CRWAS Phase I
San Juan and Dolores Basins – StateMod Model Brief

1. Introduction

This document provides general descriptions of the development and calibration of the model representing the South West basins in Colorado (termed the San Juan Model throughout this document). It is a companion document to ***"Overview of the Colorado Decision Support System"***, which summarizes the integrated Colorado Decision Support System (CDSS) and its primary components (including StateMod, StateCU and HydroBase). The following sections describe:

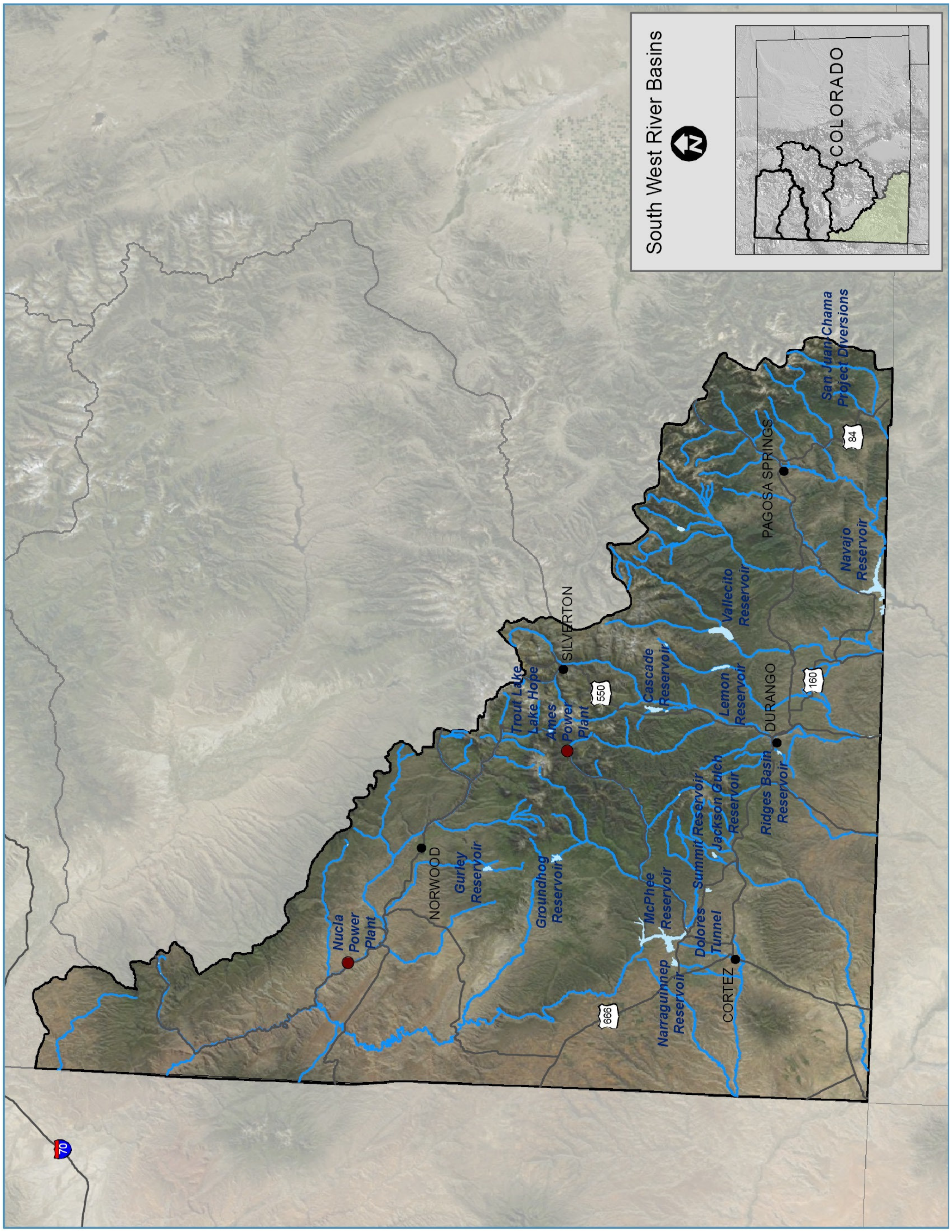
- the four primary aspects of the San Juan River Basin StateMod model: 1) inflow hydrology; 2) physical infrastructure; 3) water demands; and 4) legal and administrative conditions (Section 2) and
- the process used for model calibration (Section 3).

Each section concludes with cross-references (denoted in gray boxes entitled "Where to find more detailed information:") that guide the reader to specific sections of existing CDSS documentation for further reading (e.g., Model User's Manual, Information Reports, and other CDSS documents). An Appendix describes primary water supply project operations.

Several large diversions from the Dolores River Basin, including the Dolores Project and the Montezuma Valley Irrigation Company diversions and diversions for the Summit Irrigation Company, serve irrigated lands adjacent to McElmo Creek and the Mancos River, both tributaries to the San Juan River. Therefore, although the Dolores River Basin is administered in Division 4, it is represented with the San Juan Basin (Division 7) for the StateMod modeling efforts.

