PECOS RIVER DECISION SUPPORT SYSTEM: TOOLS FOR MANAGING CONJUNCTIVE USE OF SURFACE AND GROUND WATER RESOURCES.

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ABSTRACT

The New Mexico Office of the State Engineer (OSE), Interstate Stream Commission (ISC), and the U.S. Bureau of Reclamation, have developed a suite of models, the Pecos River Decision Support System ("PRDSS"), which simulates major components of the groundwater and surface water hydrology and water operations associated with the Pecos River from Santa Rosa Reservoir to the New Mexico-Texas Stateline. The significant interdependencies between the Pecos River and the underlying aquifer systems and the significant response of the river to changes in ground water use makes it imperative to evaluate management activities with a basin-wide perspective. The need for these models arose from several distinct activities: the New Mexico State Engineer's administration of groundwater resources, negotiations involving the adjudication of the Pecos River, two ongoing Environmental Impact Statements (EIS), and New Mexico's need to determine how the Pecos River system can be managed to ensure water delivery obligations to Texas under the Pecos River Compact and Amended Decree are met. Under these programs, land and water retirement, water leasing, augmentation well management, supplemental water supplies and replacement water supplies are all actively used components of water management in the Pecos River Basin.

INTRODUCTION

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This paper describes the need for and development of a suite of modeling tools (the Pecos River Decision Support System or PRDSS) to simulate the effects of water management actions in the Pecos River Basin, New Mexico. The models were developed and refined largely independently of one another over a 15 year span. Beginning in 2000, and as a result of two significant basin-wide policy-affecting activities, these modeling tools were brought together and linked to form a single tool for evaluating the combined effects of surface and ground water management actions across the basin. One of these actions is the Pecos River Adjudication Settlement Agreement, which settles outstanding water rights claims and provides a permanent mechanism to meet New Mexico's obligations under the Pecos River compact and to avoid the need for a priority call on the river. The second is the Carlsbad Project Water Operations and Water Supply Conservation EIS, whose primary purposes are to conserve and protect the threatened Pecos Bluntnose Shiner and to conserve the Carlsbad Project water supply.

The models were extensively tested and peer reviewed in a public forum, as part of the Carlsbad Project Water Operations and Water Supply Conservation EIS. As part of the tests, the models were calibrated to reproduce the hydrologic history of the Pecos River system. Once calibrated, the models were used to evaluate effects of current and/or proposed management activities on a variety of resource indicators throughout the basin. This paper provides an overview of the Pecos River and the PRDSS modeling tools, and two companion papers by New Mexico Interstate Stream Commission staff further illustrate the model applications and the institutional setting for water management in the Pecos River Basin.

HYDROLOGY AND WATER OPERATIONS

The Pecos River originates in the Sangre de Cristo Mountains of north central New Mexico, and travels from there through southeastern New Mexico in to Texas (figure 1). It merges with the Rio Grande near Del Rio Texas, about 150 miles east of Big Bend National Park. Snowmelt from the Sangre de Cristo Mountains is a significant source of the river's reliable water supply. From these mountains, the river travels through desert or semi-desert regions where ephemeral tributary inflows are generated by very unpredictable and highly variable precipitation events. In addition to inflows from precipitation events, the river receives significant base inflow from underlying aquifers in southeastern New Mexico. The models described in this paper are used to simulate water operations and hydrologic conditions in the highlighted area of figure 1.

The primary use of both surface and ground water in the study area is agricultural irrigation. Two irrigation districts (Carlsbad and Fort Sumner), irrigate up to 25,000 and 7,000 acres, respectively. The primary water supply source for these districts is the Pecos River. About 60% of the irrigated acreage in the Carlsbad Irrigation District (CID) has supplemental well rights, which allow those acres to

be irrigated by ground water from the underlying Carlsbad aquifer system when surface water supplies are limited. The Carlsbad Project – a Reclamation Project – operates four main-stem reservoirs on the Pecos River with a combined conservation storage capacity of 176,500 acre-feet. CID historically is the sole user of Carlsbad Project water, and historically diverts about 75,000 acre-feet annually for its irrigators.

