STAKEHOLDER PARTICIPATION IN TARGET FLOW MODELING ON THE MIDDLE RIO GRANDE

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Abstract: The Upper Rio Grande Water Operations Model (URGWOM), a modeling tool to assist water managers in unified operations of the Upper Rio Grande, is a joint effort by six federal agencies and several cities, water districts, research institutes and interested NGOs. The primary developers of the model are the Corps of Engineers, Albuquerque District, the Bureau of Reclamation, Albuquerque Area Office, and the US Geological Survey New Mexico Water Science Center. These agencies collaborated to develop a numerical computer model capable of simulating water storage and delivery operations in the Rio Grande from its headwaters in Colorado to below Caballo Dam in New Mexico and for flood control modeling from Caballo Dam to Fort Quitman, Texas. The model will be used in flood control operations, water accounting, and evaluating water operations alternatives. The URGWOM was developed using RiverWare™, a general river and reservoir modeling tool developed at the University of Colorado - Center for Advanced Decision Support for Water and Environmental Systems (CU-CADSWES). RiverWare provides modeling of water ownership and ability to specify operational rules that include information about water accounting as well the physical system. The testing phase of the URGWOM development process allowed the collaborating agencies, stakeholders and interested parties to run the model and experiment with alternative inputs. One area of particular interest in the testing focuses on one of the main operational challenges on the Upper Rio Grande, ensuring minimum flows in critical reaches for endangered fish species. Reliably meeting these target flows with upstream reservoirs releases is difficult due to variable routing parameters, changing channel and sediment configurations, and dynamic groundwater interactions. This paper describes the modeling of flows and the operational rules intended to meet the target flows in the model, and also describes the RiverWare™ features that allow non-expert modelers to examine results, input sensible and feasible alternative values, and compare the results of their alternative runs with the baseline runs developed by the URGWOM technical team.

INTRODUCTION

Water resources in the Upper Rio Grande Basin (Figure 1) are in ever-increasing demand for diverse uses such as irrigation, municipal, industrial, endangered species, and recreation. To provide for these water uses, water managers from federal agencies, state agencies, municipalities, water districts, tribes, research institutes and interested NGO's need modeling tools to assist in unified operations for the Rio Grande Basin. The Upper Rio Grande Water Operations Model (URGWOM) is one of these tools. Developed in RiverWare™ (RiverWare), the URGWOM simulates the basin from the headwaters downstream to Caballo Dam including all major reservoirs, reaches, and diversions.

Figure 1. Rio Grande Basin from headwaters to Fort Quitman, Texas

RiverWare is a general river and reservoir modeling tool developed at the University of Colorado Center for Advanced Decision Support for Water and Environmental Systems (CU-CADSWES). RiverWare provides modeling of water ownership and ability to specify prioritized operational rules. In the URGWOM, operational rules define the basin policy such as reservoir releases and

diversion amounts. Major physical processes such as evaporation, groundwater interaction, and return flows are simulated on objects that represent physical features like reaches, reservoirs, and water users. Ownership and type of water including Rio Grande water, San Juan water, and contractor ownership is tracked in an accounting network. Because of the public nature of this work, stakeholder involvement in the model is encouraged. This was accomplished through a testing phase.

The testing phase of the URGWOM development process allowed the collaborating agencies, stakeholders and interested parties to run the model and test alternative inputs. One area of particular interest in the testing focused on ensuring minimum flows in critical reaches for endangered fish species. Reliably meeting these target flows with upstream reservoirs releases is difficult due to variable routing parameters, changing channel and sediment configurations, and dynamic groundwater interactions. This paper describes the modeling of flows and the operational rules intended to meet the target flows in the model using a feature called hypothetical simulation. Also described is the RiverWare features that allow non-expert modelers to examine results, input sensible and feasible alternative values, and compare the results of their alternative runs with the baseline runs developed by the URGWOM technical team.

