list of potential independent variables available to the Mixed Station Model. Approximately 65 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" and is available on the CDSS website. 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 White River 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 3 percent loss, returns to the stream. The 3 percent loss represents water lost to the hydrologic system altogether, through, for example, non-crop consumptive use, deep groundwater storage, or evaporation. This value is recommended as an appropriate estimate of incidental use for the CDSS basins, and is the same value used in the StateCU estimate of consumptive uses and losses in the Upper Colorado River Basin (Consumptive Uses and Losses Report (1998-1995), October 1999, Leonard Rice Engineers).

The model is supplied with the 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, and is estimated to be 54 percent throughout the White River basin.

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 evapotranspiration (ET) at the maximum efficiency.

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 **SW** be defined as surface water available to the crop, i.e., river diversion times maximum efficiency, and let **CU_i** be defined as irrigation water requirement. Then,

when $SW \geq CU_i$:

$$CU_w = CU_i$$

$$SS_f = SS_i + \min[(SS_m - SS_i),(SW - CU_i)]$$

$$SR = SW - CU_i - (SS_f - SS_i)$$

$$TR = 0.90 * (SR + (1.0 - \eta_{max}) * \text{diversion})$$

And when $SW < CU_i$:

$$CU_w = SW + \min[(CU_i - SW), SS_i]$$

$SS_f = SS_i - \min[(CU_i - SW), SS_i]$

$SR = 0$

$TR = 0.90 * ((1.0 - \eta_{max}) * \text{diversion})$

where CU_w is water supply limited consumptive use;

SS_m is the maximum soil moisture reservoir storage;

SS_i is the initial soil moisture reservoir storage;

SS_f is the final soil moisture reservoir storage;

SR is the delivered water in excess of crop requirement;

η_{max} is the maximum efficiency; and

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

More descriptively, it is assumed that 54 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 water returns to the stream, subject to 3 percent loss, along with the 40 percent delivery inefficiency, also subject to 3 percent loss. In this case, the crop needs are completely satisfied, and the water-supply-limited consumptive use equals the crop irrigation water requirement.

When 54 percent of the diverted amount is less than the irrigation water requirement, the crop extracts water from soil moisture storage, limited by the available soil moisture and the unsatisfied irrigation water requirement. Water-supply limited consumptive use is the sum of supply due to the diversion 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 crop (non-consumed), less 3 percent 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 Efficiency for Other Uses and Special Cases

In specific cases, the White River model applies an assumed, specified annual or monthly efficiency to a diversion in order to determine consumptive use and return flows. In the case of monthly efficiencies, the efficiency varies by month, but the monthly pattern is the same in each simulation year. This approach is applied in the CDSS models to municipal, industrial, and transbasin users, as well as reservoir feeders and any irrigation diversion for which crop water requirement has not been developed.

The two explicitly modeled municipal systems in Colorado (Meeker and Rangely) have been given typical monthly efficiencies that reflect indoor use only in the winter, and combined indoor and outdoor use during the irrigation season. The California Company Pipeline use is reported to be 100 percent consumptive, so an annual efficiency of 100 percent was assigned to that structure. Finally, the Coal Creek Feeder Ditch has an efficiency of zero percent, because water diverted from Fawn Creek is delivered without loss to Coal Creek. (The diversions of record are measured at the Coal Creek end of the ditch, after any losses that would have occurred.)

Finally, every structure in the model, including irrigation structures operating by variable efficiency, has monthly efficiencies assigned to it in the model input files. For irrigation structures, these are average monthly efficiencies based on historical diversions and historical crop water requirement over the period 1975-2006, but may not exceed 0.54. These are used by DMI components of CDSS to create time series of headgate demands for input to the model, as described in Section 4.9.1.

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 Irrigation Parameter file (Section 5.5.2)
  - Soil moisture capacity in the StateCU Structure 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. Three return flow patterns are used in the White River model. One represents instantaneous (or within the same month as the diversion) returns and is applied to the municipal diversions and the Coal Creek Feeder Ditch. The other two patterns are generalized irrigation return patterns, applicable to irrigated lands "close" to the stream (center of acreage is less than 1,000 feet from the stream), and “further” from the stream (center of acreage is greater than 1,000 feet from the stream). They both assume incidental losses of 3 percent. The two patterns 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 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. Two different values of x, representing lands “close to” and “further from” a live stream, were assumed in two Glover analyses that were otherwise the same, to produce the two return flow patterns.

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 4.3 and graphed in Figure 4.2**.** Month 1 is the month in which the diversion takes place. Note that the sum of the monthly return fractions is 0.97, meaning that 3 percent of the non-consumed water is lost to the stream through processes such as evaporation or non-beneficial evapotranspiration.

Table 4.3
Percent of Return Flow Entering Stream in Month n after Diversion

Month n	For Lands “Close” to Stream (%)	For lands “Further” from Stream (%)
1	75.6	57.4
2	11.3	14.5
3	3.2	7.2
4	2.2	5.0
5	1.6	3.7
6	1.2	2.7
7	0.8	2.0

8	0.6	1.5
9	0.5	1.1
10	0	0.8
11	0	0.6
12	0	0.5
Total	97	97

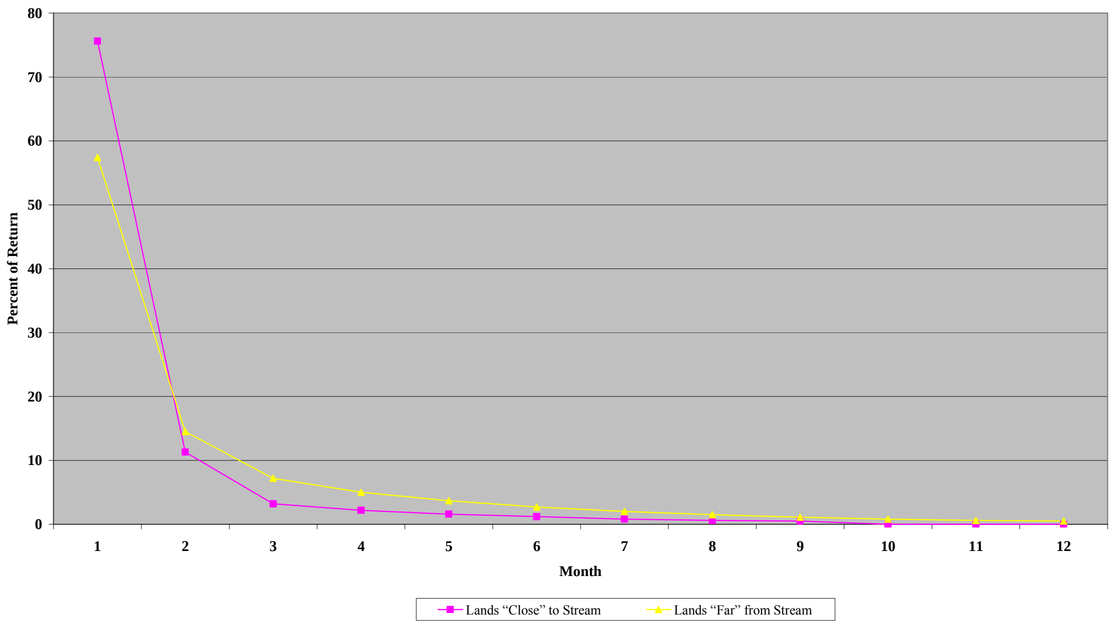


Figure 4.2 - Percent of Return in Months after Diversion

Where to find more information

- CDSS Memorandum "Colorado River Basin Representative Irrigation Return Flow Patterns", Leonard Rice Engineers, January, 2003, available on the CDSS website.

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 6 personnel. Some return flow locations were modified during calibration.

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 completed prior to executing any simulations, and the resulting baseflow file became part of the input data set for 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 4.4.2 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.

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 4.3 illustrates a hypothetical basin and the areas associated with each of three gages and an ungaged location.

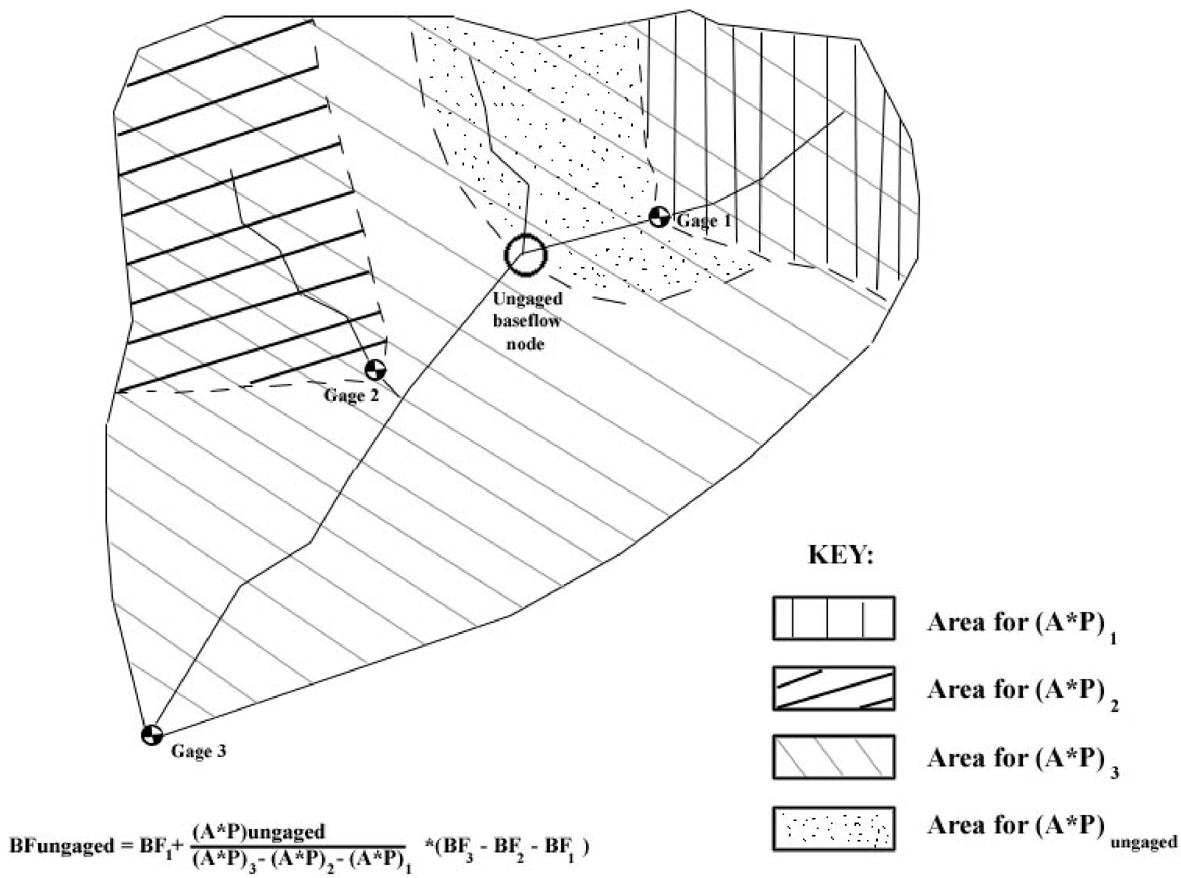


Figure 4.3 - Hypothetical Basin Illustration

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 appear 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 stream gages, reservoir levels, and diversions. In other CDSS models, calibration was carried out in two steps. In the first, there is relatively little freedom in the model with respect to reservoir operations and multiple-headgated system operating rules and the objective is to refine baseflow hydrology. In the second step, operations other than direct diversions from the stream are more rule-driven, and operational parameters for these rules are tested and refined.

In the White basin model, there was no need to calibrate in two steps, because neither of the modeled reservoirs release for downstream demands. Historical end-of-month contents reflect releases only for historical maintenance, which none of the CDSS models have included in their baseline models. Similarly, there are no collection systems in the White basin that divert from several sources simultaneously to satisfy a centralized demand. Thus there were no operations to calibrate.

The issues encountered and results obtained in calibration are described in Section 7.

Where to find more information

- Section 7 of this document describes calibration of the White River model.

4.9 Baseline Data Set

The Baseline data set is intended as a generic representation of recent conditions on the White River, 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 1950 through 2006 is generated directly, by dividing the crop irrigation water requirement for each month by average monthly irrigation efficiency for the period 1975-2006. The irrigation efficiency may not exceed 0.54, however, which represents a practical upper limit on efficiency for flood irrigation systems. Thus Calculated demand for a perennially shorted diversion (diversion divided by irrigation water requirement is, on average, greater than 0.54) will be greater than the historical diversion for at least some months. By setting calculated demand to the historical diversion when the historical diversion exceeds the calculated demand, practices such as irrigating to fill the soil moisture reservoir or diverting to water stock can be simulated.

Prior to 1950, calculated demands were filled using the automated time series filling technique described in Section 4.4.2. This is done because climate records are generally not available until 1950.

4.9.2 Municipal and Industrial Demand

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

4.9.3 Reservoirs

Reservoirs are represented as being on-line throughout the study period, at their current capacities. Initial reservoir contents were set to full.

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 White 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. 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 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 *wm2009B.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
wm2009.ctl	Control file – specifies execution parameters, such as run title, modeling period, options switches	Section 5.2
wm2009.rin	River network file – lists every model node and specifies connectivity of network	Section 5.3.1
wm2009.ris	River station file – lists model nodes, both gaged and ungaged, where hydrologic inflow enters the system	Section 5.3.2
wm2009.rib	Baseflow Parameter file – gives coefficients and related gage IDs for each baseflow node, with which StateMod computes baseflow gain at the node	Section 5.3.3
wm2009.rih	Historical streamflow file – Monthly time series of streamflows at modeled gages	Section 5.3.4
wm2009x.xbm	Baseflow data file – time series of undepleted flows at all nodes listed in *wm2009.ris*	Section 5.3.5
wm2009.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
wm2009.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
wm2009.ddh	Historical Diversions – Monthly time series of	Section 5.4.3

File Name	Description	Reference
	historical diversions	
wm2009B.ddm	Monthly demand file – monthly time series of headgate demands for each direct diversion structure	Section 5.4.4
wm2009.ddr	Direct diversion rights file – lists water rights for direct diversion	Section 5.4.5
wm2009.str	Soil Parameter file – soil moisture capacity by structure, for variable efficiency structures	Section 5.5.1
wm2009.ipy	CU Time series file – maximum efficiency and irrigated acreage by year and by structure, for variable efficiency structures	Section 5.5.2
wm2009.iwr	Irrigation Water Requirement file – monthly time series of crop water requirement by structure, for variable efficiency structures	Section 5.5.3
wm2009B.res	Reservoir station file – lists physical reservoir characteristics such as volume, area-capacity table, and some administration parameters	Section 5.6.1
wm2009.eva	Evaporation file – gives monthly rates for net evaporation from free water surface	Section 5.6.2
wm2009.eom	Reservoir End of month contents file – Monthly time series of historical reservoir contents	Section 5.6.3
wm2009B.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
wm2009.rer	Reservoir rights file – lists storage rights for all reservoirs	Section 5.6.5
wm2009.ifs	Instream flow station file – lists instream flow reaches	Section 5.7.1
wm2009.ifa	Instream flow demand file – gives the decreed monthly instream flow rates	Section 5.7.2
wm2009.ifr	Instream flow right file – gives decreed amount and administration number of instream flow rights associated with instream flow reaches	Section 5.7.3
wm2009B.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	Section 5.8

File Name	Description	Reference
	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	

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 wm2009.rsp. The baseflow response file calls for different diversion demand and reservoir station file from the Baseline response file, 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 wm2009.xbf. The response file for the third step, in which StateMod distributes baseflow to ungaged points, is named wm2009x.rsp. The only difference between the first-step response file wm2009.rsp and third-step response file wm2009x.rsp is that the name wm2009.xbf is supplied for both the baseflow file and the historical gage file.

5.2 Control File (*.ctl)

The control file is hand-created using a text editor. It contains execution parameters for the model run, including 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 White River model. Control file switches are all specifically described in the StateMod documentation. Users most typically adjust the simulation period parameters (starting and ending year).

5.3 River System Files

5.3.1 River Network File (*.rin)

The river network file is created by StateDMI from the graphical network representation file created within the StateDMI – StateMod Network interface.

The river network file describes the location and connectivity of each node in the model. Specifically, it is simply 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.

Figure 4.1 in Section 4.2.1 illustrates the network, which starts in the upper North Fork and South Fork of the White River, and ends at the State Line gage in Utah.

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. Table 5.1 shows how many nodes of each type are in the White River model.

Table 5.1
River Network Elements

Type	Number
Diversion	127
Reservoirs	6
Instream Flow	8
Wells	0
Plans	0
Stream Flow	13
Total	154

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 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 13 gages in the model and 32 ungaged baseflow locations, for a total of 45 hydrologic inflows to the White River model. Ungaged baseflow nodes include all ungaged headwater nodes, all key reservoir nodes, many of the aggregated diversion nodes, and any other nodes where calibration revealed a need for additional baseflow. In the last case, 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 drainage area multiplied by precipitation (A*P) 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 increment in the product of drainage area and average precipitation from the reach's upstream gage(s) to its downstream gage.

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 drainage 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 tributaries:

Tributary Name	Baseflow WDID	Neighboring Gage
Coal Creek	430578	09304000
Flag Creek	430813	09306007
Evacuation Creek	43_ADW015	09306007

In addition, a user-specified proration factor 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 list, the percent of the gage-to-gage baseflow gain to be applied at the ungaged baseflow location was set directly. The value of the baseflow percent was established during calibration, as described in Section 7.3.4 Baseflow Factor Adjustments.

Tributary Name	Baseflow WDID	Baseflow Percent	Downstream Gage
Big Beaver Creek	433633	35%	09304200
Miller Creek	430652	50%	09304200
Elk Creek	430623	15%	09304200

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 1909-2006, for modeled gages. This file is used for baseflow generation and to create comparison output that is useful during model calibration. Records are taken directly from streamflow tables in the database, which include both USGS and DWR-operated gages. Missing values, when the gage was not in operation, are denoted as such, using the value "-999."

Table 5.2 lists the gages used, their periods of record, and their average annual flows over the period of record.

Table 5.2
Historical Average Annual Flows for Modeled White River Basin Stream Gages

Gage ID	Gage Name	Period of Record	Historical Average Flow (af/yr)
9303000	North Fork White River at Buford	1911-1915,1920, 1952-2001	229,247
9303400	South Fork White River near Budge's Resort	1977-1995	143,417
9303500	South Fork White River near Buford	1911-1915,1943-1947,1968-1992	186,975
9304000	South Fork White River at Buford	1920, 1952-1997	185,176
9304200	White River above Coal Creek	1962-2006	401,620
9304500	White River near Meeker	1910-2006	449,500
9304800	White River below Meeker	1962-2006	471,919.
9306007	Piceance Creek below Rio Blanco	1975-1998	15,199
9306200	Piceance Creek below Ryan Gulch	1965-2006	20,798
9306222	Piceance Creek at White River	1965-1966,1971-2006	25,762
9306224	White River above Crooked Wash near White River City	1983-1989	684,952
9306290	White River below Boise Creek near Rangely	1983-2006	532,247
9306395	White River near Colorado State Line, Utah	1977-1985	596,954

5.3.5 Baseflow Files (*.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 four gages with complete records throughout the calibration period (1975-2006).

Table 5.3
Streamflow Comparison
1975-2006 Average (af/yr)

Gage ID	Gage Name	Baseflow	Historical	Difference
09304200	White River above Coal Creek	483,289	400,452	82,837
09304500	White River near Meeker	507,426	446,760	60,667
09304800	White River below Meeker	510,698	479,062	31,636
09306222	Piceance Creek at White River	33,924	27,573	6,351

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, wm2009.sum and wm2009.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.

5.4 Diversion Files

5.4.1 Direct Diversion Station File (*.dds)

StateDMI is used to create the direct diversion station file.

The direct diversion station file describes the physical properties of each diversion simulated in the White River model. Table 5.4 is a summary of the White River model's diversion station file contents, including each structure's diversion capacity, irrigated acreage served, average annual system efficiency, and average annual headgate demand. This last 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 diversion station file also specifies return flow nodes, timing of returns, and average monthly efficiencies. Footnotes to Table 5.4 identify municipal and industrial diverters, carriers, and other non-irrigation structures.

Generally, the diversion station ID and name, diversion capacity, and irrigated acreage are gathered from Hydrobase by StateDMI. Return flow locations and timing are specified to the DMI in a hand-edited file WhiteF.rtn. The return flow locations and spatial distribution are based on physical locations of irrigated lands and discussions with Division 6 personnel, as well as calibration efforts. Return flow timing is based on distance from the irrigated area to the stream, and generalized return patterns which are described more fully in Section 5.4.2. StateDMI computes monthly system efficiencies for each irrigation structure from historical diversions and historical crop irrigation requirements, and writes the efficiencies into the diversion station file. For non-irrigation structures, monthly efficiency is specified by the user as input to StateDMI. Diversion station parameters for different structures or structure types are described in more detail after Table 5.4.

Table 5.4
Direct Flow Diversion Summary Average
1975-2006

#	Model ID#	Name	Diversion Cap (cfs)	Irrigated Area (acres)	Average System Efficiency (percent)	Average Annual Demand (af)
1	430511	B A & B Ditch No 1	20	92	8	2,068
2	430513	B M & H Ditch 1	13	217	33	1187
3	430526	Barbour North Side D	12	23	2	1,348
4	430537	Beckman Ditch	20	301	39	2,012
5	430539	Big Beaver Ditch	10	66	14	1,208
6	430543	Black Eagle D No 1	6	36	29	288
7	430544	Black Eagle D No 2	6	61	48	234
8	430546	Blair Ditch	15	191	31	1,401
9	430563	Calhoun Ditch	8	71	52	265
10	430564[2]	California Co Water Pl	14	0	100	512
11	430570	Calvat Ditch	10	35	23	559
12	430572	Charlie Smith Ditch	17	140	30	1,732
13	430573	Chase & Coltharp D	20	89	38	657
14	430575	Cloherty Ditch	8	44	25	1093
15	430577[1]	Coal Creek Feeder Ditch	25	0	0	0
16	430578	Coal Creek Mesa Ditch	63	747	46	4,119
17	430605	Dorrell Ditch 2	3	59	34	350
18	430607	Dreifuss Ditch	15	75	15	1,817
19	430608	Dreyfuss Ditch	11	77	8	1,577
20	430623	Elk Creek Ditch	9	154	34	1,246
21	430625	Emily Ditch	7	110	19	985
22	430640	Forney Corcoran Ditch	12	142	30	1015
23	430652	G V Ditch	8	49	13	1,369
24	430653	George S Witter Ditch	15	141	26	1,606
25	430665	Greenstreet Ditch Ext	9	93	18	753

#	Model ID#	Name	Diversion Cap (cfs)	Irrigated Area (acres)	Average System Efficiency (percent)	Average Annual Demand (af)
26	430678	Hanrahan Ditch No 1	2	17	49	75
27	430681	Hay Bretherton Ditch	40	265	9	4,719
28	430684	Hay Ditch 2	7	77	20	671
29	430687	Hefley Pump Plant No 1	16	80	23	1127
30	430688	Hefley Pump Plant No 2	20	79	21	1089
31	430693	Herwick Ditch 1	5	23	25	305
32	430694	Highland Ditch	257	1851	7	36,269
33	430695	Hill Creek No 3 Ditch	10	52	32	495
34	430696	Hill Creek No 2 Ditch	17	78	19	1,944
35	430701	Home Ditch	6	43	16	751
36	430710	Imes & Reynolds Ditch	26	153	11	2,632
37	430711	Independent Ditch	21	114	40	647
38	430714	Ivo E Shults D & Pump	5	22	11	235
39	430718	James Hayes Ditch	12	144	19	1,242
40	430719	Janes Ditch	3	6	50	48
41	430753	Lake Creek Pool Ditch	7	12	18	331
42	430754	Larson Ditch	3	0	0	117
43	430758	Lawrence Ditch No 1	5	82	37	388
44	430769	Little Ditch	17	186	15	2,095
45	430777	Lowland Ditch	46	73	7	2,722
46	430782	M H M German Cons D	18	255	33	1221
47	430788	Marcott Ditch	31	236	17	4,438
48	430789	Martin Ditch	10	21	3	1,516
49	430790	Marvine Ditch 1	10	81	20	1,290
50	430791	Marvine Ditch 3	5	27	14	525
51	430808	Meeker Ditch	30	129	4	4,811
52	430809	Meeker Power Ditch	182	15	10	196
53	430810[1,2]	Meeker Water Sys	10	0	36	0
54	430813	Melvin Ditch	19	65	32	606
55	430815	Metz & Reigan Ditch	7	68	10	1060
56	430816	Metz Ditch	9	73	11	1008
57	430818	Mikkelson Ditch	3	11	47	75
58	430819	Miller Creek Ditch	133	2226	11	28,520

#	Model ID#	Name	Diversion Cap (cfs)	Irrigated Area (acres)	Average System Efficiency (percent)	Average Annual Demand (af)
59	430823	Miner Martin Ditch	8	50	21	688
60	430828	Mooney Ditch	11	89	27	1,369
61	430831	Morgan Ditch 2	2	0	0	79
62	430832	Morgan Ditch 1	2	0	0	140
63	430841	New Archer Warner Ditch	10	54	19	1032
64	430842	Niblock Ditch	96	1384	16	14,800
65	430848	Oak Ridge Park Ditch	133	1864	11	24,005
66	430849	Old Agency Ditch	59	567	11	8,480
67	430850	Oldland Ditch 1	14	120	19	1,253
68	430851	Oldland Ditch 2	19	31	14	777
69	430862	Pattison Ditch No 1	7	67	36	742
70	430867	Pease Ditch	29	340	14	4,642
71	430868	Pedrick Ditch	25	364	20	3,109
72	430873	Piceance Creek Ditch	8	112	18	1007
73	430881	Pothole Ditch	16	89	20	1,448
74	430883	Powell Park Ditch	101	1784	18	15,177
75	430889[2]	Rangely Water	31	0	36	1709
76	430895	Reddin Ditch	2	11	39	92
77	430903	Robert Mckee Ditch	15	138	15	1,553
78	430908	Ryan Ditch	11	98	47	434
79	430909	Rye Grass Ditch	12	164	30	1136
80	430919	Sayer Ditch	6	27	18	313
81	430923	Schutte Ditch	15	49	19	771
82	430926	Sheridan & Morton D	10	35	9	968
83	430928	Simpson Ditch	7	35	13	847
84	430929	Sizemore Ditch 1	5	26	17	334
85	430931	Skelton Ditch	15	13	4	1,250
86	430934	Soldier Creek Ditch	7	58	46	463
87	430935	South Side Highline D	57	428	8	7,239
88	430944	Sprod Ditch 1	6	140	25	636
89	430948	Square S Cons D Sys	21	303	23	2,424
90	430949	Stadtman Ditch	12	76	44	856
91	430954	Storey Ditch 1	10	72	49	325

#	Model ID#	Name	Diversion Cap (cfs)	Irrigated Area (acres)	Average System Efficiency (percent)	Average Annual Demand (af)
92	430961	Sweede Ditch	22	220	29	2,887
93	430965	Thomas Ditch	7	76	45	393
94	430966	Thomas Ditch 2	10	70	40	401
95	430975	Upper Ditch	2	32	53	93
96	430980	Ute Creek Ditch	15	62	7	2,325
97	431010	White River Mesa Ditch	13	119	35	788
98	431027	Belot Moffat Ditch	17	117	14	1,625
99	431031	Gordon Ditch	3	15	34	182
100	431033	Lawrence Ditch	6	87	41	471
101	431034	Mcdowell No. 1 Ditch	8	131	60	206
102	431108	Jacobs Pump & Pl	4	99	49	253
103	431272	Cox Pump No 1	17	205	54	1023
104	431273	Reigan Pump No 1	6	124	59	582
105	431494	Goff Ditch	10	66	34	614
106	432099	Kenney Pump No 1	14	98	44	778
107	436045[1,2]	Meeker Wells	4	0	36	0
108	43_ADW001	NORT_ADW WhiteNorthF	51	388	14	6,356
109	43_ADW002	SOUT_ADW WhiteSouthF	22	267	46	2,222
110	43_ADW003	WHIT_ADW WhiteAbCole	37	596	26	5,857
111	43_ADW004	WHIT_ADW WhiteNrMeek	36	598	45	3,251
112	43_ADW005	WHIT_ADW WhiteNBLMee	11	164	34	1066
113	43_ADW006	WHIT_ADW WhiteAbPice	24	217	11	3,262
114	43_ADW007	PICE_ADW Upper	29	307	37	2,412
115	43_ADW008	PICE_ADW PicCrBlRioB	11	63	18	973
116	43_ADW009	PICE_ADW PicCrAbHunt	44	467	18	5,582
117	43_ADW010	PICE_ADW PicCrBlRyan	69	723	33	5,596
118	43_ADW011	PICE_ADW Piceance@Wh	18	286	25	1,922
119	43_ADW012	WHIT_ADW WhiteBlBois	61	822	34	3,784
120	43_ADW013	WHIT_ADW WhiteBlDoug	72	837	26	5,349
121	43_ADW014	WHIT_ADW WhiteNrStat	45	454	17	3,675
122	43_ADW015	EVAC_ADW Evac Creek	26	250	46	1,269
123	43_ADW016	WHIT_ADW WhiteSBLMee	30	477	29	3,536
124	43_AMW001[2]	WHIT_AMW AggMuni&Ind	999	0	60	1,104

#	Model ID#	Name	Diversion Cap (cfs)	Irrigated Area (acres)	Average System Efficiency (percent)	Average Annual Demand (af)
125	950810[2]	MEEKER DEMAND	999	0	36	368
126	FUD001		0	0	60	0
127	FUD002		0	0	60	0
TOTAL			-----	26,602	-----	302,872

[1] Carrier ditch or feeder ditch to a reservoir
[2] Municipal/industrial diversion

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 White basin, diversion structures with water rights totaling 4.8 cfs or more were designated key structures, except in the Piceance Creek basin, where structures with smaller water rights were represented explicitly in order to improve calibration. 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 diversion structures in the White basin are for irrigation, although several exceptions were noted above by footnote in Table 5.4.

Average historical monthly efficiencies for each irrigation 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 given 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 and industrial diverters, StateMod uses the efficiencies in the diversion station file directly during simulation to compute consumption and return flows. Municipal diversion efficiency is set to values that reflect indoor use in winter and a blend of indoor and outdoor use in the summer. The California Company Water Pipeline's diversion for oil extraction were assigned an efficiency of 100 percent, as there are no returns. The Coal Creek Feeder Ditch is zero percent efficient, meaning its diversions are delivered without loss.

Diversion capacity is stored in Hydrobase for most structures and is generally taken directly from the database. In preparing this file, however, the DMI 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.

Return flow parameters in the diversion station file specify the nodes at which return flows will re-enter the stream system, and divide the returns among several locations as appropriate. The locations were determined primarily on a case-by-case basis from topography and from conversations with water commissioners and users.

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. One of these gives the return flow locations and percent of return flow to each location, for every diversion structure in the model.
- 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-basins were combined and represented at aggregated nodes. Aggregated irrigation structures were given the identifiers "wd_ADWxxx", where "wd" is the Water District number, and "ADW" stands for Aggregated Diversion White; the "xxx" ranged from 001 to 016. Similarly, the aggregated municipal and industrial structures were named "WD_AMY001" for Aggregated Municipal White.

Efficiency for the aggregated M&I diversion was set to 100 percent because demands for this structure were modeled as depletions.

Where to find more information

- Section 4.2.2.2 describes how small irrigation structures were aggregated into larger structures.
- Appendix A – Subtask 2.03 White River Aggregated Irrigation Structures describes the original aggregation of irrigated lands under small structures

5.4.1.3 Special Structures

Town of Meeker

The Town of Meeker historically diverted at two surface water structures; 430810 and 430811, located very near the town. More recently, according to the current water commissioner, the town began taking its water supply at a wellfield approximately 5 miles upstream. Meeker had three alluvial wells, structures 436045, 436046, and 436139, decreed alternate points of diversion to the original water rights, and to each other.

The Town of Meeker is represented by three nodes in the model: 1) structure 436045, representing the alluvial wellfield, 2) structure 430810 representing the historical location of diversions prior to development of the wellfield, and 3) structure 950810, a node representing the current level of demand for the Town of Meeker. Structure 436045 was made a diversion system with structures 436046 and 4346139 so that it represents the combined water rights, historical diversions, diversion capacity, and demand of three wells that compose the wellfield. (Structures 436046 and 436139 are not in the model, but their information is in Hydrobase. StateDMI retrieves this information and incorporates it into parameters for 436045.) Similarly, structure 430810 represents the combined characteristics of structures 430810 and 430811, using the diversion system modeling device.

In the Baseline data set, Meeker's demand is located at structure 950810, and operating rules deliver water from the wellfield to the demand node. The historical structure 430810 is inactive in this scenario, diverting nothing and having no impact on the hydrologic system. Demands and operations at the Meeker nodes are explained in more detail in subsections 5.4.4 and 5.8.1, respectively.

Monthly efficiencies for this municipal structure reflect indoor use in winter and a blend of indoor and outdoor use in summer:

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
26%	0%	10%	10%	12%	14%	44%	55%	62%	61%	56%	44%

Return flows from Meeker's diversions are modeled as being "instantaneous", meaning they return in the same time step as the diversion.

Meeker Power Ditch

Despite its name, the Meeker Power Ditch is an ordinary irrigation diversion structure. It is owned by the Town of Meeker and was originally decreed for a variety of uses including both irrigation and power generation. With four rights that total over 180 cfs, it appears to be one of the largest users in the basin; however, the power generation project envisioned has not yet been developed. The Town exercises only one right for 1.8 cfs to irrigate 15 acres at the town cemetery.

Town of Rangely

Like Meeker, Rangely historically supplied its water works by a direct surface water diversion from the White River; recently, however, the Town developed alluvial wells and had them decreed alternate points of diversions for their historical rights. The wells are in the vicinity of the original diversion site, and as a result, a single structure is used to model Rangely's water use. The structure (430889) is made a diversion system in the model, with 432622 and 432623, the Town's two active wells. Using this approach, the modeled structure has the combined demand, historical diversions, and water rights of all three structures.

The monthly efficiencies shown above for Meeker are also used at the Rangely diversion station. Return flows are modeled as "instantaneous".

Coal Creek Feeder Ditch

The Coal Creek Feeder Ditch is a trans-tributary diversion facility which delivers water from the headwaters of Fawn Creek (a tributary of the North Fork of the White River) into the headwaters of Coal Creek (a tributary of the White River). The diversion facility is located near the top of the drainage divide in a fairly remote area. The Water Commissioner reports that the recorded diversions are measured at the Coal Creek end of the ditch, and there may be a small amount of un-decreed use between Fawn Creek and the measurement. This use is not included in the model, partly because it is minor (40 acres), and partly because the records reflect the delivery to Coal Creek.

Water from the ditch is turned into Coal Creek, and is not shepherded to particular users. Amount of the diversion depends only on the physical and legal supply available. Accordingly, the structure is modeled as returning to Coal Creek Mesa Ditch, the most upstream modeled structure on Coal Creek, having zero percent efficiency and instantaneous returns.

California Company Water Pipeline

The California Company Water Pipeline diverts water for use in oil extraction. The process is 100 percent consumptive. Use patterns changed dramatically in about 2000, with diversions dropping from several thousand acre-feet per year to several hundred acre-feet per year. The Water Commissioner believes the change was related to changes in technology or process. Modeled efficiency of the California Water Company Pipeline is 100 percent, meaning that none of the diversion returns to the stream.

Future Use

Two diversion stations in the network are “placeholders” for modeling future conditions. They are named FUD001 and FUD002, denoting “Future Use Diversion”. Both are located on Piceance Creek, and could be used, for example, to simulate rights which are conditional. Strictly speaking, they are not part of the Baseline data set, and are disabled in this data set. Demands are set to zero or rights are either absent or turned off.

5.4.2 Return Flow Delay Tables (*.dly)

The wm2009.dly file, which is hand-built with a text editor, describes the estimated re-entry of return flows into the river system. Each table gives the percent of the return flow generated by month n’s diversion, that reaches in the stream in month n, month n+1, month n+2, and so on until extinction of the return. The file contains 10 patterns, some of which are intended for use in other CDSS basins and are not referenced in the White River model.

Irrigation return patterns are based on Glover analysis for generalized characteristics of the alluvium, and have been applied to other West-slope basin models. The percent return flow in the first month for the Glover-derived patterns is adjusted to reflect “incidental loss”, losses to the stream due to non-beneficial consumption or evaporation. The default amount of incidental loss in the White River model is 3 percent, based on a recommendation made in “Consumptive Uses and Losses Report, Comparison between StateCU CU & Losses Report and the USBR CU & Losses Report (1995-1998)” (Leonard Rice Engineers, October 1999). The lag times represent the combined impact of surface and subsurface returns.

Pattern 1 represents returns from irrigated lands relatively close to a live stream or drain (<1000 feet). Pattern 2 represents returns from irrigation further from a live stream (>1000 feet). Pattern 4 represents immediate returns, as for municipal and industrial uses, or feeder canals. Table 5.5 shows these three patterns.

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

Month n	Pattern 1	Pattern 2	Pattern 4
1	75.6	57.4	100
2	11.3	14.5	0
3	3.2	7.2	0
4	2.2	5.0	0
5	1.6	3.7	0
6	1.2	2.7	0
7	0.8	2.0	0
8	0.6	1.5	0
9	0.5	1.1	0
10	0	0.8	0
11	0	0.6	0
12	0	0.5	0
Total	97	97	100
Note: month 1 is the same month as the 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 headgate diversions for each structure. It is not actually input to a Baseline simulation, but StateMod uses the file for estimating baseflows (*.xbm file) and developing irrigation demand (*B.ddm), both of which are required for a Baseline simulation. Furthermore, StateMod outputs comparisons of simulated diversions and the historical diversions in this file, which is useful during calibration.

StateDMI gathers historical diversions for most structures from Hydrobase, and then fills the resulting time series where data are missing. When StateDMI fills an historical diversion time series, it limits the estimated diversion to the structure's water rights at the time. Based on the appropriation date expressed in the administration number in the direct diversion rights (*.ddr) 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 1896, and the other for 6 cfs with an appropriation date of 1932. When StateDMI estimates diversions prior to 1932, it limits them to a constant rate of 2.5 cfs for the month, regardless of the average from available diversion records. This approach was adopted to better reflect historical use during the early part of the modeling period, for the purpose of both baseflow estimation and historical simulation.

5.4.3.1 Key Structures

In the White River model, StateDMI accesses Hydrobase to get historical diversion records for all key irrigation and M&I structures. That is, there are no instances of developing historical diversions independent of Hydrobase. StateDMI accumulates historical diversions across several structures for diversion systems.

5.4.3.2 Aggregate Structures

Aggregated irrigation diversion structures are assigned the sum of the member structures' historical diversion records from Hydrobase.

Historical diversions for the aggregated M&I node 43_AMW001 are modeled as the consumed or depletive portion of the diversion. The node represents non-irrigation consumptive use that is not modeled by key structures. Task Memorandum 2.09-11, "Non-Evaporation (Other Uses) Consumptive Uses and Losses in the White River Basin" (8/16/96) documents how basin-wide, total non-irrigation consumption was estimated. Consumptive use of the key municipal diverters, Rangely and Meeker, was subtracted from the basin-wide M&I consumption, to derive historical basin-wide consumptive use attributable to small M&I users. This number is assumed to be distributed uniformly across the year, and does not vary from year to year.

5.4.3.3 Special Structures

Town of Meeker

Modeled historical diversions for structure 430810 are computed as the combined diversions recorded for structures 430810 and 430811, which served the Town concurrently until 2003. Modeled historical diversions for structure 436045 are a combination of the recorded historical diversions of 436045, 436046, and 436139, three wells that Meeker now uses to supply the Town.

Town of Rangely

Modeled historical diversions for structure 430889 are the sum of recorded historical diversions by structures 430889, 432622, and 432623. The first is Rangely's historical surface water diversion, and the latter two are alluvial wells currently in use.

Future Use

The future use structures have historical diversions set to zero because they did not divert historically.

5.4.4 Direct Diversion Demand File (Baseline) (*.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.

5.4.4.1 Key Structures

Irrigation demand is computed as crop irrigation water requirement divided by monthly efficiency for the structure, 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 4.4.1. Monthly efficiency is the average efficiency over the efficiency period (1975 through 2006) but capped at 0.60. Exceptions are made when the historical diversion exceeds the calculated irrigation demand – in which case historical diversions are incorporated in the demand file. This approach addresses non-irrigation season diversions which may be for stock watering or wetting the soil, and typical wet year diversions when the ditch operates at lower-than-usual efficiency.

Demands for Rangely and the California Company Water Pipeline are set to monthly averages from the period 1998 through 2006. Demand for Meeker is set to monthly averages for 2003 through 2006. Historical diversions for Meeker changed significantly in 2003. According to the Water Commissioner, the recent values are metered and are more accurate than the earlier values.