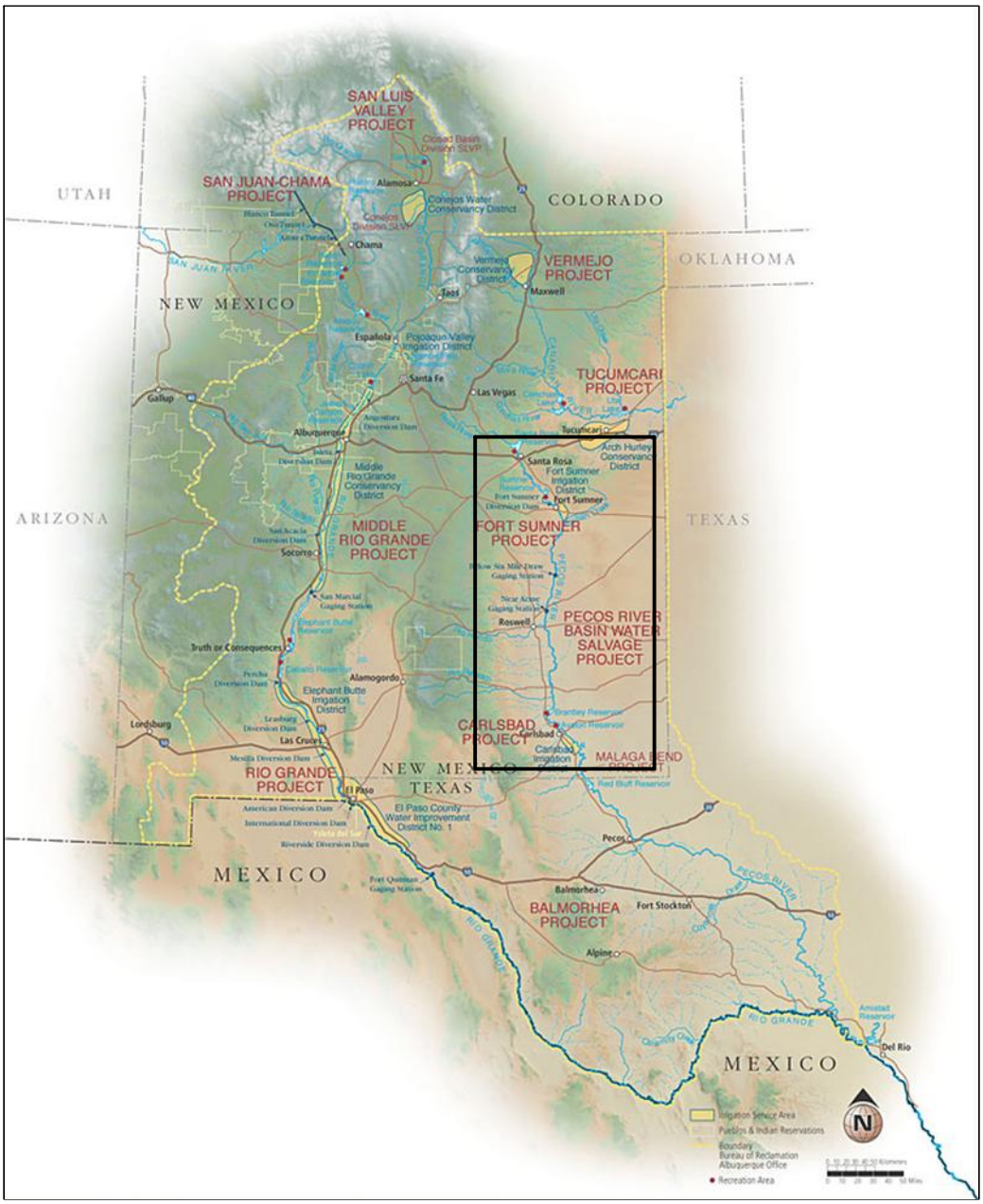

Figure 1. The Pecos River Basin with highlighted study area.