MOTIVATION AND HISTORY OF URGWOM DEVELOPMENT

The Upper Rio Grande Basin is operated to meet demand for such diverse uses as irrigation, municipal, industrial, endangered species, and recreation. In the past 10 years, dry conditions have added stress on the basin by decreasing supply. The Middle Rio Grande Basin entered into a drought cycle in the mid 1990's. These drought conditions may persist for an additional ten to twenty years, which will put more stress on water managers in the basin. As a result of the drought conditions, article VII of the Rio Grande Compact has been in effect since July 2002. Under that article New Mexico and Colorado are prohibited from increasing water storage in reservoirs built after year 1929. In addition, the Middle Rio Grande is home to two federally listed endangered species: the Rio Grande silvery minnow (Hybognathus amarus) and the southwestern willow flycatcher (Empidomax trailli extimus). Endangered species demand is defined by the existing Biological Opinion (March 17, 2003) which requires minimum flow targets at specific locations in the Middle Rio Grande Basin according to the type of flow year, i.e., wet, average or dry year and article VII status of the Rio Grande Compact.

Meeting agriculture demand and flow targets to recover the endangered species and protect their habitat requires water managers to carefully plan for and operate the system to meet short and long-term needs. A robust management tool that accurately accounts for storage and delivery of water to specific demand is necessary to assist in the planning and operation of the water resources.

The plan to develop a unified water operations model for the Upper Rio Grande Basin originated in the fall of 1995 when certain Federal agencies initiated discussions regarding the necessity for a system management tool that could be utilized by numerous interested parties. This led to a Memorandum of Understanding (MOU) that was signed by six Federal Agencies (and subsequently other agencies/entities have also become signatories) to establish a partnership to

develop a unified water operations model for the upper portion of the Basin. The purpose of the URGWOM is to provide a decision making tool for use in addressing contemporary water management needs, including ecosystem health and diversity and provide for more efficient and effective system management of water in the Basin.

After exhaustive research into reservoir models, in 1998 a multi-agency committee (the URGWOM steering committee) chose RiverWare as the modeling system that could best model the complexity of the river and reservoir system, including tracking transbasin water and contractor accounts. A Test Case was conducted to assure that the requirements of the modeling process could be met. The Test Case (modeling the Rio Chama reservoir/river system) with RiverWare was deemed successful and subsequent modeling has progressed since to achieve the original objectives set out in the MOU.

HYPOTHETICAL TARGET SIMULATION TO DETERMINE RELEASES TO MEET TARGET FLOWS IN THE MIDDLE VALLEY

One of the objectives of the model is to allow stakeholders and users to determine the release necessary from upstream reservoirs to ensure minimum flows in critical reaches in the middle valley. RiverWare provides modeling of water ownership and the functionality to specify operational rules. Prioritized rules are written into a ruleset (using the RiverWare Policy Language (RPL)) that represents the policy and regulations under which reservoirs are operated in the Basin. Rules look at the state of the system and then typically set reservoir releases and diversion requirements. Releases are then routed downstream using simulation algorithms to account for lags, gains, and losses. The routing, gain, and loss methods are often non-linear or iterative in nature and involve many separate simulation objects. In the past, the RPL was often not capable of accurately calculating the release required to meet a downstream target because of these complex physical processes.

To address this problem, functionality was developed in RiverWare rulebased simulation that allow users to perform a “hypothetical simulation” involving multiple objects on the workspace. The hypothetical simulation uses the physical process methods selected for the given objects yet do not impact the final results or values. This is termed hypothetical simulation because this is a temporary simulation that uses the full capabilities of the RiverWare objects but no values are set in the simulation. The hypothetical simulation results are used by the rule logic to decide what value to set.

A number of hypothetical simulation options were implemented as predefined functions that can be called from any rule. One of these hypothetical simulation functions, HypTargetSim (short for Hypothetical Target Simulation), can automatically iterate to determine the required upstream flow (typically a release from a reservoir), to meet a target value at a downstream location that has a number of days travel time. Following is a summary of the RiverWare Online Help (CU-CADSWES, June 2005) description of the function utilized in the URGWOM ruleset to set reservoir releases to meet downstream target flows.

