

## **REPRESENTING POLICY FOR OPERATIONS IN THE UPPER RIO GRANDE WATER OPERATIONS MODEL**

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**Abstract:** Operations for facilities in the Rio Grande basin from the Colorado-New Mexico state-line to below Elephant Butte Reservoir including the Rio Chama are modeled in the Upper Rio Grande Water Operations Model (URGWOM). URGWOM was developed using the RiverWare software application developed by the Center for Advanced Decision Support for Water and Environmental Systems (CADSWES) at the University of Colorado at Boulder. The rule policy language (RPL) editor in RiverWare is used to code various aspects of policy for operations for flood control, ecological benefits, recreation, and deliveries to irrigation districts, municipalities, and other water users. Specific details are coded for operation restrictions per stipulations of the Rio Grande Compact, and coding policy involves the use of complex accounting for tracking the storage and release of San Juan-Chama Project water for different contractors along with the varying uses of native Rio Grande water. With the representation of the physical system in URGWOM and methods for key physical processes in the basin, changes in operations or other proposed actions can be analyzed with URGWOM to evaluate the impact on the water supply, river flows, and water deliveries. Such changes that may be evaluated may include water leases, Emergency Drought agreements, or deviations to standard policy for storing water. URGWOM provides a means to efficiently analyze innovative solutions to meeting the increasing water demands throughout the Rio Grande basin in New Mexico.

### **INTRODUCTION**

The primary purpose of the Upper Rio Grande Water Operations Model (URGWOM) is to facilitate more efficient and effective accounting and management of water in the Upper Rio Grande Basin. Historically, water of the Rio Grande has been used primarily for crop irrigation; however, rapid population growth in the basin and urbanization in many areas has resulted in increasing and diversifying demands on the hydrologic system. Water management decisions are becoming increasingly complex and difficult because of the broad range of interests and issues that must now be addressed including flood control, irrigation demands, transmountain diversions, the Rio Grande Compact, municipal and industrial demands, Native American water rights, Endangered Species Act compliance, and recreational uses. With the limited water supply, higher levels of precision and reliability in water accounting and forecasting are required.

**URGWOM:** URGWOM is a daily timestep computational model developed through an interagency effort and used to simulate processes and operations of facilities in the Rio Grande Basin in New Mexico and complete accounting calculations for tracking the delivery of water allocated to specific users. Policy for setting dam releases along with diversions and other demands are represented in coded rules in an URGWOM ruleset. Various methods are included

to represent physical processes such as floodwave travel times; reservoir evaporation and seepage; conveyance losses to deep percolation, open water and wetted sands evaporation, and transpiration; surface water-groundwater interaction; and irrigation return flows.

A water operations module of URGWOM is used to complete simulations through a current calendar year to prepare Annual Operating Plans with forecasted operations and system conditions given forecasted snowmelt runoff. This ability to forecast water operations results in reduced waste, elimination of unnecessary reservoir spills, prevention of unwanted downstream flooding, and more equitable distribution of available water supplies.

A planning module of URGWOM is used to complete rulebased simulations for different operation scenarios to evaluate subsequent long-term impacts of proposed actions on various indicators in the basin including deliveries to water users, river flows, interstate Compact deliveries and Compact status, and the overall water budget. The Planning Model has been used to evaluate alternatives for National Environmental Policy Act (NEPA) processes and preparing Biological Assessments (BA) as part of consultation with the Fish and Wildlife Service for Endangered Species Act (ESA) compliance. Planning studies typically entail completing model runs with a baseline model and ruleset using a given hydrology and comparing the results to output from an alternate simulation completed with a proposed change to modeled policy for operating a specific facility or the entire system. Model runs are completed using either historical hydrology or synthetic hydrologic sequences developed with reference to paleo-data.