The Pecos Valley Artesian Conservancy District (PVACD) irrigates approximately 120,000 acres almost exclusively with groundwater pumped from aquifers in the Roswell Artesian Basin, which lies under and west of the Pecos River in the central part of the study area. The Roswell aquifers provide a significant source of water to the Pecos River as base inflows. These base inflows in turn are a significant source of water for the CID. Ground water extraction by PVACD irrigators over the last 60 years has caused a significant reduction in base inflows to the Pecos River.

Operation of the four Carlsbad Project reservoirs is guided primarily by the need to store and deliver water to CID, and to bypass sufficient water to meet FSID's right, which has the senior *direct flow* right in the study area. The historic operation of these reservoirs with respect to CID's water is based on the need to maximize storage and delivery efficiency. Generally, the water is stored preferentially in the upstream reservoirs (Santa Rosa and Fort Sumner). Water from these upstream reservoirs is delivered downstream to Brantley and Avalon only when it is need. This provides multiple benefits; the first is a potential reduction in evaporation losses, the second is increased capacity for capturing flood inflows in Brantley reservoir downstream, and the third is a reduction in transport losses. Transport losses are minimized by delivering water in "blocks". These "block releases" are staged releases of water (over 1000 cfs) released at a constant rate for 14 to 20 days. These block releases occur two to three times per year, depending on supply and demand within the CID (Longworth and Carron, 2003b).

INSTITUTIONAL NEEDS DRIVING MODEL REQUIREMENTS

Development of the Pecos River Decision Support System was driven by multiple parallel needs including NEPA activities surrounding the federally threatened Pecos Bluntnose Shiner, settlement of outstanding water rights adjudication claims, and ongoing efforts by New Mexico to meet its obligations under the Pecos River Compact and Amended Decree. Management actions proposed or required as part of these activities include:

- Leasing or purchasing and transfer of water rights
- Operational modifications for purposes of meeting aquatic habitat requirements
- Water exchanges
- Augmentation of water supplies via ground water pumping
- Delivery of leased and/or purchased water to meet Pecos River Compact obligations
- Offsetting of increased depletions caused by altered operations

Most of these activities involve the conjunctive use of surface and ground water resources. The significant interdependencies between the Pecos River and the underlying aquifer systems and the significant response of the river to changes in

ground water use makes it imperative to evaluate management activities with a basin-wide perspective.