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 member structures. Similarly diversions are summed across all member structures, and average efficiency is based on efficiency of the aggregation in toto. Demand for the aggregated M&I structure is the same as it is in the historical diversion file.

5.4.4.3 Future Use

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

5.4.5 Direct Diversion Right File (*.ddr)

The direct diversion right file contains water rights information for each diversion structure in the model. StateDMI creates the diversion right file, based on the structure list in the diversion station file. The diversion right file contains only absolute rights.

The information in this file is used during simulation to allocate water in the right sequence or priority and to limit the allocation by decreed amount. The file is also an input to StateDMI when it fills historical diversion time series, as described in Section 5.4.3.

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. In addition, structures that historically diverted more than their decreed water rights were 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 amount under free river conditions, provided their demand is unsatisfied and water is legally available.

5.4.5.2 Aggregate Structures

Aggregated irrigation structures include many structures, each having multiple water rights. Therefore, aggregated irrigation structures were assigned up to 8 water rights, one for each of 8 water right classes. Appendix A describes the procedure and results for determining appropriate water right classes for the basin. The decreed amount for a given aggregate water right was the sum of all water rights that 1) were associated with the member structures included in the aggregate structure, and 2) had an administration number that fell within the water right class. The administration number for each aggregate right was calculated as the average administration number for the individual rights it represented, weighted by their decreed amounts.

The aggregated M&I structure was assigned a decreed amount equal to the uniform monthly demand for the structure, and assigned an administration number of 1.00000 (very senior).

5.4.5.3 Special Diversion Rights

Town of Meeker

Meeker's wellfield (436045) was assigned the absolute junior rights of the three currently operating wells it represents (436045, 436046, and 436139). In addition, it was given rights with the characteristics of water rights associated with Meeker's historical diversion structures (430810 and 430811), for which the wells are decreed alternate points.

Structure 430810 was assigned both its own absolute rights, and those associated with historical structure 430811. This latter right is less than 4.8 cfs, which is the reason that 430811 was not considered a key structure and represented explicitly.

The model is set up so that structures 430810 and 436045 never have a positive demand at the same time. Thus there is no risk of the historical structure's rights being exercised at two different places in the same model time step.

Meeker Power Ditch

The Meeker Power Ditch's large rights for power generation are turned off in the direct diversion right file. The rights have absolute status in Hydrobase, but have apparently not been put to beneficial use. A right for 1.8 cfs is left on. Daily diversion records show a maximum and often recorded rate of 1.8 cfs for this structure.

Town of Rangely

The Town of Rangely diversion structure (430889) was made a diversion system with structures 432622 and 432623, so that the structure's rights would include the wells' rights. At the current time, these wells have no absolute rights. If the well rights' status changes in Hydrobase, the command file will cause the additional, presumably junior, rights to be reflected in the direct diversion right file.

Future Use

Future use structures are listed in the direct diversion rights file, but the rights are turned off. This effectively disables the structure with regard to having an impact on the river.

Where to find more information

- Appendix A Subtask 2.05 Define Water Right Classes explains how water right classes for aggregated irrigation structures were established.

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 diversion.

5.5.1 StateCU Structure File (*.str)

This file contains the soil moisture capacity of each irrigation structure 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 is assembled by StateDMI from hand-built files.

5.5.2 Irrigation Parameter Yearly File (*.ipy)

This file contains conveyance efficiency and maximum application efficiency by irrigation type, for each irrigation structure and each year of the study period. The file also contains acreage by irrigation type – either flood or sprinkler. In the White River model, all acreage is flood irrigated and maximum system efficiency is assumed to be 54 percent. The irrigated acreage is based on 1993 aerial imagery.

5.5.3 Irrigation Water Requirement File (*.iwr)

Data for the irrigation water requirement file is generated by StateCU for the period 1950 through 2006, then filled and formatted into StateMod file format by StateDMI. For lands below elevation 6,500 feet, StateCU was executed using the SCS modified Blaney-Criddle monthly evapotranspiration option with TR-21 crop coefficients. For structures irrigating pasture grass above 6,500 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, available on the CDSS website.

The irrigation water requirement for 1950 through 1999 is based on 1993 irrigated lands information stored in Hydrobase; for 2000 through 2006, updated acreage based on year 2000 aerial imagery is used in the irrigation water requirement computations.

5.6 Reservoir Files

5.6.1 Reservoir Station File (*.res)

This file describes physical properties and some administrative characteristics of the reservoirs in the White River basin. It is assembled by StateDMI, using information in Hydrobase supplemented with information provided in the command file. Two key reservoirs, two aggregated reservoirs, and two aggregated stockponds are included in the model. The aggregate structures account for evaporation from numerous small storage facilities. One aggregate reservoir and one aggregate stock pond were located on the White River above the state line gage; the other reservoir and stockpond were located on the White River above the Piceance Creek confluence. These general locations were selected based on reservoir locations and stock pond assignment to Hydrologic Units. The reservoir structures are listed below with their capacity and their number of accounts or pools:

ID #	Name	Capacity (af)	# of Owners
433633	Big Beaver Creek Reservoir	7,658	1
434433	Taylor Draw Reservoir	13,800	1
43_ARW001	Agg Res near Colo-Utah Stateline	2,117	1
43_ARW002	Agg Res above Piceance Creek	2,117	1
43_ASW001	Stock Pond near Colo-Utah Stateline	2,388	1
43_ASW002	Stock Pond above Piceance Creek	2,388	1

5.6.1.1 Key Reservoirs

Parameters related to the physical attributes of key reservoirs include inactive storage where applicable, total active storage, area-capacity data, applicable evaporation/precipitation stations, and initial contents. For the explicitly modeled reservoirs, storage and area-capacity information was obtained from Division personnel, the reservoir owners, or filing maps and construction drawings associated with the storage rights for the reservoirs. Initial contents for all reservoirs are set to full in the Baseline data set.

Administrative information includes reservoir account ownership, administrative fill date, and evaporation charge specifications. Annual administration is turned off at all reservoirs in the White River model, and evaporation is charged completely to the only account in each reservoir.

5.6.1.2 Aggregate Reservoirs

The amount of storage for aggregated reservoirs was based on storage decrees as related in the memorandum Subtask 2.11 White River Basin Aggregate Reservoirs and Stockponds (see Appendix B). Surface area for the reservoirs was developed assuming they are straight-sided pits with a depth of 24 feet. Initial contents were set to full.

5.6.1.3 Reservoir Accounts

Big Beaver Creek Reservoir

Big Beaver Creek Reservoir is named such in the State's database but is more commonly known as Lake Avery. The Division of Wildlife owns the reservoir, which it keeps full for recreational and piscatorial uses. Construction drawings obtained from the State Engineer's Office indicate that the reservoir has no dead storage. It is therefore modeled as having a single account which is kept full.

Taylor Draw Reservoir

Taylor Draw Reservoir was constructed by the Colorado River Water Conservation District in the mid-1980s, and ownership was transferred to the Rio Blanco Water Conservancy District in 1990. The reservoir is used for recreation and power generation, and for irrigation of a small amount of lawn at the marina. According to Dan Eddy, current operator of the Taylor Draw Hydropower Plant, the FERC license under which it operates requires them to pass through all inflows. Early CDSS research cited a 1,735-af pool for the Town of Rangely and an 8,235-af pool for other water sales. However, recent operations do not reflect releases for Rangely or any other users. Accordingly, the reservoir is modeled as having a single account which is kept full.

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 at Meeker 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 using the factors listed in Table 5.6. These monthly distributions are used by the State Engineer's Office.

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

Month	Greater than 6,500 ft	Less than 6,500 ft
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

The resulting net monthly free water surface evaporation estimates for the White River basin are shown below:

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
.13	.04	-.05	-.06	.02	.09	.16	.30	.41	.41	.27	.24

5.6.3 EOM 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 during calibration. The file is created by Tstool, which reads data from Hydrobase and fills it under a variety of user-specified algorithms.

5.6.3.1 Key Reservoirs

Data for the two key reservoirs was generated by converting sporadic observations from Hydrobase to month-end data. The user-specified tolerance for defining the end of the month was set to 14 days, because the observations were sparse. Short gaps were filled by linear interpolation, and longer gaps were filled with the average historical contents for the month (Big Beaver Creek Reservoir) or with reservoir capacity (Taylor Draw Reservoir).

Table 5.7 presents the on-line date for each reservoir. Historical contents in the *.eom file are set to zero prior to these dates

Table 5.7
Reservoir On-line Dates

Reservoir	On-Line Date
Big Beaver Creek	1964
Taylor Draw	1984

5.6.3.2 Aggregate Reservoirs

Aggregated reservoirs were assigned contents equal to their capacity, because there is no actual data. Aggregated reservoirs were 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 are set to zero and maximum targets are set to capacity for all reservoirs. These targets allow maximum control of reservoir levels by storage rights and releases to meet demands.

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 the CDSS database and correspond to the State Engineer's official water rights tabulation.

5.6.5.2 Aggregate Reservoirs

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

5.7 Instream Flow Files

5.7.1 Instream Station File (*.ifs)

Eight instream flow reaches are defined in this file, which is created by 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 White River model along with its maximum flow rate. With the exception of instream flow structure 954433, these rights represent decrees acquired by CWCB.

Structure 954433 represents an un-decreed minimum bypass requirement below Taylor Draw Reservoir. The Final Environmental Impact Statement (Army Corps of Engineers, June 1982) and biological opinion (Letter from U.S. Fish and Wildlife Service to Army Corps of Engineers, May 20, 1982) for the Taylor Draw Project indicate that the operation of the project would allow for bypassing water to meet temperature and flow requirements for the Colorado squawfish. The project operating criterion related to the squawfish is that 200 cfs (or reservoir inflow if it is less than 200 cfs) must be maintained below the dam. This release condition currently does not come into play because the reservoir's FERC license requires that all reservoir inflow be bypassed. Furthermore inflow below 200 cfs is rare, and has not been experienced by the current operators.

Table 5.8
Instream Flow Summary

ID	Name	Location	Max Flow Rate (cfs)
431845	White River MSF	Confluence N. Fork White River and S. Fork White River to confluence Piceance Creek	200
432334	Marvine Creek MSF	Confluence W. Marvine Creek to N. Fork White River	40
432337	Miller Ck MSF	Confluence Moog Gulch to confluence White River	10
432338	North Fk White R MSF-L	Confluence Marvine Creek to confluence S. Fork White River	120
432339	North Fk White R MSF-U	Confluence Ripple Creek to confluence Marvine Creek	70
432344	South Fork White R MSF	Confluence Swede Creek to confluence N. Fork White River	80
432372	Ute Creek MSF	Papoose Lake to confluence N. Fork White River	6
954433	Taylor Draw Bypass	Below Taylor Draw Reservoir (single point)	200

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. The instream flow rights included in the White River model are all uniform. That is, the demands (decreed rates) do not vary from winter to summer as for many CWCB instream flow rights.

5.7.3 Instream Right File (*.ifr)

The instream flow right file contains the decreed flow rate and administration number for each modeled instream flow right. These data were obtained from Hydrobase, with the exception of instream flow structure 954433. This right is assigned an administration number just senior to the Taylor Draw Reservoir storage right.

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 one 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 White River model, three different types of operating rights are used:

- Type 9 – a release from storage to the river to meet a reservoir target. This operating rule type is used at both Big Beaver Creek and Taylor Draw Reservoirs because neither releases to downstream demand, and is the only type of rule used for reservoir releases in the White River model.

- 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 White River model, for example, the rule is used to satisfy demand at Meeker from a wellfield several miles upstream from the town.

- Type 22 – The type 22 operating right 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 is 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 is withdrawn from the soil reservoir to meet unsatisfied demands.

Where to find more information

- StateMod documentation describes all the different types of operating rights that can be specified in this file, and describes format of the file.

5.8.1 Big Beaver Creek Reservoir

Big Beaver Reservoir, also known as Lake Avery, is located on Big Beaver Creek, a tributary of the White River just west of Buford. The Colorado Division of Wildlife (DOW) owns and operates Lake Avery. DOW does not release from Lake Avery to provide supplemental water supplies, but maintains the reservoir for recreational and piscatorial purposes. A single operating right is used to specify Lake Avery operations:

Right #	Destination	Reservoir Account	Admin #	Right Type	Description
1	N/A	1	99999.99999	9	Release to target

Operating right 1 releases water when reservoir contents exceed the end-of-month maximum storage target. The administration number is set to a very high value so that the release occurs after all other operations in the time step are complete. In the Baseline data set, the target is set to the reservoir capacity, which effectively disables the operating rule. This is because the reservoir currently makes no releases for downstream flow maintenance or to downstream users. In the calibration run, maximum targets are set to historical end-of-month contents, and this rule allows the reservoir to mimic historical operations unrelated to downstream water supply.

5.8.2 Taylor Draw Reservoir

Taylor Draw Reservoir, or "Kenney Reservoir", is on the White River just east of Rangely. Kenney Reservoir is used only for hydropower and recreation, although it is decreed for irrigation, municipal, domestic, and stock use as well. The reservoir is operated for run-of-the-river power generation, under a FERC license requiring that they pass inflows through the reservoir.

A single operating right is used to simulate Kenney Reservoir operations:

Right #	Destination	Reservoir Account	Admin #	Right Type	Description
1	N/A	1	99999.99999	9	Release to target

Operating right 1 releases water when reservoir contents exceed the end-of-month maximum storage target. The administration number is set to a very high value so that the release occurs after all other operations in the time step are complete. In the Baseline data set, the target is set to the reservoir capacity, which effectively disables the operating rule. This is because the reservoir currently makes no releases for downstream flow maintenance or to downstream users. In the calibration run, maximum targets are set to historical end-of-month contents, and this rule allows the reservoir to mimic historical operations unrelated to downstream water supply.

No operating right is required for the minimum bypass requirement, since water is not taken out of storage to satisfy the requirement. The administration number of the bypass requirement is just senior to the reservoir storage right, which causes the model to allocate water to the bypass before it allocates water to the reservoir. In this way, the bypass is maintained.

5.8.3 Town of Meeker

The Town of Meeker Demand (WDID 950810) is satisfied by diversions from a wellfield (WDID 436045) several miles upstream from the Town. The demand for the Town is at a node separate from the wellfield because in the Historical and Calculated data sets, the Town is satisfied by a surface diversion near the Town (WDID 430810) through 2002, and by the wellfield afterwards. Without that history, it would have been possible to place the Town's demand at the wellfield and use direct diversion rights to satisfy it. Instead, the demand is placed at node 950810 and carrier operating rights are used to move water from the diversion structure to the demand.

Right #	Destination	Admin #	Right Type	Description
1	Town of Meeker Demand	27265.19854	11	Carrier to direct diversion
2	Town of Meeker Demand	36648.00001	11	Carrier to direct diversion
3	Town of Meeker Demand	39313.00001	11	Carrier to direct diversion

Operating rights 1 through 3 correspond to the wellfield's three most senior water rights, which are the source of water in these operating rights. These rights are alternate points for rights originally decreed to the Town's historical surface diversion structure (430810). The administration number is just junior to the original water rights' administration numbers.

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 White River model characterizes it, under these assumptions.

6.1 Baseline Streamflows

Table 6.1 shows, for each gage, the average annual flow from the Baseline simulation, based on the entire simulation period (1909 – 2006) water years. In general, this value is presumably a little 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 or equal to the total simulated flow.

Figure 6.1 illustrates the average annual simulated gage flow and available flow, in geographic context. Two bars are shown at each gage location. The bar on the left represents the total simulated gage flow, and the bar on the right represents the available flow.

Temporal variability of the historical and Baseline simulated flows for all the modeled gages is illustrated in Figures 6.2 through 6.14. Each figure shows two graphs: an average annual hydrograph based on the entire modeling period; and overlain hydrographs of historical gage flow, simulated gage flow, and simulated available flow for 1975 through 2006. The annual hydrograph is a plot of monthly average flow values, for the three parameters.

Table 6.1
Simulated Baseline Average Annual Flows for White River Gages

Gauged ID	Gage Name	Simulated Flow (af)	Simulated Available Flow (af)
9303000	North Fork White River At Buford	228,210	133,022
9303400	South Fork White River Near Budges Resort, Co.	141,707	85,590
9303500	South Fork White River Near Buford, Co.	185,562	114,767
9304000	South Fork White River At Buford	184,036	121,495
9304200	White River Above Coal Creek	402,029	259,990
9304500	White River Near Meeker	442,323	293,947
9304800	White River Below Meeker	476,938	324,340
9306007	Piceance Creek Below Rio Blanco	10,050	8,402
9306200	Piceance Creek Below Ryan Gulch	18,073	17,084

Gauged ID	Gage Name	Simulated Flow (af)	Simulated Available Flow (af)
9306222	Piceance Creek At White River	21,616	21,587
9306224	White River Above Crooked Wash Near White River City	528,075	375,305
9306290	White River Below Boise Creek Near Rangely	506,049	375,863
9306395	White River Near Colorado State Line, UT	521,098	521,098

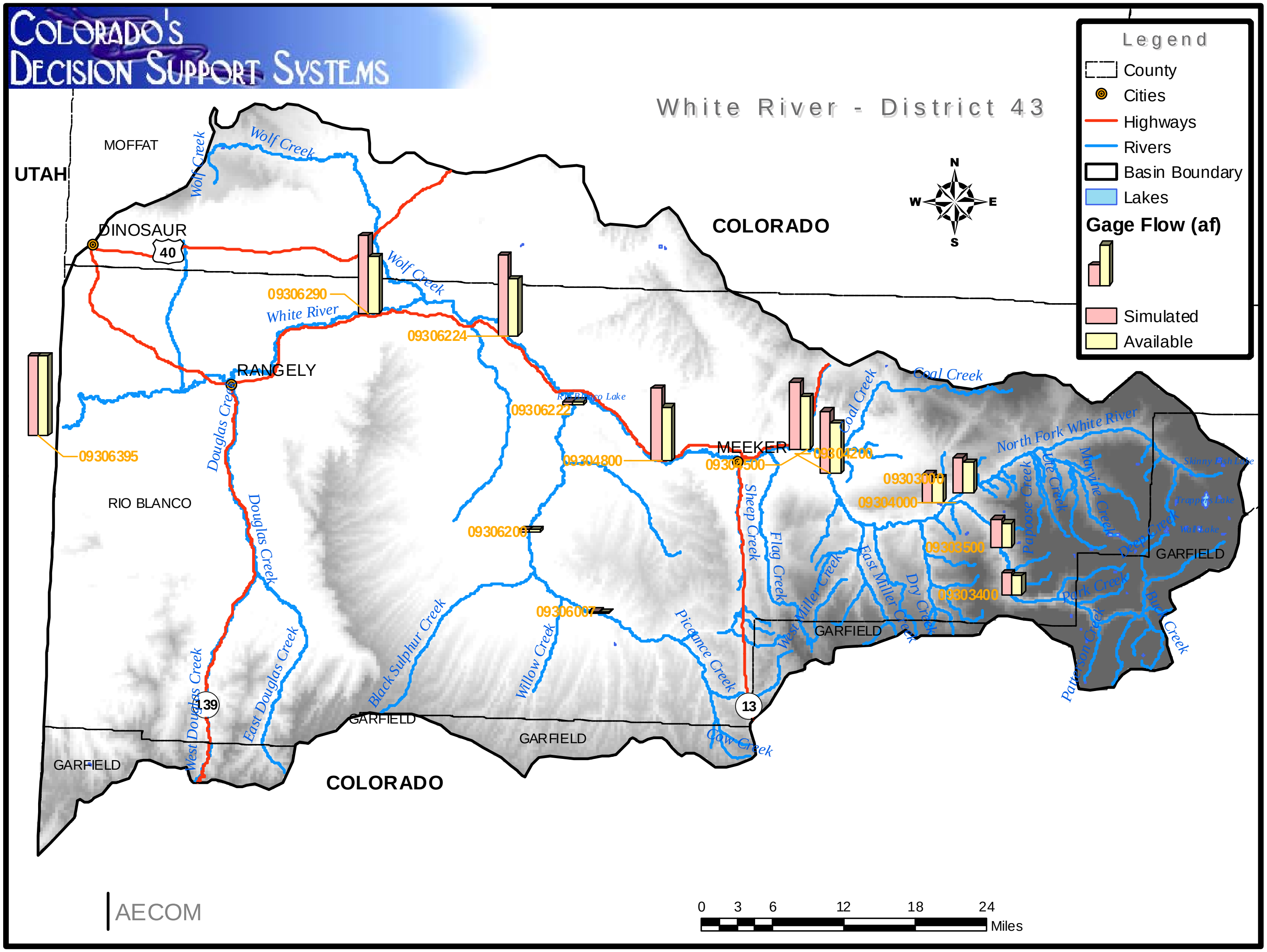
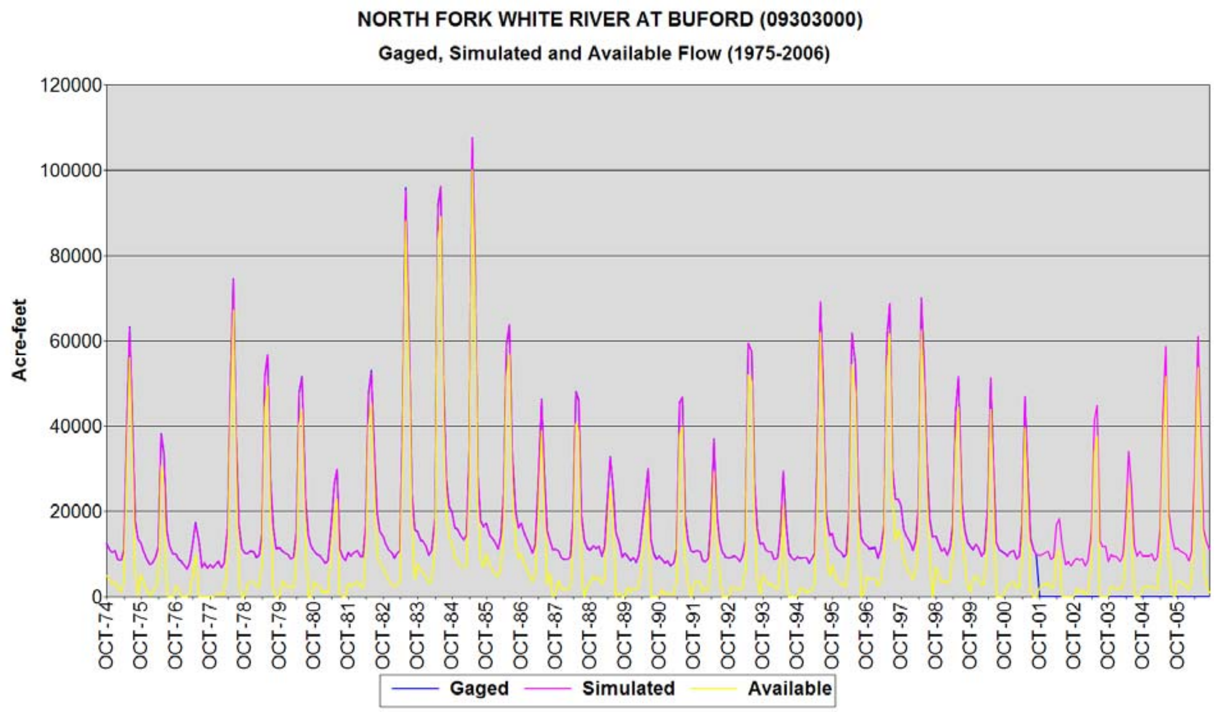


Figure 6.1 - Average Annual Simulated Gage Flow (Left) and Average Annual Available Gage Flow (Right) at White Model Gages



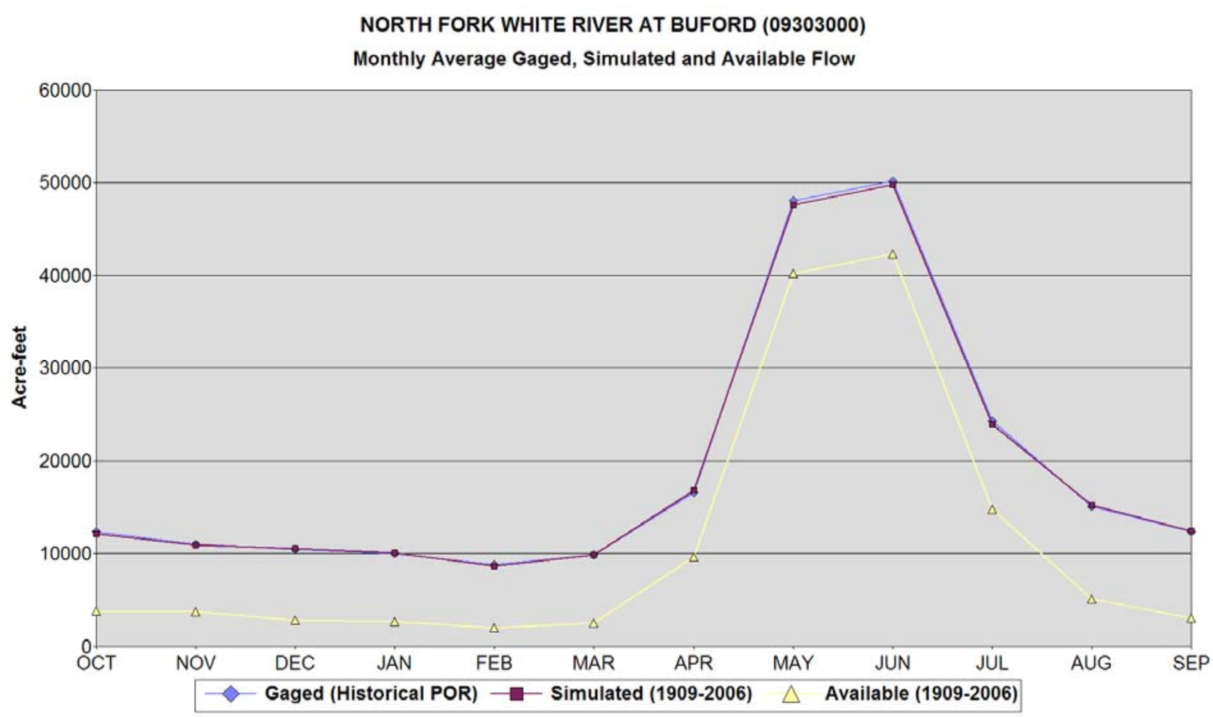
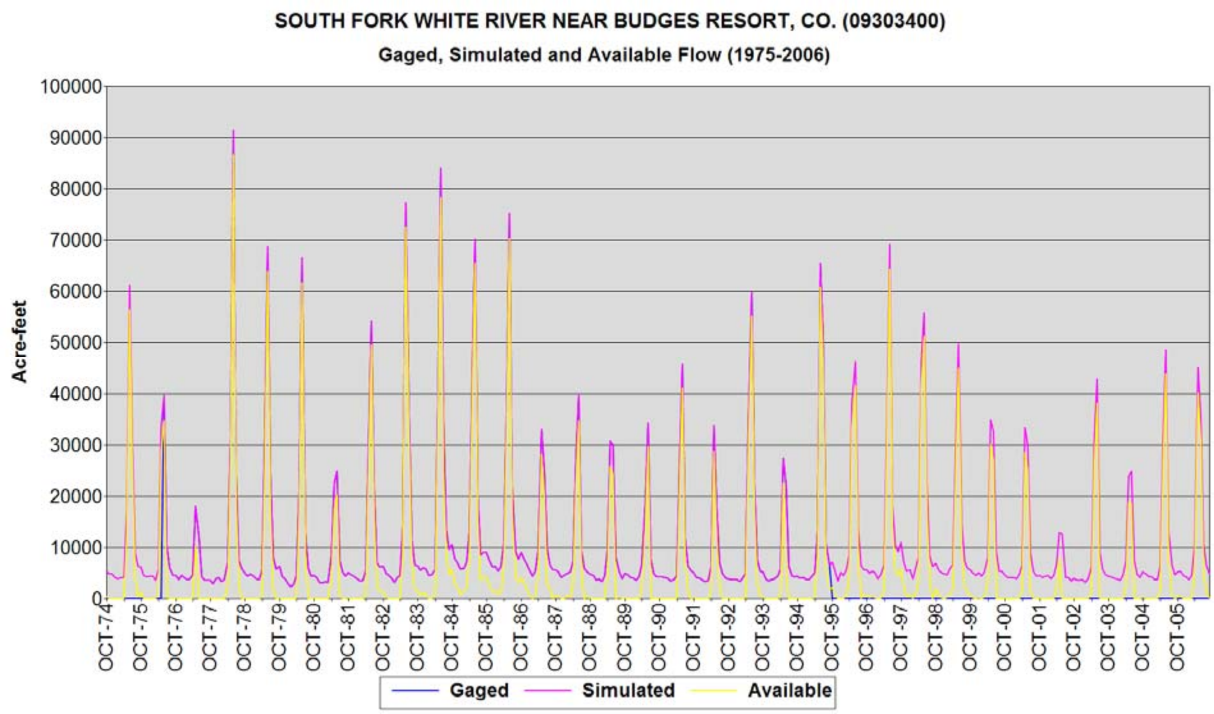


Figure 6.2 - Gaged, Baseline Simulated, and Available Flows



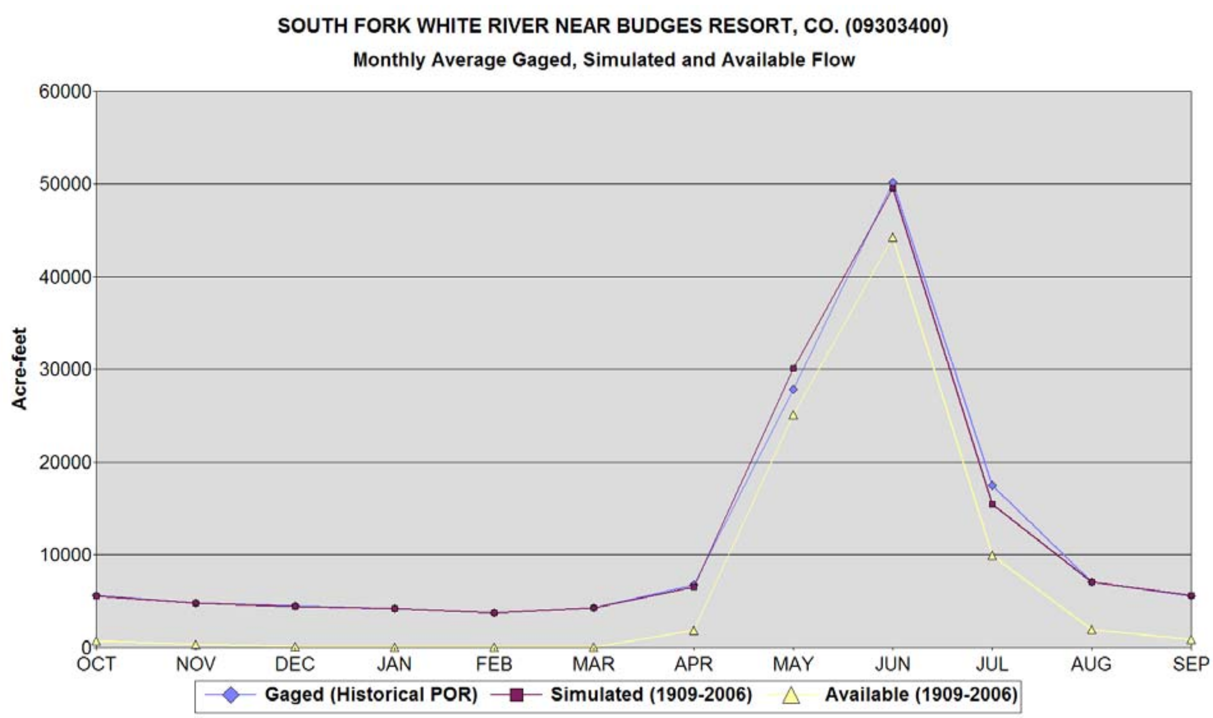
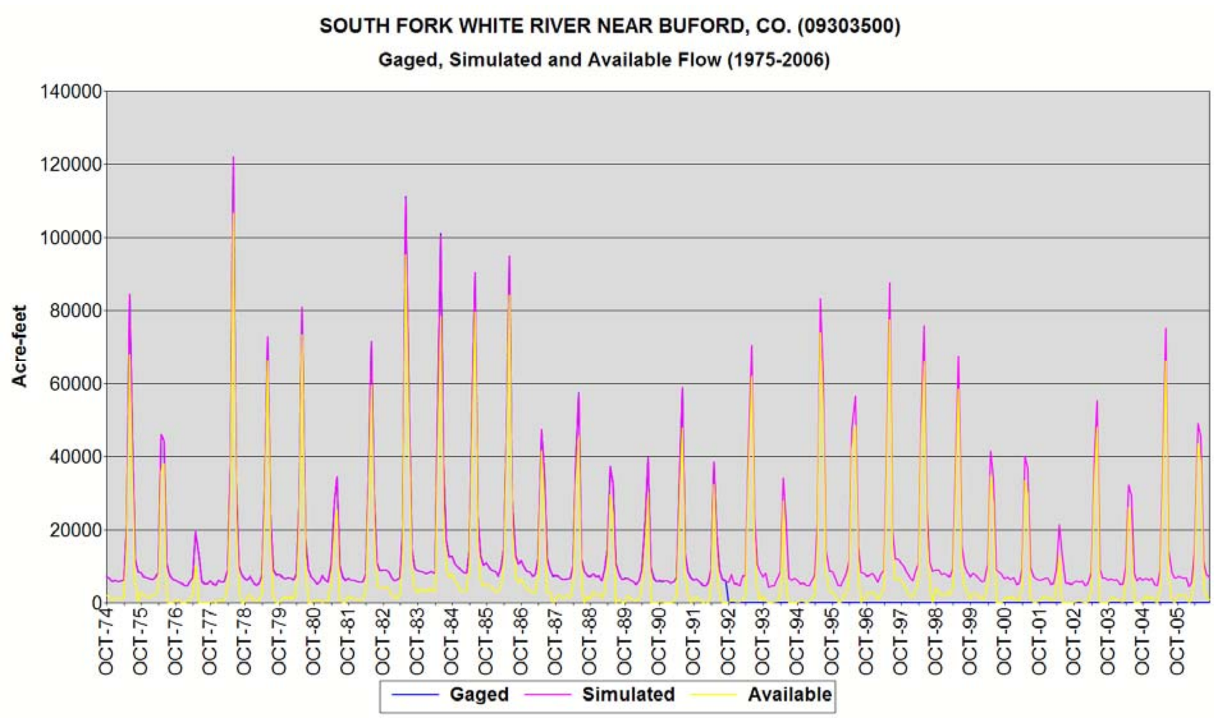


Figure 6.3 - Gaged, Baseline Simulated, and Available Flows (South Fork White River near Budges Resort, CO.)



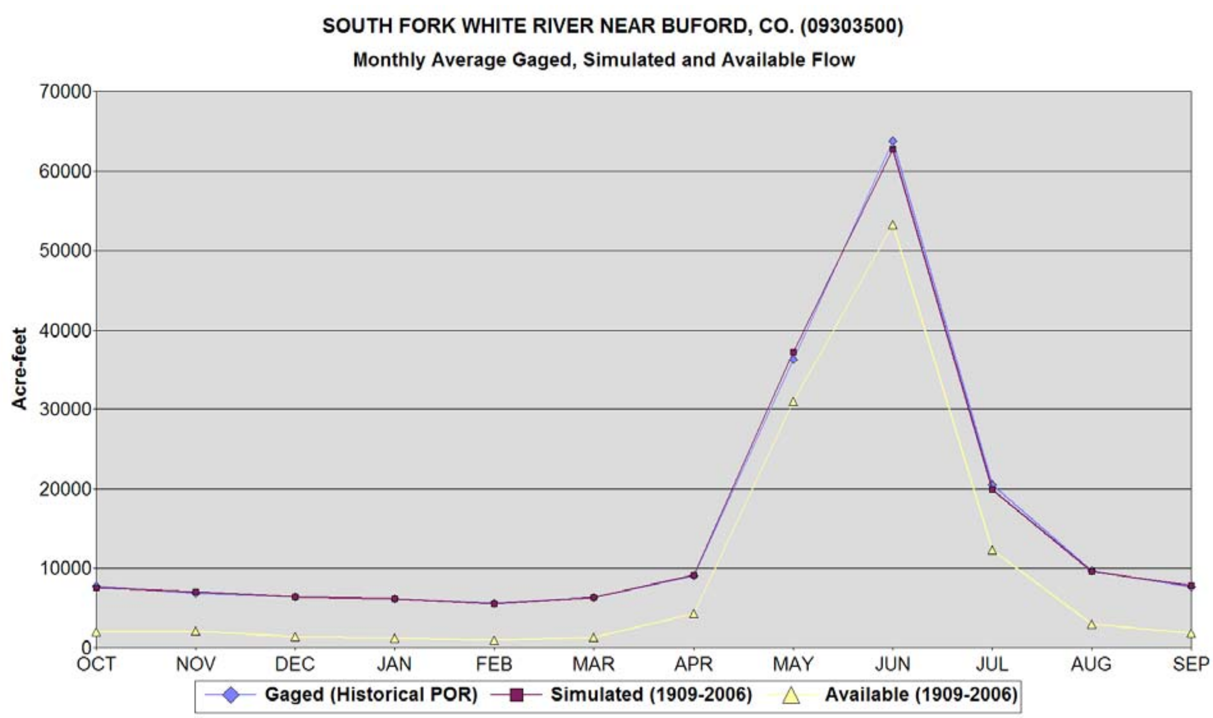
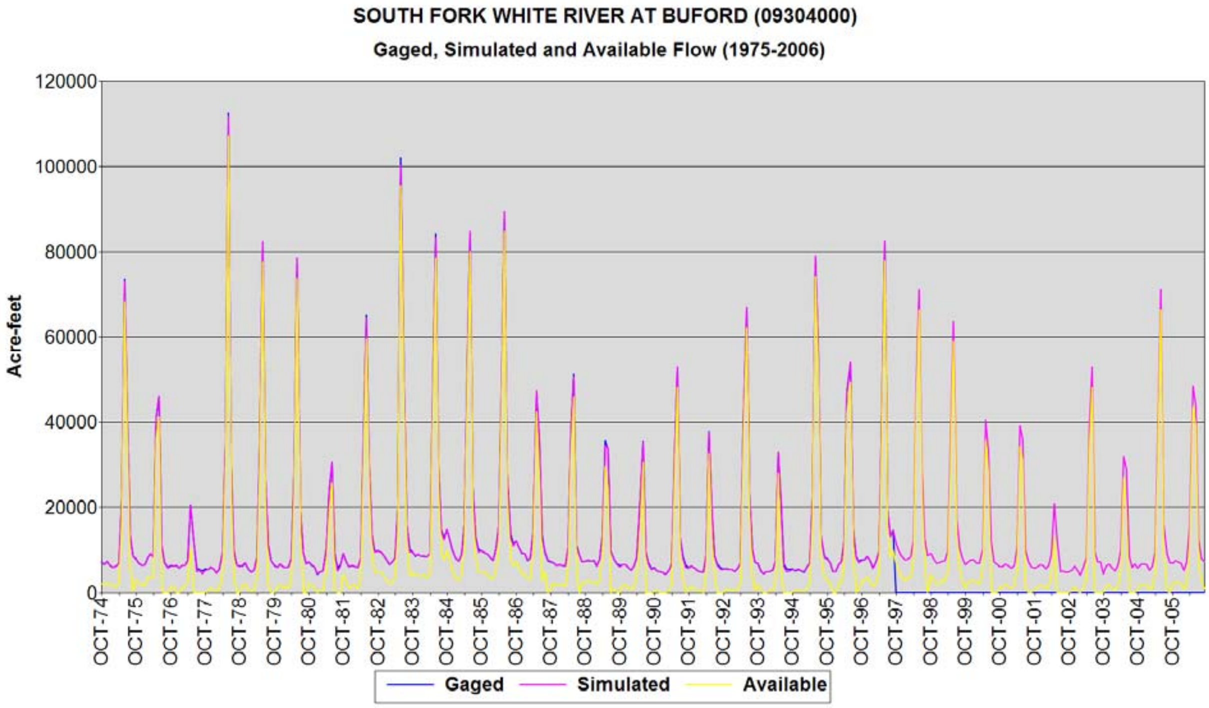


Figure 6.4 - Gaged, Baseline Simulated, and Available Flows (South Fork White River Near Buford, CO.)