**Study Area:** The area currently modeled with URGWOM consists of the Rio Chama and the Rio Grande from the Colorado-New Mexico State-line to the New Mexico-Texas State-line and includes Heron, El Vado, and Abiquiu Reservoirs on the Rio Chama and Cochiti, Elephant Butte, and Caballo Reservoirs on the Rio Grande. Refer to Figure 1 for a map of the basin from the headwaters in Colorado past the New Mexico Texas State-line. Diversions and consumptive use by the Middle Rio Grande Conservancy District (MRGCD) are represented, and diversions by the Albuquerque Bernalillo County Water Utility Authority are also included. Flows from Colorado are input to URGWOM.

**San Juan-Chama Project:** In 1962, Congress authorized construction of the San Juan-Chama Project which is a transbasin diversion system that imports water from tributaries of the San Juan River in Colorado and provides a portion of New Mexico's allotment under the Upper Colorado River Basin Compact (State of New Mexico et al. 1948). Water is delivered through the Azotea Tunnel that runs under the continental divide to Willow Creek then to the Rio Grande via Heron Reservoir and the Rio Chama. San Juan-Chama Project water is used to supplement the native flow of the Rio Grande for the principal purposes of furnishing water for agricultural, domestic, and municipal and industrial (M&I) uses and for providing recreation and fish and wildlife benefits (Sidlow et al. 2007). The introduction of San Juan-Chama Project water complicates modeling of water operations due to the need to track water for individual contractors for San Juan-Chama Project water. Water is often transferred between contractors or with native Rio Grande water users through leases and paper water exchanges. The release, transport, storage, and use of San Juan-Chama Project water is carefully accounted for in URGWOM to assure there is no impact to existing uses of native Rio Grande water in the system. This required accounting is a key need fulfilled with URGWOM and a complex component of the model.

Separate accounts are established for the different contractors for San Juan-Chama Project water and all the different potential water uses for each contractor.