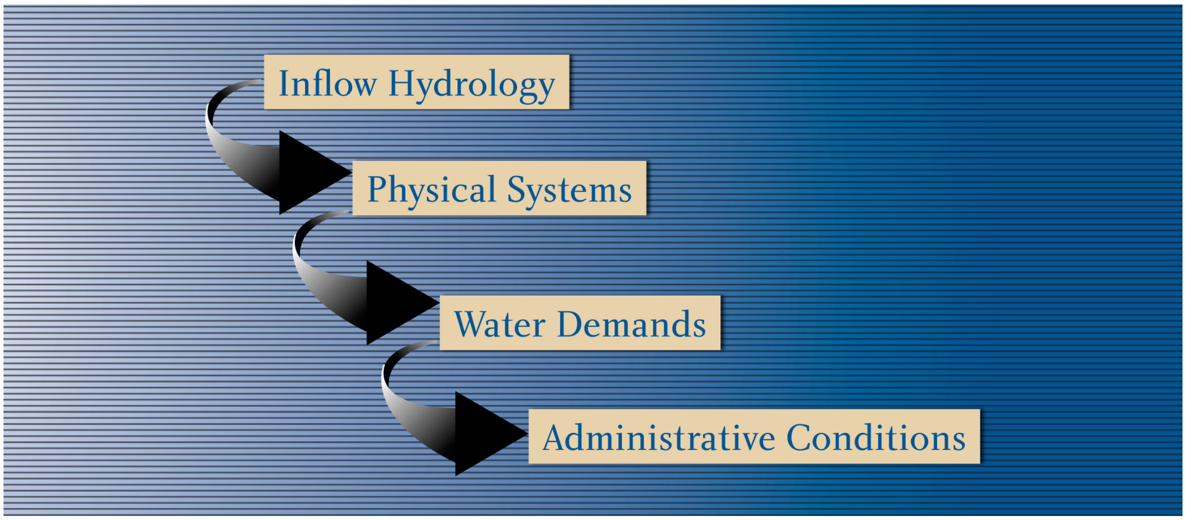
Figure 1 highlights the model extent of the San Juan and Dolores basins and the key rivers, streams, towns and water storage facilities.

Figure 1: San Juan and Dolores River Basins - Key Hydrography and Facilities



2. Model Components

The major components of the San Juan Model are input files representing the basin's unique hydrology, diversions, water demands, and legal and administrative conditions affecting project operations. The model consists of the following four major components:

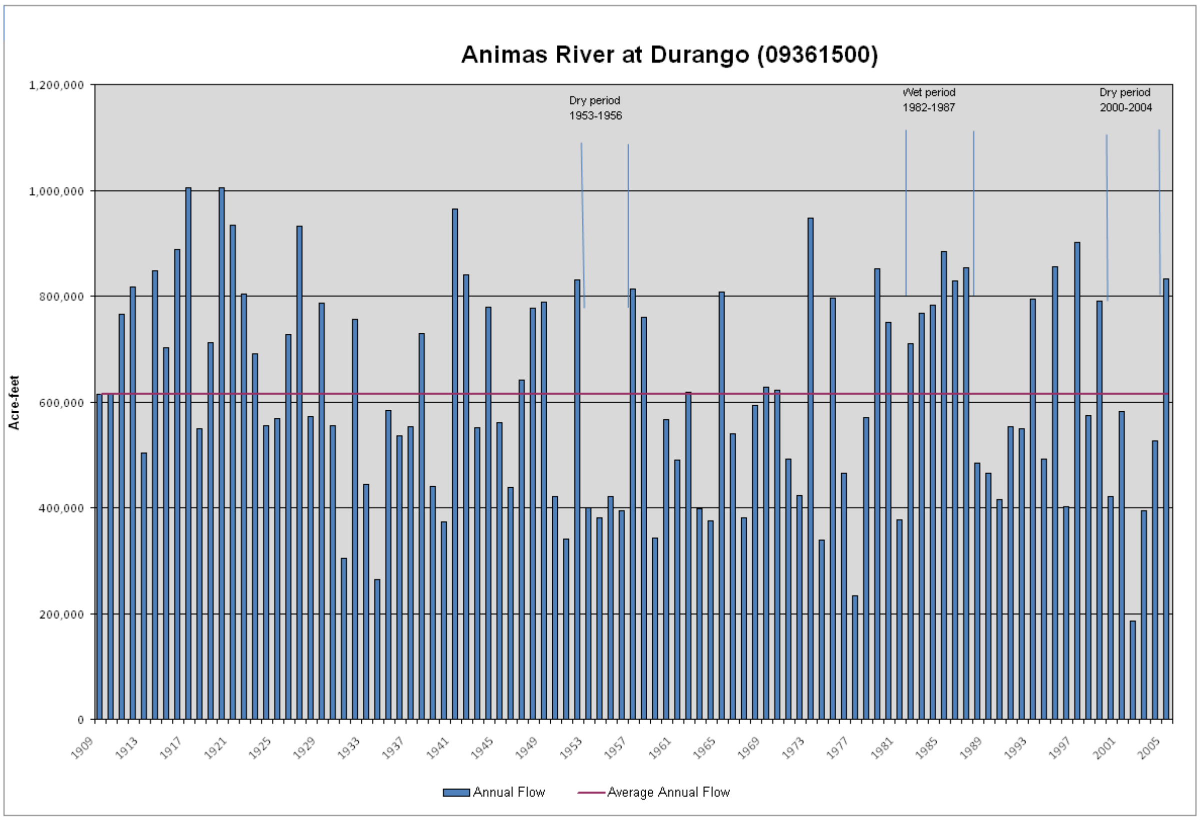


2.1 Inflow Hydrology

In order to simulate river basin operations, the model starts with 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 natural flows. Note that "baseflow" is synonymous with natural flow, and is the term used in the San Juan/Dolores River Basin Water Resources Planning Model User's Manual. Natural flows represent the conditions upon which simulated diversion, reservoir, and minimum streamflow demands were superimposed. StateMod estimates natural flows 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 natural flow at gage sites to ungaged locations using proration factors representing the fraction of the reach gain estimated to be tributary to a natural flow point.

Given data on historical diversions; estimated timing and location of return flows; and reservoir operations; StateMod can estimate natural flow time series at specified discrete inflow nodes. San Juan and Dolores River basin natural flows were estimated in three steps: 1) remove affects of man at USGS stream gage flows using historical records of operations to get natural flow time series for the gage period of record; 2) fill the gage location natural flow time series by regression against other natural flow time series; 3) distribute natural flow gains above and between gages to user-specified, ungaged inflow nodes.

Monthly natural flows for the USGS water year period 1909 through 2005 were developed to allow a long hydrologic period to "drive" the model. Because measured data was limited in the early period, and the development of natural flows required significant data-filling, the period 1950 through 2005 was chosen for the purposes of the Colorado River Water Availability Study (CRWAS). Additional discussion on this chosen model period is provided in this Model Brief's companion document entitled "Overview of the Colorado Decision Support System." This period includes extended wet, dry, and average periods plus both extreme drought and high runoff years. The wide variation in hydrology provides the ability to check that the model adequately represents historical river administration and operations under differing flow regimes. The following natural flow graph, representing the Animas River at Durango gage, illustrates that wet, dry, and average years are all represented in the modeling period. Successive years with annual flows below the average (e.g.,1953-1956) constitute extended dry periods; conversely, successive years with flows above the average (e.g., 1982-1987) constitute extended wet periods.



Natural flows are introduced to the San Juan Model at 185 gaged and headwater locations on more than 80 San Juan and Dolores River tributaries. Extended hydrology based on tree-ring data and alternate hydrology based on climate change and forest modification scenarios will replace the natural flows at the 54 USGS stream gage locations, and the automated process developed as part of CDSS will allow the distribution of these new natural flows to the remaining ungaged inflow nodes.

In addition to the main stem San Juan and Dolores Rivers, main tributaries represented include:

- Rio Blanco
- Animas River
- McElmo Creek
- Piedra River
- La Plata River
- San Miguel River
- Los Pinos (Pine) River
- Mancos River

Nearly 70 other sub-tributaries are also included. The decision on which streams to include in the model was generally based on the extent of acreage irrigated served by diversions.

2.1.1 Data Sources and Filling Techniques

Data required to generate natural flows include historical streamflow data, diversion records, reservoir storage data, irrigation water requirements, and net evaporation rates.

Historical streamflow data used to generate natural flows were recorded by the USGS and by Division of Water Resources (DWR). Historical streamflow data from both sources (USGS and DWR) are stored in HydroBase. The natural flow algorithm does not require that historical streamflow records be complete. Gaps in the data are filled only for natural flows estimated at gage locations, after the effects of human activity have been removed, using the automated USGS Mixed Station Model. The name refers to its ability to use regression correlations to fill missing natural flows for many stations, using natural flows from available stations.

Historical diversions are recorded by water commissioners and stored in HydroBase. For most water districts in the San Juan and Dolores basins, diversion records have been digitized from field notebooks and are generally complete from 1974 on. Many of the larger structures have diversion records in HydroBase back to the early 1950s. Diversion records are filled prior to being used in the natural flow calculation using a wet/dry/average month approach using an automated algorithm available in the CDSS DMIs. Each water district is associated with a long-term gage used to statistically assign each month in the study period a wet, dry, or average hydrologic designation. If diversion records for a ditch are missing in a designated "wet" month, then the average of diversion records for available "wet" months for that ditch will be used.

Historical reservoir end-of-month contents for the larger reservoirs are generally measured by the reservoir operators. In recent years, this information is provided to the water commissioners and stored in HydroBase. Several of the reservoirs included in the San Juan Model are USBR projects, and generally pre-1974 end-of-month contents data were supplied directly from either the Durango or Grand Junction USBR offices. Historical records are generally between 80 and 95 percent complete for most reservoirs. Missing records are filled based on linear interpolation if a maximum of three consecutive months are missing, then remaining missing data is filled using the wet/dry/average approach. Again, this filling procedure has been automated using the CDSS DMIs.