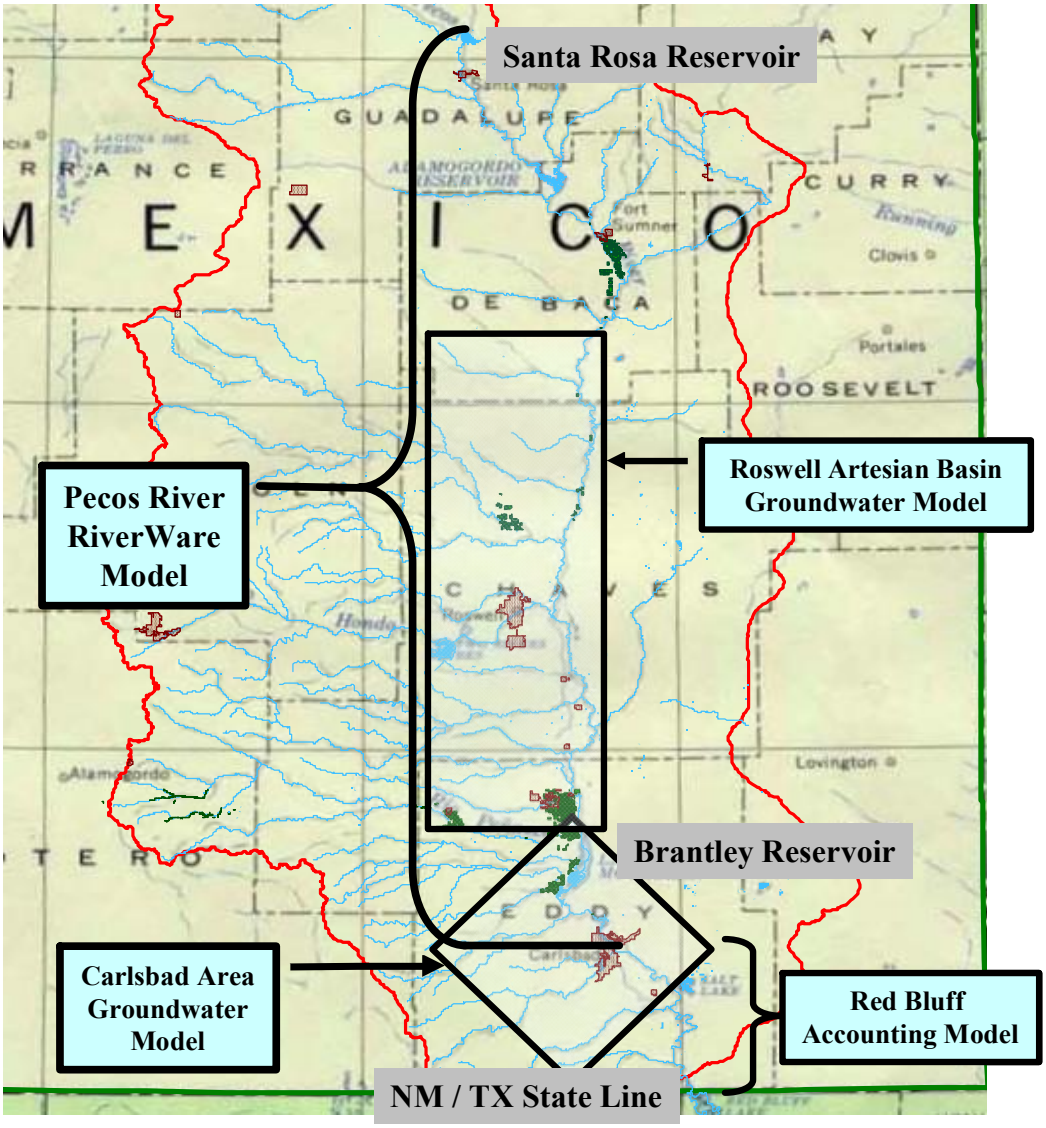

Figure 2. Spatial domain of the model elements of the Pecos River Decision Support System.

The PRDSS model suite (Figure 2) consists of

- A RiverWare surface water model of the Pecos River
- The Carlsbad Area Groundwater Model (CAGW) (A MODFLOW Model)
- The Roswell Artesian Basin Groundwater Model (RABGW) (A MODFLOW Model)
- The Data Processing Tool (DPT)
- The Red Bluff Accounting Model (RBAM), and
- Data management utilities and databases.

Each of these model components is discussed below.