> HypTargetSim: Given a control slot (a slot is a set of data, in this case a time series), a target slot, target date/time, and target value, this function uses

hypothetical simulation (hypothetically simulate a portion of the workspace with user input values and return requested result values) to find a value x such that if the control slot were set to x at all timesteps from the current date to the target date, then the target slots value would equal the target value. If the value x exceeds the physical constraint for that slot at a particular timestep (max outflow on a reservoir for example), then the constrained value is used instead of the x value for that timestep.

Utilizing such functions in RiverWare allows modelers to achieve short-term goals of determining required reservoir releases to meet target flows and long-term goals of establishing how much water is needed to be stored in order to continually meet the target flow requirements. Figure 2 shows a hydrograph plot of the San Acacia streamgage location for model runs for both meeting and not meeting the target flow of 100 cubic feet per second (cfs) during a low flow period. The figure also shows the amount of flow released from Abiquiu Reservoir needed to meet the target.

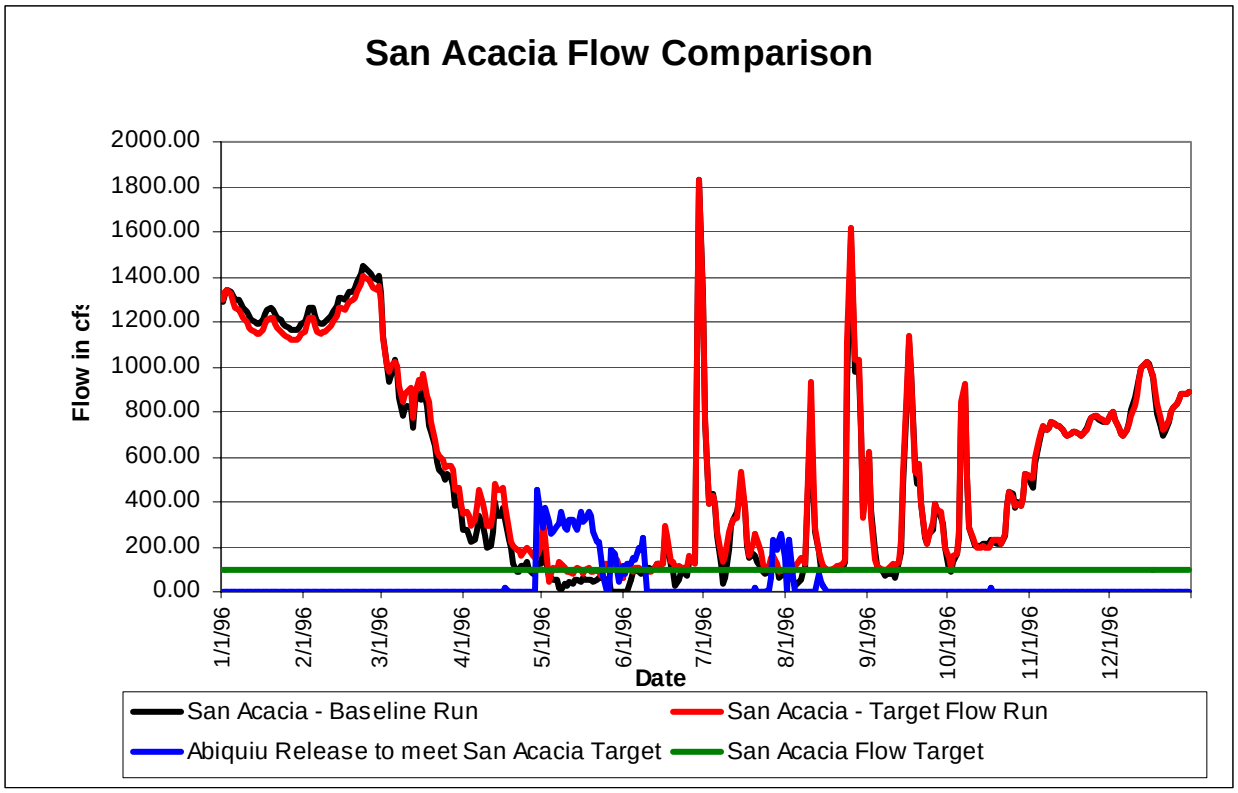

Figure 2. San Acacia Flow Comparison

Note that the flow at San Acacia for the flow target run does not exactly meet the target of 100 cfs each day. Because of assumptions made for diversions and the release from Cochiti which are held constant in the model for the number of days of travel time from the reservoir to the target location, along with variable routing parameters, changing channel and sediment configurations, and dynamic groundwater interactions, the model does not compute a steady target flow exactly matching the target flow. There is room for improving the results of the