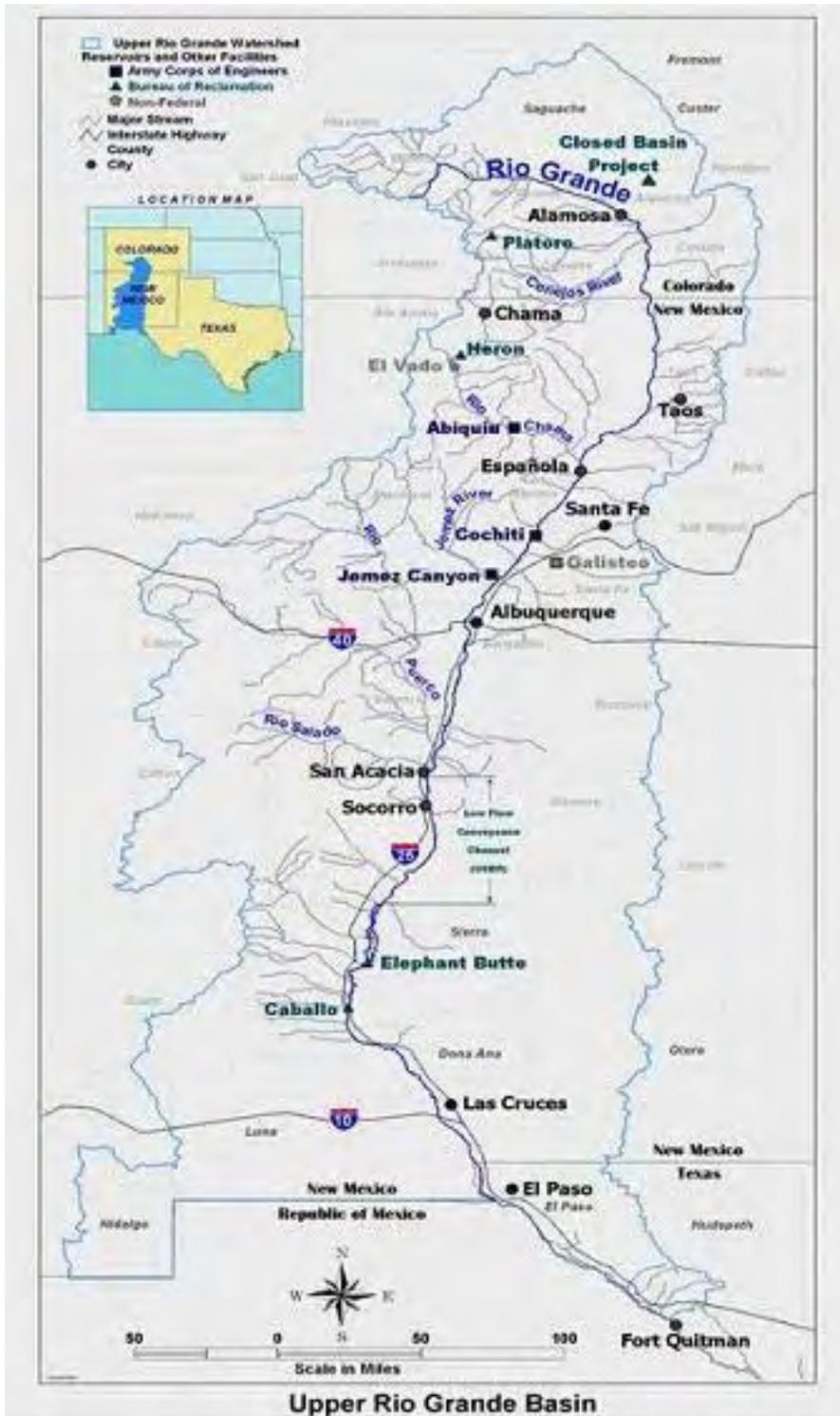


Figure 1. Rio Grande Basin Map

**RiverWare:** Different software options were considered to use for URGWOM, and after a thorough review of several reservoir and river simulation software packages against the specific needs for URGWOM, RiverWare was selected. A key benefit of RiverWare is that software development is ongoing and new methods and capabilities can be added to RiverWare by the software developers to meet the evolving needs for URGWOM. RiverWare was developed by the Center for Advanced Decision Support for Water and Environmental Systems (CADSWES) at the University of Colorado at Boulder. Software development continues to be sponsored and supported by the Tennessee Valley Authority (TVA), Bureau of Reclamation (Reclamation), and Corps of Engineers (Corps). RiverWare is a generalized river basin modeling environment that can be used to develop an operations model for any configuration and to simulate operations to meet needs for flood control, water supply, recreation, water quality, and navigation. Numerous methods are available for representing key physical processes in a basin. RiverWare is designed to provide river basin managers with a tool for scheduling, forecasting, and planning reservoir operations and includes extensive capabilities for rulebased simulations and water accounting. Refer to Figure 2 for a screen capture of a portion of the Rio Grande system in URGWOM and the graphical user interface (GUI) in RiverWare.