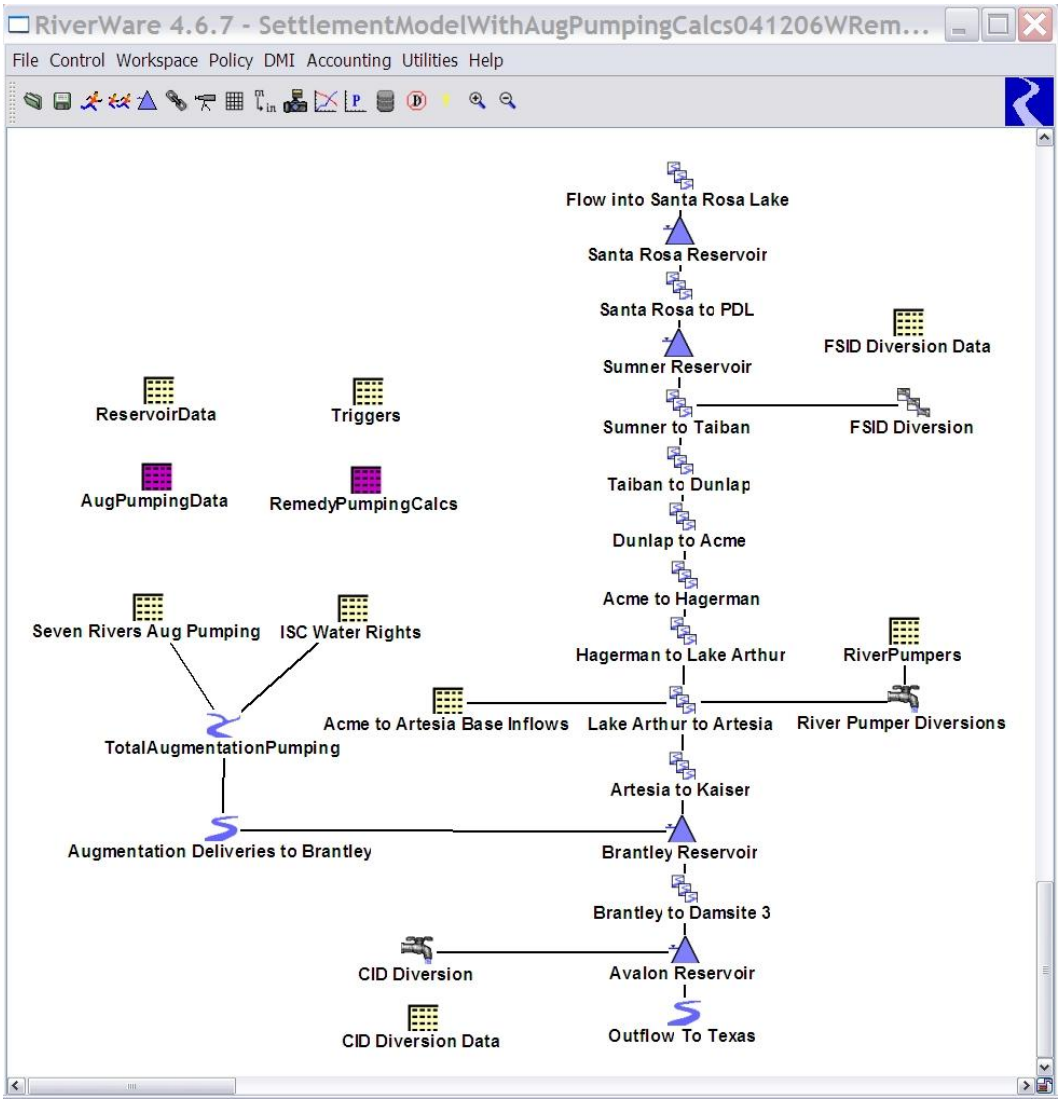

Figure 3. The Pecos River RiverWare model network.

PECOS RIVER RIVERWARE MODEL

River and reservoir operations from Santa Rosa Dam downstream to Avalon Dam are simulated by the Pecos River RiverWare model (Figure 3). The model uses historical river inflows for mainstem inflows to Santa Rosa reservoir and for gaged tributary inflows. Ungaged tributary inflows were derived from mainstem gage data. Base inflows from the Roswell Artesian Basin were developed from the RABGW model, and are influenced by changes in ground water usage for irrigation and other needs such as augmentation supply and exchange water. The

model simulates the significant physical processes acting on the surface water system, including reservoir operations (spills, evaporative losses, bank storage, etc), river hydrology (routing, bank storage, evapo-transpiration, seepage), and diversions for irrigation (consumptive use, return flows, etc.). The model operates on a daily timestep using a rule-based simulation routine. The RiverWare rule-base simulation solver allows operational policy to be represented in the model environment by a series of prioritized "if-then" type statements. These simulation rules plus the hydrologic inputs drive the simulation, and provide a user-friendly approach to quickly and efficiently evaluate a variety of management options. RiverWare™ can simulate a wide range of rule types, allowing the ISC to consider flood operations, conservation storage, irrigation district operations, Pecos River Compact under-delivery contingencies, and endangered species needs.