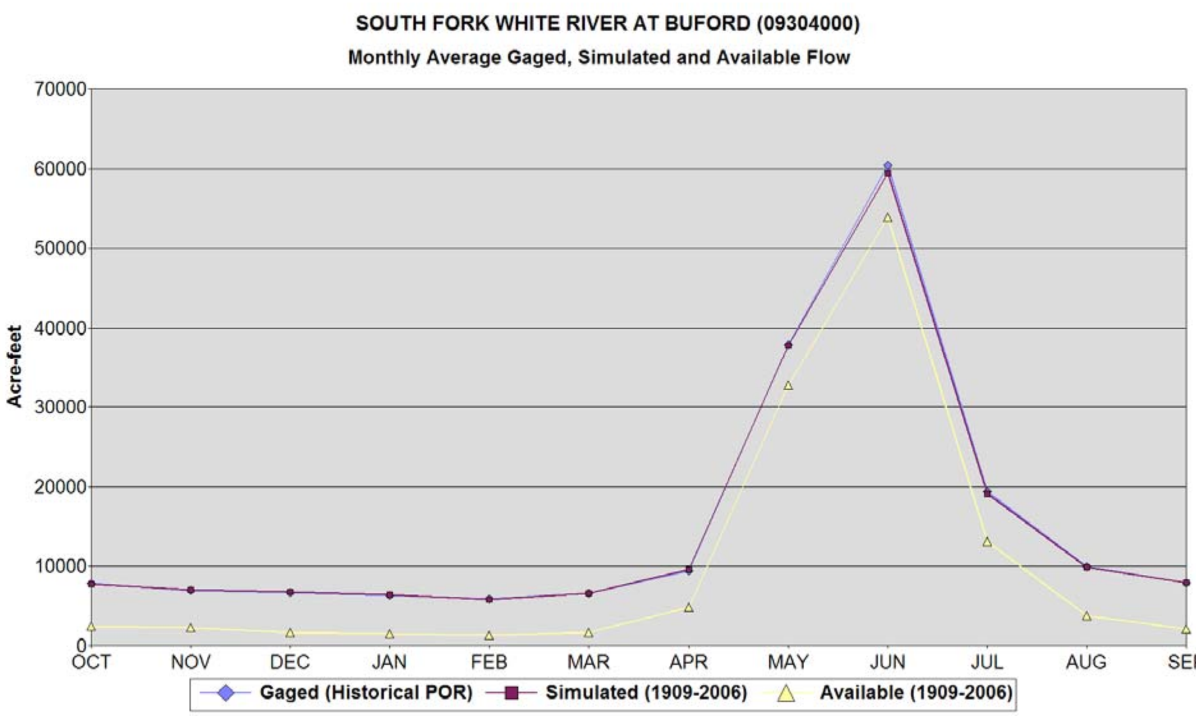
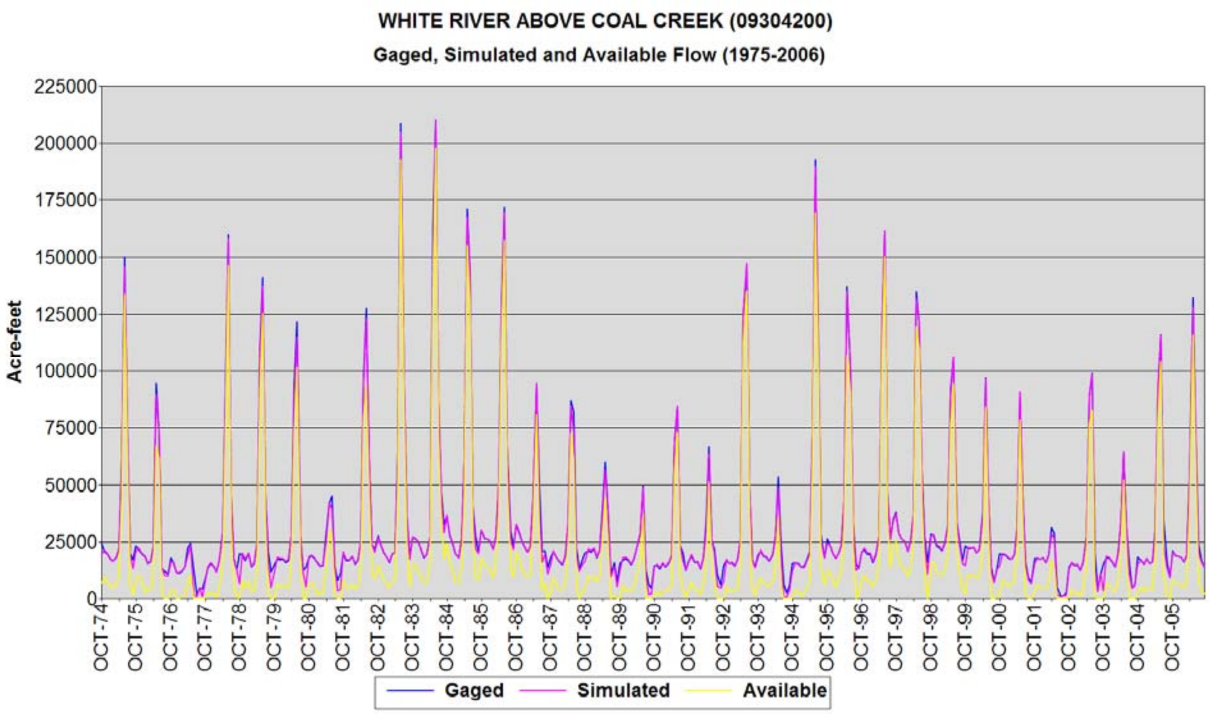


Figure 6.5 - Gaged, Baseline Simulated, and Available Flows (South Fork White River at Buford)



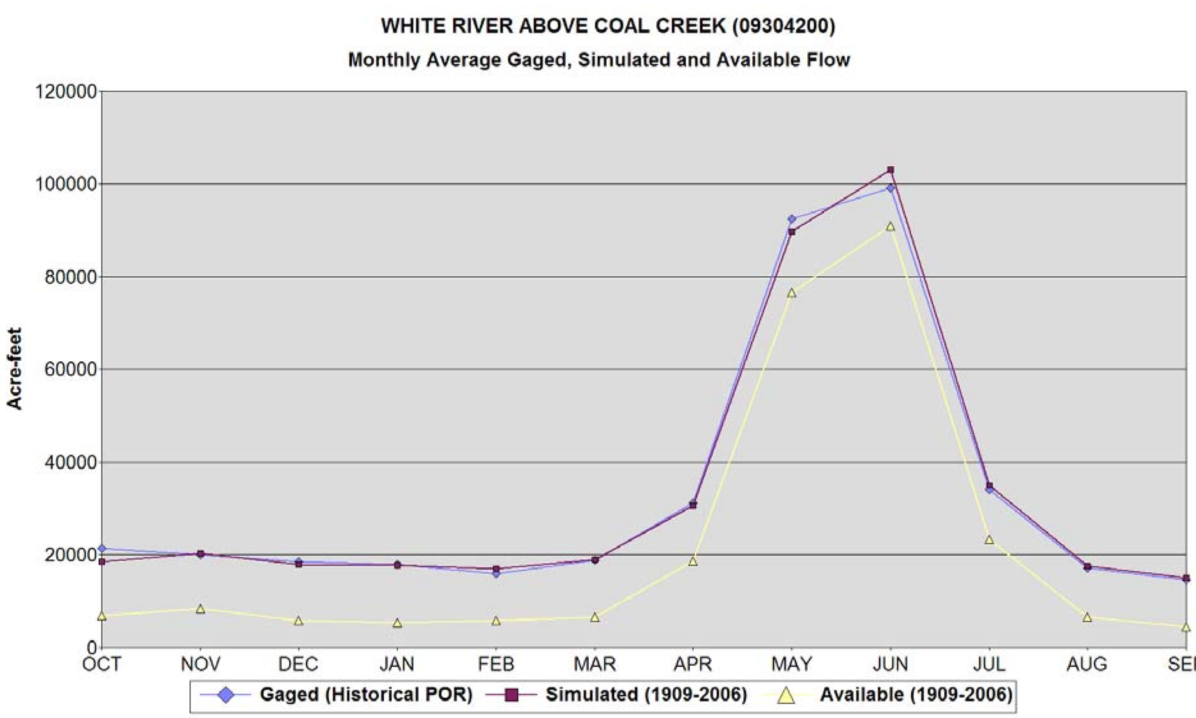
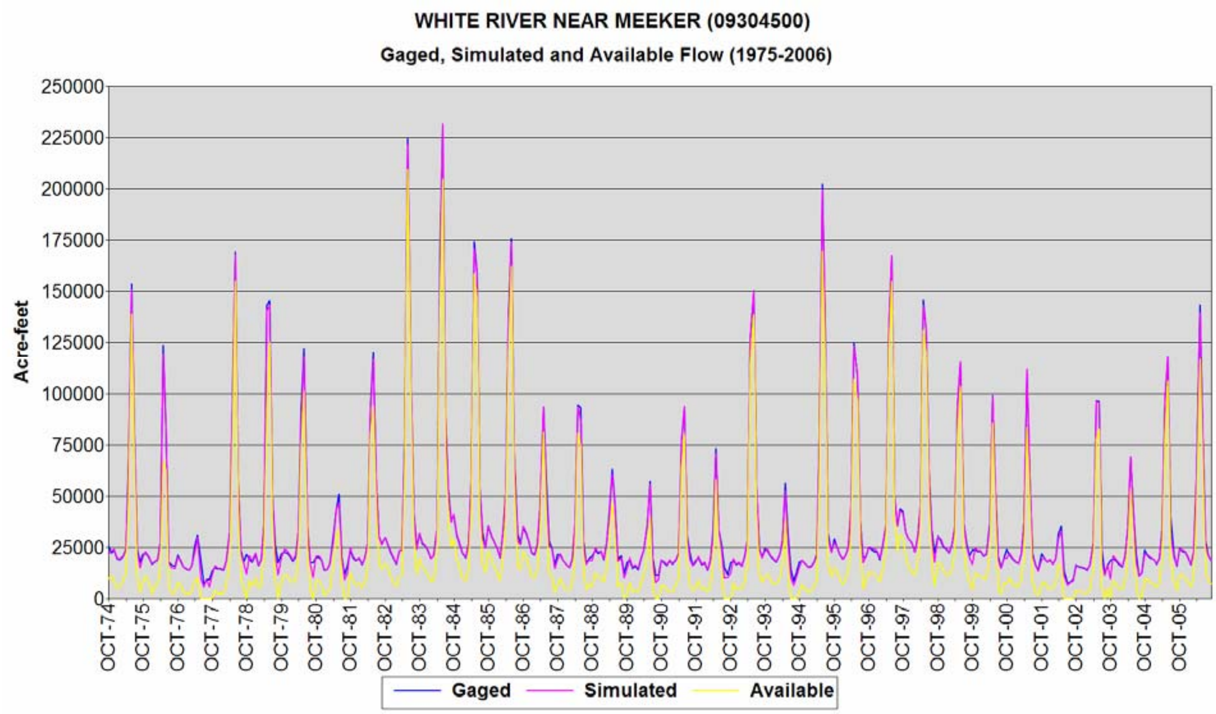


Figure 6.6 - Gaged, Baseline Simulated, and Available Flows (White River above Coal Creek)



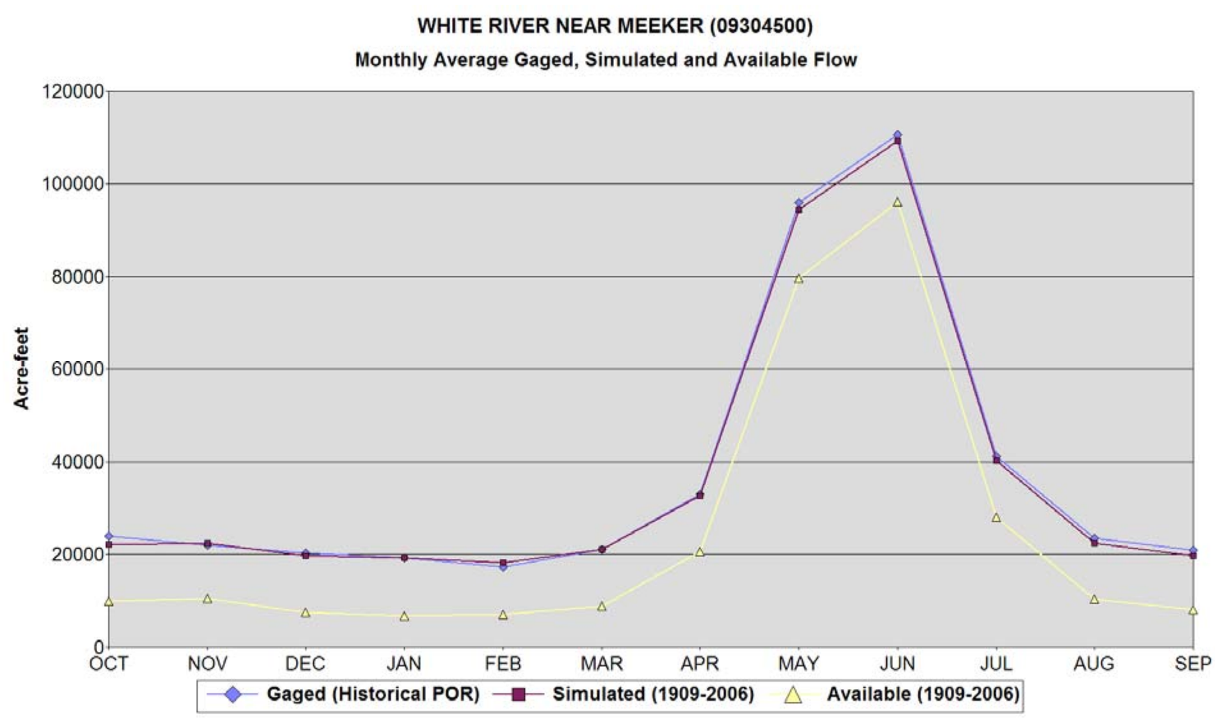
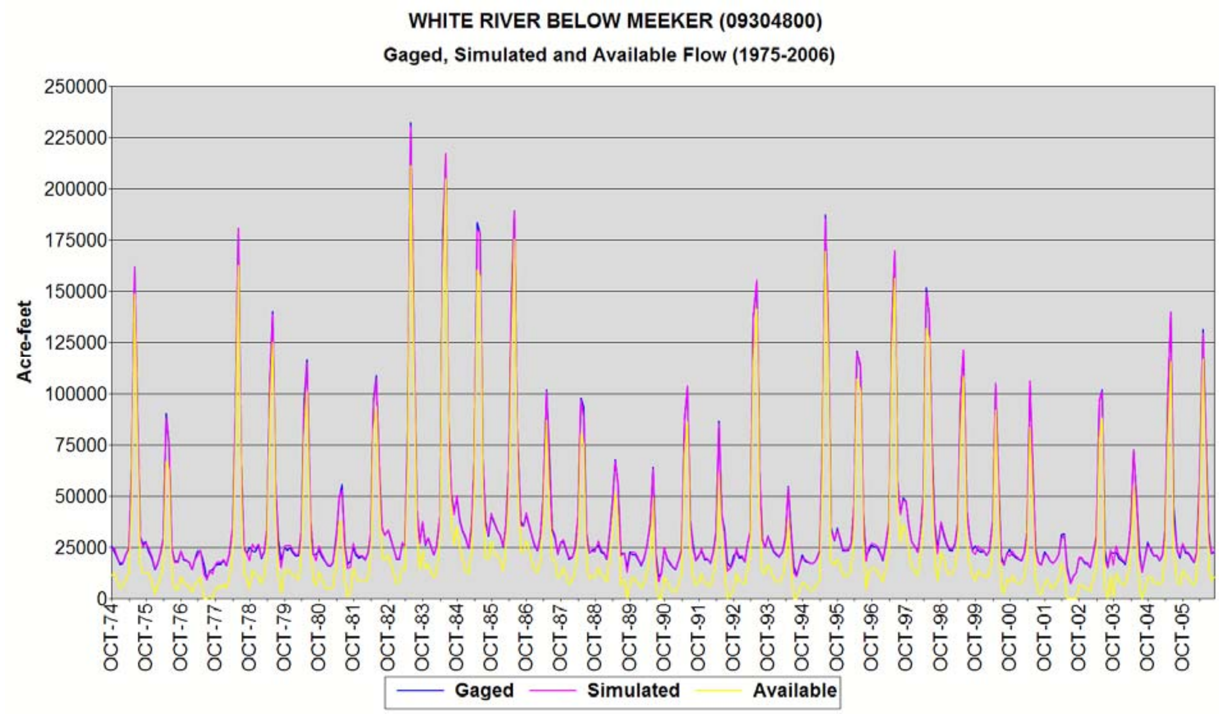


Figure 6.7 - Gaged, Baseline Simulated, and Available Flows (White River near Meeker)



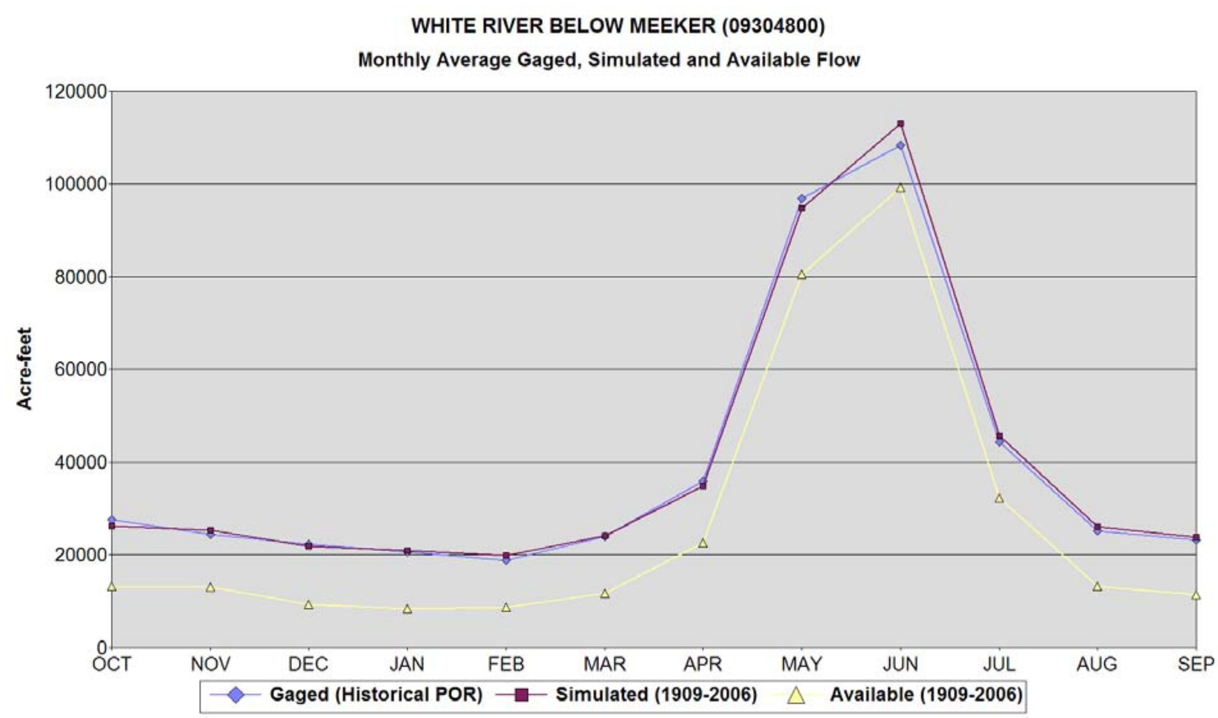
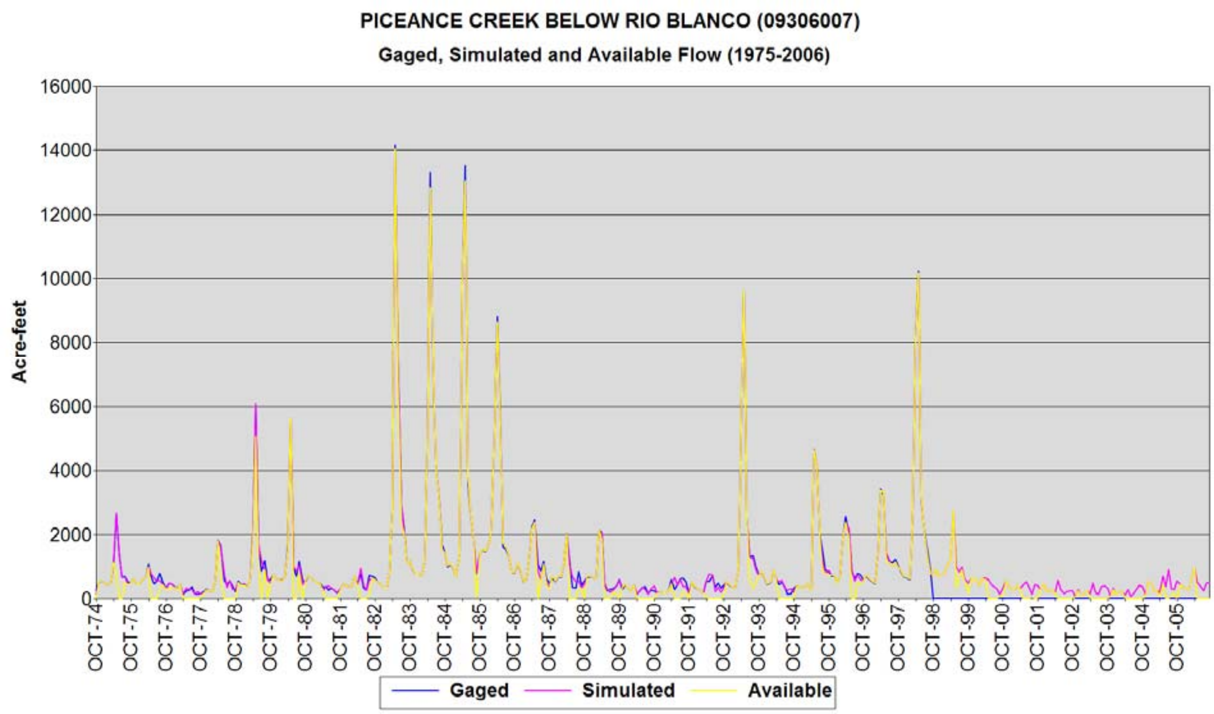


Figure 6.8 - Gaged, Baseline Simulated, and Available Flows (White River below Meeker)



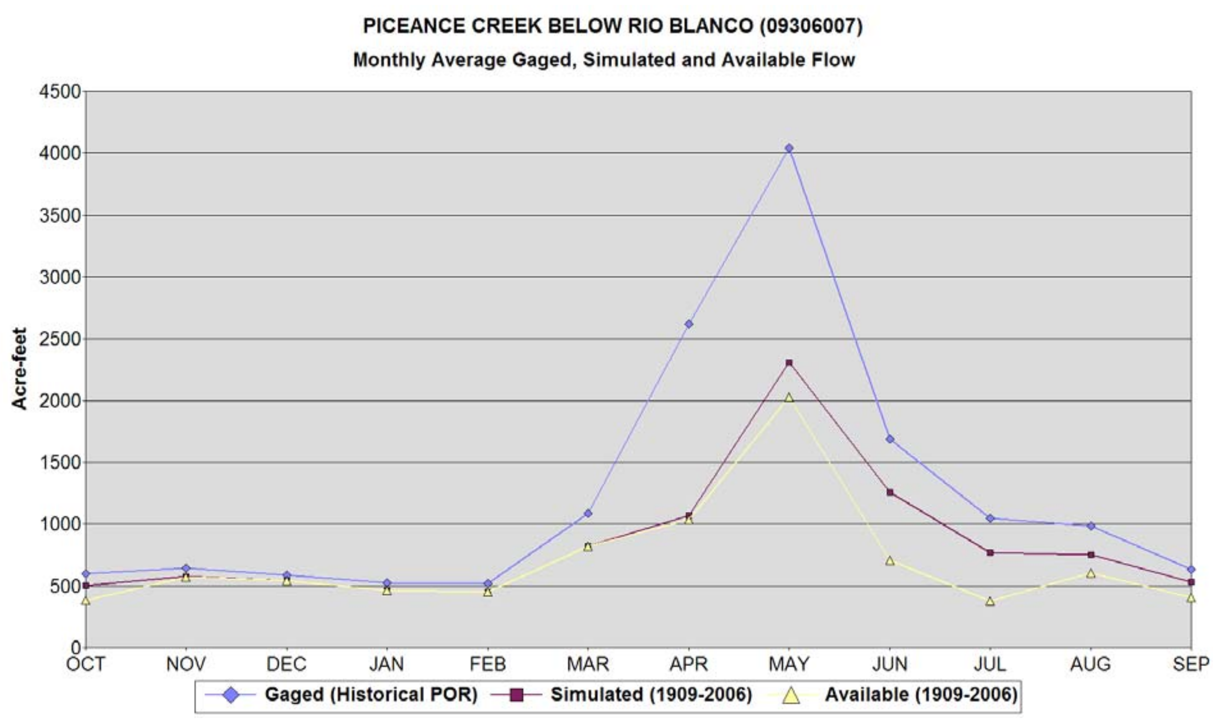
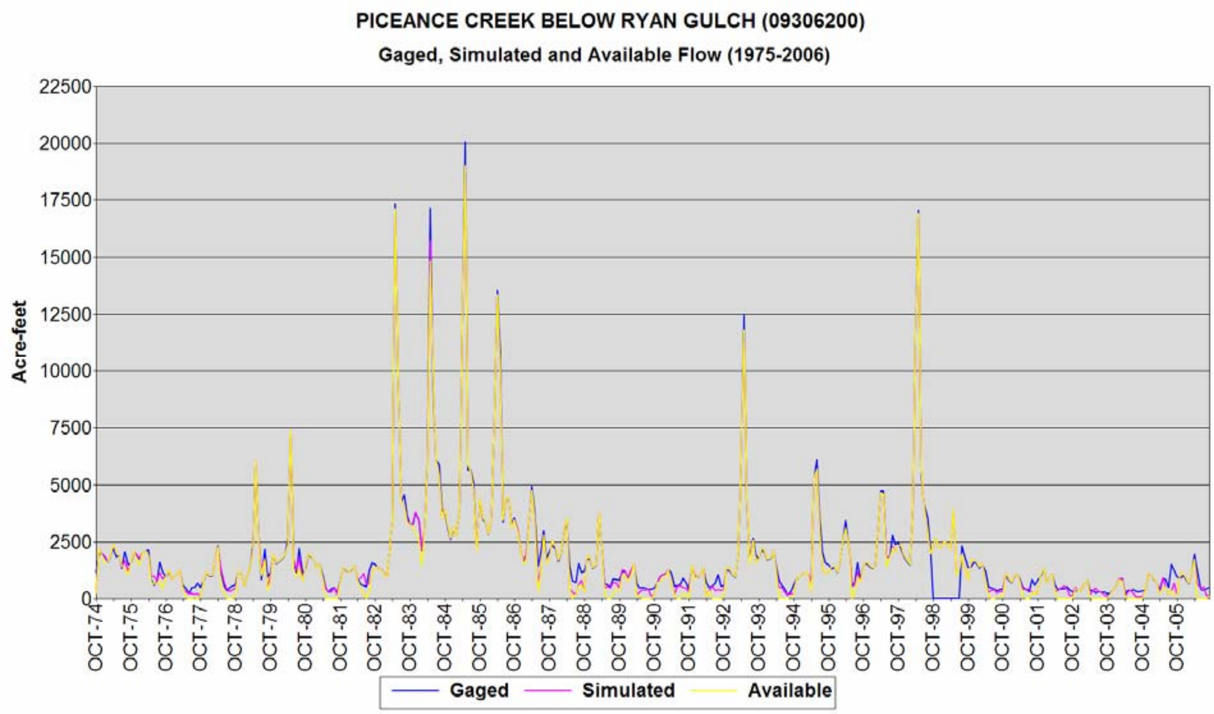


Figure 6.9 - Gaged, Baseline Simulated, and Available Flows (Piceance Creek below Rio Blanco)



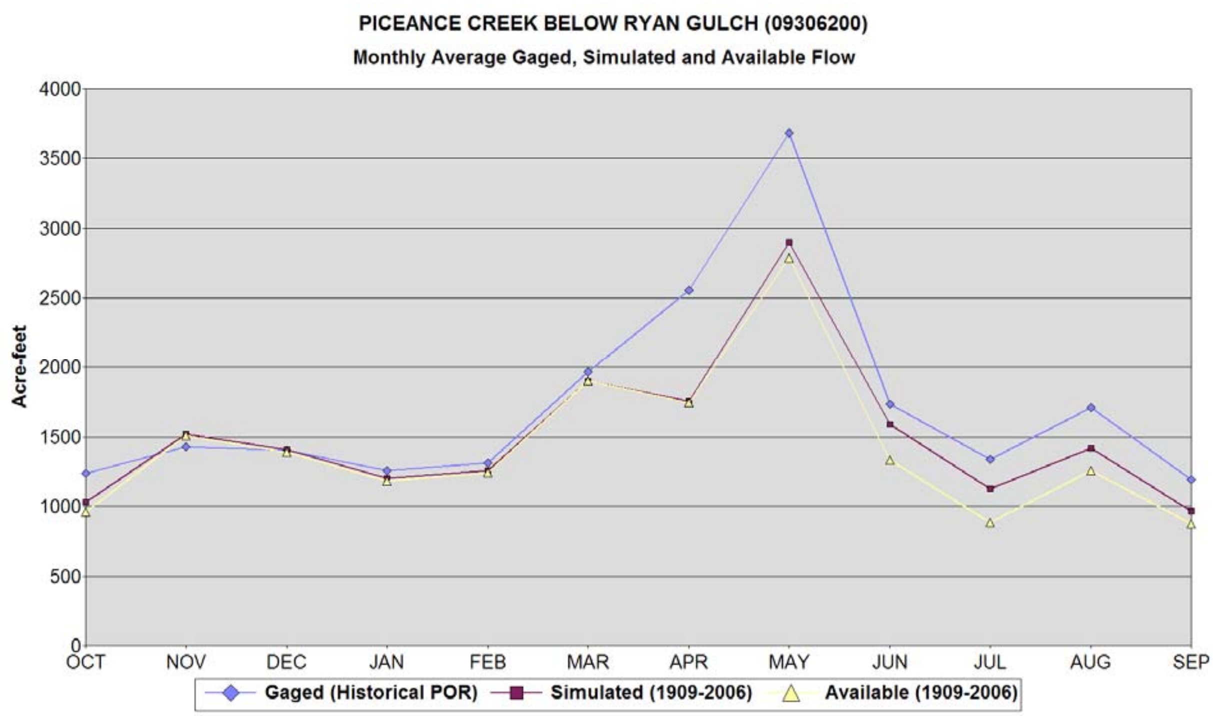
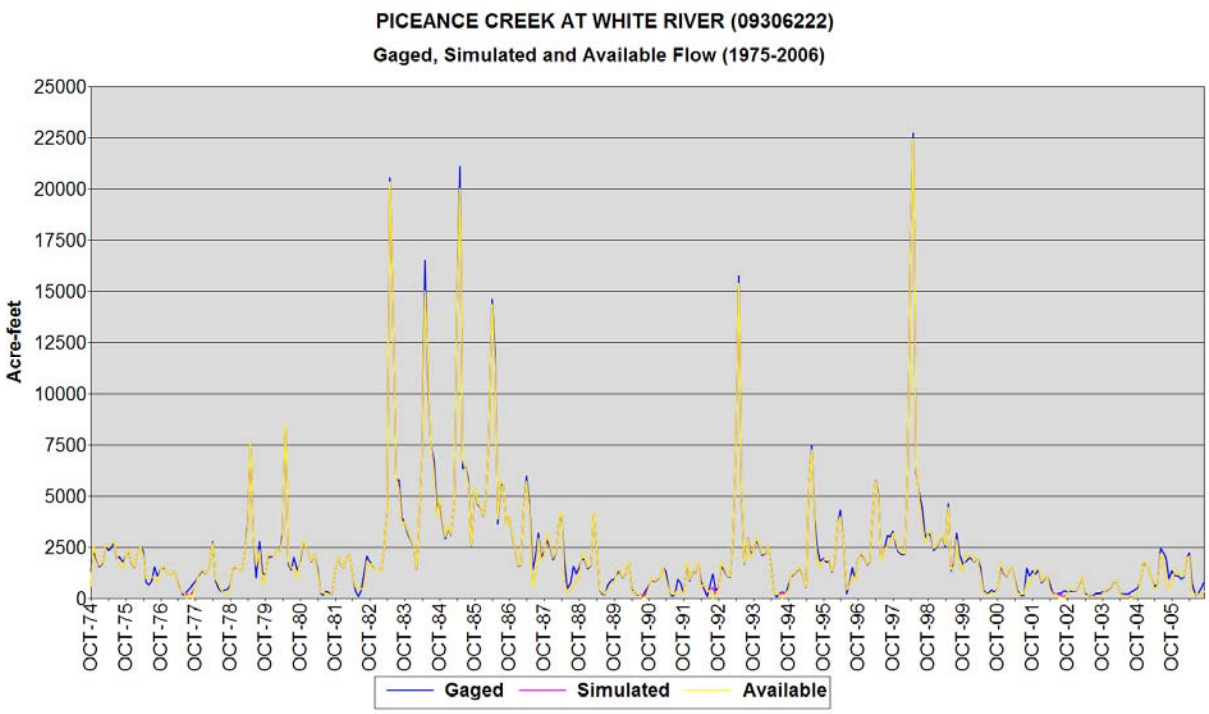


Figure 6.10 - Gaged, Baseline Simulated, and Available Flows (Piceance Creek below Ryan Gulch)



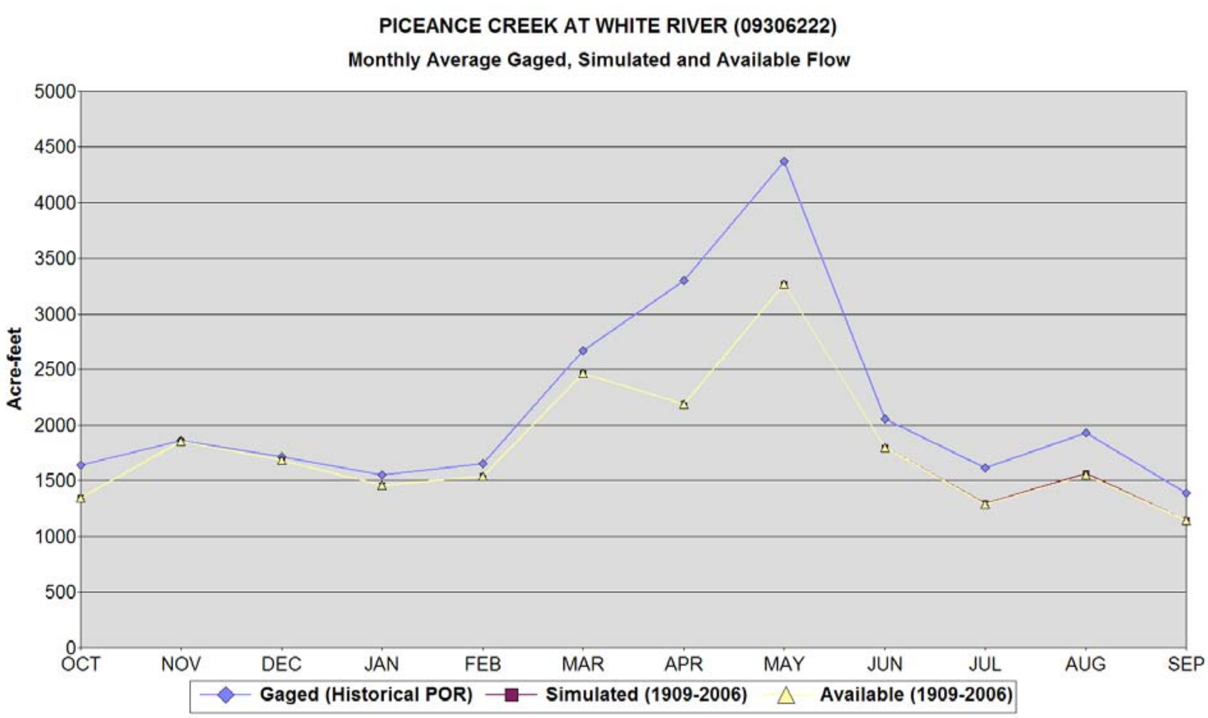
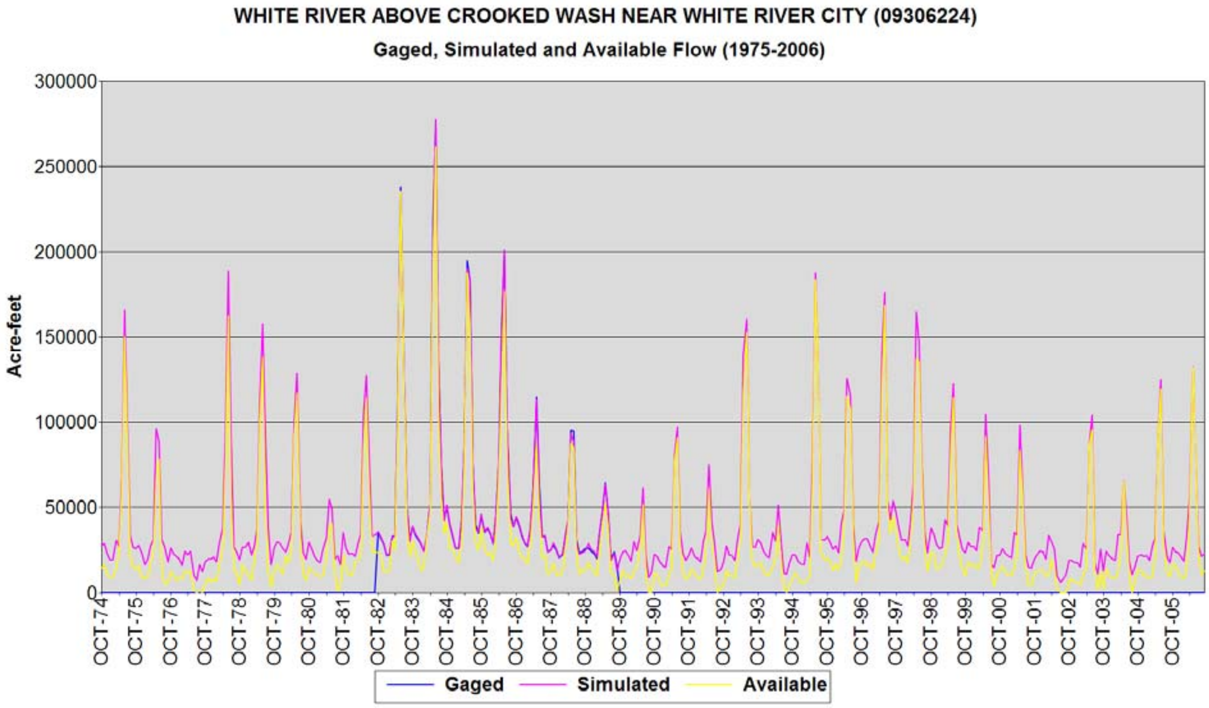


Figure 6.11 - Gaged, Baseline Simulated, and Available Flows (Piceance Creek at White River)