model to determine the correct release to better match the target flow, but at the same time it is not realistic in the real world operations to exactly meet a target, that in this case, has a travel time of about five days from Abiquiu Dam to the downstream target location (San Acacia).

The model is very useful for determining the volume of water required to store, and the approximate magnitude of the release to meet target flows. This should help water managers and other stakeholders within the Basin make informative short and long-term decisions regarding when and how much water to store and release to ensure minimum flows at critical reaches for endangered species sustainability and recovery in the Middle Rio Grande Basin.

SCENARIO MANAGEMENT IN RIVERWARE

The testing phase of the URGWOM development process allowed the collaborating agencies, stakeholders and interested parties to run the model and experiment with alternative inputs. A useful interface was developed to facilitate stakeholder involvement and collaboration of the URGWOM. This RiverWare feature, called the Scenario Manager, allows those not thoroughly involved with the development of the model (non-expert modelers) to examine results, input sensible and feasible alternative values, and compare the results of their alternative runs with the baseline runs developed by the URGWOM technical team.

The Scenario Manager allows stakeholders to explore alternative data inputs without altering the underlying model called a baseline model. With the Scenario Manager, a subset of input data can be altered to create a new scenario. The model can be viewed and run using these various scenario values and the run results can be compared to the results from the baseline model. The Scenario Manager provides a convenient interface to load, edit, and save values for these slots (slots are a place to hold data), run the model using these different slot values, and compare the baseline values with the scenario values. Scenario analysis consists of three parts: a set of scenario slots, a baseline model, and a set of alternative input data describing the scenario.

The scenario slot list is a set of slots to be used in the scenario. These slots contain the data that the user wants to modify and test. Typically the model developer selects this list of slots and can specify minimum and/or maximum values for this data. This helps to prevent input data that is unrealistic. The modeler then saves the model specifying that this is a baseline model. Once a model has been saved as a baseline model, model topology, methods, and non-scenario slots become uneditable. Slots cannot be added or deleted from the scenario slot list. By preventing editing of the baseline model and the scenario slot list, the integrity of the baseline model is preserved and the scope of the scenarios is limited.

The user, typically the stakeholder, creates a scenario and enters input data on the scenario slots. The scenario data must be in the range defined in the scenario slot. The scenario data is saved separately from the model file making it easily shared between users and model developers. The user loads the scenario into the baseline model and activates the scenario to make a model run. Once a run has been made, the output in the model file represent the scenario. The baseline model cannot be overwritten with this new data, but the results can be re-saved as a non-baseline run.

The Scenario Manager allows for comparisons between slots in the baseline run and scenario runs. Comparisons are managed through features called the Snapshot Manager and the Output Manager. The user takes a "snapshot" of the data results, which is then saved in the model and can be compared to different snapshots or output from scenario or baseline runs. Plotting tools in the Output Manager are available to compare the scenario outputs.

The use of the Scenario Manager in RiverWare allows stakeholders to perform what-if scenarios without requiring thorough knowledge of the model, ruleset, and user interface. This lets stakeholders with knowledge of the river system, but not experts on the model itself, make alternative runs and review the results to see if they make sense and are reasonable representations of the real world operations and river dynamics.

SUMMARY

The URGWOM modelers have been seeking input and collaboration with stakeholders since the beginning of model development. It is hoped that these RiverWare features, hypothetical simulation to determine releases to meet target flows, and the Scenario Manager, for alternative analyses, will assist in future partnership in the use and improvement of the URGWOM.

REFERENCES

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