Irrigation water requirements are determined, by ditch, for the period 1950 through 2005 using StateCU. The calculation methods require mean monthly temperature and total monthly precipitation. Twelve climate stations are used to represent temperature and precipitation in the San Juan and Dolores River basins. The climate stations selected for the analysis are maintained by the National Oceanic and Atmospheric Administration (NOAA). NOAA provides recorded data to DWR, and it is stored in HydroBase. Most of the climate stations used in the analysis have complete data for this period, therefore only minor filling was required. Mean monthly temperature was filled based on nearby climate station's data using monthly regression and monthly precipitation was filled based on monthly averages for the measured data, automated using the CDSS DMIs. Irrigation water requirements for the study period prior to 1950 are estimated using the automated wet/dry/average approach discussed above.

Average net monthly evaporation rates are based on annual pan evaporation and precipitation measurements made at several climate stations stored in HydroBase, many located at reservoir sites in the basin.

Where to find more detailed information:

- Section 4.7 of the San Juan/Dolores River Basin Water Resources Planning Model User's Manual, available on the CDSS website, provides details of the Baseflow (Natural Flow) Estimation process.
- Table 5.2 of the San Juan/Dolores River Basin Water Resources Planning Model User's Manual lists the gaged locations where natural flows are introduced to the model.
- Section 4.4.2 of the San Juan/Dolores River Basin Water Resources Planning Model User's Manual describes the automated time series filling algorithms.
- Section 4.4.3 of the San Juan/Dolores River Basin Water Resources Planning Model User's Manual describes the natural flow filling using the Mixed Station Model.
- Section 5.6.2 of the San Juan/Dolores River Basin Water Resources Planning Model User's Manual describes the evaporation rates and source used for each reservoir.

2.2 Physical Systems

The San Juan Model includes active diversion structures, reservoirs, carrier systems, and instream flow reaches. Although every active diversion structure or reservoir is not explicitly included in the San Juan Model, 100 percent of the estimated irrigated acreage and storage in the basin is represented. 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. Explicit structures were selected based on a variety of criteria including amount and seniority of water rights, quantity of historical diversions, importance in administration, and participation in reservoir projects.

Eighty-five percent of use in the basin is explicitly represented at correct river locations relative to other users, with correct priorities relative to other users. The remaining structures are grouped into "aggregates" based generally on tributary boundaries, gage locations, critical administrative reaches, and instream flow reaches. The model includes over 300 explicit structures and 25 aggregates.

Similarly, not every reservoir and stock pond is explicitly included in the San Juan Model. In general, reservoirs with minimum decreed capacities of 3,000 acre-feet are considered key reservoirs, and are explicitly modeled. There are 13 key Colorado reservoirs with a combined total capacity of approximately 665,000 acre-feet, or 84 percent of the total modeled storage capacity in the Colorado portion of the basin. Navajo Reservoir is also included in the model, with a capacity of over 1.7 million acre-feet. The remaining basin storage is grouped into five aggregate reservoirs and three aggregate stock ponds. Long Hollow Reservoir and Ridges Basin Reservoir are physically included in the model for future scenarios, but their water rights are turned off for the Baseline simulation.

There are 54 CWCB instream flow segments modeled, accounting for instream flow segments decreed prior to 2005 that may affect basin operations. Headwater instream flow segments above the most upstream modeled diversions have, in some cases, been excluded. Instream flow segments on tributaries not specifically represented in the model are also not included. There are also 11 minimum bypass requirements for reservoirs and transbasin diversions included.

The location of each structure or instream flow segment, in relationship to tributaries and other structures (upstream or downstream), is defined based on CDSS GIS coverages, available straight-line diagrams, and discussions with water commissioners. Physical information about diversion structures and reservoir capacities is required to constrain modeled water use – diversion structures are not allowed to divert more than canal capacity and reservoirs are not allowed to store more than reservoir storage capacity. In addition, the model will constrain controlled releases from reservoirs to downstream river channel capacity.

Physical information that represents the location of irrigated land, in terms of timing and location of return flows, is also incorporated into the model input files. Information required for reservoirs includes area/capacity curves, minimum reservoir pools, and user accounts within a reservoir.

2.2.1 Data Sources and Filling Techniques

Physical information regarding capacities (ditches and reservoirs) is stored in HydroBase. Little information was available from original permits and decrees, therefore ditch capacities were often set in HydroBase as the sum of direct water rights under the ditch and reservoir capacity was often set as the sum of storage rights. As information continues to be gathered during the CDSS efforts, capacity information in HydroBase is updated to reflect user-provided information. Therefore, for the larger ditches that warranted user interviews, ditch capacities are set based on user-supplied information. For the remaining ditches, the data centered DMI approach allows ditch capacity to be set based on the maximum daily diversion recorded.

Reservoir capacity, area-capacity curves, dead pool and user-account information was collected based on interviews with the reservoir owners and operators. As noted above, much of that information has now been incorporated into HydroBase and is extracted directly for use in the modeling effort.