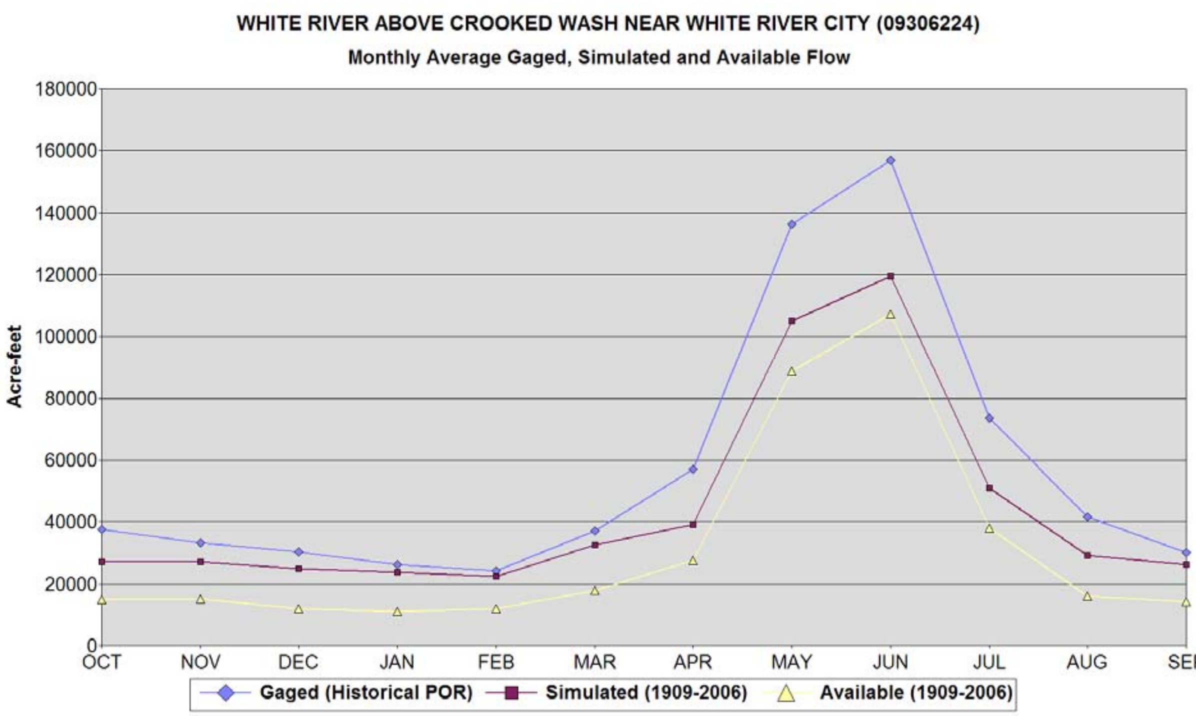
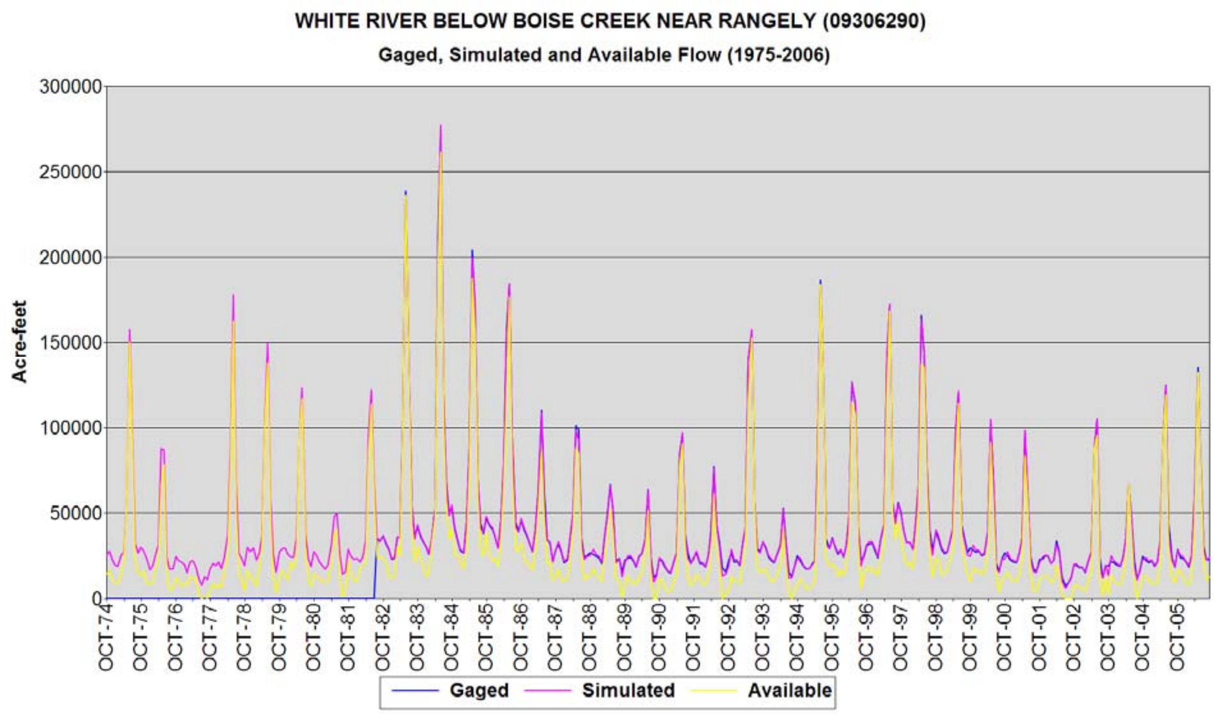


Figure 6.12 - Gaged, Baseline Simulated, and Available Flows (White River above Crooked Wash near White River City)



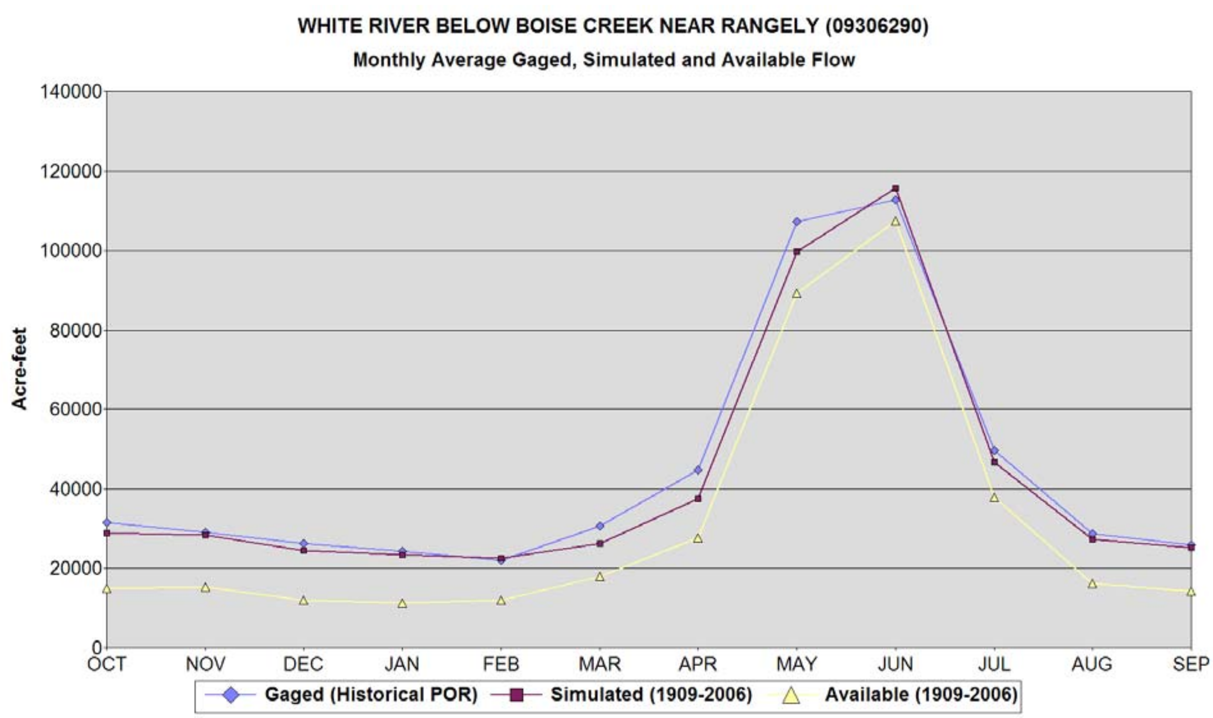
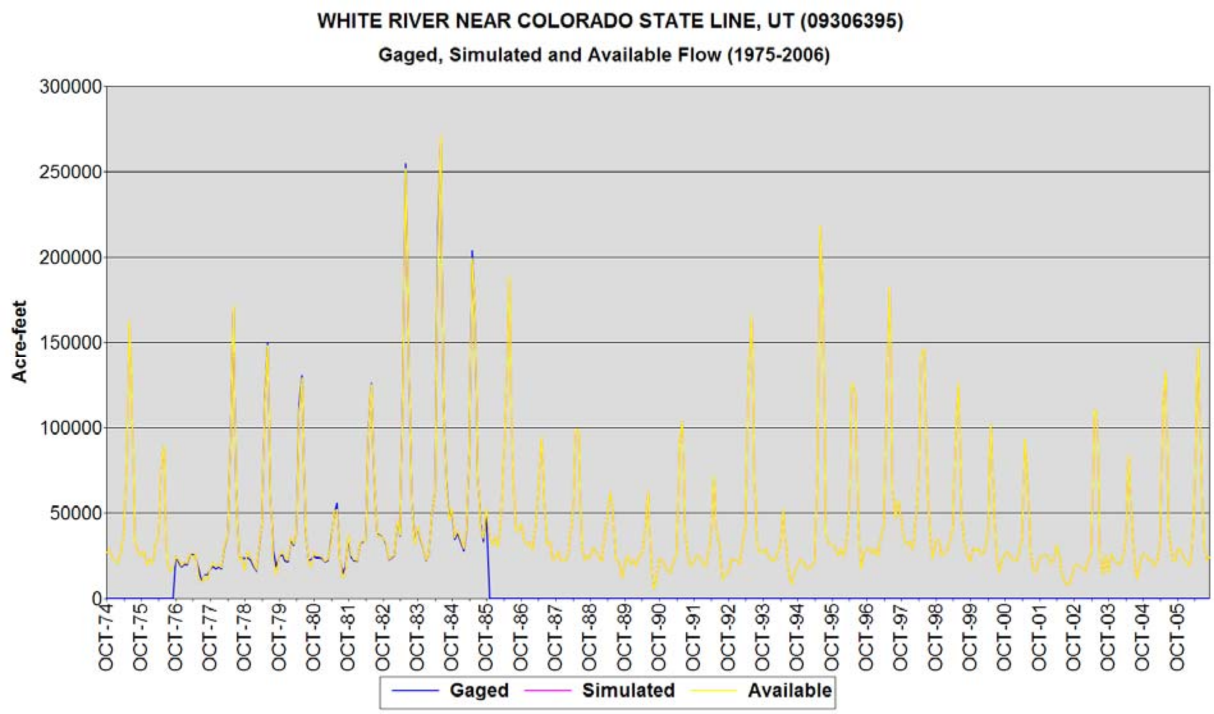


Figure 6.13 - Gaged, Baseline Simulated, and Available Flows (White River below Boise Creek near Rangely)



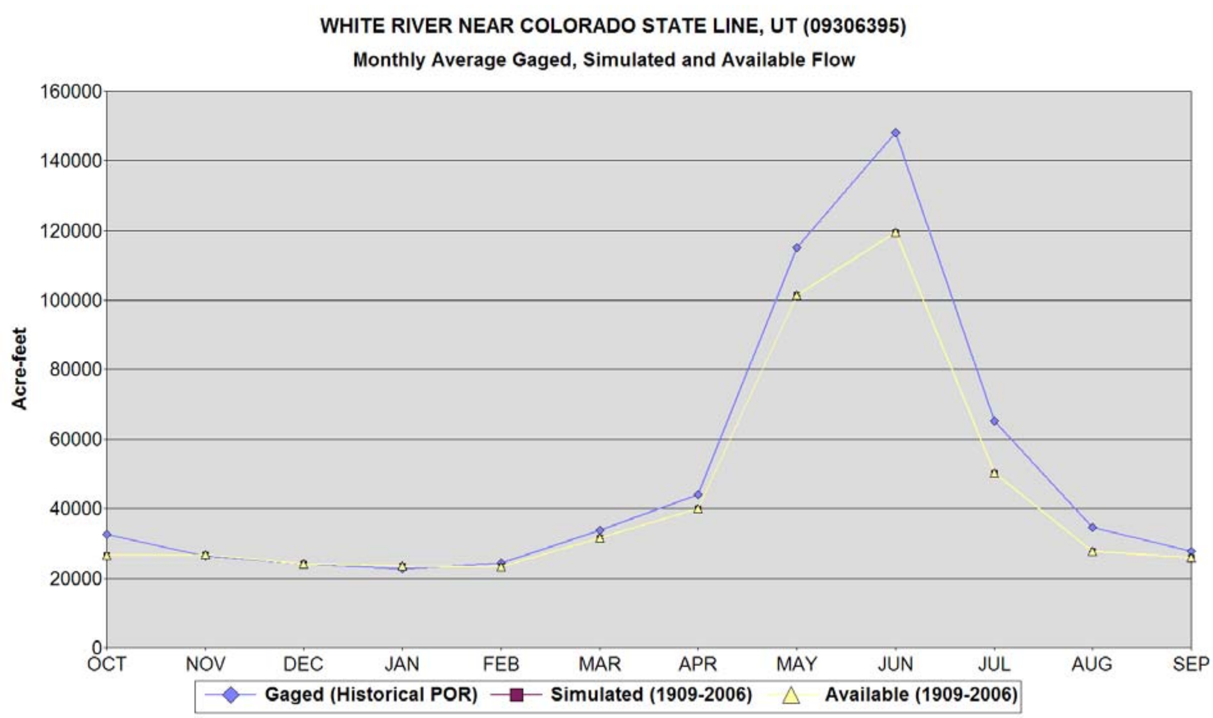


Figure 6.14 - Gaged, Baseline Simulated, and Available Flows (White River near Colorado State Line, UT

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 White River model. It describes specific areas of the basin that were worked on, and it presents summaries comparing modeled results for 1975 through 2006 with historical values for the period.

7.1 Calibration Process

The White River model was calibrated using the period 1975 through 2006. In the calibration data set (the Historical data set) 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 to the stream to achieve their historical end-of-month contents. 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 occur. 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. Modeled 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 higher up, and typically, that type of change is accompanied by an offsetting reduction in incremental inflow lower in the system. Calibration might also expose errors such as incorrect placement of a gage or return flows.

7.2 Historical Data Set

Calibration is based on supplying input that represents historical conditions, so that resulting simulated 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 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.

7.2.2 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 to zero (as they were historically in 1909), and storage targets (*.tar file) are set to zero until the reservoir actually began to fill. Storage targets assume the value of the historical end-of-month contents.

7.2.3 Operational Rights File

Operational rights in the Historical simulation reflect the operations that were in place historically, and how they may have changed over time. In contrast, the Baseline operational rights file reflects our best estimate of how reservoirs and systems work now or in the near future. For instance, the Town of Meeker used one source of water through 2002, and a different source after 2002. Accordingly, the Historical operational rights file has two sets of rights governing the Town of Meeker, operating over the appropriate time periods. The Baseline operational rights file has only the post-2002 operational rights in it, and they are in force throughout the simulation.

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	Historical diversions
Reservoir target (*.tar)	Current maximum capacity	Historical e/o/m contents, 0 prior to historical operation
Operational right (*.opr)	Simulate current operations	Simulate historical operations

7.3 Calibration Issues

This section describes areas of the model that were investigated during calibration of the White River model.

7.3.1 Highland Ditch Return Flow Distribution

Originally, the largest shortages and greatest magnitude negative baseflows in the model were on Coal Creek. Return flow locations for diversions in the reach from gage 09304200 White River above Coal Creek to gage 09304500 White River near Meeker were reviewed, because return flows are a negative term in the baseflow computation. The majority of non-consumed flows from the Highland Ditch (430694) were found to be modeled as returning to South Side Highline Ditch (430935), above the "near Meeker" gage . Figure 7. shows that much of the Highland Ditch irrigated acreage is located downstream from the South Side Highline Ditch headgate. New fractions were tested with the result that 60 percent of the Highland Ditch returns were assigned to the Sheridan and Morton Ditch (430926), just below the "near Meeker" gage, and 40 percent were assigned, or left at, the South Side Highline Ditch. This distribution was selected based on the trade off between reduction in shortages in Coal Creek and reduction in negative baseflows in the downstream tributary (Flag Creek). The change resulted in over 60 percent reduction in negative baseflows on Coal Creek and a significant reduction in shortages on that tributary.

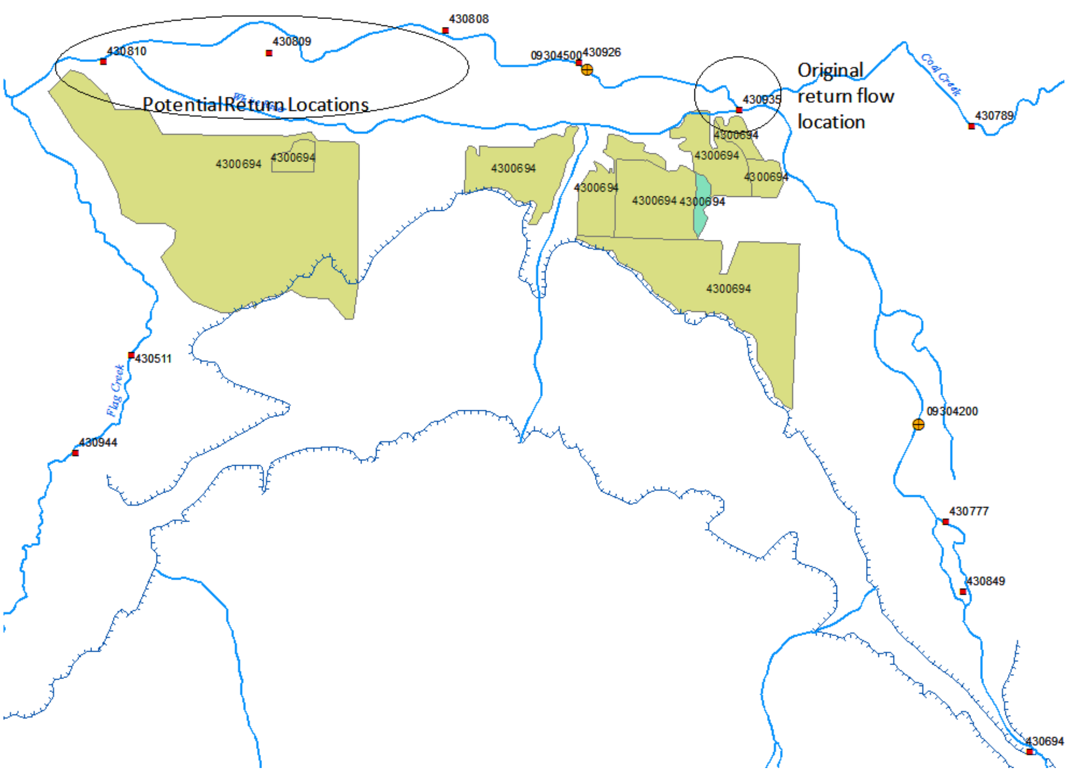


Figure 7.1 - Highland Ditch Irrigated Fields and Return Locations

7.3.2 Coal Creek Mesa Ditch Return Flows

The review of return flows described above also revealed that Coal Creek Mesa Ditch (430578) returns were modeled as accruing to Oak Ridge Park Ditch (430848). This situation was reviewed with the Water Commissioner, who noted that Oak Ridge Park Ditch irrigates lands on both sides of Coal Creek, over which it is flumed. While Oak Ridge Park Ditch might intercept water from Coal Creek Mesa Ditch irrigated acreage that supply is not reflected in the Oak Ridge Park Ditch diversions of record. Including the return flows in the baseflow computation for the gage-to-gage reach in which structure 430848 is located underestimates natural flow at the headgate. The Coal Creek Mesa Ditch return flow location was changed from Oak Ridge Park Ditch to Martin Ditch (430789), the next downstream structure on Coal Creek. Although the change reduced baseflows in the local reach, it made water available to the Martin Ditch and increased baseflow in the gage-to-gage reach above gage 09304200 White River above Coal Creek.

7.3.3 Neighboring Gage Methodology for Selected Ungaged Tributaries

Some tributaries were in gage reaches that exhibited baseflow losses from time to time. In these months for these reaches, baseflows are positive at both the upstream gage(s) and the downstream gage, but the downstream baseflow is smaller than the upstream baseflow. Here the "neighboring gage" approach was used, in which baseflow for the ungaged tributary is estimated as a proportion of baseflow at a nearby gaged tributary, to alleviate shortages. The basis of the proportion is the Area*Precipitation term for each gage, and these values were not changed from the previous model's values. This approach further reduced shortages in the tributaries listed in Table 7.2, where the "neighboring gage" methodology for baseflow estimation was implemented.

Table 7.2
Baseflow Nodes that Implement Neighboring Gage Methodology

Baseflow Node	Tributary	Neighboring Station	Proration Fraction
430813	Flag Creek	Piceance Creek Below Rio Blanco (09306007)	0.944
430578	Coal Creek	South Fork White River At Buford (09304000)	0.146
43_ADW015	Evacuation Creek	Piceance Creek Below Rio Blanco (09306007)	0.516

7.3.4 Baseflow Factor Adjustments

For several tributaries, where the neighboring gage approach was not effective, baseflow distribution factors were manipulated directly to reduce total shortages. The methodology attempted to redistribute baseflow, moving more baseflows to tributaries in the reach that presented the largest shortages in the basin. Selection of the factor took into consideration minimizing negative gains at the downstream baseflow nodes.

The baseflow factor for the Beckman Ditch (430537), headwater node on Moose Creek, was increased from 0.294 to 0.474. This change resulted in a 55 percent reduction in the Beckman Ditch's average annual shortage, while 1) maintaining the same level of shortages at structures in Hill Creek, 2) limiting negative gains at station 09303500 (as required in order to avoid "making water"), and 3) keeping a small fraction of baseflow gain at the South Fork main stem gage.

The reach upstream of station White River above Coal Creek (09304200) was investigated since shortages were occurring on Miller Creek, Elk Creek, and Big Beaver Creek. Miller Creek structures showed the largest shortages, indicating the need for an increase in the baseflow distribution fraction. The transfer of additional baseflow to Miller Creek was done incrementally since other tributaries in the reach were water short and the Big Beaver Creek Reservoir showed lower levels than historical records. An iterative approach was used to select "compromise" baseflow distribution fractions, reducing the overall shortages and providing a closer match of historical storage in the Big Beaver Creek Reservoir. Experimentation demonstrated that transferring additional water to Miller Creek was beneficial not only for this creek's structures, but it also improved conditions in other structures upstream. The solution was achieved when no significant improvements were gained by transferring additional baseflows to Miller Creek and Big Beaver Creek. The calibrated fractions are summarized in Table 7.3. This adjustment reduced water shortages in this reach by approximately 15%.

Table 7.3
Baseflow Transfer Fraction for Reach Upstream of 09304200

Tributary	Baseflow Node	Baseflow Transfer Fraction	
		Initial	Final
Big Beaver Creek	433633	0.169	0.350
Miller Creek	430652	0.262	0.500
Elk Creek	430623	0.258	0.150

Aggregate nodes located immediately upstream of gages were assigned baseflow factors such that they received all remaining gains in the reach (baseflow factor = 1). In other words, the aggregate node "sees" all the baseflow estimated at the downstream gage. The precipitation and area assigned to the aggregate node determine the aggregate's baseflow factor, and since the precipitation term is less static and less certain than area, the aggregate node's precipitation term was revised to force the baseflow factor to the desired value.

Table 7.4 shows the previous and computed precipitation for the aggregates located upstream of a gaging station. Results show zero gains between the aggregate nodes and the downstream station, with reduced negative gain amounts at the aggregate nodes.

Table 7.4
Aggregate Nodes Calculated Precipitation

ID	Description	Area (mi^2)	Previous Precipitation (in)	New Precipitation (in)
43_ADW002	SOUT_ADW WhiteSouthF	25	21.83	21.83
43_ADW003	WHIT_ADW WhiteAbCole	78.6	22.24	68.09
43_ADW004*	WHIT_ADW WhiteNrMeek	82.8	21.936	18.34
43_ADW005*	WHIT_ADW WhiteNBLMee	119	14.05	14.05
43_ADW010	PICE_ADW PicCrBlRyan	329	15.94	17.12
43_ADW011	PICE_ADW Piceance@Wh	146	14.92	14.92
43_ADW012	WHIT_ADW WhiteBlBois	709	13.078	13.08
43_ADW014	WHIT_ADW WhiteNrStat	1,028	10.458	13.12

7.3.5 Other Calibration Issues

Piceance Creek basin, the upper part of the basin in particular, exhibited shortages in the calibrated model. These shortages were reduced by disaggregating some of the structures in 43_ADW007 at the headwater of the tributary, allowing return flows to be re-used by downstream users. As a result, simulation at the three gages on Piceance Creek improved by tens of acre-feet per year, on average. Some of the difficulty in simulating this part of the basin may be due to fact that a section of the creek, indicated in Figure 7.2, regularly dries up in midsummer. When this condition occurs, the Division Engineer recognizes that a call would be futile, and does not administer. Statemod does not recognize or simulate this decision, and will permit a downstream senior below the dry reach to call out an upstream junior located above the dry reach.

The average baseflow “gain” in the reach between gage 09304500 White River near Meeker and 09304800 White River below Meeker is negative. Several months exhibit negative baseflow gains (that is, losses) that are on the order of 30,000 and 40,000 af – excessive relative to other months in the study period. For instance, the baseflow loss for May, 1979 is over 44,000 af, and for May 1976, approximately 33,000 af. Review of the baseflow computation for the gage sites shows that diversions of record for this reach are significantly less than 20% of the difference in historically gaged flow at the upstream and downstream gages. In other words, even if there were no return flows to this stream segment, the loss in gaged flow cannot be accounted for by the historical diversions. This suggests there may be error in either the gage record or diversion records in certain months. The Division 6 office has been notified of the discrepancy in the two months noted above.

Baseflow losses occur consistently in the reach between gage 09306224 White River above Crooked Wash near White River City and gage 09306290 White River below Boise Creek near Rangely. These two gages began operation in 1983, and the upstream gage was discontinued after Water Year 1989. All of the extreme losses occur prior to establishment of the gages, and are probably a function of having to fill both gages, and the CDSS technique which fills the gages independently of each other.

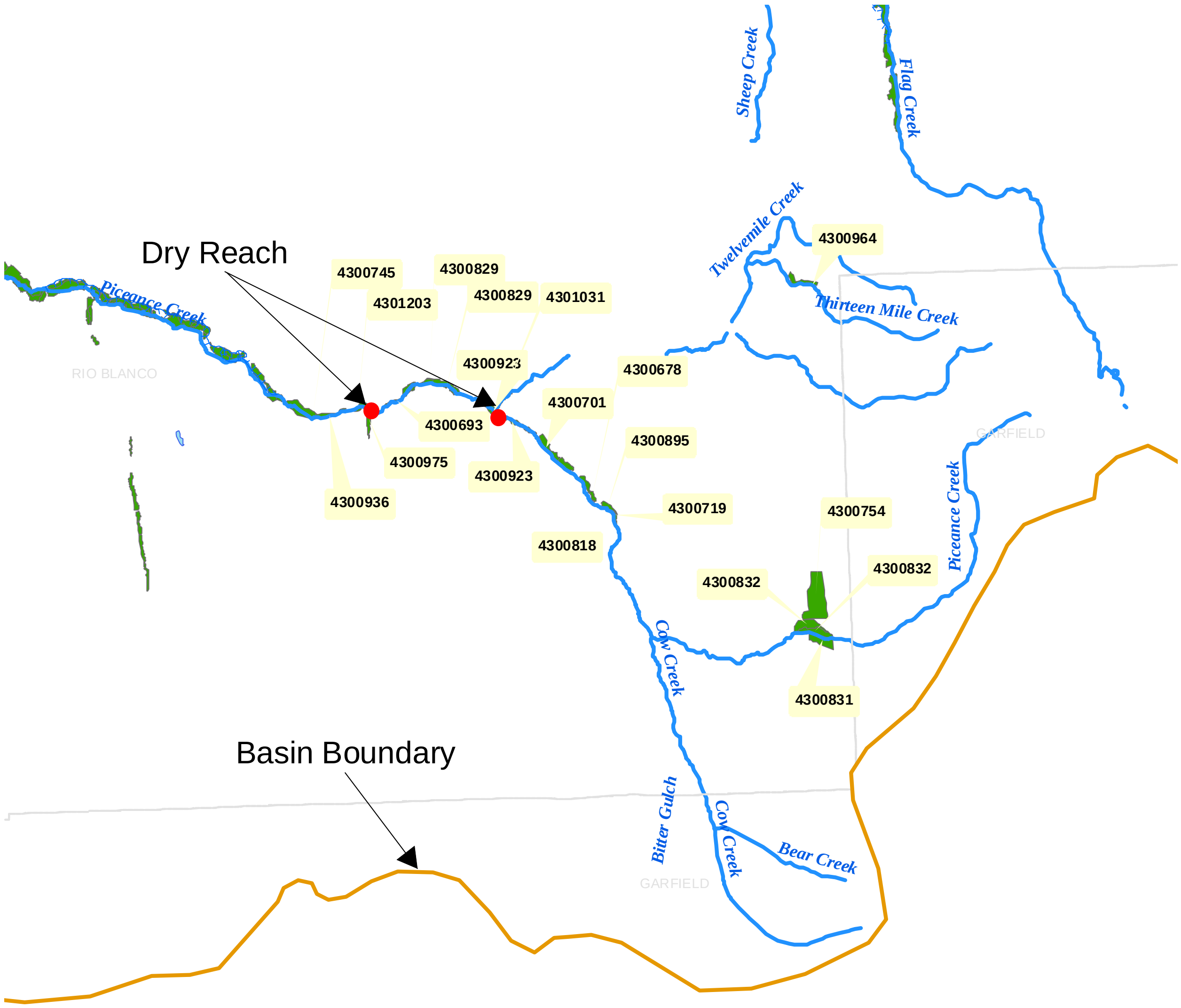


Figure 7.2 – No Flow Reach in the Upper Piceance Creek

7.4 Calibration Results

Calibration of the White River model is considered very good, with all streamflow gages deviating less than one half of one percent from historical values on an average annual basis. Approximately seventy-five percent of the diversion structures' shortages are at or below 1 percent on an annual basis, and the basin-wide shortage is less than 1 percent per year, on average. Simulated reservoir contents are representative of historical values.

7.4.1 Water Balance

Table 7.5 summarizes the water balance for the White River model, for the calibration period (1975-2006). Following are observations based on the summary table:

- Surface water inflow to the basin averages 581,720 acre-feet per year, and surface water outflow averages 526,309 acre-feet per year.

- Annual diversions amount to approximately 280,012 acre-feet on average.

- Approximately 48,000 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). The small values are due to rounding on a monthly basis and indicate that the model correctly conserves mass.

Table 7.5
Average Annual Water Balance for Calibrated White River Model (1975-2006) (af/yr)

Month	Inflow	Return	From Soil Moisture	Total Inflow	Diversions	Reservoir Evaporation	Stream Outflow	Resvr Change	To Soil Moisture	Soil Moisture Change	Total Outflow	Inflow - Outflow	CU
OCT	28,275	20,742	276	49,292	19,610	162	29,008	237	259	16	49,292	0	1,656
NOV	21,726	7,646	0	29,373	2,626	50	26,517	179	65	-65	29,373	0	275
DEC	20,864	4,725	0	25,589	1,752	-36	23,696	178	21	-21	25,589	0	242
JAN	21,640	3,715	0	25,355	1,672	-43	23,540	186	13	-13	25,355	0	236
FEB	21,094	2,917	0	24,011	1,543	25	22,364	78	10	-10	24,011	0	253
MAR	30,749	2,477	1	33,227	1,855	115	31,234	22	40	-39	33,227	0	378
APR	45,976	5,438	315	51,730	7,117	205	43,917	175	445	-130	51,730	0	1,157
MAY	115,623	24,354	671	140,648	37,140	385	102,508	-56	971	-299	140,648	0	6,156
JUN	139,402	47,804	424	187,631	69,904	525	116,890	-112	988	-564	187,631	0	11,184
JUL	69,535	43,447	657	113,639	59,081	522	53,563	-184	261	396	113,639	0	12,501
AUG	36,942	34,701	726	72,369	43,700	342	27,650	-50	227	499	72,369	0	9,108
SEP	29,894	29,631	509	60,034	34,011	303	25,421	-211	266	243	60,034	0	5,078
TOTAL	581,720	227,597	3,579	812,897	280,012	2,554	526,309	443	3,564	15	812,897	0	48,222

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

7.4.2 Streamflow Calibration Results

Table 7.6 summarizes the annual average streamflow for water years 1975 through 2006, 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. Differences between gaged and simulated average annual streamflows are less than 1 percent for all stations. Figures 7.2 through 7.14 (at the end of this section) graphically present monthly streamflow estimated by the model compared to historical observations at key stream gages. When only one line appears on a graph it indicates that the simulated and historical results are the same at the scale presented.

Table 7.6
Historical and Simulated Average Annual Streamflow Volumes (1975-2006)
Calibration Run (acre-feet/year)

Gage ID	Historical	Simulated	Historical minus Simulated		Gage Name
			Volume	Percent	
9303000	232,859	232,794	65	0	North Fork White River at Buford
9303400	143,418	143,418	0	0	South Fork White River near Budges Resort, CO.
9303500	189,830	189,840	-10	0	South Fork White River Near Buford, CO.
9304000	185,547	185,578	-31	0	South Fork White River at Buford
9304200	400,250	400,252	-2	0	White River above Coal Creek
9304500	446,709	446,711	-2	0	White River near Meeker
9304800	478,759	478,788	-29	0	White River below Meeker
9306007	15,199	15,221	-22	0	Piceance Creek below Rio Blanco
9306200	23,377	23,411	-34	0	Piceance Creek below Ryan Gulch
9306222	27,632	27,666	-34	0	Piceance Creek at White River
9306224	684,953	684,972	-19	0	White River above Crooked Wash near White River City
9306290	532,247	532,306	-59	0	White River below Boise Creek near Rangely
9306395	596,955	597,159	-204	0	White River near Colorado State Line, UT

7.4.3 Diversion Calibration Results

Table 7.7 summarizes the average annual shortage for water years 1975 through 2006, for each ditch. Estimated diversions are generally within a few percent of recorded diversions or represent a relatively small volume of water. The greatest concentration of shortages is on Piceance Creek, as noted above under “Other Calibration Issues”.

On a basin-wide basis, average annual diversions differ from historical diversions by 2 percent in the calibration run.

7.4.4 Reservoir Calibration Results

Figures 7. and 7. (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:

- Big Beaver Creek Reservoir is unable to match historical storage volumes in some months because baseflow is limiting. However, most discrepancies between historical and simulated values occur because the historical observation exceeds the nominal active storage capacity. It appears that freeboard storage may have been used occasionally, at least until the early 1990s, and the model does not replicate that operation.

- Taylor Draw Reservoir follows closely the estimated historical end-of-month content during the calibration. Small discrepancies in storage, caused by the reservoir evaporation computation, are observed along the simulation with the replenishment the reservoir during the winter months.

Table 7.7
Historical and Simulated Average Annual Diversions (1975-2006)
Calibration Run (acre-feet/year)

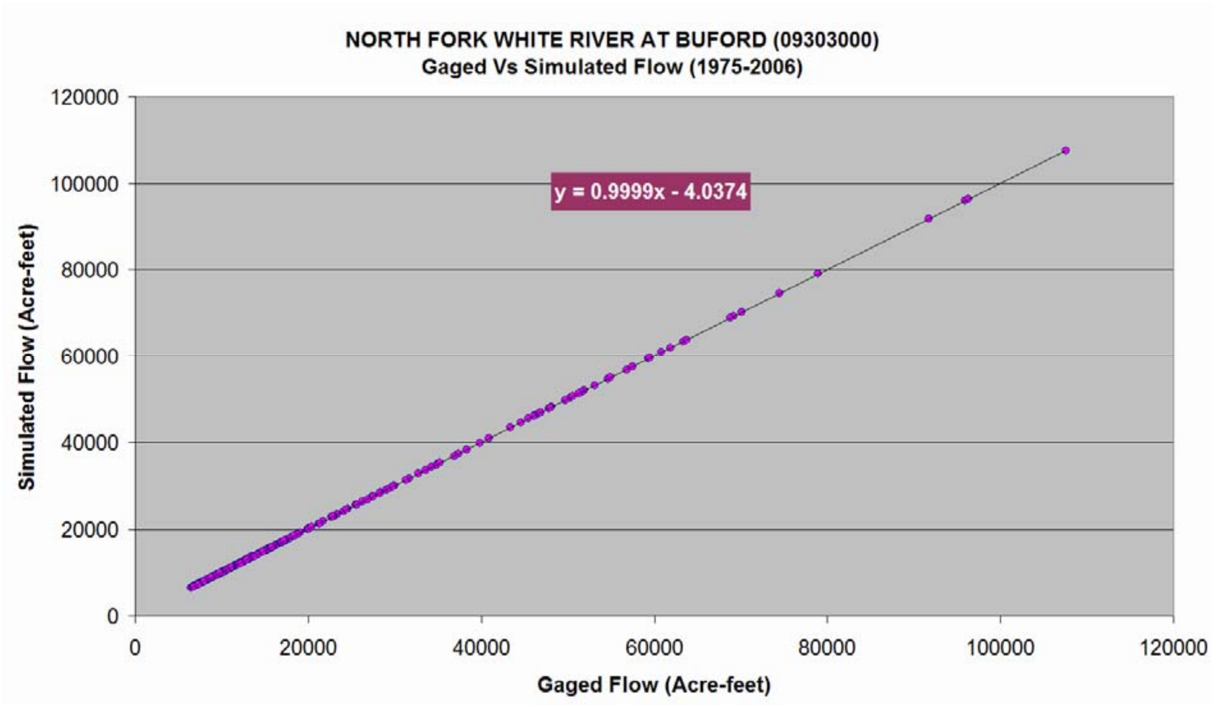
WD ID	Historical	Simulated	Historical minus Simulated		Structure Name
			Volume	Percent	
43_ADW001	6,692	6688	4	0	NORT_ADW Whitenorthf
43_ADW002	1,732	1732	0	0	SOUT_ADW Whitesouthf
43_ADW003	5,116	5116	0	0	WHIT_ADW Whiteabcole
43_ADW004	2,748	2748	0	0	WHIT_ADW Whitenrmeek
43_ADW005	918	918	0	0	WHIT_ADW Whitenblmee
43_ADW006	3011	2985	26	1	WHIT_ADW Whiteabpice
43_ADW007	1878	1874	4	0	PICE_ADW Piccrupper
43_ADW008	738	705	34	5	PICE_ADW Piccrblriob
43_ADW009	4962	4941	21	0	PICE_ADW Piccrabhunt
43_ADW010	4521	4430	90	2	PICE_ADW Piccrblryan
43_ADW011	1537	1535	2	0	Pice_Adw Piceance@Wh
43_ADW012	3404	3404	0	0	WHIT_ADW Whiteblbois
43_ADW013	4502	4502	0	0	WHIT_ADW Whitebldoug
43_ADW014	3364	3364	0	0	WHIT_ADW Whitenrstat

WD ID	Historical	Simulated	Historical minus Simulated		Structure Name
			Volume	Percent	
43_ADW015	1012	989	22	2	Evac_Adw Evac Creek
43_ADW016	3059	3059	0	0	WHIT_ADW Whitesblmee
43_AMW001	1104	1104	0	0	WHIT_AMW Aggmuni&Ind
430511	1500	1436	64	4	B A & B Ditch No 1
430513	999	999	0	0	B M & H Ditch 1
430526	1218	1204	14	1	Barbour North Side D
430537	1739	1594	145	8	Beckman Ditch
430539	1125	1037	88	8	Big Beaver Ditch
430543	164	164	0	0	Black Eagle D No 1
430544	149	149	0	0	Black Eagle D No 2
430546	1291	1291	0	0	Blair Ditch
430563	168	168	0	0	Calhoun Ditch
430564	2443	2443	0	0	California Co Water Pl
430570	620	620	0	0	Calvat Ditch
430572	1569	1566	3	0	Charlie Smith Ditch
430573	609	609	0	0	Chase & Coltharp D
430575	830	830	0	0	Cloherty Ditch
430577	544	544	0	0	Coal Creek Feeder Ditch
430578	3382	3382	0	0	Coal Creek Mesa Ditch
430605	333	333	0	0	Dorrell Ditch 2
430607	1731	1731	0	0	Dreifuss Ditch
430608	1436	1277	159	11	Dreyfuss Ditch
430623	1107	1008	99	9	Elk Creek Ditch
430625	849	838	11	1	Emily Ditch
430640	779	779	0	0	Forney Corcoran Ditch
430652	1134	1031	103	9	G V Ditch
430653	1396	1396	0	0	George S Witter Ditch
430665	535	535	0	0	Greenstreet Ditch Ext
430678	43	43	0	0	Hanrahan Ditch No 1
430681	4508	4507	1	0	Hay Bretherton Ditch
430684	617	617	0	0	Hay Ditch 2
430687	930	930	0	0	Hefley Pump Plant No 1
430688	965	965	0	0	Hefley Pump Plant No 2
430693	243	219	24	10	Herwick Ditch

WD ID	Historical	Simulated	Historical minus Simulated		Structure Name
			Volume	Percent	
430694	37550	37550	0	0	Highland Ditch
430695	683	618	65	10	Hill Creek No 3 Ditch
430696	1587	1522	65	4	Hill Creek No 2 Ditch
430701	650	629	21	3	Home Ditch
430710	2241	2241	0	0	Imes & Reynolds Ditch
430711	469	469	0	0	Independent Ditch
430714	256	256	0	0	Ivo E Shults D & Pump
430718	1117	1117	0	0	James Hayes Ditch
430719	42	42	0	0	Janes Ditch
430753	231	166	65	28	Lake Creek Pool Ditch
430754	112	112	0	0	Larson Ditch
430758	539	539	0	0	Lawrence Ditch No 1
430769	1827	1827	0	0	Little Ditch
430777	1842	1809	33	2	Lowland Ditch
430782	1039	1038	1	0	M H M German Cons D
430788	4110	4099	11	0	Marcott Ditch
430789	1198	1198	0	0	Martin Ditch
430790	1105	1105	0	0	Marvine Ditch 1
430791	502	498	4	1	Marvine Ditch 3
430808	4512	4511	1	0	Meeker Ditch
430809	218	218	0	0	Meeker Power Ditch
430810	751	751	0	0	Meeker Water Sys Pl
430813	428	428	0	0	Melvin Ditch
430815	952	950	2	0	Metz & Reigan Ditch
430816	893	874	19	2	Metz Ditch
430818	58	57	1	2	Mikkelson Ditch
430819	28148	28137	11	0	Miller Creek Ditch
430823	473	473	0	0	Miner Martin Ditch
430828	1124	1124	0	0	Mooney Ditch
430831	73	69	4	5	Morgan Ditch 2
430832	125	125	0	0	Morgan Ditch 1
430841	885	885	0	0	New Archer Warner Ditch
430842	13841	13841	0	0	Niblock Ditch
430848	24755	24755	0	0	Oak Ridge Park Ditch