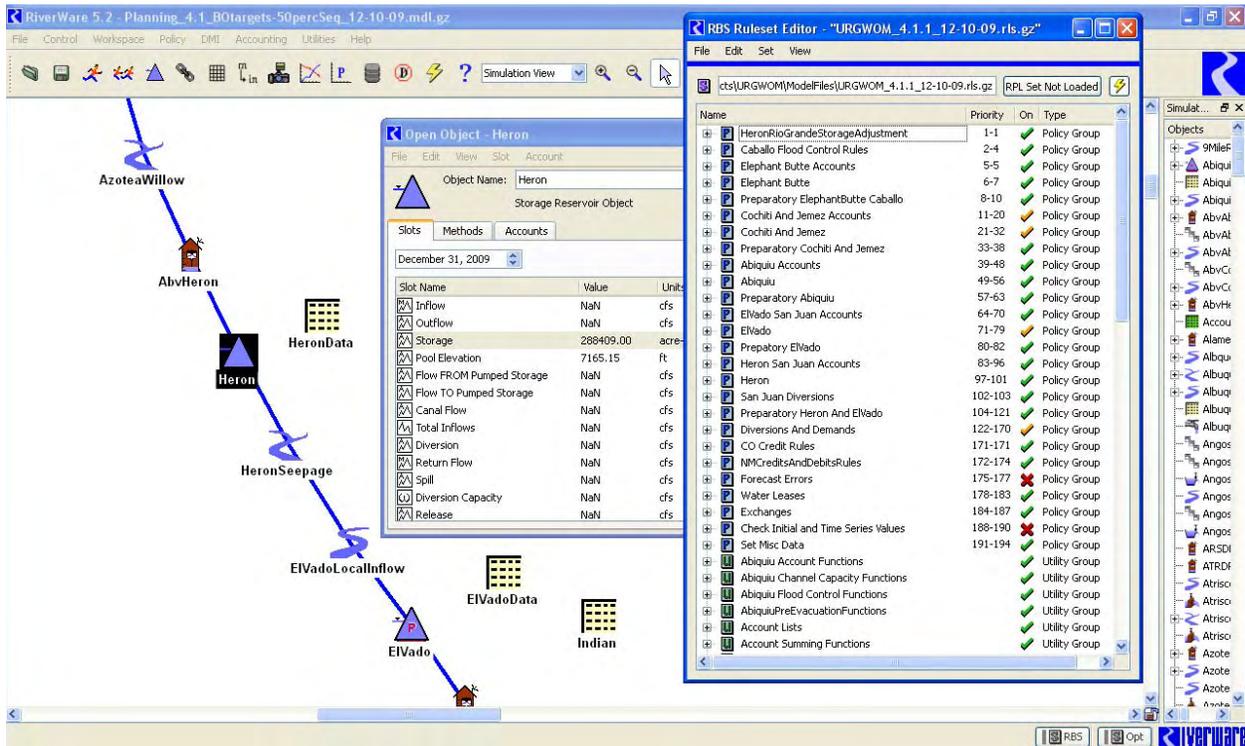


Figure 2. Screen Capture of Portion of URGWOM and GUI in RiverWare

## POLICY FOR OPERATIONS

Operations of reservoirs on the Rio Grande system in New Mexico entail meeting specific set demands within operational and legal constraints. These demands may be met with native Rio Grande water or San Juan-Chama Project water diverted from the San Juan basin. These two water types are tracked separately in URGWOM with different accounts set up for each. Rules are set up in the URGWOM ruleset to represent policy for setting reservoir releases and setting

releases and transfers of water from the different accounts. Refer to Figure 3 for a sample rule coded in the RiverWare rule policy language (RPL) that includes separate functions. User defined functions can be coded in RiverWare if an available predefined functions in RiverWare does not meet a model user's specific need.