Irrigation return flow locations have been estimated based on the location of irrigated land and topography, using CDSS GIS available coverages. Each irrigation structure has been assigned a generic return flow delay pattern that recognizes the proximity of the irrigated acreage to a surface stream or drainage. Glover or other lagging analyses have not been performed for each irrigation structure.

Where to find more detailed information:

- Section 4.2.2 of the San Juan/Dolores River Basin Water Resources Planning Model User's Manual provides details and criteria used to select explicit versus aggregate structures. Section 4.2.3 of the San Juan/Dolores River Basin Water Resources Planning Model User's Manual provides details and criteria used to select explicit versus aggregate reservoir structures.

- Table 5.4 of the San Juan/Dolores River Basin Water Resources Planning Model User's Manual lists each of the key structures represented in San Juan/Dolores Model.

- Appendix A and Appendix B of the San Juan/Dolores River Basin Water Resources Planning Model User's Manual describes the aggregation process for irrigation and non-irrigation structures and reservoirs.

2.3 Water Demands

The San Juan Baseline Model demands reflect current levels of irrigation, population, and reservoir capacity superimposed over historical natural flow hydrology from 1909 through 2005. Irrigation headgate demands are set to the irrigation water requirement for the specific time step and structure, divided by the historical efficiency for that month of the year. Irrigation water requirements allow demands to reflect full supply, and not be limited by water rights and administration. Historical system efficiencies reflect irrigation practices associated with application methods, conveyance losses, and other user choices such as early and late season diversions to fill the soil reservoir.

Municipal demands in the baseline data set are based on average monthly diversions over the recent period 1998 through 2005 for the entire model period of 1909 through 2005. Transbasin demands are based on the average monthly diversion over the 1975 through 1991 period.

Instream flow demands are set to the decreed monthly rates for the entire period of 1909 through 2005. Reservoir and transbasin diversion bypass requirements are set monthly based on their associated operational agreements.

Minimum and maximum reservoir target storage limits are set as reservoir "demands". Reservoirs may not store more than the maximum target, or release to the extent that storage falls below the minimum target. In the Baseline data set, the minimum targets were set to zero, and the maximum targets were set to capacity for reservoirs that operate primarily for agricultural and municipal diversion storage. Maximum targets were set to operational targets according to rule curves provided by USBR for Lemon and Vallecito Reservoirs.

2.3.1 Data Sources and Filling Techniques

Irrigation water requirements and average historical monthly efficiencies used to estimate irrigation demands are calculated by StateCU. Data sources and filling techniques used to determine Baseline irrigation water requirements are described in Section 4.9.1 of the San Juan/Dolores River Basin Water Resources Planning Model User's Manual. Average historical monthly efficiency is the average system efficiency (combined conveyance and application efficiency) over the period 1975 through 2004, capped at 60 percent. These efficiencies are calculated by StateCU based on historical acreage for the period and historical diversions. Historical diversion records are extracted from HydroBase and filled if needed, as described in Section 4.4.1 of the San Juan/Dolores River Basin Water Resources Planning Model User's Manual.

Monthly decreed demands for instream flow segments are extracted from the water rights tabulation stored in HydroBase. As discussed above, operational targets for some USBR reservoirs were obtained directly from those sources.

Where to find more detailed information:

- Section 4.9.1 and Section 5.4.4 of the San Juan/Dolores River Basin Water Resources Planning Model User's Manual provides details and criteria used to estimate calculated demands for diverting structures.

2.4 Legal and Administrative Conditions

Legal and administrative conditions include water rights (direct, storage, instream flow); policies and agreements such as minimum bypass flows; and reservoir operations. The method used to impose these conditions on the demands highlights why StateMod is an appropriate tool for representing Colorado's water rights system. Each water right and operational right is assigned an administration number. For water rights the administration number is calculated from the appropriation and adjudication dates.

The administration number assigned to an operating rule that defines a reservoir release to an irrigation structure with a direct flow right is just junior to the direct flow right. StateMod allocates water to meet the irrigation demand using the direct flow, and then allocates reservoir releases if the demand is not fully satisfied.

Primary project operations requiring operational rights in the model include the following, which are further described in the Appendix:

- San Juan-Chama Project Operations
- Summit Reservoir System Operations
- MVIC/Dolores Project Operations
- Vallecito Reservoir Operations
- Lemon Reservoir Operations
- Jackson Gulch Reservoir Operations
- Navajo Reservoir Operations
- Cascade Reservoir Operations
- Gurley Reservoir Operations
- Trout Lake and Lake Hope Operations
- La Plata Compact Operations

More specific information on these primary project operations is presented in the Appendix at the end of this document.

2.4.1 Data Sources and Filling Techniques

Direct flow water rights are assigned to each diversion structure; storage rights are assigned to each reservoir; and instream flow rights are assigned to each instream flow segment. The CDSS DMIs automate the assignment of these rights directly from the water rights tabulation in HydroBase.

Seven different operating rules types are used in the San Juan Model Baseline data set. The complexity of the basin requires a total of 160 operational rights. Typically, these are 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 appropriate rules to apply to each complex operation were generally determined based on information from reservoir operators and water administrators.