WD ID	Historical	Simulated	Historical minus Simulated		Structure Name
			Volume	Percent	
430849	7756	7698	58	1	Old Agency Ditch
430850	912	899	13	1	Oldland Ditch 1
430851	575	507	68	12	Oldland Ditch 2
430862	523	523	0	0	Pattison Ditch No 1
430867	4228	4228	0	0	Pease Ditch
430868	2654	2654	0	0	Pedrick Ditch
430873	819	770	49	6	Piceance Creek Ditch
430881	1326	1162	164	12	Pothole Ditch
430883	14581	14581	0	0	Powell Park Ditch
430889	1332	1332	0	0	Rangely Water Plant
430895	76	74	2	3	Reddin Ditch
430903	1210	1175	35	3	Robert Mckee Ditch
430908	285	285	0	0	Ryan Ditch
430909	807	761	46	6	Rye Grass Ditch
430919	229	221	8	3	Sayer Ditch
430923	635	590	45	7	Schutte Ditch
430926	703	699	4	1	Sheridan & Morton D
430928	721	720	1	0	Simpson Ditch
430929	414	321	93	22	Sizemore Ditch 1
430931	954	954	0	0	Skelton Ditch
430934	314	222	92	29	Soldier Creek Ditch
430935	7174	7174	0	0	South Side Highline D
430944	878	705	173	20	Sprod Ditch 1
430948	2049	2039	10	0	Square S Cons D Sys
430949	499	499	0	0	Stadtman Ditch
430954	390	390	0	0	Storey Ditch 1
430961	2584	2584	0	0	Sweede Ditch
430965	287	287	0	0	Thomas Ditch
430966	300	300	0	0	Thomas Ditch 2
430975	43	43	0	0	Upper Ditch
430980	2038	2031	7	0	Ute Creek Ditch
431010	537	510	27	5	White River Mesa Ditch
431027	1138	1102	36	3	Belot Moffat Ditch
431031	143	138	5	3	Gordon Ditch

WD ID	Historical	Simulated	Historical minus Simulated		Structure Name
			Volume	Percent	
431033	512	512	0	0	Lawrence Ditch
431034	142	142	0	0	Mcdowell No. 1 Ditch
431108	236	236	0	0	Jacobs Pump & Pl
431272	870	870	0	0	Cox Pump No 1
431273	493	493	0	0	Reigan Pump No 1
431494	536	536	0	0	Goff Ditch
432099	632	632	0	0	Kenney Pump No 1
436045	45	45	0	0	Meeker Wells
950810	0	0	0	0	Meeker Demand
FUD001	0	0	0	0	Future Demand Piceance Ck 1
FUD002	0	0	0	0	Future Demand Piceance Ck 2
Total	282,170	280,016	2,154	0.8	



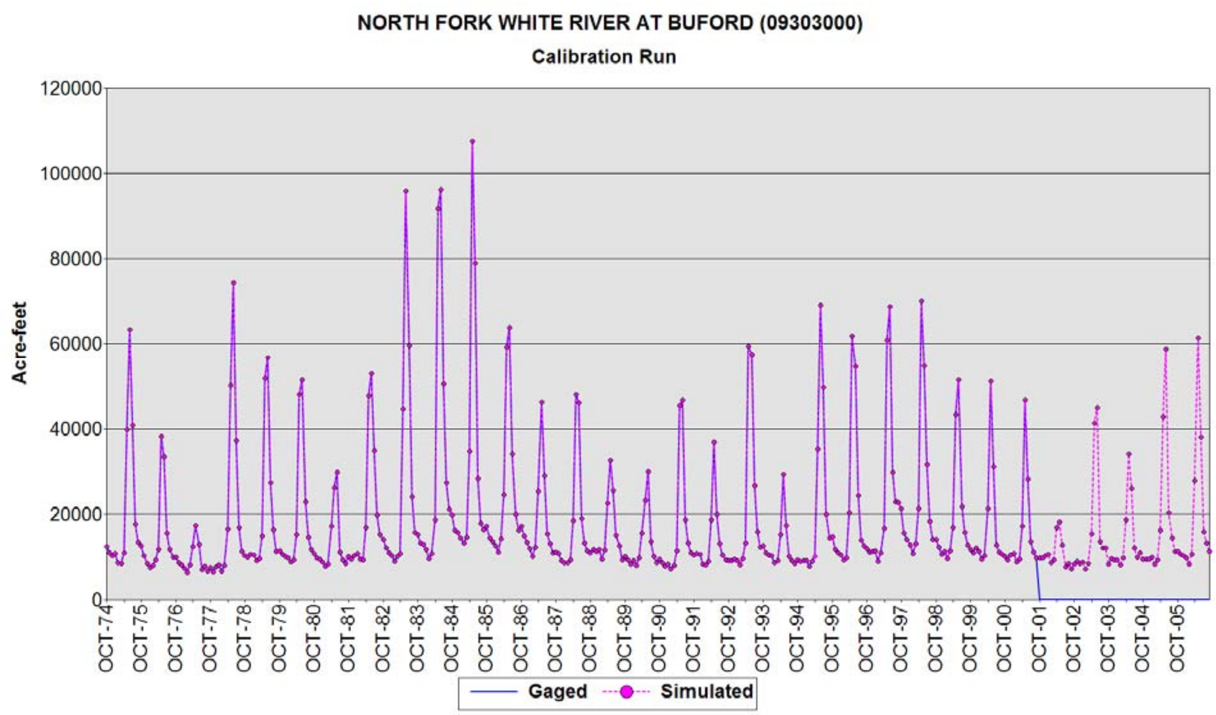
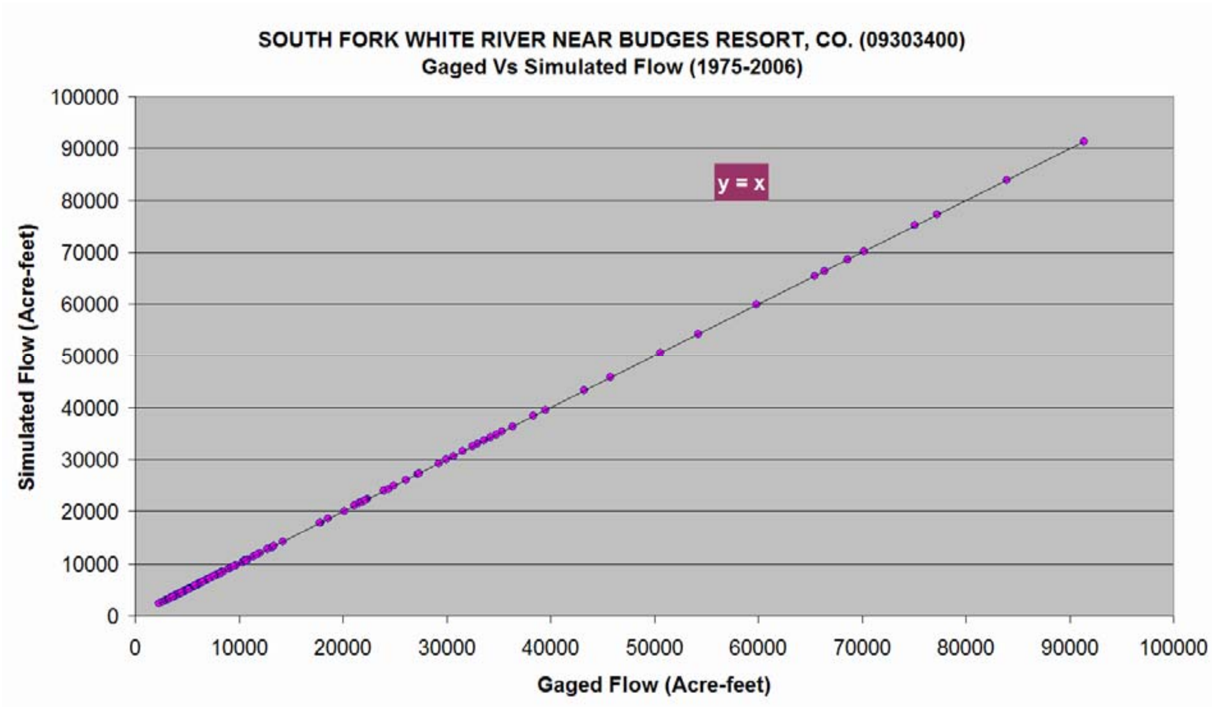


Figure 7.3 - Stream Flow Calibration - North Fork White River at Buford



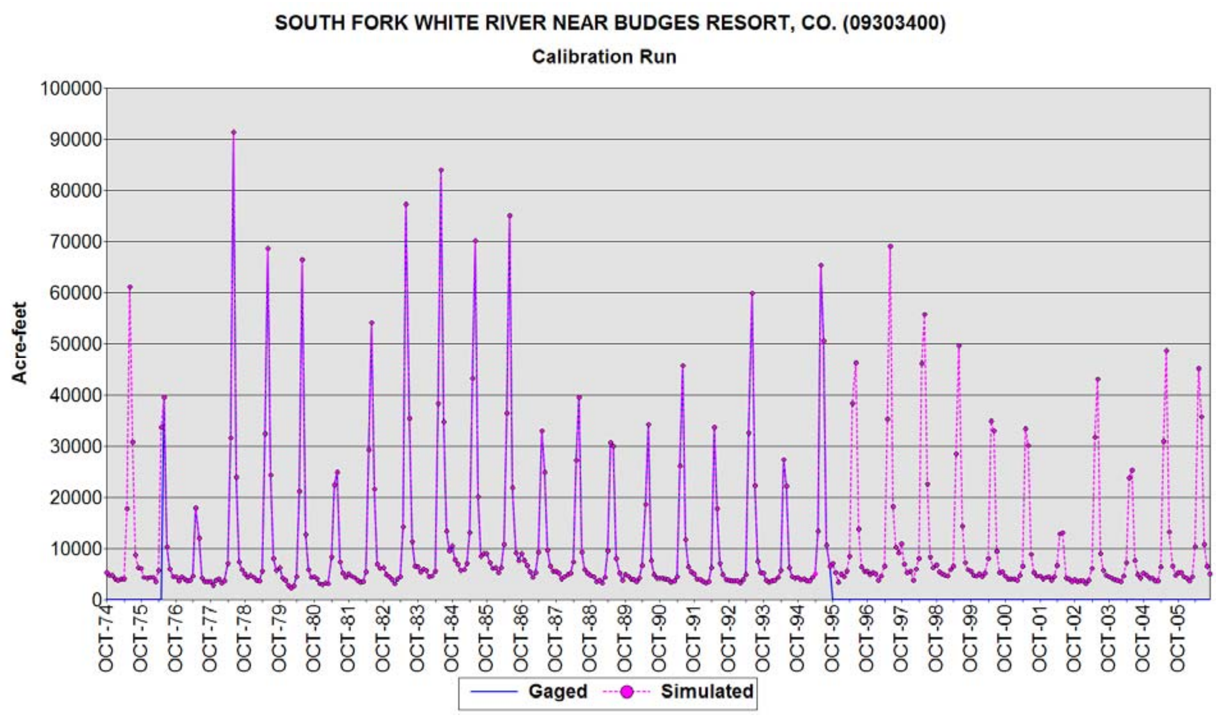
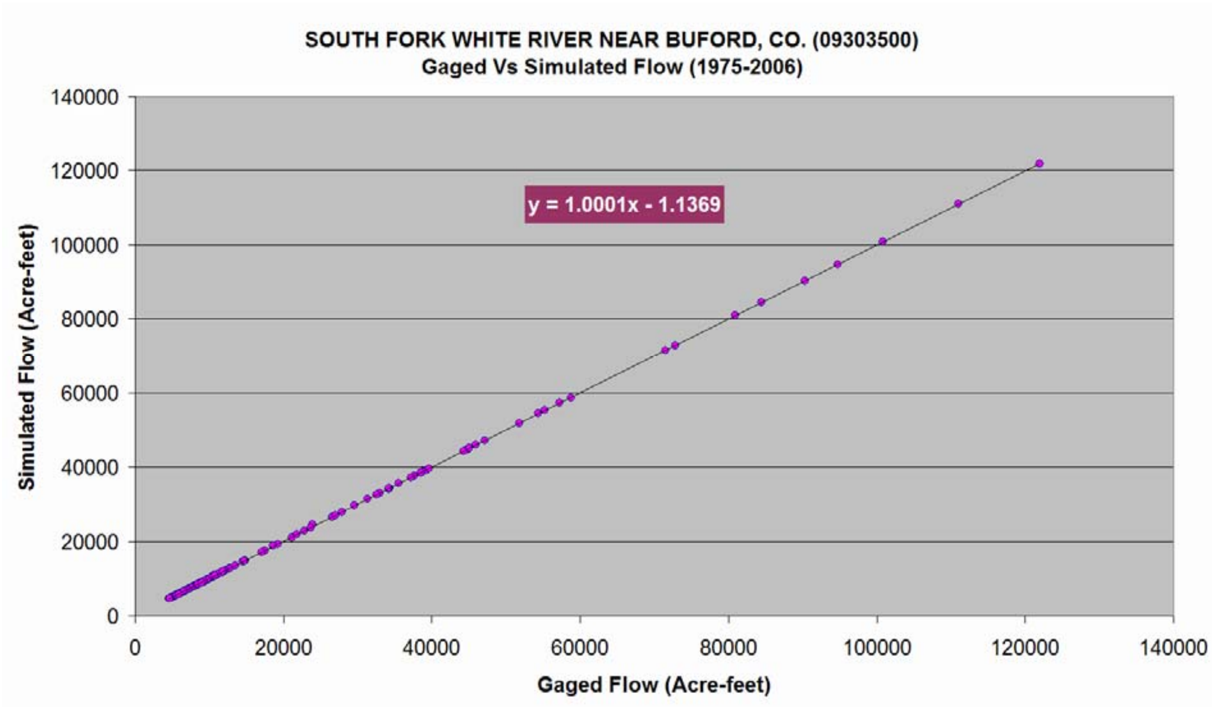


Figure 7.4 - Stream Flow Calibration – South Fork White River near Budges Resort, CO.



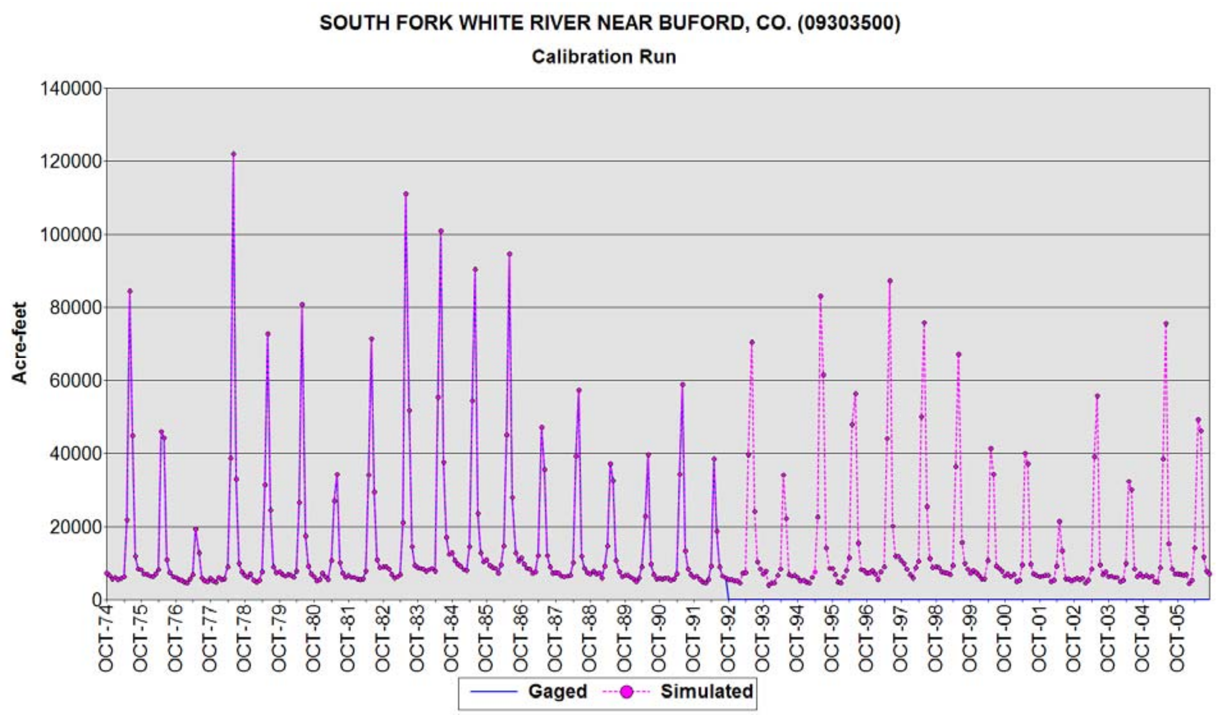
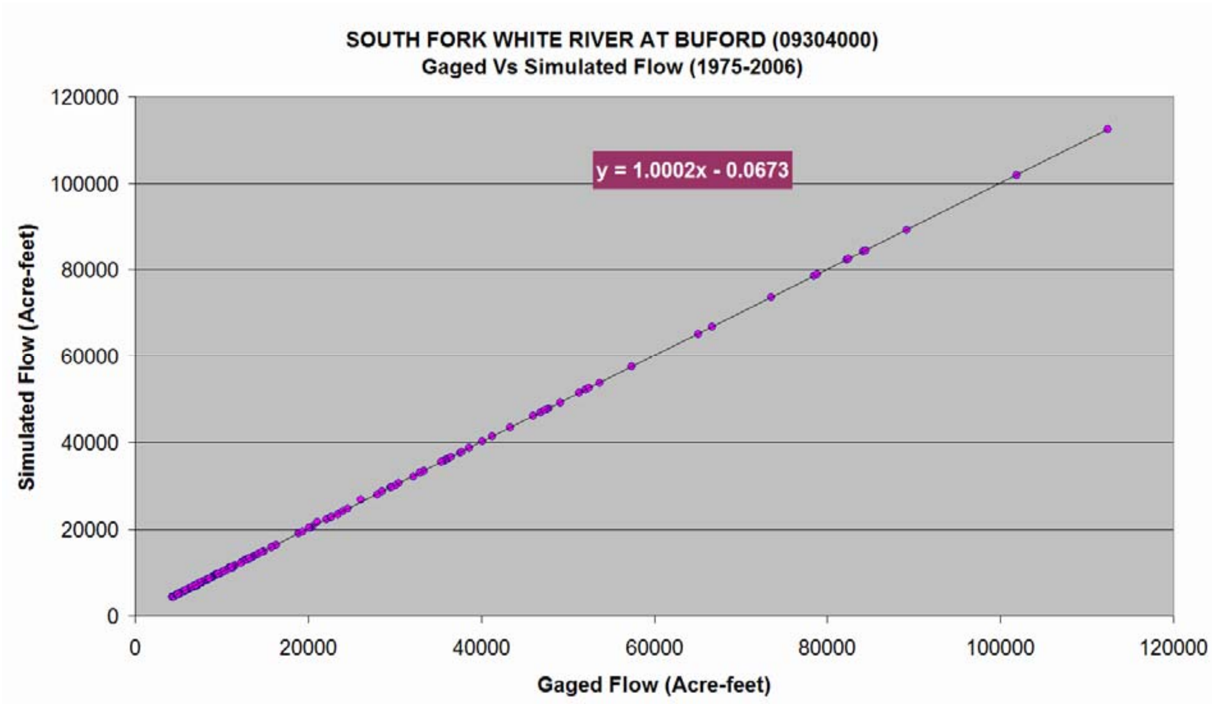


Figure 7.5 - Stream Flow Calibration – South Fork White River near Buford, CO.



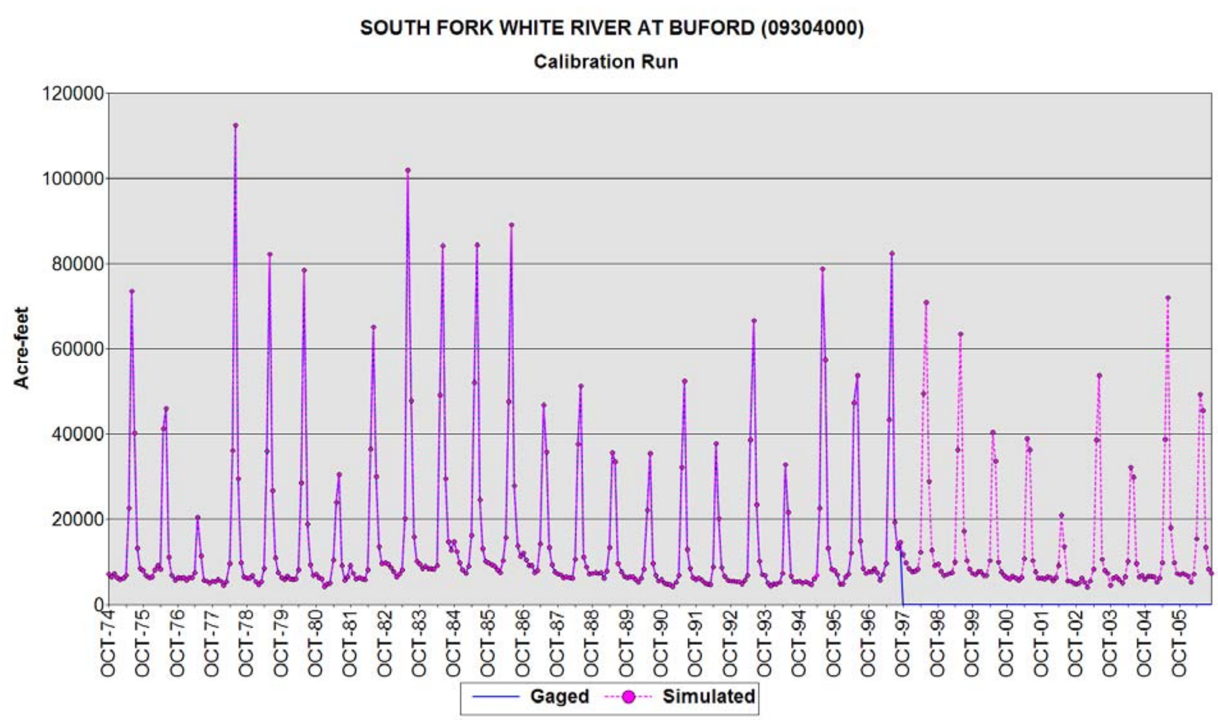
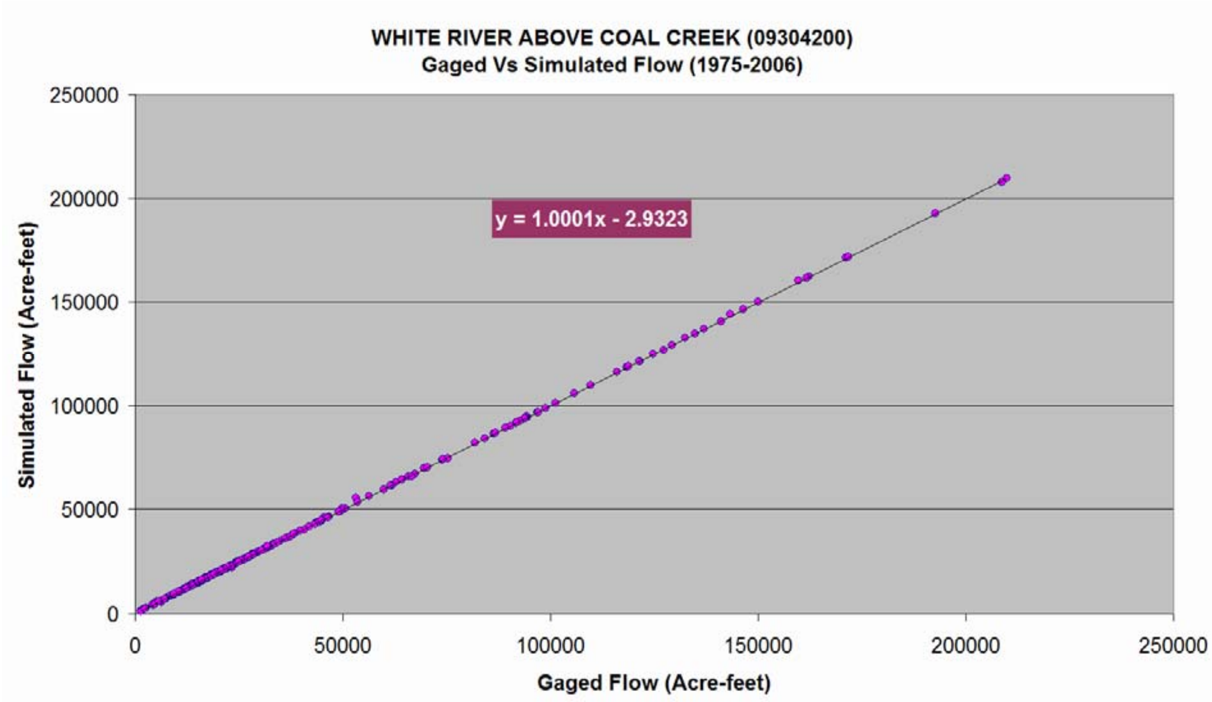


Figure 7.6 - Stream Flow Calibration – South Fork White River at Buford



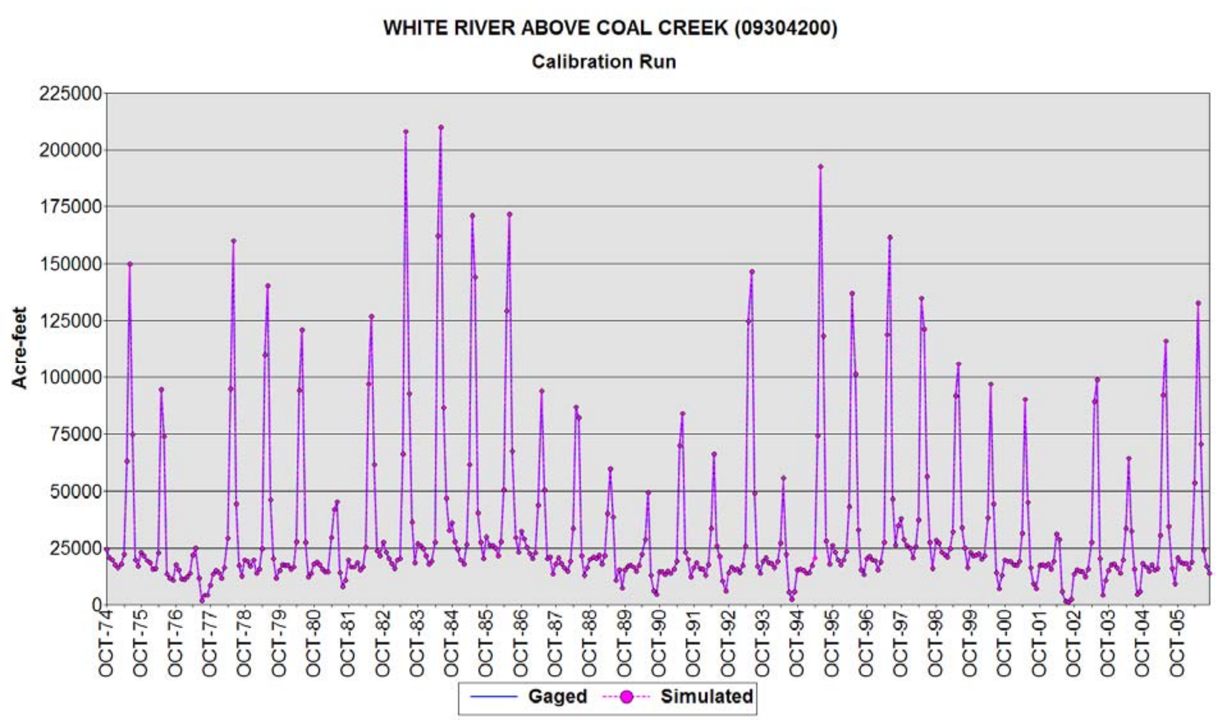
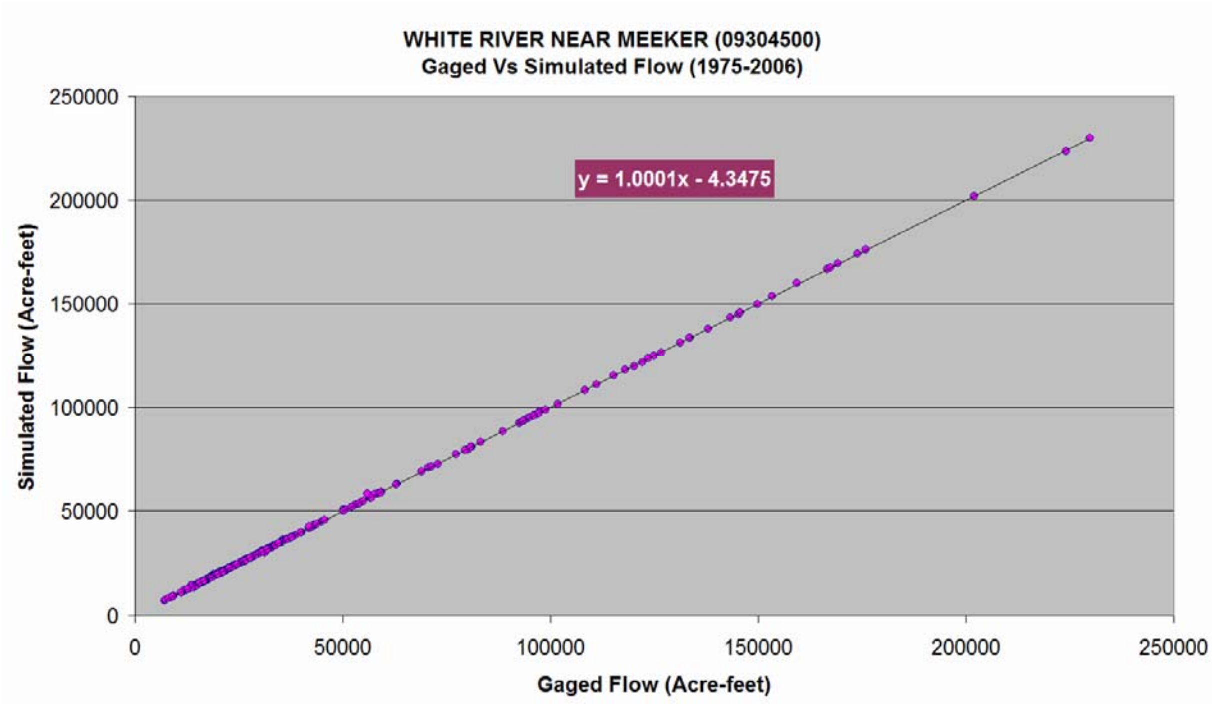


Figure 7.7 - Stream Flow Calibration – White River above Coal Creek



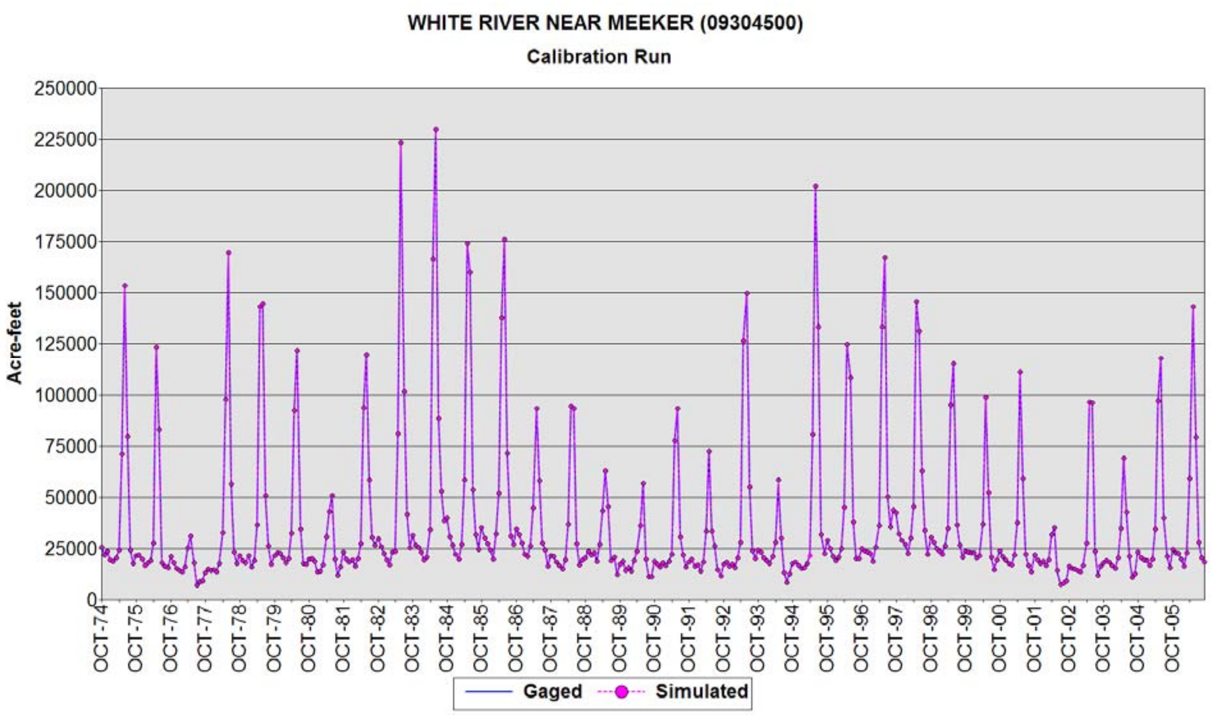
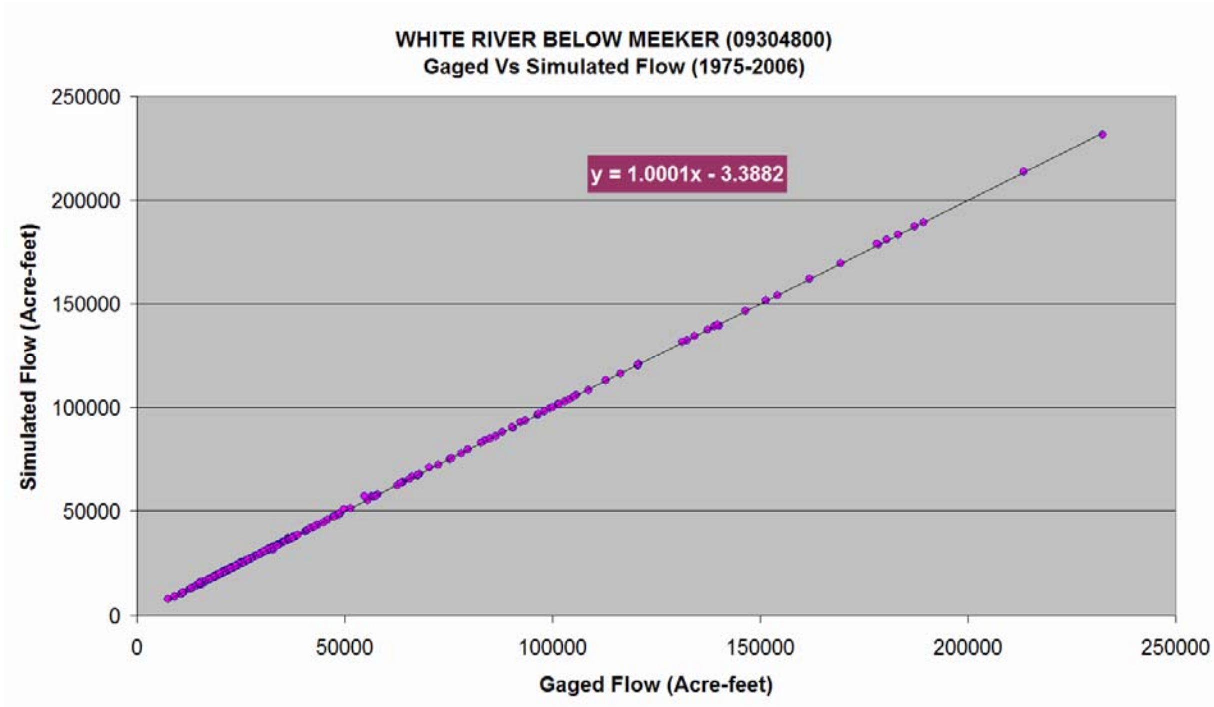


Figure 7.8 - Stream Flow Calibration – White River near Meeker



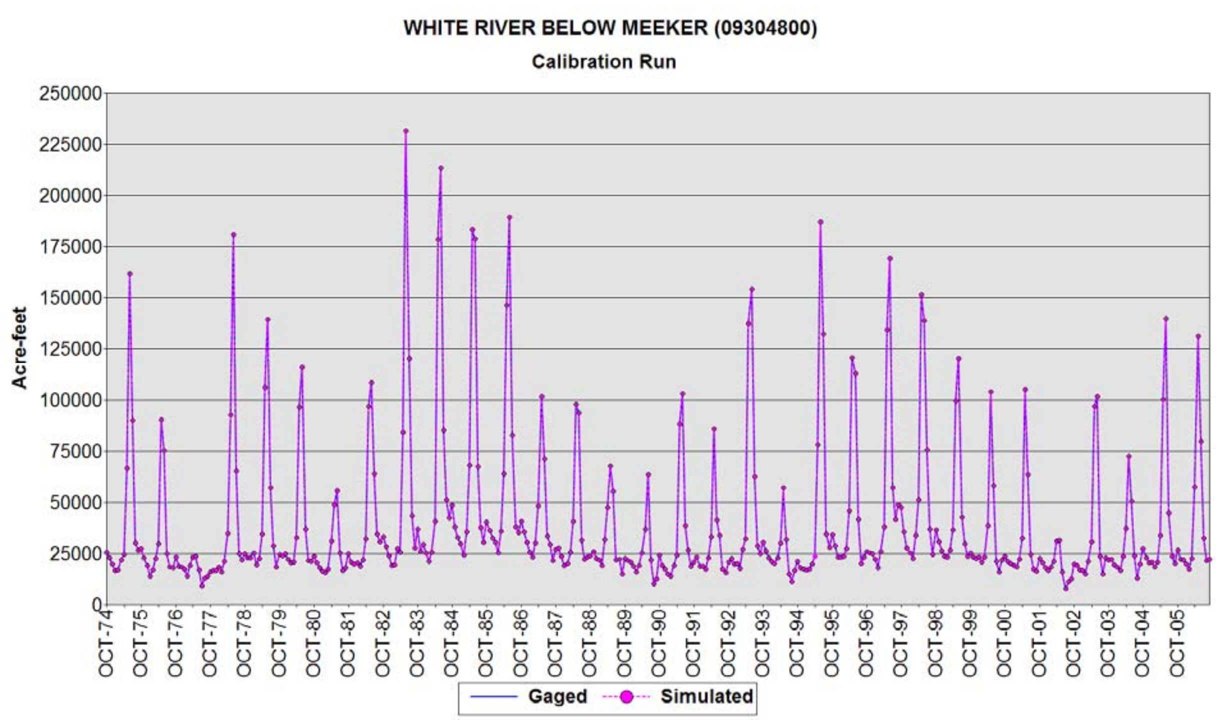
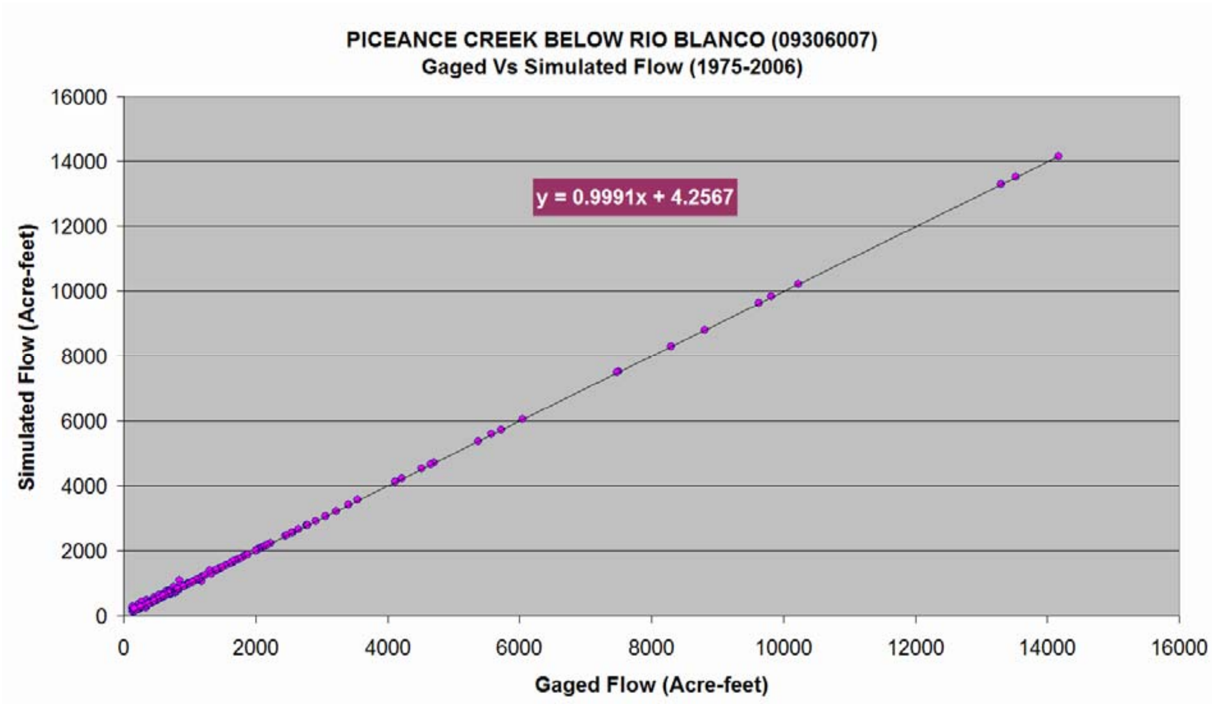