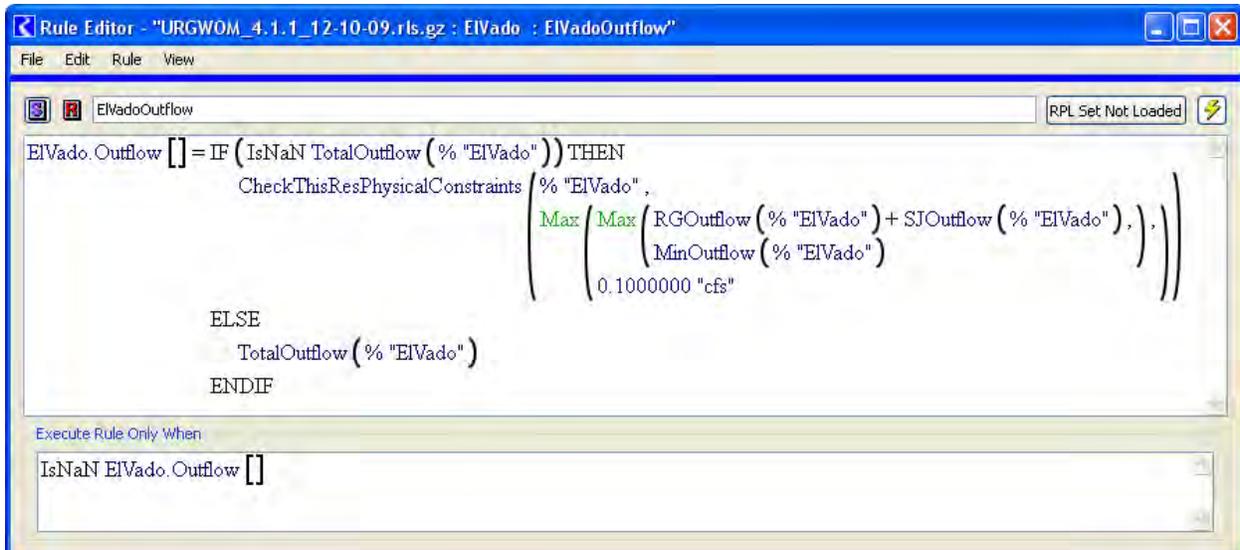


Figure 3. Sample RiverWare Rule Policy Language Used for Coding Policy in URGWOM

**San Juan-Chama Project Water:** Diversions from the San Juan basin are made within the model with consideration for physical and legal diversion restrictions coded in the rules and allocations are made at Heron Reservoir to individual contractors at the beginning of each calendar year with subsequent allocations if full allocations cannot be made at the beginning of the year. Contractor water is then delivered to meet different potential uses. Allocated San Juan-Chama Project water must be moved out of Heron Reservoir by the end of the calendar year or the contractor's water is essentially lost and reverted back to a common pool at Heron Reservoir to be used for future year allocations. Reclamation may issue waivers which are tracked in URGWOM to allow for contractors to continue storing water at Heron Reservoir into the year following the allocation year if there is a clear benefit for Reclamation's operations (Corps, Reclamation, and ISC, 2007). Refer to Figure 4 for a screen capture of a portion of the RiverWare accounting view from URGWOM that shows the different accounts set up for potential paper water transfers at Heron Reservoir. The numerous different accounts from Heron Reservoir downstream represent the different potential deliveries from contractor's storage accounts at Heron Reservoir to various downstream delivery locations.