3. Model Calibration

As noted above, the San Juan River Model study period for CRWAS from 1950 through 2005 was selected to include representative hydrologic periods. A subset of the study period, 1975 through 2005 was selected for model calibration. This calibration period was selected because historical diversion data were readily available (limited data filling required) and the period includes both dry (1977, 2000-2004) and wet cycles (1982-1987).

Calibration is the process of simulating the river basin under historical conditions, and judiciously adjusting parameter values to achieve agreement between observed and simulated values of streamflow gages, reservoir levels, and diversions. The San Juan Model was calibrated in a two-step process as follows:

3.1 First Step Calibration

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

The objective of the first calibration run was to refine natural flow hydrology and return flow locations before introducing uncertainties related to rule-based operations. Diversion shortages, that is, the inability of a water right to divert what it diverted historically, indicated possible problems with the way natural flows were represented or with the location assigned to return flows back to the river. Natural flow issues were also evidenced by poor simulation of the historical gages. Generally, the parameters that were adjusted related to the distribution of natural flows (i.e., the method for distributing natural flows to ungaged locations), and locations of return flows.

3.2 Second Step Calibration

In the second calibration run, constraints on reservoir operations were relaxed. As in the first calibration run, reservoirs were simulated for the period in which they were on-line historically. Reservoir storage was limited by water rights and availability and reservoir releases were controlled by downstream demands. The objective of the second calibration step was to refine operational parameters. For example, poor calibration at a reservoir might indicate poor representation of administration or operating objectives. Calibration was evaluated by comparing simulated gage flows, reservoir contents, and diversions with historical observations of these parameters. The model at the conclusion of the second step is considered the calibrated model.

The model is calibrated on a basin-wide level, meaning that major projects, diversions, and basin operations were specifically reviewed and modified, if necessary, so they are represented appropriately. Because calibration efforts concentrated on gage and reservoir locations, ungaged tributaries were not reviewed to the level of detail as gaged areas. The purpose of the Colorado River Water Availability Study is to determine the potential basin-wide effects of climate variability; therefore the calibrated model provides an appropriate prediction tool. When using this model for future analyses involving areas of the basin without historical stream gages that rely on derived hydrology, it is recommended that further stream flow evaluations be conducted. A refined calibration will improve results of local analyses. Average annual streamflow calibration results are presented in the **Table 3.1** for gages with complete records during the calibration period.

Table 3.1
Historical and Simulated Average Annual Streamflow Volumes (1975-2003)
Calibration Run (acre-feet/year)

			Historical -Simulated		
Gage ID	**Historical**	**Simulated**	**Volume**	**Percent**	**Gage Name**
09339900	64,983	64,983	0	0	East Fork San Juan River above Sand Creek
09342500	283,880	284,039	-159	0	San Juan River at Pagosa Springs
09343300	34,450	34,450	0	0	Rio Blanco bl Blanco Div Dam
09344000	83,902	83,903	-1	0	Navajo River at Banded Peak Ranch
09344400	48,284	48,339	-55	0	Navajo River bl Oso Diversion Dam nr
09346400	449,666	449,668	-2	0	San Juan River near Carracas
09349800	305,465	305,274	191	0	Piedra River near Arboles
09352900	106,037	106,037	0	0	Vallecito Creek near Bayfield
09354500	188,403	189,273	-870	0	Los Pinos River at La Boca
09355000	24,124	24,164	-40	0	Spring Creek at La Boca
09355500	875,505	882,354	-6,849	-1	San Juan River near Archuleta
09357500	77,578	77,579	-1	0	Animas River at Howardsville
09361500	583,380	583,330	50	0	Animas River at Durango
09362999	73,870	73,870	0	0	Florida River ab Lemon Reservoir
9365500	30,970	30,995	-25	0	La Plata at Hesperus
09366500	27,452	27,609	-157	-1	La Plata River at CO-NM State Line
09368499	10,687	10,687	0	0	Above Jackson Gulch Reservoir (USBR data)
09371000	39,123	39,080	43	0	Mancos River near Towaoc
09372000	39,385	39,462	-77	0	McElmo Creek near CO-UT State Line
09379500	1,563,647	1,565,265	-1,618	0	San Juan River near Bluff
09165000	97,155	97,159	-4	0	Dolores River below Rico
09166500	317,356	317,934	-578	0	Dolores River at Dolores
09169500	270,404	266,268	4,136	2	Dolores River at Bedrock
09171100	279,550	275,455	4,095	1	Dolores River near Bedrock
09172500	181,283	182,045	-762	0	San Miguel River near Placerville
09177000	273,243	272,395	848	0	San Miguel River at Uravan

As shown in the Table 3.1, calibration at each complete stream gage is within two percent.

Table 3.2 summarizes the average annual shortage for water years 1975 through 2005, by tributary or sub-basin. On a basin-wide basis, average annual diversions differ from historical diversions by around one percent in the calibration run. The Dolores River main stem irrigation demands are generally met; the shortages generally occur on the West Fork and Fish Creek tributaries where there is limited gage data.