Figure 7.9 - Stream Flow Calibration – White River below Meeker



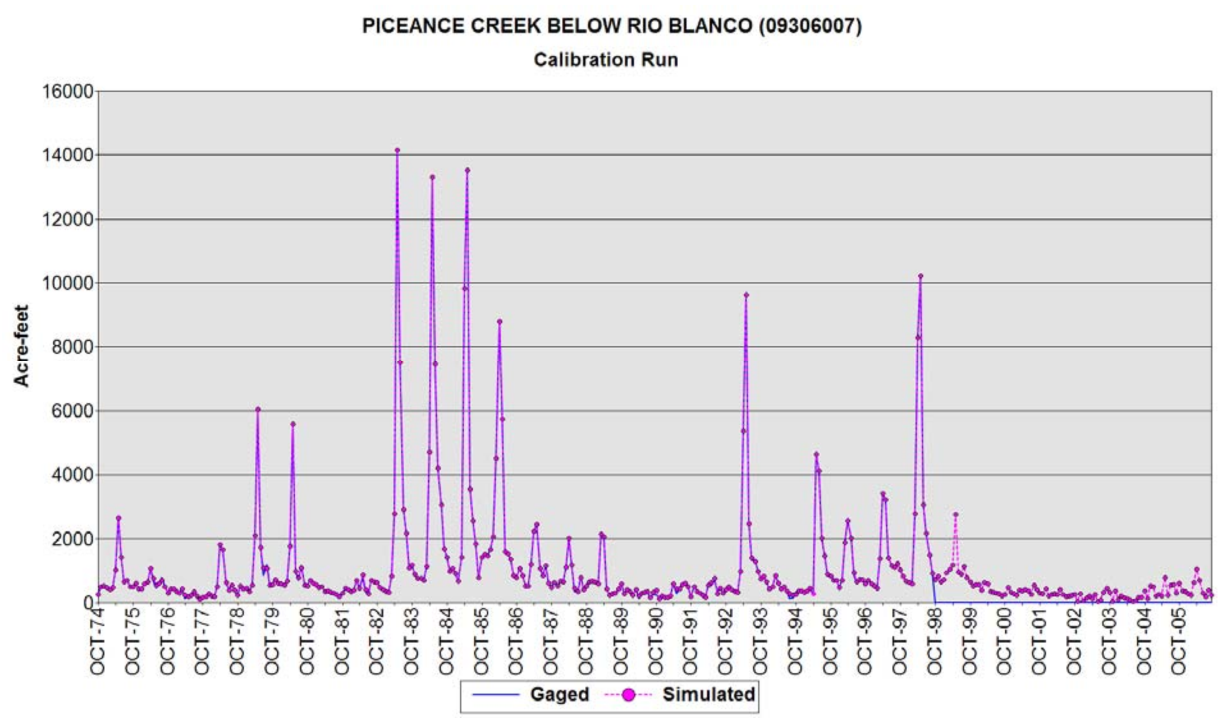
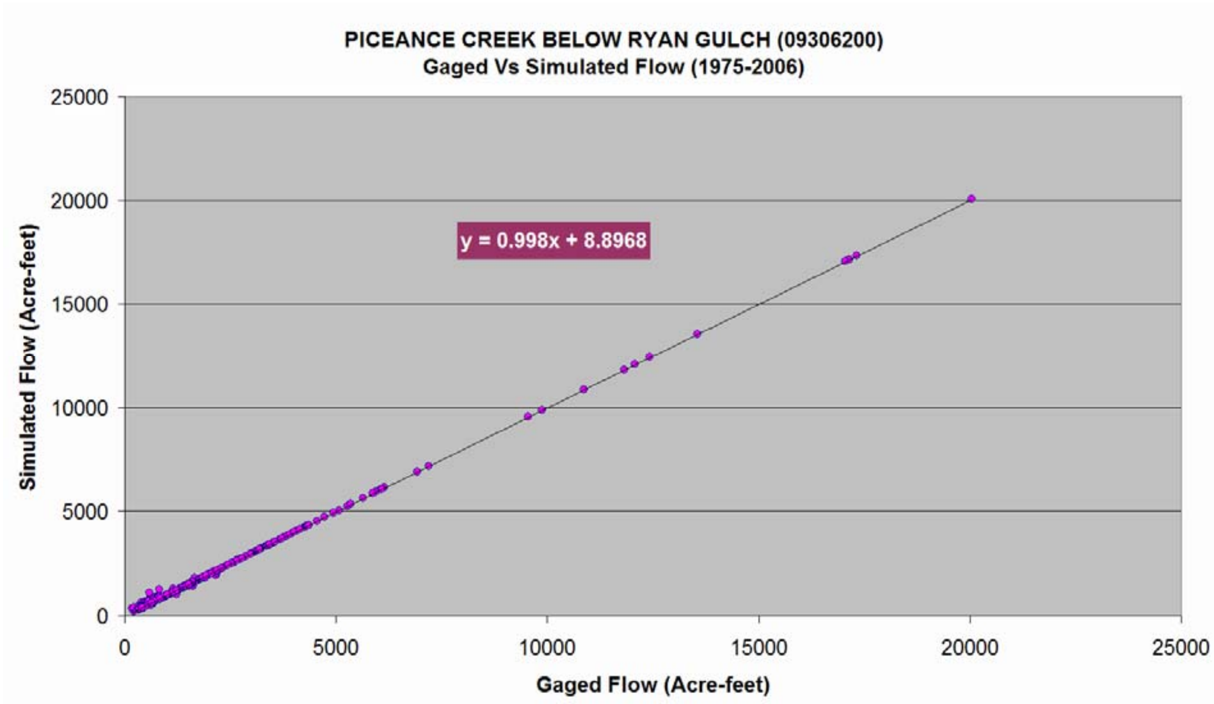


Figure 7.10 - Stream Flow Calibration – Piceance Creek below Rio Blanco



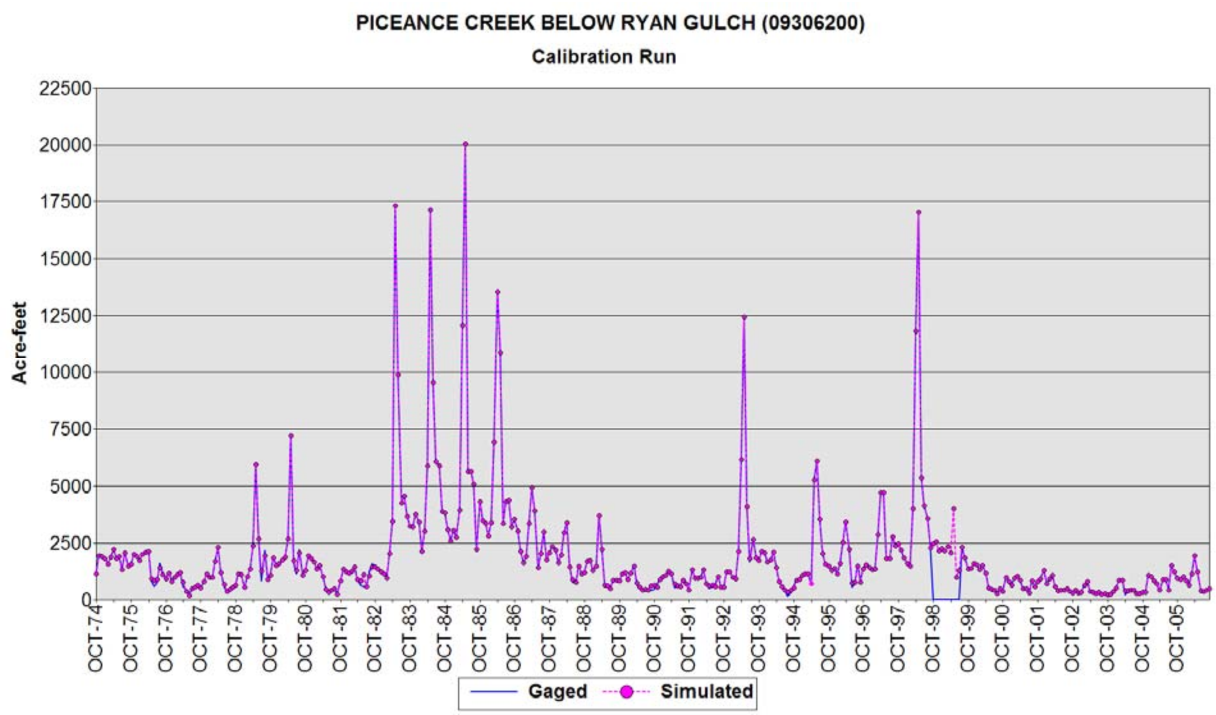
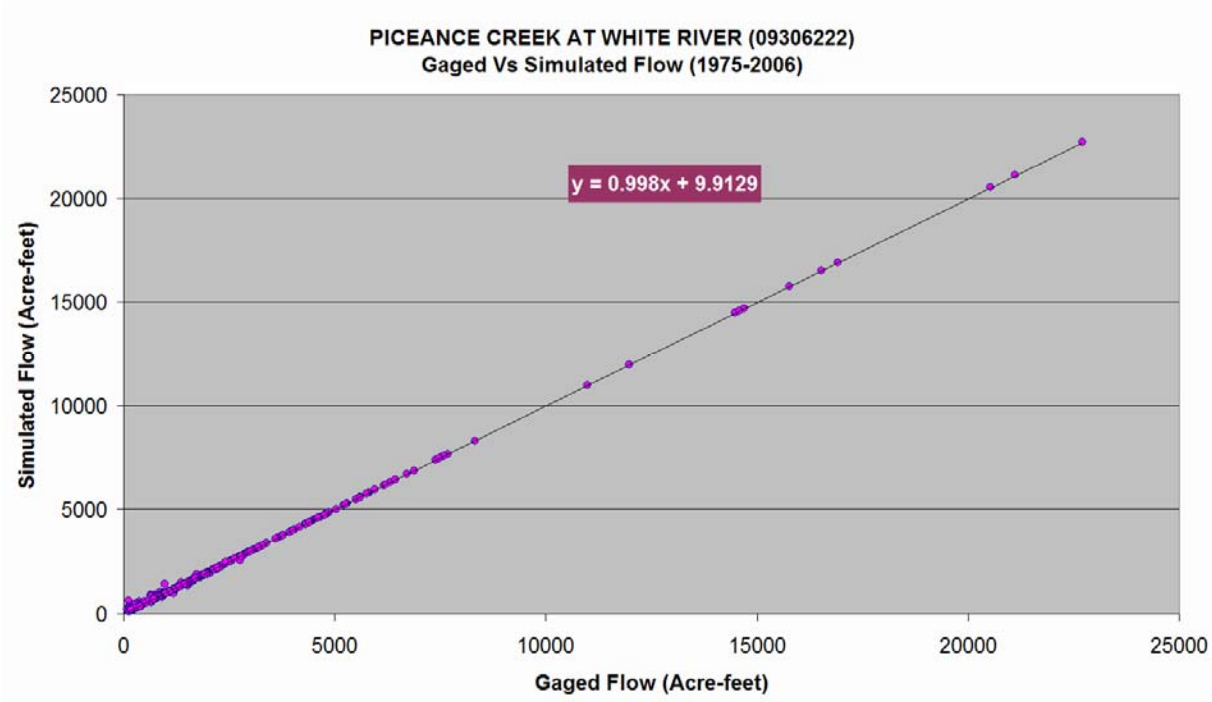


Figure 7.11 - Stream Flow Calibration – Piceance Creek below Ryan Gulch



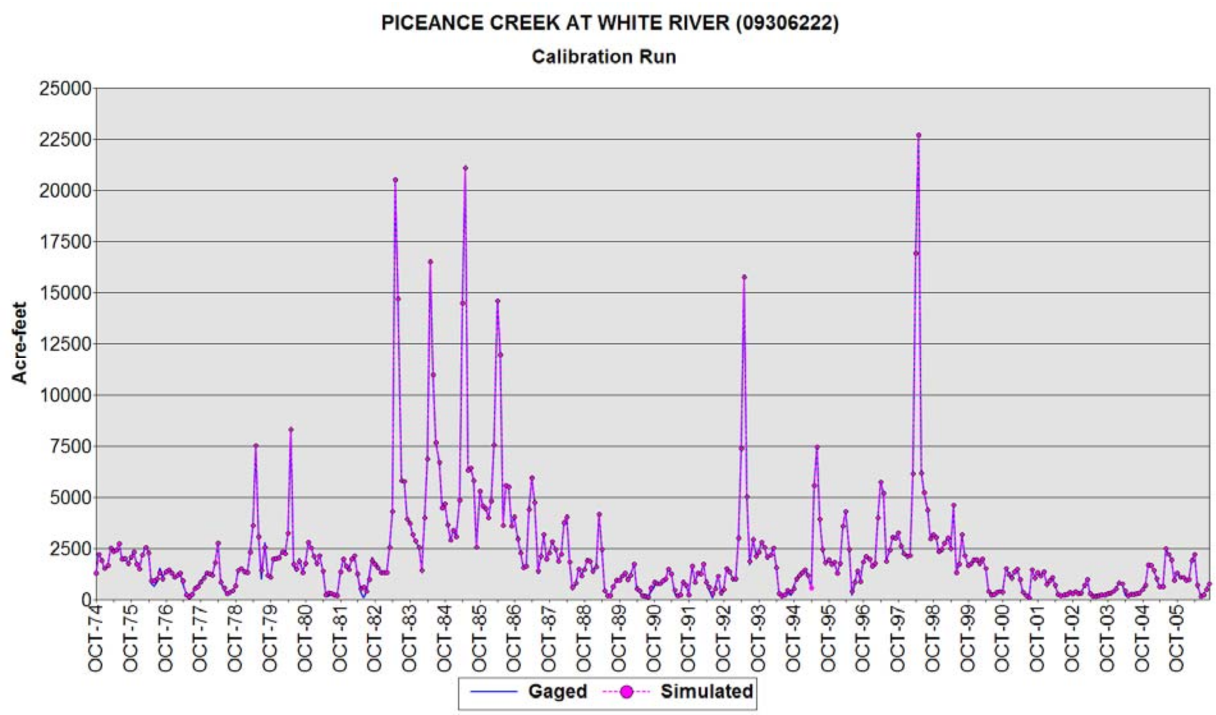
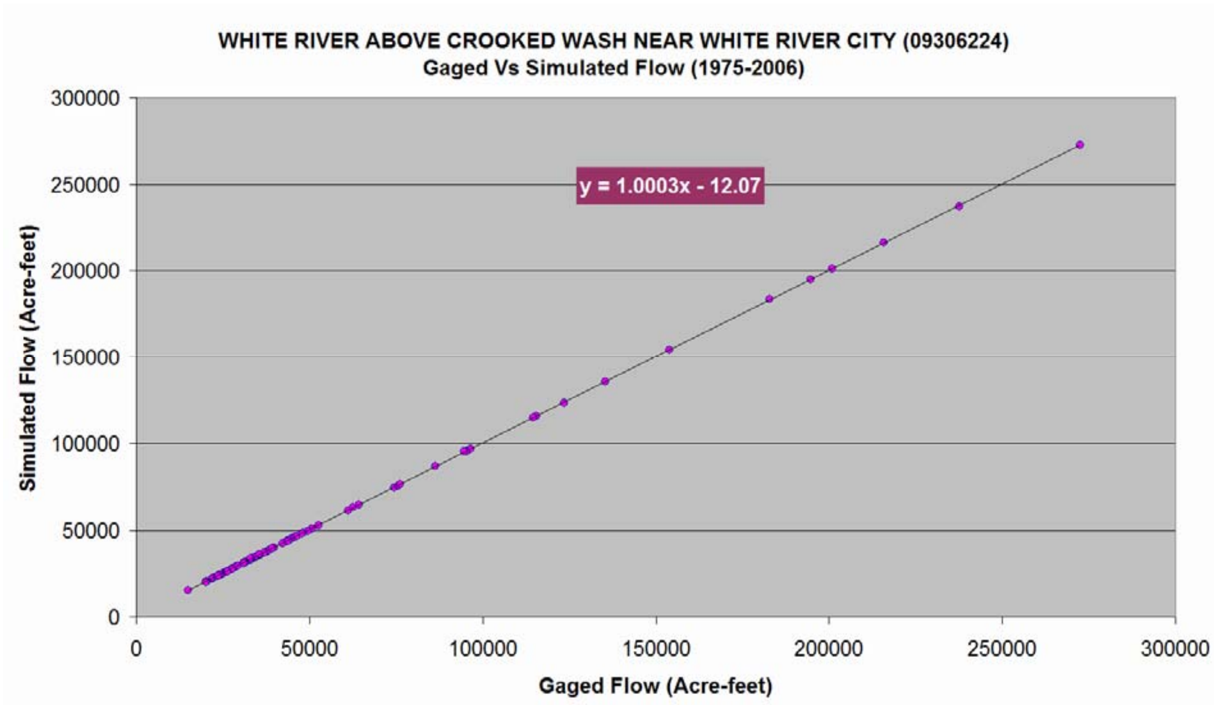


Figure 7.12 - Stream Flow Calibration - Piceance Creek at White River



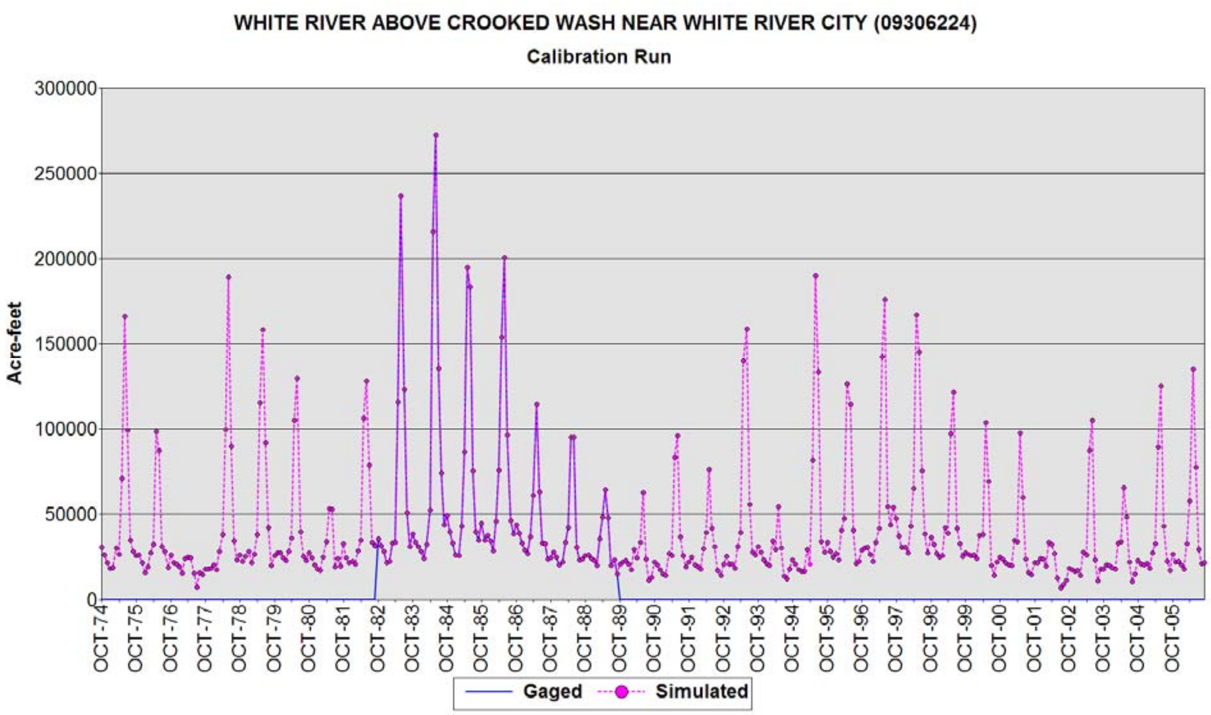
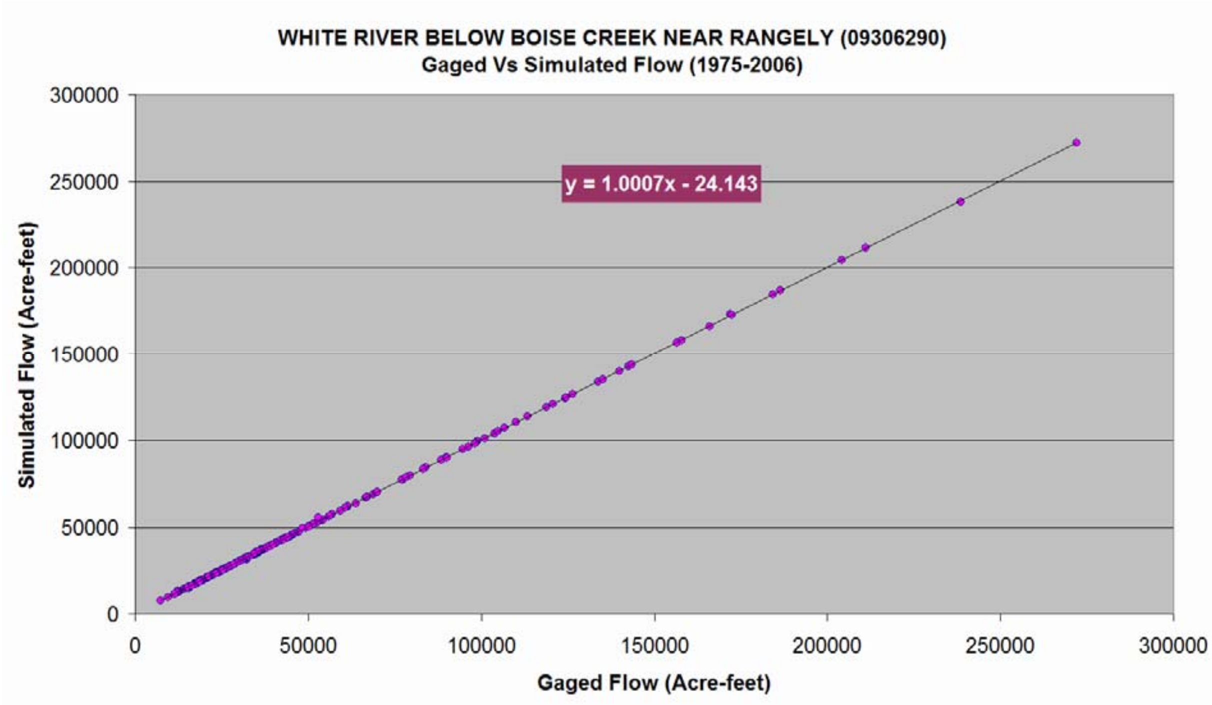


Figure 7.13 - Stream Flow Calibration – White River above Crooked Wash near White River City



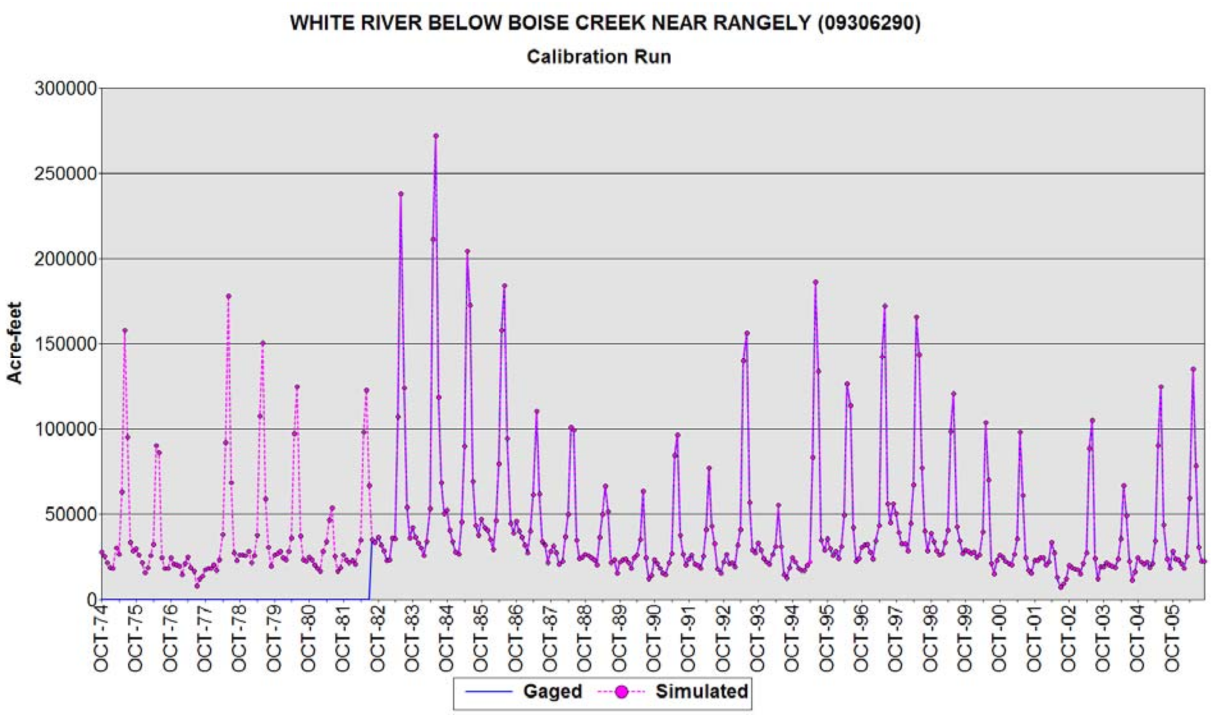
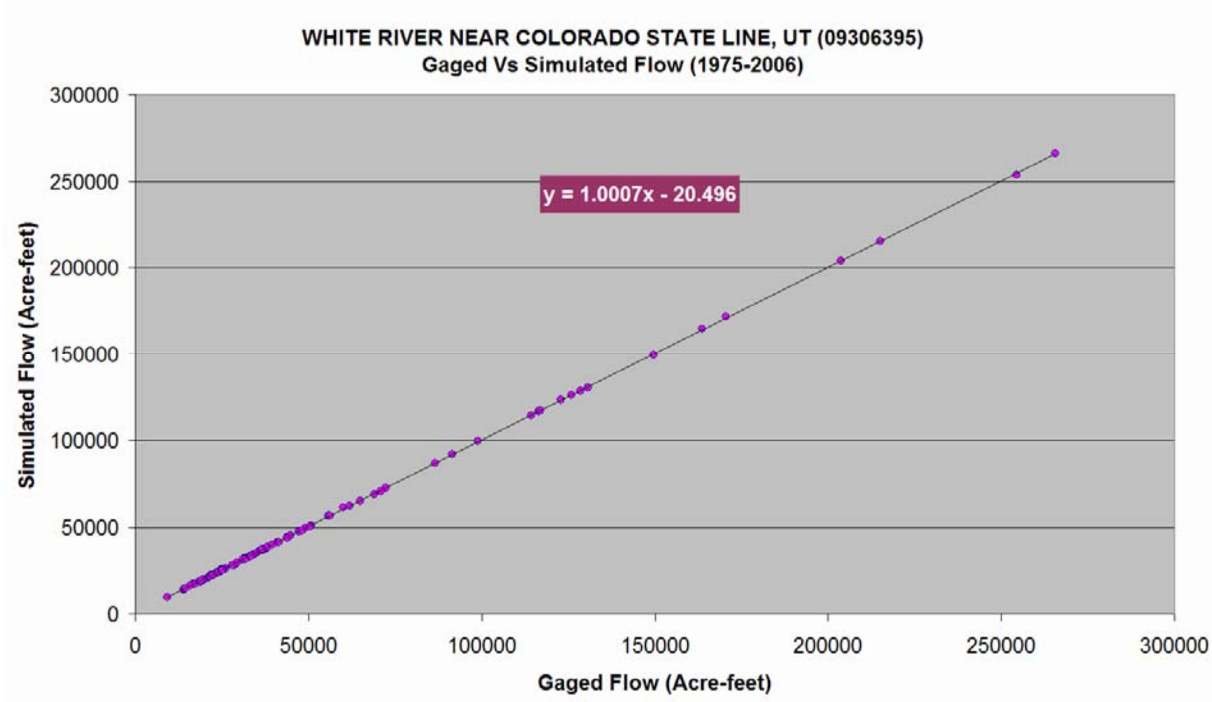


Figure 7.14 - Stream Flow Calibration - White River below Boise Creek near Rangely



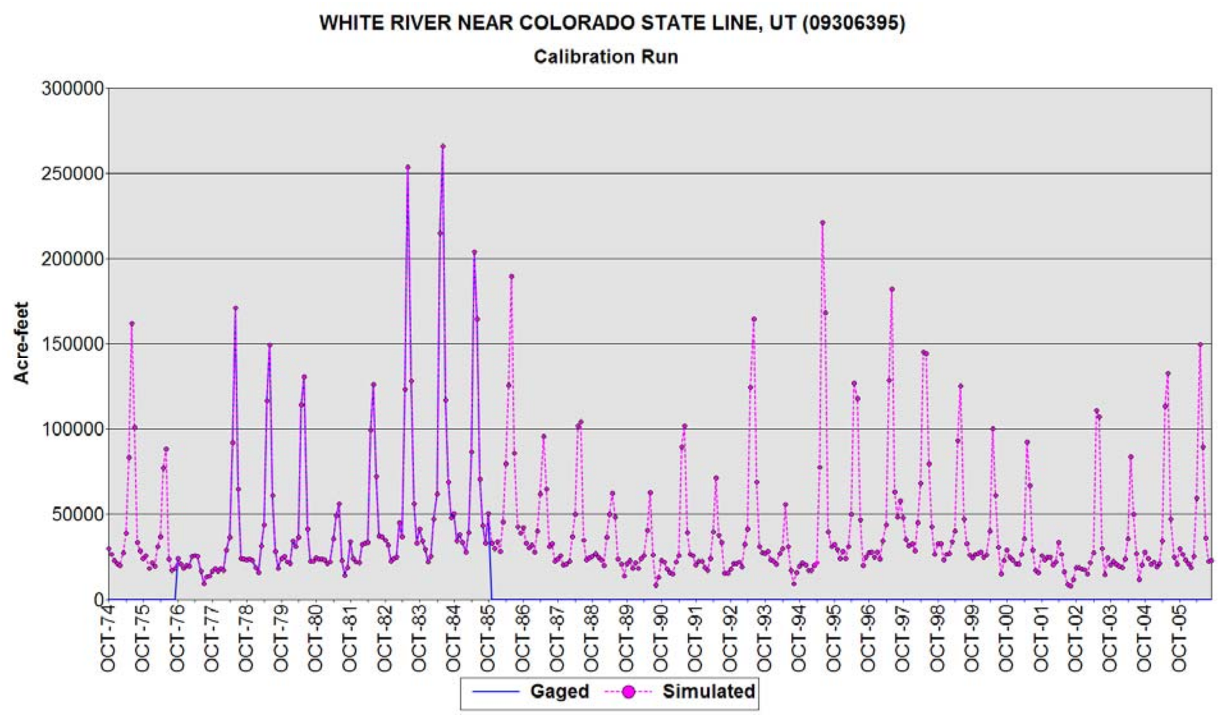


Figure 7.15 - Stream Flow Calibration - White River near Colorado State Line, UT

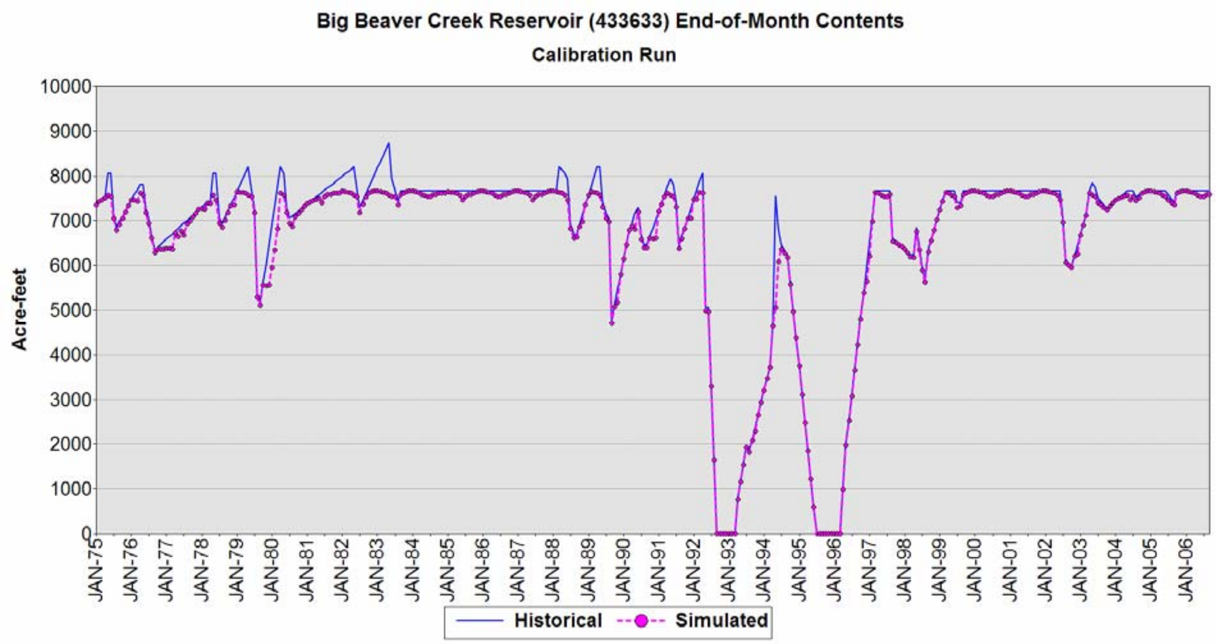


Figure 7.16 - Reservoir Calibration - Big Beaver Creek Reservoir

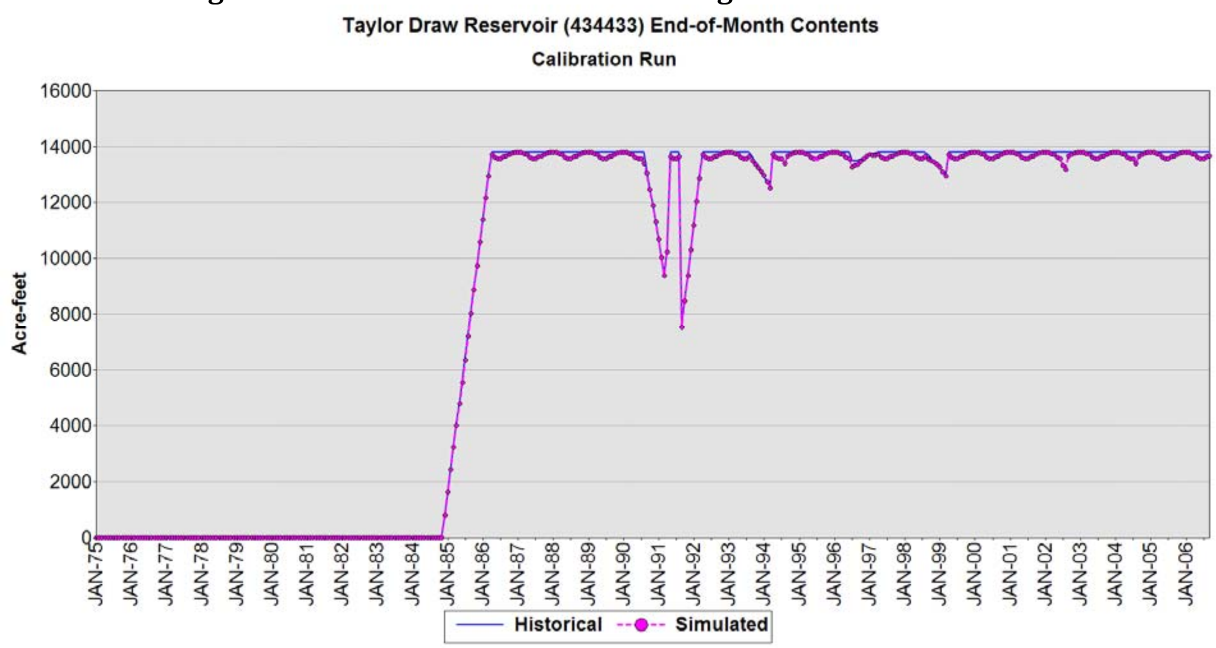


Figure 7.17 - Reservoir Calibration – Taylor Draw Reservoir

Index

Appendix A

Aggregation of Irrigation Diversion Structures

1. CDSS Memorandum Sub task 2.03
White River Aggregated Irrigation Structures

2. CDSS Memorandum Sub task 2.04
White River Add Aggregated Irrigation Structures to Network

3. CDSS Memorandum Subtask 2.05
Define Water Right Classes

Note: Memoranda in this Appendix are historical. They were produced when irrigation structures were aggregated and introduced into the model for the first time. Details may have changed through successive refinement and calibration, but the general approach remains the same. Details for the current model can be verified by reviewing DMI command files and Statemod input files.

September 4, 1996

MEMORANDUM

To: File

From: Ray R. Bennett

Subject: Sub task 2.03 White River Aggregated Irrigation Structures

Introduction

This memo describes the results of Sub task 2.03, White River Aggregated Irrigation Structures. The objective of this task was as follows:

> *Aggregate the Irrigation structures not explicitly modeled in Phase II by manually drawing aggregation boundaries on the map. All irrigation structures falling within a boundary will be aggregated into a single structure. A table will be generated from ARC/INFO listing the individual WDID's associated with each aggregation boundary.*

Approach and Results

Identify Aggregated Boundaries As presented on **Exhibit 1**, 16 aggregated boundaries were identified for the White River Basin. These were selected base on:

- Base flow hydrology,
- Spatial proximity
- Endangered Species instream flow reaches,
- Existing structures modeled
- New tributaries,
- Critical Administrative reaches,
- Return flows,
- Aggregated irrigated area size (should not exceed 1,000 acres)

Aggregated Structures **Exhibit 2** presents a summary of the structures and acreage associated with each of the 16 aggregated areas. As presented, these areas range from less than 100 acres (43_ADW006_WhiteAbPiceanceC) to more than 600 acres (43_ADW012_WhiteBlBoiseCr). In addition, **Exhibit 2** presents 6 structures which were added in Phase IIIa for modeling explicitly. These were selected in order to refine the modeling of critical areas within the White River. **Exhibit 3** presents a list of each structure associated with each aggregated group.

Comment

The following should be noted:

- The ID convention adopted (e.g. 43_ADW001) stands for **A**ggregated **D**iversion in the **W**hite River Basin. The numbers began from upstream to down stream but currently have no spatial significance.
- The naming convention adopted (e.g. 43_ADW001_WhiteNorthFork) ties to the ID, the regional area and/or a nearby stream gage.
- No aggregated structures (WD ID combinations) occur in more than one aggregated area.
- The Evacuation Creek area was added to the White River network downstream of the State line gage but upstream of the model terminus. This connection allows depletions associated with the White River Basin to be quantified without accounting for water use in Utah.
- A new base flow node was required at Evacuation Creek. Additional base flow nodes may be required during the calibration.
- Whenever an aggregated node was located near a stream gage, gains associated with the gage were moved to the aggregated node location. This allows total depletions to be quantified at gagged locations in the model but resulted in 11 new base flow nodes at the following locations: 43_ADW001, 43_ADW002, 43_ADW003, 43_ADW004, 43_ADW005, 43_ADW007, 43_ADW008, 43_ADW009, 43_ADW010, 43_ADW011 and 43_ADW014. They were considered within scope because they did not require calculating drainage area or average precipitation (data at the gage was simply transferred to the aggregated node).
- The 6 structures added for explicit modeling as part of Phase III were anticipated under Sub task 1.17, Modified Phase II model. They were located within the river network through discussions with Kent Holt of Division 6 on August 2, 1996 using river mile data recently developed. These discussions resulted in revising the location of structure 430948, Square S Consolidated, to be below gage 09306200, Piceance Creek below Ryan Gulch. Because the timing was appropriate, this refinement was included in the final Phase II results.