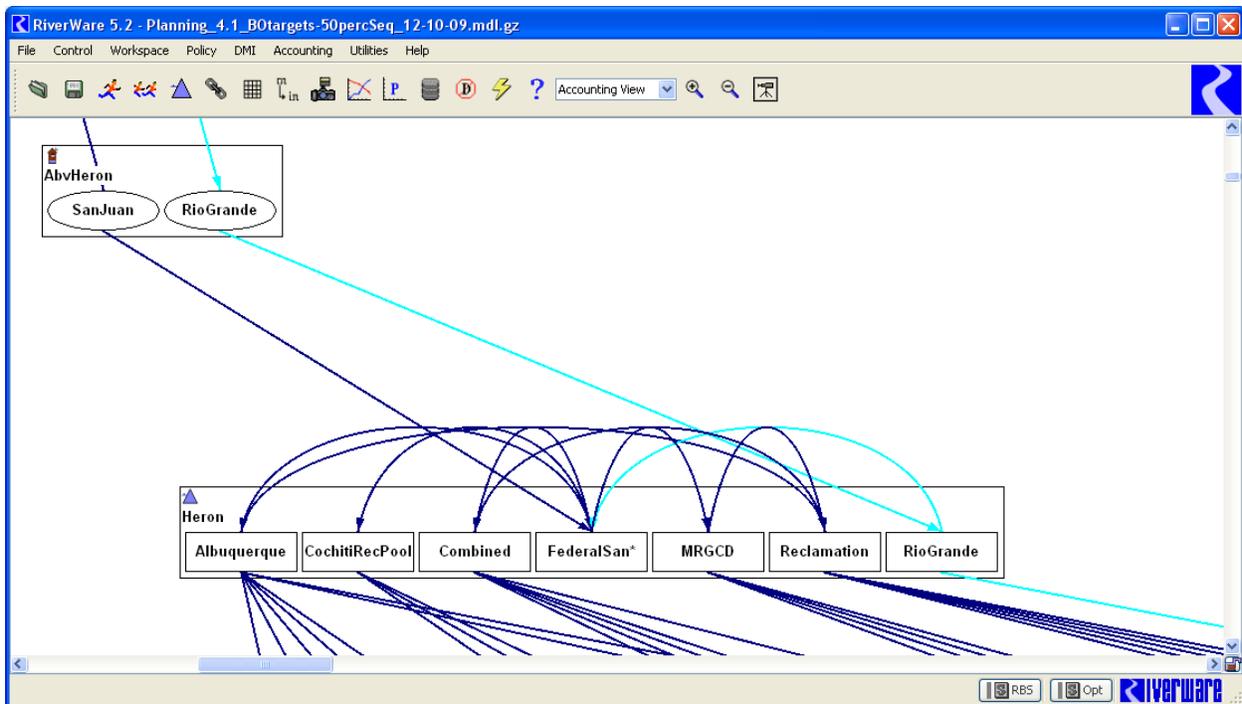


Figure 4. Sample Portion of Accounting View from URGWOM

**Rio Grande Water:** Native Rio Grande water is bypassed each month at Heron Dam unless storage is required due to physical constraints. Rio Grande water can be stored at El Vado Reservoir if storage is needed to ensure water can be provided for the six Middle Rio Grande Pueblos or if stipulations of Article VII of the Rio Grande Compact permit storage (States of New Mexico, Colorado, and Texas, 1938). Rio Grande water that is stored when permitted, based on the Compact status, is used by MRGCD to meet their downstream diversion demand. Any MRGCD San Juan-Chama Project water in storage is used after native supplies become insufficient to meet demands. Native Rio Grande water is bypassed at Abiquiu and Cochiti Dams unless water must be stored for flood control operations. Any stored water under flood control operations may be held in storage until the irrigation season is over.

**Emergency Drought Agreements:** Temporary Emergency Drought Agreements have been modeled with URGWOM which entail relinquishing Compact credit water at Elephant Butte Reservoir in return for allowing storage of native Rio Grande water at El Vado Reservoir when stipulations of Article VII of the Compact would otherwise have prevented storage. This stored water is then available for MRGCD, Reclamation, and municipalities, as tracked with separate accounts in URGWOM, to be used to meet regular water needs. Such agreements have been modeled and have occurred in the past but continued implementation of such agreements is entirely dependent on agreement from involved parties, but URGWOM has served as an excellent tool for agencies and stakeholders to analyze the impact of such agreements on various indicators in the basin.

**Cochiti Deviations:** Operations at Cochiti may deviate from typical operations to temporarily allow water to be stored and then be released in a manner to specifically provide flows for spawning and recruitment of species listed under the Endangered Species Act (Corps, 2009).

Such operations are implemented when the runoff would not naturally provide such recruitment flows but the runoff is sufficient that defined recruitment flows could be provided with temporary storage at Cochiti Reservoir before the runoff peak. Such operations may also entail providing higher overbank flows if criteria for this alternate operation are satisfied. URGWOM has been an excellent tool for reviewing the impacts of such deviations from typical operations on river flows and system conditions.

**Water Uses:** Releases of San Juan-Chama Project water and native Rio Grande water at Heron, El Vado, and Abiquiu Dams are made as needed to meet specific water uses. URGWOM includes objects and methods to represent the physical system including MRGCD diversions and associated consumptive use and the Albuquerque Bernalillo County Water Utility Authority surface water diversions for a new drinking water plant. An additional routine demand is letter water deliveries for contractors to effectively payback the river for depletions caused by groundwater pumping in the basin. Contractors may move water to fill allocated storage space at El Vado Reservoir or Abiquiu Reservoir until the water is needed. Water may also be delivered for contractors to payback another contractor for a past loan, and contractors have historically leased allocated San Juan-Chama Project water to the Bureau of Reclamation (Reclamation) on occasion to be used to maintain target river flows for biological interests.

**Middle Rio Grande Conservancy District:** MRGCD diverts water at four locations in the Middle Valley defined as the segment of the river between Cochiti Dam and Elephant Butte Reservoir. Diversions just below Cochiti Dam and at the Angostura, Isleta, and San Acacia diversion dams are input in URGWOM but are driven by the need for irrigation of MRGCD lands where the consumptive use is represented based on input irrigated acreage and evapotranspiration (ET) rates. Since MRGCD will divert return flows to the river from upstream irrigation at their downstream diversions, a total demand for water from upstream sources is not a simple summation of requested diversions but is derived based on historical seasonal water needs to meet expected diversions.