Table 3.2
Historical and Simulated Average Annual Diversions by Sub-basin (1975-2003)
Calibration Run (acre-feet/year)

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

Where to find more detailed information:

- Section 7 of the San Juan/Dolores River Basin Water Resources Planning Model User's Manual provides detailed calibration results, including time-series graphs and scatter plots of streamflow and reservoir calibrations.

Appendix: San Juan and Dolores River Basins Primary Project Operations

1. San Juan-Chama Project Operations

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

Three operating rules are used to simulate the Baseline operations associated with the San Juan-Chama Project as follows:

- Carry water through the San Juan-Chama collection points on Navajo River, Little Navajo River, and Rio Blanco to meet the total San Juan-Chama demand.

2. Summit Reservoir System Operations

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

Eight operating rules are used to simulate Summit Reservoir Operations:

- Carry water from Turkey Creek via Turkey Creek Ditch for storage in Summit Reservoir
- Carry water from Lost Canyon via Summit Ditch for storage in Summit Reservoir
- Carry direct water from Turkey Creek via Turkey Creek Ditch to meet irrigation demand below Summit Reservoir
- Carry direct water from Lost Canyon via Summit Ditch to meet irrigation demand below Summit Reservoir
- Release water from Summit Reservoir to meet irrigation demands

3. MVIC/Dolores Project Operations

MVIC and the Dolores Project include McPhee, Groundhog, and Narraguinnep reservoirs. The project meets agricultural and municipal demands in both the Dolores River basin and McElmo Creek drainage. MVIC irrigation use is represented by two demands corresponding to the main canals that can deliver water to the irrigated lands (MVIC Dolores Tunnel demand and MVIC U Lateral demand). Project irrigation demands also include Towaoc Canal demands and Dover Creek Canal demands. Municipal demands include the Town of Cortez and the Montezuma Water Company.

Thirty operating rules are used to simulate the project Baseline operations. Storage rights allow McPhee Reservoir to store water from the Dolores River without the need to specify operating rules. Likewise, Groundhog Reservoir can store water directly from Groundhog Creek. Narraguinnep Reservoir is an off-channel reservoir filled with Dolores River water. Operating rules are used to allow the model to perform the following project operations associated with direct flow water from the Dolores River as follows:

- Carry water from the Dolores River via Main Canal No. 1 for storage in Narraguinnep Reservoir
- Carry water from the Dolores River via Main Canal No. 2 (also known as Great Cut Dike) to meet MVIC U Lateral irrigation demand
- Carry water from the Dolores River via the Dolores Tunnel to meet MVIC Dolores Tunnel irrigation demand
- Carry water from the Dolores River via Main Canal No. 1 to meet the Town of Cortez and the Montezuma Water Company municipal demands

Operating rules are used to deliver McPhee Reservoir water as follows:

- Carry water from McPhee Reservoir via Main Canal No. 1 to meet MVIC Dolores Tunnel irrigation demand
- Carry water from McPhee Reservoir via Main Canal No. 2 to meet MVIC U Lateral irrigation demand
- Carry water from McPhee Reservoir via Main Canal No. 1 to meet Towaoc Canal irrigation demand
- Carry water from McPhee Reservoir via Main Canal No. 2 to meet Dove Creek Canal irrigation demand
- Carry water from McPhee Reservoir via Main Canal No. 1 to meet the Town of Cortez and the Montezuma Water Company municipal demands
- Release water from McPhee Reservoir to meet an instream flow demand per agreement with the Fish and Wildlife Service

Operating rules are used to deliver supplemental Groundhog Reservoir and Narraguinnep Reservoir water as follows:

- Release water from Groundhog Reservoir to Main Canal No. 1 to meet MVIC Dolores Tunnel irrigation demand
- Release water from Groundhog Reservoir to Main Canal No. 2 to meet MVIC U Lateral irrigation demand
- Release water from Groundhog Reservoir to operate to 2,300 acre-feet exchange between the reservoir and miscellaneous water users on the Dolores River
- Release water from Narraguinnep Reservoir to MVIC U Lateral irrigation demand

4. Vallecito Reservoir Operations

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

Twenty-two operating rules are used to simulate the Baseline operations associated with Vallecito Reservoir. Storage rights allow the reservoir to store Pine River water without the need to specify operating rules. Direct diversion rights on the Pine River allow water to be diverted directly to meet the individual ditch demands without the need to specify operating rules. Operating rules are used to allow the model to perform the following project operations:

- Release water from Vallecito Reservoir to meet supplemental irrigation demands associated with 22 modeled downstream project ditches

5. Lemon Reservoir Operations

Lemon Reservoir was constructed by the USBR in the early 1960s as a part of the Colorado River Storage Project (CRSP). The majority of the irrigated area supplemented by Lemon Reservoir releases is located on the Florida Mesa, adjacent to the Florida River.