Exhibit 1

White River Basin Aggregated Structures

(map - not available)

Exhibit 2
White River Basin
Phase IIIa Structure Summary

ID	Name	Acres	Count
430605	DORRELL DITCH 2	58.51	1
430718	JAMES HAYES DITCH	143.94	1
430816	METZ DITCH	72.87	2
430873	PICEANCE DITCH	112.26	2
430908	RYAN DITCH	97.81	1
431108	JACOBS PUMP	98.74	2
43_ADW001	43_ADW001_WhiteNorthFork	259.83	15
43_ADW002	43_ADW002_WhiteSouthFork	246.33	9
43_ADW003	43_ADW003_WhiteAbColeCr	596.08	27
43_ADW004	43_ADW004_WhiteNrMeeker	452.39	15
43_ADW005	43_ADW005_WhiteNBLMeeker	155.6	13
43_ADW006	43_ADW006_WhiteAbPiceanceC	94.31	3
43_ADW007	43_ADW007_PiceanceUpper	425.25	20
43_ADW008	43_ADW008_PiceanceBlRioBla	181.46	17
43_ADW009	43_ADW009_PiceanceAbHunter	459.96	26
43_ADW010	43_ADW010_PiceanceBlRyanGu	551.05	22
43_ADW011	43_ADW011_Piceance@WhiteR	317.12	17
43_ADW012	43_ADW012_WhiteBlBoiseCr	617.2	27
43_ADW013	43_ADW013_WhiteBlDouglasCr	504.47	29
43_ADW014	43_ADW014_WhiteNrStateLn	429.67	22
43_ADW015	43_ADW015_EvacuationCr	151.06	10
43_ADW016	43_ADW016_WhiteSBLMeeker	410.38	25
Total		6436.29	306

Exhibit 3
White River Basin
Phase IIIa Structures

ID	Name	wd_id	Acres	Count	Subtotal
430605	DORRELL DITCH 2	430605	58.51	1	58.51
430718	JAMES HAYES DITCH	430718	143.94	1	143.94
430816	METZ DITCH	430816	72.87	2	72.87
430873	PICEANCE DITCH	430873	112.26	2	112.26
430908	RYAN DITCH	430908	97.81	1	97.81
431108	JACOBS PUMP	431108	98.74	2	98.74
43_ADW001	43_ADW001_WhiteNorthFork	430527	63.35	3	
		430557	5.66	1	
		430562	27.05	2	
		430639	12.49	1	
		430691	11.12	1	
		430757	7.01	1	
		430764	38.12	1	
		430984	33.2	1	
		430988	25.39	2	
		431003	4.9	1	
		431041	31.55	1	259.84
43_ADW002	43_ADW002_WhiteSouthFork	430518	55.97	2	
		430643	26.09	1	
		430655	9.92	1	
		430750	48.47	1	
		430812	19.05	1	
		430869	71.67	2	
		430946	15.16	1	246.33
43_ADW003	43_ADW003_WhiteAbColeCr	430510	17.18	2	
		430585	19.25	1	
		430596	49.81	1	
		430597	30.95	2	
		430598	15.88	2	
		430645	28.17	1	
		430647	19.37	1	
		430752	45.68	1	
		430779	3.95	1	
		430840	46.04	1	
		430871	43.07	1	
		430890	9.78	1	
		430891	24.31	1	
		430914	8.88	1	
		430996	58.44	2	
		431001	27.23	1	
		431002	11.12	1	
		431019	46.77	2	
		431025	44.86	1	
		431026	26.2	1	
		431101	19.13	2	596.07

43_ADW004	43_ADW004_WhiteNrMeeker	430522	8.23	1	
		430580	52.47	1	
		430606	31.68	2	
		430675	38.85	1	
		430720	13.55	1	
		430773	51.08	2	
		430969	67.75	2	
		430981	36.51	1	
		430982	74.15	1	
		430994	34.17	1	
		430997	43.97	2	452.41
43_ADW005	43_ADW005_WhiteNBLMeeker	430760	14.95	2	
		430761	22.32	1	
		430774	17.08	1	
		430957	13.6	2	
		430960	26.04	3	
		430971	43.98	2	
		430986	17.62	2	155.59
43_ADW006	43_ADW006_WhiteAbPiceance C	431036	76.34	1	
		431747	17.97	2	94.31
43_ADW007	43_ADW007_PiceanceUpper	430642	54.45	2	
		430662	6.57	1	
		430678	16.92	1	
		430693	23.03	1	
		430701	43.15	1	
		430759	63.34	1	
		430818	11.44	1	
		430829	17.22	1	
		430895	10.58	1	
		430923	48.51	2	
		430964	26.62	1	
		430975	31.64	1	
		430990	9.57	1	
		431031	15.41	1	
		431038	4.01	1	
		431048	12.76	1	
		431089	6.95	1	
		432416	23.07	1	425.24
43_ADW008	43_ADW008_PiceanceBlRioBla	430547	8.09	1	
		430637	14.54	1	
		430724	13.02	1	
		430745	14.29	2	
		430852	13.37	1	
		430875	16.6	1	
		430999	13.92	3	
		431046	13.55	1	
		431107	19.84	2	
		431139	41.63	1	
		432410	9.73	1	
		432411	1.4	1	
		432412	1.49	1	181.47

43_ADW009	43_ADW009_PiceanceAbHunter	430619	27.16	1	
		430656	6.83	1	
		430707	23	2	
		430755	32.72	1	
		430765	66.79	2	
		430853	46.99	1	
		430858	33.09	4	
		430876	42.85	2	
		430916	12.45	1	
		430963	24.66	1	
		431014	7.7	1	
		431030	29.02	1	
		431081	19.57	2	
		432473	36.17	2	
		432474	5.73	1	
		432475	17.18	1	
		432476	10.3	1	
		432477	17.74	1	459.95
43_ADW010	43_ADW010_PiceanceBlRyanGu	430520	39.98	1	
		430548	25.53	1	
		430594	60.29	1	
		430611	30.71	1	
		430697	42.11	2	
		430708	26.24	1	
		430794	5.37	1	
		430801	24.05	1	
		430820	50.13	4	
		430836	51.07	2	
		430846	25.5	1	
		430847	43.65	1	
		430924	95.43	3	
		431099	29.07	1	
		431550	1.91	1	551.04
43_ADW011	43_ADW011_Piceance@WhiteR	430560	17.19	1	
		430561	12.5	1	
		430683	25.88	3	
		430704	14.35	1	
		430706	11.26	1	
		430800	31.27	1	
		430861	51.51	1	
		430897	10.63	1	
		430920	19.85	1	
		431084	22.73	1	
		431092	11.26	1	
		432054	42.06	1	
		432309	3.04	1	
		435005	4.17	1	
		435007	39.44	1	317.14
43_ADW012	43_ADW012_WhiteBlBoiseCr	430536	52.82	1	

		430727	71.89	2	
		430756	85.22	3	
		430778	22.28	1	
		430796	61.88	1	
		430806	13.7	1	
		430886	78.8	1	
		430983	37.27	1	
		431039	0.83	1	
		432450	14.78	1	
		432451	8.73	1	
		432454	16.46	1	
		432456	86.66	3	
		432458	56.14	2	
		435019	1.71	1	
		435020	1.79	1	
		435021	0.67	1	
		435042	1.26	1	
		435043	1.36	1	
		435046	1.47	1	
		435047	1.48	1	617.2
43_ADW013	43_ADW013_WhiteBlDouglasCr	430500	42.88	1	
		430501	32.82	2	
		430521	41.4	1	
		430552	24.3	4	
		430553	1.4	1	
		430556	57.82	2	
		430892	29.5	2	
		430915	25.48	2	
		430939	48.19	1	
		430955	14.75	1	
		430956	19.27	1	
		431000	18.75	1	
		431040	11.12	2	
		431083	68.51	3	
		431274	50.24	3	
		431338	1.74	1	
		432149	16.31	1	504.48
43_ADW014	43_ADW014_WhiteNrStateLn	430877	90.11	4	
		431244	6.03	1	
		431254	75.42	1	
		431255	36.92	1	
		431256	58.32	4	
		431258	16.24	2	
		431261	63.56	1	
		431262	25.64	4	
		431723	8.33	1	
		432160	16.49	1	
		432305	32.11	1	
		432361	0.5	1	429.67
43_ADW015	43_ADW015_EvacuationCr	430627	14.13	1	
		430733	28.28	3	
		430854	9.88	1	
		430857	46.39	2	

		430900	10.13	1	
		430968	33.42	1	
		430989	8.83	1	151.06
43_ADW016	43_ADW016_WhiteSBLMeeker	430515	19.89	1	
		430533	52.18	4	
		430535	10.33	1	
		430612	101.76	3	
		430634	16.84	1	
		430705	61.36	8	
		430943	7.09	1	
		430945	5.16	1	
		431024	33.62	1	
		431042	11.51	1	
		431094	11.2	1	
		432056	29.86	1	
		432106	49.6	1	410.4
Total			6436.33	306	6436.33

September 19, 1996

MEMORANDUM

To: File

From: Ray R. Bennett

Subject: Sub task 2.04 White River Add Aggregated Irrigation Structures to Network

Introduction

This memo describes the results of Sub task 2.04, Add Aggregated Irrigated Structures to Network. The objective of this task was as follows:

> *Incorporate the aggregated groups of irrigation structures defined in Sub task 2.03 into the Phase III model network.*

Approach and Results

Add Aggregated Irrigation Structures to Network Exhibit 1 presents a line diagram which includes the 16 aggregated structures and 6 new explicitly modeled structures associated with Phase IIIa White River Model. To aviod having multimple copies of the network, Wxhibit 1 also includes refinements make in subtask 2.10 and aggregated M&I structures and subtask 2.11 for Aggregated Reservoirs and Stock Ponds.

Comment

The following should be noted:

- Whenever an aggregated node was located near a stream gage, gains associated with the gage were moved to the aggregated node location. This allows total depletion's to be quantified at gagged locations in the model but resulted in 11 new base flow nodes at the following locations: 43_ADW001, 43_ADW002, 43_ADW003, 43_ADW004, 43_ADW005, 43_ADW007, 43_ADW008, 43_ADW009, 43_ADW010, 43_ADW011 and 43_ADW014. The reassignment of base flows was considered within scope because it did not require calculating drainage area or average precipitation (data at the gage was simply transferred to the aggregated node). This approach was approved by the State Management team at a meeting on August 22, 1986.

November 19, 1996

MEMORANDUM

To: File

From: Ray R. Bennett

Subject: Subtask 2.05 Define Water Right Classes

Introduction

This memo describes the results of Subtask 2.05, Define Water Right Classes. The objective of this task was as follows:

> *Define approximately 10 water administration classes to be used to model the aggregated irrigation and reservoir groups in the White River Basin.*

Approach and Results

Plot Water Rights A plot was generated with the following data (**Exhibit 1** bottom to top):

- Line 1, All Absolute diversion water rights
- Line 2, Absolute water rights to be modeled in Phase IIIa
- Line 3, Absolute water rights associated with an irrigated parcel
- Line 4, Absolute water rights modeled in Phase II

Line 1, the list of all absolute water rights, was obtained by executing *Watright*, a Data Management Interface that extracts such information from the CRDSS database. Line 3, the list of absolute water rights associated with an irrigated parcel, was obtained by linking structures with irrigated land identified in the GIS coverage to the water rights presented in Line 1. Line 4, the list of absolute water rights modeled in Phase II, was obtained by linking structures modeled in Phase II to the water rights presented on Line 1. Line 2, the list of Absolute water rights to be modeled in Phase IIIa is a sum of the structures modeled in Phase II (Line 4) and those with irrigated acreage which had not yet been modeled.

Obtain Call Information Kent Holt of Division 6 was contacted by phone on July 26, 1996 regarding frequent calls in the White River Basin. Results were as follows:

River	Structure Name	ID	Right (cfs)	Admin. Number
Piceance Creek	Square S Consolidated	430948	2.2	13509.00000
Coal Creek	Coal Creek Mesa	430578	7.7	13940.00000
White River	Highland Ditch	430694	48.2	32172.16923

Note the White River call has only occurred one time, in 1977. Also, other small streams may have their own calls but are outside the intent of this study.

Water Right Groups Water Right aggregation groups were developed using the following data:

- District 43 call information,
- Incremental right group size (attempted to have incremental rights in each group of a similar size unless dictated by call information).

The resulting 8 categories are presented below:

#	Admin. Number From	Admin. Number To	Cumulative Right (cfs)	Incremental Right (cfs)
1	0	13509.00000	181	181
2	13509.00001	13940.00000	299	118
3	13940.00001	25767.16000	650	351
4	25767.16001	32172.16923	992	342
5	32172.16924	32172.24570	1273	281
6	32172.24571	38474.00000	1614	341
7	38474.00001	45504.00000	1959	345
8	45504.00001	Infinity	2132	173

Comments

Following are comments related to the execution of Subtask 2.05, Define Water Right Classes:

- Following is a break down of absolute direct flow decrees in the White River Basin:

Description	Decrees (cfs)	Percent (%))
Phase II tied to Irrigated land	1,559.60	54
Phase II not tied to Irrigated land	76.85	3
Phase III added	495.61	17
Subtotal (Phase III modeled)	**2132.06**	**73**
Other Rights	769.78	26
Total	**2,901.84**	**100**

- Regarding **Exhibit 1** and the above table, a spot check of the 'Other Right' (water rights that occur between Line 1 (All Absolute Water Rights) and Line 2, (Absolute Water Rights to be Modeled in Phase III), indicates they include rights which no longer operate, are associated with non consumptive activities, or are relatively small municipal and industrial rights. The following table identifies two of the larger rights within this group. In addition to those categories described above, the water rights that were not modeled are expected to include ditches which may currently divert but were not tied to irrigated land during the 1993 survey. They might be added if the irrigated acreage data is updated.

Ditch	Decree (cfs)	Comment
430809 Meeker Power Ditch	161.88	No longer operational
430888 Rainbow Lake Ditch	31.75	Non Consumptive

Appendix B

Aggregation of Non-Irrigation Structures

1. CDSS Memorandum Sub task 2.10
White River Basin Aggregated Municipal and Industrial Use

2. CDSS Memorandum Sub task 2.11
White River Basin Aggregated Reservoirs and Stock Ponds

September 19, 1996

MEMORANDUM

To: File

From: Ray R. Bennett

Subject: Sub task 2.10 White River Basin Aggregated Municipal and Industrial Use

Introduction

This memo describes the results of Sub task 2.10 White 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 The following table presents the 1975 to 1991 average annual Municipal and Industrial diversions and consumptive use modeled in Phase II. Note, the efficiency was revised from the 70% assigned in Phase II to the 30% recommended by WW Wheeler. Also, the California water company diversion is used for oil field near Rangely.

Ditch	**Diversion (AF)**	**Depletion (AF)**
Meeker (430810)	624	187
Rangely (430889)	1,083	325
Sub total	**1,707**	**512**
Cole Creek Feeder (430577)	726	0
Calif. Water Co. (430564)	3,831	3,831
Subtotal	**4,557**	**3,831**
Total	**6,264**	**4,343**

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 2.09-11, Non-Evapotranspiration (Other Uses) Consumptive Uses and Losses in the White River Basin (8/16/96).

Category	Depletion (AF)
Municipal	459
Mineral	728
Livestock	424
Total	**1,611**

Aggregated M&I Diversion Based on the above data and the relatively small amount of consumption, one aggregated M&I demand (AMW_001) was added to the model as one aggregated node (AMW_001) at the White River just above the state line gage (see Subtask 2.04 for a network diagram which includes the aggregated M&I demand). The structure was assigned a depletive demand (efficiency of 100%) of 1,099 AF/yr (1,611 AF - 512 AF) over 12 months evenly. Note this demand recognizes that the consumptive uses and losses estimates do not include the California water company demands which may be interpreted to be a depletion to the surface water system but not to the basin since the water is injected underground and held in storage. The aggregated M&I structure was assigned a water right of 2 cfs and a senior administration number of 1.

March, 1999

MEMORANDUM

To: File

From: Ray R. Bennett

Subject: Sub task 2.11 White River Basin Aggregate Reservoirs and Stock Ponds

Introduction

This memo describes the results of Sub task 2.11, 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 storage facilities in the White River Basin.*

Approach and Results

Reservoirs and Stock Ponds The following table presents the net absolute storage rights located the White River Basin that were modeled in Phase II along with those to be added in Phase III**. Exhibit 1** lists the individual structures associated with the reservoirs to be modeled in Phase III. **Exhibit 2** lists the SQL script used to obtain this data.

Phase	Reservoir	Absolute Decree (AF)	Percent of Total
Phase II	Taylor Draw	13,800	45
Phase II	Big Beaver	7,658	25
subtotal		**21,458**	**70**
Phase III	Reservoirs	4,234	14
Phase III	Stock ponds	4,776	16
subtotal		**9,010**	**30**
Total		**30,468**	**100**

Also presented on the above table is the storage associated with stock ponds which are to be modeled in Phase III. Stock pond capacity was obtained from the year 2 product, Task Memo 2.09, Non-Evapotranspiration (Other Uses) consumptive uses and Losses in the White River Basin (8/16/96).

Number of Structures and Location Based on a review of the Phase II reservoir coverage map and the location of stock ponds with regard to USGS hydrologic units, the Phase III reservoirs were incorporated into the model as two aggregated reservoirs; one on the White River above the state line gage (ARW_001) and another on the White River above the confluence with the Piceance Creek (ARW_002). Similarly, two reservoirs which represent stock ponds (ASW_001 and ASW_002) ponds were added at the same locations. Subtask 2.04 contains a network diagram which includes the aggregated reservoirs and stock ponds.

Accounts Each reservoir was assigned one account and an initial storage equal their capacity as follows:

Structure	**Capacity (AF)**	**Initial Contents(AF)**
Aggregated Reservoirs	2,117	2,117
Aggregated Stock Ponds	2,388	2,388

Area-Capacity and Evaporation Data Each aggregated reservoir was assigned a simple 2 point area capacity curve based on a 10 foot deep reservoir as follows:

Aggregated Reservoir Area-Capacity

Capacity (AF)	**Area (ac)**
0	0
2117	211.7

Aggregated Stock Pond Area-Capacity

Capacity (AF)	**Area (ac)**
0	0
2388	238.8

Evaporation The evaporation station assigned to each aggregated reservoir and stock pond is the same as that determined for Big Beaver Reservoir in Phase 2.

Operational Rules, Target Contents and End-of-Month Data No operating rules were implemented for aggregate reservoirs.

Comment

The following should be noted:

- ***Watright*** was scoped to develop one aggregated reservoir decree. In order to model two aggregated reservoirs it was necessary to hand edit the reservoir right file (*.rer).
- ***Statemod*** implements the one fill rule by priority. For example if a reservoir has 200 AF in storage at the administration date and two decrees as follows;

  100 AF at Priority 1 and

  400 AF at Priority 2

  then the first priority decree would not be allowed to divert for that year while the second priority decree would be limited to 300 af for the year. This approach required stock ponds and reservoir be modeled separated rather than combined as scoped.

wd	id	res_name	abs_af
43	3642	JOHNNY JOHNSON RES	1036.000
43	3769	BIG LICK RES	481.000
43	3659	SKINNEY FISH RESERVOIR	300.700
43	3644	KEYSTONE CR BEN PRICE RE	286.810
43	3643	KEYSTONE NO 2 RESERVOIR	151.000
43	3668	WATKIN RESERVOIR AND D	134.520
43	4287	PAGODA LAKE	120.000
43	3671	WILSON RES	103.000
43	3651	MC GINNIS MEADOW RES	87.000
43	3649	LUNNEY RESERVOIR	82.120
43	4504	TAYLOR RES	81.000
43	3669	WEST MILLER RESERVOIR	77.800
43	3717	BAXTER RES	64.600
43	3652	MC HATTEN RESERVOIR	64.200
43	4497	DESPERADO M SEDIMENT RP4	62.000
43	3647	LARSON RES	61.900
43	3632	BEAVER LAKE RESERVOIR	59.000
43	3893	MARK RES NO 1	54.800
43	3896	ALBRIGHT RES NO 2	52.200
43	4308	THEOS NO 1 RES	51.000
43	3639	GREGOR RESERVOIR	47.000
43	3634	BLACK GULCH RES	40.750
43	4284	NINE MI RANCH RES 1	40.710
43	4272	JACOBS RESERVOIR	38.300
43	4291	RAINBOW LAKE	36.700
43	4499	REEVES RES	34.000
43	3645	KEYSTONE RES NO 3	31.200
43	4280	MARK RES NO. 2	31.020
43	3717	BAXTER RES	30.000
43	3657	SEVENTH LAKE RESERVOIR	29.500
43	3897	MARK RES NO 3	28.300
43	3895	KIRBY RES NO 2/60	27.800
43	4463	VANDIVER POND	24.830
43	3894	BANTA RES NO 1	23.700
43	3630	BAILEY LAKE RETAIN POND	22.800
43	3769	BIG LICK RES	21.900
43	3671	WILSON RES	21.160
43	4320	JENSEN RES NO 1	19.000
43	3904	BALL LAKE RESERVOIR	18.000
43	3636	CABINE LAKE RESERVOIR	16.060
43	4249	DORTCH POND NO 1	13.600
43	3672	W STEWART GULCH RES	13.300
43	4327	SADDLE HORSE PARK RES	12.000
43	3660	STUMP LAKE RESERVOIR	10.230
43	4487	WILLIAMS POND	10.000
43	3661	TAWNEY HIRONS RESERVOIR	8.000
43	3631	BARBOUR POND	7.800
43	3632	BEAVER LAKE RESERVOIR	7.450
43	4461	KAWCAK POND NO 1	7.400
43	4385	DESPERADO POND RP-2 + 3	7.400

43	4383	DESPERADO MINE POND DP-1	7.036
43	3656	PROCTER RESERVOIR	6.660
43	4307	TERLEP POND	6.500
43	4285	NINE MILE RANCH RES NO 2	6.310
43	4497	DESPERADO M SEDIMENT RP4	6.000
43	3935	DIETZ SPG NO 1 POND	6.000
43	3716	JOY JOY AND WATSON RES	5.880
43	3638	GOOSMAN RESERVOIR	5.600
43	4351	JENSEN RES. NO. 2	5.000
43	4250	DORTCH POND NO 2	5.000
43	4318	YELLOW CREEK RES NO 1	5.000
43	4492	R R LOADOUT LOOP POND	4.930
43	3646	LADY LAKE	4.410
43	4262	FLAG CREEK RES NO 8	4.250
43	3934	FILENER RESERVOIR	4.000
43	3663	URRIOLA NO 1 RES	4.000
43	4386	DESPERADO MINE POND RP-1	3.530
43	4325	NORTHERN POND B	3.170
43	3670	WHITNER FISH POND	3.065
43	4253	FLAG CREEK RES NO 10	3.060
43	4326	NORTHERN POND C	3.000
43	3658	SHADOW LAKE RESERVOIR	2.600
43	3640	HERRELL FISHPOND	2.500
43	4488	SEVEN K RES	2.380
43	3657	SEVENTH LAKE RESERVOIR	2.120
43	4271	INDIAN SPG RESERVOIR	2.000
43	4260	FLAG CREEK RES NO 2	1.610
43	4276	LOVE RES NO 1	1.500
43	4493	STITT STOCK TANK + POND	1.500
43	4257	FLAG CREEK RES NO 16	1.380
43	4294	RAT MT POND NO 1	1.000
43	4446	JOHNSON POND NO 15	1.000
43	4445	JOHNSON POND NO 14	1.000
43	4440	JOHNSON POND NO 9	1.000
43	3667	VEACH GULCH STOCK POND 1	1.000
43	4322	JENSEN NO 3 RES	1.000
43	4242	BILL ALLEN RESERVOIR	1.000
43	3654	MONUMENT MT STKWTR PD	1.000
43	3655	NONAME STOCK WATER POND	1.000
43	3666	VEACH GULCH STKWTR PD 2	1.000
43	3635	BRADY GULCH STOCK POND	1.000
43	3641	JEAN URRUTY NO 2 RES	1.000
43	3901	JEAN URRUTY RES 1	1.000
43	3664	URRUTY RES 3	0.750
43	4273	JONES STOCK A FISH POND	0.750
43	3653	MC GINNIS MEADOW RES	0.700
43	3662	TRAPPERS LAKE RETAIN PD	0.690
43	4324	NORTHERN POND A	0.630
43	4437	JOHNSON POND NO 6	0.500
43	4459	JOHNSON POND NO 4	0.500
43	3899	ELK DRAW RES	0.500
43	3637	EVACUATION CR LAKE RES	0.500
43	4268	HARRY MANGUS SEEP POND	0.500
43	3665	URRUTY STOCK WATER TANK	0.500

43	4264	FLAG CK SPG NO 5	0.430
43	3886	GORDON RES NO 3	0.290
43	4265	FLAG CK SPG NO 6	0.290
43	4266	FRED SLIFKA SPG POND	0.250
43	4309	UPPER MOYER POND	0.250
43	4278	LOWER POND 2/67	0.250
43	4247	CRAWFORD POND	0.250
43	4277	LOWER MOYER POND	0.250
43	4255	FLAG CREEK RES NO 13	0.230
43	4261	FLAG CREEK RES NO 4	0.190
43	4297	ROAD POND	0.167
43	4311	WEST HUNTER CREEK POND	0.150
43	3892	GORDON SPG RES NO 2	0.140
43	4254	FLAG CREEK RES NO 12	0.140
43	4300	SADDLE POND 1/67	0.125
43	4289	POWER LINE POND 3/67	0.125
43	4267	GORDON SPG RES NO. 1	0.110
43	4259	FLAG CREEK RES NO 19	0.110
43	4448	JOHNSON POND NO 17	0.100
43	4279	MALCOLM POND	0.100
43	4256	FLAG CREEK RES NO 15	0.060
43	4423	HARP POND	0.050
43	4258	FLAG CREEK RES NO 18	0.040
43	4293	RANGELY RESERVOIR	0.000
43	4304	STOREY GULCH RES	
43	4305	STRAWBERRY CREEK RES	
43	4306	SUPERIOR OIL TERM RES	
43	4275	KENNY RESERVOIR NO 1	
43	4246	CATHEDRAL RES NO. 1	
43	4274	KELLOG GULCH RES	
43	4310	WALKER RESERVOIR	
43	4270	HUNTER CK RES	
43	4313	WOLF CK RES	
43	4313	WOLF CK RES	
43	4313	WOLF CK RES	
43	4314	WOLF RIDGE RES	
43	4315	WRAY GULCH RES	
43	4316	WRAY GULCH RES	
43	4317	YELLOW CREEK RES	
43	4290	R L BROWN RES	
43	4245	BUCKEYE RESERVOIR	
43	4269	HENRY RES	
43	4263	FOURTEEN MILE RES 1 ENL	
43	4244	BLACKS GULCH RES	
43	4243	BLACK SULPHUR RES	
43	4251	DUCK CREEK RES	
43	4348	E. NO NAME GULCH RES.	
43	4252	FIGURE FOUR RES	
43	4282	MILLER CK RES	
43	4727	DIETZ CABIN RES	
43	4288	POWELL PARK RES	
43	4384	DESPERADO MINE POND RP-4	
43	4286	NORTH ELK RES.	
43	4284	NINE MI RANCH RES 1	

43 4292 RALEY RESERVOIR
43 4430 JOHNSON RES NO 2
43 4431 JOHNSON RES NO 1
43 3650 MARTIN VILLA RESERVOIR
43 4433 TAYLOR DRAW RESERVOIR
43 4434 JUMPS CABIN RES
43 4435 HOWELLS CABIN RES
43 4436 STAKE SPRINGS RESERVOIR
43 4283 MOELLER RES NO. 1
43 4438 JOHNSON POND NO 7
43 4439 JOHNSON POND NO 8
43 4293 RANGELY RESERVOIR
43 4441 JOHNSON POND NO 10
43 4442 JOHNSON POND NO 11
43 4443 JOHNSON POND NO 12
43 4444 JOHNSON POND NO 13
43 4282 MILLER CK RES
43 4295 RIO BLANCO RESERVOIR
43 4447 JOHNSON POND NO 16
43 4296 RIPPLE CREEK RESERVOIR
43 4449 CORRAL GULCH RES UPSTRM
43 4450 BOX ELDER GULCH RES ALT
43 4451 STAKE SPRING RES DWNSTRM
43 4453 CORRAL GULCH RESERVOIR
43 4454 WATER GULCH WATER FACIL
43 4455 STAKE SPGS RES H20 FACIL
43 4456 JOHNSON POND NO 1
43 4457 JOHNSON POND NO 2
43 4458 JOHNSON POND NO 3
43 4281 MEADOWS RES 1 ENL
43 4460 JOHNSON POND NO 5
43 3648 LOST PARK RESERVOIR
43 4462 HATCH GULCH RES
43 3647 LARSON RES
43 4464 WILLOW CR RES 1
43 4465 UPPER PICEANCE RES
43 4466 LOWER PICEANCE RES
43 4467 BEAR VALLEY RES + POND
43 4468 SPENCER DRAW POND =1
43 4469 SPENCER DRAW POND =2
43 4470 SPENCER DRAW POND =3
43 4471 SPENCER DRAW POND =4
43 4472 SPENCER DRAW POND =5
43 4473 UPPER WOLF CREEK POND
43 4474 UPPER WOLF CREEK LOWER P
43 4475 EAST TWIN WASH RESERVOIR
43 4476 TWIN WASH POND =1
43 4477 TWIN WASH POND =2
43 4478 TWIN WASH POND =4
43 4479 TWIN WASH POND =5
43 4480 TWIN WASH POND =6
43 4481 TWIN WASH POND =7
43 4482 TWIN WASH POND =8
43 4483 TWIN WASH POND =9

43	4484 TWIN WASH POND =10
43	4485 TWIN WASH POND =11
43	4486 TWIN WASH POND =13
43	4298 RYAN GULCH RESERVOIR
43	3907 BUCK CREEK RESERVOIR
43	4248 CROOKED WASH RES
43	4301 SAWMILL MOUNTAIN RES
43	4302 SOUTH FORK RESERVOIR
43	3902 BOIES RESERVOIR
43	4497 DESPERADO M SEDIMENT RP4
43	4498 JUDY BEARD RES
43	4303 STILLWATER RESERVOIR
43	4500 SPRING CR RES
43	4501 BOISE CR RES
43	4502 SMITH GULCH RESERVOIR
43	4503 P L RES NO 1
43	4304 STOREY GULCH RES
43	4504 TAYLOR RES

Appendix C

Calculated Data Set

Note: This Appendix describes a Calculated Data Set that was completed in October, 2008. The White River Model Historical (calibration), Baseline, and Calculated data files were updated in October 2009, and the 2009 calibration and Baseline data sets are described in the main body of this user manual. Inconsistencies between the 2008 and 2009 data sets are minor, and include:

1) maximum irrigation efficiency set to 0.60 in 2008, and set to 0.54 in 2009
2) small 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
3) adjustments to the network and baseflow hydrology in the upper Piceance Creek basin.

The approach described for the Calculated Data Set is accurate, except for item 1) above. Table values in this appendix are similar to, but not exactly, what is produced by the 2009 Calculated data set.

Calculated Data Set

The "Calculated Data Set" is a data set that was created to further look at calibration of the White River basin 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 and historical efficiency. The scenario is historical in the sense that it uses historical operating rules, and reservoirs come on-line when they did historically, but the irrigation demand is not strictly historical. In the 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 that would be reflected in the calibration data set. Demand in the Calculated data set reflects the theoretical crop needs, that is, the amount that should be diverted if the crop is to acquire a full supply.

Because demand in the Calculated Data Set is not tightly tied to actual diversions, results from a historical run with the Calculated Data Set tend to deviate from observed values a little more than the calibration run. On the other hand, the run provides insight into historical needs and shortages that the calibration run does not provide. This is because the calibration run assumes there is no crop demand above the historically diverted amount, when in fact, supply, (or the means to supply) may have been limiting.

Calculated Demand

Calculated demand is computed by **StateDMI** based on time series of historical diversions and crop irrigation water requirement. Based on a period specified by the user, the DMI computes an average efficiency for each structure, for each month of the year. Efficiencies in the sample for which the monthly average is derived are computed as the monthly irrigation crop water requirement divided by the month's diversion amount.

For some structures, the average monthly efficiency computed this way exceeded 60 percent, typically in July, August, or September. It was assumed when this occurred that the crop was supply limited. For the purpose of developing a theoretical monthly diversion demand, the average monthly efficiency was not allowed to exceed 60 percent. Demand was then estimated in each month as the irrigation crop water requirement, divided by the average monthly efficiency (constrained to 60 percent).

Since historical diversions tend to be available in the database back to 1975 for the White basin, the period used for developing irrigation efficiency was 1975 through 2006. **StateDMI** calculated a theoretical diversion demand for each month within this time frame based on the particular month's crop water requirement and average efficiency. Outside that period, Calculated demand was filled using the standard time series filling method described in Section 4.

Basinwide Calculated demand over the calibration period (1975-2006) amounts to 341,108 af/yr on average. This compares with historical diversions which averaged 275,459 af/yr over the same period.

Calculated Data Set Calibration Results

Calibration of the White River model is considered very good, with most streamflow gages deviating less than one percent from historical values on an average annual basis. The majority of the diversion structures show a negative difference between historical and simulated annual volumes, indicating for those structures larger volumes diverted in this simulation compared with historical diversions. Less than five percent of the diversion structures present shortages with respect to their historical diversion, and the basinwide shortage with respect to historical diversions is less than 1 percent per year, on average. Simulated reservoir contents are representative of historical values.

Water Balance

Table C.1 summarizes the water balance for the White River model, for the calibration period (1975-2006). Following are observations based on the summary table:

- Surface water inflow to the basin averages 582,178 acre-feet per year, and surface water outflow averages 520,893 acre-feet per year.
- Annual diversions amount to approximately 331,000 acre-feet on average.
- Approximately 53,000 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). The small values are due to rounding on a monthly basis and indicate that the model correctly conserves mass.

Streamflow Calibration Results

Table C.2 summarizes the annual average streamflow for water years 1975 through 2006, as estimated using the Calculated data set. 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. Differences between gaged and simulated average annual streamflows small, but greater than for the Historical calibration run. Differences are attributable to greater demand and diversions in this data set. The greater demand in the Calculated data set may reflect irrigation water requirement early and late in the season (April, September, and October), when irrigators have chosen not to irrigate; however, this conclusion has not been verified.

Figures C.1 through C.13 (at the end of this appendix) graphically present monthly streamflow estimated by the model compared to historical observations at key streamgages. When only one line appears on a graph it indicates that the simulated and historical results are the same at the scale presented.

Table C.1
Average Annual Water Balance for Calculated Data Set Calibration, White River Model (af/yr)

Month	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	28,403	27,634	17	56,054	27,423	162	28,204	248	139	-122	56,054	0	1,880
NOV	21,959	9,172	0	31,131	2,576	50	28,325	180	19	-19	31,131	0	275
DEC	20,996	5,458	0	26,454	1,723	-36	24,591	177	1	-1	26,454	0	242
JAN	21,732	4,226	0	25,958	1,647	-43	24,169	186	1	-1	25,958	0	236
FEB	21,168	3,255	0	24,423	1,513	25	22,806	78	1	-1	24,423	0	253
MAR	30,804	2,702	2	33,508	1,812	115	31,557	22	7	-5	33,508	0	379
APR	45,953	8,204	6	54,163	10,660	205	43,117	175	46	-40	54,163	0	1,281
MAY	115,336	31,074	35	146,445	45,774	385	100,308	-56	58	-24	146,445	0	6,706
JUN	139,101	55,000	183	194,284	78,088	525	115,602	-114	38	146	194,284	0	11,943
JUL	69,479	49,645	114	119,237	67,009	522	51,775	-183	38	75	119,237	0	13,524
AUG	37,233	40,571	19	77,824	51,378	342	26,135	-51	88	-68	77,824	0	10,092
SEP	30,013	35,721	43	65,778	41,347	303	24,306	-222	57	-14	65,778	0	5,741
TOTAL	582,178	272,662	419	855,258	330,950	2,554	520,893	443	493	-74	855,259	0	52,551

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

Table C.2
Historical and Simulated Average Annual Streamflow Volumes (1975-2006)
Calculated Data Set (acre-feet/year)

Gage ID	Historical	Simulated	Historical minus Simulated		Gage Name
			Volume	Percent	
09303000	232,859	232,449	410	0	NORTH FORK WHITE RIVER AT BUFORD
09303400	143,418	143,418	0	0	SOUTH FORK WHITE RIVER NEAR BUDGES RESORT, CO.
09303500	189,830	189,744	86	0	SOUTH FORK WHITE RIVER NEAR BUFORD, CO.
09304000	185,547	181,484	1,063	1	SOUTH FORK WHITE RIVER AT BUFORD
09304200	400,250	387,918	12,332	3	WHITE RIVER ABOVE COAL CREEK
09304500	446,708	438,076	8,633	2	WHITE RIVER NEAR MEEKER
09304800	478,759	476,391	2,368	0	WHITE RIVER BELOW MEEKER
09306007	15,199	15,109	90	1	PICEANCE CREEK BELOW RIO BLANCO
09306200	23,377	22,386	991	4	PICEANCE CREEK BELOW RYAN GULCH
09306222	27,632	27,053	580	2	PICEANCE CREEK AT WHITE RIVER
09306224	684,593	680,935	4,018	1	WHITE RIVER ABOVE CROOKED WASH NEAR WHITE RIVER CITY
09306290	532,247	527,982	4,265	1	WHITE RIVER BELOW BOISE CREEK NEAR RANGELY
09306395	596,955	592,103	4,852	1	WHITE RIVER NEAR COLORADO STATE LINE, UT

Diversion Calibration Results

Table C.3 summarizes the difference between average annual historical diversions and average annual simulated diversions for water years 1975 through 2006, for each ditch. Where the difference is negative, the Calculated demand was larger than historical diversions, and the model shows that the higher level of demand could have been met. Note that the differences in this table reflect both modeling error and differences between the Calculated demand and actual diversions.