**Letter Water Deliveries:** Many contractors for San Juan-Chama Project water actually pump groundwater to meet their needs and their allocated San Juan-Chama Project water is delivered downstream to effectively payback the river for the impacts of this pumping on river flows. The New Mexico Office of the State Engineer uses separate groundwater models and other tools to determine delivery requirements for contractors to payback the river, and deliveries are made based on the requests documented in letters from the Office of the State Engineer to Reclamation, hence the name “letter water deliveries.” The timing for these deliveries is generally established to distribute the payback appropriately between the irrigation season when MRGCD would use water and the winter to augment Compact deliveries to Elephant Butte Reservoir. These deliveries schedules are set up as inputs to URGWOM based on the estimated delivery schedules provided by the Office of the State Engineer. In RiverWare, a debt for contractors to payback the river is established as an exchange. Rules are coded to establish the debts for accounts based on the input schedules, and deliveries are made to payback the debt then or as soon as the contractors have the water to make a delivery.

**Albuquerque Bernalillo County Water Utility Authority:** In 2009, Albuquerque began diversions at a new surface water diversion to provide water for a new drinking water plant.

Allocated San Juan-Chama Project water is diverted as river conditions allow per the diversion permit which includes threshold minimum river flows that must be exceeded for Albuquerque to divert their full demand. Releases of Albuquerque's San Juan-Chama Project water from upstream storage are driven by this demand along with their needed letter water deliveries to payback the river for the impacts of groundwater pumping.

**Target Flows:** The Rio Grande provides habitat for listed threatened and endangered species including the Rio Grande silvery minnow (*Hyboganthus amarus*) and the southwestern willow flycatcher (*Empidonax trailii extimus*). A Biological Opinion issued by the Fish and Wildlife Service (2003) includes seasonal target flows for specific locations in the Middle Valley and operations have also historically included discretionary operations to manage for the flow recession after the snowmelt runoff and to control the rate of drying after river rewetting. Water needs to ensure target flows are provided are computed in URGWOM and drive the release of available supplemental water supplies upstream. Supplemental water supplies may include San Juan-Chama Project water leased by Reclamation and native Rio Grande water stored through an Emergency Drought Agreement. Such supplies are tracked with separate accounts.

**Operations to Meet Demands:** Water needs from upstream sources for the different water uses are computed with consideration for physical losses. Hypothetical simulations are completed within RiverWare to identify upstream releases needed to meet downstream demands or target flows with consideration for conveyance losses and other processes represented by all the methods in the model. These upstream water needs are then used to compute separate initial estimates for the total demand for Rio Grande water and the total demand for San Juan-Chama Project water. The resulting total release is checked against physical constraints and flood control restrictions. Final reconciled releases of Rio Grande water and San Juan-Chama Project water are then referenced when setting final releases for individual accounts. If all deliveries cannot be made, deliveries are made from individual accounts based on input priorities for the different types of water use and for the contractors designated as higher priority.

## SUMMARY AND CONCLUSIONS

A fundamental need to be addressed through continued computational modeling with URGWOM is assisting managers in delivering supplies to all entitled water users on time, in the desired quantities, and with minimum conflict between users with specific focus on deliveries, exchanges, and leases of water allocated to contractors for San Juan-Chama Project water. URGWOM is used to provide the community of water managers and water users with a clear, consistent, and common set of data to formulate, evaluate, and support decisions. With the established model for the Rio Grande system in New Mexico including methods representing the key physical processes in the basin and established accounts, rulebased simulations can be completed with the URGWOM ruleset set up to simulate baseline operations of the system and resulting river and system conditions. Rules are coded for meeting all the different demands using available supplies for those specific water uses as tracked with separate accounts. Coded rules allow for Annual Operating Plans to be developed with accurate representation of different implemented water agreements and any deviations from typical operations. In addition, URGWOM provides managers with the tool needed to complete detailed long-term investigations of potential solutions to meeting the increasing water needs in New Mexico.

Changes in operations or other proposed actions can be analyzed with URGWOM to evaluate the impact on the water supply, river flows, and water deliveries.

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