THE ROSWELL GROUNDWATER MODEL

An important input to the RiverWare model is the inflow of ground water from the Roswell Artesian Basin to the Pecos River (represented graphically by the "Acme to Artesia Base Inflow" object in figure 3. These inflows are influenced by pumping in the basin, which intercepts ground water that would otherwise have discharged to the river. Inflows from the Roswell Artesian Basin may contribute as much as 50% of the annual surface water supply for the Carlsbad Project. Since these inflows could be modified by changes in the management of the ground water resource in the Roswell Basin, a physical process-based model was required. The Roswell Artesian Basin Groundwater Model (RABGW) was originally developed by OSE and ISC staff and consultants, using standard USGS MODFLOW software. The model is based upon decades of geologic and hydrologic investigation of the Roswell Basin, a huge set of water level and stream gage data, and has been developed, tested and refined by a number of different groups over the past 15 years. RABGW simulates the Roswell artesian aquifer, the overlying confining unit and shallow alluvial aquifer, and the interaction of these aquifers with the Pecos River (Barroll et al., 2003).

The RABGW model has been instrumental in understanding the effects of well pumping on base inflows to the Pecos River. One of the key findings from the RABGW model was a better understanding of the spatial and temporal variability in the effects of ground water extraction on base inflows, and the long period of response (as long as 100 years in some instances) that have significant bearing on management decisions.

THE CARLSBAD GROUNDWATER MODEL

Downstream from the Roswell Basin, the Carlsbad area contains two large aquifer systems, the Carlsbad Reef aquifer, and a shallow alluvial aquifer. Overlying

these aquifers and significantly impacting their hydrology is the Carlsbad Irrigation District (CID). The Pecos River RiverWare model ends at Lake Avalon, which is the diversion structure for the Carlsbad Irrigation District (CID). RiverWare simulates the delivery of surface water through the river and reservoir system and ultimately into the CID Main Canal. Absent any flood control operations, all of the waters of the Pecos River are diverted into this canal, and the river typically has zero flow immediately below Avalon Dam (except for seepage from the Dam and the Main Canal itself). Return flows and seepage associated with irrigation in the District and natural base inflows from the aquifers therefore make up a very large component of New Mexico's delivery to Texas, which is recorded at the Red Bluff gage approximately 30 river miles below Avalon Dam. Irrigation is almost exclusively by flood irrigation. Surface water irrigation return flows and supplemental well pumping significantly impact the return flow and base inflow regimes in this region.

The Carlsbad Area Groundwater Model (CAGW) was developed by OSE and ISC staff and consultants, again using standard USGS MODFLOW software. The model is based upon substantial geologic and hydrologic investigations published by the OSE and USGS, and upon a large set of water level and stream gage data extending from the 1940's to the present day. This model simulates the shallow alluvial aquifer and the reef aquifer in the Carlsbad area, as well as natural and man-made sources of water to, and discharge of water from, those aquifers. The model calculates the outflow of ground water into the Pecos River, and also calculates water levels in both aquifers. The operations of the CID surface water irrigation system and its affect on aquifer flows are simulated based on inputs from the RiverWare model and computed additional supplemental well pumping that is used in times of surface water shortages (Barroll et al., 2003).

COMPACT ACCOUNTING AND OTHER DATA PROCESSING UTILITIES

An accounting model that tracks compliance with the Pecos River Compact, plus numerous data processing utilities are managed by a set of Access database and VBA tools. These utilities provide a user-friendly data management environment for performing data Input/Output between the various models and for scenario archiving and simulation results analyses. The tools constitute the "links" between RiverWare and the two MODFLOW models. They are used to generate stress files for ground water pumping and recharge for different scenarios, and perform temporal and spatial aggregation and dis-aggregation functions when moving data between models. One of the databases also serves as an archival tool and is a central repository for results and analyses generated as part of the NEPA programs ongoing in the basin.

SUMMARY

A suite of modeling tools (the Pecos River Decision Support System or PRDSS) has been developed to evaluate the impacts of both surface and ground water management options and their hydrologic interdependencies. The tools comprising the PRDSS have been peer reviewed in a public forum (the Carlsbad Water Operations and Water Supply Conservation EIS), and are currently being used to evaluate management options in two NEPA activities and a water rights adjudication proceeding. Companion articles in this conference proceeding describe application of the PRDSS (Elhassan and Carron, 2006; Sims and Smith, 2006)

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