Table C.3
Historical and Simulated Average Annual Diversions (1975-2006)

Gage ID	Historical	Simulated	Historical minus Simulated Volume	Historical minus Simulated Percent	Gage Name
43_ADW001	6,266	7,589	-1,323	-21	NORT_ADW WhiteNorthF
43_ADW002	1,680	2,145	-465	-28	SOUT_ADW WhiteSouthF
43_ADW003	4,855	5,694	-839	-17	WHIT_ADW WhiteAbCole
43_ADW004	2,667	3,654	-987	-37	WHIT_ADW WhiteNrMeek
43_ADW005	847	1,236	-389	-46	WHIT_ADW WhiteNBLMee
43_ADW006	1,695	2,164	-469	-28	WHIT_ADW WhiteAbPice
43_ADW007	3,459	3,872	-413	-12	PICE_ADW PicCrUpper
43_ADW008	714	667	47	7	PICE_ADW PicCrBlRioB
43_ADW009	4,594	5,238	-644	-14	PICE_ADW PicCrAbHunt
43_ADW010	4,199	4,806	-607	-15	PICE_ADW PicCrBlRyan
43_ADW011	1,422	1,828	-406	-29	PICE_ADW Piceance@Wh
43_ADW012	2,892	3,513	-621	-22	WHIT_ADW WhiteBlBois
43_ADW013	3,374	4,270	-895	-27	WHIT_ADW WhiteBlDoug
43_ADW014	2,317	3,019	-701	-30	WHIT_ADW WhiteNrStat
43_ADW015	717	1,114	-398	-55	EVAC_ADW Evac Creek
43_ADW016	2,894	3,428	-534	-18	WHIT_ADW WhiteSBLMee
43_AMW001	1,104	1,104	0	0	WHIT_AMW AggMuni&Ind
430511	1,500	1,873	-374	-25	B A & B DITCH NO 1
430513	999	1,241	-242	-24	B M & H DITCH 1
430526	1,218	1,499	-281	-23	BARBOUR NORTH SIDE D
430537	1,739	2,160	-421	-24	BECKMAN DITCH
430539	1,125	1,316	-191	-17	BIG BEAVER DITCH
430543	164	260	-95	-58	BLACK EAGLE D NO 1
430544	149	241	-92	-62	BLACK EAGLE D NO 2
430546	1,291	1,722	-431	-33	BLAIR DITCH
430563	168	276	-108	-64	CALHOUN DITCH
430564	2,443	2,443	0	0	CALIFORNIA CO WATER PL
430570	620	834	-214	-34	CALVAT DITCH
430572	1,569	2,138	-569	-36	CHARLIE SMITH DITCH
430573	609	820	-212	-35	CHASE & COLTHARP D
430575	830	1,095	-266	-32	CLOHERTY DITCH
430577	544	544	0	0	COAL CREEK FEEDER DITCH
430578	3,143	4,296	-1,153	-37	COAL CREEK MESA DITCH

Gage ID	Historical	Simulated	Historical minus Simulated		Gage Name
			Volume	Percent	
430605	333	429	-97	-29	DORRELL DITCH 2
430607	1,731	2,177	-447	-26	DREIFUSS DITCH
430608	1,436	1,540	-104	-7	DREYFUSS DITCH
430623	1,107	1,254	-147	-13	ELK CREEK DITCH
430625	849	889	-40	-5	EMILY DITCH
430640	779	1,132	-352	-45	FORNEY CORCORAN DITCH
430652	1,134	1,335	-201	-18	G V DITCH
430653	1,396	1,863	-467	-33	GEORGE S WITTER DITCH
430665	535	793	-258	-48	GREENSTREET DITCH EXT
430681	4,508	5,426	-918	-20	HAY BRETHERTON DITCH
430684	617	812	-195	-32	HAY DITCH 2
430687	930	1,236	-306	-33	HEFLEY PUMP PLANT NO 1
430688	965	1,289	-324	-34	HEFLEY PUMP PLANT NO 2
430694	37,550	43,357	-5,806	-16	HIGHLAND DITCH
430695	683	864	-181	-27	HILL CREEK NO 3 DITCH
430696	1,587	1,948	-360	-23	HILL CREEK NO 2 DITCH
430710	2,241	3,059	-817	-37	IMES & REYNOLDS DITCH
430711	469	682	-213	-45	INDEPENDENT DITCH
430714	256	429	-172	-67	IVO E SHULTS D & PUMP
430718	1,117	1,422	-305	-27	JAMES HAYES DITCH
430753	231	227	4	2	LAKE CREEK POOL DITCH
430758	539	760	-221	-41	LAWRENCE DITCH NO 1
430769	1,827	2,410	-583	-32	LITTLE DITCH
430777	1,842	2,409	-567	-31	LOWLAND DITCH
430782	1,039	1,300	-261	-25	M H M GERMAN CONS D
430788	4,110	4,904	-794	-19	MARCOTT DITCH
430789	1,198	1,593	-396	-33	MARTIN DITCH
430790	1,105	1,460	-355	-32	MARVINE DITCH 1
430791	502	655	-154	-31	MARVINE DITCH 3
430808	4,512	5,697	-1,185	-26	MEEKER DITCH
430809	218	273	-55	-25	MEEKER POWER DITCH
430810	751	0	751	100	MEEKER WATER SYS PL
430813	428	571	-143	-33	MELVIN DITCH
430815	952	1,127	-175	-18	METZ & REIGAN DITCH
430816	893	933	-41	-5	METZ DITCH
430819	28,148	31,761	-3,614	-13	MILLER CREEK DITCH

Gage ID	Historical	Simulated	Historical minus Simulated		Gage Name
			Volume	Percent	
430823	473	687	-214	-45	MINER MARTIN DITCH
430828	1,124	1,474	-350	-31	MOONEY DITCH
430841	885	1,181	-296	-34	NEW ARCHER WARNER DITCH
430842	13,841	16,400	-2,559	-19	NIBLOCK DITCH
430848	24,755	29,179	-4,425	-18	OAK RIDGE PARK DITCH
430849	7,756	9,267	-1,511	-20	OLD AGENCY DITCH
430850	912	970	-58	-6	OLDLAND DITCH 1
430851	575	499	76	13	OLDLAND DITCH 2
430862	523	715	-192	-37	PATTISON DITCH NO 1
430867	4,228	5,066	-838	-20	PEASE DITCH
430868	2,654	3,598	-944	-36	PEDRICK DITCH
430873	819	879	-60	-7	PICEANCE CREEK DITCH
430881	1,326	1,377	-51	-4	POTHOLE DITCH
430883	14,581	17,028	-2,447	-17	POWELL PARK DITCH
430889	1,332	1,332	0	0	RANGELY WATER PLANT
430903	1,210	1,282	-72	-6	ROBERT MCKEE DITCH
430908	285	424	-139	-49	RYAN DITCH
430909	807	790	16	2	RYE GRASS DITCH
430919	229	330	-101	-44	SAYER DITCH
430926	703	985	-282	-40	SHERIDAN & MORTON D
430928	721	956	-234	-33	SIMPSON DITCH
430929	414	417	-3	-1	SIZEMORE DITCH 1
430931	954	1,229	-274	-29	SKELTON DITCH
430934	314	325	-11	-4	SOLDIER CREEK DITCH
430935	7,174	8,835	-1,661	-23	SOUTH SIDE HIGHLINE D
430936	376	413	-37	-10	SPAULDING D
430944	878	848	30	3	SPROD DITCH 1
430948	2,049	2,599	-551	-27	SQUARE S CONS D SYS
430949	499	748	-250	-50	STADTMAN DITCH
430954	390	616	-226	-58	STOREY DITCH 1
430961	2,584	3,339	-755	-29	SWEEDE DITCH
430965	287	503	-215	-75	THOMAS DITCH
430966	300	452	-152	-51	THOMAS DITCH 2
430980	2,038	2,498	-459	-23	UTE CREEK DITCH
431010	537	601	-64	-12	WHITE RIVER MESA DITCH
431027	1,138	1,153	-15	-1	BELOT MOFFAT DITCH

Gage ID	Historical	Simulated	Historical minus Simulated		Gage Name
			Volume	Percent	
431033	513	730	-218	-43	LAWRENCE DITCH
431034	142	314	-172	-121	MCDOWELL NO. 1 DITCH
431108	236	480	-245	-104	JACOBS PUMP & PL
431272	871	1,222	-352	-40	COX PUMP NO 1
431273	493	666	-173	-35	REIGAN PUMP NO 1
431494	536	749	-214	-40	GOFF DITCH
432099	632	885	-253	-40	KENNEY PUMP NO 1
436045	45	0	45	100	MEEKER WELLS
950810	0	796	-796	N/A	MEEKER DEMAND
FUD001	0	0	0	N/A	FUTURE DEMAND PICEANCE CK 1
FUD002	0	0	0	N/A	FUTURE DEMAND PICEANCE CK 2

Reservoir Calibration Results

Figures C.14 through C.15 (located at the end of this appendix) present reservoir EOM contents estimated by the model using the Calculated data set, compared to historical observations, at selected reservoirs.

Figure C.1

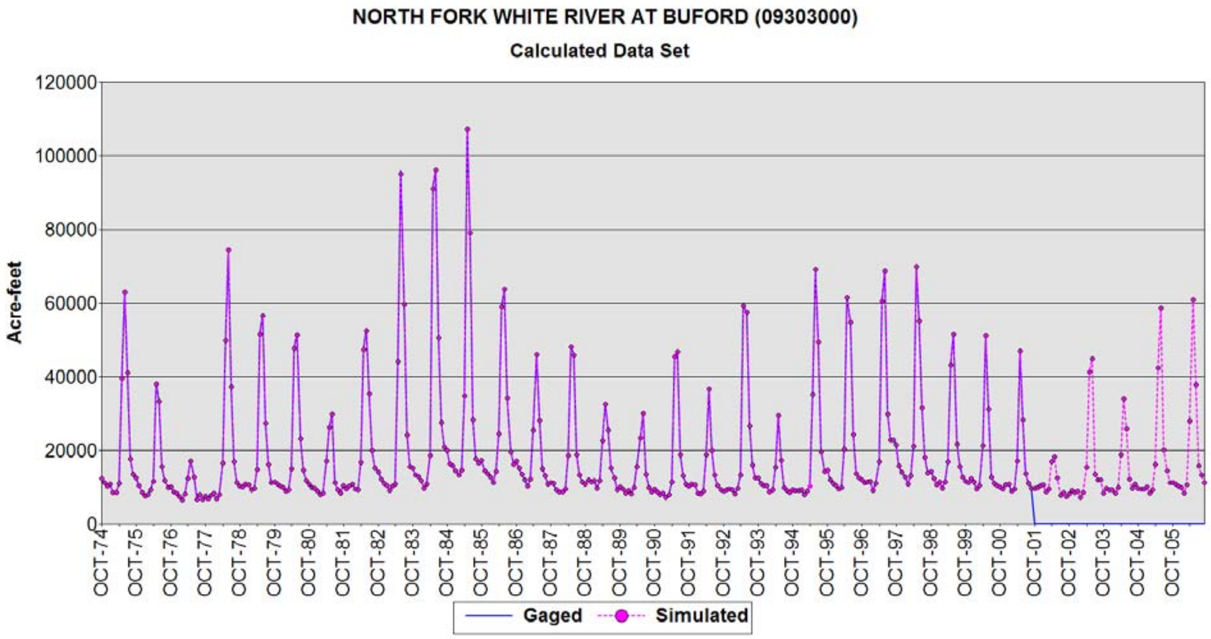


Figure C.2

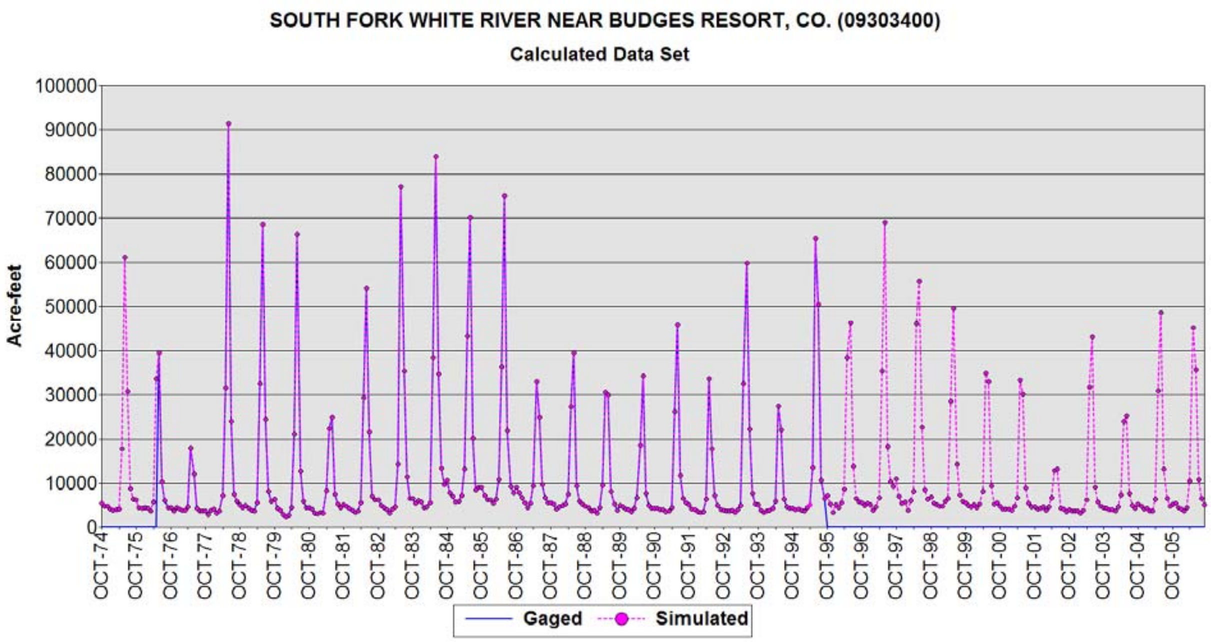


Figure C.3

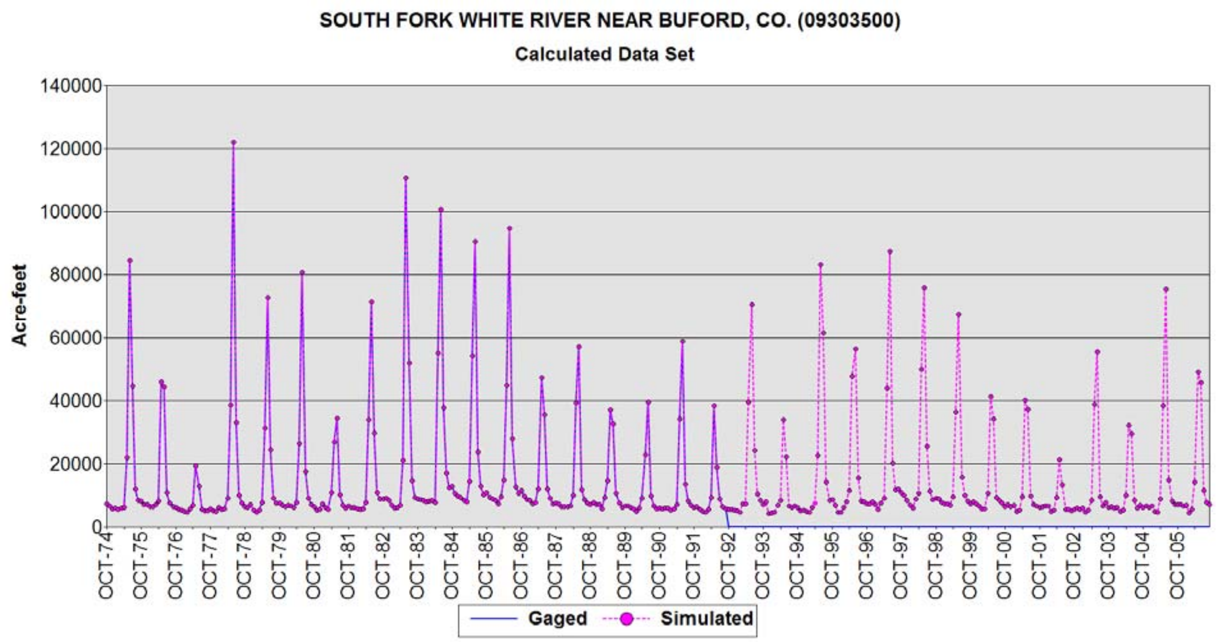


Figure C.4

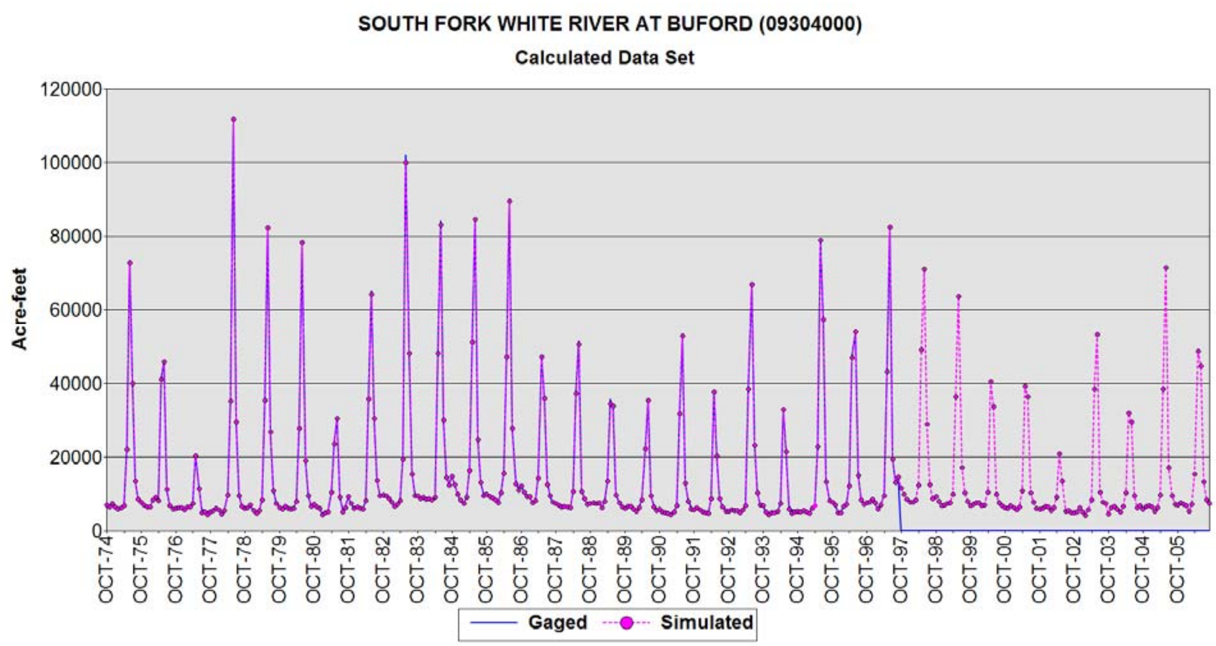


Figure C.5

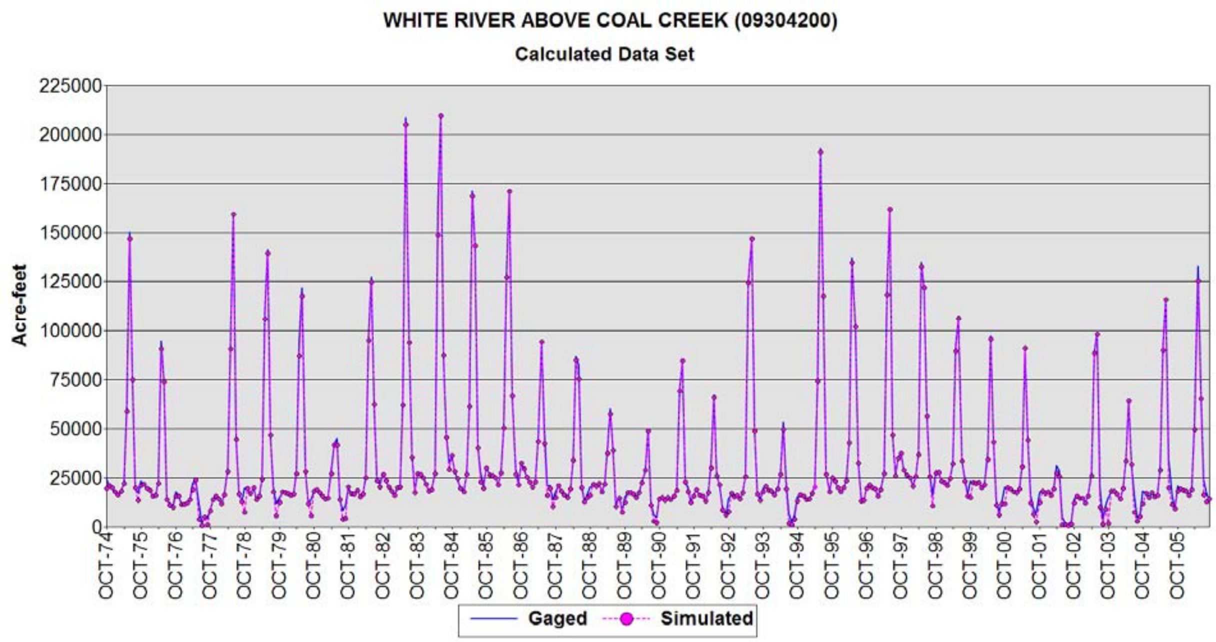


Figure C.6

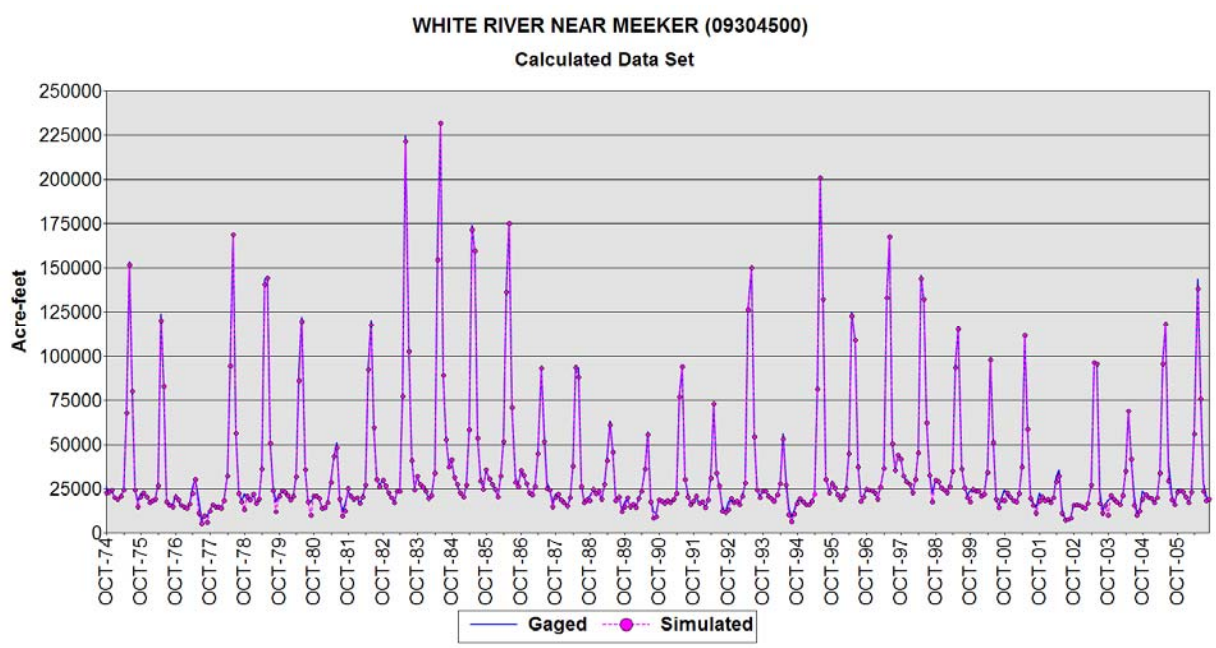


Figure C.7

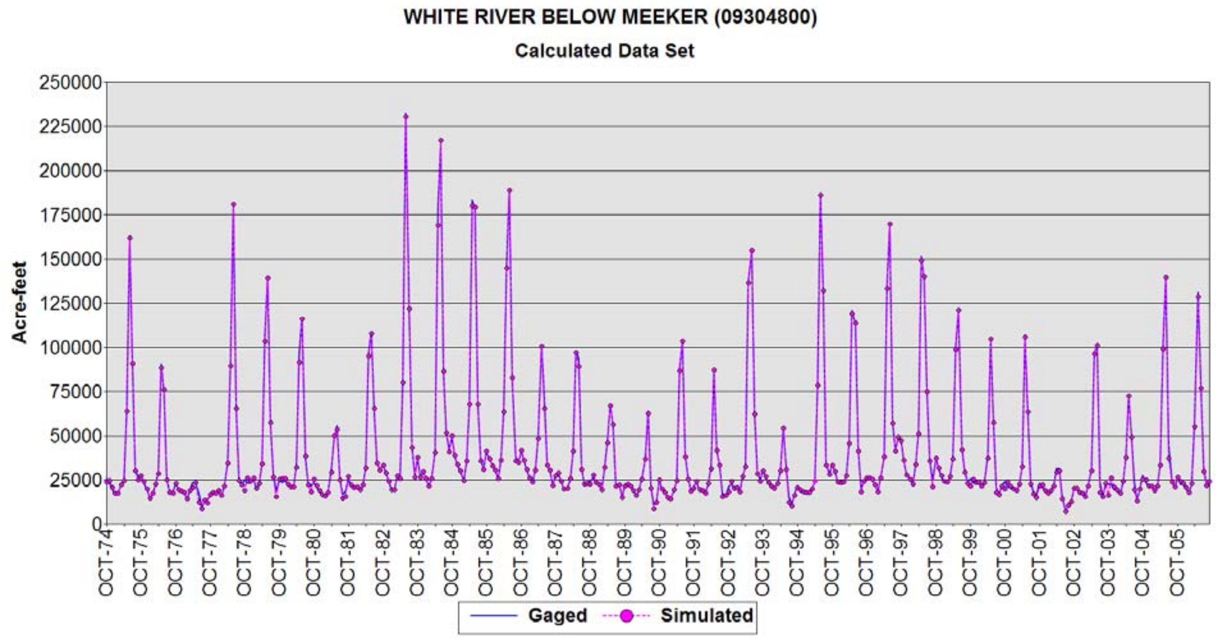


Figure C.8

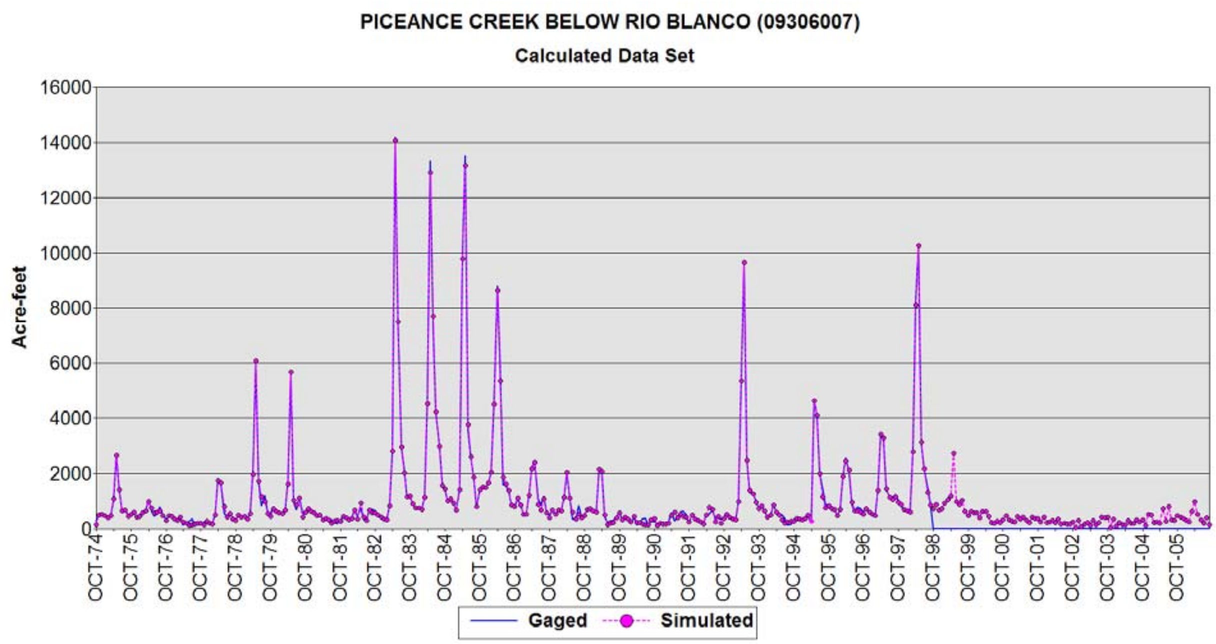


Figure C.9

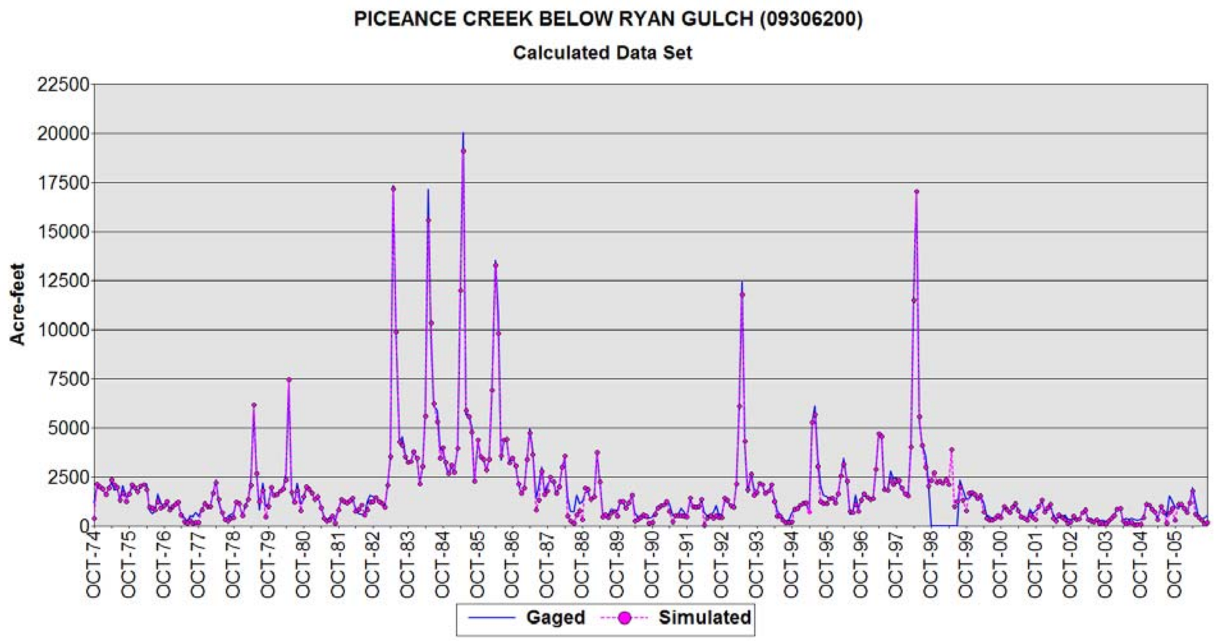


Figure C.10

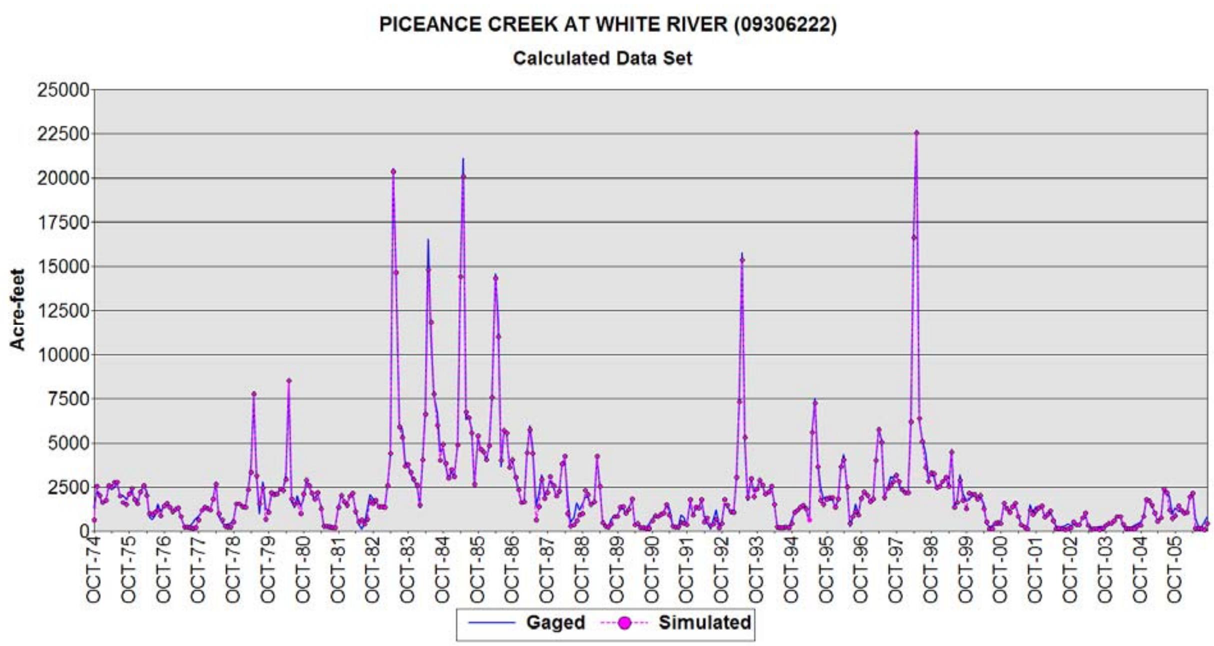


Figure C.11

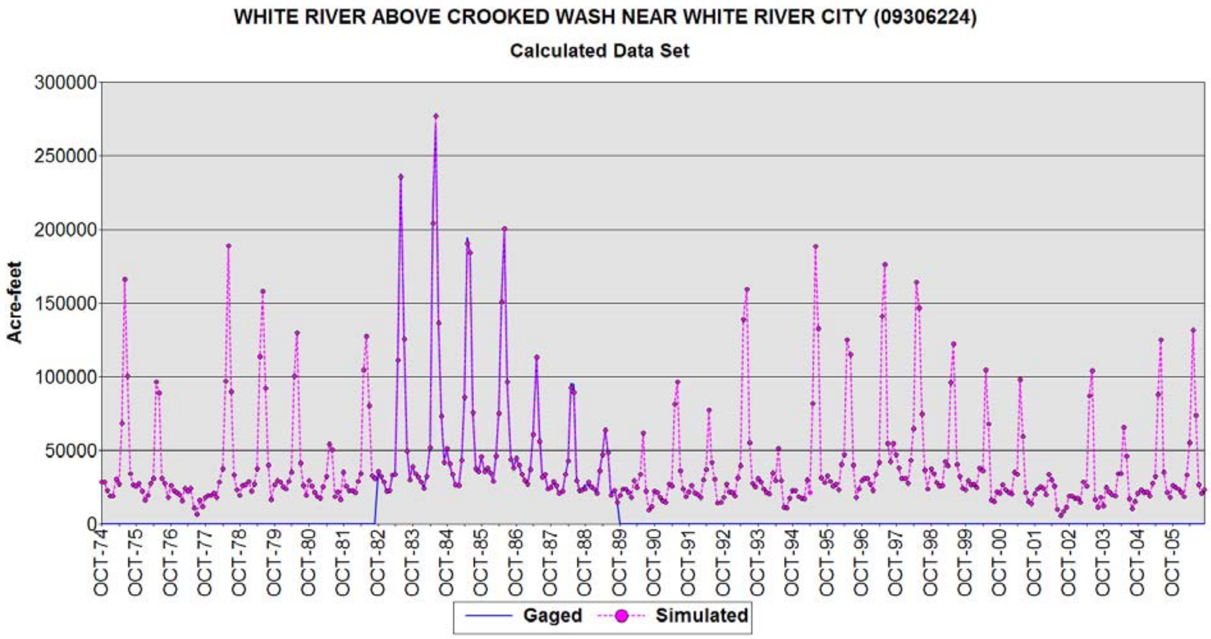


Figure C.12

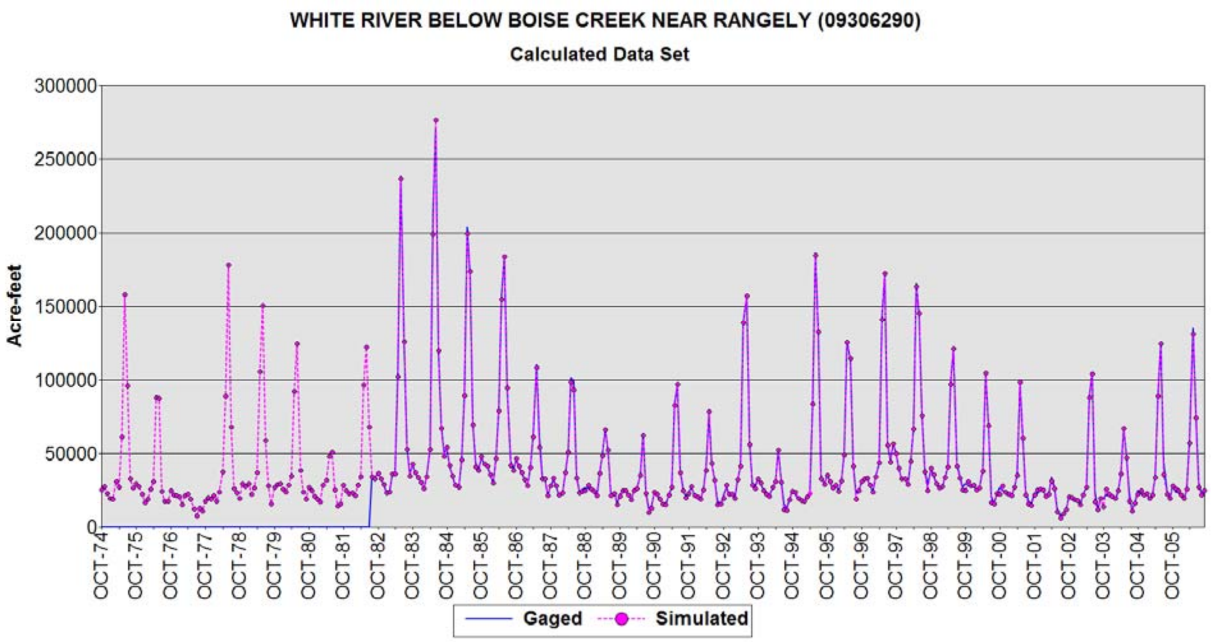
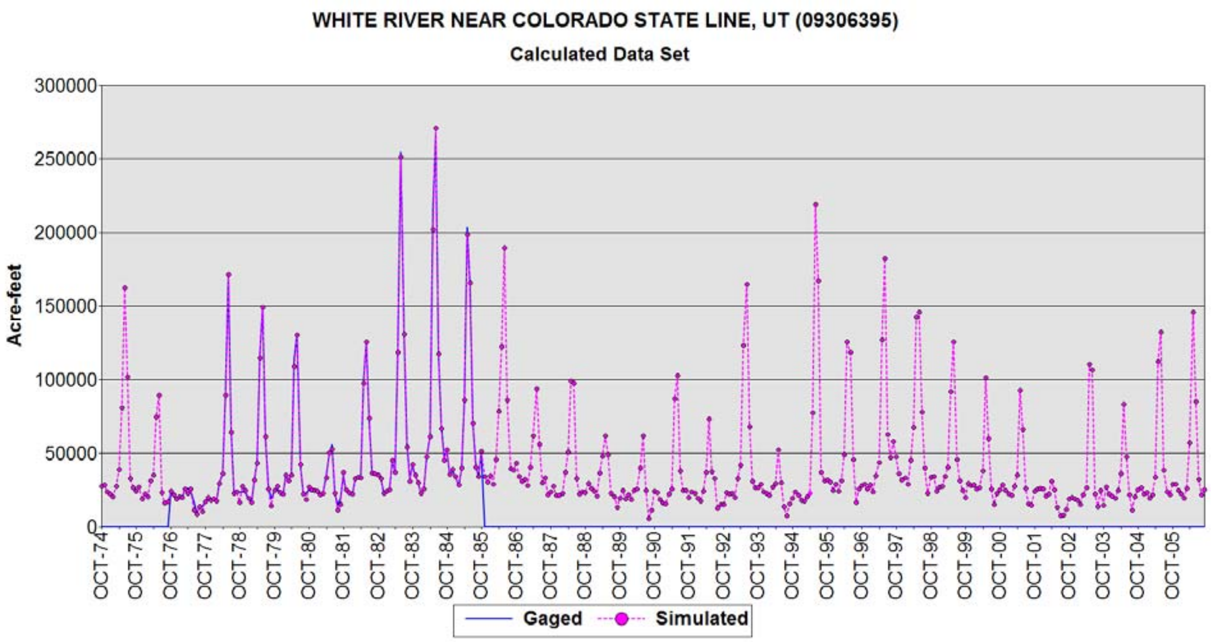


Figure C.13


WHITE RIVER NEAR COLORADO STATE LINE, UT (09306395)
Calculated Data Set
Acre-feet
300000
250000
200000
150000
100000
50000
0
OCT-74
OCT-75
OCT-76
OCT-77
OCT-78
OCT-79
OCT-80
OCT-81
OCT-82
OCT-83
OCT-84
OCT-85
OCT-86
OCT-87
OCT-88
OCT-89
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OCT-00
OCT-01
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OCT-03
OCT-04
OCT-05
Gaged
Simulated

Figure C.14

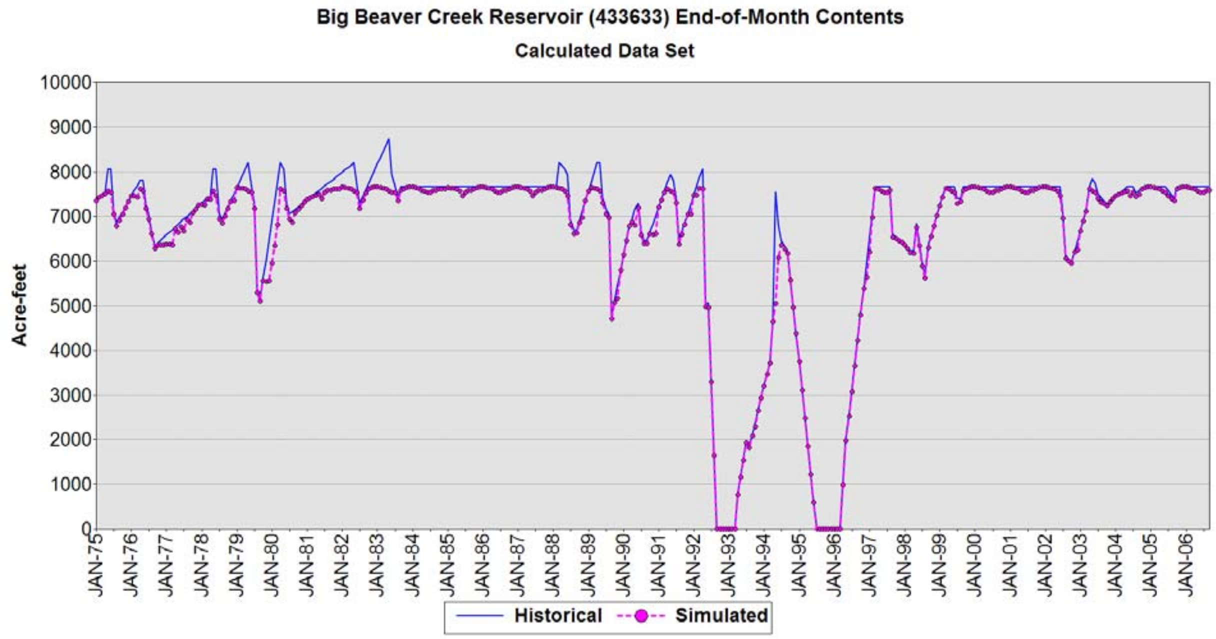

Figure C.15