Seven operating rules are used to simulate the Baseline operations associated with Lemon Reservoir. Storage rights allow the reservoir to store Florida River water without the need to specify operating rules. Direct diversion rights on the Florida River allow water to be diverted directly to meet the individual ditch demands without the need to specify operating rules. Operating rules are used to allow the model to perform the following project operations:

- Release water from Lemon Reservoir to meet supplemental irrigation demands associated with six modeled downstream project ditches
- Release water from Lemon Reservoir to meet the downstream minimum streamflow agreement

6. Jackson Gulch Reservoir Operations

Jackson Gulch Reservoir is the principal feature of the Mancos Project, constructed by the USBR in the late 1940s. The reservoir is filled by diversions from the Jackson Gulch Inlet Canal located on the West Mancos River. Some of the rights for the inlet canal were either transferred to the inlet canal from other irrigation ditches, or have named the canal as an alternate point of diversion.

Twenty-eight operating rules are used to simulate the Baseline operations associated with the Mancos Project. Storage rights allow Jackson Gulch Reservoir to store available water from Chicken Creek without the need to specify operating rules. Direct diversion rights on the Mancos River and its tributaries allow water to be diverted directly to meet individual ditch demands without the need to specify operating rules. Operating rules are used to allow the model to perform the following project operations:

- Carry water from West Mancos River via Jackson Inlet for storage in Jackson Reservoir
- Release water from Jackson Reservoir to meet supplemental downstream ditch demands for eleven modeled project ditches
- Release water from Jackson Reservoir to meet demands for the Town of Mancos Ditch
- Release water in exchange for upstream diversions to meet supplemental demands for seven project ditches

7. Navajo Reservoir Operations

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

Twenty operating rules are used to simulate the Baseline operations associated with Navajo Reservoir. Storage rights allow Navajo Reservoir to store available water from San Juan River without the need to specify operating rules. Direct diversion rights on the San Juan River allow water to be diverted directly to meet downstream ditch demands in New Mexico without the need to specify operating rules Operating rules are used to allow the model to perform the following project operations:

- Release water from Navajo Reservoir to meet supplemental irrigation demands for 16 downstream ditches
- Release water from Navajo Reservoir directly to Navajo Indian Irrigation Project demands
- Release water from Navajo Reservoir to meet San Juan Recovery Implementation Program recommended minimum fish flows

8. Cascade Reservoir Operations

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

Three operating rules are used to simulate the Baseline operations associated with the Tacoma Project operations. Storage rights allow Cascade Reservoir to store available water from Elbert without the need to specify operating rules. Operating rules are used to allow the model to perform the following project operations:

- Carry water from Cascade Creek via the Cascade Canal for storage in Cascade Reservoir
- Carry water from Cascade Creek via the Cascade Canal directly to Power Canal No 1
- Release water from Cascade Reservoir to Power Canal No 1

9. Gurley Reservoir Operations

Gurley Reservoir is located on a tributary to the San Miguel River and is used to provide supplemental irrigation to approximately 20,000 acres in the area near Norwood. It has a small tributary drainage area, therefore receives most of its supply via the Naturita Canal. Because the individual structures that irrigate from Gurley Reservoir have small decreed amounts, their diversions have been incorporated into the model as an aggregated diversion system demand.

Eight operating rules are used to simulate the Baseline operations associated with the Gurley Reservoir operations. Operating rules are used to allow the model to perform the following project operations:

- Carry water via the Naturita Canal for storage in Gurley Reservoir
- Release water from Gurley Reservoir to meet downstream demands

10. Trout Lake and Lake Hope Operations

Trout Lake and Lake Hope reservoirs are used together by the Public Service Company of Colorado for power generation at the Ames and Nucla Power Plants. Trout Lake delivers storage water to both plants. The Ames plant also receives storage water from Lake Hope in late summer and fall.

Five operating rules are used to simulate the Baseline operations associated with the Gurley Reservoir operations. Storage rights allow both reservoirs to store available inflow without the need to specify operating rules. Operating rules are used to allow the model to perform the following project operations:

- Release water from Trout Lake to satisfy demands at Ames Power Plant
- Release water from Lake Hope to satisfy demands at Ames Power Plant
- Release water from Trout Lake to satisfy demands at Nucla Power Plant

11. La Plata Compact Operations

La Plata compact requirements are modeled as an instream flow demand at the Colorado/New Mexico state line. The Type 13 operating rule allows an instream flow to operate based on its location on the river and the flow at a remote location. The La Plata Compact operating rule defines Colorado’s commitment to deliver water to New Mexico for each time step based on the flow at the upstream La Plata River at Hesperus index gage.

Where to find more detailed information:

- Section 5.8 of the San Juan/Dolores River Basin Water Resources Planning Model User's Manual provides details regarding project operations and operating rules.
- Section 2 of the San Juan/Dolores River Basin Information Report, available on the CDSS website, provides historical and overview information on San Juan and Dolores River Projects and Special Operations.
- Section 3 of the San Juan/Dolores River Basin Information Report provides Division 4 personnel recommendations on how to model basin project operations.
- Section 4.13 of the State of Colorado's Water Resources Model (StateMod) Documentation provides available operating rules, guidelines for selecting the appropriate rules based on water source and destination, and examples of how each operating rule has been applied to represent real Colorado operations.